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Shaping the Future

Final Report



Merced River and Riparian Vegetation Assessment

June 2012

Contract No. C2000092900/Task Order No. TO 05 T2030101006

Prepared For

Yosemite National Park, National Park Service

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Prepared for
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Acronyms

AA	Assessment Area
AFHZ	Alluvial Fan Hazard Zone
AHZ	Avulsion Hazard Zone
cfs	Cubic Feet per Second
cm	Centimeter
CMZ	Channel Migration Zone
CRAM	California Rapid Assessment Method
DBH	Diameter at Breast Height
DAVHZ	Disconnected Avulsion Hazard Zone
DEHA	Disconnected Erosion Hazard Area
DVA	Disconnected Valley Alluvium
EHA	Erosion Hazard Area
GIS	Geographic Information System
ha	Hectare
HAWS	Height above Water Surface
HMZ	Historic Migration Zone

km	Kilometer
LWD	Large Woody Debris
m	Meter
NPS	National Park Service
PDAHZ	Protected Disconnected Avulsion Hazard Zone
PDEHA	Protected Disconnected Erosion Hazard Area
PDVA	Protected Disconnected Valley Alluvium
USGS	United States Geological Survey
VA	Valley Alluvium
WHR	Wildlife Habitat Relationships
WY	Water Year

Executive Summary

The purposes of the study were: 1) to evaluate and determine current riparian, channel, and wildlife habitat condition of a 16 kilometer (km) reach of the Merced River flowing through Yosemite National Park, 2) to describe changes to the riparian corridor and river channel that have occurred since this reach of the Merced River was designated as Wild and Scenic under the Wild and Scenic Rivers Act, and 3) to develop and suggest metrics that describe riparian and river condition, which would be used to monitor future trends and to develop natural resource management objectives within the park.

The study relied on recent (summer to winter 2010) field surveys that mapped the riparian corridor, qualitatively assessed the riparian corridor using the California Rapid Assessment Methodology (CRAM), mapped the Channel Migration Zone (CMZ), surveyed the amount and distribution of large woody debris (LWD), and assessed wildlife habitat. Developed in consultation with Yosemite National Park, these field studies will best inform the ongoing development of the Merced Wild and Scenic River Comprehensive Management Plan in the park (see below). The CMZ mapping and LWD surveys also allowed a projection of future channel migration and LWD loading that informed the development of monitoring metrics and restoration and management objectives. The assessment of wildlife habitat was based upon historical and recent studies conducted by the National Park Service and others, and were summarized and analyzed in this report. Data to determine the baseline to evaluate changes to riparian corridor and river channel since Wild and Scenic River designation include previous reports, maps, and aerial photography that documented condition just before or after 1987 (the year of designation). These historical sources were compared to more recent information (when available) and the results of field surveys conducted for this study. This description of changes also includes a summary restoration projects conducted by Yosemite National Park since 1991.The results of the field surveys were integrated to describe river and riparian corridor condition, to identify stressors, and to make restoration and management recommendations.

The information in this report will inform the ongoing development of the Merced Wild and Scenic River Comprehensive Management Plan in Yosemite National Park. That plan will guide the management of the Merced River and South Fork Merced River within Yosemite National Park for the next 20-30 years. The management plan will include an environmental impact statement, which will consider a variety of alternatives for future management of the rivers. A fundamental part of most or all alternatives will be a restoration plan for the river, its banks, Yosemite Valley meadows, and other outstandingly remarkable values in need of restoration action. As with the alternatives to be considered in the EIS, the restoration plan will also utilize the information presented in this report.

The study occurred from the Happy Isles Bridge to approximately 1 km downstream of the Pohono Bridge near the intersection of Big Oak Flat and El Portal roads. To evaluate discrete sections of river and riparian corridor, the 16 km study reach was divided into eight geomorphic reaches based upon channel gradient and sinuosity, entrenchment, bankfull width, and valley width. Beginning upstream, these geomorphic reaches were: Happy Isles, Above Tenaya, Below

Tenaya, Upper Meadows, Inter-Meadows, Lower Meadows, Above Pohono Bridge, and Below Pohono Bridge (See Appendix A for reach map and for maps of study results).

Methods

Riparian Corridor Mapping and Riparian Vegetation Condition Assessment. Vegetation communities within the Merced River riparian corridor were mapped in the field in September 2010 and categorized according to the Yosemite National Park National Vegetation Classification System (NatureServe 2007). The 2010 vegetation map was compared to 1992 and 1997 vegetation maps for Yosemite Valley (National Park Service [NPS] 1992, 1997) and evaluated to identify changes in distribution of vegetation types within the riparian corridor since Wild and Scenic designation (1987). The Merced River riparian corridor was assessed following the California Rapid Assessment Method (CRAM) for unconfined riverine riparian areas (Collins et al. 2008a, 2008b). The CRAM is a rapid, standardized assessment method that provides information on the overall condition and functional capacity of the riparian corridor and the stressors that may be affecting it.

Channel Migration Zone Mapping and Large Woody Debris Surveys. The Channel Migration Zone (CMZ) was mapped in September 2010 to determine the extent of potential future lateral erosion and channel avulsion within the next 100 years. The mapping identified floodplain areas with potential to erode via chronic (e.g., channel migration, bank erosion) or episodic (e.g., channel avulsion) processes and areas disconnected from the floodplain by roads and channel revetments. Large woody debris (LWD) within the channel was inventoried using a Global Positioning System (GPS) unit equipped with a specialized data dictionary to record characteristics of the wood, such as piece dimension, recruitment mechanism, and geomorphic role. The amount of future potential LWD was estimated from CMZ extent and current riparian cover, assuming that trees within the CMZ would eventually enter the channel via bank erosion.

Wildlife Habitat Assessment. The wildlife habitat assessment was based on data from the Wildlife Condition Assessment for the Merced River Corridor in Yosemite Valley (Espinoza et al. 2010). The assessment included the following elements: 1) predicted occurrence of wildlife species using California Wildlife Habitat Relationships (CWHR) models, 2) surveys for amphibians, reptiles, birds, and mammals to test the CWHR models, 3) characterization of wildlife communities using existing datasets and additional surveys, and 4) assessment of the health of the Yosemite Valley riparian and meadow habitats in relation to wildlife focal species.

Results

Current Condition of Merced River and Riparian Corridor

Riparian Corridor Mapping and Riparian Vegetation Condition Assessment. The Ponderosa Pine-Incense Cedar Forest Alliance, the most common vegetation type within the riparian corridor, made up 35 percent of riparian area followed by the Black Cottonwood-Temporarily Flooded Forest Alliance (16 percent), Douglas Fir-Ponderosa Pine-Incense Cedar Forest (11 percent), and Ponderosa Pine-Incense Cedar-California Black Oak Forest (10 percent) (Table 3-2).. Oak and conifer communities dominated the study reach in 1992, 1997, and 2010 (66 to 70 percent of total area), decreasing slightly (5 percent from 1992 to 2010 (Figure 3-1 and Appendix A [1992 to 1997 and 1997 to 2010 Riparian Vegetation Map Series]). The proportion of meadow vegetation within the riparian corridor remained similar from 1992 to 2007, while black cottonwood forest communities increased in area by nearly 10 percent, and the area of willow-dominated communities decreased by 8 percent. Although the cause of the decrease in the proportion of the Willow Riparian community is not known at this time, it could be due to a greater susceptibility to scour from high flows compared to cottonwoods as they generally establish closer to the stream margins (the relative proportion of mixed cottonwood and willow communities increased), an increase in dominance of cottonwoods within the riparian corridor due to recent successful recruitment events, trampling of young willows that may have established after the 1997 flood event near recreation areas., or were burned during recent prescribed burns, particularly in the early 1990s in the Lower, Inter-, and Upper Meadows reaches (e.g., 1993 in the Sentinel Beach area). It is important to note that changes in the proportion of area within each of the categories between the years could also reflect differences in mapping methods and/or classification of sub-dominant species between years.

Overall CRAM scores for all Assessment Areas (AAs; 200 meter long study plots extending outward from the channel to include area with potential to input wood and vegetation) along the Merced River study reach ranged from 0.56 to 0.93[1], with a median score of 0.77 (average of 0.78) (Figure 3-4). The AAs with comparatively "higher" overall CRAM scores (top 20th percentile) had scores of 0.87 or greater (n=17). The majority of these AAs were present in the Upper Meadows and Above Pohono Bridge geomorphic reaches. The AAs with comparatively low overall CRAM scores (lowest 20th percentile, with values of 0.70 or less [n=17]), were concentrated in the three following geomorphic reaches: (1) Above Tenaya; (2) Below Tenaya; and (3) Below Pohono Bridge (Appendix A, CRAM Scores Map Series). The CRAM data are summarized in Appendix C.

<u>Channel Migration Zone Mapping and Large Woody Debris Surveys</u>. The total channel migration zone area ranged from 9 hectares (ha) (Below Pohono Bridge) to 245 ha (Upper Meadows). Of this total CMZ area within each reach, the percent disconnected, either by channel revetment or presence of infrastructure, ranged from 39 percent (Below Tenaya) to 0.3 percent (Above Tenaya). Disconnected portions of the CMZ represent maintenance challenges, but are also restoration opportunities. The LWD inventory counted 835 pieces or 2,273 m^3 of LWD along 16 km, with wood loading along the channel ranging from 0 pieces/100 m to 66 pieces/100 m (Figure 3-9). The greatest wood loading occurred in the Happy Isles and Above Tenaya reaches at the upstream end of the study reach.

<u>Wildlife Habitat Assessment</u>. A total of 44 individuals (living and dead) of two amphibian, and at least four reptile species (including one unidentified lizard species) were detected either visually or through auditory cues in July and September 2010. A total of 953 individual birds and 41 species were detected during the bird surveys conducted in June and July 2010. Relative abundance (total number of individuals divided by three field visits) was estimated at 317.67 individuals overall for the study (Espinoza et al. 2010). Of the 41 species detected, there were 28 probable and 17 confirmed locally breeding species. Surveys documented a high diversity of bats. Of the 17 bat species that are known to occur in Yosemite National Park (Pierson et al.

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[1] CRAM scores can vary from 0.27 to 1.00. Higher scores indicate that the riparian corridor is in better condition, while lower scores indicate that it is in poorer condition.

2001), 11 species were detected at the two survey locations (Yosemite Creek and North Pines Campground). The North Pines Campground had the highest number of individuals detected (1,496 individuals – which represents 100 percent of the species detected during the study) compared to the Yosemite Creek site (89 individuals, and 54.5 percent of the species) during the study (Espinoza et al. 2010). Two California Species of Special Concern and BLM Sensitive species were detected at both sites during the study. They were the spotted bat (*Euderma maculatum*) and western mastiff bat (*Eumops perotis*). The spotted bat had the second highest number of detections of all bats during the study (1 at Yosemite Creek and 351 at North Pines Camp). The hoary bat (*Lasiurus cinereus*) had the most individuals detected overall (59 at Yosemite Creek and 638 at North Pines Camp) during the study.

Changes to the Riparian Corridor and River Channel since Wild and Scenic River Designation

<u>Riparian Vegetation</u>**.** The majority of the riparian corridor within the study reach was dominated by community types comprised of different combinations of late seral species, including conifers, oaks, and incense cedar (Figure 3-1). The proportion of these community types decreased slightly between 1992 and 2010 (4.5 percent) (Appendix A, 1992 to 1997 and 1997 to 2010 Riparian Vegetation Map Series). The proportion and distribution of meadow and herbaceous communities have also remained relatively constant over time.

In comparison, the distributions and/or proportions of early seral community types dominated by black cottonwood or willow species have changed between 1992 and 2010. These communities are generally established closer to the river channel than oaks and conifers and, consequently, are more susceptible to periodic scour and/or burial during high flow events, including the 1997 winter flood. The 1997 flood scoured vegetation that had been established along the channel margins, creating new potential locations for riparian species establishment.

Although willows have been very successful in recent restoration projects throughout the study reach (see Section 4.4), the overall proportion of area dominated by willow communities has decreased since 1992 by approximately 7.6 percent. In comparison, the proportion of black cottonwood forest increased by 11.2 percent between 1992 and 2010. It is possible that the willows on the bars in 1992 were scoured by the 1997 winter flood and have not re-established as well compared to cottonwoods. The reason for the decline in dominance of willows is not known at this time, but could be due to a greater susceptibility to scour compared to cottonwoods as willows generally establish closer to the river channel, an increase in dominance of cottonwoods within the riparian corridor due to recent successful recruitment events, trampling of young willows that may have established after the 1997 flood near recreation areas (e.g., near Sentinel Beach picnic area and the swinging bridge), or were burned during recent prescribed burns, particularly in the early 1990s in the Lower, Inter-, and Upper Meadows reaches (e.g., 1993 in the Sentinel Beach area).

<u>Channel Migration Zone.</u> The overall channel form of the Merced River within Yosemite Valley has not changed since Wild and Scenic River Designation in 1987. Channel reaches that were straight or meandering remain so to date, however there has been lateral erosion primarily along the outside bends of the river channel. Additional bank erosion has occurred within the straightened reaches, and no channel avulsions have taken place.

Digitized historical channel alignments following Wild and Scenic River Designation (2005, 2009) were compared to 1987. Comparison of these data shows a net increase in channel area (widening) between 1987 and 2005, at an average rate of 0.05 ha/yr.The flood of record (1997) occurred during this time period and yet there is no significant increase in erosion rates compared to the rates measured from 1944 to 1987. Between 2005 and 2009 there is a marked increase in the rate of erosion, (0.4 ha/yr). The increase in channel erosion between 2005 and 2009 is likely linked to general decreases in revetment lengths. Much of the loss of revetment from 1987 to the present is likely linked to failure during the 1997 flood.

Wood Loading. Madej (1994) provides the first inventory of LWD loading in the Merced River for direct comparison to the 2010 survey completed for this study. LWD surveys in Madej (1994) had a minimum DBH of 25 cm, and frequencies were reported for two study reaches. The upper reach extended from Clarks Bridge to Sentinel Bridge, and the lower reach from Sentinel Bridge to El Capitan Bridge. The upper reach reported 12 pieces/km, and the lower reach 29 pieces/km. In order to compare these findings with the 2010 LWD survey, the data were summarized by the same reaches reported in Madej (1994). The 2010 survey found 44 pieces/km in the upper reach, and 60 pieces/km for the lower reach. It is likely that the 2 to 4 fold increases in pieces/km are related to significant recruitment resulting from bank erosion that occurred during the 1997 flood, and a shift in NPS LWD management practices discouraging removal from the river.

Riparian and River Condition Metrics

Riparian Corridor Metrics. Based on the results of the CRAM, five attributes/metrics were strong determinants of the conditions of the Merced River riparian corridor within the study area:

1. Buffer condition (extent and quality of vegetation cover and intensity of human use).
2. Hydroperiod or channel stability (degree of channel aggradation or incision, including bank erosion, and extent of revetment along the channel).
3. Average buffer width.
4. Biotic condition (in particular, the number of co-dominant species, number of multi-plant species associations, and the degree of overlap between plant canopy layers).
5. Physical structure (overall variability in micro- and macro-topographic relief that may affect moisture gradients and/or flowpaths).

Channel Migration Zone Metrics. While the CMZ should not drastically change in the short term, several key metrics to describe channel migration processes should be monitored periodically:

1. Bank erosion rates through channel cross-section surveys
2. Locations of existing and future bank protections and revetments
3. LWD recruitment and flux (see below for specific metrics)

LWD Metrics. The suggested metrics to describe current and future river LWD dynamics are:

1. Piece location along (longitudinally) and within (cross-sectionally) the channel
2. Piece type (log with rootwad, log, rootwad)
3. Dimension (length and diameter)
4. Wood influence on channel (role in pool formation)
5. Recruitment mechanism
6. Decay class

Summary

The current condition of each geomorphic reach was summarized from key riparian and channel (CMZ and LWD) metrics, and wildlife habitat data. The results show that riparian, channel and wildlife habitat conditions vary by geomorphic reach in response to stressors that potentially deteriorate habitat quality (Table 5-1). The Happy Isles geomorphic reach had wide riparian buffers with complex physical structure, a high degree of connection between floodplain and river, high wood loading, and good wildlife habitat, while the Below Tenaya reach had low riparian patch richness and vegetation structural complexity, the lowest degree of connection between river channel and floodplain, low wood loading, and poor wildlife habitat. The primary stressors within the 16 km study reach are related to recreational use and the presence of infrastructure and channel stabilization measures (revetments). Infrastructure and revetments lead to the disconnection of the channel migration zone, limiting lateral connectivity (floodplain connectivity) between the river and the riparian corridor, and limiting erosional processes that create geomorphic surfaces for riparian regeneration and recruit LWD to the channel. Recreational use and presence of infrastructure may also limit the development of the riparian forest limiting thereby wildlife species.

Chapter 1
Introduction

1.1 Physical Setting

The Merced River originates at the crest of the Sierra Nevada in Yosemite National Park and flows westward 225 kilometers (km) to its confluence with the San Joaquin River in the Central Valley of California. The headwaters of the river lie at approximately 2,440 meters (m) in altitude; the river then flows through steep canyons before reaching the study reach in the Yosemite Valley, which ranges from 1,150 m to 1,280 m above sea-level (Milestone 1978). The study reach of the Merced River extends 16 km through the Yosemite Valley. In this segment of the river, gradient decreases and the channel widens as the river leaves the canyon upstream.

The drainage basin of the Merced River encompasses approximately 4,500 km^2 and major tributaries in the Yosemite Valley include Tenaya, Yosemite, Bridalveil, Illilouette, Sentinel, and Ribbon creeks. The climate in the Merced River basin is temperate: cold, moist winters and hot, dry summers. Most precipitation occurs between November and April and average annual precipitation in Yosemite Valley is 930 millimeters (mm). Heavy snowfall in the winter above 1,800 m in elevation contributes to river flow as snowmelt, with peak flows late-spring and early summer; low flows typically occur in early-fall (United States Geological Survey [USGS] 2009).

The Happy Isles and Pohono Bridge stream gages (United States Geological Survey [USGS] stream gages 11264500 and 11266500, respectively) provide long-term surface flow records for the study reach (Periods of record: Water Years [WY] 1915 to present and1917-present, respectively). The Happy Isles gage is at the upstream end of the study reach (upstream drainage area = 468 km^2), while the Pohono Bridge gage is at the downstream end (upstream drainage area = 831 km^2) and includes flow from Tenaya, Yosemite, Sentinel, and Bridalveil creeks. Mean monthly flows for the period of record at both gages are greatest in May and June and lowest in September and October. The flood of record at both gages occurred in 1997, with other large flows occurring 1955, 1959, 1937, and 1964 (Table 1-1). Examination of mean annual flow records for both gages indicates recent dry periods in WY 1976-1977 and from WY 1987-1991.

Table 1-1. Peak flows recorded at Happy Isles and Pohono Bridge USGS stream gages over periods of record[1,2]

Happy Isles (USGS Gage # 11264500)[1]		Pohono Bridge (USGS Gage # 11266500)[2]	
Peak Flow (cfs)	Date	Peak Flow (cfs)	Date
10100	1/2/1997	24600	1/3/1997
9860	12/23/1955	23400	12/23/1955
9260	11/18/1950	23000	11/19/1950
9240	12/23/1964	22000	12/11/1937
8400	12/11/1937	18000	12/23/1964
5900	5/16/1996	13200	2/1/1963

5680	5/16/2005	12500	5/16/1996
5450	5/29/1983	11200	4/11/1982
5220	7/9/1995	11000	1/13/1980
5200	2/1/1963	10200	5/16/2005

1 Happy Isles period of record: WY 1915 to present

2 Pohono Bridge period of record: WY 1917 to present

The bedrock geology in Yosemite National Park is dominated by the granite of the Sierra Nevada batholith. Bedrock of schist, slate, limestone, and volcanic rocks also occur in the park (Madej et al. 1991). The Sierra Nevada consists primarily of the uplifted granitic rocks of the batholith, which formed roughly 200 million years ago (Ma) over a period of about 130 million years (USGS 1985). From 38 to 10 Ma, volcanic activity occurred, followed by extensive erosion and exposure of the underlying plutonic rocks of the batholith. The subsequent uplift of the batholith between 25 to 15 Ma was the result of continental crust tensional forces. The stretching of the crust created a series of north-south trending uplifted mountain ranges and down-dropped valleys, including the Basin and Range province (USGS 1985).

A series of glaciations from 3 to 2 Ma brought alpine glaciers down the slopes of the mountains, leaving erosional features such as U-shaped valleys and cirques and depositional features such as glacial till and moraines. The most recent glaciation was the Tioga event, beginning 60,000 years ago. The last glacial maximum occurred 20,000 years ago, when the Tioga glacier extended westward as far as Bridalveil Meadow, the site of the terminal glacial moraine (Huber 1989). The lake that formed behind the terminal moraine, known as Lake Yosemite, resulted in the deposition of fine-grained materials that are part of the 300-600 m of sediment filling the Yosemite Valley (Gutenberg et al. 1956, National Park Service [NPS] 2004).

The vegetation zones of the Sierra Nevada generally follow the elevation gradient. Yosemite National Park supports the following biotic communities: foothill woodland, lower montane forest, upper montane forest, subalpine forest, and alpine meadow (NPS 2004). Yosemite Valley lies within the lower montane mixed conifer zone, with community types including wet meadow, grass meadow, riparian forest, upland forest of canyon live oak, upland mixed conifer/canyon live oak talus forest and cliff communities (NPS 2004).

Although indigenous resource management included harvesting, pruning, irrigation, burning, and vegetation thinning, land use in the last 150 years has reduced and fragmented the productive and diverse meadow and riparian habitats (NPS 2004). Grazing, agriculture, recreation, and fire suppression have altered watershed processes. Bank protection structures, flow diversion, bridge installation and the removal of riparian vegetation and wood from the river have adversely impacted river and floodplain processes (Milestone 1978).

1.2 Past History of Channel Manipulation along the Merced River within the Yosemite Valley

Prior to the National Park Service taking over management responsibility of Yosemite in 1916, Yosemite Valley was managed by the Yosemite Board of Commissioners from 1877-1904 and the U.S. Army from 1904-1916. Milestone (1978) states that the greatest human impact on the

Merced River occurred in 1879 when a section of the river at the El Capitan moraine was blasted to reduce backwatering upstream and reduce seasonal flooding on pasture land. Large boulders comprising the channel bed were blasted over an approximate 76 m reach to reduce the flow constriction created by the moraine and increase flow velocities in the reach. Anecdotal evidence and field observations suggests the blasting lowered the base level of the river by 1.2-1.5 m. A base level lowering of this magnitude would have resulted in channel incision in the Merced River and tributaries.

Much of the early management of the river focused on reducing the rate of lateral bank erosion to protect property and large riparian trees. All log jams and other flow obstructions were removed from the river to improve flow conveyance and enhance perceived aesthetics (Milestone 1978).

The NPS maintained a similar river management philosophy as the Yosemite Board of Commissioners when it took over management of the Yosemite Valley, including constructing bank revetments, clearing channels, building bridges and dams, and undertaking other projects that did not foster natural physical processes. In addition to armoring banks in response to flood-related erosion, the NPS initiated a policy of preventative measures aimed at increasing control over the river to reduce or eliminate the risk of future flood damage to infrastructure. These actions included using larger rock in new revetments at locations where future erosion could damage roads, campgrounds, and tourist facilities (Milestone 1978), construction of reinforced retaining walls, and larger drainage structures to more quickly drain flood waters. Projects to control the river and protect infrastructure built in the floodplain and in the path of the river's future lateral channel migration continued after World War II and into the early 1970s. Milestone (1978) reports that the rate of implementing new stream control projects decreased substantially by the late 1960s because the intense river management activities of the previous decades were so effective in preventing future lateral migration in problematic areas.

1.2.1 Riprap Bank Revetment

By the late 1970s there was approximately 4,420 m of riprap revetment along the banks of Yosemite Valley Streams (Milestone 1978) (Table 1-2).

Table 1-2. Length of Riprap Bank Revetment Along Yosemite Valley Streams (Milestone 1978)

Stream	Reach	Length (m)
Merced River	Happy Isles to El Capitan Moraine	2,716
Merced River	El Capitan Moraine to Diversion Dam	168
Tenaya Creek	Tenaya Cascades to Merced River	171
Royal Arch Creek	Valley Wall to Merced River	126
Indian Creek	Valley Wall to Merced River	156
Lost Arrow Creek	Valley Wall to Merced River	532
Yosemite Creek	Valley Wall to Merced River	548
Ribbon Creek	Valley Wall to Merced River	9
Total		**4,425**

1.2.2 Bank Armoring with Vegetation

Prior to extensive use of large rock riprap revetment, willows were commonly planted along the banks of the Merced River in an effort to limit bank erosion and control lateral channel migration (Milestone 1978). Willows were also often planted in combination with rock riprap to provide extra protection and to make the rock lined banks more aesthetically pleasing. The use of willow plantings as a stream control technique reached its peak in the 1930s when thousands of willows were planted by the Civilian Conservation Corps.

1.2.3 Diversion Dams in Yosemite Valley

As of the late 1970s, seven diversion dams existed in Yosemite Valley. The functions of the dams ranged from water and frazil ice diversion to hydroelectricity generation. The NPS removed the Cascades diversion dam, located 2.4 km downstream of Pohono Bridge (near the intersection of the Big Oak Flat and the El Portal [CA Hwy 140] roads) in 2003, and the Happy Isles diversion dam, located 150 m downstream of the confluence between the Merced River and Illilouette Creek, in 2004.

Two diversion dams on Yosemite Creek function to divert water down Yosemite Creek’s middle fork, thus preventing flooding of Yosemite Lodge and Lost Arrow residents (Milestone 1978). The Yosemite Creek diversion dams also block frazil ice from moving down the east and west forks of the channel, thus preventing the ice from damaging bridges and homes of the Lost Arrow and Yosemite Lodge area.

Three wing dams constructed of large granite cobbles that extend about 2 m out into the channel at a 30 degree angle to the flow are located on the Merced River. The wing dams were constructed by the U.S. Army in the late 1800s to very early 1900s. One of the wing dams was located at the west end of the Lower River Campground upstream of the mouth of Indian Creek, while the second and third wing dams were located on the river’s north bank just west of the Swinging Bridge. The wing dams are designed to direct the erosive energy of the river flow away from a section of the bank, however, it was noted in the 1930s that the eddies created on the downstream side of the wing dams actually created new bank erosion problems (Milestone 1978).

1.2.4 Bridges

By the late 1970s there were 38 bridges across Yosemite Valley streams, 15 of which crossed the Merced River (Table 1-3.) (Milestone 1978). Construction of five of the most notable stone arch bridges located on the Merced River began in 1928. The bridges have a stone façade, and because they were not built on bedrock, thousands of 8-31 cm diameter incense cedar trees were pile-driven into the loamy sand to provide the bridge’s foundation (Milestone 1978). The bridges were constructed from gravel mined from the river channel. The stone arch bridges and other bridges throughout the Valley often have narrow openings that are major constrictions at high flow events. Milestone (1978) compared the bridge opening width with the natural channel width to calculate the constriction created by the Merced River bridges (Table 1-3).

Table 1-3. Channel Constrictions Created by Merced River Bridges (Milestone 1978)

Bridge	Bridge Opening (m)	Natural Channel Width (m)	Percent Constriction
Happy Isles Foot Bridge	10	19	48%

- West Fork			
Happy Isles Foot Bridge - Middle Fork	17	27	37%
Happy Isles Foot Bridge - East Fork[1]	12	20	42%
Happy Isles Stream Gage[2]	17	33	47%
Happy Isles Road Bridge	24	27	11%
Clark Bridge	21	36	42%
Sugar Pine Bridge	30	57	48%
Ahwahnee Bridge	37	49	26%
Stoneman Bridge	27	50	46%
Curry Housekeeping Bridge	40	50	19%
Sentinel Bridge[3]	24	44	45%
Old Village Bridge[4,5]	54	40	0%
Swinging Bridge[5]	58	49	0%
El Capitan Bridge	51	54	6%
Pohono Bridge	23	40	43%

1 No longer in place, damaged by January 1997 flood.

2 Removed in 2001, though right bank concrete abutment remains

3 Replaced with wider opening in 2000

4 referred to now as Superintendant's Bridge

5 The Old Village Foot Bridge and the Swinging Bridge have potential channel widths greater than the natural channel, but the bridge's channel width between piers is restricting with pier width values of 10.9 m and 16.2 m, respectively (Milestone 1978).

1.2.5 In-channel Sediment Mining

Milestone (1978) reports that mining of gravel from the Merced River and other Yosemite Valley streams to provide material for construction projects and making concrete dates back to the late 1800s. The total volume of reported sand and gravel removed from the system is 5,649 cubic meters (m^3) and 9,763 m^3, respectively (Milestone 1978). The actual volume of material removed is far greater than the reported values because much of the excavated material used to build bridges, warehouses, miles of valley roads, the Ahwahnee Hotel, and other projects, is not reported in records (Milestone 1978).

1.2.6 Large Wood Removal

Large woody debris (LWD) accumulating in the channel was often removed over the past century to improve flow conveyance and prevent bank erosion that might jeopardize park infrastructure. In the 1930s, the Civil Conservation Corps undertook an extensive channel clearing project. It is reported that in 1934 work crews removed 126 trees, 161 tree stumps, and broke-up 138 log jams over a 1,829 m reach of the Merced River (Milestone 1978). Additionally, it is reported that much of the floating debris that had been accumulating for years in the river was also removed in the same period by the work crews (Milestone 1978).

1.3 Historical Merced River Condition

In addition to the Milestone (1978) study of human impacts on the streams in Yosemite Valley, another major research project was an analysis of bank erosion magnitude and causes on the Merced River by Madej et al. (1994), titled "Analysis of Bank Erosion on the Merced River, Yosemite Valley, Yosemite National Park, California, USA". This research examined channel changes that have occurred on the river from 1919 to 1989 in two study reaches. One of the reaches (upper reach) was a high use area that includes all the major campgrounds from Clarks Bridge to Sentinel Bridge. The second reach (lower reach) was established as a control reach with relatively low visitor use extending 3.5 km downstream of the Sentinel Bridge to the El Capitan Bridge. Channel widths (measured from the break-in-slope between the floodplain and river banks [approximately the 10-year recurrence interval flow elevation]) at 24 cross-sections were measured in the field in 1986 and 1989. The results were compared with 1:2,400 topographic maps with (0.6 m [2 ft]) contour intervals, created by the USGS in 1919, to determine channel width has changed in the two reaches.

Channel width in the upper reach increased by an average of 27 percent, with 23 of 24 cross-sections increasing in width. The greatest change in channel width was an increase of 117 percent. In contrast, in the lower reach channel width increased by an average of 4 percent, with 10 of 21 cross-sections increasing in width. The greatest channel width increase was an increase of 38 percent. Erosion on straight reaches was as common as on meander bends in the upper reach, whereas in the lower reach the greatest erosion occurred on a meander bend, as is common for natural channels.

Madej et al. (1994) investigated the causes for the discrepancy in bank erosion rates between the upper and lower reaches. The soils in both reaches are coarse, sandy loam with low clay content and low cohesive properties, which makes them susceptible to bank erosion and lateral channel movement. As of 1994, over one thousand campsites were within 0.5 km of the Merced River in the upper reach, and a large number of rafters float this section of the river. A strong correlation was found between level of visitor use and bank instability. High use areas were adversely affected by removal of vegetation for camper's firewood and foot trampling. These activities compact bank soils and damage existing vegetation, making it more difficult for new vegetation to establish and bank soils more susceptible to erosion. All of the cross-sections with an increase of 20 percent or more were located in high use areas.

The NPS actively removed large woody debris from the Merced River until 1989 as part of park policy (Madej et al. 1994). An inventory of woody debris pieces with sizes greater than 0.2 m in diameter in the upper and lower study reaches showed that the upper reach had 12 pieces/km compared to 29 pieces/km in the lower reach. Madej et al. (1994) report that the lower volume of woody debris in the upper reach may be contributing to increased bank erosion since woody debris can naturally protect banks from erosive forces and can discourage humans from accessing those areas, thus reducing the potential for compaction and trampling.

1.4 Purpose of Study

The purposes of the study were: 1) to evaluate and determine current riparian, channel, and wildlife habitat condition of a 16 kilometer [km] reach of the Merced River flowing through Yosemite National Park, 2) to describe changes to the riparian corridor and river channel that have occurred since this reach of the Merced River was designated as Wild and Scenic under the under the Wild and Scenic Rivers Act, and 3) to develop and suggest metrics that describe riparian and river condition, which would be used to monitor future trends and to develop natural resource management objectives within the park.

The study relied on recent (summer to winter 2010) field surveys that mapped the riparian corridor, qualitatively assessed the riparian corridor using the California Rapid Assessment Methodology (CRAM), mapped the Channel Migration Zone (CMZ), surveyed the amount and distribution of large woody debris (LWD), and assessed wildlife habitat. Developed in consultation with Yosemite National Park, these field studies will best inform the ongoing development of the Merced Wild and Scenic River Comprehensive Management Plan in the park (see below). The CMZ mapping and LWD surveys also allowed a projection of future channel migration and LWD loading that informed the development of monitoring metrics and restoration and management objectives. The assessment of wildlife habitat was based upon historical and recent studies conducted by the National Park Service and others, and were summarized and analyzed in this report. Data to determine the baseline to evaluate changes to riparian corridor and river channel since Wild and Scenic River designation include previous reports, maps, and aerial photography that documented condition just before or after 1987 (the year of designation). These historical sources were compared to more recent information (when available) and the results of field surveys conducted for this study. This description of changes also includes a summary restoration projects conducted by Yosemite National Park since 1991.The results of the field surveys were integrated to describe river and riparian corridor condition, to identify stressors, and to make restoration and management recommendations.

The information in this report will inform the ongoing development of the Merced Wild and Scenic River Comprehensive Management Plan in Yosemite National Park. That plan will guide the management of the Merced River and South Fork Merced River within Yosemite National Park for the next 20-30 years. The management plan will include an environmental impact statement, which will consider a variety of alternatives for future management of the rivers. A fundamental part of most or all alternatives will be a restoration plan for the river, its banks, Yosemite Valley meadows, and other outstandingly remarkable values in need of restoration action. As with the alternatives to be considered in the EIS, the restoration plan will also utilize the information presented in this report.

Chapter 2
Methods

2.1 Geomorphic Reach Delineation

To facilitate reporting of results and evaluation of discrete sections of river and riparian corridor, this assessment divided the study area into geomorphic reaches based upon channel gradient channel planform (sinuosity), entrenchment, bankfull width, and valley width. The project team determined these characteristics from United States Geological Survey (USGS) topographic maps, light detection and ranging (LiDAR) data from September 2006 (with portions updated in February 2008 using data collected in 2007 for Half Dome area) supplied by the National Park Service and aerial photographs. Geomorphic reach breaks occurred at significant changes in the above parameters and were named using local landmarks.

2.2 Riparian Corridor Mapping

Vegetation communities within the riparian corridor along the Merced River were mapped in the field in September 2010. The vegetation was mapped from approximately Happy Isles Bridge to approximately one km downstream of Pohono Bridge (approximately 16 km). The mapping extended approximately 30m laterally from each stream bank.

The vegetation was categorized according to the Yosemite National Park National Vegetation Classification System (NatureServe 2007). The scheme is based on the United States National Vegetation Classification System, developed as part of a larger effort to standardize vegetation data for each national park (NatureServe 2007). This classification system categorizes vegetation types by overstory cover (e.g., tree, shrub, herb), overstory type (e.g., evergreen, deciduous), and dominant species. In addition, methods included reviewing existing classification systems previously used to develop vegetation maps of Yosemite Valley, including along the Merced River (e.g., Acree 1992; NPS 1992 and 1997).

Vegetation was mapped in the field as polygons on 2009 aerial photographs[2],, with a minimum mapping size of 0.08 hectare (ha)for most upland vegetation and 0.02 ha for riparian and meadow vegetation. Each polygon was assigned a vegetation category following NatureServe (2007). After completion of the field mapping, additional vegetation categories were developed because existing categories in NatureServe (2007) did not describe certain combinations of dominant species found within the riparian corridor. These new categories generally followed those included in the Manual of California Vegetation (Sawyer et al. 2009). For example, shining willow (*Salix lucida*) was dominant on some exposed sand and gravel bars along the Merced River –a community for which NatureServe (2007) does not have a category. A complete list of vegetation categories used in this analysis and a cross-map to Sawyer et al. (2009) and NatureServe (2007) are provided in Table 2-1. The vegetation polygons were subsequently

[2] 2009 aerial imagery was ortho-rectified and polygons were georeferenced during digitizing.

digitized in Geographic Information System (GIS), with the associated attribute data. The area of each community type was determined for the entire study area and for each geomorphic reach.

Table 2-1. Vegetation Types Mapped within the Merced River Riparian Corridor and Comparisons with the Yosemite National Park National Vegetation (NatureServe 2007) and Manual of California Vegetation (Sawyer et al. 2009) Classification Schemes

Map Number	Mapped Vegetation Type	Yosemite Vegetation Key[3]	Manual of California Vegetation[4]	Dominant Species	Notes
0	Bare	400	None	None	Included unvegetated areas, including bars.
1	Canyon Live Oak Forest Alliance	100A.1	*Quercus chrysolepis* Forest Alliance	*Quercus chrysolepis*	Stands with approximately even cover with *Acer macrophyllum*. Sometimes had a second canopy layer of *Pinus ponderosa*. Observed at the western end of the study area.
2	Canyon Live Oak - Whiteleaf Manzanita Forest	100A.1Ab	*Quercus chrysolepis - Arctostaphylos viscida* Association	*Quercus chrysolepis* *Arctostaphylos viscida*	One stand observed on a steep south-facing slope in the western part of the study area.
3	Ponderosa Pine - Incense Cedar Forest Alliance	100A.2Ba.9	*Pinus ponderosa – Calocedrus decurrens* Forest Alliance	*Pinus ponderosa* *Calocedrus decurrens*	Most common forest type observed, occupying areas with different slopes, aspects, and soils. In some cases, *Quercus kelloggii* was abundant, but less than 25 percent cover. Other species that occurred in this type, but do not attain sufficient cover to be considered a different mapped type, included *Quercus chrysolepis*, and *Pseudotsuga menziesii*.
4	Incense Cedar Forest Alliance	100A.2Bc.1	*Calocedrus decurrens* Forest Alliance	*Calocedrus decurrens*	*Calocedrus decurrens* was the only dominant species. Observed in a few relatively small patches in the study area. *Alnus rhombifolia* was sub-dominant in some areas.
5	Douglas Fir - White Fir - Incense Cedar Forest	100A.2Bd.1a	*Pseudotsuga menziesii* Forest Alliance	*Pseudotsuga menziesii* *Abies concolor* *Calocedrus decurrens*	*Abies concolor* was an uncommon vegetation component downstream of the El Capitan bridge. May also include sub-dominant *Pinus ponderosa*.

3 NatureServe (2007)

4 Sawyer et al. (2009)

Table 2-1. Vegetation Types Mapped within the Merced River Riparian Corridor and Comparisons with the Yosemite National Park National Vegetation (NatureServe 2007) and Manual of California Vegetation (Sawyer et al. 2009) Classification Schemes

Map Number	Mapped Vegetation Type	Yosemite Vegetation Key[3]	Manual of California Vegetation[4]	Dominant Species	Notes
6	Douglas Fir - Ponderosa Pine - Incense Cedar Forest	100A.2Bd.1b	*Pinus ponderosa - Pseudotsuga menziesii* Forest Alliance	*Pseudotsuga menziesii* *Pinus ponderosa* *Calocedrus decurrens*	Most commonly observed in the lower reaches of the study area (below El Capitan Bridge). Sub-dominant *Abies concolor* or *Quercus chrysolepis* was occasionally present. Understory variable, but often included *Acer macrophyllum* and/or *Cornus nuttallii*.
7	Dusky Willow Riparian Scrub	100A.2Be	Not described	*Salix melanopsis*	Occasionally, patches of *Populus balsamifera* ssp. *trichocarpa* were intermixed in this type. Occurred on frequently flooded bars and supported open stands.
8	California Black Oak Forest Alliance	100B.1Ba	*Quercus kelloggii* Forest Alliance	*Quercus kelloggii*	One stand of this type was observed, in the vicinity of Bridalveil Falls. Trees are relatively short in stature and the canopy is open. Understory was primarily non-native annual grasses. *Quercus kelloggii* in the study area tended to be intermixed with other forest species.
9	White Alder Forest	100B.2Aa	*Alnus rhombifolia* Forest Alliance	*Alnus rhombifolia*	Co-dominants can include *Cornus nuttallii* and *Quercus kelloggii*.
10	Black Cottonwood Temporarily Flooded Forest Alliance	100B.2Ab	*Populus trichocarpa* Forest Alliance	*Populus balsamifera* ssp. *trichocarpa*	Often occurred on sandy bars and floodplains in pure stands or mixed with *Salix lucida* and/or *Salix melanopsis*. Some areas had an understory of *Carex nudata* and/or *Scirpus microcarpus*.
11	Incense Cedar - White Alder Forest	100C.1B	*Calocedrus decurrens - Alnus rhombifolia* Association	*Alnus rhombifolia* *Calocedrus decurrens*	This type occurred in scattered locations adjacent to mixed conifer forests adjacent to the Merced River.
12	Ponderosa Pine - Incense Cedar – California Black Oak Forest	100C.1Da	*Pinus ponderosa – Calocedrus decurrens* Forest Alliance	*Pinus ponderosa* *Calocedrus decurrens* *Quercus kelloggii*	This Alliance is similar to 100A.2Ba.9, except that *Quercus kelloggii* contributed at least 25 percent cover. *Pseudotsuga menziesii* and *Cornus nuttallii* frequently were present in this mapped type.

Table 2-1. Vegetation Types Mapped within the Merced River Riparian Corridor and Comparisons with the Yosemite National Park National Vegetation (NatureServe 2007) and Manual of California Vegetation (Sawyer et al. 2009) Classification Schemes

Map Number	Mapped Vegetation Type	Yosemite Vegetation Key[3]	Manual of California Vegetation[4]	Dominant Species	Notes
13	Blue Wild Rye Herbaceous Alliance	300A.1Aa.1	*Elymus glaucus* Herbaceous Alliance	*Elymus glaucus*	*Elymus glaucus* was strongly dominant with over 50 percent relative cover. Other species that may be present included *Equisetum* spp. and *Agrostis gigantea*.
14	Wooly Sedge Meadow	300A.1Ab.5	Not Described	*Carex lanuginosa*	*Carex lanuginosa* identification tentative, based on very old flowering material, vegetative material, and literature specific to the Yosemite Valley. *Elymus glaucus* and *Artemisia douglasiana* typically also present.
15	Water	400	Not Described	None	River channel and other areas with water.
16	Douglas Fir- Canyon Live Oak Forest	Not described	Not described	*Quercus chrysolepis* *Pseudotsuga menziesii*	Observed in one location, on a steep north-facing granite slope in the western part of the study area.
17	Shining Willow Riparian Scrub	Not Described	*Salix lucida* Woodland Alliance	*Salix lucida*	Generally in pure stands of *Salix lucida*. Other riparian species may be present in small amounts, particularly *Salix melanopsis*.
18	Blue Wild Rye – Mugwort Herbaceous Alliance	Not Described	Not Described	*Elymus glaucus* *Artemisia douglasiana*	Frequently observed in meadows adjacent to the Merced River. Other common species included *Mentha* ssp., *Agrostis gigantea*, and *Euthamia occidentalis*.
19	Panicled Bulrush Herbaceous Alliance	Not Described	*Scirpus microcarpus* Herbaceous Alliance	*Scirpus microcarpus*	Occurred along bars, in close proximity to water. Also observed as an understory in *Populus balsamifera* ssp. *trichocarpa* Forest Alliance.
20	California Black Oak – Ponderosa Pine Forest	None	*Quercus kelloggii-Pinus ponderosa* Association	*Quercus kelloggii* *Pinus ponderosa*	Occurred in one general location in the vicinity of the Housekeeping Camp. This type is closely tied to Yosemite National Park Classification 100C.1D.

Table 2-1. Vegetation Types Mapped within the Merced River Riparian Corridor and Comparisons with the Yosemite National Park National Vegetation (NatureServe 2007) and Manual of California Vegetation (Sawyer et al. 2009) Classification Schemes

Map Number	Mapped Vegetation Type	Yosemite Vegetation Key[3]	Manual of California Vegetation[4]	Dominant Species	Notes
21	Ponderosa Pine - Incense Cedar - Canyon Live Oak Forest	110A.2Ba. 9b.1	*Pinus ponderosa-Calocedrus decurrens / Quercus chrysolepis – Quercus vacciniifolia* Association	*Pinus ponderosa* *Calocedrus decurrens* *Quercus chrysolepis*	Scattered in xeric portions of the river bank, particularly at the upper and lower reaches of the study area.
22	Dogbane Meadow	None	None	*Apocynum cannabinum*	Relatively pure stands of *Apocynum cannabinum*. Widely scattered on the river bank.
23	Creeping Bent Grassland	None	*Agrostis (gigantea, stolonifera)-Festuca arundinacea* Semi-natural Herbaceous Stands	*Agrostis gigantea*	Low-diversity stands dominated by the non-native species *Agrostis gigantea.*
24	Blue Wild Rye - Creeping Bent Herbaceous Alliance	300A.1Aa.1	None	*Elymus glauca* *Agrostis gigantea*	Common association in meadows.
25	California Black Oak – Incense Cedar Forest	100B.1Ba.1	*Quercus kelloggii-Calocedrus decurrens* Association	*Calocedrus decurrens* *Quercus kelloggii*	Uncommon along the Merced River.
26	Ponderosa Pine - Douglas Fir - Canyon Live Oak Forest	100A.1A	None or *Pinus ponderosa-Pseudotsuga menziesii-Quercus chrysolepis/Galium bolanderi* Association	*Pinus ponderosa* *Quercus chrysolepis* *Pseudotsuga menziesii*	*Pinus ponderosa* and *Pseudotsuga menziesii canopy* over lower stature *Quercus chrysolepis.*
27	Douglas Fir Forest Alliance	100A.2Bd.1	*Pseudotsuga menziesii* Forest Alliance	*Pseudotsuga menziesii*	*Pseudotsuga menziesii* comprised at least 50% of the tree canopy.

2.2.1 Comparison with Historical Riparian Corridor Mapping

The 2010 vegetation map was compared to 1992 and 1997 vegetation maps for Yosemite Valley (NPS 1992, 1997)[5]. The time series was evaluated to identify changes in distribution of vegetation types within the riparian corridor since the time (approximate) of Wild and Scenic designation (1987)[6]. The 1992 vegetation mapping was used as a surrogate for baseline conditions in 1987. The 1992 mapping was conducted after six years with comparatively low annual peak flows (less than 2,310 cubic feet per second [cfs]) (USGS gauging station #11264500, Merced River at Happy Isles Bridge near Yosemite, CA). The 1997 mapping occurred after the January 1997 flood, which was the largest flow on record (1915-2010). Annual peak flows between 1997 and 2010 ranged in magnitude from 1,180 to 5,680 cfs.

The 1992 and 1997 vegetation polygon data were clipped in a geographic information system (GIS) to include the same coverage area along the Merced River as the 2010 mapping. The 1992, 1997, and 2010 mapping efforts used different classification schemes that could not be directly cross-mapped. Therefore, the vegetation classifications that were used for each of the three vegetation maps were simplified into six broad categories to show changes in the distribution of community types within the riparian corridor dominated by upland, riparian (e.g., cottonwood, alder, or willow), and meadow species; and bare areas (e.g., bars), as follows:

1. Bare (including oxbow and cutoff channels)
2. Oaks and Conifers[7]
3. Meadow
4. Cottonwood[8]
5. Alder (including mixed with big leaf maple and conifers)[9]
6. Willow Riparian

The 1992, 1997, and 2010 vegetation communities that were included within each of these broad categories are provided in Appendix B.

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[5] The minimum patch sizes mapped in 1992 and 1997 within the riparian corridor (30 meters of each stream bank) were 0.06 ha and 0.16 ha, respectively.

[6] The 1992 vegetation mapping was used as a surrogate for the 1987 vegetation community conditions (baseline conditions). These data were developed from interpretation of 1990 aerial imagery with ground-truthing in 1992 (NPS 1992).

[7] Upland species, including both oaks and conifers, were grouped into one category because when oaks and conifers were evaluated as separate categories, substantial changes in cover between 1992 and 2010 occurred. Substantial changes in cover between oaks, conifers, and mixed oaks and conifers are unlikely as most of the species are long-lived. The differences observed were more likely due to differences in the specific classification schemes for the upland species, mapping scales and methods, and sub-dominant species.

[8] The Black Cottonwood Temporarily Flooded Forest Alliance vegetation type in the 1997 and 2010 mapping included pure stands of cottonwoods or were mixed cottonwoods with willows. Stands that were dominated by willows were classified in one of the willow vegetation types (refer to Table 2-1).

[9] Big leaf maple was included with alders because alders and big leaf maples were classified in one community type in the 1997 classification system. They were classified as separate communities in the 1992 and 2010 classification systems.

In 1992, areas with oxbows or cutoff channels were classified as Oxbow and Cutoff Channels. In comparison, the vegetation that was present within these areas in 1997 and 2010 (e.g., willows, meadows, black cottonwoods, or oaks/conifers) was mapped as vegetation community types. To provide a more accurate comparison of changes in vegetation composition and bare area within the study reach over time, these areas were not included in the calculation of the total area of the vegetation types. Vegetation communities types mapped within these features in 1997 and 2010 were compared.

The proportion of area within each of the above six categories was then compared for each year (1992, 1997, and 2010) and summarized for the entire study area and by each geomorphic reach. Two maps series were developed in GIS that compared the (1) 1992 and 1997 vegetation data and (2) 1997 and 2010 vegetation data (Appendix A, 1992 to 1997 and 1997 to 2010 Riparian Vegetation Map Series). It is important to note that changes in the proportion of area within each of the categories between the years could also reflect artifacts in the differences in mapping methods and/or classification of sub-dominant species. Although the 1992, 1997, and 2010 vegetation community types were simplified into broader community categories, these categories were developed to be able to identify trends in the overall distribution and relative proportion of upland communities; riparian (cottonwood, willow, alder species), meadow communities, and bare areas) in response to management decisions.

2.3 Riparian Vegetation Condition Assessment

The riparian corridor along the Merced River was assessed following the California Rapid Assessment Method (CRAM) for unconfined riverine riparian areas (Collins et al. 2008a, 2008b**)**. The CRAM is a rapid, standardized assessment method that provides information on the overall condition and functional capacity of the riparian corridor and the stressors that may be affecting it. This information can be used to identify reaches and metrics/attributes in poorer condition that may require more intensive and quantitative studies to identify the factors that may be limiting the functionality of the riparian corridor, and to help prioritize and plan river and riparian management and restoration activities. The CRAM also provides a means of comparison for monitoring status and trends in the condition of the riparian corridor over time. The assessment was conducted concurrently with the vegetation community mapping described in Section 2.2.

The study area was divided into assessment areas (AAs). The sizes of the assessment areas were determined as described in Collins et al. (2008a). Laterally, the AAs extended outward from the channel to include the area adjacent to the channel with potential for direct woody and vegetation inputs into the channel. The preferred length of a riverine AA is ten times the bankfull width. However, the maximum length of an AA should not exceed 200 m because larger AAs may bias the results. A number of the attributes are sensitive to structural complexity, which increases with larger areas. Within the study area, the bankfull width is approximately 47 m (based on evaluation of 243 cross-sections). Therefore, the AAs within the study area were generally 200 m in length. Except for a few that were shortened due to proximity to man-made structures, AAs were of nearly uniform length to reduce potential variability in the CRAM scores. If a riparian area is approximately twice as large as the preferred size of an AA (i.e., 200 m for riverine areas) and the purpose is to assess the average condition of the riparian corridor, then one of the AAs is assessed and the results are reported for the entire area (Collins et al. 2008a). To ensure reasonable coverage and even distribution along the river corridor, AAs were surveyed along alternate sides of the river approximately every 200 m. For example, if one AA was surveyed on the north bank, the two adjacent surveyed AAs were on the south bank. The CRAM score was then reported for both sides of the river. A total of 81 AAs were surveyed. The locations of the AAs are shown in Appendix A (CRAM Assessment Area Map Series).

The CRAM includes the evaluation of four main attributes and fourteen metrics to assess the overall condition of the riparian corridor. The Buffer and Landscape Context Attribute is evaluated from the assessment of four metrics:

- **Landscape Connectivity**: Longitudinal continuity of the riparian corridor
- **Percent of AA with Buffer**: Percent of the area around the AA that is in a natural or semi-natural state and would protect the AA from stress and disturbance that would adversely affect buffer functions
- **Average Buffer Width**: Distance to the nearest non-buffer land cover (e.g., parking lots, development, multi-lane roads, heavy use and wide pedestrian trails)
- **Buffer Condition:** Extent and quality of vegetation cover, overall condition of substrate, and intensity of human visitation

The Hydrology Attribute is evaluated from the assessment of three metrics:

- **Water Source**: Unnatural or impairment of dry season flow conditions
- **Hydroperiod or Channel Stability**: Degree of channel aggradation or incision, and extent of revetment within the AA
- **Hydrologic Connectivity**: Degree of channel entrenchment (entrenchment ratio calculation)

Structure is evaluated based on the evaluation of Physical and Biotic Structure Attributes. The Physical Attribute is determined from the assessment of two metrics:

- **Structural Patch Richness**: Number of different types of physical features or surfaces (patch types at least 3x3 m in size) that may provide habitat
- **Topographic Complexity**: Overall variability in micro- and macro-topographic relief that may affect moisture gradients and/or flow paths

The Biotic Structure Attribute is determined from the assessment of five metrics:

- **Number of Plant Layers** Present: Number of plant layers (aquatic layer, short vegetation [<50 centimeters (cm) in height], medium vegetation [50-75 cm in height], tall vegetation [75-150 cm in height], or very tall vegetation [>150 cm in height]) that cover at least 5 percent of the area within the AA
- **Number of Co-Dominant Species**: Number of species by plant layer that cover at least 10 percent of the area within the AA

- **Percent Invasion**: Percentage of the co-dominant species that are invasive species (as determined by Cal-IPC [2006])
- **Horizontal Interspersion or Zonation**: Number of multi-species associations and amount of edge between them
- **Vertical Biotic Structure**: Degree of overlap among the plant layers

Each metric was evaluated by choosing the set of narrative descriptions best describing observed conditions from a list of four ranked alternative conditions that are specified in the CRAM manual (Collins et al. 2008a). The set of descriptions for each metric evaluates conditions on an "A" to "D" scale from the "best achievable" to the "worst commonly observed". The narrative descriptions for each metric were developed for the CRAM to describe the full range of possible conditions[10]. An overview of each attribute and metric and the scoring process for each metric are provided in Appendix C.

CRAM also specifies guidelines for identifying stressors that might account for low scores. The datasheets and checklists for identifying stressors from Collins et al. (2008b) are also provided in Appendix C.

Prior to the field effort, aerial photography; maps of the study area (including road maps, USGS quadrangle maps, National Wetland Inventory [NWI] maps, and previously developed vegetation maps [e.g., NPS 1992,1997]); and other relevant background information provided by that NPS were reviewed. The metrics were evaluated following the protocols outlined in Collins et al. (2008a, 2008b), with two modifications. First, the entrenchment ratio was determined for three cross-sections within each AA using LiDAR in combination with channel cross-section data, rather than field surveys across the entire valley bottom. The methodology for calculating the entrenchment ratio is described in Appendix D. Second, data collected as part of the other studies completed for this report were also used to supplement the data collected for the CRAM, including locations of rip rap and bank erosion.

The letter scores for each metric were converted to whole integer scores to calculate an overall "CRAM score" for each AA (on a scale from 0.27 to 1.00). The score is an indication of the overall condition of the riparian corridor relative to the best achievable conditions for riverine riparian corridors in California. Higher scores indicate that the AA is in better condition, while lower scores indicate that it is in poorer condition. Due to differences in geomorphic setting, river characteristics, recent and historical flow regime, successional stage, and stressors, it is unlikely that the same overall CRAM scores in two different AAs represent the same condition of the different metrics (Collins et al 2008a). Therefore, the four attribute scores and each metric score, in addition to the overall CRAM scores, were examined to evaluate the current condition of the riparian corridor and to identify metrics that would help focus management efforts and that may be useful for defining desired riparian corridor conditions.

[10] See Collins et al. (2008a) for more information the developmental framework of the CRAM, including development of the narrative descriptions, calibration of the metrics, and validation of the overall performance of the CRAM.

To identify the AAs that were in comparatively "higher" and "lower" overall condition, the distribution and range of scores within the study reach were examined. Specifically, the top and bottom 20th percentiles of the overall CRAM scores were calculated, and the AAs with overall CRAM scores that exceeded the top 20th percentile were categorized as "higher", and AAs below the lowest 20th percentile were categorized as "lower." The other AAs were categorized as "moderate" condition. Within each of these overall categories (higher, moderate, or lower), the scores ("A" to "D") of the different metrics were examined, as follows.

- Metrics that were typically in good condition within all the AAs (e.g., "A" rating) and varied little among the AAs, regardless of the overall CRAM score were identified. These metrics would not explain differences in the overall condition among the AAs, and likely would change little over time (unless future management decisions adversely impact the metric).
- The metrics that were typically in good condition (e.g., "A" or "B" score) in the AAs with "higher" overall CRAM scores and in poorer condition (e.g., "C" or "D" score) in the AAs with "lower" overall scores were identified. These metrics would be good determinants of the overall condition of the AAs, could be evaluated in further detail to determine limiting factors, and used to help focus management and activities in the reaches in which the scores were lower. Improvement of these metrics in response to management or restoration could also be monitored over time.

The overall CRAM condition and metrics identified as strong determinants of overall CRAM condition were mapped in GIS within the study area. The results were also evaluated for each geomorphic reach, and were examined further to identify potential trends in the CRAM scores in relation to bridges or proximity to recreation facilities or roads.

2.4 Channel Migration Zone Mapping

The Channel Migration Zone (CMZ) describes current channel condition and evaluates the extent of potential future lateral erosion and channel avulsion within the next 100 years[11] along the Merced River within Yosemite Valley from approximately Happy Isles Bridge to approximately one km downstream of Pohono Bridge (approximately 16 km). The future condition was used to develop restoration and management recommendations in Chapter 5.5. In addition to the Merced River, the CMZ for Tenaya Creek from the confluence with the Merced River upstream to Tenaya Creek Bridge on Mirror Lake Road was also delineated as part of this study. Areas that may erode via chronic (e.g., channel migration, bank erosion) or episodic (e.g., channel avulsion) processes were identified, classified (Rapp and Abbe [2003]), and mapped into four main categories as follows:

1. **Historic Migration Zone (HMZ) –** current and historic channel locations
2. **Avulsion Hazard Zone (AHZ) –** area prone to channel avulsion (not including the HMZ)

[11] Selection of a 100-year time period for the CMZ analysis represents a relatively short period of time for geomorphic processes.

3. **Erosion Hazard Area (EHA) –** prone to bank erosion or mass wasting (not including the HMZ and AHZ)
4. **Valley Alluvium (VA) –** area composed of alluvium from the Merced River and its tributaries (not including the HMZ, AHZ, and EHA)

Within each of these categories, two sub-categories were identified and mapped:

1. **Disconnected (D) Migration Areas -** These are areas in which facilities or roads are located within areas susceptible to erosion and are currently not protected by revetments, but would likely be protected should they become at immediate risk from channel migration. Areas identified as "Disconnected" Migration Areas were designated with a "D" (e.g., DEHA, DAHZ, and DVA).

2. **Protected Disconnected (PD) Migration Areas –** These are areas where human-made structures (e.g., revetments) prevent channel migration and disconnect portions of the floodplain from the CMZ. These areas represent erosion risk areas and are constraints on natural channel migration. Areas identified as "Protected Disconnected" Migration Areas were designated with a "PD" (e.g., PDEHA, PDAHZ, PDVA).

The key data used to develop the CMZ delineation included current and historic aerial photographs and maps, as well as LiDAR topography obtained from the NPS (Table 2-2). Additional data used included USGS topographic, geologic and hazard reports and maps (Wieczorek et al. 1999; Peck 2002). These data were supplemented with field surveys that included identification and mapping of revetment locations, bedrock outcrops, fluvial landforms, surficial geology, and channel bank conditions.

Table 2-2. Dates of aerial photographs, maps, and LiDAR used in CMZ delineation

Aerial photographs	1944, 1987, 2005, 2009
Historic maps	1878, 1888, 1912, 1919, 1920, 1934, 1962
LiDAR	2006

In order to project potential future channel conditions over the next 100 years, several assumptions were been made in the development of the CMZ delineation, including 1) sediment and wood flux through the river system will not change significantly, 2) hydrologic conditions will not change peak flows significantly, 3) locations where bank protection is currently present will be maintained, 4) no additional bank protection will be installed, 5) all bridges will be maintained, 6) the Yosemite Valley Loop Road and roads over bridges will be maintained, 7) the future migration rates will be similar to those of the past, and 8) current land use will not change.

Hazards associated with the CMZ zones include lateral bank erosion and channel avulsion. Existing infrastructure (roads, bridges, buildings, utilities, etc) as well as natural resources (riparian forests, meadows, side channels, wetlands, in-stream habitats, etc) represent features within the park that may be exposed to these hazards. The risks associated with the CMZ areas delineated are a function of the probability of the hazard occurring and the value of the feature impacted. The probability of a hazard occurring within the HMZ, AHZ, and EHA is moderate to high, and low within the VA and Disconnected and Protected Disconnected areas (assuming they remain disconnected). Because the distribution of park features were not part of this analysis, the risk associated for any given area was not determined. However, because features are present throughout the mapped CMZ, any change in the probability of a hazard occurring results in a subsequent change to risk.

2.4.1 Historic Migration Zone (HMZ)

The HMZ is the area the channel has occupied over the course of the historic record (1878-2009). To determine this area, the channel margin was digitized in GIS on each of the historic aerial photographs and maps (Table 2-2). The channel margin was identified as the top of bank on either side of the channel to provide a consistent feature for comparison between historic aerial photographs and maps (rather than the wetted channel). Once completed, all of the digitized historic channel alignments were overlaid and the outer-most extent was delineated as the HMZ.

Several limitations to this analysis include: 1) rectification accuracy of the aerial photographs and maps (how well they align), 2) resolution of the aerial photographs and maps, 3) obstruction of channel banks due to overhanging vegetation, and 4) time period over which data were available. In order to mitigate these limitations, the rectification accuracy of the aerial photographs and maps were evaluated to ensure alignment of static features (such as road intersections, buildings, bridges). Where overhanging vegetation on the aerial photographs obscured channel banks, the topographic maps (1934) were used to identify the channel margins in areas with no significant channel migration.

2.4.2 Avulsion Hazard Zone (AHZ)

The Avulsion Hazard Zone lies beyond (i.e., farther away from the channel perimeter) the Historic Migration Zone. These areas typically include secondary and relic side channels, areas within tight meander bends, and swales/depressions within the adjacent floodplain that represent historic channel locations prior to the earliest data used for the HMZ delineation. The AHZ was delineated using the methods described below, and verified during field surveys.

A terrain analysis was conducted using the LiDAR topographic dataset to identify areas within the river corridor with the potential for avulsion. The LiDAR topographic dataset was processed to re-define the vertical datum from mean sea-level to the water surface of the river. By adjusting the datum of the LiDAR to the river water surface, fluvial features on the adjacent floodplain were more readily identifiable and their position relative to the water surface elevation is relatively easy to determine. The methodology for making the datum adjustment followed Jones (2006). The resulting topographic dataset (a height above water surface [HAWS]); with floodplain elevations relative to the adjacent channel is shown in Appendix A, HAWS Map Series. Secondary and relic side channels and historic channel alignments prior to the earliest aerial photographs and maps were readily identifiable using the HAWS dataset (Table 2-2). The local width of the mainstem channel was superimposed over the floodplain feature (side channel or depression) to determine the potential occupation area of the new channel following avulsion. This area, including and between these features and the HMZ, were delineated as the AHZ.

2.4.3 Erosion Hazard Area (EHA)

The Erosion Hazard Area is adjacent to the HMZ and AHZ with the potential for lateral bank erosion via stream flow and/or mass wasting initiated by fluvial processes. Historic channel alignments digitized for determining the HMZ were used to evaluate bank erosion potential. The distances between bank positions of the channel alignments were measured. Dividing the measured distance by the number of years between the digitized channel alignments yields an average migration rate over time. This analysis was performed at 16 locations to establish a typical migration rate for local geomorphic reaches where erosion was observed to have occurred by comparing sequential aerial photographs (Table 2-3). The migration rates were then projected to 100 years to determine the local EHA width. Revetments along the channel banks can obscure historic migration rates measured from sequential historic aerial photographs, as further erosion is limited. Because locations where significant erosion has taken place are more likely to be protected with revetments, historic migration rates were determined over the time period that erosion occurred. For example, a bank that eroded 10 m over 2 years and then did not erode to the next 40 years would have a migration rate of 5 m/yr, and not 0.2 m/yr.

In addition to the projected migration width from observed historic erosion, historic fluvial landscape features found adjacent to the HMZ and AHZ from the HAWS mapping are included within the EHA. Inclusion of these areas forms an envelope encompassing the channel planforms, which by definition must have a width greater than the planform amplitude it envelops, since those forms migrate within the CMZ (assuming no geologic control).

Table 2-3. Erosion rates used as part of the EHA delineation

Location (river kilometer) / Geomorphic Reach	Measured Erosion (m)	Time Period Erosion Occurred	Migration Rate (m/yr)
208.5 / Happy Isles	35	1944 - 1987	0.81
206.6 / Below Tenaya	22.5	1934 - 1944	2.3
206.6 / Below Tenaya	12.3	1944 - 1987	0.29
206 / Below Tenaya	33.4	1944 - 1987	0.78
205.7 / Upper Meadows	34	1944 - 1987	0.79
205.3 / Upper Meadows	59	1944 - 1987	1.4
205.2 / Upper Meadows	41.5	1944 - 1987	0.97
204.6 / Upper Meadows	11.4	1944 - 1987	0.27
204.1 / Upper Meadows	23.3	1944 – 1987	0.54
203.8 / Upper Meadows	64	1944 – 1987	1.5
203.7 / Upper Meadows	35.1	1934 – 1944	3.5
203.3 / Upper Meadows	31.9	1934 - 1944	3.2
203.3 / Upper Meadows	22.8	1944 - 1987	0.53
202.4 / Upper Meadows	29.6	1934 - 1944	3
202.4 / Upper Meadows	32.3	1944 - 1987	0.75
201.1 / Inter-Meadows	23.8	1944 - 1987	0.55
199.8 / Lower Meadows	56.6	1944 - 1987	1.3
198.4 / Lower Meadows	41.9	1944 - 1987	0.97
196.3 / Above Pohono Bridge	22.8	1934 - 1944	2.3
196.3 / Above Pohono Bridge	41	1944 - 2005	0.67
196.1 / Above Pohono Bridge	28	1944 - 1987	0.65

2.4.4 Valley Alluvium (VA)

The VA is the area outside of the HMZ, AHZ, and EHA with a low potential for avulsion and/or lateral erosion. The boundaries of the VA were taken from geologic (Peck 2002) and hazard (Wieczorek et al. 1999) reports and maps. The Qal (Holocene alluvium) at the base of the Yosemite Valley was digitized from 1:62,500 geologic maps (Peck 2002). This unit represents gravel, sand, and silt deposited by the Merced River over recent geologic time. More detailed geologic mapping defining rock-fall hazard areas (Wieczorek et al. 1999) informed refinement of the VA boundary. A more detailed boundary between the valley alluvium and colluvial deposits along the valley margin was used to refine the VA boundary.

2.4.5 Disconnected and Protected Migration Areas

The intent of defining the Disconnected and Protected Disconnected Migration Areas was to demonstrate the impact of structures on fluvial processes, such as bank erosion and channel migration. For this analysis, the project team assumed that structures causing disconnection (existing channel revetments, existing bridges over the Merced River, and the Yosemite Valley loop road and roads over bridges) would be maintained over the 100-year timeframe of the CMZ.

After the HMZ, AHZ, and EHA were delineated, the Disconnected and Protected Disconnected Migration Areas were identified and mapped. The analysis assumed that structures in the areas classified as Disconnected Migration Areas would be protected from erosion should the river migrate laterally and threaten to undermine the structures. These areas are at risk from channel migration should any of the structures no longer be maintained at some time in the future. Disconnected Migration Areas were included in the CMZ area.

Protected-Disconnected Mitigation Areas were not considered to be part of the CMZ, and therefore were not included in the CMZ area. These areas are shown on the CMZ maps. Disconnected and Protected-Disconnected Migration Areas are prime locations to consider for restoration.

The total area of each type of CMZ area and the percentage of each type of CMZ of the total area for the entire study reach and by geomorphic reach were determined. In addition, the total area of Disconnected and Protected Disconnected Migration Areas was calculated for the entire study reach and for each geomorphic reach.

2.4.6 Historical Channel Alignments

Changes in channel form, alignment, and channel width were compared in aerial photographs from before (1934, 1944, and 1987) and after (1987, 2005, and 2009) the Wild and Scenic designation. The same historic channel alignments that were digitized for the CMZ analyses were used for this comparison. The results of this analysis are presented in Section 4.2.

2.5 Actual and Potential Wood Loading

2.5.1 Actual Wood Loading

The project team (two-person field crew) mapped large woody debris (LWD) in fall 2010 over a 16 km reach of the Merced River, extending from the Happy Isles Bridge to approximately 1.5 km downstream of Pohono Bridge. The location along the channel (longitudinal) and position within the channel (cross-sectional) of each piece of LWD was documented within the study area using a Trimble GeoXT GPS with sub-meter accuracy. A piece of wood had to have a minimum size of 5 m long and 0.2 m diameter at breast height (DBH) to be counted. Pieces with dimensions smaller than this were ignored in the inventory. The size criteria are similar to the >0.25 m diameter criteria used in Madej et al. (1994), and other LWD inventory studies (Fox 2001, Fox and Bolton 2007). Wood pieces smaller than this size are less likely to play a key role in influencing channel morphology and habitat creation.

The crew members walked along opposite sides of the river channel to inventory and map wood within the channel. All observed wood that met the minimum size requirements within the bankfull elevation of the main or side channels was recorded. This included wood in the low-flow channel, on unvegetated and vegetated bars, on mid-channel islands, and on the floodplain that partially extended into the bankfull channel. Since the inventory was performed during low-flow conditions in the fall, most of the wood in the channel was observable from the stream banks or by wading out into the channel. It is estimated that the bed of the channel was visible in over 90 percent of the channel within the study area. It was not possible to observe and record any wood that may have been present in the deepest pools (approximately 10-15 locations within the study area). If wood was observed within these inaccessible pools, information on the wood that could be collected from a distance was recorded. At locations where multiple pieces of wood were combined to form large wood jams, data were collected to map and describe the key member of the jam. The number, dimensions, and stability of the other pieces forming the jam were recorded in field notebooks. Photographs were taken of notable wood jams or other pieces of wood exhibiting unique characteristics.

A GPS data dictionary was created to standardize the information collected at each piece of LWD inventoried. The data dictionary included detailed categories that prompted the user to describe multiple characteristics, such as the morphology of the river where the wood was located, the dimensions and other physical properties of the wood, the wood's orientation, stability, and influence on channel form and processes. The data dictionary was developed to not only aid in spatially describing the volume of wood in the river, but to also provide additional knowledge of how the wood was interacting with other river processes. The following is a description of the key parameters in the 18 categories of the data dictionary and how the parameters were evaluated in the field.

- Category 1: Channel Characterization – The morphology of the channel reach containing the inventoried LWD was described by noting bankfull widths (measured from top-of-bank to top-of-bank), the presence of point bars, mid-channel bars, and islands, and by noting any obvious evidence of channel instability in the form of aggradation or incision or accelerated bank erosion. Channel widths were not measured at every piece of wood inventoried. Instead, approximately every 200-300 feet a rangefinder was used to measure the width. This was done mostly to ground truth the LiDAR topographic data from which channel dimensions can also be determined.
- Category 2: Piece Location – The location of the wood was described as being in the channel's water, on a bar, and whether or not it was attached to or touching a bank.

- Category 3: Piece Type – Record whether the wood had an attached rootwad or was a rootwad without a log.
- Category 4: Piece Dimensions – The circumference of rootwads were determined by estimating the length along four radial axes originating from the center of the rootwad. The basal diameter of the log was measured just above the rootswell and the tip diameter of the log and the length of the log were measured to obtain an approximate volume of the piece of wood.
- Category 5: Wood Buried – The percentage of the rootwad and/or log end of the wood that was buried was recorded.
- Category 6: Decay Class – This category describes the state of decay of the wood to estimate how long it has been since the tree died. Descriptions range from a live tree in the channel to older wood with extensive rot.
- Category 7: Species – The species type was noted if it could be identified.
- Categories 8 and 9: Horizontal and Vertical Orientation to Flow – The orientation of the wood in relation to flow and the ground was described.
- Categories 10 and 11: Recruitment Mechanism and Origin – The method of delivery of the wood into the system was recorded if it was clear to define. The most easily defined mechanisms were bank erosion, where it was obvious the wood fell into the channel when the bank eroded, and fluvial transport that moved the wood from its source to its current location in the river. Otherwise, "unknown" was checked if the method was not clear. If the tree was located where it fell, then it was recorded.
- Category 12: Cut Log – Logs that had been cut were recorded.
- Categories 13 and 14: Association and Key Piece – The number of other logs meeting the minimum size requirements in contact with the inventoried log was recorded. If the inventoried log was a key piece adding to the stability of the other logs, then it was noted.
- Category 15: Stability – This category gathers information to describe the stability of the log, and if stable, the reason for the stability, such as the log buried in the bed or bank or pinned by another log, rock or bridge.
- Category 16 Percent within Bankfull Channel (percent of length) – Since the LWD inventory only included wood connected to the bankfull channel, in most cases 100 percent of the logs were within the bankfull channel. Exceptions included logs on the floodplain with only a portion of the total length extending over the bank into the bankfull channel.
- Category 17: Wood Influence on Channel – Two potential influences on channel morphology were noted. If a log was associated with or the cause of pool formation, then the dimensions of the pool were noted. Also, if the log was associated with sediment trapping and bar development, then the nature of the bar was recorded.

- Category 18: Trapping Small Wood Debris – If the log was trapping debris of sizes too small to be inventoried as individual logs, then the volume of trapped debris was estimated.

Wood loading and characteristics of the LWD were evaluated for the study area and by geomorphic reach. Specifically, the total number of pieces and number of pieces per 100 m of channel were determined. General trends in the LWD recruitment (how the piece arrived at its channel position), association (occurring within a logjam [three pieces or greater], touching another piece or occurring as a single piece), role in pool formation, and location within the channel were identified and described.

Wood loading in the Merced River through Yosemite Valley was then compared to wood inventory data from other regional rivers (e.g., from northern California and Washington State). However, these rivers have a wider range of channel sizes and different forest types compared to the Merced River. The 2010 wood loading data (number of pieces per km) were also compared to LWD survey data from 1994 (Madej et al. 1994) collected in two of the same reaches to determine trends in LWD loading since the Wild and Scenic Designation and changes in LWD management.

2.5.2 Potential Wood Loading

Geomorphic processes leading to future channel migration will recruit additional large woody debris as trees are undermined and fall into the active channel. The areas of the Merced River fluvial system within the study area with the potential to provide large woody debris in the future were determined from the results of the CMZ delineation and were used to develop restoration and management recommendations in Chapter 5.5. The amount of future potential LWD within the area delineated as part of the CMZ was determined through a series of GIS processes, supplemented with field data. Wood volume estimates were calculated using the equation for the volume of a conical frustum (Equation 2-1), using the DBH as the basal width and positing 0.1m for the tip width:

$$V= (\pi*h) / (3*(d^2 + t^2 + dt)) \qquad (2\text{-}1)$$

where V is volume; h is height; d is basal diameter; t is tip diameter.

To determine the height (h) of the potential sources of LWD, the LiDAR topographic dataset (provided by NPS) was processed to show both a “first return” terrain model and a “bare earth” terrain model. The “first return” terrain model was developed using the elevation of the first return of each datapoint acquired during the LiDAR flight. The “bare earth” terrain model was developed using the elevation of the last return of each datapoint acquired during the LiDAR flight. The first return represents the highest/tallest object the LiDAR laser pulse hit as the beam was shot from the airplane. The last return represents the lowest object the LiDAR laser pulse hit. In vegetated areas, the first return elevation is the top of the tree canopy, and the last return elevation is the ground. By subtracting the “bare earth” (last return) terrain model from the “first return” terrain model, a new terrain was generated of the vegetation height.

Vegetation heights were classified into the categories listed in Table 2-4. Within each of these height classes, the area for individual trees was measured in GIS and an average canopy area by height class was calculated. A typical DBH (d) was defined for each height class based on field observations and considering the variability within species and local environmental drivers.

The calculated volume (V) represents the estimated volume for an area equal to the measured average canopy area. The measured volume was divided by the typical canopy area (in ha) to determine the volume per ha for each height class. The wood volume per ha was then multiplied by the area (ha) of each CMZ to determine the potential wood recruitment volume from each CMZ area. Further summaries by geomorphic reach were calculated.

Table 2-4 Metrics Used for Determining Wood Volume Estimates from LiDAR Data

Tree height class (m)	Average individual tree canopy area (m^2)	Average DBH (m)
5-10	25	0.15
10-15	25	0.2
15-20	36	0.3
20-25	30	0.4
25-30	30	0.6
30-40	36	1
40-50	64	1.5
>50	100	1.75

2.6 Wildlife Habitat Assessment

2.6.1 Review and Summary of Historical Wildlife Investigations Conducted in the Study Area

A review of past investigations and studies pertaining to wildlife presence/absence and possible habitat condition was conducted for the study area. A general summary of the findings of these investigations is provided in Section 3.6.1. The summary is limited to specific wildlife taxa due to their known sensitivity to ecosystem disturbance and to provide a consistent foundation of information for comparison with the data collected in 2010 by the NPS described in Section 2.6.2. The discussion will be limited to amphibians and reptiles, birds, and bats occurring in the Yosemite Valley.

2.6.2 Review and Analysis of National Park Service Wildlife Condition Assessment

The NPS conducted a wildlife assessment during 2010 in order to characterize the present ecosystem related to the Merced River and to assess habitat integrity (Espinoza et al. 2010). Additional details are contained in the NPS Wildlife Condition Assessment for the Merced River Corridor in Yosemite Valley (Espinoza et al. 2010). The objectives of the study were to:

- Model predicted occurrence of wildlife species in the riparian and meadow habitat adjacent to the Merced River in Yosemite Valley using California Wildlife Habitat Relationships (CWHR) models and validation tools;
- Conduct surveys for amphibians, reptiles, birds, and mammals to test the CWHR models;
- Characterize the wildlife communities using existing datasets and additional surveys; and
- Assess the health of the Yosemite Valley riparian and meadow habitats in relation to wildlife focal species.

2.6.2.1 Summary of NPS Wildlife Assessment Methods

Amphibian, Reptile, and Invasive Aquatic Species Surveys

Two sets of Visual Encounter Surveys (VES) for amphibian, reptile, and invasive aquatic species were conducted using standardized protocols described by Crump and Scott (1994). VES were conducted during July and September 2010. Two crew members performed the surveys along twenty-seven (27) 100-m transects located within randomly established permanent visitor use monitoring plots located on the north side of the Merced River within a 0.25 km buffer of the river corridor (Appendix A, Wildlife Observation Points Map). All data, including date, time, transect, wind speed, air temperature, water temperature, cloud cover, species, and number of individuals per species were recorded on standardized data sheets. No substrates or cover objects were moved during the surveys. Both living and dead individuals were recorded. Incidental detections of amphibian, reptiles, and invasive aquatic species detected within the river corridor were also recorded along with the latitude and longitude of the locations. Additional details regarding specific survey methods are included in Espinoza et al. 2010.

Bird Surveys

Three sets of bird surveys were conducted at 26 of the 27 established visitor use monitoring plots during the 2010 breeding period (May 15-July 31) using standardized point count protocol for monitoring landbirds (Ralph et al. 1993 and Nur et al. 1999). Site 006 was not surveyed for birds. The point count protocol involves an observer standing in one spot and recording all birds seen or heard. Each set of surveys were spaced at least 10-days apart and involved conducting a set of point count surveys at the center of pre-established vegetation plots. Surveys began fifteen minutes after local sunrise and were completed within four hours (no later than 10 am). All data, including date, time, point count location, species, number of individuals per species, and distance from observer were recorded on a standardized data sheet. All points were projected in GIS for facilitating site standardization among researchers. Between visits, NPS alternated transects and survey direction in order to reduce sample bias. Additional details regarding specific survey methods are included in Espinoza et al. 2010.

Bat Surveys

Acoustic surveys were conducted at two locations within the Merced River Corridor in Yosemite Valley (Yosemite Creek and North Pines Campground) during June and July 2010 to determine bat species presence/absence, composition, and activity. SonoBat™ bat detectors were mounted on trees and secured in a locked cash box. The detectors were positioned to face forest openings to increase detection probability of foraging bats. Echolocation call data from each site were analyzed using the batch process option in SonoBat™ and then reanalyzed using the manual option for species confirmation. Bat calls were also compared to reference bat calls for species identification using SonoBat™. Additional details regarding specific survey methods are included in Espinoza et al. 2010.

Wildlife Habitat Relationships Modeling

The NPS used a three-step process (conservative approach) for generating species lists for the Merced River Corridor within Yosemite Valley.

- Habitat types were determined using the park's GIS vegetation map (Aerial Information Systems 1997);

- The California Department of Fish and Game's California Wildlife Habitat Relationships System Software (2008) was used to run Wildlife Habitat Relationships models; and
- Professional judgment was used to edit the species lists; drawing on knowledge of the natural history of the species, the habitat, observations made as part of past and current NPS research, anecdotal observations from the Yosemite Wildlife Observation Database (WOD 2010), and previous park research.

Two relevant habitat types (montane riparian and wet meadow) were used to generate two community-level matrix models associating wildlife species to a standardized habitat classification scheme that included all available elements and included all seasons. Each species was assigned the "arithmetic" average suitability for each habitat type, status, and source (if relevant). Suitability refers to "predicted density and frequency of occurrence" and was indicated as low, medium, or high suitability for the two habitat types (Espinoza et al. 2010). The NPS included the source of all species that have been observed and documented by a research study or anecdotal sighting in the study area. All observations were included regardless of the date of observation or a validation of the observation. The NPS identified special status species as those that are: listed by the United States Fish and Wildlife Service (USFWS) as endangered, threatened, proposed, or candidate; listed by the State of California as endangered, threatened, candidate, a species of special concern, or fully protected, or are listed as California Bird Species of Special Concern (Espinoza et al. 2010).

Data sources included:

- California Natural Diversity Database (CNDDB) – a database maintained by the State of California's Natural Heritage Program (CDFG 2010).
- Museum of Vertebrate Zoology (MVZ) Collections Database – includes all specimens housed at the museum (U.C. Berkeley 2010).
- Wildlife Observation Database (WOD) – includes all observations of wildlife in Yosemite National Park that are submitted by park staff, researchers, and members of the public (WOD 2010).
- NPS field surveys conducted in 2010 (Espinoza et al. 2010).
- Birds of Yosemite (BOY), Gaines 1992 – an all-encompassing textbook of species accounts written by a California renowned professional birder.
- Point Reyes Bird Observatory (PRBO) contracted surveys – conducted as part of the Merced River Alliance Project Biological Monitoring and Assessment Report (Stillwater 2008).
- Pierson and Rainey bat surveys, 1993-2001 (Pierson 1997; Pierson and Rainey 1993, 1996; and Pierson et al. 2001).

2.6.3 Correlation of Results from NPS CWHR Model with Results from Riparian Corridor Mapping, CRAM, CMZ, and LWD Studies

Results from the NPS CWHR Model were integrated and correlated with the results obtained from the riparian corridor mapping, CRAM, CMZ, and LWD studies in order to paint a picture of the current wildlife and habitat conditions in the Yosemite Valley area.

This task involved office assessment of the results of all of the 2010 studies and investigations conducted as part of this Merced River and Riparian Vegetation Assessment. A discussion of the condition of wildlife and habitat is presented in Sections 5.2 and 5.3 for the study area and by geomorphic reach, respectively.

Riparian corridor mapping, CRAM, CMZ, and LWD results were summarized in a table by reach in order to provide a snapshot view of habitat conditions observed during 2010. The metrics that were used to classify each of these studies were assessed (poor to high) to provide a basic indication of habitat condition and whether it could be considered poor, moderate, or high.

These results were then compared to the available 2010 wildlife field survey results to see how they correlated. In addition, data collected as part of the PRBO (Stillwater Sciences 2008) and data from Pierson and Rainey bat surveys (Pierson 1997; Pierson and Rainey 1993, 1996; 1998; and Pierson et al. 2001) were reviewed to provide additional information on current wildlife and habitat conditions. These comparisons serve to paint a picture of current conditions or potential health of the habitat and associated wildlife based on available data and information, and professional judgment. Results of this assessment may also provide an indication of additional data needs in order to make a more robust assessment in the future.

Chapter 3

Results

3.1 Geomorphic Reach Delineation

Geomorphic reach delineation yielded eight geomorphic reaches along the study reach (Table 3-1). From the upstream end these include: Happy Isles, Above Tenaya, Below Tenaya, Upper Meadows, Inter-Meadows, Lower Meadows, Above Pohono Bridge, and Below Pohono Bridge (Appendix A, Geomorphic Reach Map).

Table 3-1. Geomorphic Reaches within Study Area

Reach	Length (km)	planform (sinuosity[1])	entrenchment[2]	bankfull width (m)	valley width (m)	gradient (%)	Description
Happy Isles	1	low-sinuosity (1.16)	5.9	48.04	320	0.9	High gradient with coarse substrate and banks, abundant LWD and logjams, and generally undeveloped
Above Tenaya	0.73	straight (1.05)	16	46.98	495	0.28	Straight channel with coarse substrate and banks, less LWD and logjams, and developed campgrounds on both sides of the channel
Below Tenaya	1.23	high sinuosity (1.57)	12.8	56.53	615	0.22	Meandering planform, coarse substrate and fine-grained banks, developed campgrounds on the left bank and an abandoned camping area on the right bank, and a significant length of channel revetments on the right bank
Upper Meadows	3.94	high sinuosity (1.39)	10.1	53.68	550	0.09	Mixed substrate and fine-grained banks, a meandering planform, wide bankfull channel and floodplain, and large meadows on either floodplain adjacent to the channel.
Inter-Meadows	2.11	moderate-sinuosity (1.29)	4.8	47.39	142	0.04	Mixed substrate and fine-grained banks, and elevated forested floodplains on either side of the channel.
Lower Meadows	2.41	moderate sinuosity (1.24)	8.2	43.25	360	0.09	Mixed substrate and banks, a meandering planform, wider and lower floodplains on either side of the channel, and a large meadow (El Capitan Meadow) on the right bank.
Above Pohono Bridge	2.69	moderate sinuosity (1.28)	3.4	49.62	194	0.71	Higher gradient, coarser substrate and banks, narrow bankfull width, and elevated floodplains
Below Pohono Bridge	1.72	straight (1.06)	1.9	41.3	63	2	Steep gradient, narrow bankfull channel, step-pool morphology, and coarse substrate and banks.

[1]Sinuosity = channel length/valley length

[2]Smaller value indicates greater entrenchment; see Appendix D for description of entrenchment calculation

3.2 Riparian Corridor Mapping

3.2.1 Study Reach Results

3.2.1.1 2010 Vegetation Mapping

The Ponderosa Pine-Incense Cedar Forest Alliance, the most common vegetation type within the riparian corridor, made up 35 percent of riparian area followed by the Black Cottonwood-Temporarily Flooded Forest Alliance (16 percent), Douglas Fir-Ponderosa Pine-Incense Cedar Forest (11 percent), and Ponderosa Pine-Incense Cedar-California Black Oak Forest (10 percent) (Table 3-2) White Alder Forest (5 percent) occurred between Happy Isles Bridge and Sentinel Bridge and between Bridalveil Creek and Pohono Bridge (See Appendix A [2010 Riparian Vegetation Map Series] for distribution along the study reach). Shining Willow Scrub (3 percent) was discontinuously distributed along the river from Stoneman Bridge to the downstream end of the study reach. Black cottonwood forests occurred along channel margins between Stoneman Bridge and El Capitan Bridge, with bare areas found along approximately 3 percent of the river corridor. All other vegetation community types were relatively uncommon (2 percent or less).

3.2.1.2 Comparison with Historical Vegetation Mapping

Oak and conifer communities dominated the study reach in all three years (66 to 70 percent of total area), decreasing slightly (5 percent from 1992 to 2010 (Figure 3-1 and Appendix A [1992 to 1997 and 1997 to 2010 Riparian Vegetation Map Series]). The proportion of meadow vegetation within the riparian corridor remained similar from 1992 to 2010, while black cottonwood forest communities increased in area by nearly 10 percent, and the area of willow-dominated communities decreased by 8 percent. Bars and channel margins with established willow communities in 1992 were mapped as bare in 1997 and 2010, likely reflecting scour by the January 1997 flood (Appendix A, 1992 to 1997 Riparian Vegetation Map Series Map 4). Prescribed burns in the Upper, Inter-, and Lower Meadows reaches in the early 1990's that burned through the riparian corridor may also resulted in the decrease in the proportion of willow communities, particularly with more severe burns. The oxbow and cutoff channels (about 10.4 ha in total within the study reach) were vegetated primarily with oak and conifer communities and black cottonwood, including mixed with willow in both 1997 and 2010 (78 percent). The proportion of each vegetation communities mapped within the oxbow and cutoff channels were similar in 1997 and 2010 (Figure 3-1)[12].

[12] The differences in the proportion of area within each of the categories between the years could also reflect artifacts in the differences in mapping methods and/or classification of sub-dominant species. Although the 1992, 1997, and 2010 vegetation community types were simplified into broader community categories, these categories were developed to be able to identify trends in the overall distribution and relative proportion of upland communities; riparian (cottonwood, willow, alder species), meadow communities, and bare areas) in response to management decisions.

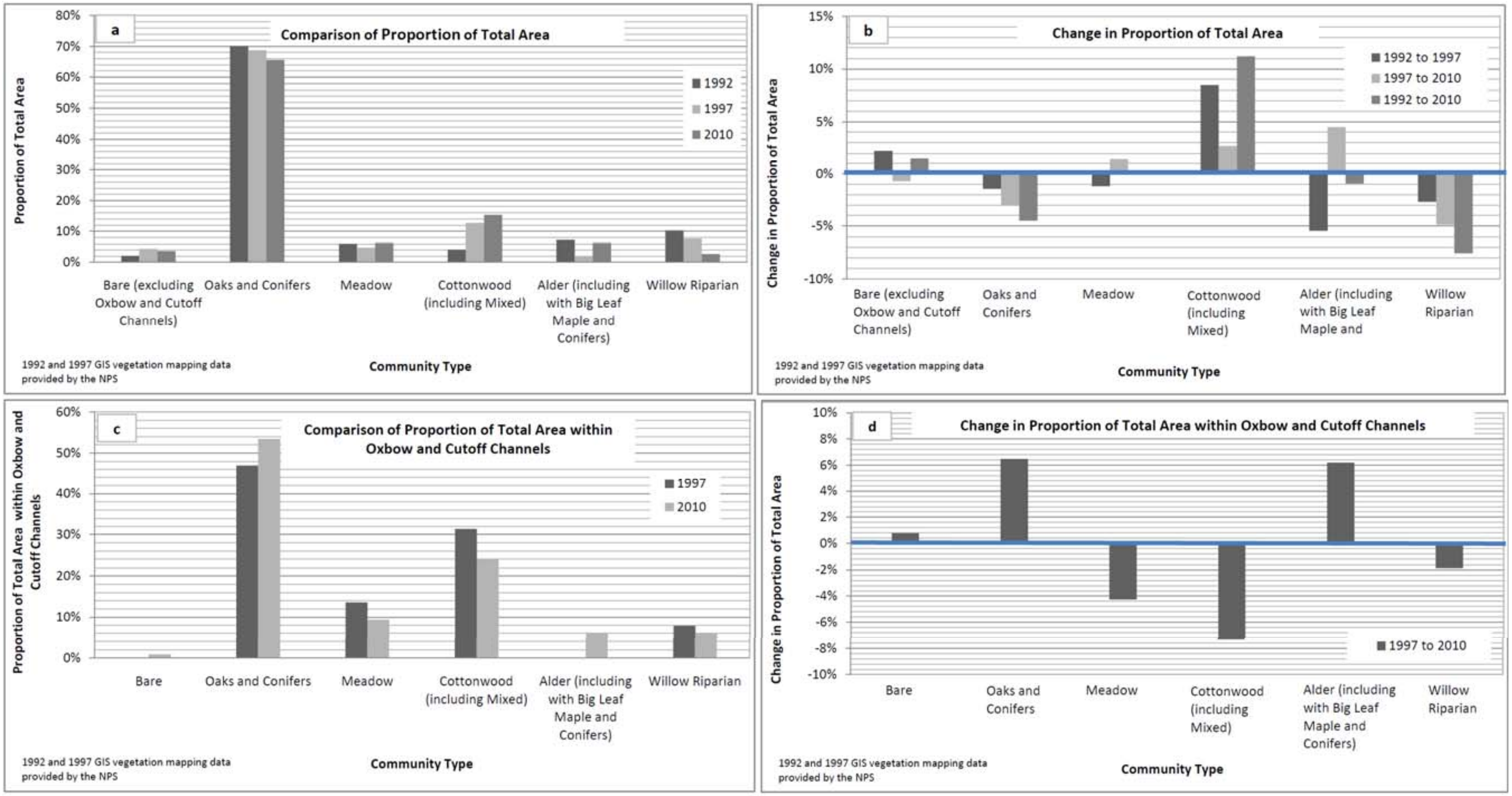

Figure 3-1. Comparison of the Proportion of Total Area of Each Community Type(a) and Change in the Proportion of Each Community Type (b) within the Merced River Corridor (1992, 1997, and 2010) and within Oxbow and Cutoff Channels (c and d)[1].

1 The differences in the proportion of area within each of the categories between the years could also reflect artifacts in the differences in mapping methods and/or classification of sub-dominant species. Although the 1992, 1997, and 2010 vegetation community types were simplified into broader community categories, these categories were developed to be able to identify trends in the overall distribution and relative proportion of upland communities; riparian (cottonwood, willow, alder species), meadow communities, and bare areas) in response to management decisions.

Table 3-2. Summary of Vegetation Types within the Merced River Riparian Corridor

Map Number	Vegetation Type[1]	Area (hectare)	Proportion (excluding water) (%)
0	Bare	3.6	3%
1	Canyon Live Oak Forest Alliance	0.5	<1%
2	Canyon Live Oak - Whiteleaf Manzanita Forest	0.4	<1%
3	Ponderosa Pine - Incense Cedar Forest Alliance	37.1	35%
4	Incense Cedar Forest Alliance	0.5	<1%
5	Douglas Fir - White Fir - Incense Cedar Forest	2.0	2%
6	Douglas Fir - Ponderosa Pine - Incense Cedar Forest	11.5	11%
7	Dusky Willow Riparian Scrub	0.4	<1%
8	California Black Oak Forest Alliance	1.6	2%
9	White Alder Forest	5.9	5%
10	Black Cottonwood Temporarily Flooded Forest Alliance	17.3	16%
11	Incense Cedar - White Alder Forest	0.8	1%
12	Ponderosa Pine - Incense Cedar – California Black Oak Forest	10.3	10%
13	Blue Wild Rye Herbaceous Alliance	2.4	2%
14	Wooly Sedge Meadow	0.8	1%
15	Water	46.8	-
16	Douglas Fir- Canyon Live Oak Forest	0.3	<1%
17	Shining Willow Riparian Scrub	2.9	3%
18	Blue Wild Rye – Mugwort Herbaceous Alliance	1.5	1%
19	Panicled Bulrush Herbaceous Alliance	1.6	2%
20	California Black Oak – Ponderosa Pine Forest	1.5	1%
21	Ponderosa Pine - Incense Cedar - Canyon Live Oak Forest	2.0	2%
22	Dogbane Meadow	0.2	<1%
23	Creeping Bent Grassland	0.2	<1%
24	Blue Wild Rye - Creeping Bent Herbaceous Alliance	0.2	<1%
25	California Black Oak – Incense Cedar Forest	0.1	<1%
26	Ponderosa Pine - Douglas Fir - Canyon Live Oak Forest	0.6	1%
27	Douglas Fir Forest Alliance	0.4	<1%

[1] Refer to Appendix B for descriptions of each of the vegetation type.

3.2.2 Geomorphic Reach Results

3.2.2.1 2010 Vegetation Mapping

The most common vegetation type along the study reach, the Ponderosa Pine-Incense Cedar Forest Alliance, made up 13 to 70 percent of riparian vegetation area within geomorphic reaches, but other vegetation types showed more localized distribution (Table 3-3 and Appendix A [2010 Riparian Vegetation Map Series]) Ponderosa Pine-Incense Cedar-California Black Oak Forest dominated the riparian area in the Above and Below Tenaya geomorphic reaches (26 percent and 55 percent, respectively). The two most downstream geomorphic reaches, Above and Below Pohono Bridge, supported the greatest area of Douglas Fir-White Fir-Incense Cedar Forest (42 percent and 26 percent, respectively) and White Alder Forest was most common in the Happy Isles (24 percent), Above Tenaya (21 percent), and Below Tenaya (13 percent) geomorphic reaches. The Upper and Lower Meadows geomorphic reaches included large proportions of the Black Cottonwood Temporarily Flooded Forest Alliance (43 percent and 20 percent, respectively). This community type was also present as a minor component in most of the geomorphic reaches (<10 percent). Shining Willow Riparian Scrub was fairly common in the Inter-Meadow geomorphic reach (12 percent). Meadow and herbaceous community types were present in the Upper, Inter-, and Lower Meadows geomorphic reaches. The proportion of areas mapped as bare was greatest in the Below Tenaya geomorphic reach (6 percent), and was lowest in the Above Tenaya and Above Pohono Bridge geomorphic reaches.

Table 3-3. Summary of Vegetation Types by Geomorphic Reach within the Merced River Riparian Corridor

Map Number	Vegetation Type	Geomorphic Reach - Hectares and Proportion of Total (excluding water) (%)															
		Happy Isles		Above Tenaya		Below Tenaya		Upper Meadows		Inter-Meadows		Lower Meadows		Above Pohono Bridge		Below Pohono Bridge	
0	Bare	0.3	4%	-	-	0.4	6%	1.2	4%	0.2	1%	0.7	4%	0.1	<1%	0.2	4%
1	Canyon Live Oak Forest Alliance	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	Canyon Live Oak - Whiteleaf Manzanita Forest	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	2%
3	Ponderosa Pine - Incense Cedar Forest Alliance	2.7	37%	0.5	13%	1.3	16%	7.4	27%	9.8	70%	9.0	51%	3.1	17%	1.3	27%
4	Incense Cedar Forest Alliance	0.1	1%	-	-	-	-	0.3	1%	-	-	0.1	1%	-	-	-	-
5	Douglas Fir - White Fir - Incense Cedar Forest	-	-	-	-	-	-	-	-	-	-	0.7	4%	0.7	3%	0.3	7%
6	Douglas Fir - Ponderosa Pine - Incense Cedar Forest	1.0	13%	-	-	-	-	-	-	-	-	-	-	7.5	42%	1.2	26%
7	Dusky Willow Riparian Scrub	-	-	-	-	-	-	-	-	-	-	-	-	0.3	2%	0.1	2%
8	California Black Oak Forest Alliance	0.1	2%	1.3	34%	-	-	-	-	-	-	-	-	0.2	1%	-	-
9	White Alder Forest	1.8	24%	0.8	21%	1.0	13%	0.7	2%	0.3	2%	-	-	1.2	7%	-	-
10	Black Cottonwood Temporarily Flooded Forest Alliance	-	-	0.1	2%	0.5	7%	11.5	43%	0.7	5%	3.5	20%	0.5	3%	0.3	7%
11	Incense Cedar - White Alder Forest	0.3	5%	-	-	-	-	-	-	-	-	-	-	0.5	3%	-	-
12	Ponderosa Pine - Incense Cedar – California Black	-	-	1.0	26%	4.3	55%	0.7	3%	-	-	1.3	7%	2.4	14%	0.2	3%

Table 3-3. Summary of Vegetation Types by Geomorphic Reach within the Merced River Riparian Corridor

Map Number	Vegetation Type	Geomorphic Reach - Hectares and Proportion of Total (excluding water) (%)															
		Happy Isles		Above Tenaya		Below Tenaya		Upper Meadows		Inter-Meadows		Lower Meadows		Above Pohono Bridge		Below Pohono Bridge	
	Oak Forest																
13	Blue Wild Rye Herbaceous Alliance	-	-	-	-	-	-	2.1	8%	-	-	0.4	2%	-	-	-	-
14	Wooly Sedge Meadow	-	-	-	-	-	-	0.2	1%	0.2	2%	-	-	0.3	2%	-	-
15	Water	2.4	-	1.6	-	3.3	-	12.4	-	6.3	-	10.0	-	7.0	-	4.6	-
16	Douglas Fir-Canyon Live Oak Forest	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	1%
17	Shining Willow Riparian Scrub	-	-	-	-	-	-	0.6	2%	1.6	12%	0.2	1%	0.1	1%	0.3	7%
18	Blue Wild Rye – Mugwort Herbaceous Alliance	-	-	-	-	-	-	-	-	0.5	3%	1.0	6%	-	-	-	-
19	Panicled Bulrush Herbaceous Alliance	-	-	-	-	0.3	3%	0.5	2%	0.5	4%	0.4	2%	-	-	-	-
20	California Black Oak – Ponderosa Pine Forest	-	-	-	-	-	-	1.4	5%	-	-	-	-	-	-	-	-
21	Ponderosa Pine - Incense Cedar - Canyon Live Oak Forest	-	-	-	-	-	-	-	-	-	-	-	-	0.7	4%	0.7	14%
22	Dogbane Meadow	-	-	-	-	-	-	<0.1	<1%	-	-	-	-	-	-	-	-
23	Creeping Bent Grassland	-	-	-	-	-	-	0.2	1%	-	-	0.1	1%	-	-	-	-
24	Blue Wild Rye - Creeping Bent Herbaceous Alliance	-	-	-	-	-	-	0.1	<1%	0.1	1%	0.1	<1%	-	-	-	-
25	California Black Oak – Incense	-	-	0.1	4%	-	-	-	-	-	-	-	-	-	-	-	-

Table 3-3. Summary of Vegetation Types by Geomorphic Reach within the Merced River Riparian Corridor

Map Number	Vegetation Type	Geomorphic Reach - Hectares and Proportion of Total (excluding water) (%)															
		Happy Isles		Above Tenaya		Below Tenaya		Upper Meadows		Inter-Meadows		Lower Meadows		Above Pohono Bridge		Below Pohono Bridge	
	Cedar Forest																
26	Ponderosa Pine - Douglas Fir - Canyon Live Oak Forest	0.6	8%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	Douglas Fir Forest Alliance	0.4	6%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hectares (excluding water)		7.3		3.7		7.		27.0		13.9		17.5		17.8		4.7	

3.2.2.2 Comparison with Historical Vegetation Mapping

Happy Isles Geomorphic Reach

The vegetation composition was fairly stable between 1992 and 2010, primarily comprised of oaks and conifers, and white alder/big leaf maple/conifer community types (Table 3-4, Figure 3-2, and Appendix A [1992 to 1997 and 1997 to 2010 Riparian Vegetation Map Series]). One area mapped with cottonwoods in 1992 was bare in 1997 and 2010, increasing the proportion of bare area within the reach by 4 percent. The proportions of the other community types were similar between 1992 and 2010.

Above Tenaya Geomorphic Reach

The riparian corridor was primarily composed of oak and conifer and alder/big leaf maple/conifer community types. In 1992 and 1997, the entire corridor was mapped as oaks and conifers. In 2010, approximately 21 percent of the reach was mapped as white alder-dominated communities and 2 percent was mapped as black cottonwood forest. It is possible that this reflects a difference in the classifications of these community types or the distribution of alders has increased within the reach since 1992 and 1997.

Below Tenaya Geomorphic Reach

The riparian corridor is primarily composed of oak and conifer and alder/big leaf maple/conifer community types. The riparian corridor near the Tenaya Creek confluence was mapped as oak and conifer communities in 1992 and 1997. In 2010, this area was mapped as alder/big leaf maple/conifer community types. It is possible that this reflects a difference in the classifications of these community types or an increase in the distribution of alders within the reach since 1992 and 1997. The proportion of bare area increased in 1997 compared to 1992 by 5 percent, and remained the same between 1997 and 2010. The proportion of black cottonwood forest remained similar between 1992 and 2010; while the proportion of willows decreased slightly (by 3 percent). In oxbow and channel cutoffs (approximately 0.5 ha in total), an area downstream from Stoneman Bridge that was mapped as primarily willow in 1997 was mapped as mixed black cottonwood and willow in 2010 (Figure 3-3).

Upper Meadows Geomorphic Reach

The proportion of oak and conifer dominated communities was comparatively lower within this reach compared to the other reaches. The proportion of bare area increased in 1997 compared to 1992 by 4 percent, and little change between 1997 and 2010. The proportion of meadow community types within the reach has remained fairly constant between 1992 and 2010. The proportion of black cottonwoods increased by 20 percent between 1992 and 1997, and by 10 percent between 1997 and 2010; while the proportion of oaks and conifers decreased by 18 percent between 1992 and 1997. The proportion of willows remained similar between 1992 and 1997, but declined between 1997 and 2010 by 18 percent. Areas that had previously been dominated by willows were mapped as a cottonwood-willow mixed community. This reflects recent successful recruitment and survival of cottonwoods (since 1992 and 1997) within this reach, following the 1997 flood, and possibly prescribed burns that burned through the riparian corridor in the early 1990s (e.g., near Sentinel Beach). Vegetation communities mapped within the oxbow and cutoff channels were similar in 1997 and 2010.

Inter-Meadows Geomorphic Reach

Oaks and conifers dominated the riparian corridor in this reach. The proportion of the reach mapped as meadow community types has increased over time, by 4 percent between 1992 and 1997 and 4 percent between 1997 and 2010. The proportion of black cottonwood forest increased slightly between 1992 and 1997 (2 percent) and between 1997 and 2010 (2 percent), while the proportion of willow declined between 1992 and 1997 (by 8 percent). In addition, a long reach dominated by willows was mapped on river right downstream of Sentinel Beach picnic area in 1992. In 1997 and 2010, this area was mapped as oaks and conifers. It is possible that the willows that were mapped in 1992 were scoured by the January 1997 flood or were burned by prescribed burns that occurred in the early 1990s (e.g., near Sentinal Beach). Within oxbow and cutoff channel areas, patches of willow within meadow communities were mapped in 2010 within the reach previously mapped in 1997 entirely as meadow communities.

Lower Meadows Geomorphic Reach

The proportion of black cottonwood forest increased between 1992 and 1997 by 18 percent, and remained constant between 1997 and 2010. Black cottonwood forests were established in areas previously dominated by willow communities in 1992. The proportion of willow-dominated communities decreased by approximately 18 percent between 1992 and 1997. This reflects recent successful recruitment and survival of cottonwoods (since 1992) within this reach. In addition, willows on a few mid channel and point bars in 1992 were bare in 1997 and 2010, likely scoured by the 1997 flood. Willows and understory may also have been burned by prescribed fires that occurred in certain areas within the reach in the early 1990s. The proportion of bare areas increased substantially between 1992 and 1997 (10 percent), but the bare areas have become revegetated since then. Within oxbow and cutoff channel areas, a few areas mapped in 1997 as black cottonwood forests were mapped as oak and conifer dominated communities in 2010 (approximately 0.7 ha).

Above Pohono Bridge Geomorphic Reach

The vegetation composition was fairly stable between 1992 and 2010, primarily comprised of oaks and conifers, and alder/big leaf maple community types. The proportion of the alder/big leaf maple/conifer communities decreased in 1997 and 2010 compared to 1992, while the proportions of the oak and conifer communities increased. There was little change in the proportion of the alder/ big leaf maple/ conifer communities between 1997 and 2010, except in the oxbow and cutoff channels. It is possible that this reflects a difference in the classifications of these community types or a decrease in the distribution of alders within the reach since 1992. The proportion of willows and black cottonwood forests have increased slightly between 1992 and 2010 (3 percent for both), while the proportion of areas mapped as meadow vegetation has slightly decreased (4 percent). Very little bare area was present within this reach during all years. In the oxbow and cutoff channels, an area near the Bridalveil Creek confluence mapped as oak and conifer communities in 1997 was mapped as the alder/ big leaf maple/ conifer communities in 2010.

Below Pohono Bridge Geomorphic Reach

The riparian corridor was dominated by oaks and conifers throughout the reach. The proportion of the alder/big leaf maple/conifer communities decreased in 1997 and 2010 compared to 1992, while the proportions of the oak and conifer communities increased. There was no change in the proportion of the alder/ big leaf maple/ conifer communities between 1997 and 2010. It is possible that this reflects a difference in the classifications of these community types or a decrease in the distribution of alders within the reach since 1992. The proportion of cottonwood and willow-dominated communities increased within the reach from 1992 to 1997 and 2010 (4 and 6 percent, respectively). The proportion of bare area within the reach increased between 1997 and 2010 by 5 percent. In the oxbow and cutoff channels, an area mapped as mixed cottonwood and willow forest in 1997 was mapped as willow-dominated in 2010 (approximately 0.34 ha).

Table 3-4. Change in Total Area and Proportion of Total Area of Each Community Type by Geomorphic Reach within the Merced River Corridor

Geomorphic Reach	Vegetation Type – Hectares and Proportion of Total (%)[1]												
	Bare		Oaks and Conifers		Meadow		Cottonwood		Alder		Willow Riparian		Total[2]
1992													
Happy Isles	-	-	5.0	65%	-	-	0.2	3%	2.5	32%	-	-	7.7
Above Tenaya	-	-	4.0	100%	-	-	-	-	-	-	-	-	4.0
Below Tenaya	<0.1	<1%	7.0	93%	-	-	0.3	4%	-	-	0.2	3%	7.5
Upper Meadows	0.3	1%	13.2	56%	3.0	13%	2.3	10%	-	-	4.9	21%	23.7
Inter-Meadows	0.2	2%	10.5	77%	-	-	0.1	<1%	0.4	3%	2.4	18%	13.5
Lower Meadows	1.2	9%	7.9	55%	1.7	12%	1.1	7%	-	-	2.3	16%	14.3
Above Pohono Bridge	<0.1	<1%	11.4	74%	1.0	6%	-	-	3.0	19%	-	-	15.4
Below Pohono Bridge	<0.1	<1%	3.1	88%	-	-	-	-	0.4	12%	-	-	3.5
1997													
Happy Isles	-	-	6.2	90%	-	-	-	-	0.7	10%	-	-	6.9
Above Tenaya	-	-	3.9	100%	-	-	-	-	-	-	-	-	3.9
Below Tenaya	-	-	5.9	97%	-	-	-	-	-	-	0.2	3%	6.1
Upper Meadows	1.3	5%	9.4	38%	1.8	8%	7.3	30%	-	-	4.8	20%	24.6
Inter-Meadows	-	-	11.0	82%	0.6	4%	0.4	3%	<0.1	<1%	1.4	10%	13.4
Lower Meadows	2.9	19%	7.3	46%	1.7	11%	3.9	25%	-	-	-	-	15.8
Above Pohono Bridge	-	-	12.6	83%	0.5	3%	0.4	2%	0.9	6%	0.9	6%	15.3
Below Pohono Bridge	-	-	3.9	93%	-	-	0.2	6%	0.0	1%	-	-	4.2
2010													
Happy Isles	0.3	4%	4.9	67%	-	-	-	-	2.1	29%	-	-	7.3
Above Tenaya	-	-	2.8	77%	-	-	0.1	2%	0.8	21%	-	-	3.7
Below Tenaya	0.4	5%	5.5	76%	0.2	3%	0.4	5%	0.8	11%	-	-	7.2
Upper Meadows	1.5	6%	8.8	37%	2.9	12%	9.4	40%	0.6	3%	0.6	2%	23.8
Inter-Meadows	0.2	1%	9.4	73%	1.0	8%	0.6	5%	0.3	2%	1.4	11%	13.0
Lower Meadows	0.9	6%	8.0	57%	1.6	11%	3.5	25%	-	-	<0.1	<1%	14.0
Above Pohono Bridge	0.1	<1%	14.1	84%	0.3	2%	0.5	3%	1.4	8%	0.4	3%	16.8
Below Pohono Bridge	0.2	5%	3.7	85%	-	-	0.3	6%	-	-	0.2	4%	4.3

[1] Bare: excludes Oxbow and Cutoff Channels classifications; Cottonwood includes Mixed classifications; and Alder includes classifications with big leaf maple and conifers. Alders were classified in one community type with big leaf maple in 1997. These two species were generally classified as individual classification types in 1992 and 2010, depending on dominance. The total acreage of vegetation by geomorphic reach is less than the total acreage for the study reach because the delineated widths of the geomorphic reaches were narrower than the mapped riparian corridor in some locations.

[2] The total area mapped varies between the different mapping years as slightly different areas were mapped, particularly along the stream margins each year. In addition, the differences in the proportion of area within each of the categories between the years could also reflect artifacts in the differences in mapping methods and/or classification of sub-dominant species. Although the 1992, 1997, and 2010 vegetation community types were simplified into broader community categories, these categories were developed to be able to identify trends in the overall distribution and relative proportion of upland communities; riparian (cottonwood, willow, alder species), meadow communities, and bare areas) in response to management decisions.

Figure 3-2 Change in the Proportion of Each Community Type by Geomorphic Reach within the Merced River Corridor (1992, 1997, and 2010)[1]

The differences in the proportion of area within each of the categories between the years could also reflect artifacts in the differences in mapping methods and/or classification of sub-dominant species. Although the 1992, 1997, and 2010 vegetation community types were simplified into broader community categories, these categories were developed to be able to identify trends in the overall distribution and relative proportion of upland communities; riparian (cottonwood, willow, alder species), meadow communities, and bare areas) in response to management decisions.

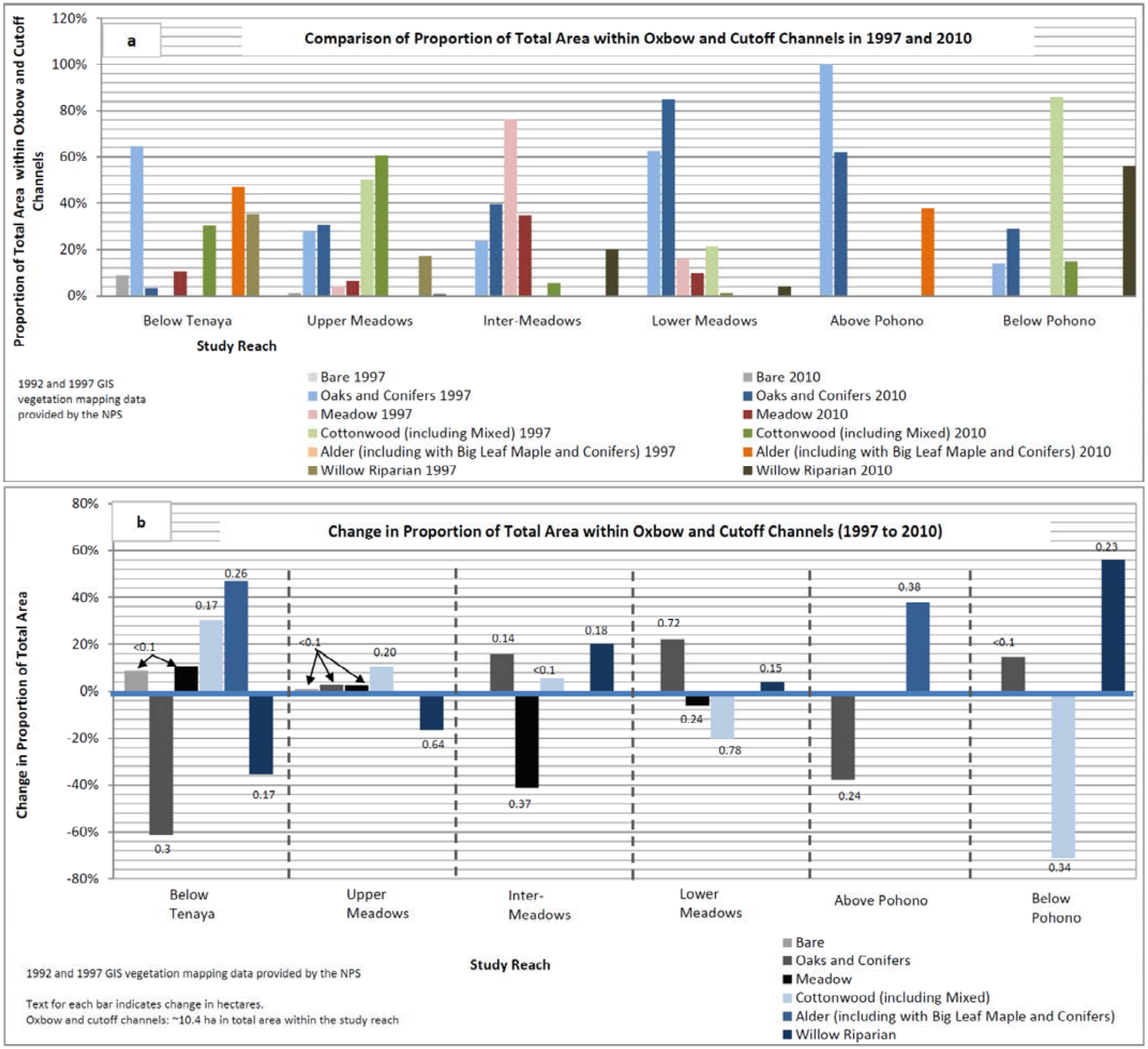

Figure 3-3. Proportion of Each Community Type by Geomorphic Reach (a) and Change in the Proportion of Each Community Type (b) within Oxbow and Cutoff Channels within the Merced River Corridor (1997 and 2010).

3.3 Riparian Vegetation Condition Assessment

3.3.1 Study Reach Results

Overall CRAM scores for the AAs along the Merced River ranged from 0.56 to 0.93[13], with a median score of 0.77 (average of 0.78) (Figure 3-4). The AAs with comparatively "higher" overall CRAM scores (top 20th percentile) had scores of 0.87 or greater (n=17). The majority of these AAs were present in the Upper Meadows and Above Pohono Bridge geomorphic reaches. The AAs with comparatively low overall CRAM scores (lowest 20th percentile, with values of 0.70 or less [n=17]), were concentrated in the three following geomorphic reaches: (1) Above Tenaya; (2) Below Tenaya; and (3) Below Pohono Bridge (Appendix A, CRAM Scores Map Series). The CRAM data are summarized by AA in Appendix C.

- The following metrics were in good condition and varied little throughout the study reach (See Appendix C for detailed scores):
  - Landscape connectivity;
  - Water source;
  - Number of plant layers present; and
  - Percent invasive species.
- Five attributes/metrics were strong determinants of riparian corridor condition:
  - Buffer condition;
  - Hydroperiod or channel stability (in particular, presence of bank protection measures and observed bank erosion);
  - Average buffer width;
  - Biotic condition, in particular biotic structure; and
  - Physical structure, in particular topographic complexity.
- In the AAs with "lower" overall condition scores (lowest 20th percentile), the conditions of the following metrics tended to be lower (e.g., "C or D" score) compared to the AAs with "moderate" or "higher" overall CRAM scores:
  - Human use and activities were moderate (in 76 percent of the AAs with comparatively low overall scores), and were extremely intense within 18 percent of the AAs (Buffer Condition metric);
  - Bank protection measures and/or extensive bank erosion were present in approximately two-thirds of the AAs (Hydroperiod or Channel Stability metric);
  - Few different types of features that may provide habitat for riparian biota and lower topographic complexity (Physical Structure metrics);

[13] CRAM scores can vary from 0.27 to 1.00. Higher scores indicate that the riparian corridor is in better condition, while lower scores indicate that it is in poorer condition.

- Narrow riparian buffer in approximately one-third of the AAs (less than 64 m in width) (Buffer Width metric); and
- Comparatively fewer co-dominant species (6-8 species with at least 10 percent cover) and less developed vegetation with lower vegetation structural complexity, including little overlap of canopy layers and few distinct plant zones within the AA (Biotic Structure metrics).

• The AAs with “moderate” overall CRAM scores were generally characterized by:

- Moderate levels of human use (Buffer Condition metric);
- Low structural patch richness (Structural Patch Richness metric); and
- Approximately one-half of the AAs have little overlap of canopy and few distinct plant zones (Biotic Structure metrics).

• Compared to AAs with “lower” overall condition scores, AAs with “moderate” overall CRAM scores generally had:

- Greater topographic complexity (Topographic Complexity metric);
- More co-dominant species (at least nine) (Plant Community metrics); and
- More developed vegetation community with greater vegetation structural complexity, including more overlap of canopy layers and more distinct plant layers within the AA (Biotic Structure metrics).

• The AAs with “higher” overall CRAM scores were generally characterized by:

- Wide buffers (at least 130 m wide) with little to no evidence of human use or activities (Buffer Width metric);
- No and minimal bank protection measures or extensive bank erosion (Hydroperiod or Channel Stability metric);
- Moderate to high topographic complexity (Topographic Complexity metric); and
- Moderate to high vegetation structural complexity, including more overlap of canopy layers and more distinct plant layers within the AA (Biotic Structure metrics).

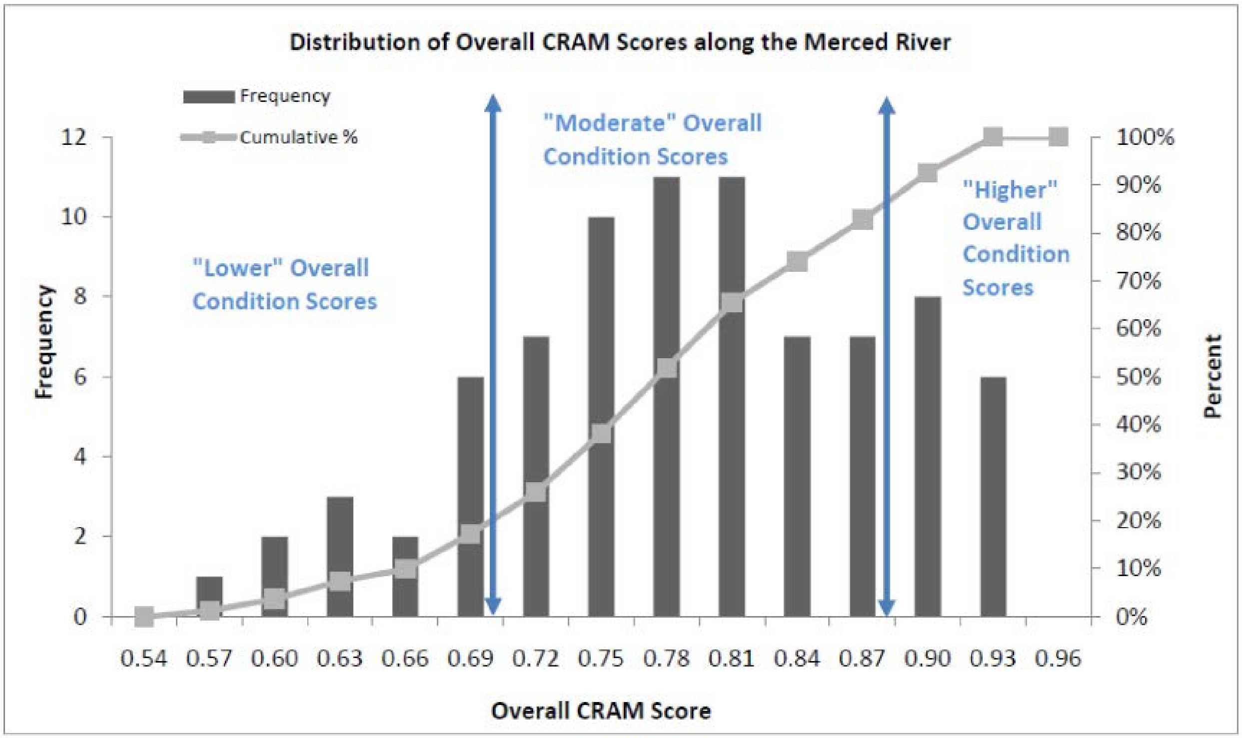

Figure 3-4. Distribution of Overall California Rapid Assessment Method Scores along the Merced River

3.3.2 Geomorphic Reach Results

Based on average overall CRAM scores for each geomorphic reach, the Happy Isles, Inter-Meadows, Lower Meadows, and Above Pohono Bridge geomorphic reaches were in comparatively better condition than the other geomorphic reaches (Figure 3-5 and Appendix C). These reaches were generally characterized by no or few locations with bank protection measures, less extensive bank erosion compared to the other geomorphic reaches, lower intensity visitor use, high topographic complexity, and a moderately developed vegetation community, with moderate vegetation structural complexity, including some overlap of canopy layers and distinct plant layers.

The riparian corridors within the Above Tenaya, Below Tenaya, and Below Pohono Bridge geomorphic reaches were in comparatively poorer condition than the other geomorphic reaches. The Above and Below Tenaya geomorphic reaches were characterized by moderate to high intensity human use; numerous channel sections stabilized with bank protection measures around meander bends and near bridges, excessive bank erosion observed throughout the reach; few types of physical features that may provide habitat for biota and low topographic complexity; and a relatively poorly developed riparian community, with few co-dominant species and low vegetation structural complexity (little canopy overlap and few distinct plant layers). Within the Below Pohono Bridge geomorphic reach, the width of the riparian buffer was considerably narrower compared to the upstream reaches due to the more confined valley bottom and close proximity of El Portal Road to the channel. Recreation use was moderate in locations near available access. Bank erosion was also observed within the reach, primarily in sections of the reach that were easily accessible from El Portal Road, such as near road turnouts. Bank protection measures were also present along the right bank (facing downstream). The riparian community was relatively poorly developed, with few co-dominant species and low vegetation structural complexity (little canopy overlap and few distinct plant layers).

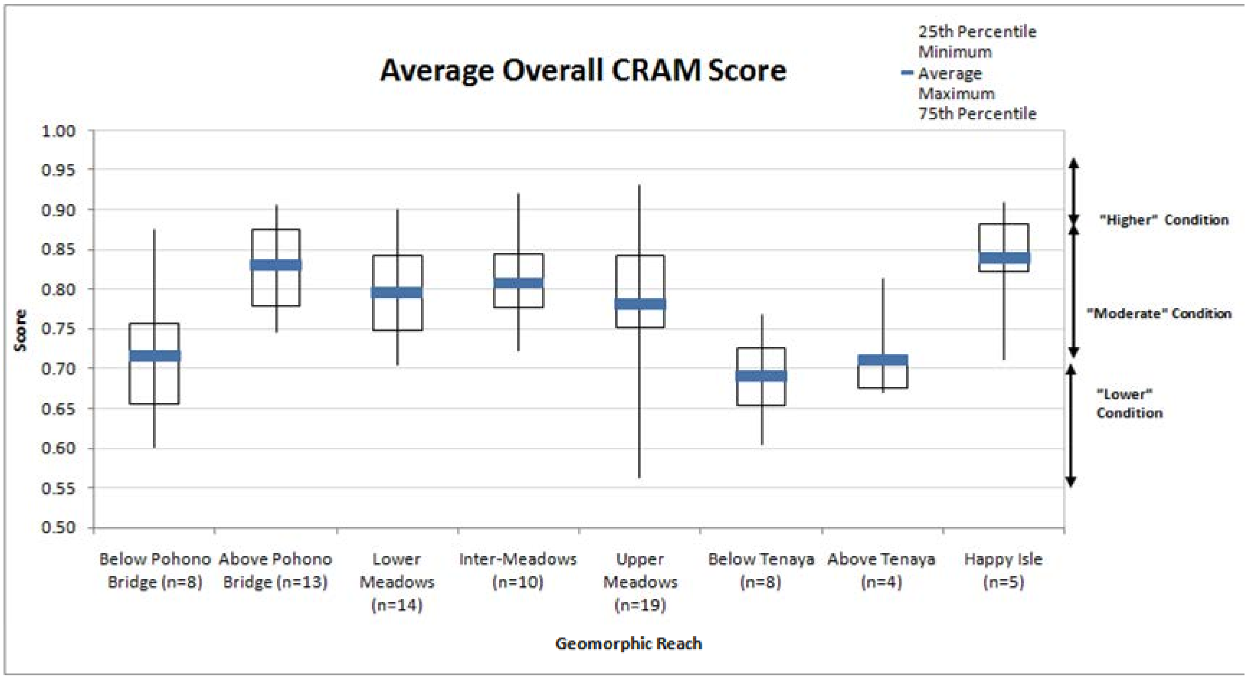

Figure 3-5. Summary of California Rapid Assessment Method Overall, Attribute, and Metric Scores by Geomorphic Reach (Average and Standard Deviation) (attribute and metric scores shown in Appendix C)

3.4 Channel Migration Zone Mapping

3.4.1 Study Reach Results

Valley Alluvium (VA) accounted for 52 percent of the Channel Migration Zone (CMZ)[14] with 41 percent of the VA disconnected (Figure 3-6). The Historic Migration Zone (HMZ), Avulsion Hazard Zone (AHZ), and Erosion Hazard Area (EHA) made up the remaining 48 percent of the CMZ. The EHA accounted for 26 percent of the CMZ and 55 percent of the area with a moderate to high probability of lateral channel erosion or channel avulsion. Approximately 14 percent of the EHA was disconnected. At 8 percent of the total CMZ area, the AHZ was the smallest of the CMZ zones delineated. Less than 1% of the AHZ was disconnected. The HMZ made up 28 percent of the total CMZ area delineated, with no part disconnected.

Disconnected AHZ and EHA areas accounted for 3 percent of the total CMZ area, with 1 percent identified as Protected Disconnected (PDEHA) (Figure 3-6). Disconnected areas accounted for 41 percent of the VA, 14 percent of the EHA (11 percent DEHA and 3 percent PDEHA), and 1 percent of the AHZ.

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[14] The CMZ includes the following classifications: (1) HMZ – Historic Migration Zone; (2) AHZ – Avulsion Hazard Zone; (3) EHA – Erosion Hazard Area; and (4) VA – Valley Alluvium. Areas within each of these classifications where roads or other infrastructure were present are identified with a "D" (Disconnected Migration Areas). Areas with revetments are identified as Protected Disconnected "PD".

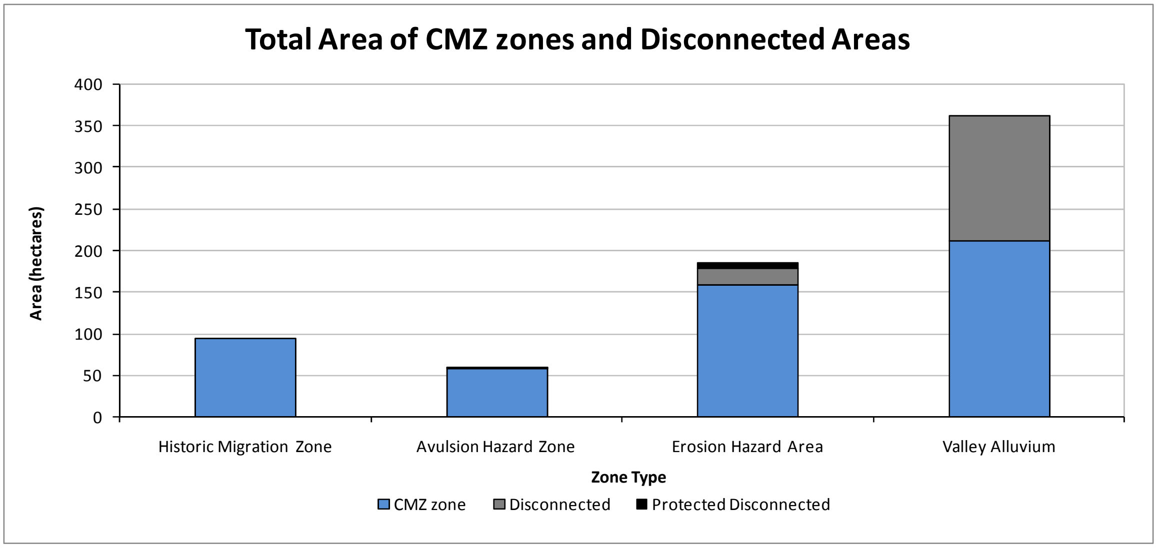

Figure 3-6. Summary of Area for Each CMZ Zone and Protected Disconnected Areas within the Project Area.

The results of the CMZ mapping within the study reach are briefly summarized below, from upstream to downstream.

AHZ were mapped in areas with high flow side channels and/or relict channels and oxbows on the floodplains that provide a shorter downstream path for floodwaters compared to the mainstem channel and/or were located on the insides of tight meander bend. The AHZ are primarily located in the following reaches:

- Happy Isles Bridge to Clarks Bridge (See Appendix A, Channel Migration Zone Map Series);
- Downstream of Clarks Bridge, including Lower Pines Campground;
- Downstream of Sentinel Bridge to the Sentinel Bridge Picnic Area;
- Immediately upstream of Swinging Bridge on the left bank;
- Downstream of Eagle Creek alluvial fan on the right and left bank floodplains;
- Across from the Bridalveil Creek alluvial fan; and
- Left bank of Tenaya Creek.

Erosion Hazard Areas represent areas prone to lateral bank erosion and lie beyond the AHZ and HMZ (away from the channel edge). The local width of the EHA is correlated with adjacent measured historic migration rates (a wider EHA occurs in areas with greater historical migration rates) (Table 2-3). Measured historical migration rates were highest between Sentinel Bridge and Sentinel Picnic Area (3.5 m/yr). Segments of study reach bordered by EHA include

- Between Happy Isles and Clarks bridges;
- Between Clarks and Stoneman bridges;
- First meander downstream of Stoneman Bridge;

- Downstream of Stoneman Bridge, including the western side of the Housekeeping Camp on the left bank floodplain and many structures along Camp 6 Road, and adjacent to the Yosemite Valley Loop Road near Sentinel Bridge;
- Downstream of Sentinel Bridge Picnic Area to Eagle Creek alluvial fan (comparatively narrower EHA due to higher floodplain elevation and coarser substrate from contributing alluvial fans);
- Eagle Creek alluvial fan to confluence with Ribbon Creek; and
- Between the confluences with Ribbon and Bridalveil creeks (narrow).

Substantial sections of bank protection occur in the following reaches (Protected Disconnected Migration Areas):

- Below Tenaya Creek confluence to Stoneman Bridge on the right bank;
- Stoneman Bridge to near Sentinel Bridge; and
- Downstream of Pohono Bridge at the base of El Portal Road.

Existing roads were mapped in EHA zones in a number of reaches (Disconnected Migration Areas). It is assumed that should the road become directly at risk from erosion in the future, management measures would be implemented to protect the road. This is a critical assumption and it must be remembered that Disconnected Protected Migration Areas remain at risk of erosion without maintenance. These reaches include the following:

- Yosemite Valley Loop Road between Stoneman Bridge (portions of) and to near Sentinel Bridge;
- Yosemite Valley Loop Road between Eagle Creek alluvial fan to the confluence with Ribbon Creek;
- Yosemite Valley Loop Road between the confluences with Ribbon and Bridalveil creeks; and
- Yosemite Valley Loop Road near the Bridalveil Creek alluvial fan.

Disconnected AHZ and EHA areas accounted for only 3 percent of the total area delineated, with 1 percent of the total area identified as disconnected protected (PDEHA) (Figure 3-6). Disconnected areas accounted for 41 percent of the VA, 14 percent of the EHA (11 percent DEHA and 3 percent PDEHA), and 1 percent of the AHZ. These disconnected areas represent opportunities not only for restoring land within the CMZ to fluvial processes (erosion, flooding, and wood recruitment), but for reducing risks by moving development out of the hazard areas.

3.4.2 Geomorphic Reach Results

The relative percent (top) and total area (bottom) of each CMZ category by geomorphic reach are provided in Figure 3-7. The Happy Isles reach (most upstream) had considerably more AHZ by percent area (34 percent) compared to the geomorphic reaches downstream (Figure 3-7, top). No AHZ occurs within either the Below Pohono Bridge or Inter-Meadows reaches, primarily due to their straight and entrenched character. The Below Pohono reach had the greatest proportion of EHA compared to the reaches upstream. The percent area EHA is similar within the three upstream reaches (16 percent), and increases by approximately 10 percent through the Meadows (Upper, Lower, Inter-) reaches. The Lower and Upper Meadows, and Below Tenaya reaches have similar distributions of CMZ types.

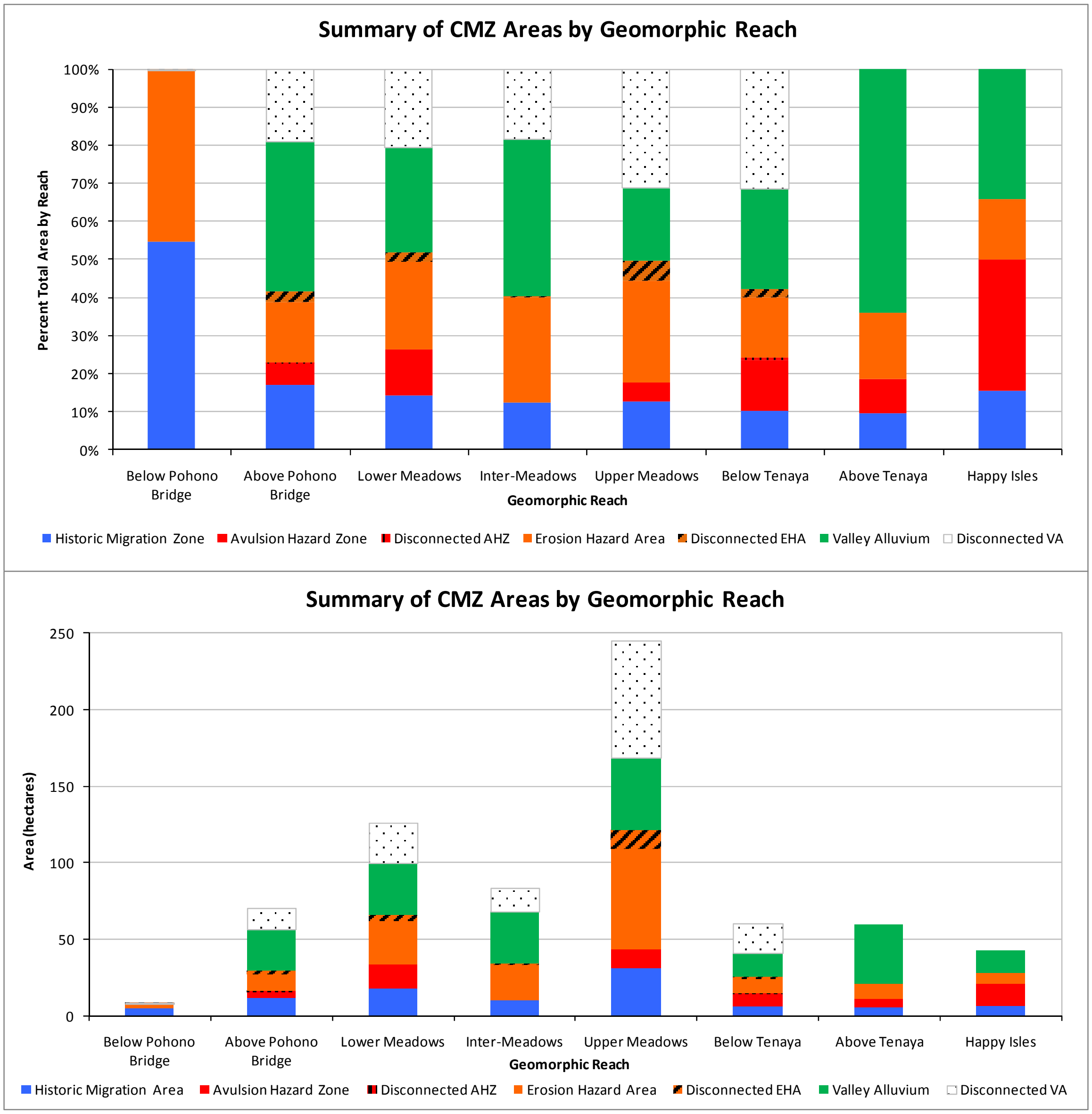

Figure 3-7. Summary of Area for All CMZ Zones Delineated by Geomorphic Reach

Disconnected and Protected-Disconnected Migration Areas represent the greatest maintenance challenges and have the greatest opportunity for restoration. The presence of these areas within a given reach is a metric for the amount of development as a result of channel revetments, bridges, and the Yosemite Valley Loop Road. The relative percentages and total area of Disconnected Migration Areas (areas with infrastructure, but no revetments) are low in the Happy Isles and Above Tenaya reaches (<1 percent) (Table 3-5 and Figure 3-8). The relative percent of Disconnected Migration Areas is greatest in the Below Tenaya and Upper Meadows reaches (37 percent). Yosemite Valley Loop Road is located within areas mapped as EHA and VA and is susceptible to erosion by channel migration within these reaches. The total area mapped as Disconnected Migration Areas is greatest in the Upper Meadows reach (Figure 3-8). The relative areas with Disconnected Migration Areas were fairly similar within the Inter-Meadows, Lower Meadows, and Above Pohono reaches (19 percent, 23 percent, and 23 percent, respectively). The relative percentages and total area of Protected Disconnected Migration Areas are low throughout all the geomorphic reaches. Bank protection measures resulted in the mapping of Protected Disconnected Migration Area within all reaches (0.2 to 12 percent) except for Lower Meadows reaches.

Table 3-5. Summary of Percent Area by Geomorphic Reach of Disconnected Areas

Geomorphic Reach	CMZ Area (ha) (AHZ, DAHZ, EHA, DEHA, HMZ, VA, DVA)	Disconnected (DAHZ, DEHA, DVA)		Protected-Disconnected (PDEHA)	
		Area (ha)	% of CMZ	Area (ha)	% of CMZ
Happy Isles	42.9	0	0	0.2	0.4
Above Tenaya	59.8	0	0	0.2	0.3
Below Tenaya	60.4	20.9	35	2.3	3.8
Upper Meadows	245.2	89.7	37	2.2	0.9
Inter-Meadows	84	15.7	19	0.2	0.2
Lower Meadows	126.2	29.3	23	0	0
Above Pohono Bridge	70.2	15.5	22	0.4	0.5
Below Pohono Bridge	8.6	< 0.1	<1	1	11.7

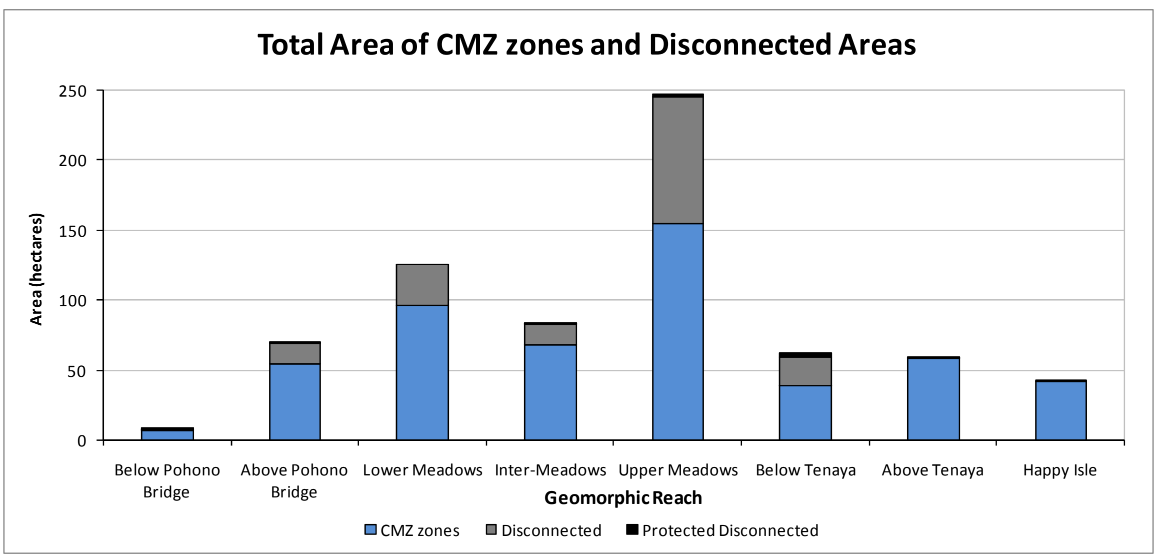

Figure 3-8. Summary of CMZ and Disconnected Areas by Geomorphic Reach

The Disconnected and Protected-Disconnected Migration Areas represent locations that would be at risk from future channel migration if not for the presence of revetments, bridges, or the Yosemite Valley Loop Road. Should this infrastructure be removed or relocated in the future, the areas included as Disconnected and Protected-Disconnected should be modified to reflect the change (for example, update PDEHA area to EHA after removal of revetment). Restoration efforts should focus on removal and or relocation of existing infrastructure in reaches with high percentages of disconnection. From the Below Tenaya geomorphic reach downstream to Pohono Bridge the Yosemite Valley Loop Road disconnects between roughly 20-35 percent of the CMZ (Table 3-5). Relocation of the road toward the valley margins to the extent possible could reduce the percentages of disconnection within these reaches, and allow more natural channel processes to occur. Removal of revetments should be evaluated in the Below Tenaya and Below Pohono Bridge geomorphic reaches as they have the highest percentage of disconnection from revetments (Table 3-5).

3.5 Actual and Potential Wood Loading

3.5.1 Actual Wood Loading

3.5.1.1 Study Reach Results

The inventory counted 835 pieces or 2,273 m^3 of LWD along 16 km, with wood loading along the channel ranging from 0 pieces/100 m to 66 pieces/100 m (Figure 3-9). The greatest wood loading occurred in the Happy Isles and Above Tenaya reaches at the upstream end of the study reach.

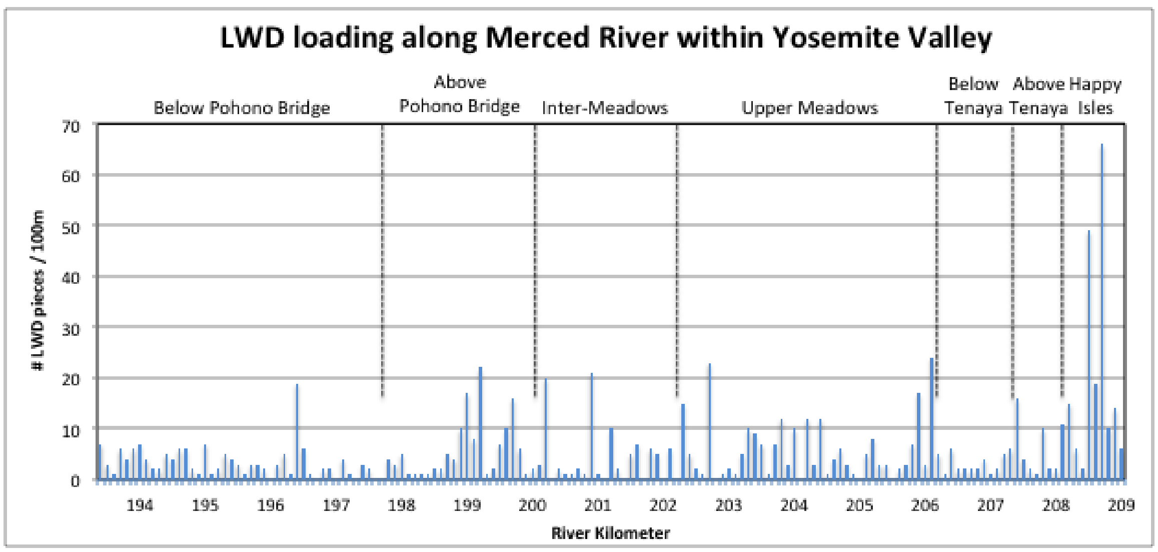

Figure 3-9. LWD Loading Along the Merced River through Yosemite Valley

The following is a general summary of the LWD inventory, from upstream to downstream, following Appendix A (Large Woody Debris Map Series).

- Downstream of the Happy Isles Bridge to Clarks Bridge there are abundant logjams with large key pieces, which are assumed to be the formative elements of the logjams (Abbe and Montgomery 1996, 2003). Overall, the LWD is large diameter, and occurs more frequently at bends in the channel and where flow splits into multiple channels. These observations are consistent with other LWD studies – larger pieces have more draft and larger rootwads, which make them more difficult to move through system (e.g., Abbe and Montgomery 1996, 2003; Braudrick and Grant 2000; Abbe et al. 2003). Straight sections of the channel have less LWD, and that which does occur, is of small dimension.

- Downstream of Clarks Bridge, the LWD dimensions tend to decrease overall in size (DBH more than length). Most pieces occur in logjams (3 or more pieces touching). The frequency of LWD per length of channel decreases dramatically downstream from Clarks Bridge to approximately 150 m past Stoneman Bridge.
- From approximately 150 m past Stoneman Bridge downstream to near Housekeeping Bridge quantities of LWD increase. The left bank is actively eroding in this section of the river, downstream of the Staircase Creek confluence. Several logjams occur along the eroding bank where trees are falling into the channel. Several single pieces of wood derived from upstream are located on either bank downstream to Housekeeping Bridge.
- Downstream of Housekeeping Bridge, the frequency of LWD per channel length decreases considerably. Most LWD pieces are located on meander bends in the channel. Straight sections of channel have less LWD, and that which does occur is typically a single, smaller piece. This condition remains until the two meander bends upstream of Swinging Bridge, where the frequency of LWD per channel length increases.
- Downstream of Swinging Bridge, the frequency of LWD per channel length decreases until Cathedral Beach picnic area. LWD within this section of the river is generally widely spaced. The LWD is generally large and forms logjams.
- From Cathedral Beach to El Capitan Bridge, LWD per river length is frequent. The LWD is generally of large size and occurs as single pieces. Significant accumulation of LWD was surveyed on the actively eroding left bank upstream of Cathedral Beach picnic area.
- LWD frequency decreases downstream of El Capitan Bridge, and remains infrequent downstream to the Bridalveil Creek confluence. In general LWD within this section of the river occurs as single pieces, and over a wide range of sizes.
- Immediately upstream of the Bridalveil Creek confluence, there is a significant accumulation of moderately sized single LWD pieces associated with a bend in the channel.
- Downstream of the Bridalveil Creek confluence to Pohono Bridge, LWD frequency per channel length is moderate, and occurs primarily as singe and 1-2 pieces touching.
- Downstream of the Pohono Bridge LWD is primarily single, moderately sized pieces, that occur in moderate frequency.

Wood loading in the Merced River was compared with data from other rivers in northern California and Washington State (Figure 3-10) (Fox 2001, Herrera 2005; USFWS 2010). LWD loading in the Merced River is comparable to the Trinity River in Northern California (with both natural and placed pieces as part of restoration actions). Key differences influencing LWD loading between the Merced and Trinity Rivers include that the Trinity River is a regulated system with historic impacts from placer mining, both of which have dramatically decreased LWD recruitment and retention. The Merced River, however, has lower wood loading than other natural (unregulated) river systems with comparable bankfull widths in Washington State (e.g., Elwha River, Queets River); although these rivers have a wider range of channel widths, different stream bank vegetation composition and hydrology than the Merced River. However included in the Fox data are unregulated streams in the Eastern Cascades, with a more comparable hydrology to the Merced River than those in the Western Cascades. The range of wood loading for the Merced River would tend to be on the low range of the Fox (2001) trendline that was developed to describe the relationship between bankfull width and the expected number of LWD pieces within the channel due to the difference in hydrologic regime (Figure 3-10). The range of LWD loading for the Merced River is outlined in red in Figure 3-10 showing roughly an order of magnitude lower wood loading when compared to the Fox (2001) trendline. While it is to be expected that LWD loading on the Merced would be lower than that described by Fox (2001), the degree to which LWD loading likely reflects LWD removal in the Merced River as part of historic and active management practice.

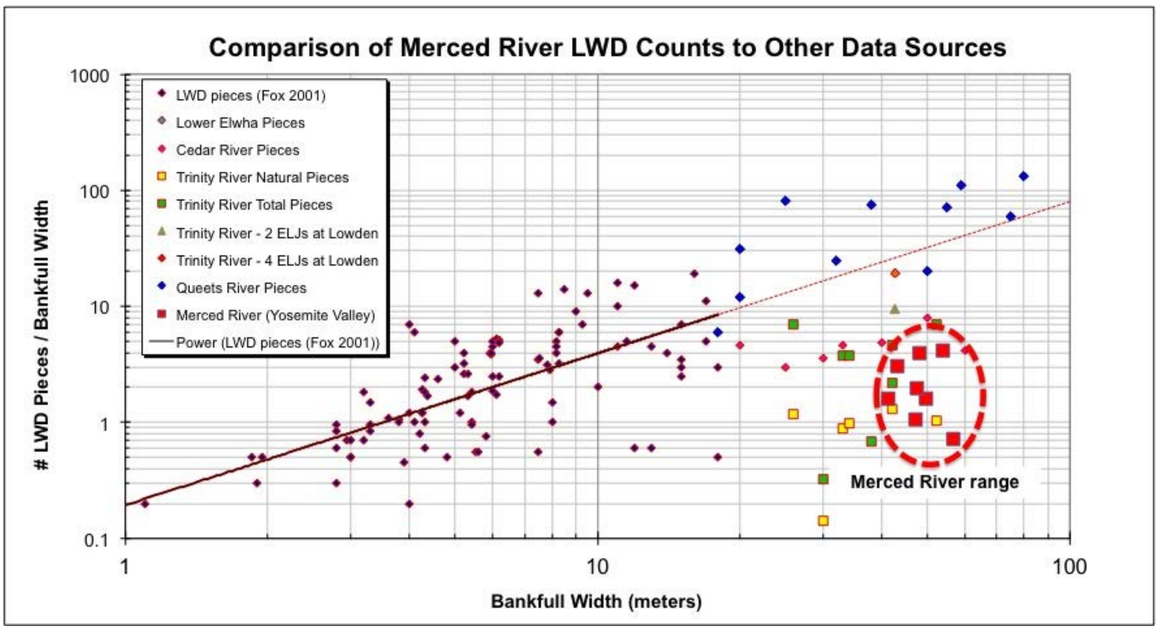

Figure 3-10. Regional LWD Loading

3.5.1.2 Geomorphic Reach Results

Wood loading generally decreased in the downstream direction, with the Happy Isles reach having the greatest wood loading and Below Tenaya and Below Pohono having the least (Figure 3-11). Most pieces in all geomorphic reaches arrived at (or were recruited to) their current channel location via fluvial transport, followed by bank erosion and tree fall. Recruitment by bank erosion predominantly occurred in the Happy Isle, Upper and Lower Meadow, and Above Pohono Bridge reaches.

From Happy Isles to the Inter-Meadows geomorphic reach, most pieces occurred within jams, with the exception of the Below Tenaya reach, where most LWD occurred as single pieces. Many pieces downstream of the Inter-Meadow geomorphic reach occurred as single pieces. In general, most pieces (>60 percent) did not play a role in pool formation, except in the Above Tenaya (> 50 percent either forming or associated with a pool) and Happy Isles (>40 percent) reaches. Most LWD downstream of the Lower Meadows reach was not forming or associated with pool habitat.

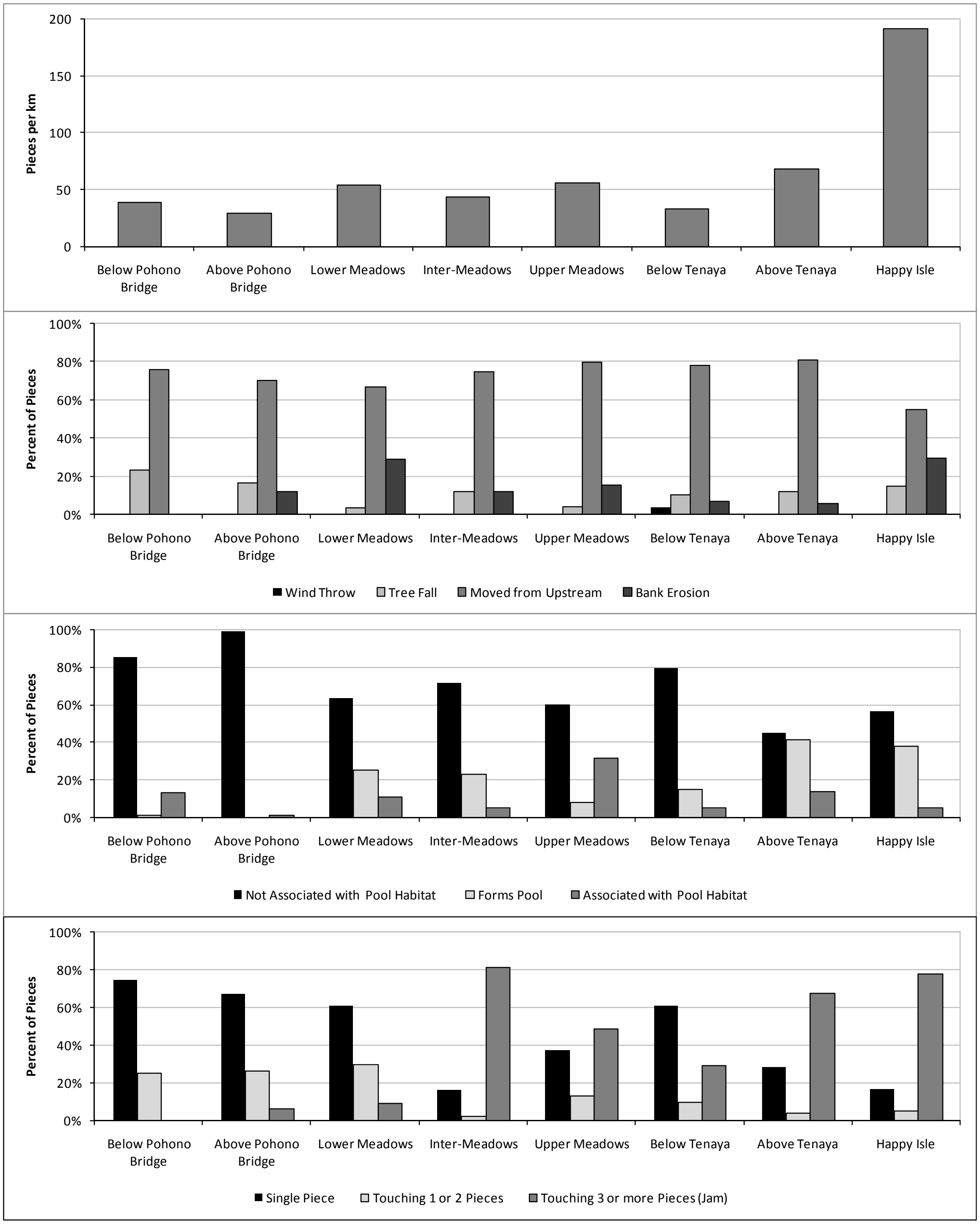

Figure 3-11. LWD Loading, Recruitment Mechanism, Association and Role in Pool Formation by Geomorphic Reach

3.5.2 Potential Wood Loading

3.5.2.1 Study Reach Results

The quantity of potential LWD recruitment (wood loading) within each of the CMZ zones by vegetation height class for the entire study reach is summarized in Figure 3-12. Larger trees, by volume, will contribute more to LWD loading within the river system than the smaller trees.

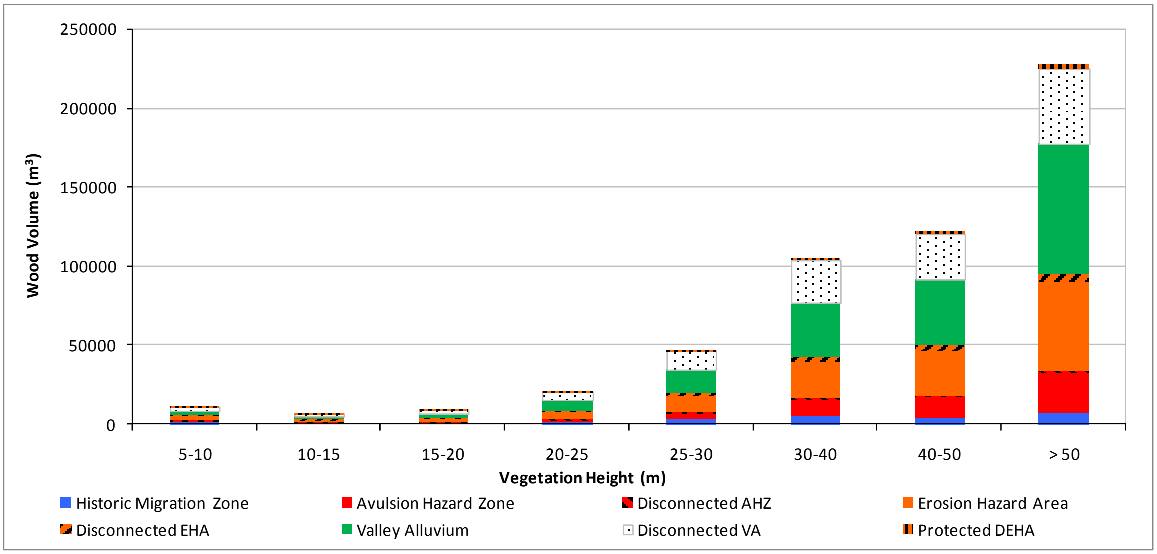

Figure 3-12. Potential LWD Recruitment Volumes for Each CMZ Area by Tree Height Class

The relative percent of potential wood volume within each CMZ area is similar for each tree height class, particularly within the EHA, DAHZ, DEHA, DVA, and PDEHA areas (Figure 3-13). The relative percent of potential LWD volume within the low risk CMZ areas (VA and DVA) and AHZ increases with increasing tree height class (from 47 percent to 57 percent and 7 percent to 12 percent, respectively). In comparison, within the HMZ, the relative percent of potential LWD volume decreases with increasing tree height (from 18 percent to 3 percent).

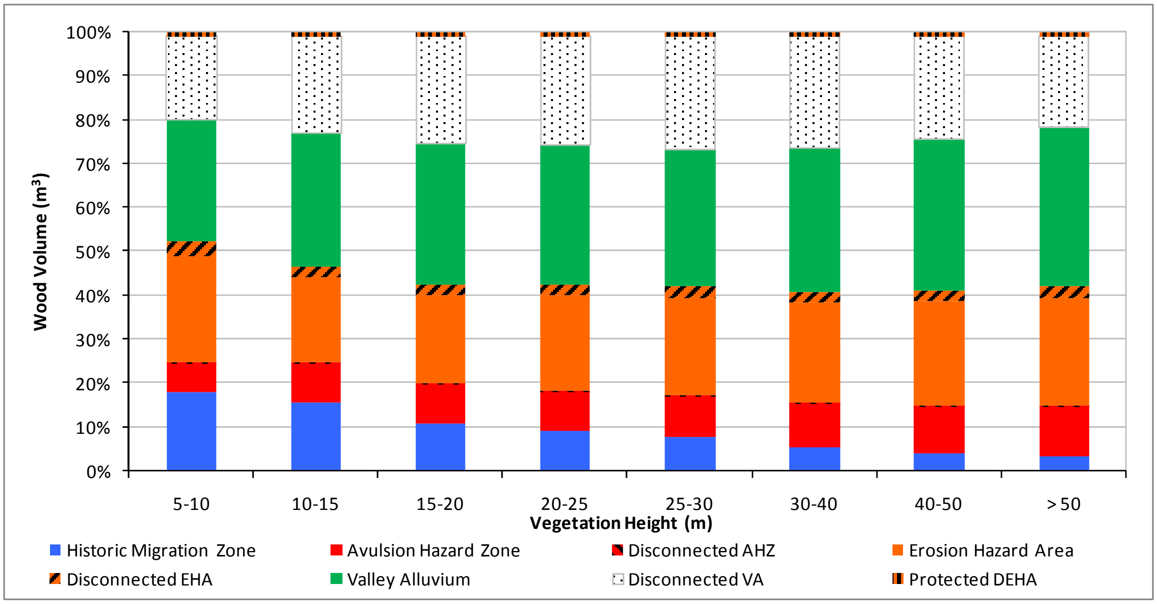

Figure 3-13. Relative percent of potential LWD Recruitment Volume for Each CMZ Area by Tree Height Class

Of the total volume of potential LWD, approximately 57 percent is found within the low risk areas (VA and DVA), 26 percent is within disconnected and protected disconnected areas (DAHZ, DEHA, DVA, PDEHA), and 24 percent is within the EHA (Figure 3-14). This finding highlights the one of the potential habitat benefits of re-connecting disconnected migration areas. Roughly a quarter of the potential future LWD recruitment volume is currently unavailable to the river system.

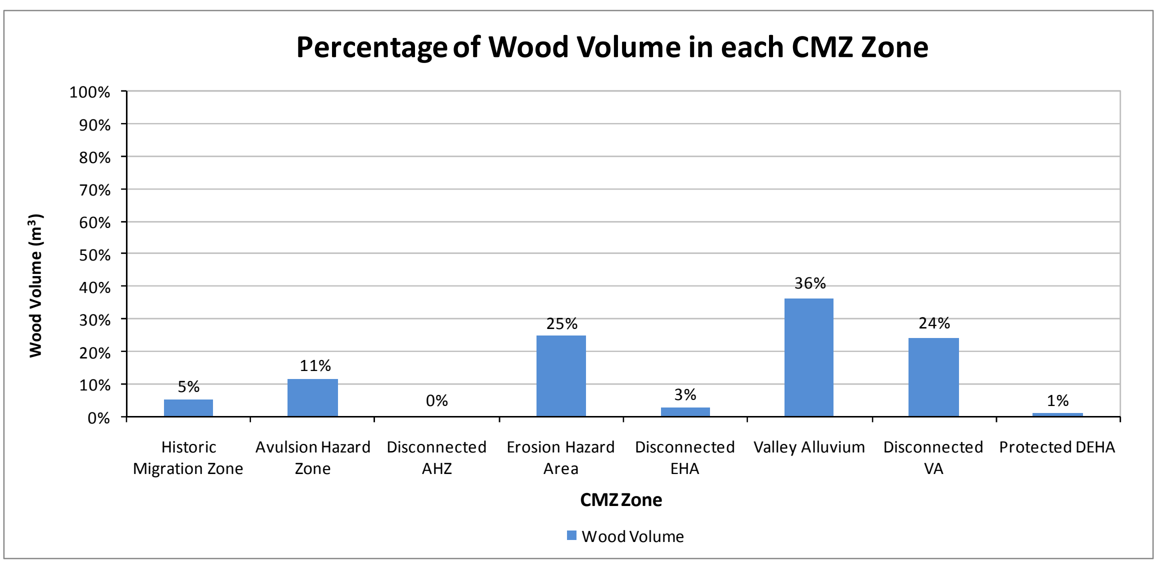

Figure 3-14. Total Volume of Potential LWD Recruitment within Each CMZ Zone for the Entire Project Reach

3.5.2.2 Geomorphic Reach Results

The potential LWD recruitment volumes by CMZ area by km and total LWD recruitment volume for each geomorphic reach are summarized in Figure 3-15 (top and bottom, respectively). The Above Tenaya and Happy Isles reaches have the greatest available LWD volumes available for future recruitment per channel length (400-800 m^3/km/yr) within the study area (Figure 3-14, top). Potential LWD recruitment volume is lowest in the Below Pohono reach (<50 m^3/km/yr). Potential LWD recruitment volumes ranged from 200-400 m^3/km/yr within the other geomorphic reaches. The Upper Meadows reach has the largest potential LWD recruitment volume (longest reach, 3.94 km), while the Below Pohono Bridge reach has the smallest potential LWD recruitment volume (Figure 3-15, bottom).

The amount of potential LWD recruitment volume from the AHZ is highest in the Happy Isles reach (approximately 200 m^3/yr/km), is approximately 50-100 m^3/yr/km in the Above and Below Tenaya reaches, and is less than 25 m^3/yr/km within the reaches further downstream. This is reflective of the difference in character in land use and vegetation where the avulsion potential exists within the reaches. In the Happy Isles reach, avulsion potential exists on a mature forested floodplain. In comparison, downstream of the Happy Isles reach, avulsion potential exists primarily on the inside of meander bends in the more sinuous reaches where the adjacent floodplain has been cleared for campground and other facility development.

The total amount of potential LWD recruitment volume from the EHA was greatest in the more sinuous middle reaches of the study area (Upper Meadows, Inter-Meadows, Lower Meadows, and Upper Pohono reaches). The mapped EHA was wider in these reaches where migration rates and LWD derived from lateral bank erosion processes were high compared to the upstream-most reaches and the Below Pohono reach.

The volume of potential LWD recruitment per river length from areas mapped as disconnected ranged from 1 m^3/yr/km to 167 m^3/yr/km, with the greatest potential for LWD recruitment in the Upper Meadows Reach (167 m^3/yr/km) (Figure 3-16, top). No potential LWD recruitment from Disconnected VAs occurs in the Happy Isles, Above Tenaya, and Below Pohono reaches.

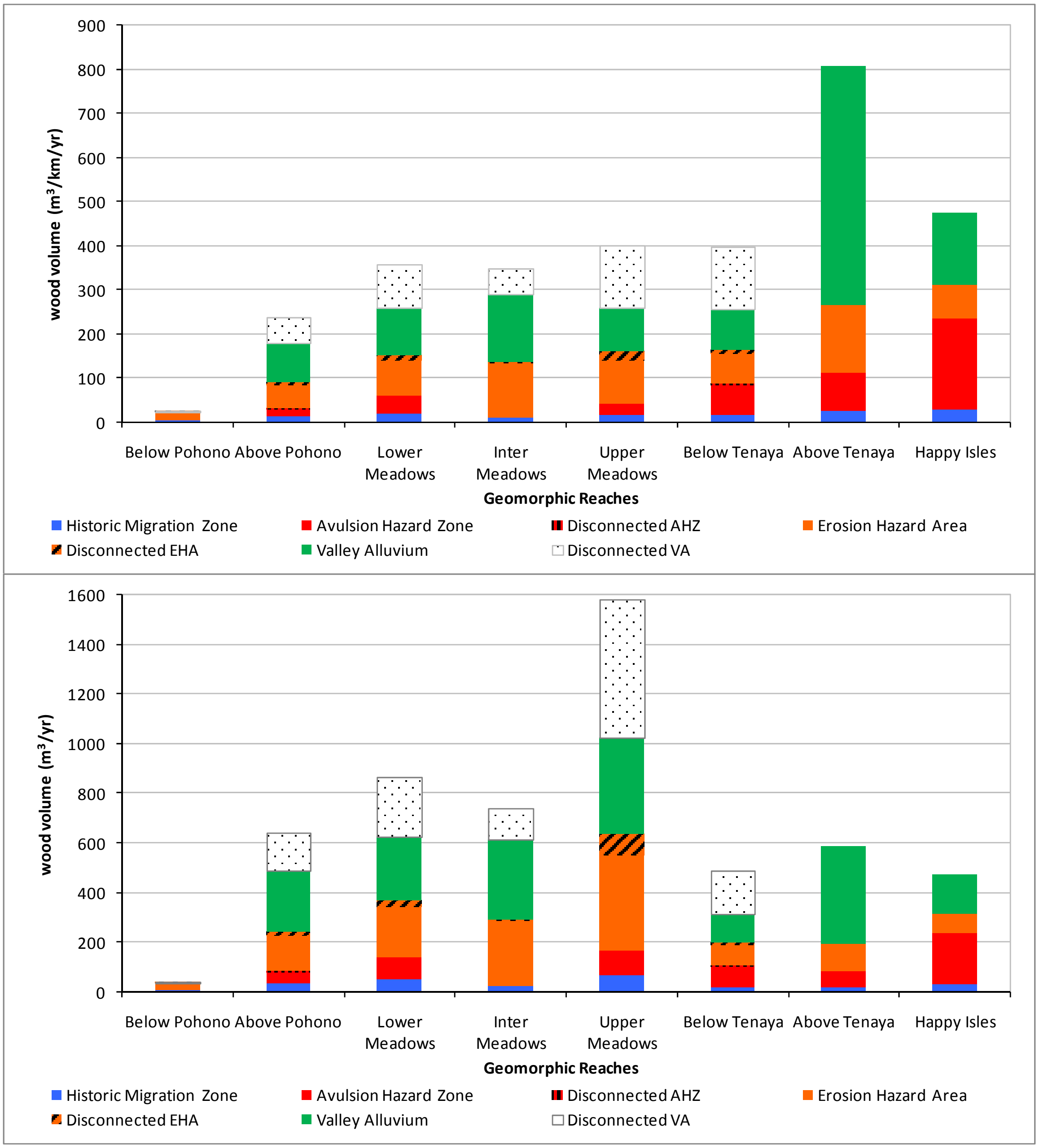

Figure 3-15. Volume Per River Length of Potential LWD Recruitment by CMZ Zone for Each Geomorphic Reach

3.6 Wildlife Habitat Assessment

3.6.1 Summary of Historic Wildlife Investigations

Table 3-6 provides a brief summary of historic wildlife investigations conducted in the study area.

Table 3-6. Brief Summary of Historic Wildlife Investigations Conducted in the Yosemite Valley

Authors and Title	Date	Brief Description
Gaines – Birds of Yosemite and the East Slope	1992	Details the distribution, status, abundance and habitat of every species known to occur in the Yosemite-Mono County region
Grinnell and Storer - Animal life in the Yosemite. An account of the mammals, birds, reptiles, and amphibians in a cross-section of the Sierra Nevada	1924	1911-1920 Surveys which provide some of the first baseline data/detailed accounts primarily for small mammals, birds, and frogs. Less information for reptiles.
Moritz - A Re-survey of the Historic Grinnell-Storer Vertebrate Transect in Yosemite National Park, California	2007	Performed a comprehensive re-survey of the Grinnell/Storer study from 2003-2006. This study provides documentation of changes in bird communities from 1920 to 2007.
Pierson – Bat Surveys, El Portal Road, Yosemite National Park.	1997	Inventory surveys; bat diversity; impacts of road modifications to bat species; and recommended conservations measures
Pierson and Rainey – Bat Surveys: Yosemite Valley and Hetch Hetchy Reservoir in July 1993	1993	Inventory surveys - Eleven species of bat detected using a variety of techniques.
Pierson and Rainey – Habitat Use by two cliff-dwelling bat species, the spotted bat, and the mastiff bat in Yosemite National Park, 1995	1996	Studies on roosting behavior of two bat species
Pierson et al. – Seasonal patterns of bat distribution along an altitudinal gradient in the Sierra Nevada	2001	Investigation of seasonal distribution of bat species along an altitudinal gradient from Oakdale to Tioga Pass
Pierson and Rainey – Distribution of Spotted Bat in California	1998	Their affinity for meadows was demonstrated by surveys conducted in Yosemite Valley, where the species was detected at seven of 13 sites in meadows or wetlands, and at none of nine forested sites; A significant constraining factor in the distribution of *E. maculatum* appears to be the availability of roosting habitat in cliffs. Wherever we found this species, there were substantial cliffs (granite, basalt, limestone, sandstone, and other sedimentary rock) within 10 km, suggesting that distribution of spotted bats is determined geomorphically. Such a constraint would help explain why the species is relatively more common in Yosemite
Siegel et al. – Extirpation of the Willow Flycatcher from Yosemite National Park	2008	They used historical records and digital maps based on remote sensing to identify and survey Yosemite's most likely breeding habitat for the species. Over the 2006 and 2007 breeding seasons they visited 71 sites, which accommodated 1709 call stations. They detected no territorial Willow Flycatchers, and concluded that the species likely no longer breeds in Yosemite National Park.
Stillwater Sciences – Merced Alliance Surveys	2008	This study was not designed to replicate historic surveys, but likely occurred near or possibly overlapped in some study areas. Data from 2006-2007. comprehensive assessment of fish, bird, and BMI (benthic macroinvertebrate) species composition and distribution in the Merced River

3.6.2 Summary of NPS Wildlife Condition Assessment Results

3.6.2.1 Wildlife Survey Results for the Study Area

Amphibians, Reptiles, and Invasive Aquatic Species

A total of 44 individuals (living and dead) of two amphibian, and at least four reptile species (including one unidentified lizard species) were detected either visually or through auditory cues during July and September 2010. Table 3-7 shows the number of living and dead individuals that were detected during the 2010 field study in the Yosemite Valley by location. Nine of the 44 individuals detected were incidental observations detected in locations that were not strictly associated with one of the 27 survey locations. No special status species were observed. Two non-native invasive species were detected; the American bullfrog and signal crayfish (invasive invertebrate species).

Unidentified Sceloporus species (spiny lizards) represented a majority of the individuals detected during the study (30 individuals, 68 percent of the total number of amphibian and reptile individuals observed). American bullfrogs were detected in the second highest frequency (5 individuals or 11 percent of the total number of amphibian and reptile individuals observed). A majority of the amphibian and reptile detections (39) were recorded during the September field visit (Espinoza et al. 2010). Five signal crayfish (invasive invertebrate) were also detected during the study.

Table 3-7. Amphibian, Reptile, and Invasive Aquatic Species Detections during 2010 Field Surveys. (Includes Living, Dead, and Incidental Detections)

		July			September		
Common Name	Scientific Name	Site Location	Living	Dead	Site Location	Living	Dead
Pacific treefrog	*Pseudacris regailla*	009	1	1	---	---	---
Greater brown skink	*Eumeces gilberti gilberti*	---	---	---	213	1	---
Western fence lizard	*Sceloporus occidentallis*	209	2	---	---	---	---
Sierra garter snake	*Thamnophis couchii*	---	---	---	002	1	---
		---	---	---	011	1	---
		---	---	---	013	1	---
Unidentified Sceloporus spp.	*Sceloporus* spp.	---	---	---	209	11	---
		---	---	---	213	11	---
		---	---	---	Incidental [2]	8	---
Unknown lizard species	*N/A*	---	---	---	006	1	---
American bullfrog[1]	*Lithobates catesbeiana*	005	1	---	006	1	---
		---	---	---	009	3	---
Signal crayfish (invertebrate)[1]	*Pacifastacus leniusculus*	203	---	1	009	1	---
		---	---	---	013	---	1
		---	---	---	203	1	---
		---	---	---	Incidental[3]	---	1
	Total		6			43	

1 Invasive Aquatic Species

2 Incidental location in between sites 209 and 213 in Happy Isles Reach

3 Incidental location near site 009 in Lower Meadows Reach

Birds

A total of 953 individual birds and 41 species were detected during the bird surveys that were conducted during the field visits in June and July 2010. Relative abundance for each species was estimated to be the average number of individuals observed across all 26 transects to account for possible duplicate observations among the three field visits. Relative abundance (total number of individuals divided by three field visits) was estimated at 317.67 individuals overall for the study (Espinoza et al. 2010). Of the 41 species detected, there were 28 probable and 17 confirmed locally breeding species. Table 3-8 shows the number of individuals that were detected during the 2010 field study in the Yosemite Valley. Data included all detections, excluding flyovers.

Table 3-8 Bird Detections during June and July 2010 Field Surveys.

Point	1	2	3	4	5	7	8	9	10	11	13	14	15	16	201	202	203	207	209	210	211	212	213	DH1	DH2	DL2	Total	Average for sites
Visits	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3		
Total individuals	62	50	54	61	64	44	30	46	28	55	46	34	50	40	17	50	19	10	5	16	23	20	4	46	65	14	953	36.65
Species richness	19	20	21	18	15	18	14	17	12	22	22	13	18	12	8	13	7	3	4	9	12	9	3	19	24	9	41	13.88
Acorn Woodpecker				2	2	2					1		1												1		9	3.00
American Dipper								1									2			2							5	1.67
American Robin	3	4	4	3	3		6	1	1	1	2	1	4	3		1	1		2	1	1	4	1		3	1	51	17.00
Anna's Hummingbird										1	1																2	0.67
Band-tailed Pigeon		1				1																					2	0.67
Black-headed Grosbeak	1	2	2		3	1	3	1		1				3		4			1	1	1	1	1	2	1	2	31	10.33
Black-throated Gray Warbler							1			1																	2	0.67
Brewer's Blackbird			3	8		3	5	2	8	1	1		7	9	2	21	2			1				4	6		83	27.67
Brown Creeper	1		2	3		1		1	1		2	7	2		1	1	3	2		4	5			2	2		40	13.33
Brown-headed Cowbird	3		3	2	8	2		2			3	1	2	1										3	2		32	10.67
Bullock's Oriole		1	1	1							1			2											1		7	2.33
Cassin's Vireo		2			2	2	1	2	1	1	2	2	1	1						2	1	3		2			25	8.33
Chipping Sparrow		1																							1		2	0.67
Common Merganser				10		1									1										1		13	4.33
Common Raven	1		2				1	1		1			1		8	5				1	1			1	1		24	8.00

Table 3-8 Bird Detections during June and July 2010 Field Surveys.

Point	1	2	3	4	5	7	8	9	10	11	13	14	15	16	201	202	203	207	209	210	211	212	213	DH1	DH2	DL2	Total	Average for sites
Visits	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3		
Total individuals	62	50	54	61	64	44	30	46	28	55	46	34	50	40	17	50	19	10	5	16	23	20	4	46	65	14	953	36.65
Species richness	19	20	21	18	15	18	14	17	12	22	22	13	18	12	8	13	7	3	4	9	12	9	3	19	24	9	41	13.88
Downy Woodpecker		1				1	1						3														6	2.00
Hairy Woodpecker	1			1						1																	3	1.00
House Wren		3									1																4	1.33
Lesser Goldfinch	3									1																	4	1.33
Lincoln's Sparrow				1																							1	0.33
MacGillivray's Warbler	6	3	1							2	1							4							1		18	6.00
Mallard				2				1			1													1			5	1.67
Mountain Chickadee	1	1	1					2			1		1			1								5	5		18	6.00
Northern Flicker	1		1	1	1					1		2					2			2	1	1				1	14	4.67
Oregon Junco		1	3							1	1	5									1	1					13	4.33
Pacific Wren																										1	1	0.33
Pacific-slope Flycatcher		2			1						3										1						7	2.33
Pileated Woodpecker			2						1							1								1	1		6	2.00
Purple Finch												1															1	0.33
Red-breasted Nuthatch	2					2			1	1	1					1								1	1		10	3.33
Red-winged Blackbird	4	1	2	7	8	7	1	2	4	8	1	2	2			6								5	8		68	22.67

Table 3-8 Bird Detections during June and July 2010 Field Surveys.

Point	1	2	3	4	5	7	8	9	10	11	13	14	15	16	201	202	203	207	209	210	211	212	213	DH1	DH2	DL2	Total	Average for sites
Visits	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3		
Total individuals	62	50	54	61	64	44	30	46	28	55	46	34	50	40	17	50	19	10	5	16	23	20	4	46	65	14	953	36.65
Species richness	19	20	21	18	15	18	14	17	12	22	22	13	18	12	8	13	7	3	4	9	12	9	3	19	24	9	41	13.88
Song Sparrow	15	8	6	3	8	6	3	7	5	6	7	5	7	4	1	1		4			4	3		6	7	1	117	39.00
Spotted Sandpiper		1	4	1	6	2		3	1	6			3	1							2			3	5		38	12.67
Steller's Jay	1	1	1	2			2			1	5	1	2	13	1	6	3		1	2	4	5	2	1	2	1	57	19.00
Warbling Vireo	6	5	4	5	5	1	1	6		3	3	1	2	1							1	1		1	4	5	55	18.33
Western Tanager	3	2	1		1		1	4	2	3	4	2	1			1			1			1		1	2	1	31	10.33
Western Wood-Pewee	6	4	5	8	8	6	3	6	2	5	1	4	5	1										4	6		74	24.67
White-headed Woodpecker	1														1										1		3	1.00
White-throated Swift						1	1										6										8	2.67
Yellow Warbler *	3	6	4		6	4		4	1	8	3		4	1	2									2	1		49	16.33
Yellow-rumped Warbler			2	1	2	1				1			2			1								1	2	1	14	4.67

* California species of special concern

Table 3-9 shows a breakdown of the most frequently encountered species, riparian focal species, California species of special concern, nest predators, and invasive species detected during the 2010 surveys. Additional details are contained in Espinoza et al. 2010.

The most frequently encountered species included the song sparrow (*Melospiza melodia*), Brewer's blackbird (*Euphagus cyanocephalus*), and the western wood-pewee (*Contopus sordidulus*). The five riparian focal species included black-headed grosbeak (*Pheucticus melanocephalus*), song sparrow, spotted sandpiper (*Actitis macularia*), warbling vireo (*Vireo gilvus*), and yellow warbler (*Dendroica petechia*). The yellow warbler was the only California species of special concern detected during the surveys. The two nest predators included steller's jay (*Cyanocitta stelleri*), and the common raven (*Corvus corax*). The brown-headed cowbird (*Molothrus ater*) was the only invasive species detected during the 2010 survey.

Table 3-9. Breakdown of Bird Detections during June and July 2010 Field Surveys

	Common Name	Total Number Individuals	Relative Abundance[1]
Most Frequently Encountered Species			
	Song sparrow	117	39.00
	Brewers blackbird	83	27.67
	Western wood-pewee	74	24.67
California Partners in Flight Riparian Focal Species			
	Black-headed grosbeak	31	10.33
	Song Sparrow	117	39.00
	Spotted sandpiper	38	12.67
	Warbling vireo	55	18.33
	Yellow Warbler	49	16.33
California Species of Special Concern			
	Yellow warbler	49	16.33
Nest Predators			
	Steller's jay	57	19.00
	Common raven	24	8.00
Invasive Species			
	Brown-headed cowbird	32	10.67

1 Average number of individuals observed across all 26 points

Bats

A high diversity of bats was documented during the 2010 field surveys. Of the 17 bat species that are known to occur in Yosemite National Park (Pierson et al. 2001), 11 species were detected at the two survey locations (Yosemite Creek and North Pines Campground). The North Pines Campground had the highest number of individuals detected (1,496 individuals – which represents 100 percent of the species detected during the study) compared to the Yosemite Creek site (89 individuals, and 54.5 percent of the species) during the study (Espinoza et al. 2010).

Two California Species of Special Concern and Bureau of Land Management (BLM)Sensitive species were detected at both sites during the study. They were the spotted bat (*Euderma maculatum*) and western mastiff bat (*Eumops perotis*). The spotted bat had the second highest number of detections of all bats during the study (1 at Yosemite Creek and 351 at North Pines Camp). The hoary bat (*Lasiurus cinereus*) had the most individuals detected overall (59 at Yosemite Creek and 638 at North Pines Camp) during the study. Table 3-10 shows all species of bat detected during the study at both survey locations. Six other species known to occur in Yosemite National Park but that were not detected during the study are listed below (the latter three being species of special concern*).

- Long-legged myotis
- Long-eared myotis
- Fringed myotis
- Pallid bat* (California Species of Special Concern; BLM Sensitive; and USFS Sensitive)
- Western red bat* (California Species of Special Concern; and USFS Sensitive)
- Townsend's big-eared bat* (California Species of Special Concern; BLM Sensitive; and United States Forest Service [USFS]Sensitive)

Table 3-10. Bat Detections at Two Survey Sites Along the Merced River, Yosemite Valley (NPS 2010)

Common Name	Scientific Name	24 - 29 June (5 nights) Yosemite Creek (Upper Meadow Reach) # of detections	29 June - 7 July (8 nights) North Pines Camp (Above Tenaya Reach) # of detections
Big brown bat	*Eptesicus fuscus*	1	9
Spotted bat	*Euderma maculatum**	1	351
Western mastiff bat	*Eumops perotis**	24	35
Hoary bat	*Lasiurus cinereus*	59	638
Silver-haired bat	*Lasionycteris noctivagans*	0	30
California myotis	*Myotis californicus*	0	1
Small-footed myotis	*Myotis ciliolabrum*	0	1
Little brown bat	*Myotis lucifugus*	0	2
Yuma myotis	*Myotis yumanensis*	0	3
Western pipistrelle	*Parastrellus hesperus*	2	92
Mexican free-tailed bat	*Tadarida brasiliensis*	2	334
	Total	89	1,496

*California Species of Special Concern

WHR Modeling

The first unedited species list generated from the WHR model that included both montane riparian and wet meadow habitat types in the river corridor in Yosemite Valley predicted 343 vertebrate species. Using professional judgment, the NPS edited the list to include a total of 317 species (10 amphibians, 21 reptiles, 218 birds, and 68 mammals) (Espinoza et al. 2010).

From the species lists, there were 27 special status species, all of which were predicted to occur in Yosemite Valley. The list identified six invasive species, all of which are predicted to occur in Yosemite Valley. Table 3-11 shows the number of species actually detected during the 2010 field surveys compared to the predicted number of species expected to occur from the WHR model results. Additional details are contained in Espinoza et al. 2010.

When results of the herpetofauna surveys are combined with previous detections, a total of 8 of the 10 predicted amphibian species have been recorded in the Merced River Corridor (Espinoza et al. 2010). No special status amphibian species were detected during the 2010 study. The WHR model predicts that three special status species would be expected to occur. The foothill yellow-legged frog (*Rana boylii*) is a special status amphibian species that has historically been documented in the study area. Three observations were reported for Yosemite Valley in 1974 (WOD 2010). However, no individuals have been reported in the park since the mid-1970s and the species is believed to be extirpated from the park. Results of the WHR Model indicate that the suitability of the habitat is low for this species and they would be expected to occur in relatively low population densities at low frequencies (Espinoza et al. 2010). The low number of historic records is likely a reflection of the limited habitat for foothill yellow-legged frogs in the park (Hayes et al. 2007).

Table 3-11. Number of Wildlife Species Detected during 2010 Field Surveys Combined with Previous Detections Compared to Predicted Number of Species from the WHR Model

Type	2010 Survey Observed #) = special status	WHR Model Confirmed
Amphibian	2 (0)	8
Reptile	4 (0)	18[1]
Bird	41 (1)	215
Bat	11 (2)	17
Special Status Species	3	23[4]
Invasive Species	3[3]	2[2]

1 includes 2 species detected in 2010 that were not originally predicted by the WHR model to occur in the study area
2 invasive species observed in 2010 included brown-headed cowbird and American bullfrog
3 includes signal crayfish
4 represents birds, bats, amphibians, and reptiles only; does not represent other mammals

Sierra Nevada yellow-legged frogs (*Rana sierrae*) are a special status species that typically inhabit higher elevation lakes and streams and were once numerous in Yosemite (NPS 2011), but are now predicted to occur in low population densities and low frequencies (Espinoza et al. 2010). Historically there were sightings of the frogs in the park (WOD 2010). However, in recent years, its numbers have declined by as much as 95% in the Sierra Nevada including

Yosemite (NPS 2011). Multiple factors may have contributed to the decline of the frog, including the introduction of fish (trout) into naturally fishless waters throughout most of the park (Grinnell and Storer 1924; NPS 2011). Non-native trout feed on eggs, tadpoles, and young adults and compete for natural food sources (NPS 2011). Although fish stocking in Yosemite ceased in 1991, many non-native trout populations continue to exist (NPS 2011).

Eighteen of 21 predicted reptile species have been observed in the Merced River Corridor from all data sources. Only four reptile species were observed in the 2010 surveys. The WHR Model predicted that one California reptile species of special concern, the western pond turtle (*Actinemys marmorata*), would be expected to occur in relatively medium population densities at medium frequencies in the Yosemite Valley. No western pond turtles were detected during the 2010 surveys. However, these turtles may be difficult to observe in the field because they tend to dive in to the water at the slightest disturbance and can remain submerged for some time. These turtles tend to favor habitats with large amounts of emergent logs or boulders where they aggregate to bask. Historically, there were two sightings of western pond turtles in the Merced River corridor; both in Yosemite Valley in the 1950s. One sighting was at Sentinel Meadow (WOD 2010) in 1950 and the other sighting was in 1958 in Stoneman Meadow (CNDDB 2011). No western pond turtles have been detected since the 1950s in the Merced River corridor and the species may be extirpated from the park.

Bird species were the least represented during the 2010 study with only 41 species detected during the field surveys compared to the 218 species predicted by the model. In contrast, studies conducted by Stillwater Sciences (2008) indicated that the Merced River corridor supports important breeding habitat for many bird species. Results of their study found a total of 129 species in both the upper and the lower Merced River corridor. A total of 87 species were found in the upper river corridor with 31 of the species detected unique to the upper corridor (Stillwater Sciences 2008). A total of 12,540 individual birds were detected during the 2006 and 2007 breeding seasons.

In addition, 3,831 individual birds (117 species) were detected during the 2006 and 2007 fall migration study (Stillwater Sciences 2008). During the winter seasons of 2006, 2007, and early 2008, a total of 3,344 birds and 81 species were observed along the lower Merced River (no winter surveys were conducted in the upper river corridor for the winter season), (Stillwater 2008). Results of the Stillwater Sciences study (2008) and the 2010 survey results indicate that the Merced River corridor provides important breeding habitat for a diverse group of birds representing a variety of breeding niches and differing seasonal strategies (resident species, short-distance, and long-distance migrants).

The model predicted that 17 bat species are expected to occur within the Merced River Corridor in Yosemite Valley, which is similar to results of the Pierson and Rainey 1993 study in which 11 species were detected using a variety of survey techniques. Between these two studies, 15 of the 17 bat species expected to occur in Yosemite were documented (Espinoza et al. 2010). However, neither this study nor the 1993 study detected the long-legged myotis and the western red bat, a California Species of Special Concern. Both of these species were later documented in Yosemite in Pierson et al.'s (2001) study, and are expected to occur in Yosemite Valley. The Western red bat is a tree-dwelling species, primarily associated with lower elevation deciduous or mixed conifer forest while the long-legged myotis is a crevice-dwelling species, roosting in rock crevices, under bark, in snags, mines, and caves (Pierson and Rainey 1993)

3.6.2.2 Summary of NPS Wildlife Condition Assessment by Geomorphic Reach

Figures of the Wildlife Habitat Relationship (WHR) habitat types within the Merced River Corridor in Yosemite Valley by geomorphic reach are provided in Appendix A. Table 3-12 provides the total hectares and percent of total area for each WHR habitat type by geomorphic reach.

The four most common WHR habitat types are ponderosa pine (29 percent), montane hardwood conifer (18 percent), montane riparian (17 percent), and wet meadows (14 percent) as shown in Table 3-13. Upper Meadow Reach contains the highest percentage of each of these most common habitat types with the exception of ponderosa pine. Ponderosa pine is slightly higher in both the Lower Meadows Reach (54.7 hectares) and the Inter Meadows Reach (48 hectares) compared to the Upper Meadows Reach (46 hectares).

Overall, the Upper Meadows Reach was the largest reach with the highest acreage of WHR habitat types present (247 ha or 35 percent of total). Twenty four percent (24 percent) of this reach is represented by wet meadows (60 ha). Wet meadow habitat is present in the Above Tenaya, Below Tenaya, Upper Meadows, Lower Meadows, and Above Pohono reaches. Sixty two percent (62 percent) of the wet meadows in the study area are present in the Upper Meadows Reach.

Below Pohono Bridge Reach has the lowest total acreage (9 hectares) compared to all of the other reaches and represents only 1 percent of the total WHR habitat in the study area (Table 3-13). Fifty six percent (56 percent) of this reach is represented by riverine WHR habitat type. This narrow canyon reach has a poorly developed riparian habitat (only 29 percent montane riparian WHR habitat type).

All but one WHR habitat type was present in the Lower Meadows (fresh emergent wetland was not present). The Lower Meadows Reach was the second largest reach in terms of acreage of WHR habitat types present. Fresh emergent wetland was only present in the Happy Isles Reach (representing 3 percent of the total WHR habitat type present in this reach).

Table 3-12 Yosemite Valley WHR Types in Hectares by Geomorphic Reach (Also refer to Appendix A for Wildlife Habitat Relationships Map Series)

WHR Type	Happy Isle	Above Tenaya	Below Tenaya	Upper Meadows	Inter-Meadows	Lower Meadows	Above Pohono Bridge	Below Pohono Bridge	Total WHR Type in Study Area (ha)	WHR Type: Percentage of Total
Black Oak Woodland		0.3	0.3	15.8		8.2	5.2		29.9	*4%*
Fresh Emergent Wetland	1.3								1.3	*0.19%*
Lacustrine						0.4			0.4	*0.06%*
Montane Hardwood			0.5	0.3	2.5	2.9		0.6	6.8	*1%*
Montane Hardwood Conifer	16.7	20.2	23.5	34.2	10.6	13.2	7.3		125.7	*18%*
Montane Riparian	14.1	13.9	5.4	40.5	11.5	18.9	13.5	2.8	120.5	*17%*
Ponderosa Pine	6.3	12.4	14.1	46.0	47.6	54.7	21.1	0.2	202.3	*29%*
Riverine	2.6	1.6	2.9	11.2	5.7	8.6	8.2	5.3	46.2	*7%*
Sierra Mixed Conifer	0.9	0.2	2.7	6.4		0.3	6.6	0.5	17.5	*2%*
Urban	1.2	4.2	7.3	33.2	6.4	3.5	0.5	0.1	56.4	*8%*
Wet Meadow		7.1	6.0	59.9		15.3	8.2		96.4	*14%*
Total Hectares	43.1	59.9	62.7	247.4	84.2	126.1	70.6	9.4	703.3	
% of Total Hectares By Reach	*6%*	*9%*	*9%*	*35%*	*12%*	*18%*	*10%*	*1%*		100%

A summary of the results by geomorphic reach for the NPS WHR habitat relationship types and wildlife field surveys conducted during 2010 for amphibians and reptiles, birds, invasive species, and bats is provided in Table 3-13.

- **Happy Isles Geomorphic Reach.** This reach is one of the least managed reaches and is predominantly represented by montane hardwood conifer; montane riparian; ponderosa pine; and fresh emergent wetland. No bat surveys were conducted in this reach. Two survey point locations were located in this reach during 2010. No amphibians were detected in this reach. A total of 33 individual reptile species were detected within this reach. This represents 67 percent of all amphibians and reptiles that were detected overall during the study (excluding incidental detections). No invasive aquatic species were detected in this reach. Nine individual birds and 4 species were detected in this reach. This represents 1 percent of the total number of birds detected overall and 10 percent of the species. No invasive bird species were detected in this reach. One nest predator bird species was detected in this reach (Steller's jay).
- **Above Tenaya Geomorphic Reach.** This reach is predominantly montane hardwood conifer; montane riparian; ponderosa pine; wet meadow; and urban habitat types. Two survey points were located in this reach. No amphibians, reptiles, or invasive aquatic species were detected in this reach. Seven percent (7%) of the individual birds detected in the study were detected in this reach (67 individuals). Thirty nine percent (39%) of the species were represented in this reach (16 species). No invasive bird species were present in this reach. Two nest predator bird species were detected in this reach (common raven and Steller's jay). The highest diversity of bats was present in this reach with the total number of individuals detected equal to 1,946 (94% of the total for the study). Eleven bat species were present within this reach.
- **Below Tenaya Geomorphic Reach.** This reach is predominantly montane hardwood conifer; ponderosa pine; urban; wet meadow; and montane riparian habitat types. There was one survey location located on the edge of this reach (close to the beginning of the Upper Meadows Reach). There were no bat surveys in this reach. There were no amphibians, reptiles, or invasive aquatic species detected in this reach. A total of 30 individual birds (3%) and 14 species (34%) were detected in this reach. Two nest predator species were detected in this reach (common raven and Steller's jay). There were no invasive bird species detected in this reach. This reach is one of the most managed reaches in the study area.
- **Upper Meadows Geomorphic Reach.** The Upper Meadows Reach has the highest percentage of wet meadows habitat of all the reaches (62 percent); followed by ponderosa pine and montane riparian habitat types. This was the largest reach in the study area and there were a total of 7 survey sites in this reach. One reptile species (1 individual) was detected during the study. No amphibians were detected in this reach. No invasive aquatic species were detected in this reach. The largest number of individual birds (354) and bird species (35 species) were detected in this reach. One invasive bird species was detected (brown-headed cowbird), and two nest predator bird species were detected (common raven and Steller's jay). In addition, 89

individual (6 percent) bats were detected, representing a total of 6 species (55 percent).

- **Inter-Meadows Geomorphic Reach.** The Inter Meadows Reach is predominantly represented by ponderosa pine followed by montane riparian habitat type. The WHR habitat type for this reach did not have wet meadow habitat. There were four survey sites in this reach. One reptile species was present in this reach. Signal crayfish were detected in this reach as well. No other aquatic invasive species were detected and no amphibians were detected during the study. Thirty different bird species were detected (158 individuals) in this reach. One bird nest predator species (Steller's jay) and one invasive bird species (brown-headed cowbird) were detected in this reach. There were no bat surveys in this reach.

Table 3-13 Summary of NPS 2010 Survey Data for Amphibians/Reptiles/Invasive Aquatic Species, Birds, and Bats By Geomorphic Reach

Geomorphic Reach	WHR Habitat Type (Predominant types high to low overall in reach)	Survey Point ID	Amphibian, Reptile, and Invasive Aquatic Species		Birds		Bats	
			# Individuals (% of total)	# of Species	# Individuals (% of total)	# of Species (% of total)	# Individuals (% of total)	# of Species (% of total)
Happy Isles	Montane Hardwood Conifer; Montane Riparian; Ponderosa Pine; and Fresh Emergent Wetland	209; 213, incidental	33 (67%)	3 Reptiles	9 (1%)	4 (10%)	No Bat Surveys in this reach	
Above Tenaya	Montane Hardwood Conifer; Montane Riparian; Ponderosa Pine; Wet Meadow; and Urban	201; 202	0	0	67 (7%)	16 (39%)	1496 (94%)	11 (100%)
Below Tenaya	Montane Hardwood Conifer; Ponderosa Pine; Urban; Wet Meadow; and Montane Riparian	008	0	0	30 (3%)	14 (34%)	No Bat Surveys in this reach	
Upper Meadows	Wet Meadow; Ponderosa Pine; Montane Riparian; Montane Hardwood Conifer; Urban; and Black Oak Woodland	003; 007; 008; 011;015; 016; DH1; DH2	1 (2%)	1 Reptile	354 (37%)	35 (85%)	89 (6%)	6 (55%)
Inter-Meadows	Ponderosa Pine; Montane Riparian; Montane Hardwood Conifer; Urban; and Riverine	002; 010; 013; 014	3 (6%)	1 Reptile; Crayfish	158 (17%)	30 (73%)	No Bat Surveys in this reach	
Lower Meadows	Ponderosa Pine; Montane Riparian; Wet Meadow; Montane Hardwood Conifer; and Riverine	001; 004; 005; 006 [1]; 009, incidental[2]	10 (20%)	2 Amphibian[3] 1 Reptile; Crayfish	233 (24%)	30 (73%)	No Bat Surveys in this reach	
Above Pohono Bridge	Ponderosa Pine; Montane Riparian; Riverine; Wet Meadow; and Montane Hardwood Conifer	203; 207; 210; 211; DL2	2 (4%)	Crayfish	82 (9%)	18 (44%)	No Bat Surveys in this reach	
Below Pohono Bridge	Riverine; Montane Riparian; Montane Hardwood; Sierra Mixed Conifer; and Ponderosa Pine	212	0	0	20 (2%)	9 (22%)	No Bat Surveys in this reach	
Totals	8 Geomorphic Reaches	27 Sites	49 Total	2 Amphibian[3] 4 Reptile 2 Invasive[4]	953 Total Relative Abundance 317.67	41 Total	1,585 Total	11 Total

1 bird surveys were not conducted for this survey point

2 incidental observations for amphibians/reptiles and invasive aquatic species were recorded in this reach

3 includes American bullfrog

3 includes American bullfrog and signal crayfish

- **Lower Meadows Geomorphic Reach.** The Lower Meadows Reach is predominantly ponderosa pine, montane riparian, and wet meadow habitat types. There were five survey locations in this reach as well as incidental detections. Two amphibian species (including one invasive amphibian – American bullfrog), one reptile species, and signal crayfish (invasive aquatic species) were detected in this reach (9 individuals). The American bullfrog was not detected in any of the other reaches in the study. They were detected at three of the five survey sites in this reach. Twenty four percent of the total number of birds was detected in this reach (233 individuals). Two bird nest predator species (Steller's jay and common raven) and an invasive bird species (brown-headed cowbird) were detected in this reach. Thirty bird species were present (73 percent of the bird species total). No bat surveys were conducted in this reach.
- **Above Pohono Bridge Geomorphic Reach.** The Above Pohono Bridge Reach is predominantly represented by ponderosa pine, montane riparian, and wet meadow habitat types. There were five survey points in this reach. Two signal crayfish individuals (invasive species) were detected in this reach. No amphibian or reptile species were detected. A total of 82 birds were detected (9%) and 18 bird species (44%). Two nest predator bird species (Steller's jay and common raven) and one invasive bird species (brown-headed cowbird) were detected in this reach. No bat surveys were conducted in this reach.
- **Below Pohono Bridge Geomorphic Reach.** This narrow canyon reach is predominantly represented by riverine (56 percent); montane riparian; montane hardwood; sierra mixed Conifer; and ponderosa pine habitat types. There was one survey point in this reach. No reptiles or amphibians were detected in this reach. No invasive aquatic species were detected. Twenty (20) individual birds were detected (2 percent of total in study). Nine different bird species were detected (22 percent). One nest predator bird species was detected (Steller's jay). There were no bat surveys in this reach.

Chapter 4

Summary of Changes since Wild and Scenic River Designation

A purpose of this report is to describe changes to the riparian corridor and river channel that have occurred since this reach of the Merced River was designated as Wild and Scenic under the under the Wild and Scenic Rivers Act, which occurred in 1987. Data to evaluate changes to riparian corridor and river channel since Wild and Scenic River designation include previous reports, maps, and aerial photography that documented condition just before or after 1987. These historical sources were compared to more recent information (when available) and the results of field surveys conducted for this study. This description of changes also includes a summary restoration projects conducted by Yosemite National Park since 1991.

4.1 Riparian Vegetation

4.1.1 Study Reach

The majority of the riparian corridor within the study reach is dominated by community types comprised of different combinations of late seral species, including conifers, oaks, and incense cedar (Figure 3-1). These communities generally occur in fairly long continuous corridors along the stream banks (Appendix A, 2010 Riparian Vegetation Map Series). The proportion of these community types decreased slightly between 1992 and 2010 (4.5 percent) (Appendix A, 1992 to 1997 and 1997 to 2010 Riparian Vegetation Map Series). The proportion and distribution of meadow and herbaceous communities have also remained relatively constant over time. The proportion of bare areas decreased by less than 1 percent between 1997 and 2010[15]. The proportion of alder dominated communities has remained similar between 1992 and 2010 (1 percent decrease). The proportion of bare areas increased between 1992 and 1997, likely caused by scouring of vegetation by the January 1997 flood (a 2.2 percent increase). Some of these areas have been naturally revegetated (0.7 percent).

In comparison, the distributions and/or proportions of early seral community types dominated by black cottonwood or willow species have changed between 1992 and 2010. These communities are generally established closer to the river channel than oaks and conifers and, consequently, are more susceptible to periodic scour and/or burial during high flow events, including the 1997 winter flood. These species are well- adapted to successful establishment in fluvial and frequently disturbed environments. Specifically, they disperse many small seeds that are transported via wind and water, and also readily regenerate adventitiously. They generally require open, continuously moist, alluvial deposits for successful germination. Willows and cottonwoods release seeds in the spring, timed with the receding limb of the snowmelt

[15] See Section 3.1.1.1 for discussion of differences in mapping classifications of white alder/big leaf maple community types between the 1992, 1997, and 2010 mapping efforts, and in the differences in mapping methods and/or classification of sub-dominant species.

hydrograph. Seed germination must occur within a short period of time, as cottonwood and willow seeds have very short viability periods (less than three weeks) (Braatne et al. 1996; Karrenberg et al., 2002; Anderson 2006). Once established, these species have fast initial growth rates, and out-compete slower growing species such as oaks and conifers. Individuals generally establish in elevation zones above frequent scour by winter and spring flows, but where late summer ground water is available. The 1997 flood scoured vegetation that had been established along the channel margins, creating new potential locations for riparian species establishment. In addition, prescribed burns that burned through the riparian corridor (particularly ones that burn understory and shrubs) may also create open tree canopy and alluvial deposits and facilitate riparian recruitment. Vegetation along the channel margins is also particularly sensitive to trampling and soil compaction from human use.

Although willows have been very successful in recent restoration projects throughout the study reach (see Section 4.4), the overall proportion of area dominated by willow communities has decreased since 1992 by approximately 7.6 percent. In comparison, the proportion of black cottonwood forest increased by 11.2 percent between 1992 and 2010. In some areas, black cottonwood forests now dominate areas previously mapped as willow-dominated communities, including near Curry Village, Housekeeping Camp, Yosemite Lodge, and Sentinel Beach picnic area. Based on observations of the tree sizes during the field surveys, it appears that cottonwood recruitment and survival have been successful within the study reach since the 1997 flood during years with favorable spring and summer flows, particularly in the Upper Meadows geomorphic reach. Reduction in willow-dominated communities occurred in two main reaches, downstream of the Sentinel Beach picnic area and upstream of El Capitan Bridge (between 1992 and 2010). Within these areas, many bars that were mapped as willow-dominated in 1992 were bare or dominated by cottonwoods, sometimes mixed with willows, in 2010. It is possible that the willows on the bars in 1992 were scoured by the 1997 winter flood and have not re-established as well compared to cottonwoods. The reason for the decline in dominance of willows is not known at this time, but could be due to a greater susceptibility to scour compared to cottonwoods as willows generally establish closer to the river channel, an increase in dominance of cottonwoods within the riparian corridor due to recent successful recruitment events, or trampling of young willows that may have established after the 1997 flood near recreation areas (e.g., near Sentinel Beach picnic area and the swinging bridge), or were burned during recent prescribed burns, particularly in the early 1990s in the Lower, Inter-, and Upper Meadows reaches (e.g., 1993 in the Sentinel Beach area).

4.1.2 Geomorphic Reaches

The riparian corridor in the Happy Isles, Above Tenaya, and Below Tenaya geomorphic reaches are primarily comprised of late seral riparian community types, comprised of oaks, conifers, white alder, and/or big leaf maple (Table 3-3). One new stand of black cottonwood forest was identified in 2010 near North Pines Campground. The proportion of willow-dominated communities decreased between 1997 and 2010 by approximately 3 percent. The proportion of bare area within the Happy Isles reach increased between 1997 and 2010 by 4 percent. In the Below Tenaya Reach, the proportion of bare area increased by 5 percent between 1992 and 1997, and remained similar between 1997 and 2010.

The Upper, Inter-, and Lower meadow geomorphic reaches are comparatively compositionally diverse, with a large number of different community types present. The proportion of oaks and conifers are generally lower compared to the other geomorphic reaches. The proportion of black cottonwood forest has increased substantially in the Upper and Lower Meadow reaches between 1992 and 2010 (30 and 18 percent, respectively), while the proportion of willow-dominated communities have decreased. Many areas dominated by willows in 1992 were dominated by black cottonwood forest (cottonwood-willow mix) in 1997 and 2010. The proportion of bare areas within these reaches increased between 1992 and 1997, likely scoured by the 1997 flood. Many of these areas were subsequently naturally revegetated. In addition, a number of prescribed burns of varying sizes and severity have occurred within these reaches, particularly in the early 1990s, which may have also resulted in the loss of understory species, including willows (e.g., in the Sentinel Beach area which burned in 1993).

In the Above and Below Pohono Bridge geomorphic reaches, the proportion and distribution of the vegetation community types have remained fairly stable over time, with new establishment of willows and black cottonwoods in a few locations.

4.2 Channel Migration Zone

4.2.1 Study Reach

The overall channel form of the Merced River within Yosemite Valley has not changed since Wild and Scenic River Designation in 1987. Channel reaches that were straight or meandering remain so to date, however there has been lateral erosion primarily along the outside bends of the river channel. Additional bank erosion has occurred within the straightened reaches, and no channel avulsions have taken place.

Using the digitized historic channel alignments used to determine the HMZ, changes in channel position were assessed. Historic channel alignments digitized in 1934, 1944, and 1987 provide information on channel planforms prior to the Wild and Scenic River Designation of 1987. Comparison of these data shows a net increase in channel area (widening) between 1934 and 1944, at a rate of 0.3 ha/yr for the entire study reach. Most of the erosion between 1934 and 1944 occurred at the downstream end of the Upper Meadows geomorphic reach (Figure 4-1).

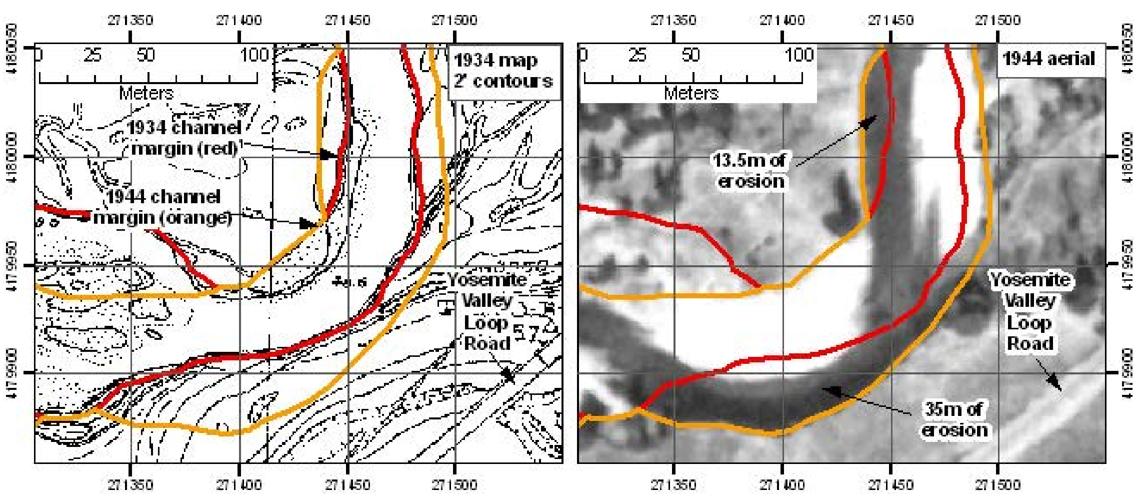

Figure 4-1 Example of Lateral Bank Erosion Between 1934 and 1944 at the Downstream End of the Upper Meadows Geomorphic Reach

Between 1944 and 1987 the channel continued to increase in width, however the rate was dramatically less at 0.05 ha/yr. It is likely that installation of bank revetments have played a key role in limiting lateral bank erosion since the mid-1940s to 1987. Possible mechanisms for channel expansion could be an increase in wood loading (deflecting flows into banks), increases in peak flows, or human impacts that destabilize banks.

The digitized historic channel alignments following Wild and Scenic River Designation (2005, 2009) were compared in a similar fashion to those prior to 1987. Comparison of these data shows a net increase in channel area (widening) between 1987 and 2005, at an average rate of 0.05 ha/yr. Interestingly, the flood of record (1997) occurred during this time period and yet there is no significant increase in erosion rates compared to the rates measured from 1944 to 1987. Between 2005 and 2009 there is a marked increase in the rate of erosion, (0.4 ha/yr). The increase in channel erosion between 2005 and 2009 is likely linked to general decreases in revetment lengths. Much of the loss of revetment from 1987 to the present is likely linked to failure during the 1997 flood. For locations where revetments were identified by NPS in 1994 and re-mapped during this survey in 2010, in general there was a decrease in length (Figure 4-2). As revetments are allowed to deteriorate and not maintained, increased lateral bank erosion should be expected. Coupled with the increase in bank erosion would be an increase in LWD recruitment where bank erosion encroaches into existing riparian forests.

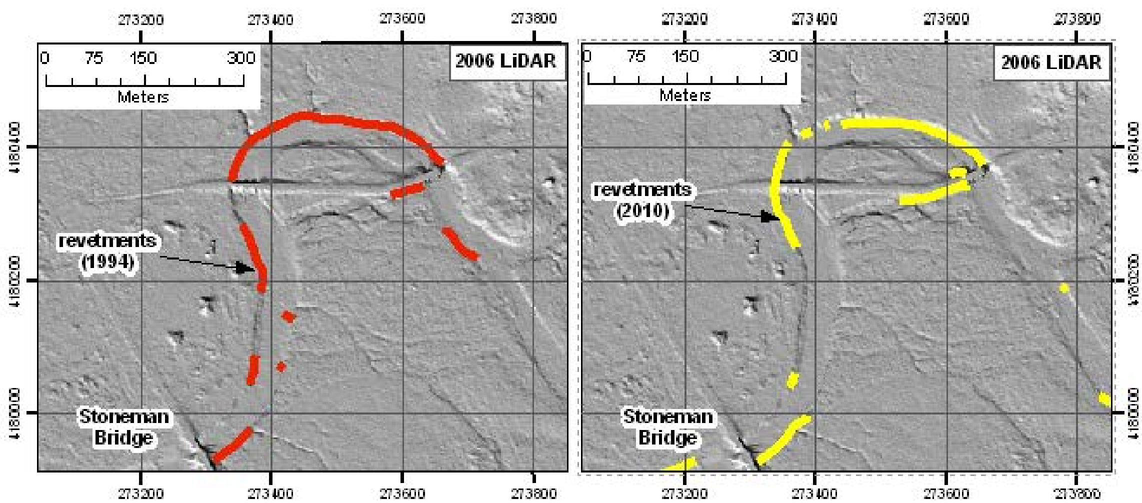

Figure 4-2 Changes in Revetment Locations Between 1994 and 2010

4.2.2 Geomorphic Reaches

Prior to Wild and Scenic River Designation in 1987, bank erosion occurred along the left bank from Clarks Bridge upstream approximately 250 m within the Happy Isles reach. Additional significant erosion within the Happy Isles reach occurred approximately 600 m upstream of the Clarks Bridge on the left bank, and is associated with the formation of a large logjam. Lateral bank erosion on the left bank is evident for approximately 320 m downstream of Clarks Bridge within the Above Tenaya when comparing aerial photographs. Erosion was noted within the Below Tenaya reach along the left bank upstream of Stoneman Bridge between 1934 and 1987. The most significant erosion took place within the lower half (downstream of Sentinel Bridge) of the Upper Meadows reach. Most of the erosion was associated with migration of a meander bend near Yosemite Lodge, and near the Sentinel Beach Picnic Area. Within the Lower Meadows reach bank erosion occurred near Cathedral Beach Picnic Area. The minimal bank erosion that occurred in the Above Pohono Bridge reach was across the channel from Bridalveil Creek alluvial fan, and on the outside of the two meander bends upstream of Pohono Bridge.

After the 1987 Wild and Scenic River Designation, a general increase in bank erosion occurred throughout the project study area. Significant erosion occurred in the Happy Isle reach, and was associated with recruitment of large volumes of LWD into the river. This LWD within this reach was observed during the 2010 survey to be driving geomorphic processes within the reach through bank erosion, pool formation, and sorting of alluvial sediments. Erosion within the Upper Meadows reach occurred primarily on the outside of meander bends, with the most significant location being near Sentinel Beach Picnic Area. Mainstem channel widening through erosion of both banks was shown in the Inter-Meadows reach, and on the outer bends in the Lower Meadows reach.

4.3 Wood Loading

References to historic surveys of LWD loading for the Merced River within Yosemite Valley were found in Milestone (1978) and Madej (1994). Prior to Wild and Scenic River Designation in 1987, logjams and other LWD were actively removed from the river to improve conveyance and prevent bank erosion (Milestone 1978). Prior to active removal, an 1877 account (Milestone 1978) of logjams and their geomorphic influence were documented in the Biennial Report of the Commissioners to Manage Yosemite Valley:

> *Large drifts of timber blockade the River, causing the high water at all times to cut away at the banks, thus undermining the trees that grew upon them and on occasion their fall.*

The role of logjams influencing channel morphology is depicted in accounts from the 1894 and 1901-1902 Biennial Reports (Milestone 1978):

> *…cleared river of logs and stumps. These logs had accumulated and changed the course of the river and threw it on the meadow banks (1894).*

> *…During the storms of winter large trees are floated down the river and find lodgement on some bar or against the bank, and the river immediately begins to cut a new channel (1901-1902).*

The earliest account found of active wood removal dates back to 1877 (Milestone 1978) during efforts to construct a road up the valley. Subsequent accounts through the nineteenth and twentieth century reference wood removal and logjams contributing to bank erosion. While no comprehensive inventory exists, given the program of active wood removal prior to Wild and Scenic River Designation in 1987, LWD loading in the Merced River within Yosemite Valley would likely have been much less than found today.

Madej (1994) provides the first inventory of LWD loading in the Merced River for direct comparison to the 2010 survey completed for this study. LWD surveys in Madej (1994) had a minimum DBH of 25 cm, and frequencies were reported for two study reaches. The upper reach extended from Clarks Bridge to Sentinel Bridge, and the lower reach from Sentinel Bridge to El Capitan Bridge. The upper reach reported 12 pieces/km, and the lower reach 29 pieces/km. In order to compare these findings with the 2010 LWD survey, the data were summarized by the same reaches reported in Madej (1994). The 2010 survey found 44 pieces/km in the upper reach, and 60 pieces/km for the lower reach. It is likely that the 2 to 4 fold increases in pieces/km are related to significant recruitment resulting from bank erosion that occurred during the 1997 flood, and a shift in NPS LWD management practices discouraging removal from the river. Comparison of the 2010 survey data to findings in Fox and Bolton (2007) show that the Merced LWD frequency is 30 percent of that found in natural systems within the Douglas fir-ponderosa pine forest of the eastern Cascades (170 pieces/km). However the minimum size of LWD recorded in Fox and Bolton (2007) was 10 cm at midpoint, and 2 m length, which is less than that for the 2010 survey.

4.4 Restoration Projects

Since 1991, restoration has occurred all along the study reach (Appendix A, Yosemite Valley Restoration Sites Map Series). These projects range from removal of bank revetment to riparian revegetation and aimed to restore specific sites rather than programmatically alter the river channel or riparian corridor. The summaries below are numbered chronologically (in parentheses). The number is also used to identify project location on the Restoration Sites Map Series in Appendix A. Appendix E presents more detailed project summaries. Summaries provided by Yosemite National Park and adapted from Tucker (1995) and from unpublished park archival information.

4.4.1 Riverbank Restoration at Lower River Campground, 1991-1994 (1)

It is important to note that both Lower and Upper River Campgrounds were closed to camping after the 1997 flood. Both areas have remained open to the public for day-use purposes.

In the spring of 1991, the stretch of riverbank on the south end of Lower River Campground immediately downstream of Stoneman Bridge was targeted for restoration due to extensive erosion along the bank. Nine campsites located on the terrace were removed along with all associated campground equipment.

Restoration work began in October 1991 with the removal of midstream and streamside riprap from the channel and asphalt parking pads, cement curbs, and campground boundary rocks from the terrace. Approximately 176 m^3 of boulders and 15 m^3 of asphalt were removed from the site. Two hazard trees were felled into the river and left to provide aquatic habitat and increase the deposition of organic material into the river. An excavator was used to recontour the banks near the felled trees as well as decompact 1,810 m^2 of terrace soils. Remaining ruts and tracks from the heavy equipment were raked out by hand. 198 m of split rail fencing was constructed to enclose the project site.

Cottonwood and willow cuttings were planted by hand 20-31 cm apart and up to one m deep along the bank. A small number of larger cottonwood branches 10-15 cm in diameter were planted using a power auger. The terrace was planted with locally salvaged sedge, rush, shrub, and California black oak seedlings. A small amount of elderberry seed collected near the project site was directly seeded onto the bare soil. The transplants and seeded areas were then mulched using woody compost.

The following summer (1992), the project area was watered twice a month for 8 hours each time to compensate for the six-year drought. Exotic plants were weeded within the project site to reduce competition with native species.

In 1993, restoration staff added mulch to the west end of the project since vegetation was sparse at that end. In the fall of 1994, workers seeded the area with a variety of herbaceous species and Sierra Club volunteers, under the guidance of restoration staff, hydrodrilled willows on the west end of the project area.

In the winter of 1994, the stumps that remained from the hazard tree removal were "naturalized" by blasting them apart with ammonium nitrate to discourage visitors from entering the restoration area to use the stumps.

4.4.2 El Capitan Picnic Area Dumpsite Restoration, 1991-1995 (2)

The El Capitan Dump is located on a spur road off of Northside Drive, 0.8 km east of El Capitan Meadow. It is adjacent to both the Merced River and the former El Capitan Picnic Area. The exposed dump material consists of various metal pieces, glass, and ceramic shards, all of which posed a threat to visitors at the picnic area and had a high potential for eroding into the river.

In October 1991, restoration and archeology staff removed a portion of the dump deposits located on the river terrace and adjacent to the river's edge. Prior to the excavation, two diseased ponderosa pines were felled and placed on the riverbank. Excavation was limited to a high-priority 31 x46-m area on the terrace. An excavator was used to bring trash deposits to the surface where they were separated from the soil by a portable conveyor belt-drive screen plant. All removed dumpsite materials were either salvaged or recycled.

Following the debris removal, the excavator was used to recontour the bank to achieve a 2:1 slope. The terrace was seeded with herbaceous species and the exposed bank was planted with 1,100 willow and 200 cottonwood cuttings. A small number of willow cuttings were planted in two test strips at opposite ends of the project. In 1994, additional herbaceous seeds were added to the terrace areas and more willow cuttings were planted on the bank using a hydrodrill. Exotics were removed in 1994 and 1995.

4.4.3 El Capitan Picnic Area Restoration, 1992-1994 (3)

The El Capitan Picnic Area is located on a spur road off of Northside Drive, 0.8 km east of El Capitan Meadow. The project is located on the outside edge of a meander bend, a river zone highly susceptible to natural erosion processes. The picnic area was a popular site for day-use visitors as well as a raft take-out area used by the concessionaire, both of which lead to trampling of the riverbank vegetation and accelerated erosion rates.

In the summer of 1992, the picnic area was closed to the public. The restoration began with the removal of 421 c^3 of riprap from 101 m of bank. Approximately 325 tons of asphalt and road base were removed from the parking areas and 7,822 m^2 of river terrace was decompacted with the use of heavy equipment. In the fall of 1992 and spring of 1993, willows and cottonwoods were planted using a hydrodrill along 192 m of bank. Near the former raft take-out site, brushlayering of willows was implemented to supplement other plantings. Native mulch was also spread across the project site.

In 1993, the crew recontoured the soil and re-planted cuttings in gullies that had developed on the riverbank at the site of the old raft take-out. Additional mulch was added to the riverbank and the terrace above this area. Willow and cottonwood plantings were irrigated in September of 1993 and June of 1994 to supplement below-average precipitation levels.

In the spring of 1994, the restoration crew used a bulldozer equipped with ripping tines to decompact the two parking areas located adjacent to Northside Drive. The decompaction zone totaled 1,487 m^2, to a depth of 15-20 cm. The crew then recontoured the site using McLeods and metal rakes. Large boulders were placed along Northside Drive to prevent cars from entering the project site and a trail was defined through the area to allow access to the Valley Loop Trail from the road.

4.4.4 Riverbank Restoration at Lower River Housekeeping Camp, 1992 (4)

This project site is located on the right bank of the Merced River, just downstream of Housekeeping Bridge. The goal of this project was to remove riprap and re-establish vegetation along the bank in this heavily-used area.

In 1992, two small Bobcat tractors were used to rip up 103 m^3 of asphalt from the paved path to Yosemite Village. The trail was relocated further back on the terrace, away from the top of the steep riverbank and was later paved by trails and roads personnel. The dirt removed during the installation of the new trail was placed along the site of the old path to improve the soil and supplement the natural seed bank.

Approximately 1,000 tons of riprap was removed from the bank using a hydraulic excavator. Two hundred and thirteen m of bank was planted with willow and cottonwood cuttings using a hydrodrill. Along the 24 m section of bank directly below the bridge, willow and cottonwood cuttings were planted using the brushlayering technique to provide additional stability to the bank.

The entire area was decompacted using a small tractor after the removal of heavy equipment. The terrace was then planted with roughly 200 plants that had been salvaged earlier from the project area. The terrace was also seeded and lightly mulched. Restoration workers constructed 335 m of Hetch Hetchy-style cedar split-rail fence to protect the project area.

4.4.5 Riverbank Restoration at Devil's Elbow, 1993-1995 (5)

Devil's Elbow is a section of the Merced River located just 0.32 km upstream of El Capitan Crossover Bridge. The site has a long history as a popular picnic area and river access point for visitors. Up until 1984, it served as the main raft take-out location for the concessionaire, resulting in extreme erosion of the bank.

In order to prevent further deterioration of natural and cultural resources, restoration of the area was proposed and work began in 1993 when workers removed picnic tables, fire rings and two pit toilets from the site. An asphalt parking lot was removed from the south side of the road and boulders were placed along the road to prevent cars from parking in the former parking areas.

Following the infrastructure removal, 1,208 m^2 of soil was decompacted using a small tractor fitted with ripping tines. Workers then planted sections of 1.5-2 m cottonwood limbs along the bank that had been salvaged from a felled tree near Sentinel Bridge. Willows were brushlayered along the steeper sections of bank. California black oak, canyon live oak, and raspberry seedlings were planted on the terrace as well as a mixture of native seeds. The entire area was mulched with local material. Several types of fencing were installed around the site totaling 587 m.

During the summer of 1994, restoration crews watered all plantings every other week and in 1995, solid double-layer plastic tree shelters were placed around the oak seedlings to prevent browse and sun damage.

4.4.6 Riverbank Restoration at Little Yosemite Valley, 1993-1994 (6)

Little Yosemite Valley is located in the Merced River Canyon above Nevada Falls at 1,859 m elevation. Due to its popularity as a wilderness destination, a ranger station and a campground were established at the site in 1972.

During the summer of 1993, archeologists and restoration specialists surveyed the 1.5-acre campground area, and determined that heavy visitor use had impacted cultural and natural resources in the area. The campground, originally established less than 31 m from the river, was moved farther back on the terrace to a more suitable location. A composting toilet facility was also constructed to replace the existing system.

The area was scanned for invasive plants and perennial grass and forb seeds were collected in the immediate area. A rustic log and block style fence was constructed around the restoration area on the riverbank using salvaged trees that were felled at the new campground location. The new fence line constructed totaled 594 m. The compacted soils of the former campground were decompacted using revegetation spades and digging forks. The crew naturalized stumps and log ends using axes and mauls.

In September of 1993 and June of 1994, a restoration crew returned to hydrodrill willow and cottonwood cuttings on the riverbank. A small quantity of aspen and azaleas were also planted with the hydrodrill technique.

4.4.7 Riverbank Restoration at Sentinel Bridge, 1994-1995 (7)

In 1987, the Federal Highway Administration and the National Park Service determined that the 1919 Sentinel Bridge needed to be replaced due to failing structural integrity. The old bridge was deconstructed and a new bridge was built 24 m upstream in 1994. The restoration goals of this project were to stabilize newly-exposed and recontoured riverbank at the site of the old bridge and to restore native vegetative cover to all sites impacted by construction activities.

Prior to construction, a variety of herbaceous plants and grasses were salvaged from the site of the new bridge. After the new bridge was completed, the riverbanks were recontoured and sterile rice straw was applied to the fill slopes along the walkway shoulder. The salvaged plants were replanted along with 50 California black oak seedlings grown from local acorns, and 100 sedge plugs. Three hundred and five m of Hetch Hetchy style split-rail fence was constructed to protect the revegetated site.

The restoration area was watered and closely monitored for invasive plant species during the summer of 1994, and in the fall, willow and cottonwood cuttings were hydrodrilled onto the north riverbank. Buck lotus and deer grass seed were also collected and planted in the project site. In 1995, willow cuttings were hydrodrilled on the right bank, downstream of the bridge.

4.4.8 Riverbank Restoration at North Pines Group Camp, 1994-1995 (8)

(It is important to note that North Pines Group Camp was closed to camping after the 1997 flood. The area has remained open to the public for day-use purposes.)

North Pines Group Camp was located at the east end of Yosemite Valley adjacent to Tenaya Creek. The campground experienced intensive visitor use during the summer months and as a result, a section of riverbank between the creek and the campground became denuded of vegetation and heavily eroded.

In the spring of 1994, workers installed 601 m of post and cable fence between the campground and Tenaya Creek which included four creek access areas. Workers used a bulldozer to decompact 1,571 m^2 of soil to a depth of 30-46 cm.

Raspberry cuttings and California black oak seedlings were planted on the terrace which also received a broadcast of seeds and 482 m^3 of mulch. The riparian zones were planted with rush and sedge transplants.

In the spring of 1995, the restoration staff and volunteers placed small boulders along the fence line to delineate a trail and prevent campers from placing their tents too close to the fence.

4.4.9 Riverbank Restoration at Swinging Bridge, 1994-1995 (9)

This project is located on the north side of the river, across from the Swinging Bridge Picnic Area. This section of the river is a very popular day use destination for visitors with a picnic area on river left, a large sand bar and river access area on river right, and a deep pool below Swinging Bridge. Heavy day use resulted in extensive trampling and a decrease in riparian vegetation on river right, though the bank on river left remained resilient due to the well-established cottonwood trees growing amongst riprap. The restoration goal for this project was to reestablish and protect riparian vegetation in order to prevent net stream widening.

In 1994 and 1995, 354 m of Hetch Hetchy style split-rail fence and 14 m of post and cable fence were constructed along the foot path on the right bank upstream from Swinging Bridge. Downstream from the bridge, 46 m of post and cable fence was installed to encourage visitors to use the sand bar to access the river instead of the steep bank.

The terrace and upper riverbank areas (767 m^2) were manually decompacted with shovels and digging forks. Willow and cottonwood cuttings were collected from nearby sources and planted with a hydrodrill along the riverbank. Sedges and bulrushes were directly transplanted along the toe of the riverbank. Sod plugs were planted on the terrace along decompacted social trails. The terrace was then mulched and seeded with native grasses.

4.4.10 Riverbank Restoration at Housekeeping Camp, 1995 (10)

Housekeeping Camp is located about 0.8 km upstream from Sentinel Bridge and is adjacent to the river for a distance of 549 m. Visitors would traditionally access the river from any point along that reach, preventing vegetation from properly establishing on the bank.

The restoration project encompassed 396 m of riverbank adjacent to the camp on the south side of the river. In 1995, 432 m^3 of riprap were removed from the bank and replaced by large woody debris to provide bank support and increase biomass along the channel. The excavator was used to create 1-m deep trenches on top of the newly created terrace in order to anchor 15 logs that averaged 8 m in length and 0.6-1.2 m in diameter. The logs were placed at a 10-20 degree angle to the flow of the river in order to deter the formation of back eddies downstream.

Willow and cottonwood cuttings were planted by brushlayering in a random fashion along 168 m of bank. Cuttings were also planted near the buried logs and hydrodrilled along the same stretch of bank. A Hetch Hetchy style split-rail fence was constructed from Housekeeping Bridge and continued downstream 395 m, to surround the grove of pine trees along the northwest edge of the camp. The pine trees were included within the project to prevent further erosion around their roots.

Rushes, raspberry cuttings, and California black oak and dogwood seedlings were planted across the terrace followed by 176 m^3 of mulch.

4.4.11 Cooks Meadow Restoration, 1998-2005 (11)

In 1998, restoration work to restore the natural processes and plant diversity in Cooks Meadow was initiated. An historic roadbed, several ditches, and paved trails passed through the meadow which inhibited the extent of seasonal inundations, affected the water table, and disrupted the vegetation communities within the meadow.

The restoration work began in 1998 with the removal of the abandoned Sentinel Road and removal of two ditches. The road material removed from the abandoned Sentinel Road was salvaged for use as fill in the meadow ditches and outlets. In 1999, two more ditches and an outlet drain were filled and planted with vegetated plugs salvaged from the meadow. Two culverts were also installed to increase surface water input from Yosemite Village, Indian Creek drainage, and the Merced River into the meadow. In the fall of 2000, the paved interpretative trail that crossed the meadow from Sentinel Bridge to Northside Drive was excavated parallel to the natural contour of the meadow. Trail access was recreated by installing a 152-m boardwalk constructed of a plastic/wood composite. In 2005, a portion of the paved trail parallel to the Merced River between Sentinel Bridge and the Superintendent’s Bridge was and replaced with a 61-m long boardwalk. The meadow’s natural contour was reestablished and vegetation was salvaged and replanted adjacent to each side of the trail.

4.4.12 Riverbank Restoration at Eagle Creek, 2002 (12)

Eagle Creek originates on the north rim of Yosemite Valley, dropping down to the valley floor between the El Capitan and Three Brothers rock features. It then passes beneath Northside Drive and meets the Merced River about 1.6 km west of Yosemite Lodge.

In 2002, fencing was installed on the terrace above the riverbank in order to mitigate trampling and promote the reestablishment of vegetation. A new footpath was delineated to provide visitors with access to the river. An abandoned sewage line was plugged with concrete and another concrete structure which spanned the creek bed was removed from the site.

Restoration crews implemented brush layering techniques for establishing willow cuttings with the aid of a small excavator along approximately 18 m of riverbank. Woody seedlings were salvaged from areas nearby and planted throughout the restoration area.

4.4.13 Cascades Diversion Dam Removal, 2003-2004 (13)

The Cascades Diversion Dam was removed in 2003 along with much of its associated infrastructure. The dam was situated on the Merced River 2.4 km downstream of Pohono Bridge. Upstream, the dam had created 1.25-acre impoundment pool and stored an estimated 7,340 to 11,468 m^3 of sediment at the time of removal. The wood and concrete dam was 56 m long and 5 m high, flanked by 9m concrete abutments.

Following the removal of the dam, restoration was executed in several stages from December 2003 to November 2004. The project was divided into units based on landform and physical characteristics, proximity to the river, and phasing of the project. The four zones - floodplain, vegetated revetment, upland and roadside - totaled 0.6 ha.

The vegetated revetment, located on the north side of the river, is a bioengineered structure comprised of local boulders, rock and sediment with riparian vegetation incorporated into the structure. It was constructed along the entire length of the project to protect newly exposed riverbanks in the impoundment and dam locations, to protect existing riparian vegetation, and to prevent damage to the adjacent El Portal Road. Heavy machinery was used to position large boulders while willow and cottonwood cuttings were placed in the gaps between them. Rock and sediment were used on-site for the bioengineered revetment or left in place to be transported by the river; no additional import (or export) of rock, sediment, or soils occurred during this process.

All of the restoration zones were planted with varying combinations of herbaceous seedlings, shrub seedlings, woody cuttings, and/or a broadcast of herbaceous seed. All seeds, cuttings and seedlings were collected and propagated from native plants within the park.

4.4.14 Happy Isles Dam Removal, 2004-2006 (14)

The Happy Isles Dam system consisted of a 1 m high wall of rock and concrete spanning 10 m of channel, two steel-reinforced concrete and iron diversion gates, and 79 m of 46 cm diameter iron intake pipes below the diversion gate.

The goal of removing the dam and associated infrastructure was to restore the free-flowing character and pool-riffle morphology of that reach of the Merced River. The dam and one of the diversion gates caused sedimentation to occur upstream and altered overbank flows of the river. A second diversion structure remains on site; it is recessed from the channel edge and is not slated for removal. This structure is at the head of a corridor created for the pipeline and would create an artificial river channel if removed.

Deconstruction was completed in November of 2005. Twenty eight m^3 of concrete and boulders were removed with the dam and 5 m^3 of concrete and iron with the intake structure. Stacked rock walls, located near the diversion gates, were deconstructed and the material positioned in the diversion channel between the removed intake structure and the remaining diversion gate.

Given the presence of abundant native riparian vegetation immediately upstream of the project area, direct revegetation efforts were not necessary. The channel sediments were left to be reworked by high-flow periods during spring runoff.

4.4.15 Riverbank Restoration below Stoneman Bridge, 2006 (15)

In 2006, the reach of river below Stoneman Bridge was selected for riverbank terrace restoration based on the eroded condition of the steep cut bank and exposure to high levels of visitor use. The project area encompassed 457 m of river terrace along the south side of the Merced River from the raft put-in site at Stoneman Bridge down to the eastern boundary of Housekeeping Camp.

Split rail fencing was constructed along the entire length of the reach, allowing for two specific river access points: one at the raft put-in directly downstream of Stoneman Bridge and one farther downstream at a popular river access point for the tenants of Curry Dorms. The terrace was then mulched with local leaf litter to inhibit erosion.

4.4.16 Riverbank Restoration below Clark's Bridge (Lower and North Pines Campgrounds), 2006 (16)

In 2006, this reach of river below Clark's Bridge was targeted for restoration based on the condition of the riverbanks and exposure to high levels of visitor use. The project sites extend along the river adjacent to North Pines and Lower Pines Campgrounds. Split rail fencing was installed at both sites with the intention of directing visitor use to less sensitive areas and to allow natural reestablishment of riparian vegetation along the banks.

In North Pines Campground, 91 m of split rail fencing was installed along the bank at the downstream (north) end of the campground.

In Lower Pines Campground, two sections of fencing totaling 366 m were constructed with a designated river access point between them. Herbaceous plant and shrub seedlings were also planted in highly denuded zones on the terrace.

4.4.17 Riverbank Restoration at South Fork Bridge, 2006 (17)

In 2005, the South Fork Bridge in Wawona was deconstructed and rebuilt during a project funded by the Federal Highways Administration. The bridge is located north of the historic Wawona Hotel, just inside the park's South Entrance.

The new bridge was completed in the fall of 2006. Minor recontouring was required on the riverbank since the new structure was built with a slightly different alignment to the river than the old one. Restoration crews installed straw wattles at the top of the terrace to lessen runoff and erosion. Four sections of fencing were installed on the terraces, totaling 148 m. Locally collected herbaceous seed was also spread along the banks throughout the site.

4.4.18 Valley View Pullout Revegetation, 2007 (18)

Valley View Pullout, located along Northside Drive across the river from Bridalveil Meadow, is one of the most famous views of Yosemite Valley from the valley floor. The pullout itself was included in the Valley Loop Road project which repaired and resurfaced roadway pavement, rehabilitated adjacent drainage features, and improved the condition of adjacent roadside parking along 20.1 km of the Yosemite Valley Loop Road.

The roadside turnout at Valley View is situated directly adjacent to the Merced River and encompasses a portion of the riverbank itself. Both grouted and non-grouted riprap was installed by the contractor to stabilize the riverbank in addition to previously existing riprap. Locally collected willow cuttings were replanted within the riprap along approximately 37 m of riverbank to reintroduce a biological component to the riverbank through leaf litter and nutrient cycling. Herbaceous seedlings were also collected from the vicinity and planted along the riverbank.

4.4.19 El Portal Road Rehabilitation at The Narrows, 2008 (19)

The Narrows is a section of the Merced River canyon upstream of the intersection of the El Portal Road and the Big Oak Flat Road. In the fall of 2008, this project repaired portions of the road and embankment that were at risk of failure as a result of damages initially caused by high-water events of the Merced River.

The mitigation and revegetation area of the project, bounded on the north by the El Portal Road and on the south by the Merced River corridor, encompassed 1 ha and consisted of 412 m of stream channel and associated riverbanks. The road rehabilitation itself included the removal of 76 m of historic guard wall, the reconstruction of historic retaining walls in two locations, and the removal of five canyon live oaks, three California Black Oaks, three ponderosa pines, three black cottonwoods, one bay laurel and several seedlings and brush species.

The revegetation of this area included the incorporation of willow shoots within riprap along approximately 31 m of riverbank, planting woody seedlings higher up along the slope of the bank, and a broadcasting of seed along the road shoulder and in the cut slopes above the road following the completion of topsoil placement on the project.

Willow cuttings were collected on-site before construction and stored until needed. Woody seedlings planted higher on the slope were propagated from seed collected near the construction site.

4.4.20 Wawona Utility Crossing, 2010 (20)

In 2010, a concrete-encased power line was tied in beneath the riverbed 0.3 km upstream of the historic Swinging Bridge in Wawona. Approximately 9 m of bank on the south side of the river required restoration action after the line was installed. Heavy machinery was used to recontour the bank and bury woody debris up to 15 m up slope from the river’s edge. The area was also seeded with herbaceous annual plants and straw wattles were put into place to inhibit erosion.

4.4.21 Yosemite Valley Abandoned Utilities Removal, 2010 (21 a-e)

In 2010, a significant portion of underground utility lines were permanently abandoned with the completion of Phase 3B of the Integrated Master Utilities Plan for Yosemite Valley. Removal of these lines from sensitive areas such as meadows and the Merced River was identified as a priority by park management. Several of the utility lines were buried at a very shallow depth below the riverbed and caused pipe dams to form, disrupting the natural flow of the river.

Eight utility line crossings were removed from the Merced River in 2010, five of which required restoration action in order to stabilize the banks on one or both sides of the river.

Upstream of Superintendents Bridge, 6 m of riverbank on the south side of the river was impacted during the removal of 15 cm sewer line. Four c^3 of rock-boulder revetment were also removed during this process. Following the construction, 12 c^3 of screened native soil was added to the site and the bank recontoured. Willow cuttings were planted on the bank using brush layering techniques and planting with a hydrodrill. Woody debris was buried on the terrace to promote bank stabilization and mitigate erosion.

Downstream of Housekeeping Bridge, a stretch of 6 m on the south side of the river required restoration action after a 15 cm sewer line and electrical conduit were removed from the river channel. Four c^3 of rock-boulder revetment were also removed. Willow cuttings were planted along the bank after construction. On the north side of the river, 3 m of bank were planted with willow cuttings. A lift station was also removed from the north side of the river, followed by adequate mulching of the area.

Downstream of Stoneman Bridge, a 46 cm water line and electrical conduit were removed along with 15 c^3 of rock-boulder revetment, disrupting 12 m of riverbank. After construction, 19 c^3 of screened native soil was added back to the site, willow cuttings were planted using brush layering techniques, cuttings were planted with the hydrodrill, and woody debris was buried along the upper terrace.

Upstream of Stoneman Bridge on the south side of the river, 9 m of bank were disturbed during the removal of a 25 cm sewer line and 12 c^3 of rock-boulder revetment. Approximately 15 c^3 of screened native soil was brought back onto to the site followed by willow brush layering and planting of willow pole cuttings.

Near Lower Pines Campground and Stoneman Meadow, 6 m of riverbank were impacted on the southeast and northwest sides of the river from removal of 31 cm water line. On the southeast bank, 8 c^3 of rock-boulder revetment were removed. Both sides of the river were given 12 c^3 of screened native soil. Herbaceous seedlings salvaged on-site prior to construction were replanted on the banks and the upper terraces were mulched with local debris.

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Chapter 5

Current Merced River Condition

5.1 Suggested Metrics to Monitor and Assess River Condition

5.1.1 Riparian Corridor Metrics

The goal of the CRAM is to provide a rapid and standardized method to assess the status and trends in the overall condition of the riparian vegetation and performance of management programs and policies (Collins et al. 2008a), and when repeated, can be used to evaluate the general progress of restoration efforts or management decisions over time. This monitoring assessment method, over time, would provide information on the trends and status of the general conditions of the riparian corridor throughout the study area. In addition, based on the results of the CRAM, five attributes/metrics were strong determinants of the conditions of the Merced River riparian corridor within the study area. The suggested metrics for focused, periodic monitoring include:

6. Buffer condition (extent and quality of vegetation cover and intensity of human use).
7. Hydroperiod or channel stability (degree of channel aggradation or incision, including bank erosion, and extent of revetment along the channel).
8. Average buffer width.
9. Biotic condition (in particular, the number of co-dominant species, number of multi-plant species associations, and the degree of overlap between plant canopy layers).
10. Physical structure (overall variability in micro- and macro-topographic relief that may affect moisture gradients and/or flowpaths).

Monitoring focused on these metrics would provide information that could be used to assess the relationships between recreation use and locations of facilities and roads (e.g., buffer condition and width), fluvial geomorphic processes and topographic complexity (e.g., channel stability and physical structure), and riparian functionality (buffer condition and width) and community characteristics (e.g., biotic condition) in response to management decisions. For example, re-connection of CMZs or changes in revetment location or width along the river will result in increased lateral connectivity (including groundwater) and inundation frequency and duration of the adjacent floodplain and a more geomorphically dynamic floodplain, which will change species composition and structure. Changes in recreation use intensity within the riparian corridor (reduced or increased) may impact channel stability (e.g., bank erosion - see Channel Migration Zone Metrics below), extent and quality of vegetation cover, and vegetation composition and structural diversity.

In addition, monitoring of invasive species populations would also provide valuable information on the riparian corridor condition over time. Although the current percentage of invasive plant species within the AAs was typically low, the high intensity of human use and close proximity to transportation corridors makes the riparian corridors susceptible to invasive species. It is also recommended that the riparian corridor vegetation is periodically mapped and extended to include the entire CMZ to detect general trends in species composition over time in response to management decisions and large flow events.

5.1.2 Channel Migration Zone Metrics

While the CMZ should not drastically change in the short term, several key metrics to describe channel migration processes should be monitored periodically:

4. Bank erosion rates through channel cross-section surveys
5. Locations of existing and future bank protections and revetments
6. LWD recruitment and flux (see below for specific metrics)

Measurement of bank erosion rates through successive cross sectional surveys will verify assumptions regarding channel migration and provide data to revise the CMZ in the future as conditions change. Because change in revetment location or length will alter CMZ area, the addition or removal of such structures should be documented and updated within a geographic database, as is currently done. In addition to measurement of bank erosion rates and presence of bank protection structure, LWD surveys should be completed to evaluate the influence of LWD on bank erosion and channel avulsion. Presence or absence of channel-spanning logjams could alter the bank erosion and avulsion potential for much of the channel length.

5.1.3 Large Woody Debris Metrics

The LWD surveys described wood using a broad range of metrics focused on dynamics and geomorphic role (see Section 2.5 for the full set of parameters). The suggested metrics to describe current and future river condition are:

7. Piece location along (longitudinally) and within (cross-sectionally) the channel
8. Piece type (log with rootwad, log, rootwad)
9. Dimension (length and diameter)
10. Wood influence on channel (role in pool formation)
11. Recruitment mechanism
12. Decay class

These metrics describe piece location and dimension, general geomorphic role, mechanism by which the piece arrived at its current location, and how recently (in relative terms) the piece entered the channel. These data yield useful information about LWD dynamics (input, storage and transport) and fluvial processes, and can be collected rapidly. As LWD dynamics are closely tied to hydrologic conditions, data should be collected after flows above a specified threshold (e.g., a 10-year flood), or semi-annually at the same time of year (e.g., in early spring) to develop an accurate picture of recruitment processes.

5.2 Study Reach Condition

5.2.1 Riparian Corridor

The CRAM assesses the overall condition of the riparian corridor by evaluating the longitudinal connectivity of the riparian corridor, the lateral dimensions and topographic complexity of the riparian buffer, and the composition and structure of the riparian community. With the exception of the bridges, longitudinal connectivity of the riparian corridor, which is important for the flow or movement of water, nutrients, sediments, and biota through the watershed, is maintained throughout the study reach.

Reaches with comparatively narrow riparian buffers are present throughout the study reach (<64 m wide), usually confined by roads, bridges, or development associated with recreation facilities. The width of the riparian buffer is generally wider in the upper portion of the study reach and narrows with downstream distance. Wider buffers generally provide higher quality habitat by promoting lateral connectivity between the channel and terrestrial ecosystems, and reducing habitat edge effects and impacts of human related activities. Lateral connectivity is important for biogeochemical and other ecological processes and for the exchange of nutrients, sediments, and biota between aquatic, riparian, and terrestrial ecosystems. Various uses of bank protection measures to protect infrastructure, property, and public safety (particularly between Clarks Bridge and Sentinel Bridge), however, reduce lateral connectivity between the channel and riparian corridor in a number of locations throughout the study reach.

Topographic complexity within the riparian corridor was generally fairly high throughout the reach, except between approximately Clarks Bridge and Sentinel Bridge. Complex topography (abundant microtopography (e.g., < 1 m relief) and breaks in slope along a channel cross-section) within the riparian zone promotes spatial and temporal variability in inundation frequencies and durations (e.g., hydroperiods) and depths to groundwater (water availability and moisture gradients) which promote greater plant diversity and habitat diversity. Patch richness, or the number of different types of physical surfaces or features that could potentially provide habitat for various aquatic or riparian species, however, was generally low throughout the study reach. Patch richness was generally greatest between Sentinel Bridge and Pohono Bridge.

The majority of the riparian corridor within the study reach has few invasive species and at least three plant layers present (e.g., various heights of trees, shrubs, herbaceous vegetation). The number of co-dominant species is generally high from Sentinel Bridge to Pohono Bridge; but is low in a number of reaches particularly in the vicinity of Clarks Bridge and Stoneman Bridge and downstream of Pohono Bridge to the downstream end of the study reach. These sections of river also have fewer different riparian community types present (Appendix A, 2010 Riparian Vegetation Map Series), and exhibited less horizontal zonation and vertical complexity within the riparian corridor compared to other reaches along the river. The riparian corridor throughout the majority of the study reach exhibits moderate horizontal interspersion and overlap among plant layers (vertical structural complexity). Multiple horizontal plant zones are generally indicative of a well-developed riparian community with high spatial heterogeneity. In addition, richer communities tend to have greater zonation and more interspersion of plant zones. More developed riparian communities in better condition, with horizontal and vertical complexity and heterogeneity, generally promote greater mammal and avian diversities.

Evidence of at least moderate levels of human use impacts were observed throughout the majority of the study reach. Areas with moderate to high levels of human use were concentrated near the developed areas between Clark Bridge and Sentinel Bridge and areas easily accessible from adjacent roads. Bank erosion was observed throughout the study reach, particularly upstream and downstream of bridges (including Clark Bridge, Stoneman Bridge, Housekeeping

Bridge, Sentinel Bridge, El Capitan Bridge, and Pohono Bridge, near recreation facilities (including Lower and North Pines campgrounds, near the Housekeeping Camp, and near Swinging Bridge, Sentinel Beach, El Capitan, and Cathedral Beach picnic areas), and around some meander bends. Areas with moderate to high human use also generally exhibited lower topographic complexity and patch richness had fewer co-dominant species, and lower community structure complexity.

5.2.2 Channel Migration Zone

The condition of the CMZ is primarily linked to the degree of disconnection as a result of development within the floodplain, and placement of revetments along the channel banks. Disconnected areas that currently have no protection from future channel migration make up 41 percent of the low-risk Valley Alluvium (VA), 11 percent of the Erosion Hazard Area (EHA), and 1 percent of the Avulsion Hazard Zone (AHZ). Disconnected areas that are currently protected from future channel migration account for 3 percent of the EHA. For the entire project reach, 25 percent of the CMZ is either disconnected or protected disconnected. Areas that have been identified as currently protected assume that the revetment will remain intact over the 100 year timeframe of the CMZ delineation, and thus would likely require continued maintenance following floods in order for the area to remain protected disconnected. Areas identified as disconnected (currently no protection from channel migration) assume that should the river directly threaten the structure, emergency measures would be taken to prevent further channel migration.

The degree of disconnection within the project reach remains below 1 percent from the upstream end of the project reach, downstream to the confluence with Tenaya Creek. Downstream of Tenaya Creek to Leidig Meadow, approximately 37 percent of the CMZ is disconnected. The Yosemite Valley Loop Road accounts for greater than 96 percent of disconnected floodplain within this section of the river, with the remaining 4 percent from channel revetments found primarily across the river from the Lower Pines Campground. Downstream of Leidig Meadow to the Pohono Bridge approximately 20-25 percent of the floodplain is disconnected by the Yosemite Valley Loop Road. Downstream of the Pohono Bridge 11 percent of the CMZ is disconnected as a result of existing channel revetments at the toe of El Portal Road.

5.2.3 Large Woody Debris

Wood loading, its function, and recruitment mechanism within the project reach were determined to evaluate the current condition of LWD within the river. LWD loading generally decreased in the downstream direction, with the Happy Isle geomorphic reach having the highest loading. Local LWD loading increases in the downstream reaches were observed to occur where banks are actively eroding into the riparian forest. Locations actively eroding into cleared and developed floodplain did not see local increases in LWD loading. In contrast, local LWD loading was lower where channel revetments line the banks. This phenomenon is linked to both a decrease in channel migration potential and recruitment of the riparian forest, and to a hydraulically smooth bank as a result of the revetment that prevents capture of mobile LWD moving through the system. The recruitment mechanism of LWD within the channel was primarily from upstream fluvial transport, with bank erosion as the sub-dominant process in the Happy Isle and Lower Meadows geomorphic reaches. The lack of channel revetments and high gradient of the Happy Isle reach relative to the other reaches promote channel migration processes within the reach, and thus bank erosion. The relatively high proportion of recruitment via bank erosion in the Lower Meadows could be a continued consequence of blasting the El Capitan moraine, as historic accounts of channel change following this event describe destabilization of channel banks as a result.

The relative proportion of LWD within logjams (> 3 pieces touching) is markedly higher above Cathedral Beach Picnic Area than downstream, with the exception of the developed reach below Tenaya Creek. The function of these larger accumulations of LWD is shown to force pool formation either directly or indirectly, and thus increasing instream aquatic habitat.

5.2.4 Wildlife Habitat

Results from the WHR model predict that the Merced River Corridor in the Yosemite Valley may support a high diversity and density of animals. However, the model only considered general habitat types and physiographic location; specific habitat attributes characterizing the montane riparian and wet meadows habitats in Merced River Corridor in Yosemite Valley were not integrated into the model. Current conditions in the study area for amphibians, reptiles, birds, and bats in Yosemite Valley are described below and include data from the NPS 2010 surveys as well as data from other sources.

Only two amphibian species were detected during the 2010 surveys conducted in the study reach (Pacific treefrog and American bullfrog [invasive species]). The lack of amphibian species detected during the 2010 surveys may be due in part to the surveys being conducted during the dry season. Amphibians are more active, and consequently more detectable, when conditions are wet, especially during the breeding season. In dry periods, Pacific treefrogs tend to be more nocturnal, but they have been spotted during the day. These frogs spend a lot of time hiding under rotten logs, rocks, long grasses, and leaf litter, where they are very difficult to see unless they move (Lannoo 2005).

Two special status amphibian species historically occurred in Yosemite Valley, but are now believed to be extirpated or nearing extirpation (foothill yellow-legged frog and Sierra Nevada yellow-legged frog, respectively). The limited number of records for the foothill yellow-legged frog is likely a reflection of there being limited suitable habitat in the Valley for this species. While other factors may be affecting the Sierra Nevada yellow-legged frog, including predation by non-native fish species (trout), possible effects from a recently-discovered chytrid fungus (Chytridomycosis), and potential effects from deposition of airborne contaminants (such as pesticides and other chemicals) (NPS 2011).

Signal crayfish (invasive aquatic species) were detected in three of the reaches (Inter-Meadows, Lower Meadows, and Above Pohono Bridge) during the study. No other reptiles or amphibians were detected in the Above Pohono Bridge Reach in 2010.

The presence of invasive species such as bullfrogs and signal crayfish is likely impacting native herpetofauna. Both non-native species have been implicated in the decline of native amphibians and reptiles (Gamradt and Kats 1996, Lannoo 2005) through predation and competition. Adult bullfrogs are voracious predators that will readily eat anything smaller than themselves (Bury and Whelan 1984). Signal crayfish are generalist omnivores and avid predators on benthic macroinvertebrates and the eggs and larvae of amphibians.

Four reptile species (and one unidentified reptile species) were detected during the 2010 surveys. Sceloporus lizard species represented a majority of the individuals detected. These lizards are insect eaters and tend to be more active during daylight hours. Skinks however, tend to remain under cover most of the day, coming out into the open to forage for insects on the ground primarily during the late afternoon or evening (Walker 1946). This difference in behavior may help explain why only one skink was detected during the 2010 surveys compared to Sceloporus species.

Western pond turtles (a special status reptile species) historically occurred within Yosemite Valley, but are now believed to be extirpated. The limited number of records is likely a reflection of there being limited habitat in the Valley for these species, but the potential loss of these species from the valley is still ecologically important. For western pond turtles, elevated nest and hatchling predation due to increased populations of predators such as raccoons, ravens and coyotes and removal of large woody debris from stream channels has likely also factored into their extirpation. However, western pond turtles may also be very difficult to observe in the field due to their tendency to dive into the water when disturbed.

Results from 2010 bird surveys and surveys conducted during 2006-2008 (Stillwater Sciences 2008) indicate that the Merced River corridor provides important breeding habitat for a diverse group of birds representing a variety of breeding niches and differing seasonal strategies (resident species, short-distance, and long-distance migrants). Birds observed in riparian associated habitats occupy breeding niches of different heights in the vertical strata, including understory, mid-story, and canopy. This finding suggests that the available habitat along the Merced River provides structural integrity beneficial to a wide variety of birds, including the yellow warbler, a California Species of Special Concern (MacArthur and MacArthur 1961; Karr and Roth, 1971).

Additional bird survey data are available from the study conducted by Stillwater Sciences (2008) which provided a comprehensive assessment of bird species composition and distribution in the Merced River corridor during the breeding season, during the fall migration, and during the winter season. The data they collected in 2006 and 2007 during the breeding season included 12,540 detections of 129 bird species (including flyovers) in both the lower and the upper Merced River corridor (Stillwater Sciences 2008). A majority of the bird detections during the breeding season point counts were songbirds.

During the 2006 and 2007 fall migration study conducted by Stillwater Sciences (2008) at total of 3,831 birds and 117 species were detected along both the upper and the lower Merced River corridor. During the winter seasons of 2006, 2007, and early 2008, a total of 3,344 birds and 81 species were observed along the lower Merced River (no winter surveys were conducted in the upper river corridor for the winter season), (Stillwater 2008). Results of the study also indicated that the extent of riparian cover and riparian zone width were both highly important variables that correlated highly with some (but not all) focal species investigated (Stillwater 2008). Both metrics provided good predictors of overall species diversity. Conversely, shrub cover in many cases (for many birds) was not as important as what type of shrub is available. Overall bird species diversity was positively associated with structural characteristics typical of mature riparian forests (Stillwater Sciences 2008).

Historical sightings of the willow flycatcher (a special status species) were recorded in the WOD database (2010). However, the WHR Model predicted that this species would likely be present in relatively low population densities at low frequencies (Espinoza et al. 2010). Siegel et al. (2008) used historical records and digital maps based on remote sensing to identify and survey Yosemite's most likely breeding habitat for the species. Over the 2006 and 2007 breeding seasons they visited 71 sites, which accommodated 1,709 call stations. They detected no territorial willow flycatchers, and concluded that the species likely no longer breeds in Yosemite National Park.

A high diversity of bat species was detected in the upper half of the Merced River Corridor during the 2010 study. Of the 17 species of bats that are predicted to occur in Yosemite National Park, 11 species were documented (two of these species are special status species). The spotted bat (a special status species) had the second highest detection rate overall (352 individuals).

Results from the NPS 2010 field survey were similar to a Yosemite Valley bat study conducted by Pierson and Rainey (1993). Eleven bat species were detected using a variety of survey techniques. Between these two studies, 15 of the 17 bat species expected to occur in Yosemite were documented. However, neither the NPS 2010 study nor Pierson and Rainey (1993) detected the long-legged myotis and the western red bat (California Species of Special Concern). However, both of these species were later documented in Yosemite in Pierson et al. (2001), and are expected to occur in Yosemite Valley.

The Western red bat is a tree-dwelling species, primarily associated with lower elevation deciduous or mixed conifer forest while the long-legged myotis is a crevice-dwelling species, roosting in rock crevices, under bark, in snags, mines, and caves (Pierson and Rainey 1993).

Yosemite Valley supports the largest known populations of the western mastiff bat and spotted bat in California (Pierson and Rainey 1996). Although these two species can be readily detected in the Valley during warmer months (with the western mastiff bat being locally more numerous), both species are considered rare (western mastiff bat), or extremely rare (spotted bat) throughout their known range (Pierson and Rainey 1996). In Yosemite Valley, these two species roost exclusively in cliff faces, and forage primarily over meadows and riparian areas.

A significant constraining factor in the distribution of the spotted bat appears to be the availability of roosting habitat in cliffs (Pierson et al. 1998). This constraint may help explain why the spotted bat has a patchy distribution and is relatively more common in places such as Yosemite Valley (Pierson et al. 1998).

In Yosemite Valley foraging habitat is likely to be more limiting than roost habitat (Pierson 1997). All bat species occurring in Yosemite National Park feed exclusively on insects or other arthropods. Most species forage directly over water or within the adjacent riparian zone, where plant and insect productivity is higher than in seasonally dry up slope areas (Pierson 1997). Pierson et al. (2006) showed that the greatest amount of bat activity (as assessed by acoustic detectors) occurred in association with water. However, individual species did show different preferences. Meadows and rock outcrops were also highly favored as foraging areas by some species (Pierson et al. 2006).

Pierson et al. (1998) found that the spotted bat was most commonly observed foraging over meadows (or old fields), generally in close proximity to trees. Their affinity for meadows was demonstrated by surveys conducted by Pierson et al. (1998) in Yosemite Valley, where the species was detected at seven of thirteen sites in meadows or wetlands, and at nine of the forested sites

Through their radio-tracking study, Pierson and Rainey (1996) discovered that the western mastiff bat makes nightly and seasonal movements up and down the Merced Canyon, suggesting that the habitat corridor is important to this species year-round. Pierson (1997) also found a significant population of the pallid bat in the Valley, which roosts in buildings, rock crevices and bole cavities, and lightning scars of oaks and ponderosa pine.

The lower number of detections at the Yosemite Creek site during 2010 surveys most likely reflects less ideal detector placement and a shorter monitoring period rather than lower bat activity at this site. The echolocation call files obtained from this site were of lower quality than those call files obtained from the North Pines Campground site, indicating that signal bounce off of nearby vegetation may have influenced overall call quality. However, species assemblages were similar between the two sites.

Overall, the entire Merced River corridor provides important habitat for birds and bats in particular. Available data from 2010 surveys provide an indication of the importance of the habitat for amphibians and reptiles as well. However, the habitat may be less suitable for some special status amphibians (foothill yellow-legged frog and Sierra Nevada yellow-legged frog). In addition, results of the 2010 study show the importance of conducting amphibian surveys during the wet season rather than the dry season. Amphibians are more active, and consequently more detectable, when conditions are wet, especially during the breeding season.

5.3 Geomorphic Reach Conditions

The condition of each geomorphic reach was determined from key riparian and channel (CMZ and LWD) metrics, and integrated with wildlife habitat data (Table 5-1). Where possible, a qualitative value was assigned to each metric (high, moderate, low) to evaluate condition relative to other geomorphic reaches. For LWD recruitment mechanism and piece association (whether the piece occurred within a jam, with one other piece, or as a single piece) the dominant and/or subdominant observations were used to indicate change in LWD process across reaches. The main stressors affecting current condition within each reach are also identified and discussed in Section 5.4, Causes of Diminished Habitat Quality.

Table 5-1. Summary of Merced River Condition by Geomorphic Reach

Metric	Geomorphic Reach							
	Happy Isles	Above Tenaya	Below Tenaya	Upper Meadows	Inter-Meadows	Lower Meadows	Above Pohono	Below Pohono
RIPARIAN								
CRAM[1]	Higher	Lower	Lower	Moderate	Higher	Higher	Higher	Lower
Buffer Condition	Moderate	Lower	Lower	Moderate	Moderate	Moderate	Higher	Higher
Buffer Width	Higher	Higher	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Hydroperiod or Channel Stability	Higher	Moderate	Lower	Moderate	Higher	Higher	Higher	Moderate
Biotic Condition	Moderate	Moderate	Lower	Moderate	Moderate	Moderate	Moderate	Moderate
Physical Structure	Moderate	Lower	Moderate	Moderate	Moderate	Moderate	Higher	Moderate
CHANNEL								
CMZ Area	Moderate	Moderate	Low	High	Low	High	Moderate	Low
CMZ Connection	High	High	Low	Low	Moderate	Moderate	Moderate	High
LWD Loading	High	Moderate	Low	Moderate	Low	Moderate	Low	Low
LWD Recruitment	Fluvial / Bank Erosion	Fluvial / Tree Fall	Fluvial / Tree Fall	Fluvial / Bank Erosion	Fluvial / Bank Erosion	Fluvial / Bank Erosion	Fluvial / Tree Fall	Fluvial / Tree Fall
LWD Association	Jams	Jams	Single Piece	Jams	Jams	Single Piece	Single Piece	Single Piece
Pool Formation	High	High	Low	Moderate	Moderate	Moderate	Low	Low
Potential LWD Loading	High	High	Moderate	Moderate	Moderate	Low	Low	Low
WILDLIFE								
Habitat Area	Moderate	Moderate	Low	High	Moderate	High	Moderate	Low
# of Species	High (Reptiles)	High (bats, birds)	Low (Birds only)	High (birds, bats)	High (birds, reptiles)	High (birds, amphibians)	Moderate (birds, invasive aquatic species - crayfish)	Low (birds only)
STRESSOR								
Stressor	Human use	Human use	Limits on channel migration Human use	Limits on channel migration Human use Invasive species	Limits on channel migration Human use Invasive species	Limits on channel migration Human use Invasive species	Limits on channel migration Human use Invasive species	Limits on channel migration

5.3.1 Happy Isles Geomorphic Reach

The Happy Isles geomorphic reach is 1 km long and characterized by low sinuosity and a 0.9 percent channel gradient (Table 3-1). The reach had the second smallest CMZ area (43 ha; (Figure 3-7) but a high degree of connection between the channel and floodplain (99.5 percent, Table 3-5). The channel had the highest LWD loading (192 pieces/km) of any geomorphic reach, nearly three-fold greater than the reach with the second highest wood loading (Above Tenaya, Figure 3-11). The dominant recruitment mechanism was fluvial transport from upstream (55 percent), followed by bank erosion (30 percent) and tree fall (15 percent). But, the reach recruited more LWD by bank erosion and tree fall (combined) than any other geomorphic reach, indicating this reach had the greatest local recruitment (i.e., not from upstream sources). The reach also had the second greatest potential wood loading (474 m^3/km/yr; Figure 3-15). The riparian corridor was, on average, in the best condition compared to the other geomorphic reaches within the study area (Figure 3-5). Specifically, buffer widths were wide throughout the reach, topographic complexity was comparatively high on average, and the community had the highest horizontal interspersion and vertical structure complexity (overlap among canopy layers) (See Appendix C, CRAM Geomorphic Reach Results). However, human use was high particularly near Happy Isles Bridge and the Clarks Bridge area, and excessive bank erosion and riprap were observed in a few localized areas within the reach, particularly in the vicinity of Clarks Bridge (Appendix A, Buffer Condition Map Series). In general, this reach supports good wildlife habitat conditions, particularly for reptiles. A majority of reptiles detected during 2010 were found in this reach. This reach is the only reach with fresh emergent wetlands present which may be a key habitat type for some species including reptiles. However, this reach had the lowest total number of individual birds detected and the lowest number of bird species in the study. No invasive bird species were detected in this reach, one nest predator bird species was detected (Steller's jay). While habitat conditions for reptiles are good in this reach, habitat conditions may be poor for birds. In addition, no amphibians and no invasive aquatic species were detected in this reach. Bat surveys were not conducted in this reach.

5.3.2 Above Tenaya Geomorphic Reach

The Above Tenaya geomorphic reach is 0.7 km in length, and is a straight, low gradient (0.28 percent) channel characterized by coarse substrate and banks. Developed campgrounds are located on the floodplains along both sides of the channel (Table 3-1). The reach contains 60 ha of CMZ, a moderate amount compared to other reaches (Figure 3-7), but nearly the entire area (99.7 percent; Table 3-5) is connected. The LWD survey recorded the second highest LWD loading (68 pieces/km) of all geomorphic reaches, and a much higher proportion of recruitment (81 percent) from upstream than the Happy Isles reach (Figure 3-11). Most LWD either directly formed a pool (41 percent) or was associated with pool habitat (14 percent), the greatest proportion of all geomorphic reaches, and accordingly occurred mainly in jams (68 percent) rather than single pieces. The reach also had the greatest potential LWD recruitment (807 m^3/ km/ yr, Figure 3-15). The riparian corridor within this reach was generally in poorer condition compared to the other geomorphic reaches (Figure 3-5). Structural patch richness and topographic complexity were in the lowest condition compared to the other geomorphic reaches within the study reach. The riparian vegetation was comparatively poor to moderately developed, with few co-dominant species and low to moderate vegetation structural complexity (little canopy overlap and few distinct plant layers). Excessive bank erosion was observed, particularly downstream of Clarks Bridge. Bank protection measures have been placed in the vicinity of

Clarks Bridge and extensive human use was observed throughout the reach. In addition, tree cutting historically occurred within the reach (Milestone 1978). The riparian corridor is readily accessible due to close proximity to recreational facilities and roads. Despite riparian conditions, the reach supported the highest diversity of bat species and the highest number of individual bat species was detected in this reach (1,496) as the wet meadow likely provides good habitat for insects. Most species forage either directly over water or within the adjacent riparian zone, where plant and insect productivity is higher than in seasonally dry up slope areas. The most important foraging habitat in the Yosemite Valley is within the riparian zone of the Merced River (Pierson 1997). More individual birds and bird species were detected in this reach compared to the Happy Isle Reach as well. No invasive bird species were present, but two nest predator bird species were detected in this reach (common raven and Steller's jay). The wildlife habitat in this reach appears to be good for bats in particular and for some birds (good habitat for insects). However, habitat conditions may be poor for reptiles and amphibians (none were detected in this reach during the study).

5.3.3 Below Tenaya Geomorphic Reach

The Below Tenaya geomorphic reach is 1.2 km long and characterized by a highly sinuous channel flowing through a wide valley (Table 3-1). The reach contained a moderate amount of CMZ area (60 ha, Figure 3-7), but a large proportion (37 percent, the largest of all geomorphic reaches) of this area was disconnected primarily due to the presence of channel revetments (Table 3-5). The channel stored a low amount of LWD (33 pieces/km), with most derived from fluvial transport (Figure 3-11). Most LWD occurred as single pieces, not within jams or with another piece and few pieces appeared to influence pool formation or were associated with a pool. The future potential LWD recruitment to this reach from channel migration or bank erosion is moderate (400 m^3/km/yr, Figure 3-15), although a portion (155 m^3/km/yr, 39 percent) of this potential wood occurs in areas currently disconnected from the CMZ. The riparian corridor within this reach was, on average, in the poorest condition compared to the other geomorphic reaches (Figure 3-5). Structural patch richness and topographic complexity scores were low compared to the other geomorphic reaches and the riparian vegetation more poorly developed, with few co-dominant species and low vegetation structural complexity (little canopy overlap and few distinct plant layers) (Appendix C, CRAM Summary Scores by Geomorphic Reach). Excessive bank erosion was observed in a number of locations (Appendix A, Buffer Condition Map Series) and bank protection measures occurred along portions of the reach. During riparian surveys, the project team observed substantial human use within the reach, as the riparian corridor is easily accessible due to close proximity to recreation facilities. Espinoza et al. (2010) recorded a low amount of habitat area (155 ha; Table 3-12). One field survey was conducted in this reach. Birds were detected in this reach (including two nest predator bird species), but no reptiles or amphibians were detected. Bat surveys were not conducted in this reach.

5.3.4 Upper Meadows Geomorphic Reach.

The Upper Meadows geomorphic reach (3.94 km length) has a highly sinuous channel that flows through a wide, low gradient (0.9 percent) portion of Yosemite Valley (Table 3-1). The reach supported the greatest overall CMZ area (245 ha, Figure 3-7), likely due to local valley widening and reach length (Table 3-1), although a large proportion of CMZ (37 percent) was disconnected due to the presence of the Yosemite Valley Loop Road (Table 3-5). The channel stored a moderate amount of LWD (57 pieces/km), with most recruited via fluvial transport from upstream (Figure 3-11). Most pieces either played a direct role in pool formation (8 percent) or were associated with pool habitat (32 percent). Most pieces occurred within jams (49 percent) or with another piece (14 percent). The potential for LWD recruitment is moderate (402 m^3/km/yr) compared to other reaches (Figure 3-15). The overall condition of the riparian corridor was near the overall study reach average (Figure 3-5). Buffer condition and channel stability were comparatively lower than most other geomorphic reaches while structural patch richness and topographic complexity were moderate (Appendix C, CRAM Summary Scores by Geomorphic Reach). Still, this reach is compositionally diverse with the greatest number of different community types (Table 3-4). The riparian vegetation was comparatively better developed, with more co-dominant species and moderate vegetation structural complexity (overlap of canopy layers and multiple distinct plant layers). Surveyors observed extensive human use throughout the reach, as the river and riparian corridor are in close proximity to a number of recreation facilities and the Yosemite Valley Loop Road. Excessive bank erosion occurred throughout the reach, particularly in the vicinity of road and walkway bridges, and picnic areas. Bank protection measures were located at a number of locations along the reach (Appendix A, Buffer Condition Map Series). Milestone (1978) also noted historical tree cutting occurred within this reach. Wildlife habitat conditions are comparatively better in this reach than the Below Tenaya reach, with high riparian community diversity likely responsible for the high number of bird species present in the reach (35 species and 384 individuals were detected). Invasive bird species (Brown-headed cowbirds) were also detected in this reach, and their presence may have an impact on the other bird species present. Two nest predator species were also detected in this reach (common raven and Steller's jay). In addition, Espinoza et al. (2010) detected 55 percent of bat species in this reach. While the total number of individual bats detected is lower than in the Above Tenaya reach, this difference is likely not related to the condition of the habitat, rather due to detector placement and shorter monitoring period. This reach may provide better habitat overall for birds in particular as well as for bats. One reptile species was detected in this reach. No amphibian species and no invasive aquatic species were detected in this reach.

5.3.5 Inter-Meadows Geomorphic Reach

The Inter-Meadows geomorphic reach (2.1 km length) has a moderately sinuous, low gradient (0.04 percent) channel that flows through a relatively narrow valley with forested floodplains (Table 3-1). The reach supports a moderate amount of CMZ area (84 ha, Figure 3-7), with a moderate amount (16 ha, 19 percent) disconnected by infrastructure presence or revetments (Table 3-5). A moderate amount of LWD (44 pieces/km) occurred within the reach, most transported by fluvial transport from upstream (75 percent, Figure 3-11). Approximately seventy percent of woody pieces were not associated with pool habitat, and most pieces (81 percent) occurred within jams. The potential for LWD recruitment is moderate (351 m^3/km/yr) compared to other reaches, although a portion (60 m^3/km/yr; 17 percent) of this potential wood occurs in areas disconnected from the CMZ (Figure 3-15). The condition of the riparian corridor was better overall compared to most other reaches (Figure 3-5). The physical structure of the riparian corridor was in moderate condition compared to the other geomorphic reaches, with moderate to high patch richness and topographic complexity (Appendix C, CRAM Summary Scores by Geomorphic Reach). The reach supported the highest average number of co-dominant species in the entire study reach, and the vegetation community was well developed with moderate to high horizontal interspersion and vertical structure complexity (overlap among canopy layers). In particular, localized excessive bank erosion was observed in few locations, near the El Capitan picnic area and around a large meander bend and few bank protection measures have been installed (Appendix A, Buffer Condition Map Series). However, human use was high throughout the reach. In general, wildlife habitat conditions are good in this reach and appear to support a good diversity of species. This reach supports a strong diversity of bird species (30 percent of species are present in this reach). A total of 158 individual birds were detected in this reach. Invasive bird species (brown-headed cowbirds) were also detected in this reach, and their presence may have an impact on the other bird species present in the reach. Steller's jay (a nest predator bird species) was also detected in this reach. One reptile species was detected in this reach. Signal crayfish (invasive species) were also detected in the reach. However, no amphibians were detected in this reach. Wildlife habitat in this reach was on average good for both birds and possibly reptiles. This is the first reach where invasive aquatic species were detected.

5.3.6 Lower Meadows Geomorphic Reach.

The Lower Meadows geomorphic reach (2.4 km length) is a moderately sinuous channel (0.09 percent gradient) flanked by floodplains and a large meadow (El Capitan Meadow) on the right bank (Table 3-1). The Lower Meadows reach had a relatively large CMZ area (126 ha, Figure 3-7), with 23 percent (29 ha) disconnected from the channel (Table 3-5). The reach stored 54 pieces/km of LWD, with most recruited by fluvial transport from upstream (67 percent), although a substantial portion arrived via bank erosion (29 percent), the second highest percent among study reaches (Figure 3-11). A moderate amount of LWD was associated with or directly formed pools, and most (61 percent) occurred as single pieces, while <10 percent occurred within jams. The potential for LWD recruitment is moderate (360 m^3/km/yr) compared to other reaches (Figure 3-15). The condition of the riparian corridor was better overall compared to most of the other geomorphic reaches (Figure 3-5). The physical structure of the riparian corridor was in moderate condition compared to the other geomorphic reaches, with moderate to high patch richness and topographic complexity (Appendix C, CRAM Summary Scores by Geomorphic Reach). The number of co-dominant species was also comparatively high. The riparian vegetation, though, was poor to moderately developed, with low to moderate vegetation structural complexity (little canopy overlap and few distinct plant layers). Compared to the other geomorphic reaches with substantial sections of stabilized river bank, none were observed within this reach (Appendix A, Buffer Condition Map Series). Excessive bank erosion was localized to areas in the vicinity of recreation areas (e.g., Cathedral Beach Picnic Area), El Capitan Bridge, and meander bends. Similar to the Upper and Inter Meadows geomorphic reaches, human use was high throughout most of the reach. This reach supports the second highest wet meadow habitat percentage (from WHR habitat types) in the study (16 percent) (Table 3-12). All of the amphibians detected during the field surveys were detected in this reach (2 amphibian species – including the American bullfrog which is an invasive species). American bullfrog was not detected in any of the other reaches in the study. They were detected at three of five survey sites in this reach. One reptile species and signal crayfish (invasive aquatic species) were also detected. Seventy three percent of bird species were detected in this reach (a total of 233 individuals and 30 species). As with Upper and Inter Meadows reaches, the Brown-headed cowbird was detected in this reach, and may have an impact on the other bird species present in the reach. The common raven and Steller's jay (bird nest predators) were also detected in this reach and may also contribute to impacts to other bird species. Compared to Inter Meadows

Reach above, wildlife habitat in this reach was slightly better for birds and for amphibians and reptiles.

5.3.7 Above Pohono Bridge Geomorphic Reach

The Above Pohono Bridge geomorphic reach (2.7 km length) is characterized by a slightly steeper gradient (0.7 percent), a narrower valley width, and a more entrenched channel than upstream (Table 3-1). These changes are reflected by a relatively low CMZ area (71 ha, Figure 3-7) with a moderate amount of disconnected CMZ area (16 ha, 23 percent; Table 3-5). The LWD survey found relatively low LWD loading (29 pieces /km) and few pieces associated with pool habitat (~1 percent), unlike upstream reaches, which had at least 20 percent of pieces associated with or forming a pool (Figure 3-11). Accordingly, very few pieces occurred within jams (6 percent) or with another piece (27 percent). The potential for LWD recruitment is moderate (238 m^3/km/yr) compared to other reaches, although a portion (61 m^3/km/yr, 26 percent) of this potential wood occurs in areas disconnected from the CMZ (Figure 3-15). Downstream of El Capitan Meadow, the floodplain is more confined than upstream reaches. As a result, the buffer widths are comparatively narrow. The condition of the riparian corridor, however, was better overall compared to most of the other geomorphic reaches (Figure 3-5). Specifically, human use was comparatively low in approximately one half of the reach, and bank protection measures were more limited in extent, and occurred in a few localized areas, particularly at the downstream end of the reach at Pohono Bridge (Appendix A, Buffer Condition Map Series). Bank erosion was observed along meanders. The physical structure of the riparian corridor was comparatively high, with moderate to high patch richness and topographic complexity. The vegetation community was compositionally diverse. The vegetation structure was fairly well developed, with moderate to high horizontal interspersion and vertical structure complexity (overlap among canopy layers) (Appendix C, CRAM Summary Scores by Geomorphic Reach). Overall wildlife habitat condition in this reach is slightly less than upstream in the Lower Meadows Reach. This reach is a little more confined than the reach above. No amphibians or reptiles were detected during the field surveys. Only 9 percent of the total number of individual birds were detected in this reach (18 species total). As with the reaches above, two bird nest predator species were present in this reach (common raven and Steller's jay) in addition to the invasive bird species, brown-headed cowbird. Wildlife habitat in this reach was poor compared to Inter Meadows and Lower Meadows reaches for birds. The presence of crayfish only in this reach and no reptiles or amphibians may be indicative of poorer aquatic wildlife habitat quality as well.

5.3.8 Below Pohono Bridge Geomorphic Reach

The Below Pohono Bridge reach (1.7 km length) is characterized by the steepest gradient of all geomorphic reaches (2 percent), the narrowest valley (63 m), and a straight, entrenched channel (Table 3-1). Accordingly, there is little CMZ area (16 ha, Figure 3-7). Despite the placement of channel revetments along substantial sections of the reach, there is relatively little disconnected area (1 ha, 11 percent, Table 3-5). LWD loading was relatively low (39 pieces/km), although not the lowest among geomorphic reaches (Figure 3-11). In comparison to the other reaches upstream, all LWD came from fluvial transport or tree fall, with none derived from bank erosion. Similar to the Above Pohono Bridge reach, few pieces formed pools (1 percent) or were associated with pool habitat (13 percent), and all occurred as a single piece (75 percent) or touching another piece (25 percent). No jams occurred within the reach. The potential for LWD recruitment is low (25 m^3/km/yr) (Figure 3-15). The riparian corridor was, on average, in poorer condition compared to the other geomorphic reaches ((Figure 3-5). Patch richness was moderate to high, but topographic complexity was low within the reach (Appendix C, CRAM Summary Scores by Geomorphic Reach). The riparian vegetation was comparatively poorly developed, with few co-dominant species and low vegetation structural complexity (little canopy overlap and few distinct plant layers). Again, similar to the Above Pohono Bridge reach, average buffer widths were comparatively narrow due to the more confined river valley and the close proximity of El Portal Road to the river. Bank protection measures occurred at the downstream end of the reach and numerous localized areas of excessive bank erosion were observed (Appendix A, Buffer Condition Map Series). The fewest number of species were observed in this reach compared to other reaches. However, there was only one survey location in this reach. No amphibians, reptiles, or invasive aquatic species were detected in this reach. Only 22 percent of bird species were present in this reach (20 individuals or 2 percent of all birds detected in the study). One nest predator bird species was present in this reach during the study (Steller's jay).

5.4 Causes of Diminished Habitat Quality

5.4.1 Riparian Corridor

The riparian corridors in the Above and Below Tenaya geomorphic reaches generally have low physical topographic complexity (patch richness and topographic variability), and poorly developed communities, with few co-dominant species and low structural complexity (little canopy overlap and few distinct plant layers). Numerous recreation facilities are located within these reaches and the riparian corridor and river are easily accessible by trail or from nearby roads. Bank erosion was observed throughout the reaches, and various types of measures to stabilize the banks have been installed to protect infrastructure, property, and public safety. The primary stressors on the condition of the riparian corridor within these reaches are related to the high recreation use, and channel stabilization measures that limit lateral connectivity and channel migration.

The condition of the riparian corridor in the Below Pohono Bridge reach is influenced in part by the narrow valley bottom that limits the buffer width, but also by the close proximity of El Portal Road and bank protection measures that have been installed to protect the road. As a result, the riparian community was relatively poorly developed, with few co-dominant species and low vegetation structural complexity (little canopy overlap and few distinct plant layers). In addition, numerous turnoffs and parking areas provide easy access from the road to the riparian corridor and river. Human–related impacts, such as trash and other refuse, were observed within the riparian corridor in the vicinity of these areas.

5.4.2 Channel Migration Zone

The current condition of the CMZ is directly related to the history of development within Yosemite Valley. The construction of the Yosemite Valley Loop Road and bridges, installation of channel revetments, and blasting of the El Capitan moraine have all affected the Merced River.

Construction of roads in close proximity to the channel and installation of revetments limit the extent of the CMZ, and has direct linkages to potential wood recruitment and loading, instream habitat, floodplain development and topographic complexity, and riparian conditions. The

Yosemite Valley Loop Road has cutoff approximately 25 percent of the CMZ within the valley. While the road is close to the valley margins for much of its length, there are sections where the road deviates from the valley margin, specifically near Yosemite Village, that disconnect significant areas of floodplain from the channel. The current extent of channel revetment disconnects nearly 1 percent of the total CMZ area within the Valley. Historic accounts of the length of channel with revetment in Milestone (1978) indicate that much more channel length was once armored than is currently. This reduction in channel revetment is likely a combination of loss during formative flood events, and a shift in policy to not maintain all revetments within the Park. This shift in policy has likely increased the CMZ from the historic condition.

Blasting of the terminal moraine in 1879, which acted as grade control, resulted in the overall lowering of the channel by approximately 1.2-1.5 m (Milestone 1978) and entrenchment of the channel. This entrenchment caused higher shear stress on channel bed and banks due to deeper flows, and accelerated further erosion in the reaches both up and downstream. Coupled with the blasting was the implementation of wood removal projects, leading to further destabilization of channel banks. A more thorough description of wood removal in the Merced River is provided in section 5.4.3. As the channel banks became more destabilized, more bank protection was constructed. This further diminished habitat quality by forcing the energy of the river to the bed. The result is a channel that is much deeper than it should be under natural conditions, and "stuck" in a planform that is inconsistent with the new hydraulic conditions. As channel revetments are allowed to break down and channel migration processes restored, the channel form will adjust to a more natural form.

The primary stressors within the riparian corridor are likely related to recreational use, and the presence of infrastructure and channel stabilization measures (revetments). Infrastructure and revetments lead to the disconnection of a relatively large portion of channel migration zone, limiting lateral connectivity between the river and the riparian corridor, and limiting erosional and depositional processes that create geomorphic surfaces for riparian regeneration and species diversity and recruit LWD to the channel. Recreational use and presence of infrastructure may also limit the expansion of the riparian forest to accommodate wildlife species.

5.4.3 Large Woody Debris

Wood loading in the Merced River within Yosemite Valley has been actively manipulated by policies dating back to the late 19th century (Milestone 1978). Historically, active removal of LWD was implemented with the intent to improve flood conveyance, reduce bank erosion, and improve aesthetics (Milestone 1978). Additional adverse impacts of NPS management activities to LWD loading included clearing of riparian forests for development of campgrounds, facilities, and other infrastructure; and installation of revetments to prevent bank erosion. The clearing of riparian forests and installation of revetments prevent future wood loading in areas where natural recruitment would have taken place.

These impacts to LWD loading are evident when evaluating current LWD loading along the study reach. In the less developed Happy Isles geomorphic reach, LWD loading is substantially higher (up to six times higher) than in the downstream reaches where development is more extensive (Figure 3-8). Fewer revetments are also present within this reach. Channel migration processes are more active compared to downstream reaches due to fewer revetments, and wood recruitment is higher. The Happy Isles reach provides an example of more natural LWD loading for the Merced River compared to the lower reaches, and demonstrates that LWD loading can be improved by removal of channel revetments thereby allowing channel migration processes to occur.

5.4.4 Wildlife Habitat

In general, diminished wildlife habitat conditions can be attributed to 1) natural physical characteristics of the stream reach (below Pohono Bridge is a narrow canyon reach with poorly developed riparian community); 2) to the effects of land management practices and human impacts (presence of recreational facilities, parking lots, roadways, historic removal of LWD, historic tree cutting activities, and presence of channel stabilization measures such as revetments in the reach); or 3) invasive species. Although riparian habitats are disproportionately important to wildlife, riparian habitat has declined by 90 percent in the United States in historic times, resulting in great conservation and management concern (Hatten et al. 2010).

The presence of invasive species plays a role in diminishing habitat for specific wildlife species within the study area. Brown-headed cowbirds are “brood parasites,” and lay their eggs in the nest of other birds. Brown-headed cowbirds have been shown to lay eggs in the nests of more than 220 species. However, some bird species may be more common hosts than others (yellow warbler, chipping sparrow, song sparrow, and red-winged blackbirds). Brown-headed cowbirds tend to frequent lowlands where meadows and pastures are situated near tracts of willows and cottonwoods (Stebbins et al. 1963). Brown-headed cowbird parasitism and destruction of suitable habitat (willow thickets) may have contributed to the decline of willow flycatchers (*Empidonax traillii*) in the past decade in Yosemite Valley (Zeiner 1988). Willow flycatchers require dense willow thickets for nesting and roosting, attributes found in montane riparian habitat (Zeiner 1988). A study conducted by Siegel et al. (2008) concluded that the willow flycatcher likely no longer breeds in Yosemite National Park.

Increased populations of native predators such as raccoons, ravens and coyotes may also be impacting native wildlife species. For western pond turtles, invasive species and elevated nest and hatchling predation due to increased populations of predators such as raccoons, ravens and coyotes and removal of large woody debris from stream channels has likely also factored into their extirpation.

Limited suitable habitat may be responsible for the lack of foothill yellow-legged frog sightings in Yosemite Valley. However, other factors (non-native predators – trout; possible effects from a fungus; and potential effects from airborne contaminants) may be responsible for the observed decline in Sierra Nevada yellow-legged frog in the park.

The presence of non-native bullfrogs and signal crayfish (invasive invertebrate) is likely impacting native herpetofauna. Both non-native species have been implicated in the decline of native amphibians and reptiles through predation and competition (Gamradt and Kats 1996; Lannoo 2005). Adult bullfrogs are voracious predators that will readily eat anything smaller than themselves (Bury and Whelan 1984). Signal crayfish are generalist omnivores and avid predators on benthic macroinvertebrates and the eggs and larvae of amphibians. Eradication efforts, which began in 2005, have substantially reduced the population of bullfrogs in Yosemite Valley.

5.5 Restoration and Management Recommendations

Restoration and management recommendations are based upon field data and observations (Section 3); assessments of riparian, channel, and wildlife habitat conditions along the study reach and within geomorphic reaches (Sections 5.2, and 5.3); and potential stressors to channel and riparian habitat (Section 5.4). The recommendations are intended as suggestions to guide Yosemite National Park personnel in making future management decisions.

- Channel migration may be limited in some geomorphic reaches due to the presence of channel revetments, roads, and park facilities. Limits on channel migration affect riparian forest condition, LWD recruitment, and aquatic habitat. In order to restore channel migration within the study reach, park managers should consider reconnecting disconnected portions of the channel migration zone, either through gradual removal of facilities and developed areas (when possible), removal of channel revetments, and/or road relocation (or a combination thereof) Initial efforts should be targeted toward geomorphic reaches with the greatest amount of disconnected area (Below Tenaya, Upper Meadows; Table 3-5), as these reaches have the greatest restoration potential and the greatest ecological effect. Restoration of channel migration would improve riparian conditions, such as buffer widths, floodplain topographic complexity and concomitant vegetation distribution, lead to the creation and maintenance of a diversity of floodplain and aquatic habitats, and potentially increase species abundance and diversity. As part of restoring channel migration, managers should consider allowing the occurrence of episodic geomorphic processes, such as oxbow formation or floodplain inundation to influence floodplain and channel form. Direct planting of native riparian vegetation would also accelerate enhancement within these areas. In reaches where managers consider reconnecting the CMZ, they should also consider assessing the inundation frequency and duration of these re-connected areas, measuring depths to summer ground water, and sources for summer water (from the Merced River or from surrounding hillslopes) in relation to riparian and meadow species that may naturally revegetate these areas or may be directly planted to accelerate enhancement. This information can be used in the restoration design phase to help ensure that natural revegetation and/or direct planting will be successful over the long term and will meet management objectives.
- Floodplain fluvial geomorphic processes are important for maintaining the functional processes and diversity patterns of riparian systems. These processes are limited in the reaches where facilities disconnect the channel from part of its natural migration zone or where channel incision has reduced the frequency of inundation within the riparian zone. In these reaches, the riparian corridor was generally characterized low topographic complexity and poorly developed riparian vegetation (few co-dominant species and low vegetation structural complexity). Restoration options could include reconnecting disconnected channel migration zones (as discussed above) and/or mechanical measures (e.g., floodplain/bank regrading) to increase the frequency of overbank inundation within the riparian zone that will increase topographic complexity that will enhance species diversity and create sites and conditions suitable for woody riparian regeneration. Park managers could also consider continuing native re-vegetation projects, including direct planting of native vegetation, to facilitate recovery of the riparian habitat within these reaches.
- Large woody debris abundance appears low in some geomorphic reaches (e.g., Below Tenaya) and may affect aquatic habitat and riparian regeneration. Park managers should consider managing LWD to accommodate the processes of LWD input,

storage, and transport through the channel network by preserving zones of LWD recruitment within reaches, areas of LWD storage (gravel bars, floodplains) and maintain pathways of LWD transport. Such management would recognize the ecological value of LWD, but also recognize the potential impact of LWD on public safety and infrastructure. A potential strategy may be to identify LWD supply areas, areas of probable logjam formation, and areas (both within and along the channel) of potential human use. This strategy may allow for the recruitment of LWD and formation of jams in areas of low human use or where safety hazards are minimal, while other areas could be managed more intensively to maintain human use and reduce hazard. Such management would include specific LWD management guidelines for the study reach to determine conditions under which wood is removed or left in place. The guidelines would balance aquatic habitat needs, flood conveyance, public safety, and infrastructural concerns and be linked to management of LWD. Other recommendations to manage and restore LWD are:

  - Regular LWD inventories to document the processes of input, storage, and transport. Inventories would use tags (or other device) to identify wood and a GPS to document piece characteristics and location along and within the channel. Regular inventories, such as after large storms, or seasonally, would allow managers to identify areas of input, storage, and transport that could be use to more effectively manage LWD to maintain riparian and aquatic habitat.
  - Increasing wood loading by establishing stable logjams that will retain mobile wood moving downstream and wood locally recruited via bank erosion and wind throw. Stable log placement, such as within engineered logjams (ELJs), provide an approach that can balance local bank protection and flood conveyance with habitat restoration (Abbe et al 1997, 2003, 2011). Based on a site inspection of the river in the Fall of 2010 following the LWD survey and after a subsequent 5 year recurrence peak flow, the project team observed pieces that had recently moved into the study reach. Wood loading depends on the presence of key pieces (Abbe and Montgomery 1996), which depends on riparian tree sizes. In the Happy Isles reach where recent erosion recruited large trees the highest wood loading and abundance of logjams retaining unstable wood was observed. LWD addition, either through log placement or ELJ installation could provide a more predictable way to restore wood loading in reaches where LWD is currently flushed out of the system.
  - Use of hazard trees and tree throw removed from roadways within the Park would provide a local and relatively inexpensive source of LWD for restoration efforts.

- Bank instability was observed in several locations within the study reach. Many of these locations were observed near bridges and in areas with high recreation use. Excessive bank erosion can cause channel widening or deepening, and adversely affect the condition of the riparian community. Restoration options could include the continuation of projects focused on the restoration, potentially with revegetation of denuded river banks and/or mechanical measures to reduce bank slope. In addition, measures could be implemented to direct visitors away from erosion sensitive areas to more resilient or visitor designated areas.

- The CRAM assessment provides a rapid, standardized, and consistent method to assess the status and trends in the overall condition of the riparian corridor. Periodic repeated surveys using the CRAM assessment, or of specific CRAM metrics, would allow managers to assess the performance of management programs and policies and restoration activities over time.
- Park managers should consider monitoring riparian and meadow vegetation within the riparian corridor following prescribed burns that burn these areas, particularly following severe burns, to document potential changes over time in community composition/ distribution and riparian corridor condition. This could provide important information for management about the potential role of fires in maintaining/ restoring vegetation within the Merced River riparian corridor and the condition of the riparian corridor where fire was historically an essential part of the ecosystem
- Park managers should consider initiating a program to educate park visitors on river processes (fluvial geomorphology) and its importance to riparian and aquatic habitat, the potential conflict between these processes and human occupation, and how the park is managing (or is planning to manage) the river and park facilities to accommodate ecological and human uses. Educational material should describe specific fluvial geomorphic processes (e.g., channel migration, LWD dynamics, and floodplain development), how the processes form habitat, and animal populations using the habitat. Materials should also describe how human use may affect these processes, habitats, and populations. A part of the program should be a description of historical river management, including development of the park, placement of structures crossing the river (e.g., bridges), and restoration activities. Such a discussion could be linked to a more general discussion on geomorphic processes occurring within Yosemite Valley (not limited to fluvial geomorphic processes).

5.6 Suggested Future Studies

The following list of suggested future studies targets gaps indentified during the assessment and intended to aid in future management and restoration of the Merced River and its riparian corridor through Yosemite Valley. The list below is intended to guide future study development, but more detailed plans should be produced before study implementation. Further, the list should not be viewed as exhaustive or comprehensive, as ideas for future studies may arise from this and other assessments.

- Conduct more quantitative studies in Above and Below Tenaya and Below Pohono reaches to characterize the vegetation community (e.g., species distribution in relation to topography, tree diameters and shrub size classes) and to identify factors that may be limiting the buffer condition, biotic condition (e.g., compositional and structural diversity), and physical structure (e.g., topographic complexity). This would provide guidance to Park managers on specific management actions that could be implemented to enhance riparian habitat within these reaches.

- Develop a comprehensive hydraulic model of the Merced River study reach to evaluate potential changes to the channel migration zone under different management prescriptions (i.e., reconnecting disconnected areas), evaluate floodplain inundation (frequency, duration, timing) in relation to riparian and meadow community characteristics and recruitment processes (e.g., cottonwoods and willows), and floodplain topographic complexity, and identify at risk facilities as channel revetments are removed. Such a model would guide future river management decisions and inform riparian vegetation planting plans.
- Develop LWD dynamics model (linked to hydraulic river model, above) to predict future wood input under different management scenarios under the short- and long-terms, potential LWD loading along the study area or areas of accumulation, and downstream transport under different hydrologic conditions. The model could be used to set LWD management goals and aquatic habitat goals.
- Conduct comprehensive aquatic habitat assessment describing current habitat condition, factors affecting key aquatic species, and potential management measures to address impaired habitat. Assessment could be linked to hydraulic river model and LWD dynamics model to develop aquatic habitat goals.
- Describe history of the Merced River in Yosemite Valley from pre-European settlement through modern times, including valley and river morphology, and riparian vegetation. The description would provide context to current and future conditions and aid in management and restoration.
- Conduct a study on how climate change may potentially affect hydrology within the study reach, and how hydrologic changes may affect river and riparian condition. Such a study would use information from existing climate change models and could be linked to proposed hydraulic and LWD dynamics models.
- As part of a wood management plan, develop a wood budget that accounts for the major elements contributing to wood loading at any given location and time. A wood budget is a quantitative framework for analyzing the mass balance of wood in river networks, and allows a process-based examination of long-term trends in wood input and transport (Benda and Sias 2003, Benda et al. 2003).
- Conduct biological monitoring to build upon previous aquatic and terrestrial species surveys to guide future management actions, and to link potential changes in diversity, abundance, or distribution to management actions.

Chapter 6

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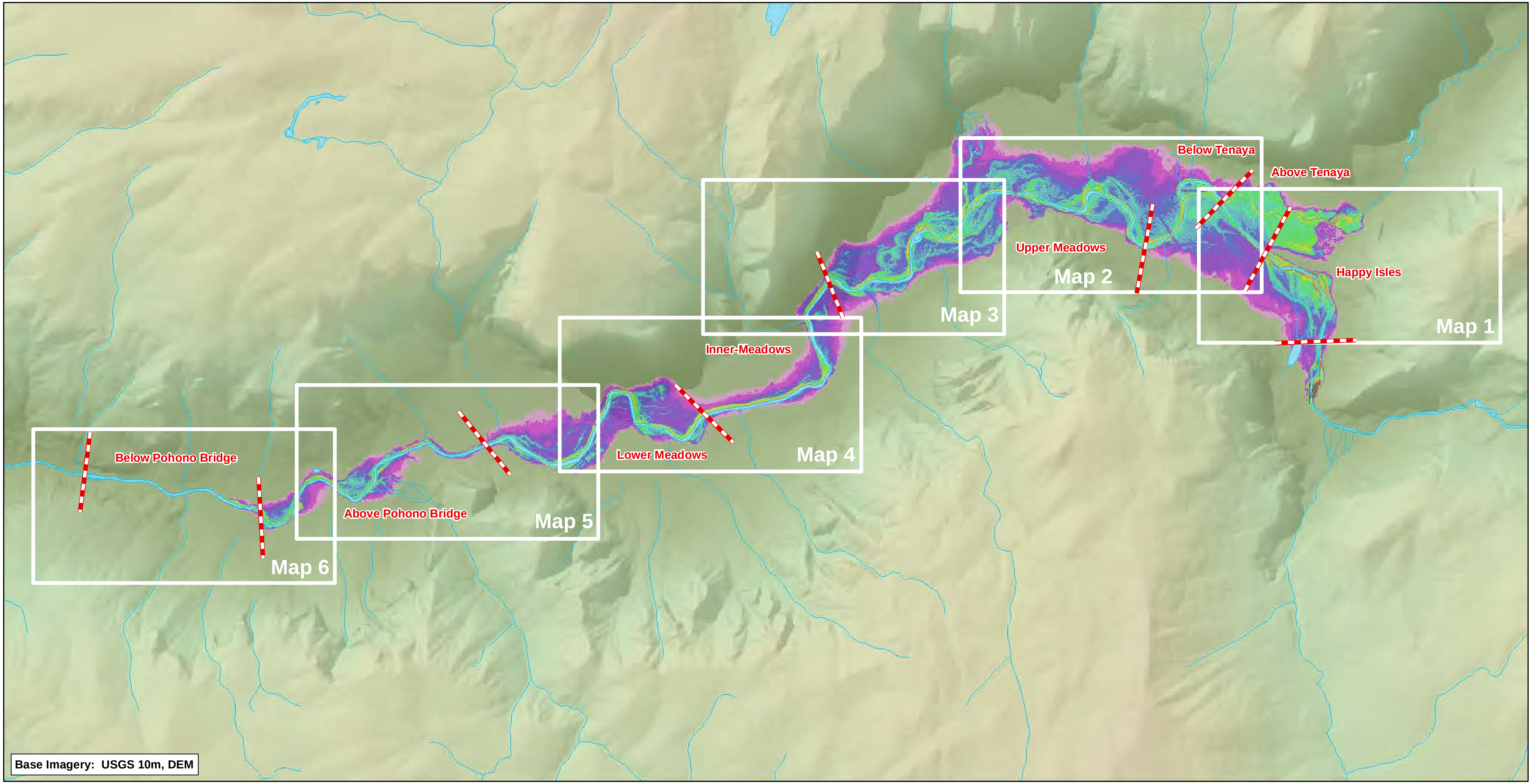
Appendix A

Map Series

Merced River and Riparian Vegetation Map Series:

1. Height Above Water Surface Map Series
2. Geomorphic Reach Map
3. 2010 Riparian Vegetation Map Series
4. 1997 to 2010 Riparian Vegetation Map Series
5. 1992 to 1997 Riparian Vegetation Map Series
6. California Rapid Assessment Method (CRAM) Assessment Areas Map Series
7. CRAM Scores Map Series
8. CRAM Buffer Condition Map Series
9. CRAM Buffer Width Map Series
10. CRAM Biotic Condition Map Series
11. CRAM Physical Structure Map Series
12. Channel Migration Zone (CMZ) Map Series
13. Large Woody Debris (LWD) Map Series
14. Wildlife Habitat Relationships (WHR) Map Series
15. Yosemite Valley Restoration Sites Map Series
16. Historical Channel Changes Map Series



Height Above Water Surface (m)

>6	2 - 2.5	-0.5 - 0	Geomorphic Reach Break
5 - 6	1.5 - 2	-0.5 - -1	Stream
4 - 5	1 - 1.5	-1 - -2	Waterbody
3 - 4	0.5 - 1	<-2	
2.5 - 3	0 - 0.5		

Merced River
Yosemite National Park

Height Above Water Surface Map Series

Height Above Water Surface for the Merced River

Index

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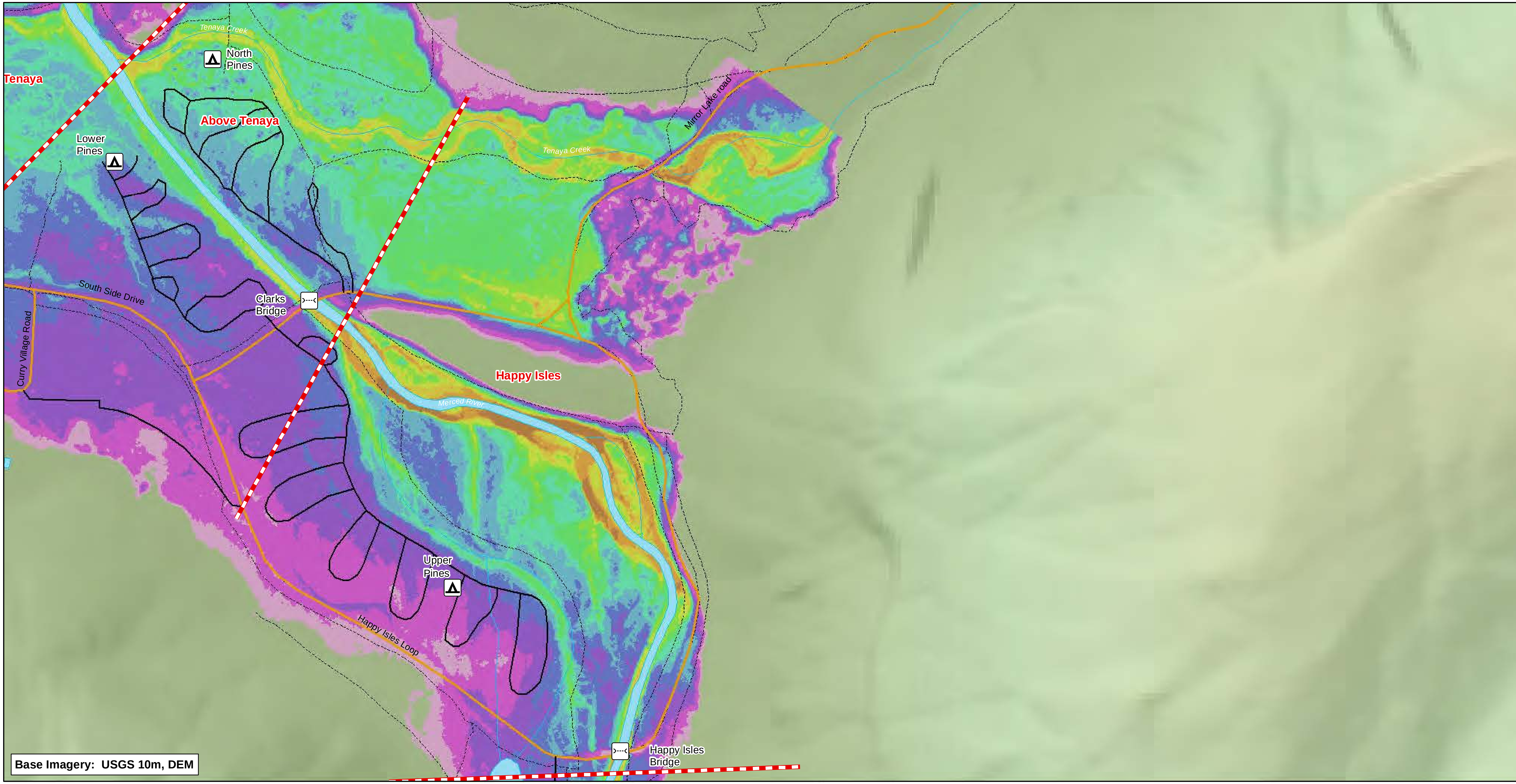
Coordinate System:
NAD 1983 UTM Zone 11 meters

N W E S

0 375 750 1,500 Meters



Height Above Water Surface (m)

- >6
- 5 - 6
- 4 - 5
- 3 - 4
- 2.5 - 3
- 2 - 2.5
- 1.5 - 2
- 1 - 1.5
- 0.5 - 1
- 0 - 0.5
- -0.5 - 0
- -0.5 - -1
- -1 - -2
- <-2

- Bridge
- Campground
- Picnic Area
- Waterfall

- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

Merced River
Yosemite National Park

Height Above Water Surface Map Series

Height Above Water Surface for the Merced River

Map 1 of 6

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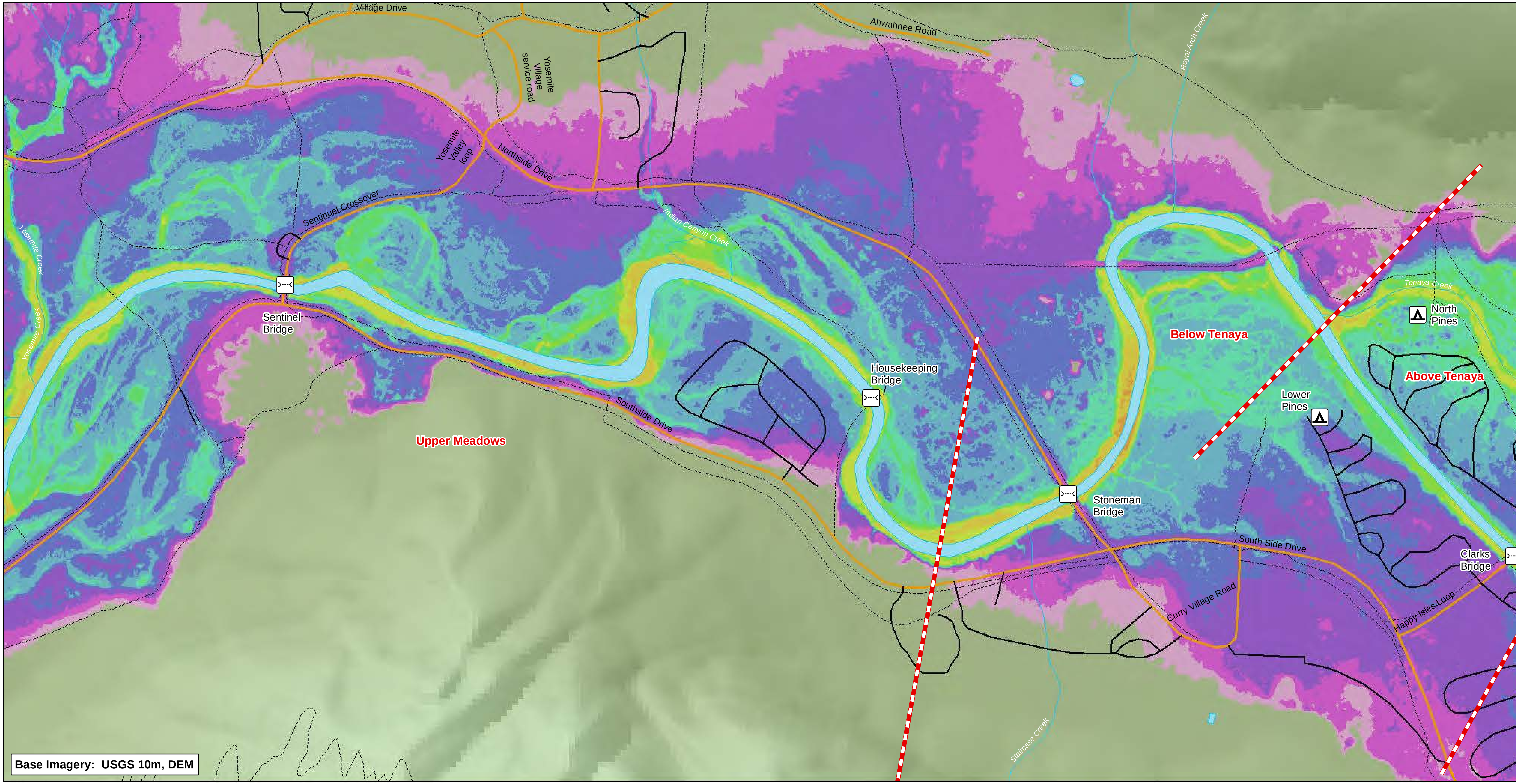
0 75 150 300 Meters



Height Above Water Surface (m)

- >6
- 5 - 6
- 4 - 5
- 3 - 4
- 2.5 - 3
- 2 - 2.5
- 1.5 - 2
- 1 - 1.5
- 0.5 - 1
- 0 - 0.5
- -0.5 - 0
- -0.5 - -1
- -1 - -2
- <-2

- Bridge
- Campground
- Picnic Area
- Waterfall

- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

Merced River
Yosemite National Park

Height Above Water Surface Map Series

Height Above Water Surface for the Merced River

Map 2 of 6

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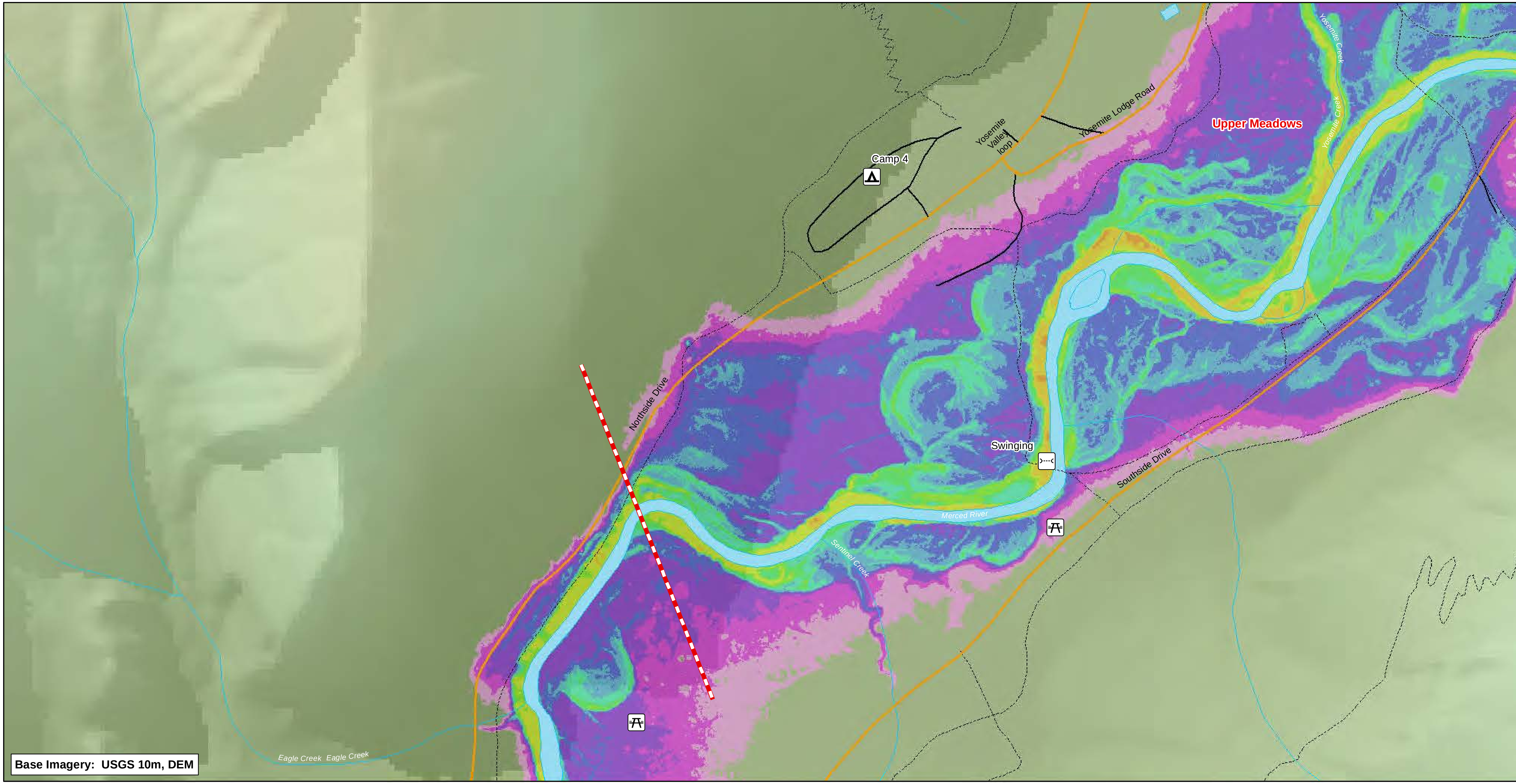
0 75 150 300 Meters

N S E W



Height Above Water Surface (m)

- >6
- 5 - 6
- 4 - 5
- 3 - 4
- 2.5 - 3
- 2 - 2.5
- 1.5 - 2
- 1 - 1.5
- 0.5 - 1
- 0 - 0.5
- -0.5 - 0
- -0.5 - -1
- -1 - -2
- <-2

- Bridge
- Campground
- Picnic Area
- Waterfall

- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

Merced River
Yosemite National Park

Height Above Water Surface Map Series

Height Above Water Surface for the Merced River

Map 3 of 6

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N W E S

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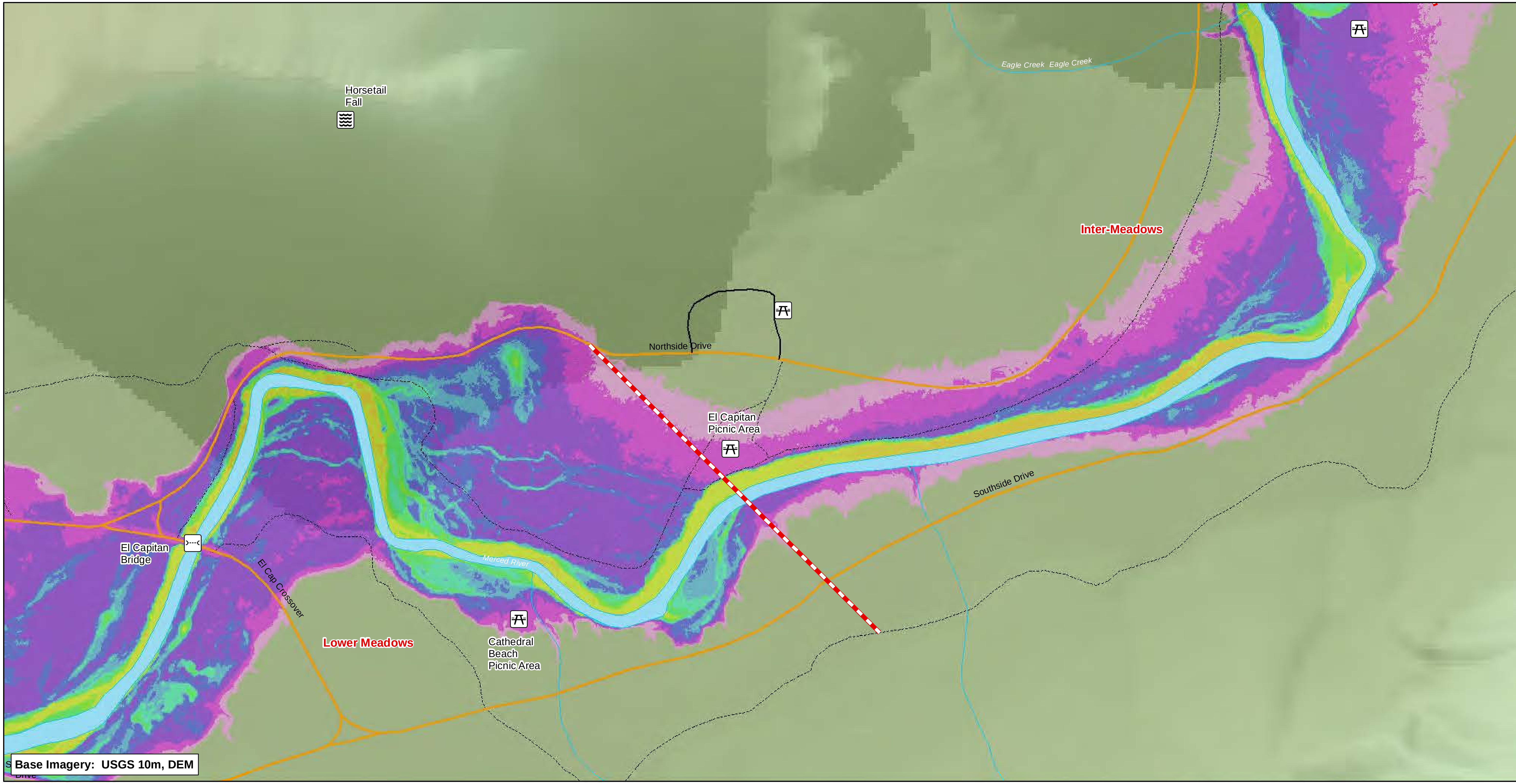

Height Above Water Surface (m)

- >6
- 5 - 6
- 4 - 5
- 3 - 4
- 2.5 - 3
- 2 - 2.5
- 1.5 - 2
- 1 - 1.5
- 0.5 - 1
- 0 - 0.5
- -0.5 - 0
- -0.5 - -1
- -1 - -2
- <-2

- Bridge
- Campground
- Picnic Area
- Waterfall

- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

Merced River
Yosemite National Park

Height Above Water Surface Map Series

Height Above Water Surface for the Merced River

Map 4 of 6

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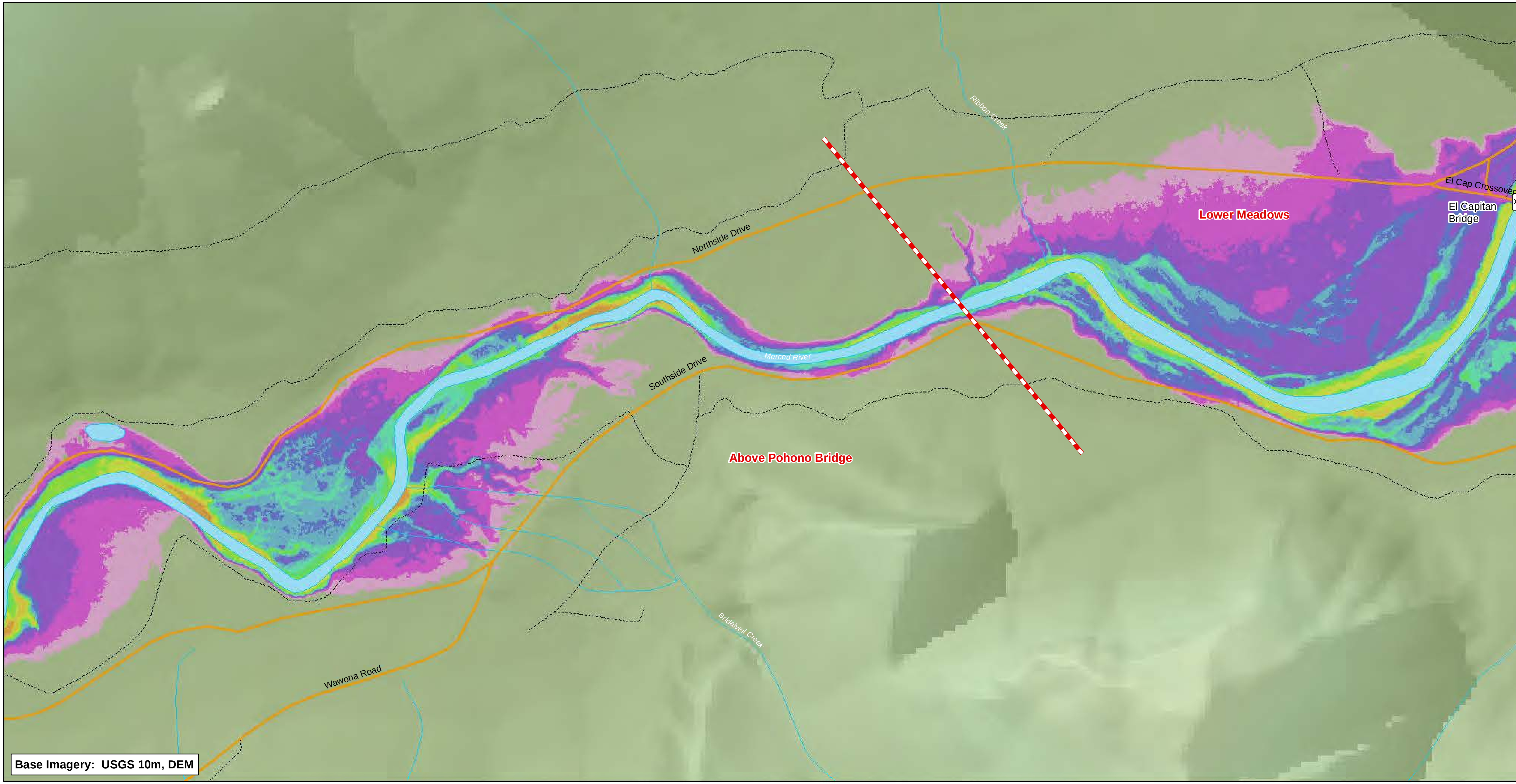
N W E S

0 75 150 300 Meters



Height Above Water Surface (m)

- >6
- 5 - 6
- 4 - 5
- 3 - 4
- 2.5 - 3
- 2 - 2.5
- 1.5 - 2
- 1 - 1.5
- 0.5 - 1
- 0 - 0.5
- -0.5 - 0
- -0.5 - -1
- -1 - -2
- <-2

- Bridge
- Campground
- Picnic Area
- Waterfall

- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

Merced River
Yosemite National Park

Height Above Water Surface Map Series

Height Above Water Surface for the Merced River

Map 5 of 6

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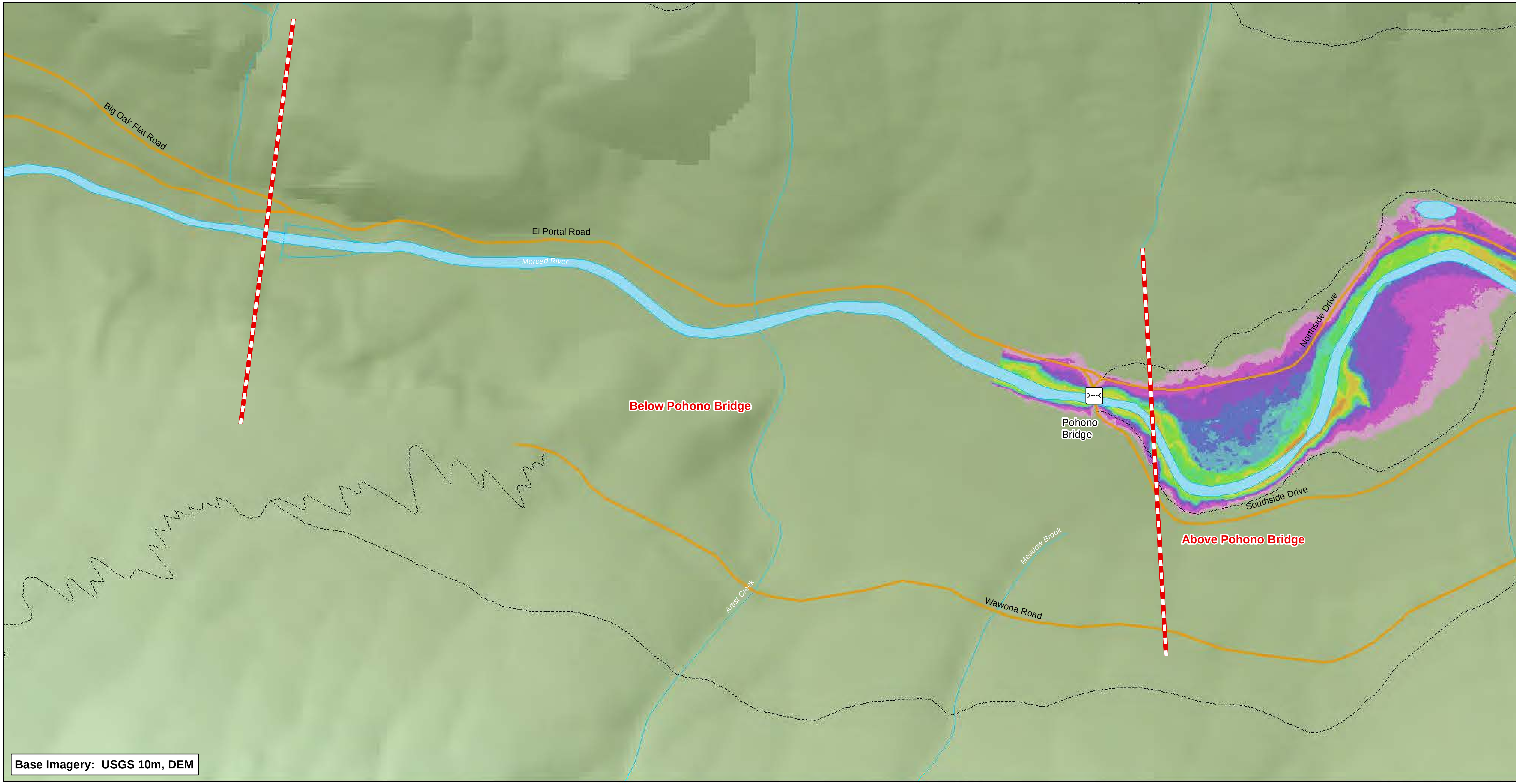
0 75 150 300 Meters

N W E S



Height Above Water Surface (m)

- >6
- 5 - 6
- 4 - 5
- 3 - 4
- 2.5 - 3
- 2 - 2.5
- 1.5 - 2
- 1 - 1.5
- 0.5 - 1
- 0 - 0.5
- -0.5 - 0
- -0.5 - -1
- -1 - -2
- <-2

- Bridge
- Campground
- Picnic Area
- Waterfall

- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

Merced River
Yosemite National Park

Height Above Water Surface Map Series

Height Above Water Surface for the Merced River

Map 6 of 6

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N S E W

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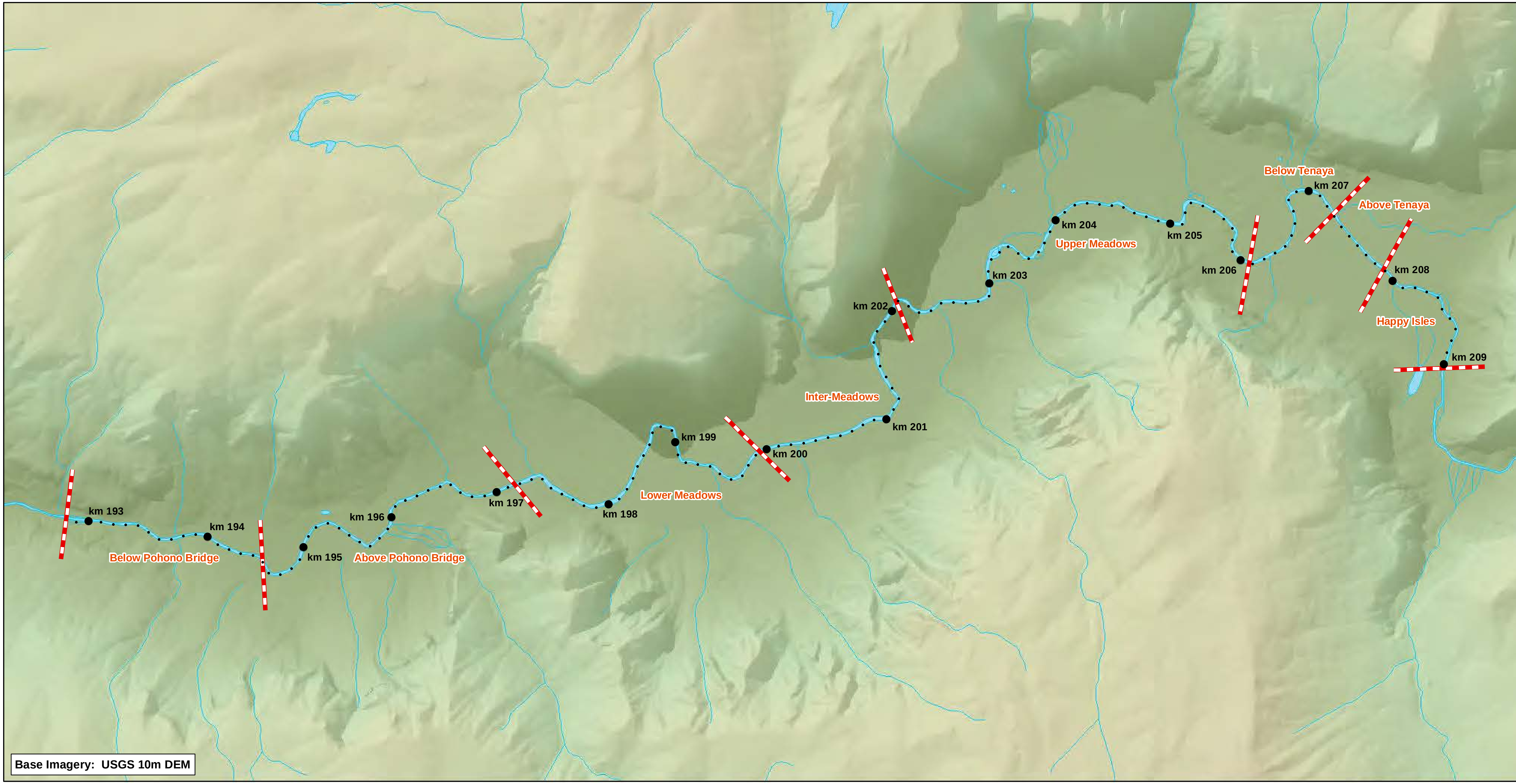
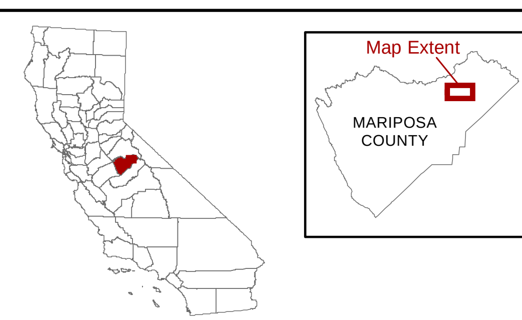


- River 1/10th Kilometer
- River Kilometer
- Geomorphic Reach Break
- Stream
- Waterbody



Merced River
Yosemite National Park

Geomorphic Reach Map

Geomorphic Reaches along the Merced River

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Coordinate System:
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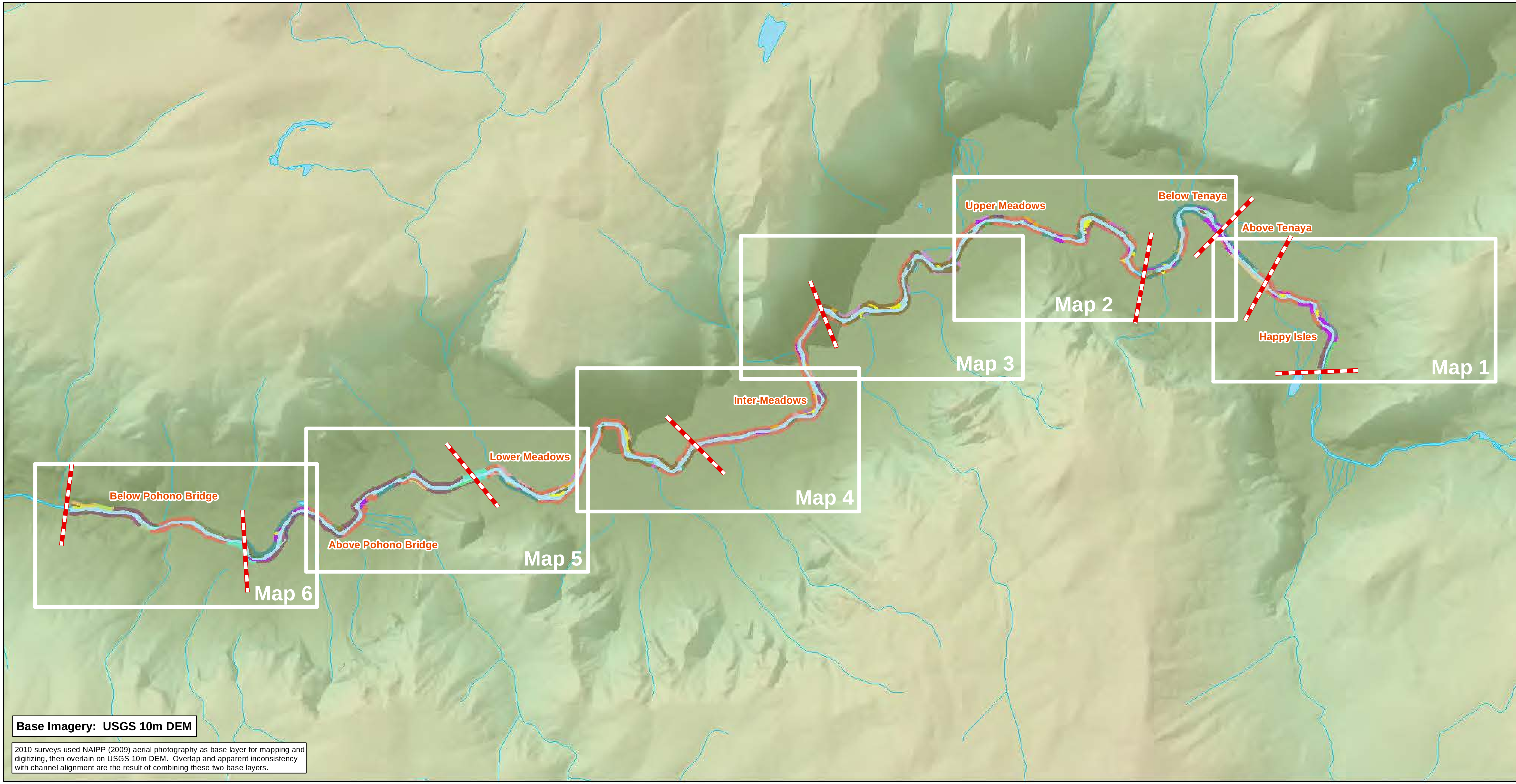
N W E S

0 250 500 1,000 Meters



VEGETATION (Refer to Table 2-1 for descriptions of each of the community types)

0 Bare
1 Canyon Live Oak Forest Alliance
2 Canyon Live Oak-Whiteleaf Manzanita Forest
3 Ponderosa Pine-Incense Cedar Forest Alliance
4 Incense Cedar Forest Alliance
5 Douglas Fir-White Fir-Incense Cedar Forest
6 Douglas Fir-Ponderosa Pin-Incense Cedar Forest
7 Dusky Willow Riparian Scrub
8 California Black Oak Forest Alliance
9 White Alder Forest
10 Black Cottonwood Temporarily Flooded Forest Alliance
11 Incense Cedar-White Alder Forest
12 Ponderosa Pine-Incense Cedar-California Black Oak Forest
13 Blue Wild Rye Herbaceous Alliance
14 Wooly Sedge Meadow
15 Water
16 Douglas Fir-Canyon Live Oak Forest
17 Shining Willow Riparian Scrub
18 Blue Wild Rye-Mugwort Herbaceous Alliance
19 Panicled Bulrush Herbaceous Alliance
20 California Black Oak-Ponderosa Pine Forest
21 Ponderosa Pine-Incense Cedar-Canyon Live Oak Forest
22 Dogbane Meadow
23 Creeping Bent Grassland
24 Blue Wild Rye-Creeping Bent Herbaceous Alliance
25 California Black Oak-Incense Cedar Forest
26 Ponderosa Pine-Douglas Fir-Canyon Live Oak Forest
27 Douglas Fir Forest Alliance

Geomorphic Reach Break
Stream
Waterbody

Merced River
Yosemite National Park

2010 Riparian Vegetation Map Series

Riparian Corridor Vegetation Communities along the Merced River (2010)

Index

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Coordinate System:
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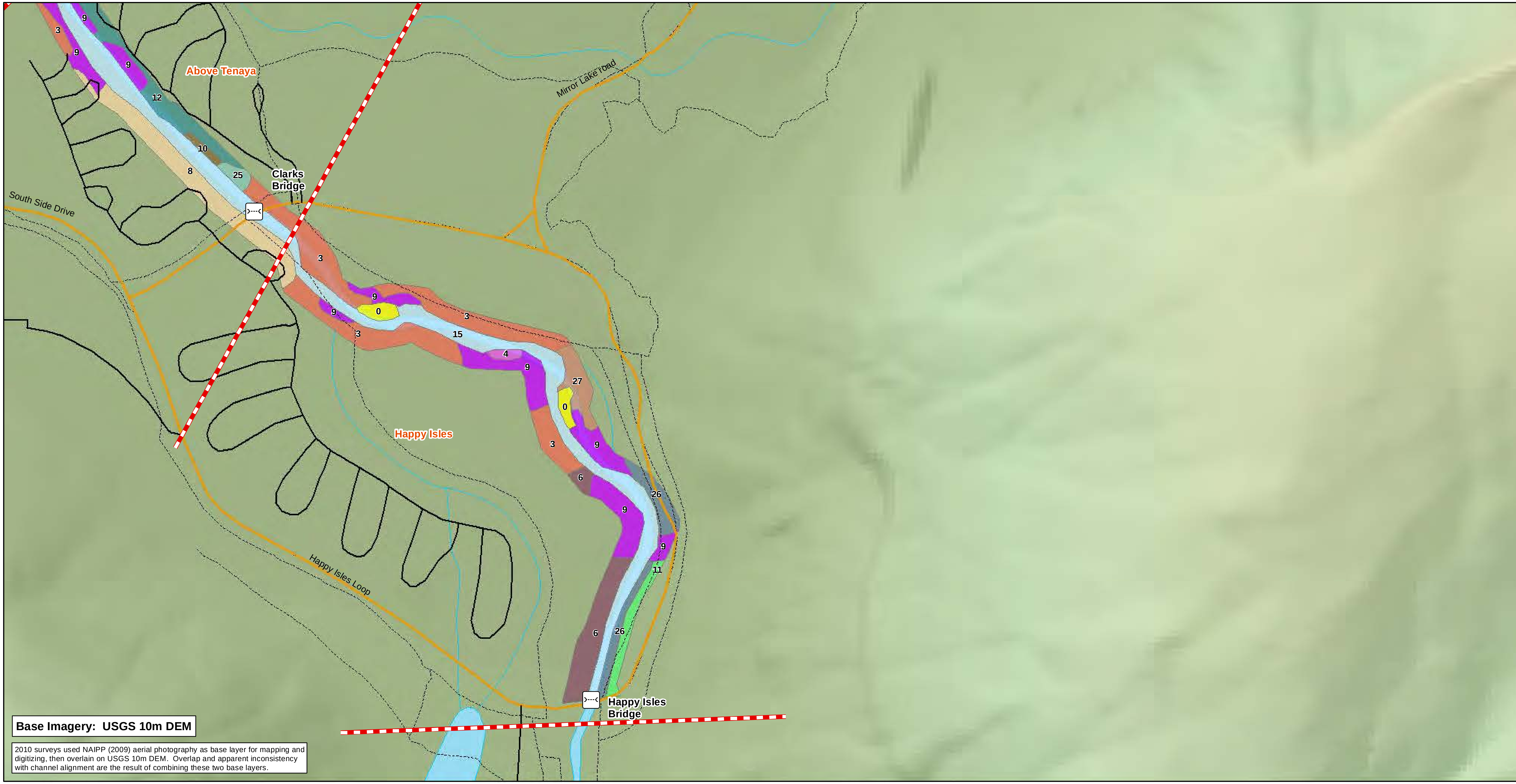
N E S W

0 375 750 1,500 Meters



VEGETATION (Refer to Table 2-1 for descriptions of each of the community types)

- 0 Bare
- 1 Canyon Live Oak Forest Alliance
- 2 Canyon Live Oak-Whiteleaf Manzanita Forest
- 3 Ponderosa Pine-Incense Cedar Forest Alliance
- 4 Incense Cedar Forest Alliance
- 5 Douglas Fir-White Fir-Incense Cedar Forest
- 6 Douglas Fir-Ponderosa Pin-Incense Cedar Forest
- 7 Dusky Willow Riparian Scrub
- 8 California Black Oak Forest Alliance
- 9 White Alder Forest
- 10 Black Cottonwood Temporarily Flooded Forest Alliance
- 11 Incense Cedar-White Alder Forest
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- 14 Wooly Sedge Meadow
- 15 Water
- 16 Douglas Fir-Canyon Live Oak Forest
- 17 Shining Willow Riparian Scrub
- 18 Blue Wild Rye-Mugwort Herbaceous Alliance
- 19 Panicled Bulrush Herbaceous Alliance
- 20 California Black Oak-Ponderosa Pine Forest
- 21 Ponderosa Pine-Incense Cedar-Canyon Live Oak Forest
- 22 Dogbane Meadow
- 23 Creeping Bent Grassland
- 24 Blue Wild Rye-Creeping Bent Herbaceous Alliance
- 25 California Black Oak-Incense Cedar Forest
- 26 Ponderosa Pine-Douglas Fir-Canyon Live Oak Forest
- 27 Douglas Fir Forest Alliance

- Bridge
- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

Merced River
Yosemite National Park

2010 Riparian Vegetation Map Series

Riparian Corridor Vegetation Communities along the Merced River (2010)

Map 1 of 6

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N W E S

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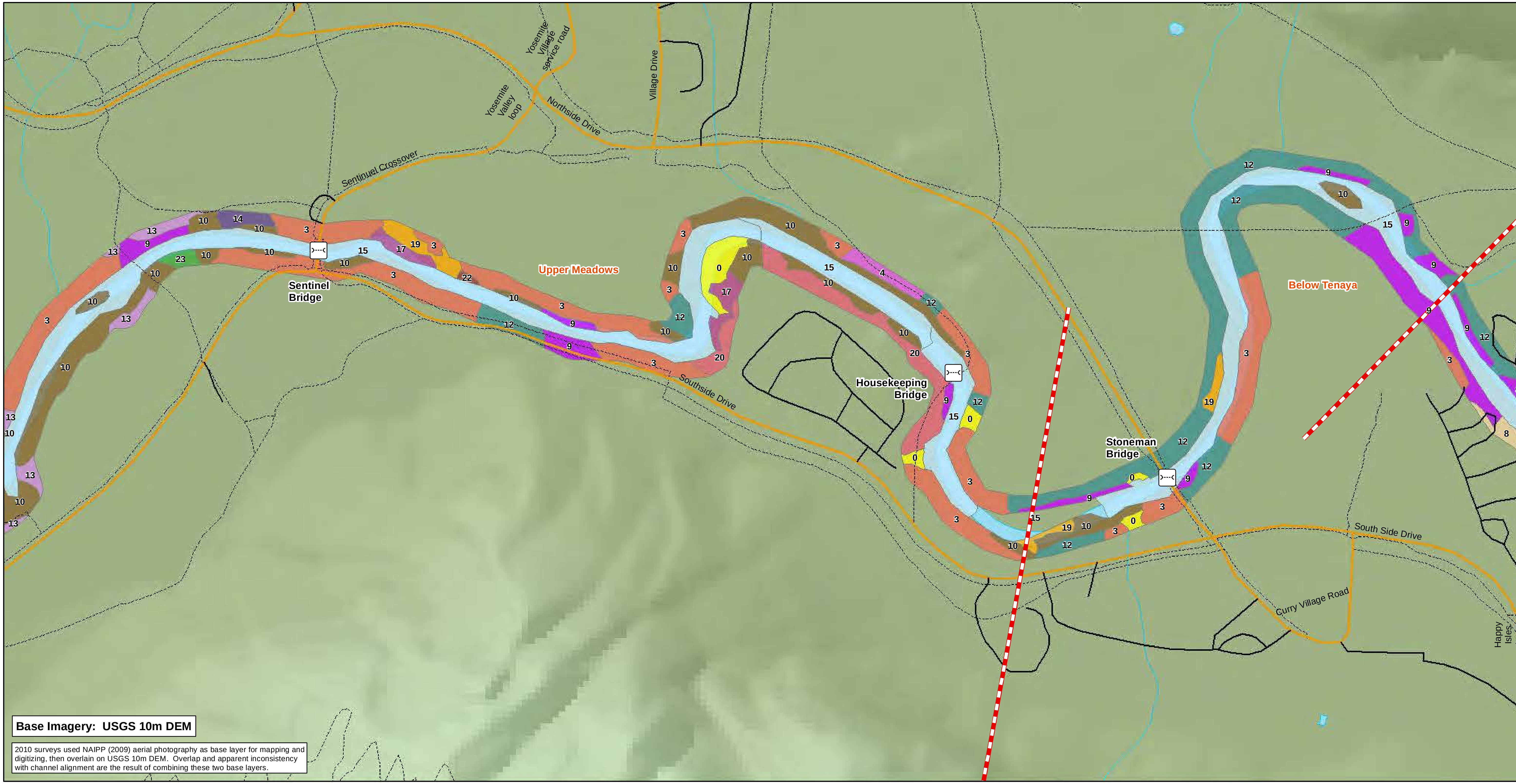

VEGETATION (Refer to Table 2-1 for descriptions of each of the community types)

- 0 Bare
- 1 Canyon Live Oak Forest Alliance
- 2 Canyon Live Oak-Whiteleaf Manzanita Forest
- 3 Ponderosa Pine-Incense Cedar Forest Alliance
- 4 Incense Cedar Forest Alliance
- 5 Douglas Fir-White Fir-Incense Cedar Forest
- 6 Douglas Fir-Ponderosa Pin-Incense Cedar Forest
- 7 Dusky Willow Riparian Scrub
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- 24 Blue Wild Rye-Creeping Bent Herbaceous Alliance
- 25 California Black Oak-Incense Cedar Forest
- 26 Ponderosa Pine-Douglas Fir-Canyon Live Oak Forest
- 27 Douglas Fir Forest Alliance

- Bridge
- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

Merced River
Yosemite National Park

2010 Riparian Vegetation Map Series

Riparian Corridor Vegetation Communities along the Merced River (2010)

Map 2 of 6

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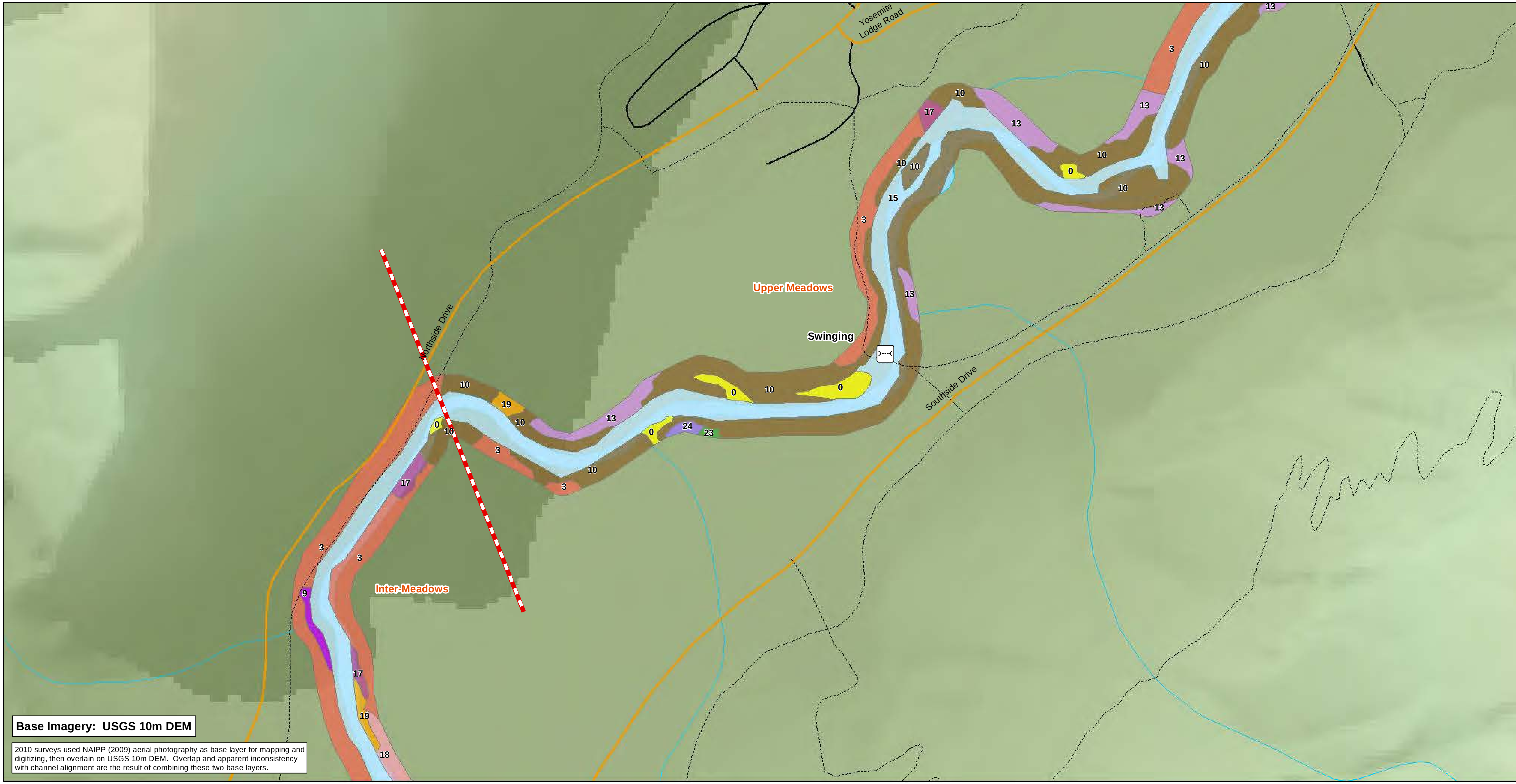

VEGETATION (Refer to Table 2-1 for descriptions of each of the community types)

- 0 Bare
- 1 Canyon Live Oak Forest Alliance
- 2 Canyon Live Oak-Whiteleaf Manzanita Forest
- 3 Ponderosa Pine-Incense Cedar Forest Alliance
- 4 Incense Cedar Forest Alliance
- 5 Douglas Fir-White Fir-Incense Cedar Forest
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Bridge
Geomorphic Reach Break
Primary Rd
Secondary/Local Rd
Trail
Stream
Waterbody

Merced River
Yosemite National Park

2010 Riparian Vegetation Map Series

Riparian Corridor Vegetation Communities along the Merced River (2010)

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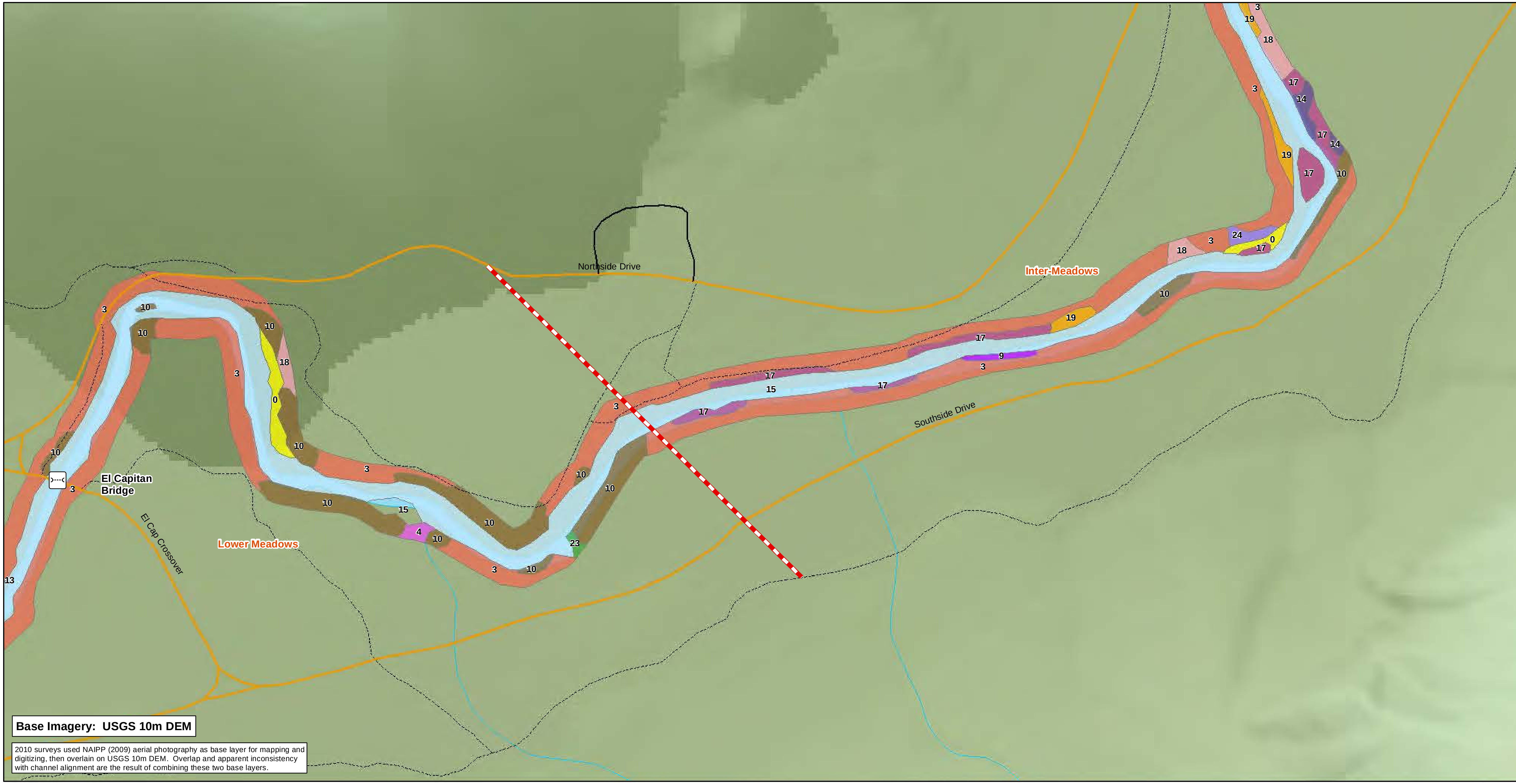

VEGETATION (Refer to Table 2-1 for descriptions of each of the community types)

- 0 Bare
- 1 Canyon Live Oak Forest Alliance
- 2 Canyon Live Oak-Whiteleaf Manzanita Forest
- 3 Ponderosa Pine-Incense Cedar Forest Alliance
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Bridge
Geomorphic Reach Break
Primary Rd
Secondary/Local Rd
Trail
Stream
Waterbody

Merced River
Yosemite National Park

2010 Riparian Vegetation Map Series

Riparian Corridor Vegetation Communities along the Merced River (2010)

Map 4 of 6

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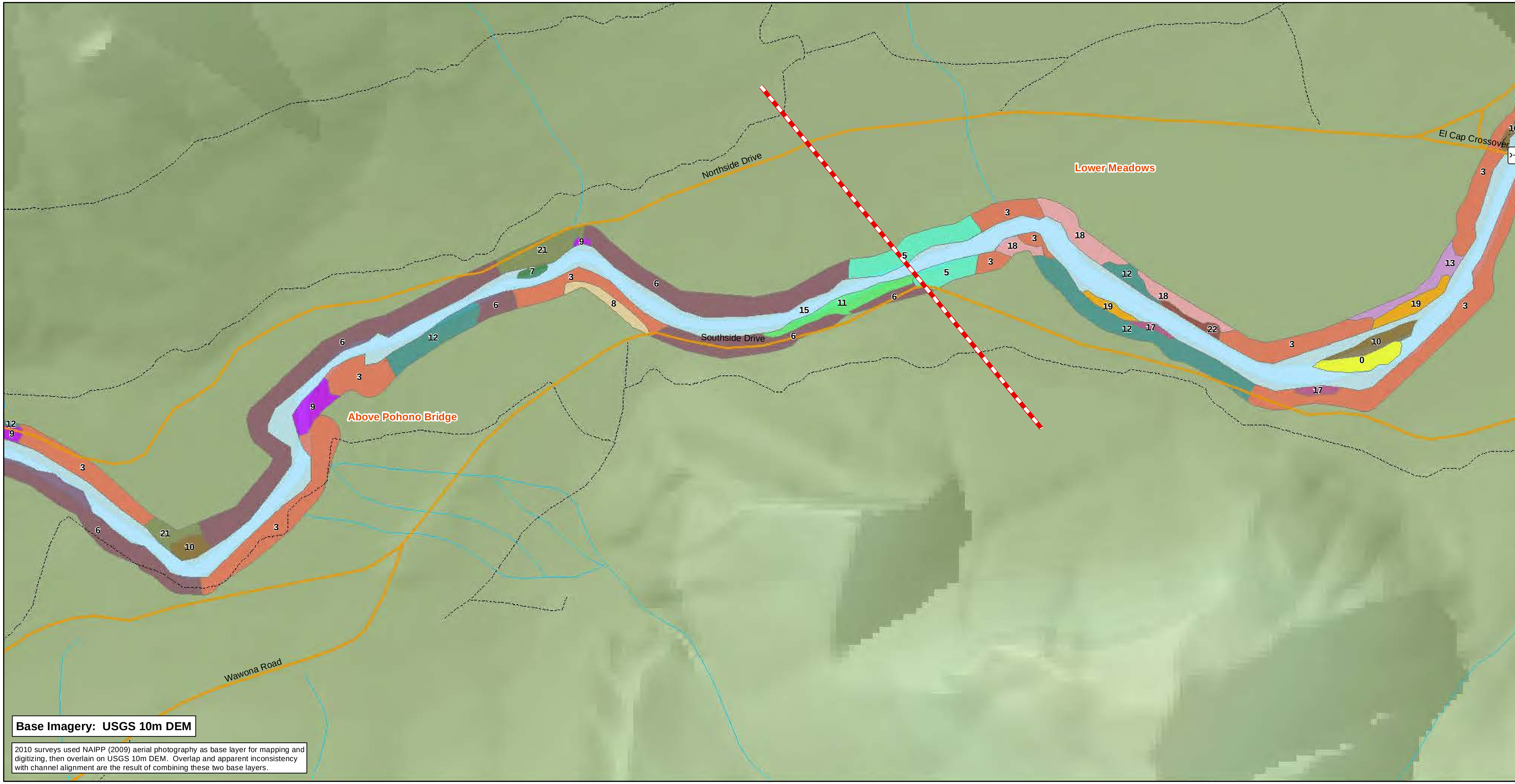
www.cardnoentrix.com

Coordinate System:
NAD 1983 UTM Zone 11 meters

N W E S
0 75 150 300 Meters



VEGETATION (Refer to Table 2-1 for descriptions of each of the community types)

- 0 Bare
- 1 Canyon Live Oak Forest Alliance
- 2 Canyon Live Oak-Whiteleaf Manzanita Forest
- 3 Ponderosa Pine-Incense Cedar Forest Alliance
- 4 Incense Cedar Forest Alliance
- 5 Douglas Fir-White Fir-Incense Cedar Forest
- 6 Douglas Fir-Ponderosa Pin-Incense Cedar Forest
- 7 Dusky Willow Riparian Scrub
- 8 California Black Oak Forest Alliance
- 9 White Alder Forest
- 10 Black Cottonwood Temporarily Flooded Forest Alliance
- 11 Incense Cedar-White Alder Forest
- 12 Ponderosa Pine-Incense Cedar-California Black Oak Forest
- 13 Blue Wild Rye Herbaceous Alliance
- 14 Wooly Sedge Meadow
- 15 Water
- 16 Douglas Fir-Canyon Live Oak Forest
- 17 Shining Willow Riparian Scrub
- 18 Blue Wild Rye-Mugwort Herbaceous Alliance
- 19 Panicled Bulrush Herbaceous Alliance
- 20 California Black Oak-Ponderosa Pine Forest
- 21 Ponderosa Pine-Incense Cedar-Canyon Live Oak Forest
- 22 Dogbane Meadow
- 23 Creeping Bent Grassland
- 24 Blue Wild Rye-Creeping Bent Herbaceous Alliance
- 25 California Black Oak-Incense Cedar Forest
- 26 Ponderosa Pine-Douglas Fir-Canyon Live Oak Forest
- 27 Douglas Fir Forest Alliance

- Bridge
- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

Merced River
Yosemite National Park

2010 Riparian Vegetation Map Series

Riparian Corridor Vegetation Communities along the Merced River (2010)

Map 5 of 6

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Coordinate System:
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N W E S

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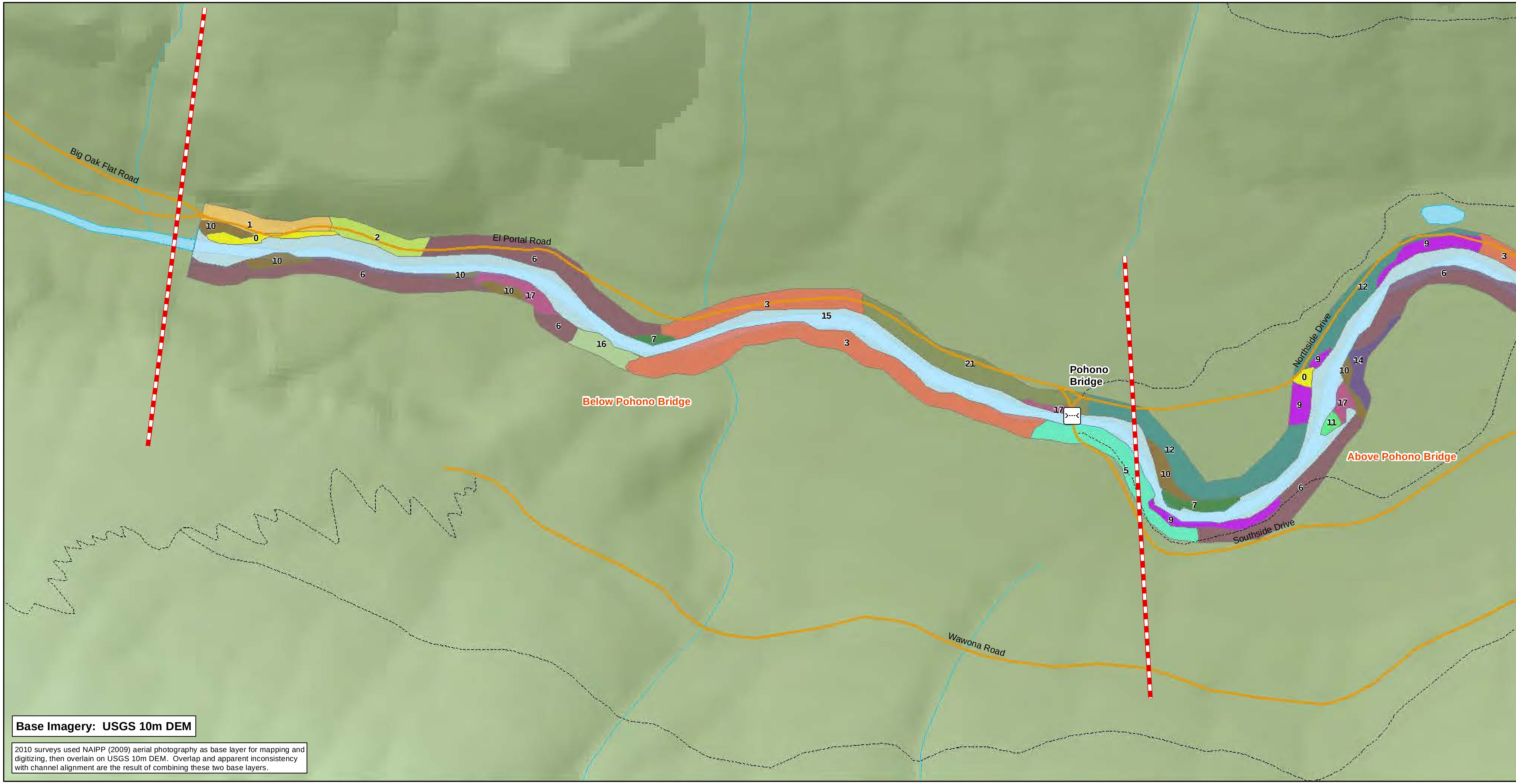

VEGETATION (Refer to Table 2-1 for descriptions of each of the community types)

0 Bare
1 Canyon Live Oak Forest Alliance
2 Canyon Live Oak-Whiteleaf Manzanita Forest
3 Ponderosa Pine-Incense Cedar Forest Alliance
4 Incense Cedar Forest Alliance
5 Douglas Fir-White Fir-Incense Cedar Forest
6 Douglas Fir-Ponderosa Pin-Incense Cedar Forest
7 Dusky Willow Riparian Scrub
8 California Black Oak Forest Alliance
9 White Alder Forest
10 Black Cottonwood Temporarily Flooded Forest Alliance
11 Incense Cedar-White Alder Forest
12 Ponderosa Pine-Incense Cedar-California Black Oak Forest
13 Blue Wild Rye Herbaceous Alliance
14 Wooly Sedge Meadow
15 Water
16 Douglas Fir-Canyon Live Oak Forest
17 Shining Willow Riparian Scrub
18 Blue Wild Rye-Mugwort Herbaceous Alliance
19 Panicled Bulrush Herbaceous Alliance
20 California Black Oak-Ponderosa Pine Forest
21 Ponderosa Pine-Incense Cedar-Canyon Live Oak Forest
22 Dogbane Meadow
23 Creeping Bent Grassland
24 Blue Wild Rye-Creeping Bent Herbaceous Alliance
25 California Black Oak-Incense Cedar Forest
26 Ponderosa Pine-Douglas Fir-Canyon Live Oak Forest
27 Douglas Fir Forest Alliance

Bridge
Geomorphic Reach Break
Primary Rd
Secondary/Local Rd
Trail
Stream
Waterbody

Merced River
Yosemite National Park

2010 Riparian Vegetation Map Series

Riparian Corridor Vegetation Communities along the Merced River (2010)

Map 6 of 6

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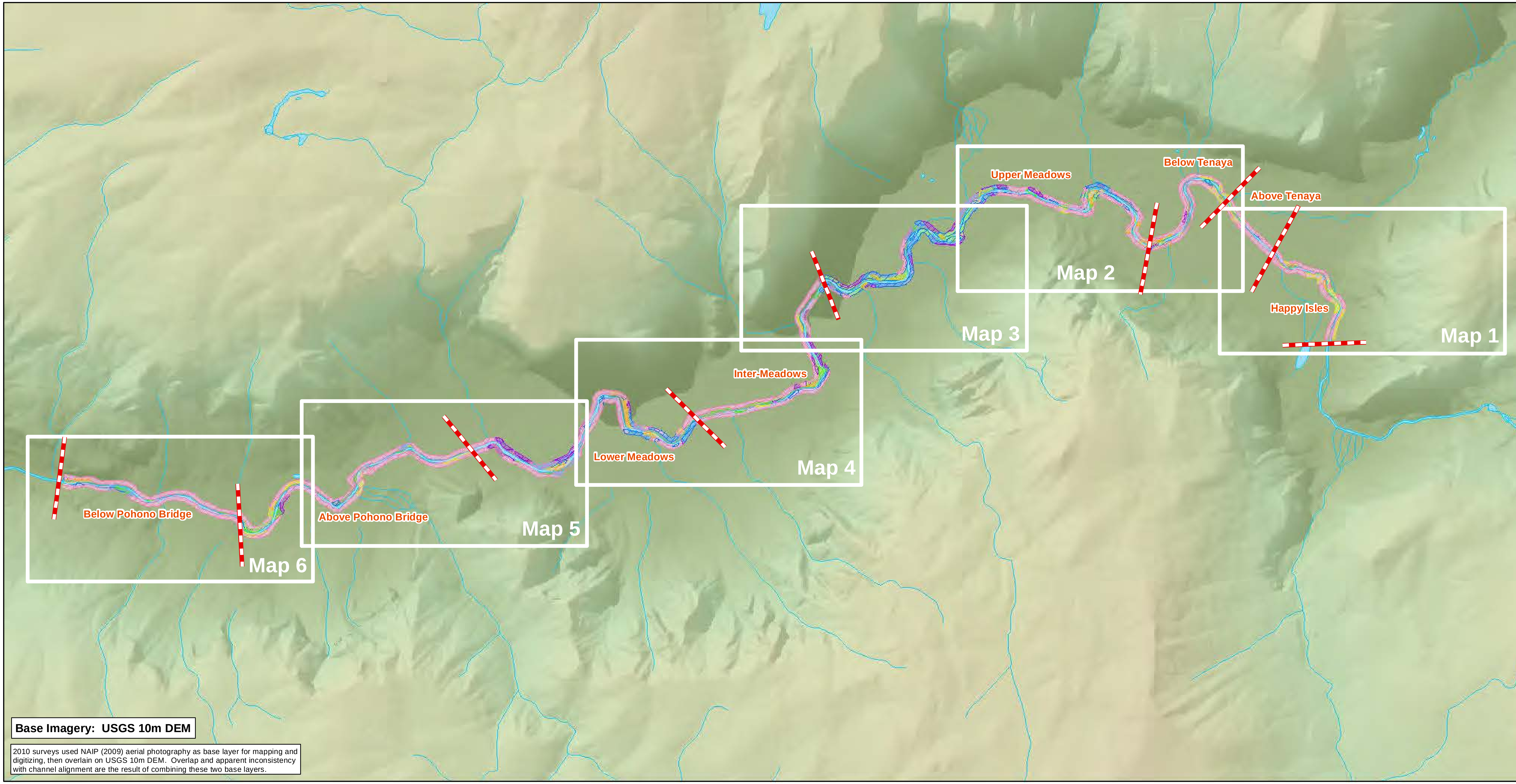

Vegetation Categories

2010	1997
1	1, Bare (including Oxbow and Cutoff Channels)
2	2, Oaks and Conifers
3	3, Meadow
4	4, Cottonwood (including mixed)
5	5, Alder (including with Bigleaf Maple and Conifers)
6	6, Willow Riparian

Geomorphic Reach Break
Stream
Waterbody

Note: 1997 GIS vegetation community mapping data provided by NPS.

Merced River
Yosemite National Park

1997 and 2010 Riparian Vegetation Map Series

Comparison of Riparian Corridor Vegetation Communities along the Merced River 1997 and 2010

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Coordinate System:
NAD 1983 UTM Zone 11 meters

N W E S

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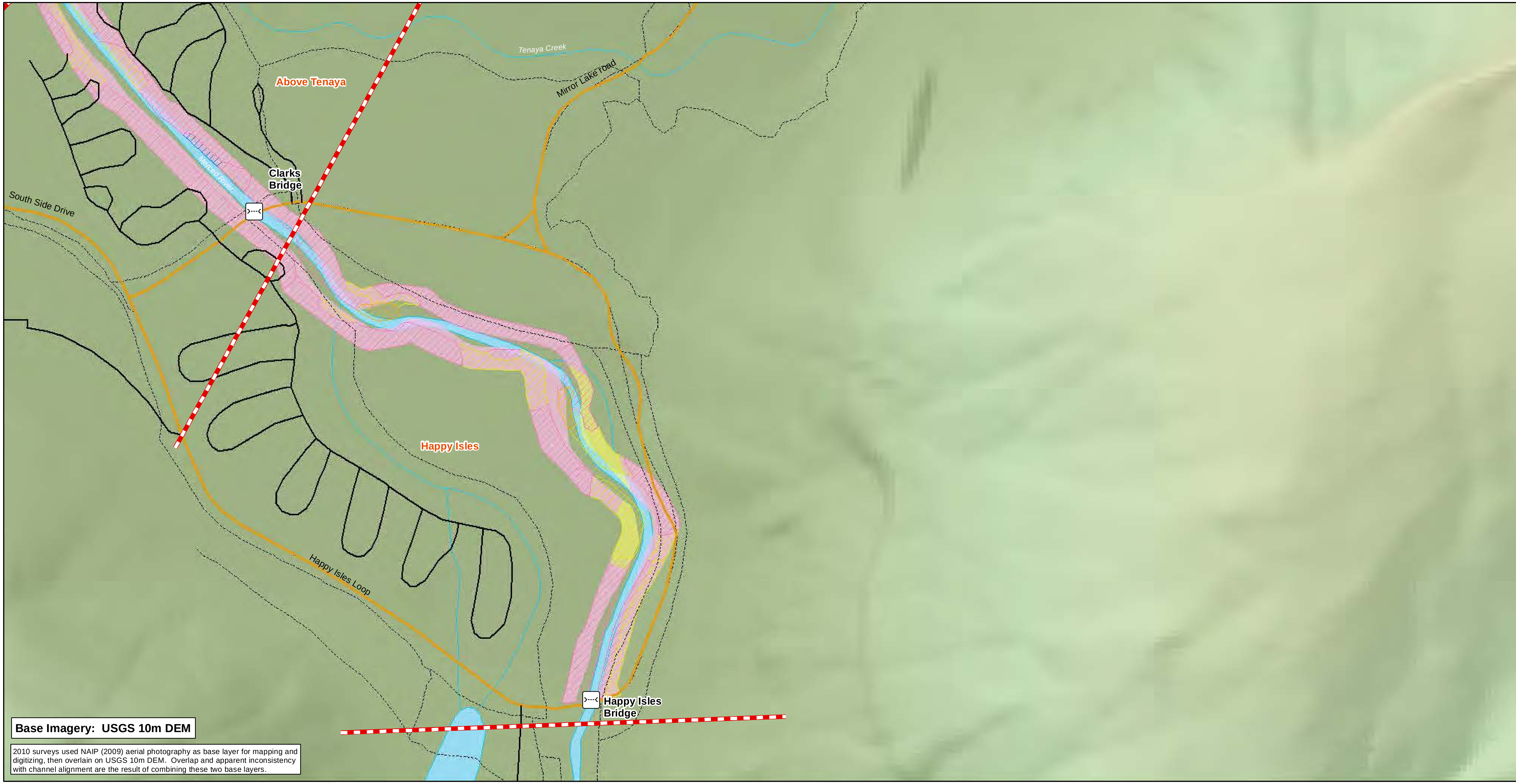

Vegetation Categories

2010	1997
1	1, Bare (including Oxbow and Cutoff Channels)
2	2, Oaks and Conifers
3	3, Meadow
4	4, Cottonwood (including mixed)
5	5, Alder (including with Bigleaf Maple and Conifers)
6	6, Willow Riparian

- Bridge
- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

Note: 1997 GIS vegetation community mapping data provided by NPS.

Merced River
Yosemite National Park

1997 and 2010 Riparian Vegetation Map Series

Comparison of Riparian Corridor Vegetation Communities along the Merced River 1997 and 2010

Map 1 of 6

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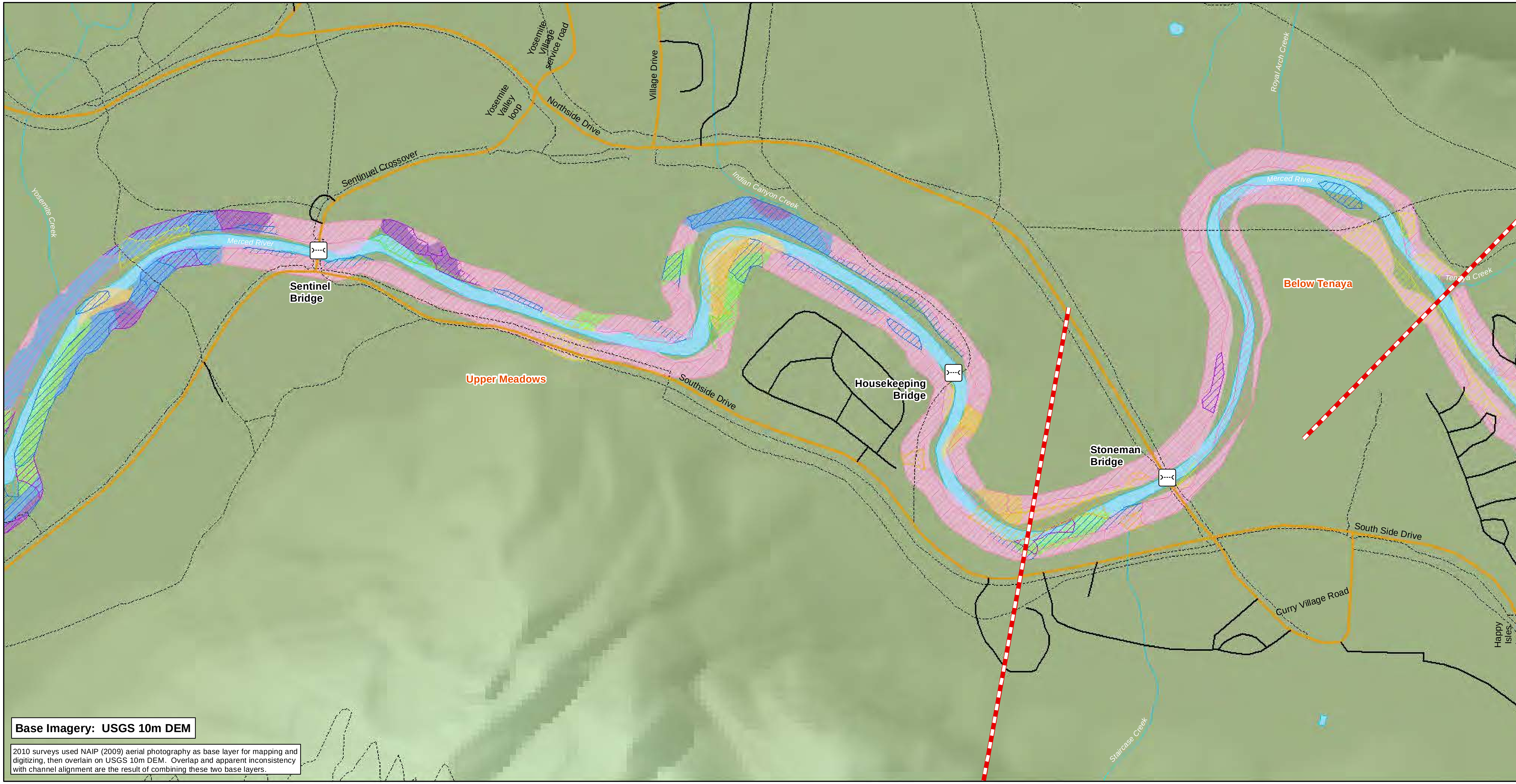

Vegetation Categories

2010	1997	
1		1, Bare (including Oxbow and Cutoff Channels)
2		2, Oaks and Conifers
3		3, Meadow
4		4, Cottonwood (including mixed)
5		5, Alder (including with Bigleaf Maple and Conifers)
6		6, Willow Riparian

- Bridge
- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

Note: 1997 GIS vegetation community mapping data provided by NPS.

Merced River
Yosemite National Park

1997 and 2010 Riparian Vegetation Map Series

Comparison of Riparian Corridor Vegetation Communities along the Merced River 1997 and 2010

Map 2 of 6

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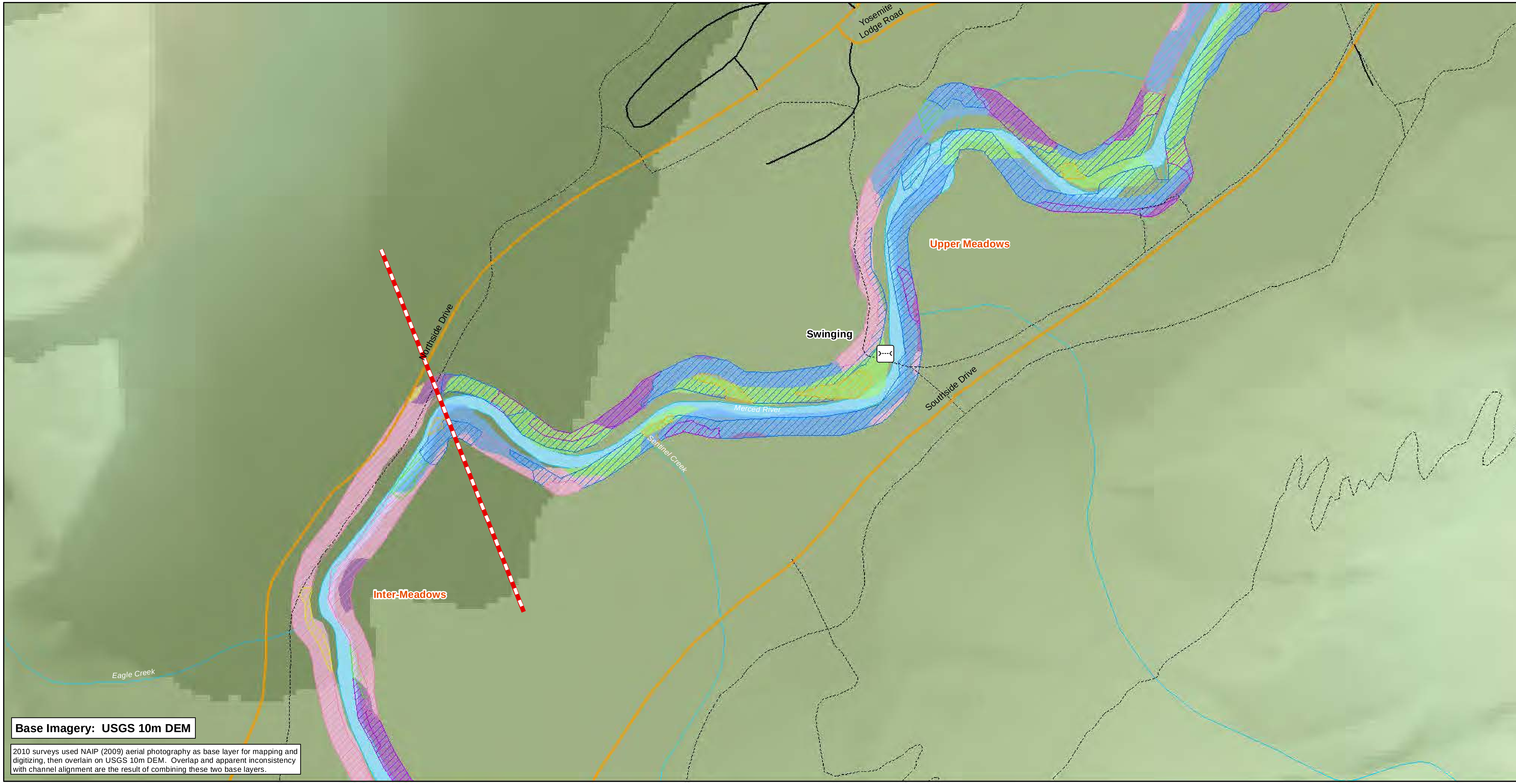

Vegetation Categories

2010	1997	
1		1, Bare (including Oxbow and Cutoff Channels)
2		2, Oaks and Conifers
3		3, Meadow
4		4, Cottonwood (including mixed)
5		5, Alder (including with Bigleaf Maple and Conifers)
6		6, Willow Riparian

Bridge
Geomorphic Reach Break
Primary Rd
Secondary/Local Rd
Trail
Stream
Waterbody

Note: 1997 GIS vegetation community mapping data provided by NPS.

Merced River
Yosemite National Park

1997 and 2010 Riparian Vegetation Map Series

Comparison of Riparian Corridor Vegetation Communities along the Merced River 1997 and 2010

Map 3 of 6

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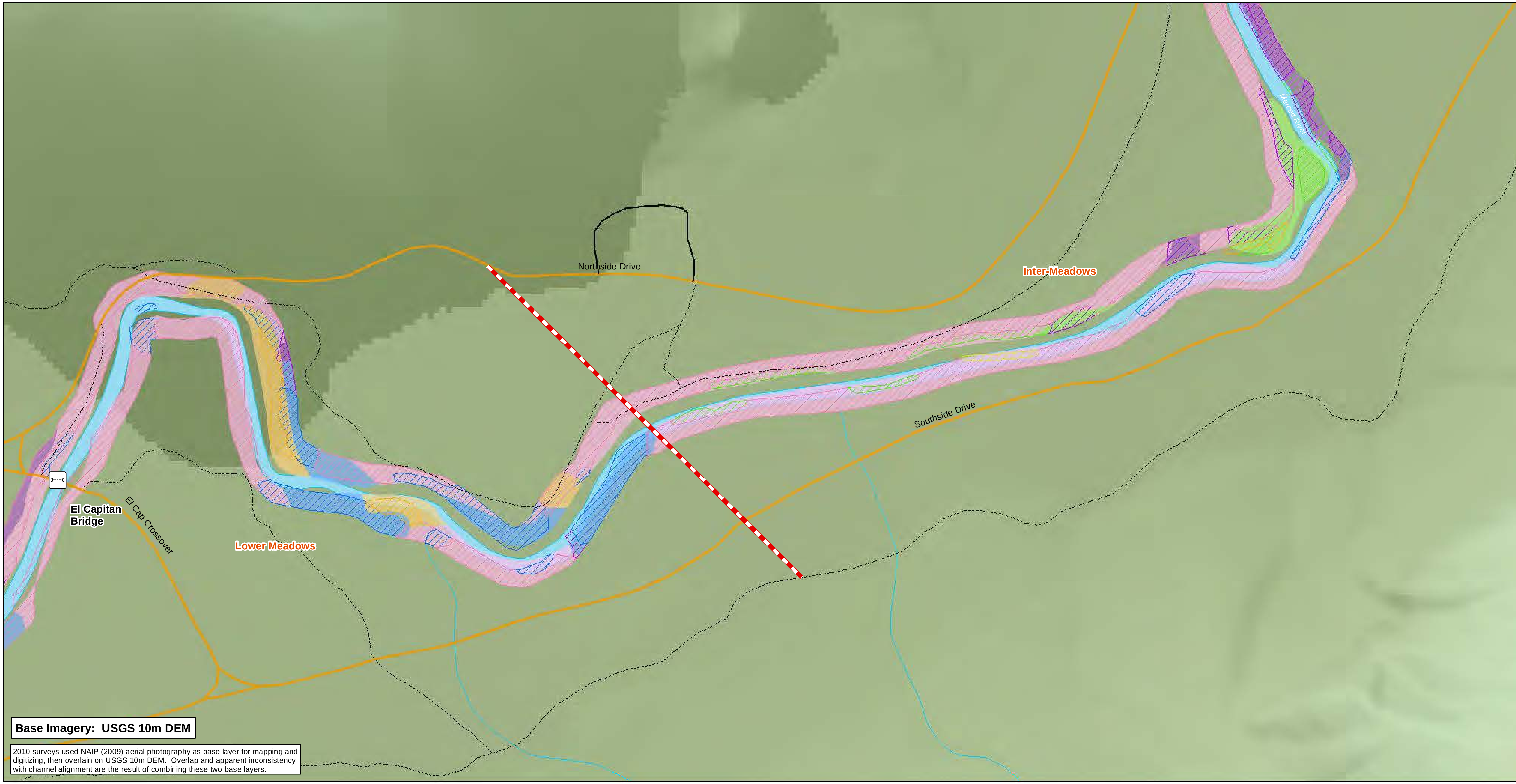

Vegetation Categories

2010	1997
1	1, Bare (including Oxbow and Cutoff Channels)
2	2, Oaks and Conifers
3	3, Meadow
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- Bridge
- Geomorphic Reach Break
- Primary Rd
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- Waterbody

Note: 1997 GIS vegetation community mapping data provided by NPS.

Merced River
Yosemite National Park

1997 and 2010 Riparian Vegetation Map Series

Comparison of Riparian Corridor Vegetation Communities along the Merced River 1997 and 2010

Map 4 of 6

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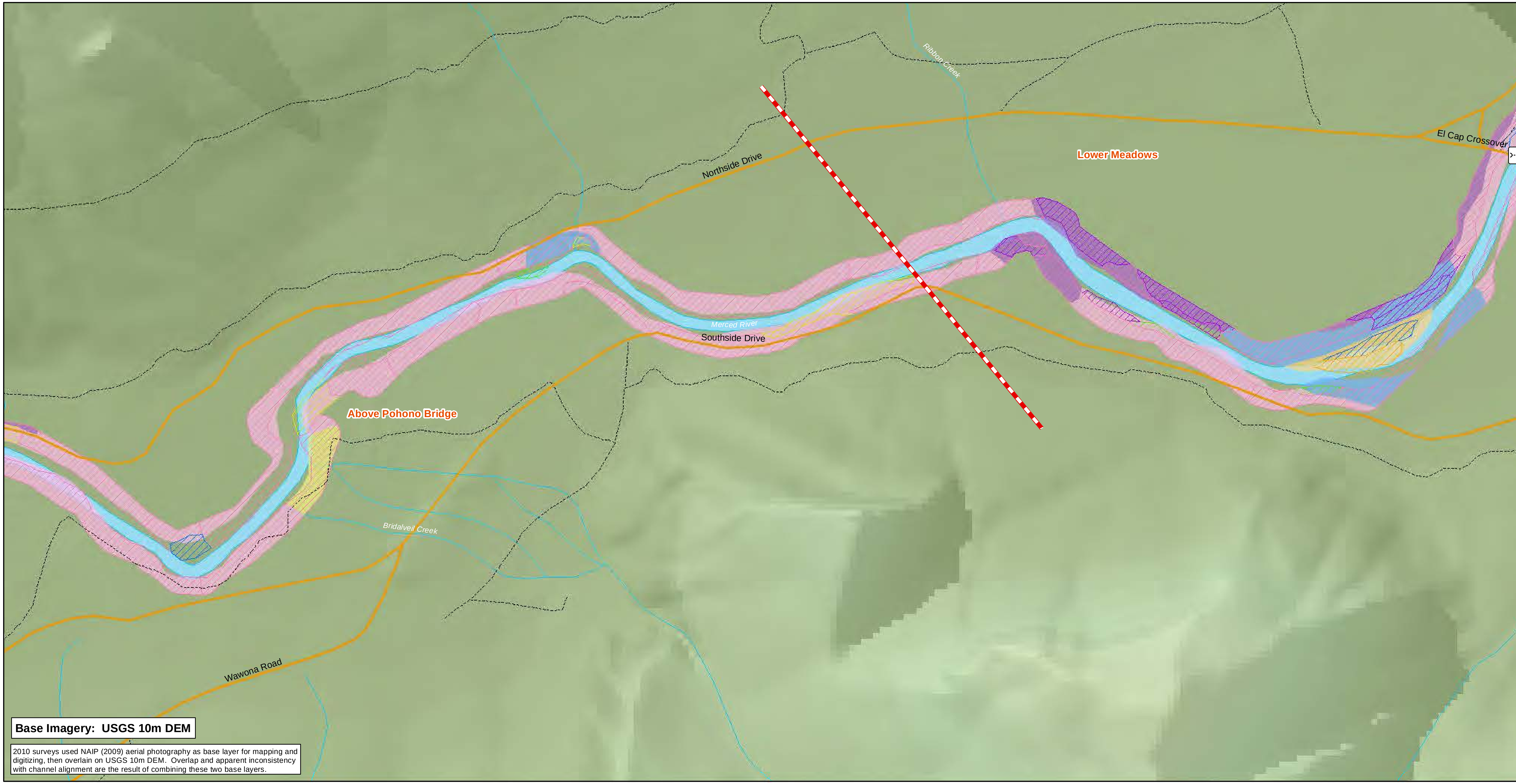

Vegetation Categories

2010	1997
1	1, Bare (including Oxbow and Cutoff Channels)
2	2, Oaks and Conifers
3	3, Meadow
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6	6, Willow Riparian

Bridge
Geomorphic Reach Break
Primary Rd
Secondary/Local Rd
Trail
Stream
Waterbody

Note: 1997 GIS vegetation community mapping data provided by NPS.

Merced River
Yosemite National Park

1997 and 2010 Riparian Vegetation Map Series

Comparison of Riparian Corridor Vegetation Communities along the Merced River 1997 and 2010

Map 5 of 6

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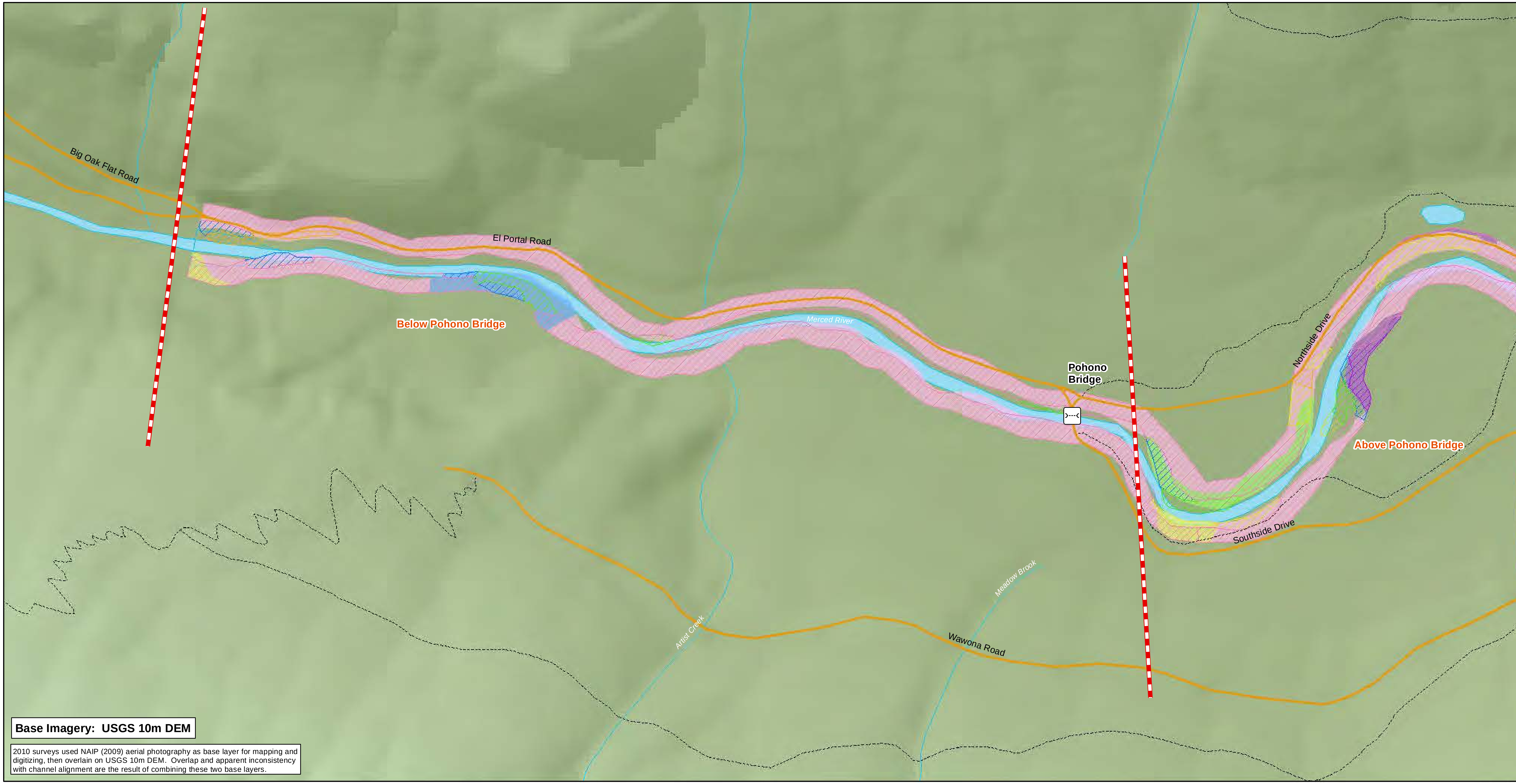

Vegetation Categories

2010	1997
1	1, Bare (including Oxbow and Cutoff Channels)
2	2, Oaks and Conifers
3	3, Meadow
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- Bridge
- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

Note: 1997 GIS vegetation community mapping data provided by NPS.

Merced River
Yosemite National Park

1997 and 2010 Riparian Vegetation Map Series

Comparison of Riparian Corridor Vegetation Communities along the Merced River 1997 and 2010

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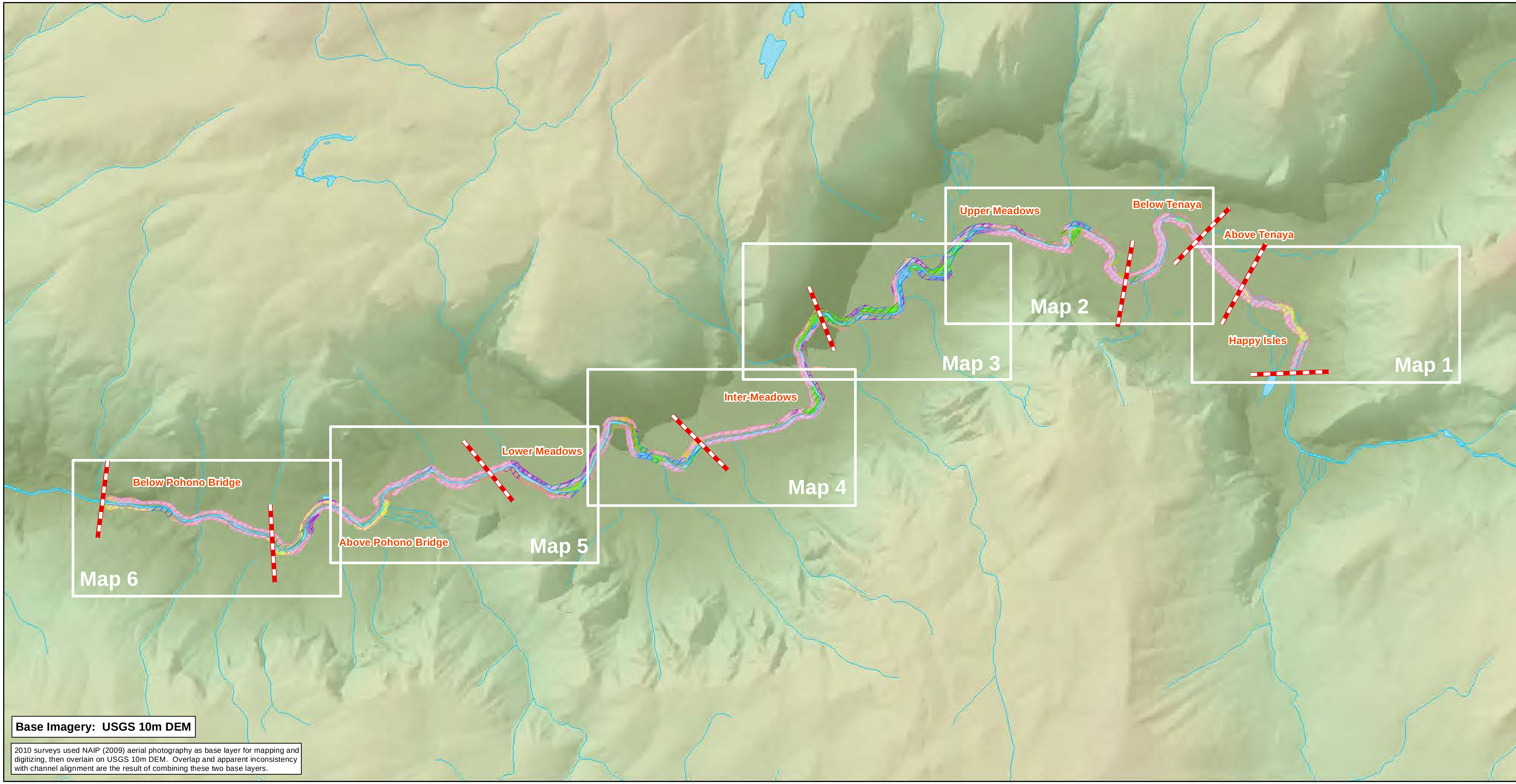

Vegetation Categories

1997	1992
1	1, Bare & 1, Oxbow and Cutoff Channels
2	2, Oaks and Conifers
3	3, Meadow
4	4, Cottonwood (including mixed)
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Geomorphic Reach Break

Stream

Waterbody

Note: 1992 and 1997 GIS vegetation community mapping data provided by NPS

Merced River
Yosemite National Park

1992 and 1997 Riparian Vegetation Map Series

Comparison of Riparian Corridor Vegetation Communities along the Merced River 1992 and 1997

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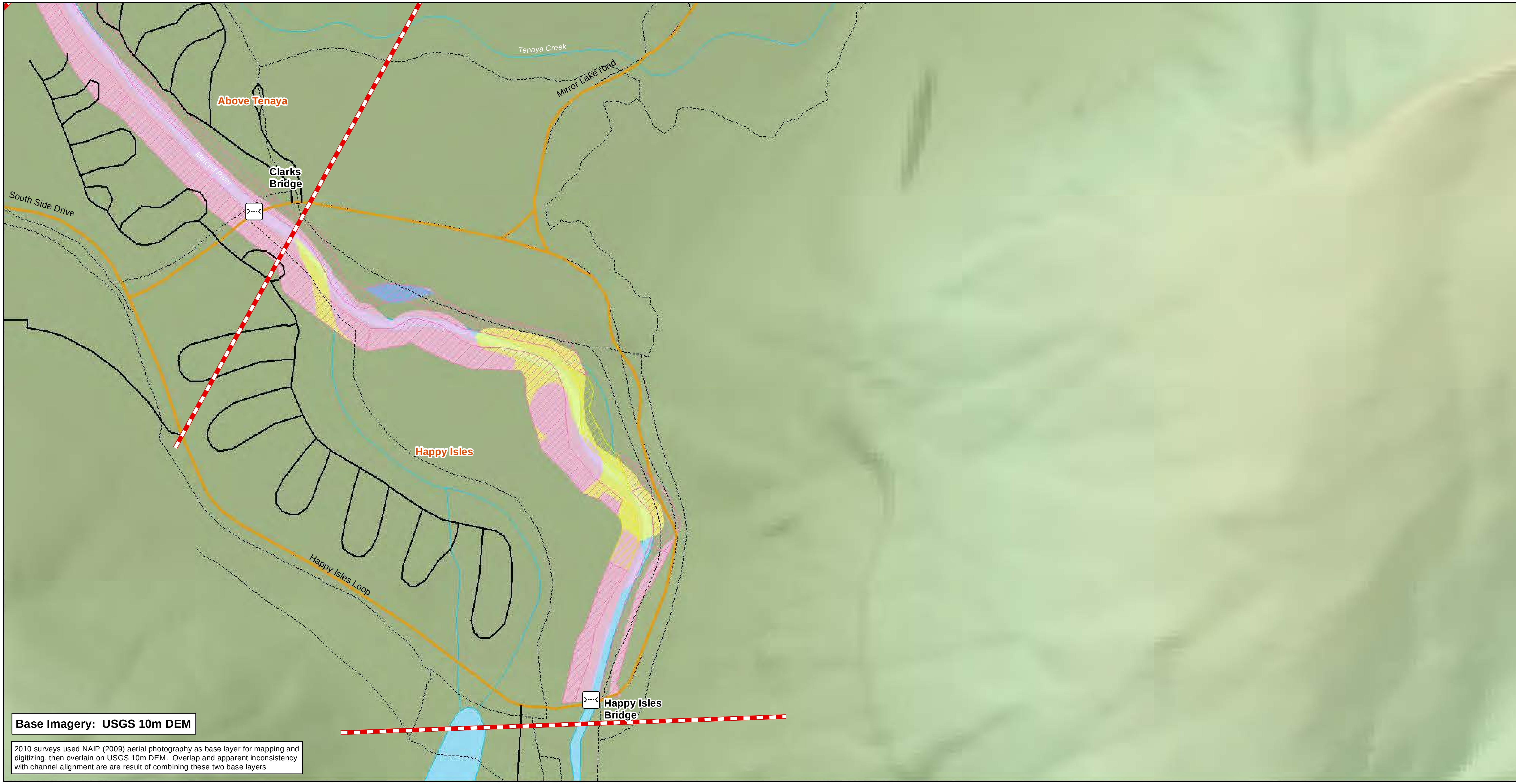

Vegetation Categories

1997	1992	
1	1, Bare &	1, Oxbow and Cutoff Channels
2	2, Oaks and Conifers	
3	3, Meadow	
4	4, Cottonwood (including mixed)	
5	5, Alder (including with Bigleaf Maple and Conifers)	
6	6, Willow Riparian	

Bridge

Geomorphic Reach Break

Primary Rd

Secondary/Local Rd

Trail

Stream

Waterbody

Note: 1992 and 1997 GIS vegetation community mapping data provided by NPS

Merced River
Yosemite National Park

1992 and 1997 Riparian Vegetation Map Series

Comparison of Riparian Corridor Vegetation Communities along the Merced River 1992 and 1997

Map 1 of 6

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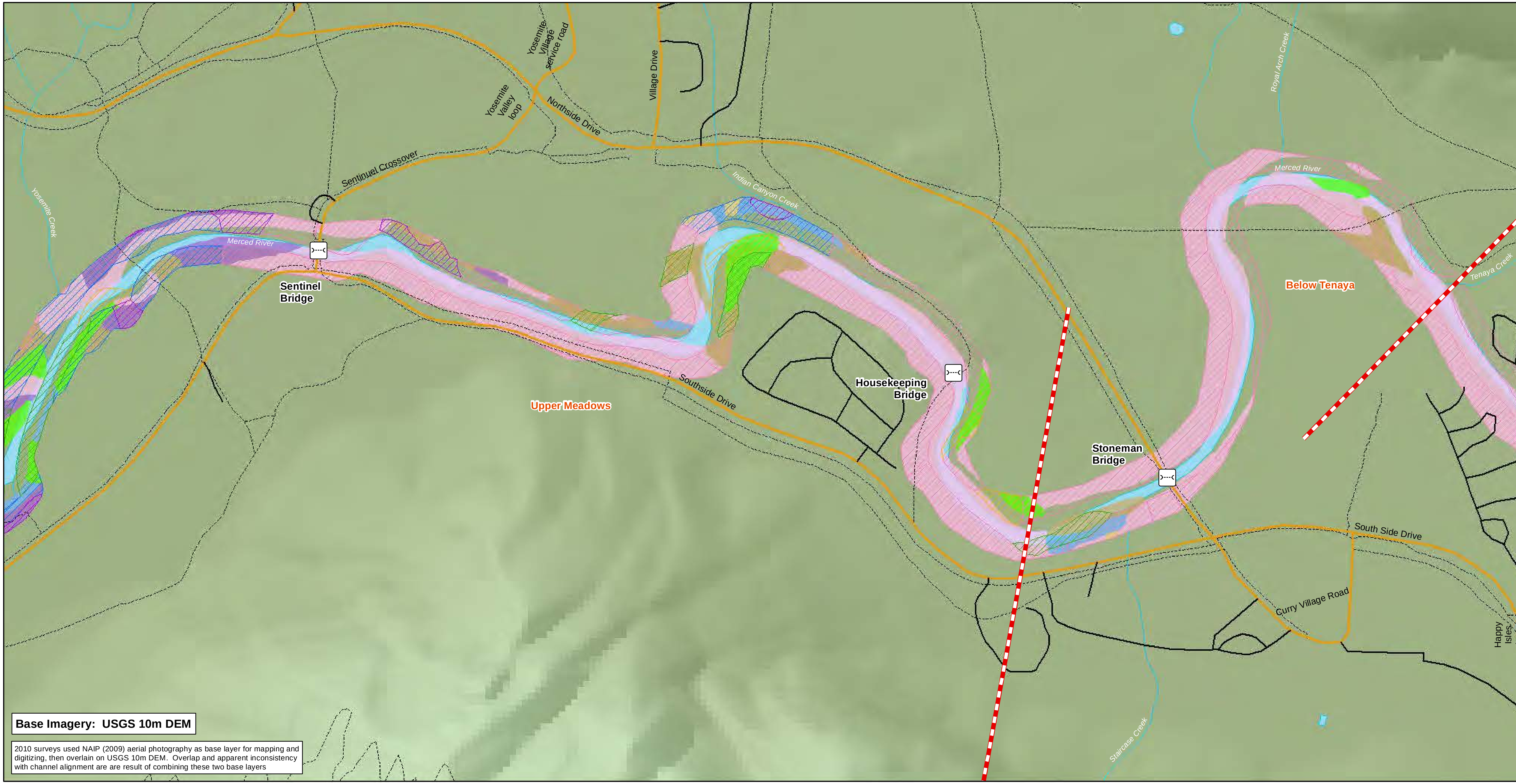

Vegetation Categories

1997	1992	
1	1, Bare &	1, Oxbow and Cutoff Channels
2	2, Oaks and Conifers	
3	3, Meadow	
4	4, Cottonwood (including mixed)	
5	5, Alder (including with Bigleaf Maple and Conifers)	
6	6, Willow Riparian	

- Bridge
- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

Note: 1992 and 1997 GIS vegetation community mapping data provided by NPS

Merced River
Yosemite National Park

1992 and 1997 Riparian Vegetation Map Series

Comparison of Riparian Corridor Vegetation Communities along the Merced River 1992 and 1997

Map 2 of 6

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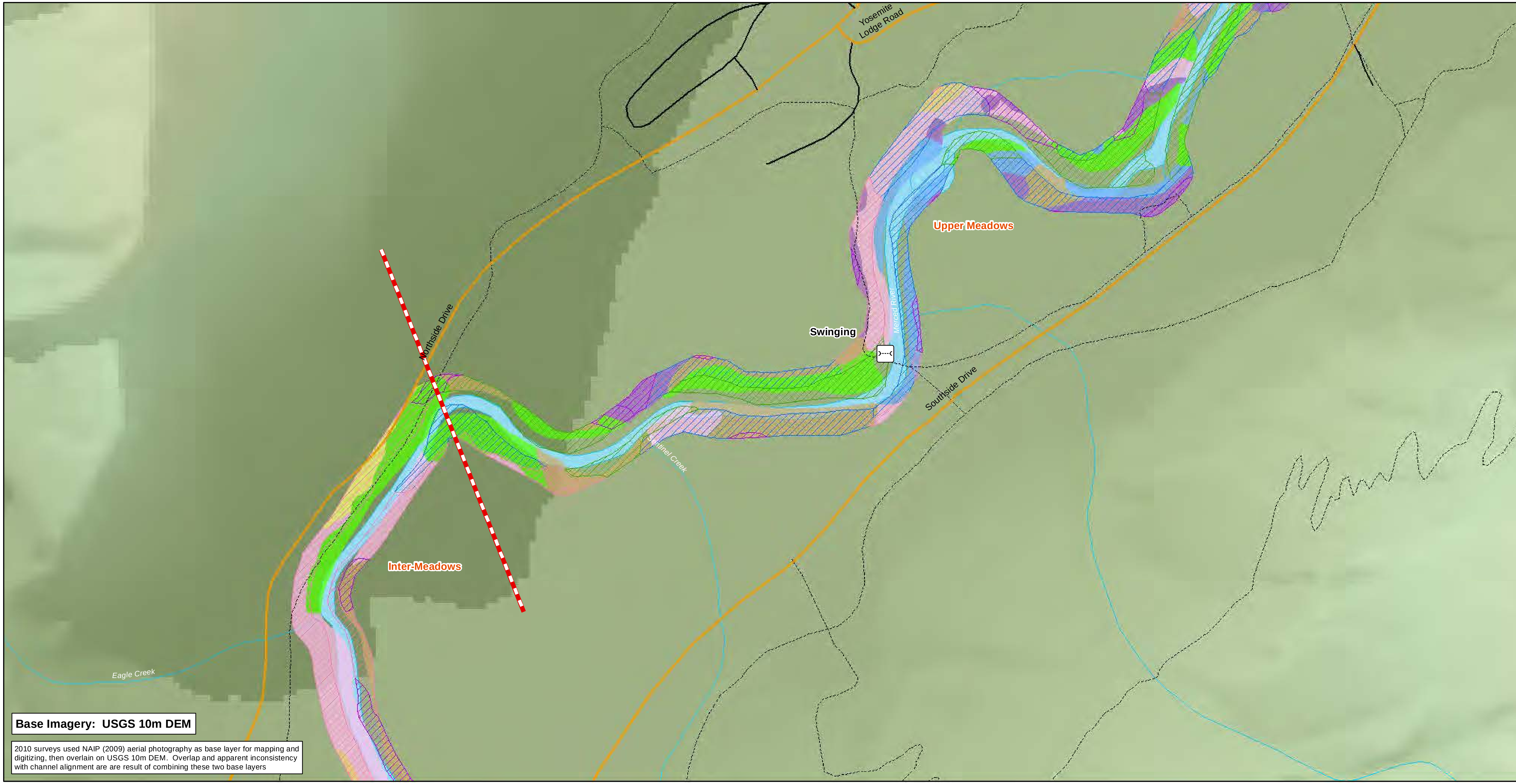

Vegetation Categories

1997	1992	
1	1, Bare &	1, Oxbow and Cutoff Channels
2	2, Oaks and Conifers	
3	3, Meadow	
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6	6, Willow Riparian	

- Bridge
- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

Note: 1992 and 1997 GIS vegetation community mapping data provided by NPS

Merced River
Yosemite National Park

1992 and 1997 Riparian Vegetation Map Series

Comparison of Riparian Corridor Vegetation Communities along the Merced River 1992 and 1997

Map 3 of 6

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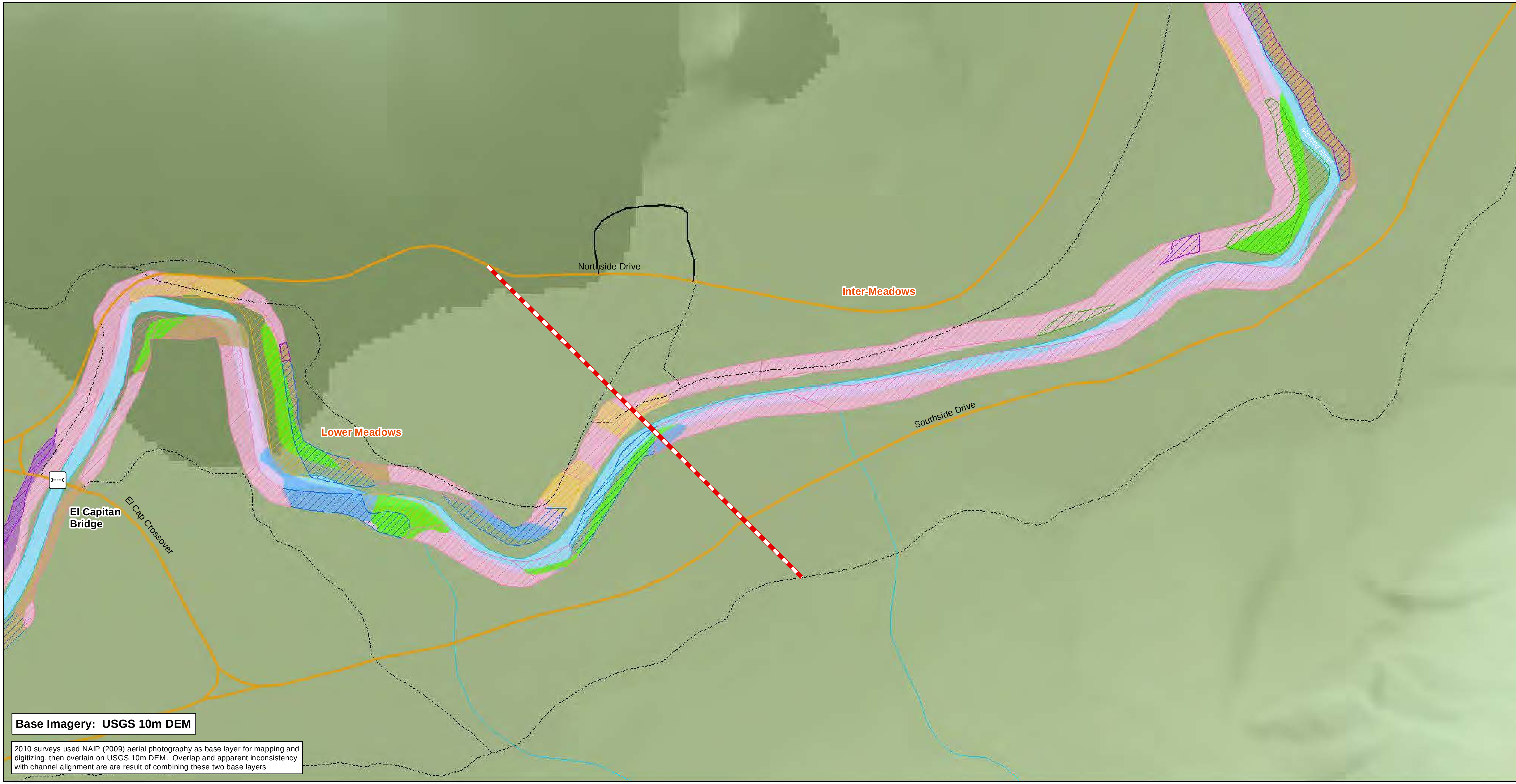

Vegetation Categories

1997	1992
1	1, Bare & 1, Oxbow and Cutoff Channels
2	2, Oaks and Conifers
3	3, Meadow
4	4, Cottonwood (including mixed)
5	5, Alder (including with Bigleaf Maple and Conifers)
6	6, Willow Riparian

- Bridge
- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

Note: 1992 and 1997 GIS vegetation community mapping data provided by NPS

Merced River
Yosemite National Park

1992 and 1997 Riparian Vegetation Map Series

Comparison of Riparian Corridor Vegetation Communities along the Merced River 1992 and 1997

Map 4 of 6

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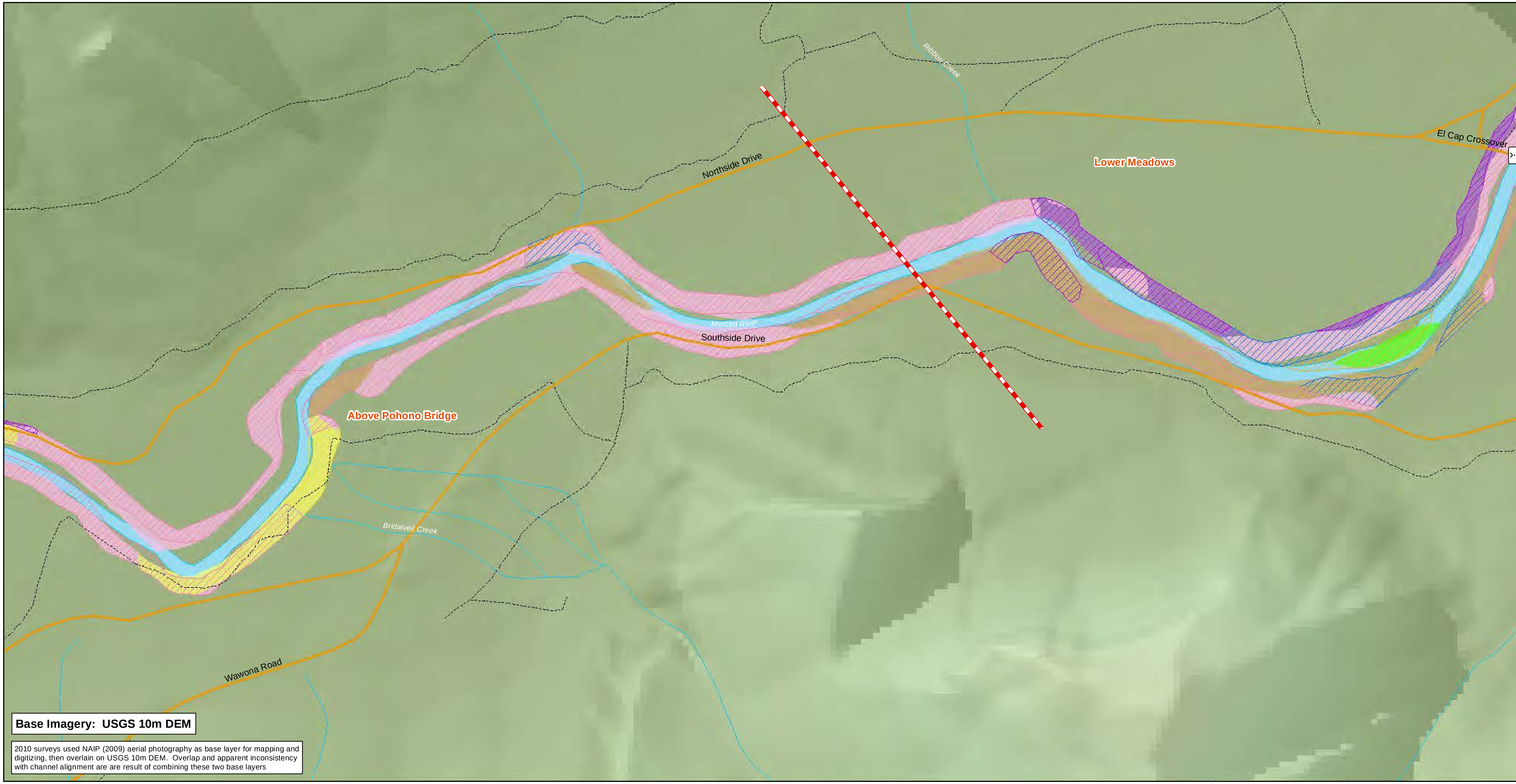

Vegetation Categories

1997	1992
1	1, Bare & 1, Oxbow and Cutoff Channels
2	2, Oaks and Conifers
3	3, Meadow
4	4, Cottonwood (including mixed)
5	5, Alder (including with Bigleaf Maple and Conifers)
6	6, Willow Riparian

- Bridge
- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

Note: 1992 and 1997 GIS vegetation community mapping data provided by NPS

Merced River
Yosemite National Park

1992 and 1997 Riparian Vegetation Map Series

Comparison of Riparian Corridor Vegetation Communities along the Merced River 1992 and 1997

Map 5 of 6

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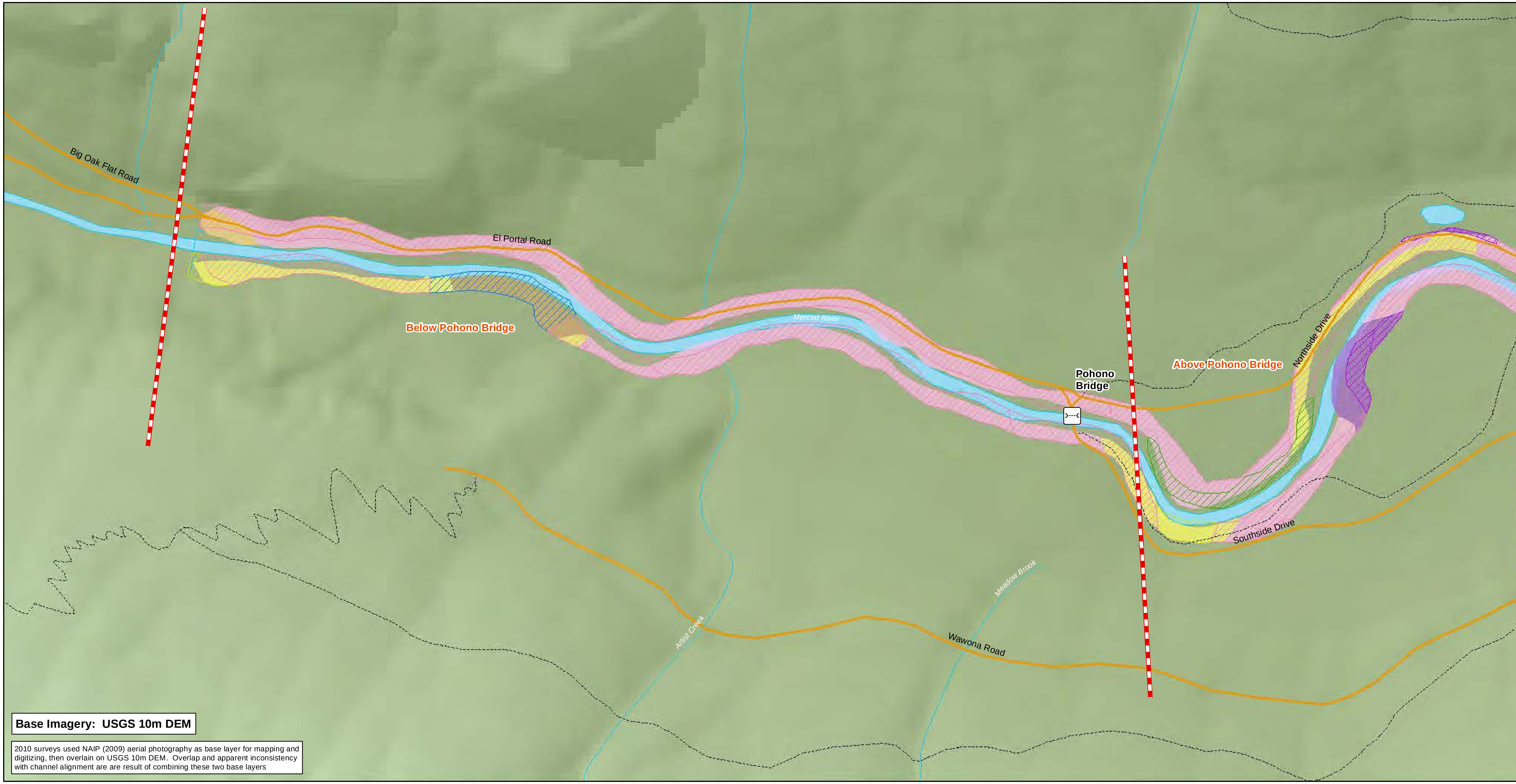

Vegetation Categories

1997	1992	
1	1, Bare &	1, Oxbow and Cutoff Channels
2	2, Oaks and Conifers	
3	3, Meadow	
4	4, Cottonwood (including mixed)	
5	5, Alder (including with Bigleaf Maple and Conifers)	
6	6, Willow Riparian	

- Bridge
- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

Note: 1992 and 1997 GIS vegetation community mapping data provided by NPS

Merced River
Yosemite National Park

1992 and 1997 Riparian Vegetation Map Series

Comparison of Riparian Corridor Vegetation Communities along the Merced River 1992 and 1997

Map 6 of 6

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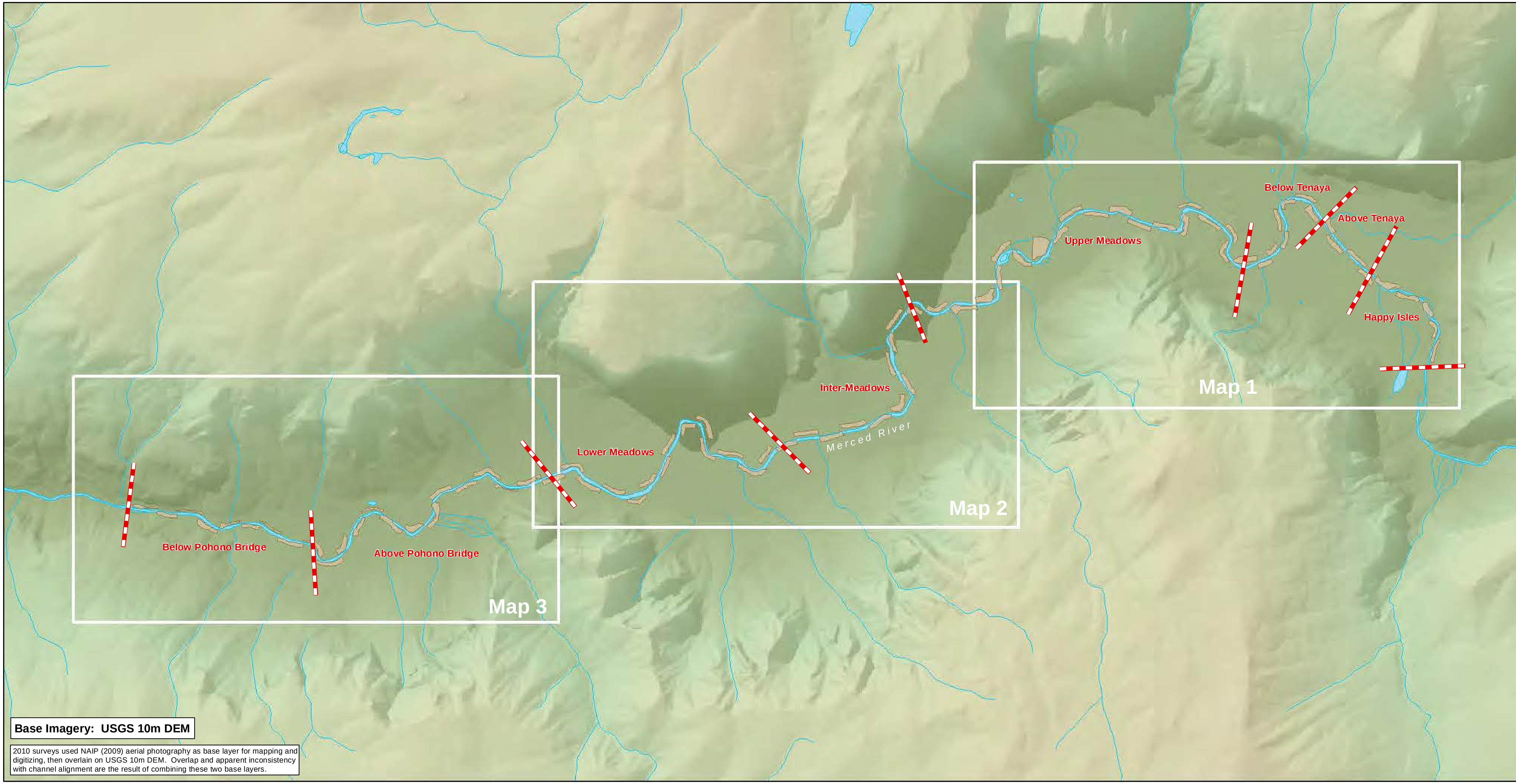

Geomorphic Reach Break
Stream
Waterbody
Assessment Area

Merced River
Yosemite National Park

CRAM Assessment Areas Map Series

Assessment Areas along the Merced River within the Study Area (2010)

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Coordinate System:
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N W E S

0 375 750 1,500 Meters

Bridge	Geomorphic Reach
Campground	Primary Rd
Picnic Area	Secondary/Local Rd
Waterfall	Trail
	Assessment Area
Stream	Waterbody

Merced River
Yosemite National Park

CRAM Assessment Areas Map Series

Assessment Areas along the Merced River within the Study Area (2010)

Map 1 of 3

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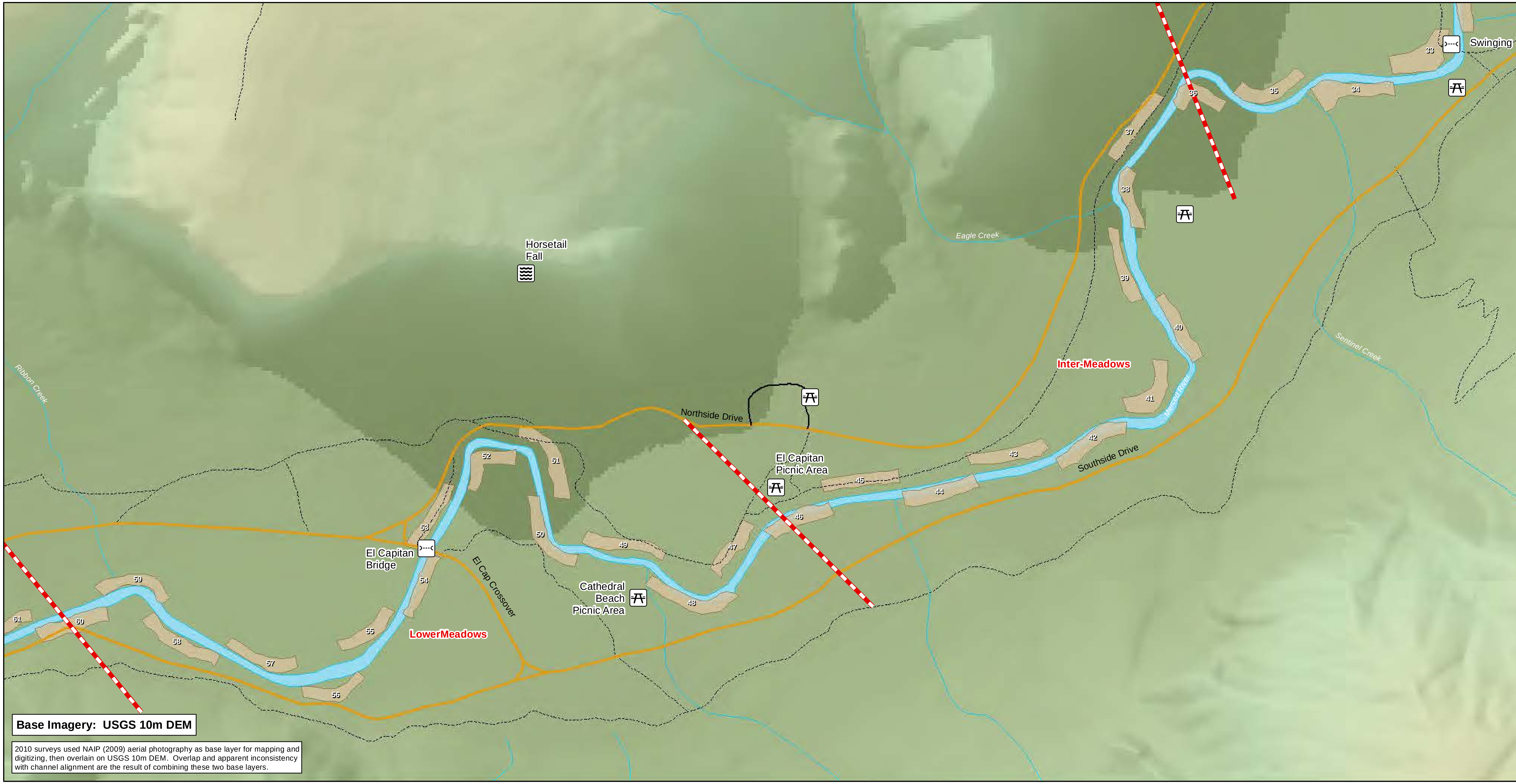
0 125 250 500 Meters

N S E W



Bridge
Campground
Picnic Area
Waterfall
Geomorphic Reach
Primary Rd
Secondary/Local Rd
Trail
Assessment Area
Stream
Waterbody

Merced River
Yosemite National Park

CRAM Assessment Areas Map Series

Assessment Areas along the Merced River within the Study Area (2010)

Map 2 of 3

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N W E S

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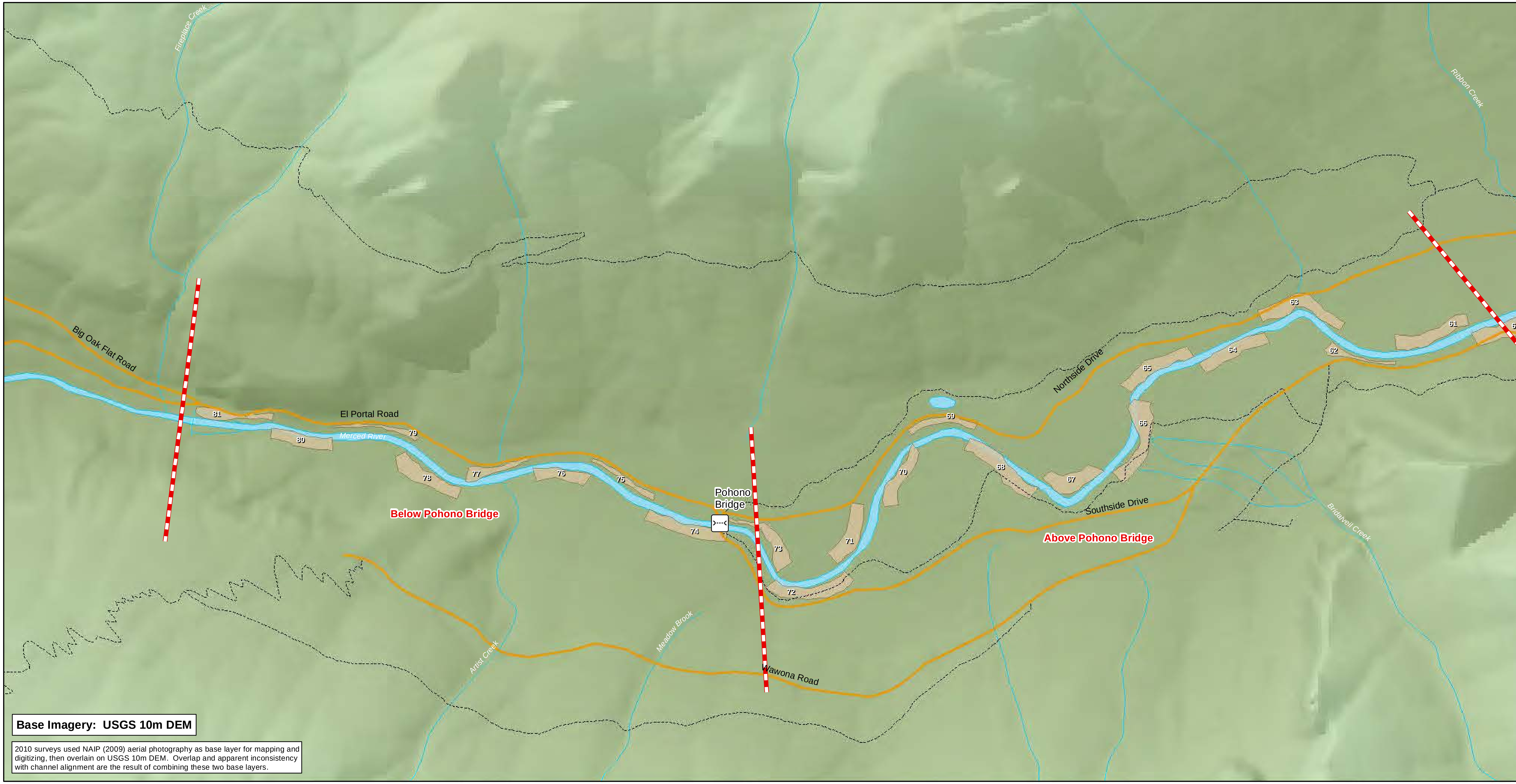

- Bridge
- Campground
- Picnic Area
- Waterfall
- Geomorphic Reach
- Primary Rd
- Secondary/Local Rd
- Trail
- Assessment Area
- Stream
- Waterbody

Merced River
Yosemite National Park

CRAM Assessment Areas Map Series

Assessment Areas along the Merced River within the Study Area (2010)

Map 3 of 3

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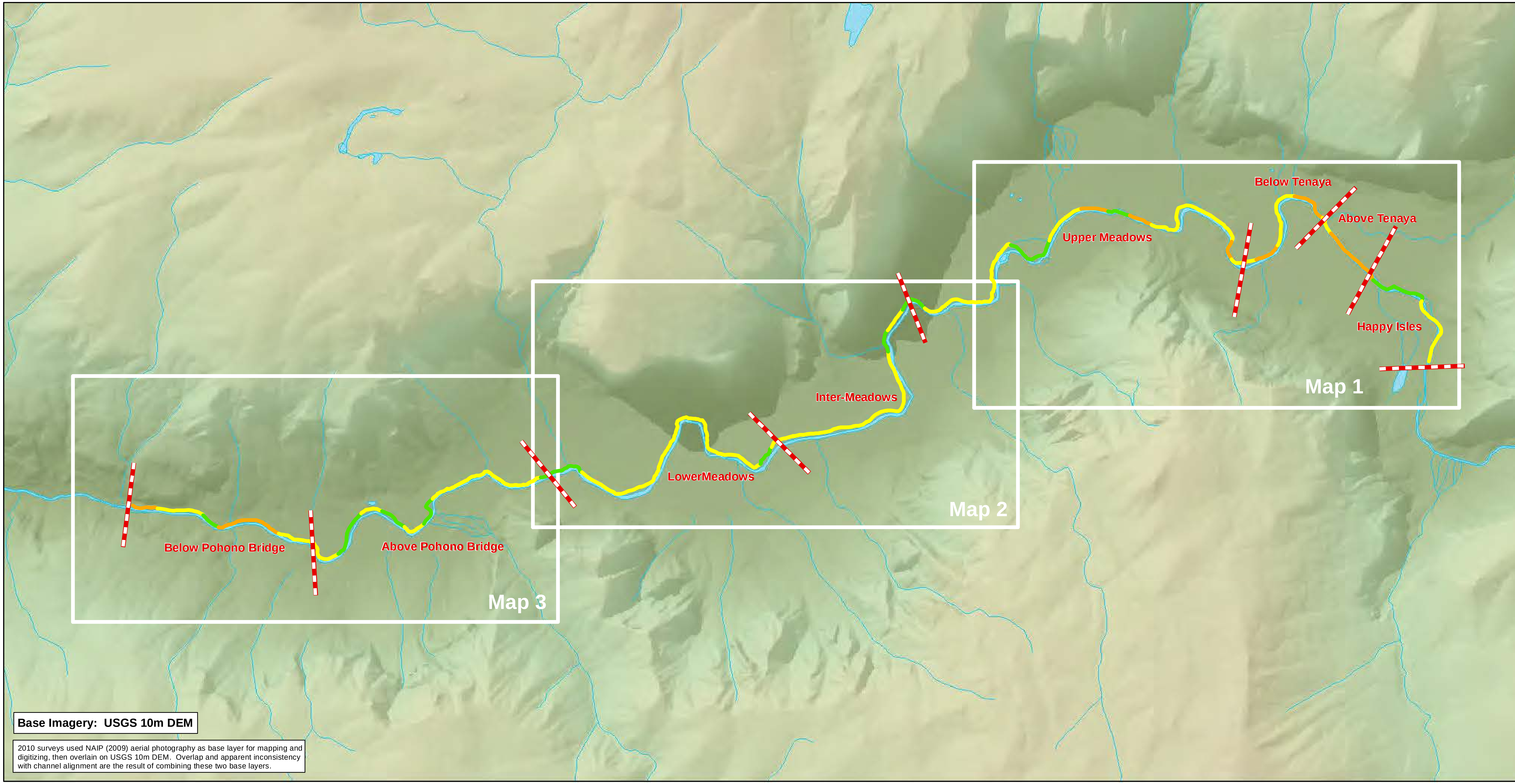

California Rapid Assessment Method Overall Scores

- "Higher" Overall CRAM Scores (> or equal to 0.87)
- "Moderate" Overall CRAM Scores (between 0.701 and 0.869)
- "Lower" Overall CRAM Scores (< or equal to 0.70)
- Geomorphic Reach Break
- Stream
- Waterbody

*CRAM data are summarized by AA in Appendix C

Merced River
Yosemite National Park

CRAM Scores Map Series

California Rapid Assessment Method Overall Scores along the Merced River within the Study Area (2010)

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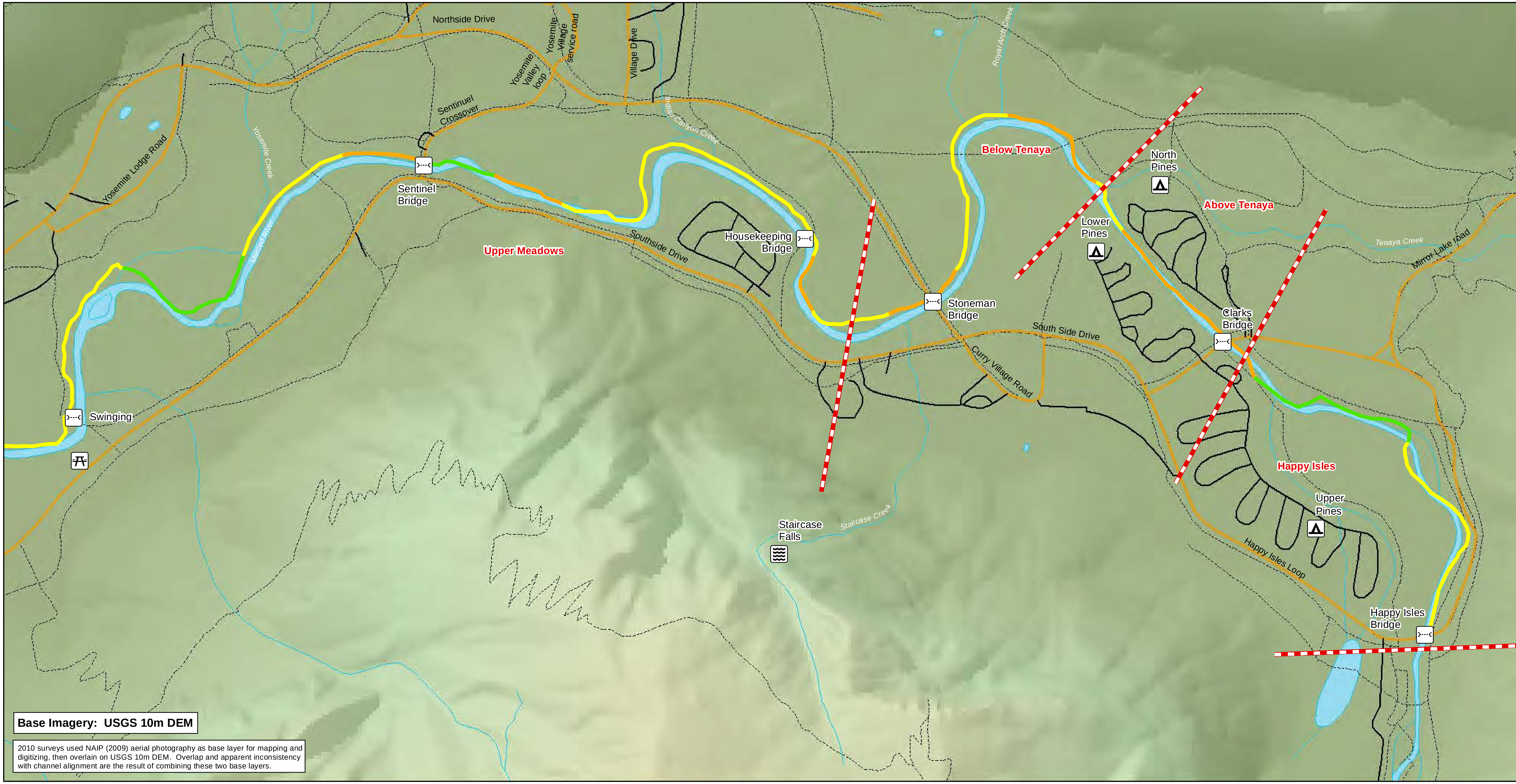
N W E S

0 375 750 1,500 Meters



California Rapid Assessment Method Overall Scores

- "Higher" Overall CRAM Scores (> or equal to 0.87)
- "Moderate" Overall CRAM Scores (between 0.701 and 0.869)
- "Lower" Overall CRAM Scores (< or equal to 0.70)

*CRAM data are summarized by AA in Appendix C

- Bridge
- Campground
- Picnic Area
- Waterfall
- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

Merced River
Yosemite National Park

CRAM Scores Map Series

California Rapid Assessment Method Overall Scores along the Merced River within the Study Area (2010)

Map 1 of 3

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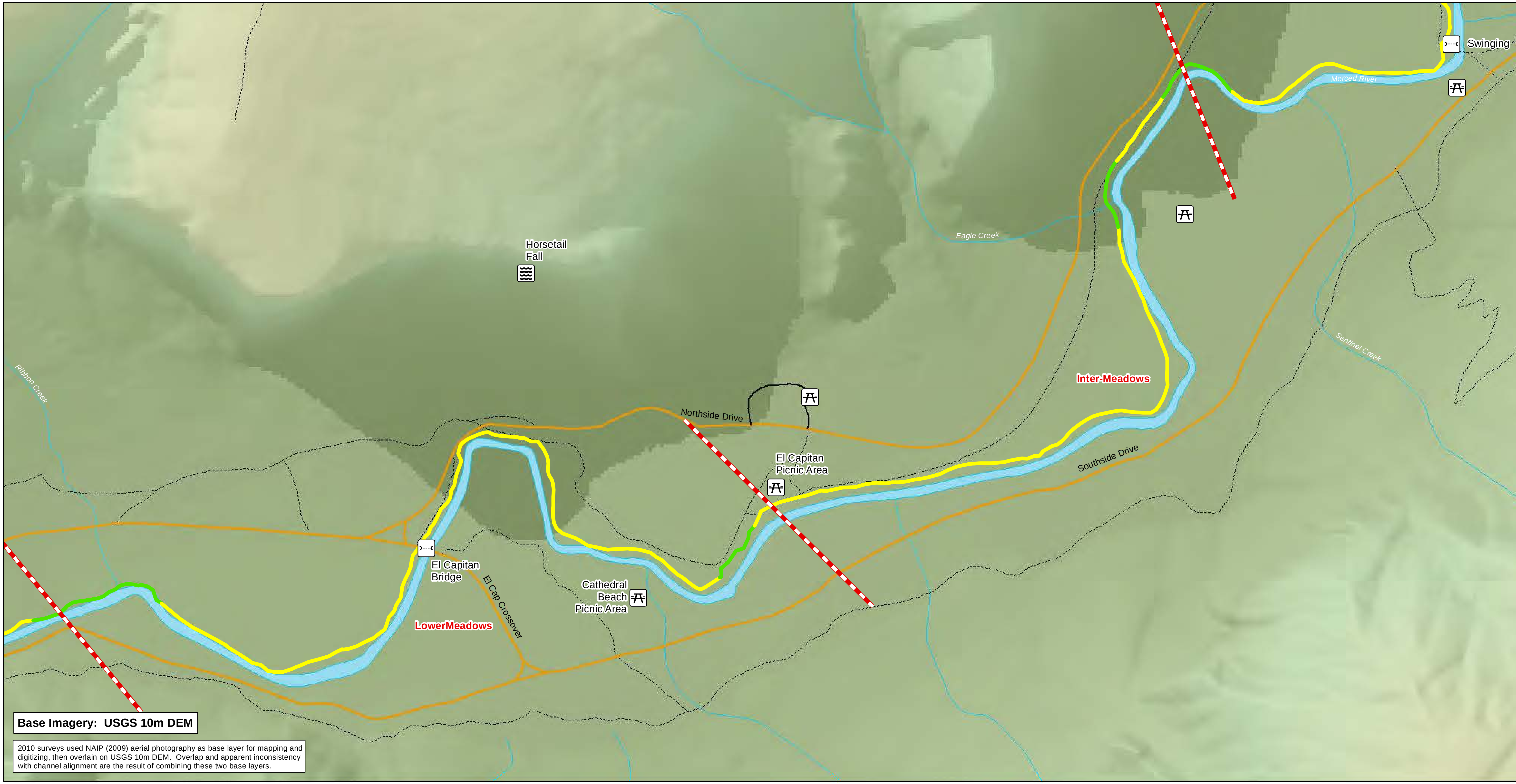
Coordinate System:
NAD 1983 UTM Zone 11 meters

N W E S

0 125 250 500 Meters



California Rapid Assessment Method Overall Scores

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- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

*CRAM data are summarized by AA in Appendix C

Merced River
Yosemite National Park

CRAM Scores Map Series

California Rapid Assessment Method Overall Scores along the Merced River within the Study Area (2010)

Map 2 of 3

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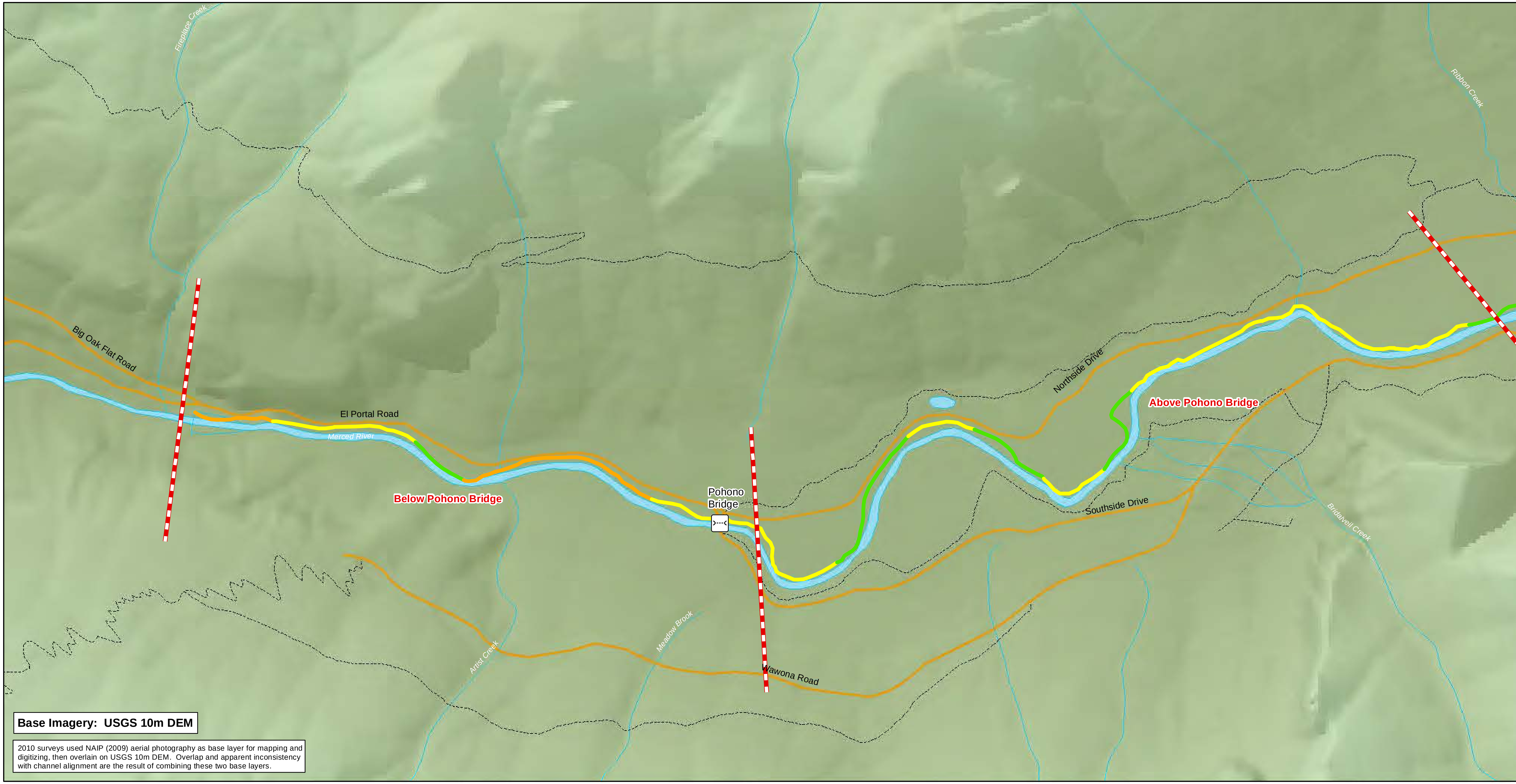
Coordinate System:
NAD 1983 UTM Zone 11 meters

N W E S

0 125 250 500 Meters



California Rapid Assessment Method Overall Scores

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- "Moderate" Overall CRAM Scores (between 0.701 and 0.869)
- "Lower" Overall CRAM Scores (< or equal to 0.70)

Bridge
Campground
Picnic Area
Waterfall

Geomorphic Reach Break
Primary Rd
Secondary/Local Rd
Trail
Stream
Waterbody

*CRAM data are summarized by AA in Appendix C

Merced River
Yosemite National Park

CRAM Scores Map Series

California Rapid Assessment Method Overall Scores along the Merced River within the Study Area (2010)

Map 3 of 3

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Coordinate System:
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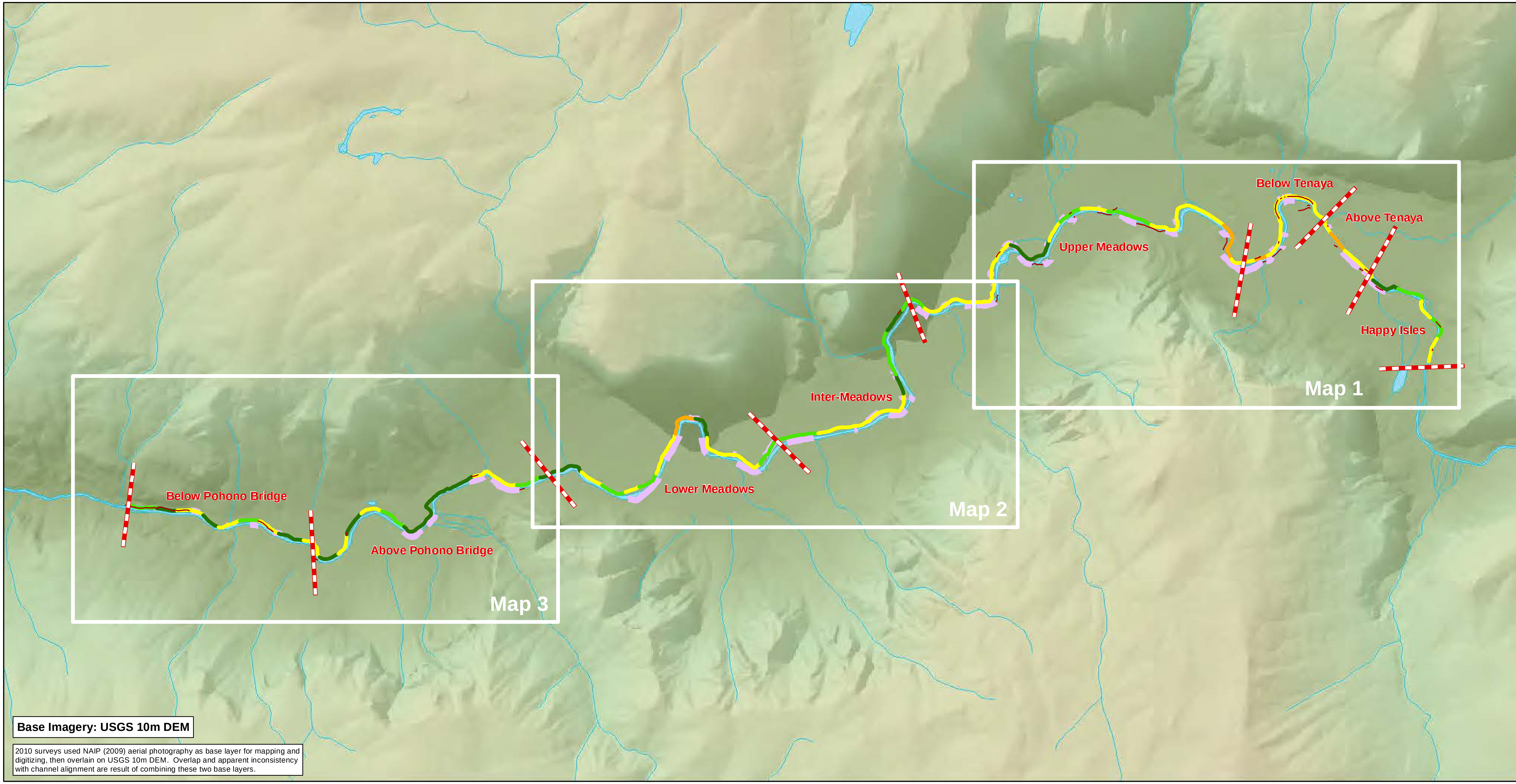
N W E S

0 125 250 500 Meters



Buffer Condition

- Undisturbed soils and little to no human visitation ("A" score)
- Mostly undisturbed soils with little to no human visitation ("B" score)
- Moderate soil disturbance/compaction and/or moderate-intensity human visitation ("C" score)
- Highly compacted/disturbed soils and/or very intense human visitation ("D" score)
- Revetment Location
- Bank Erosion
- Geomorphic Reach
- Stream
- Waterbody

*CRAM data are summarized by AA in Appendix C

Merced River
Yosemite National Park

Buffer Condition Map Series

Buffer Condition and Locations of Revetment and Bank Erosion along the Merced River within the Study Area (2010)

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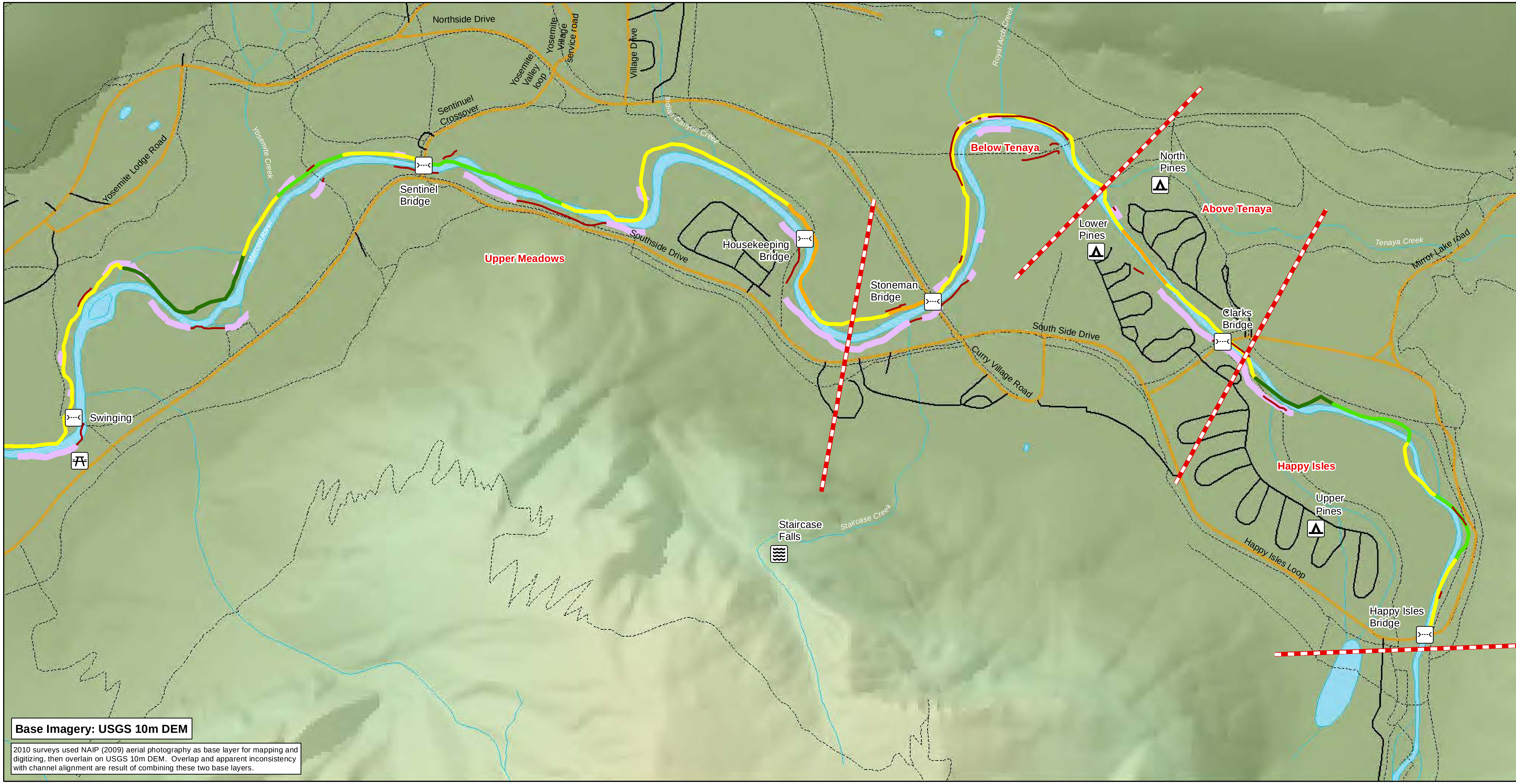
Coordinate System:
NAD 1983 UTM Zone 11 meters

N W E S

0 375 750 1,500 Meters



Buffer Condition

- Undisturbed soils and little to no human visitation ("A" score)
- Mostly undisturbed soils with little to no human visitation ("B" score)
- Moderate soil disturbance/compaction and/or moderate-intensity human visitation ("C" score)
- Highly compacted/disturbed soils and/or very intense human visitation ("D" score)
- Revetment Location
- Bank Erosion

- Bridge
- Campground
- Picnic Area
- Waterfall

- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

*CRAM data are summarized by AA in Appendix C

Merced River
Yosemite National Park

Buffer Condition Map Series

Buffer Condition and Locations of Revetment and Bank Erosion along the Merced River within the Study Area (2010)

Map 1 of 3

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Coordinate System:
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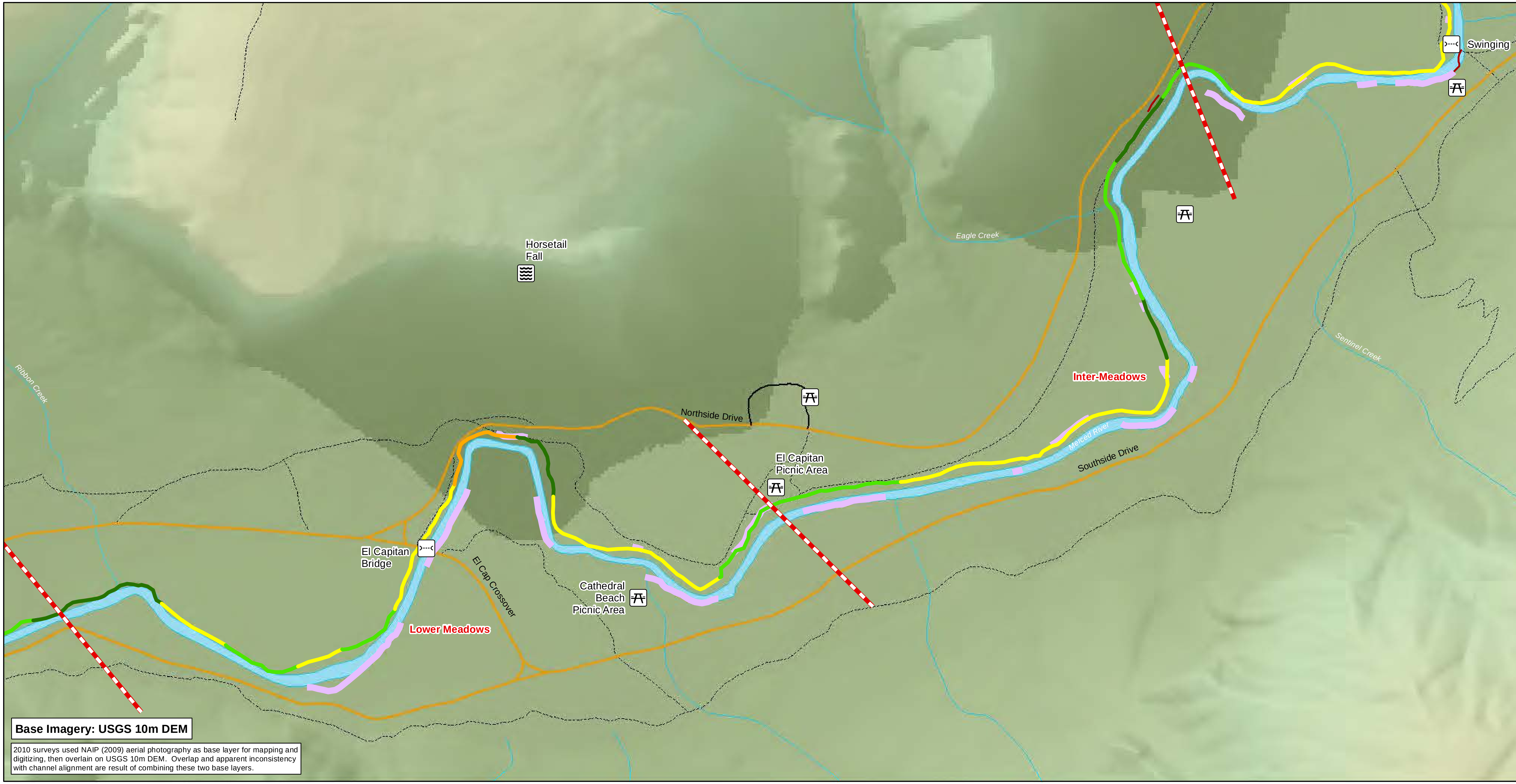
N S W E

0 125 250 500 Meters



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- Moderate soil disturbance/compaction and/or moderate-intensity human visitation ("C" score)
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- Revetment Location
- Bank Erosion

- Bridge
- Campground
- Picnic Area
- Waterfall

- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

*CRAM data are summarized by AA in Appendix C

Merced River
Yosemite National Park

Buffer Condition Map Series

Buffer Condition and Locations of Revetment and Bank Erosion along the Merced River within the Study Area (2010)

Map 2 of 3

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Coordinate System:
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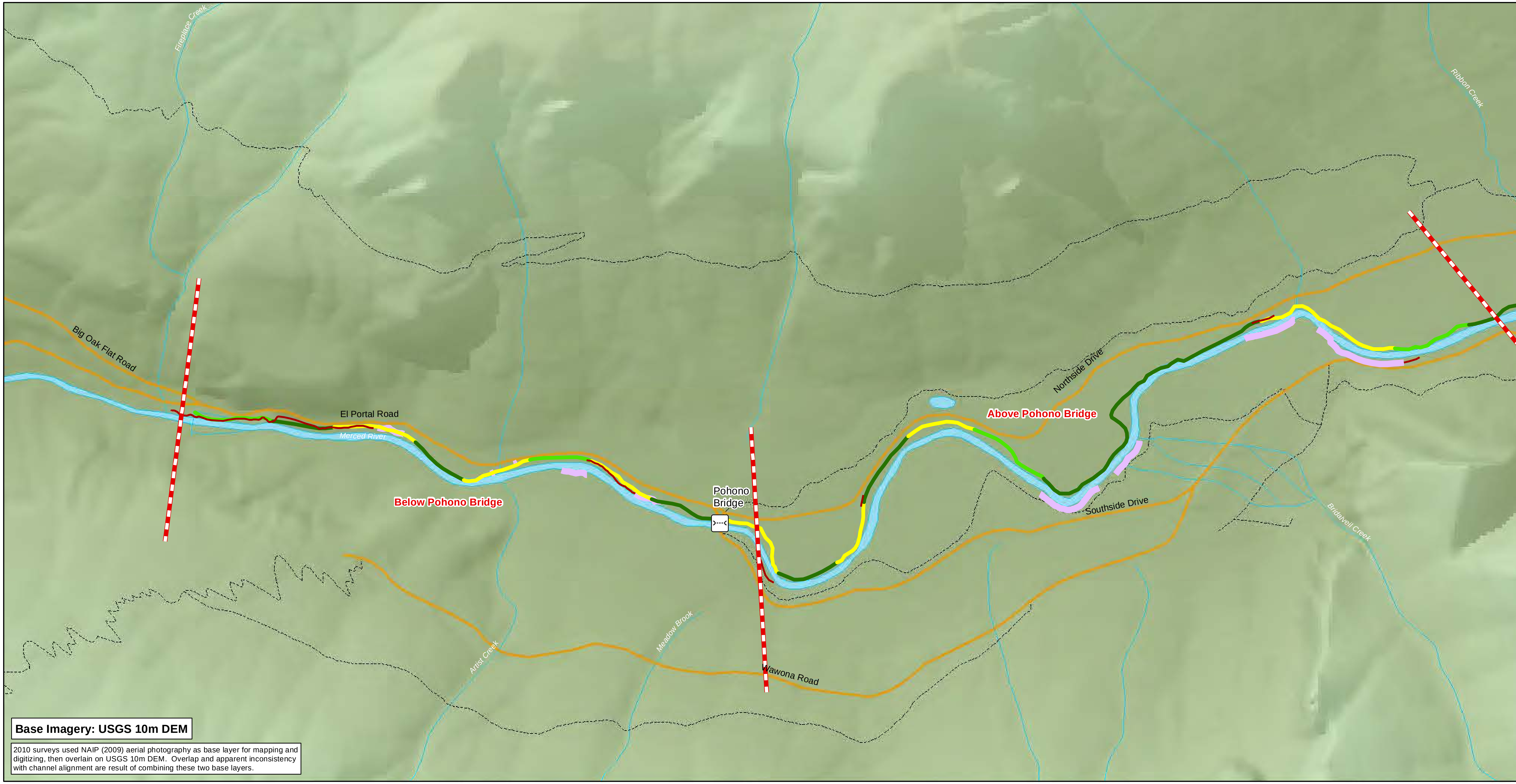
N W E S

0 125 250 500 Meters



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- Moderate soil disturbance/compaction and/or moderate-intensity human visitation ("C" score)
- Highly compacted/disturbed soils and/or very intense human visitation ("D" score)
- Revetment Location
- Bank Erosion

*CRAM data are summarized by AA in Appendix C

- Bridge
- Campground
- Picnic Area
- Waterfall
- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

Merced River
Yosemite National Park

Buffer Condition Map Series

Buffer Condition and Locations of Revetment and Bank Erosion along the Merced River within the Study Area (2010)

Map 3 of 3

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Coordinate System:
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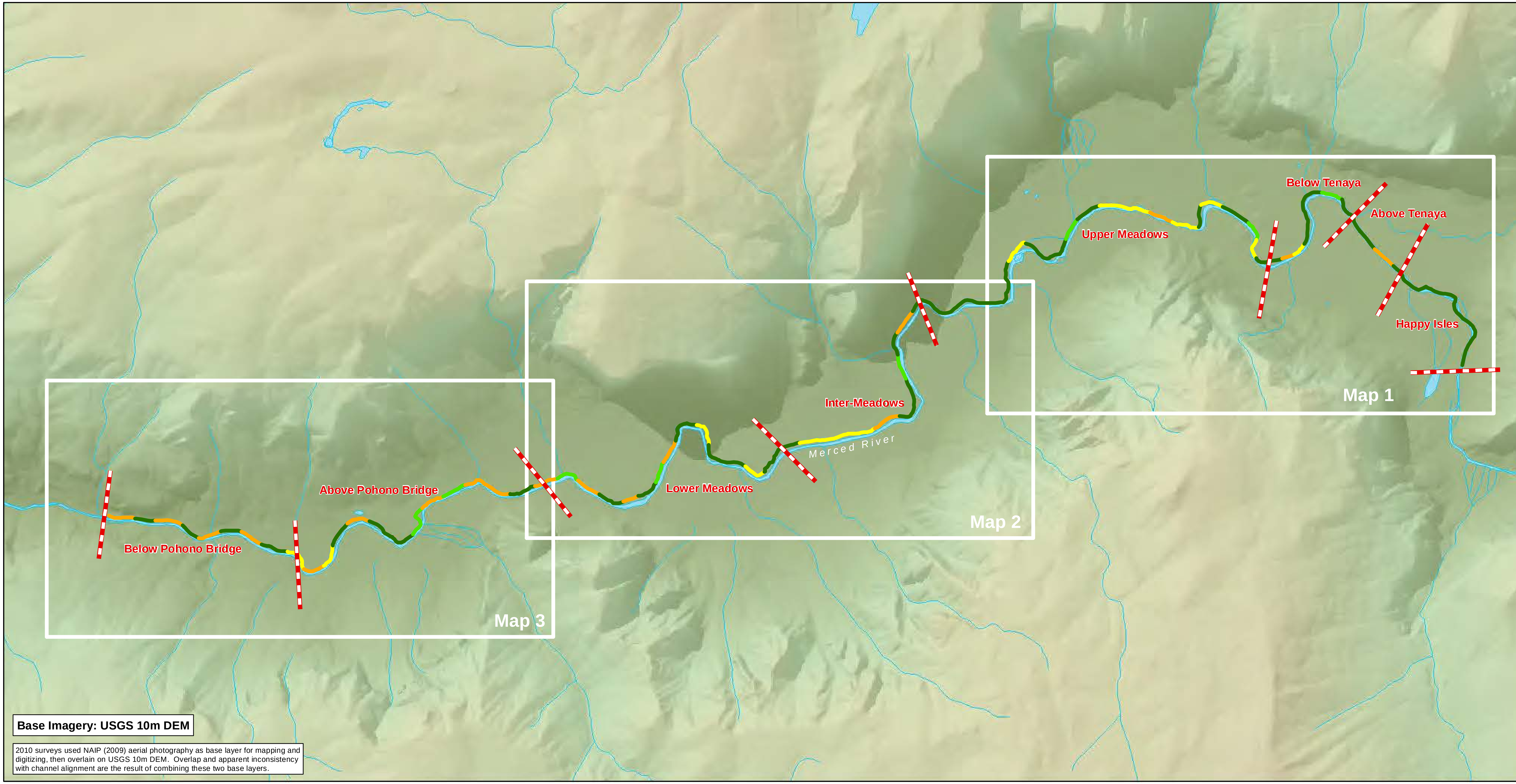
N W E S

0 125 250 500 Meters



Average Buffer Width

- 190-250 m ("A" score)
- 130-189 m ("B" score)
- 65-129 m ("C" score)
- 0-64 m ("D" score)
- Geomorphic Reach Break
- Stream
- Waterbody

*CRAM data are summarized by AA in Appendix C

Merced River
Yosemite National Park

Buffer Width Map Series

Average Buffer Width along the Merced River within the Study Area (2010)

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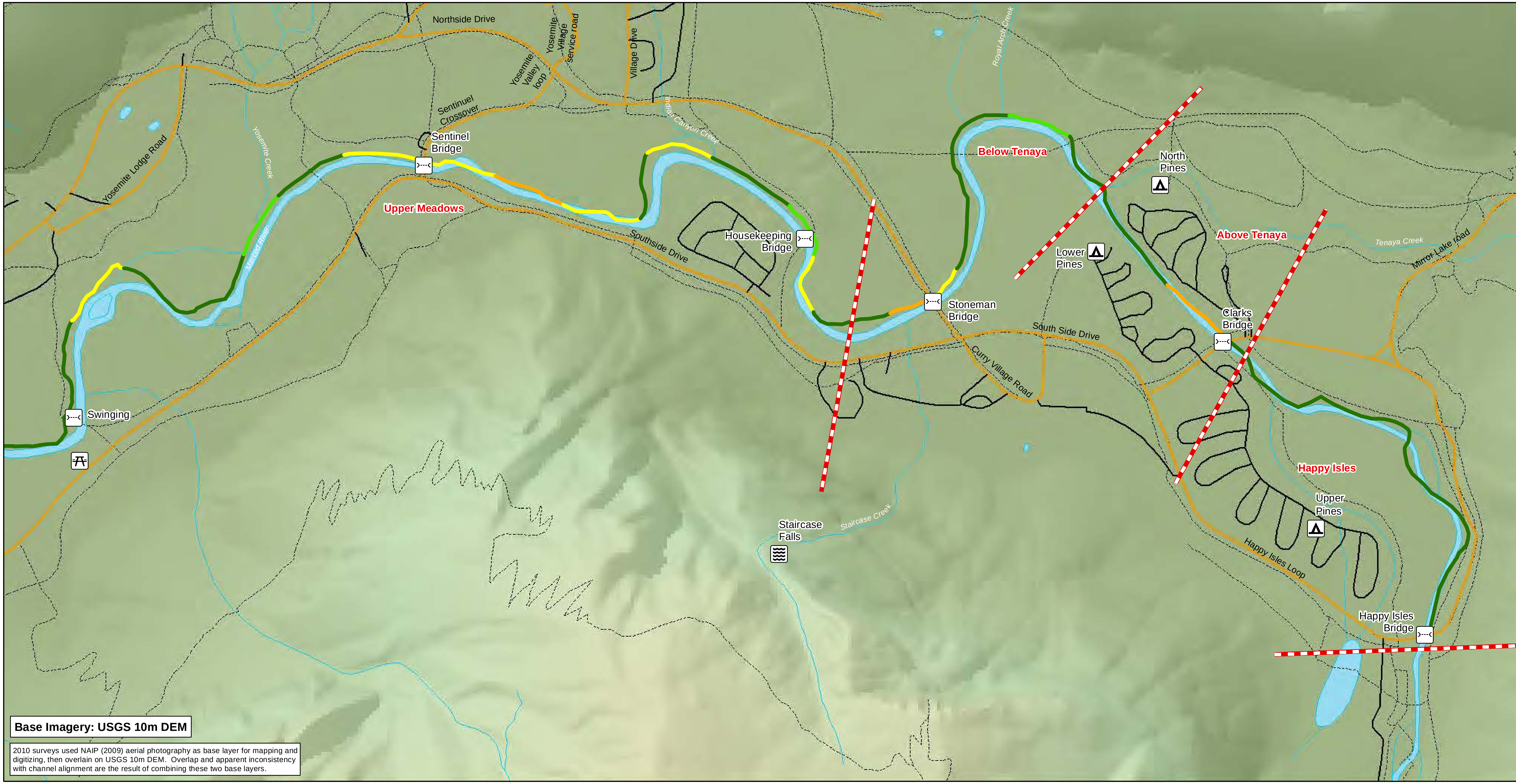
Coordinate System:
NAD 1983 UTM Zone 11 meters

N E S W

0 375 750 1,500 Meters



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Merced River
Yosemite National Park

Buffer Width Map Series

Average Buffer Width along the Merced River within the Study Area (2010)

Map 1 of 3

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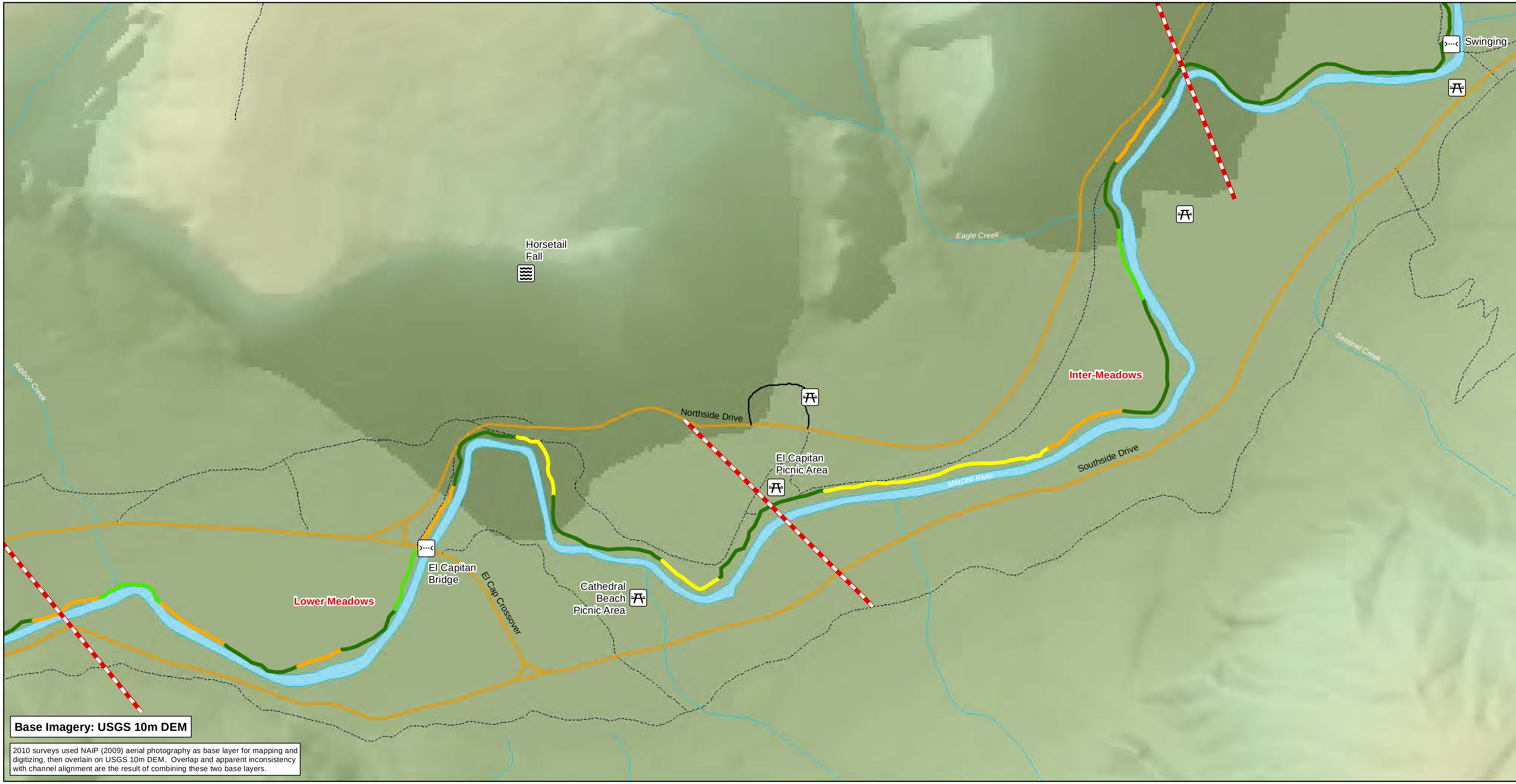
Coordinate System:
NAD 1983 UTM Zone 11 meters

N / E / S / W

0 125 250 500 Meters



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- Trail
- Stream
- Waterbody

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Merced River
Yosemite National Park

Buffer Width Map Series

Average Buffer Width along the Merced River within the Study Area (2010)

Map 2 of 3

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Coordinate System:
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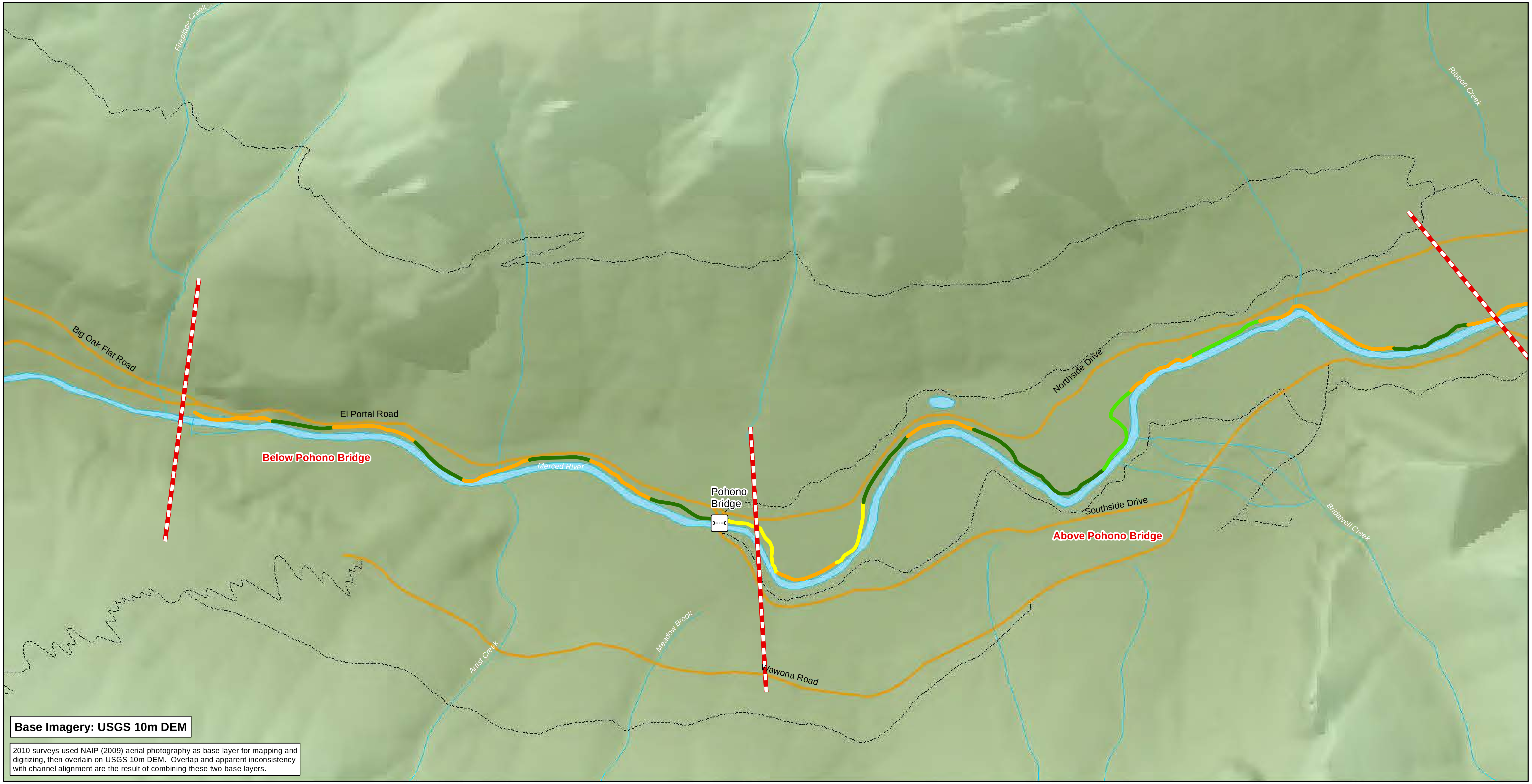
N W E S

0 125 250 500 Meters



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Merced River
Yosemite National Park

Buffer Width Map Series

Average Buffer Width along the Merced River within the Study Area (2010)

Map 3 of 3

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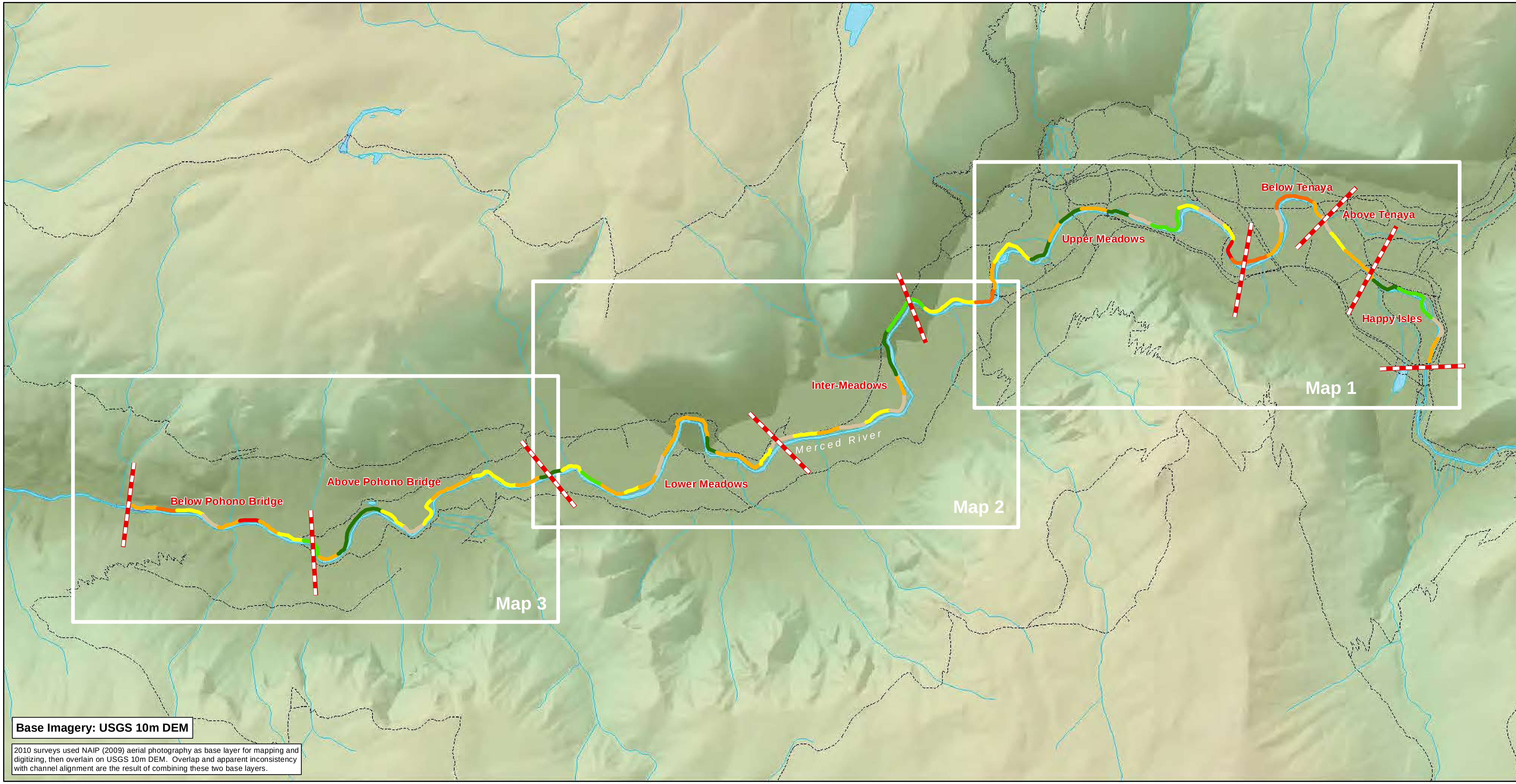

Biotic Structure

- >0.951
- 0.851 - 0.95
- 0.751 - 0.85
- 0.651 - 0.75
- 0.551 - 0.65
- 0.451 - 0.55
- <0.45

- Geomorphic Reach Break
- Trail
- Stream
- Waterbody

*CRAM data are summarized by AA in Appendix C

Note: The Biotic Structure Attribute includes the assessment of the number of plant species, number of co-dominant species, percent invasion, horizontal interspersion or zonation, and vertical biotic structure in each assessment area.

Merced River
Yosemite National Park

Biotic Structure Map Series

Biotic Structure along the Merced River within the Study Area (2010)

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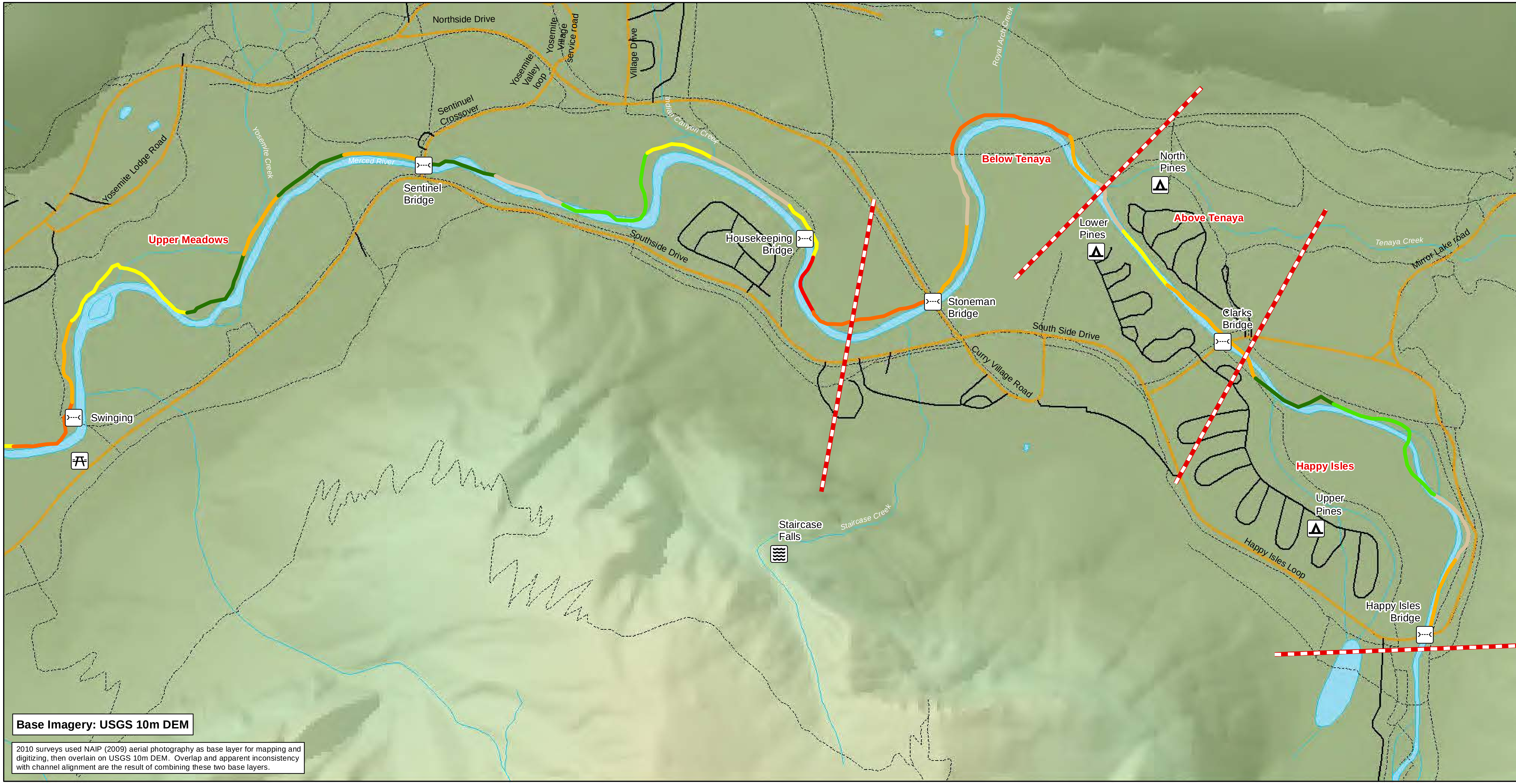
Coordinate System:
NAD 1983 UTM Zone 11 meters

N W E S

0 375 750 1,500 Meters



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Merced River
Yosemite National Park

Biotic Structure Map Series

Biotic Structure along the Merced River within the Study Area (2010)

Map 1 of 3

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0 125 250 500 Meters

N E S W

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Merced River
Yosemite National Park

Biotic Structure Map Series

Biotic Structure along the Merced River within the Study Area (2010)

Map 2 of 3

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Coordinate System:
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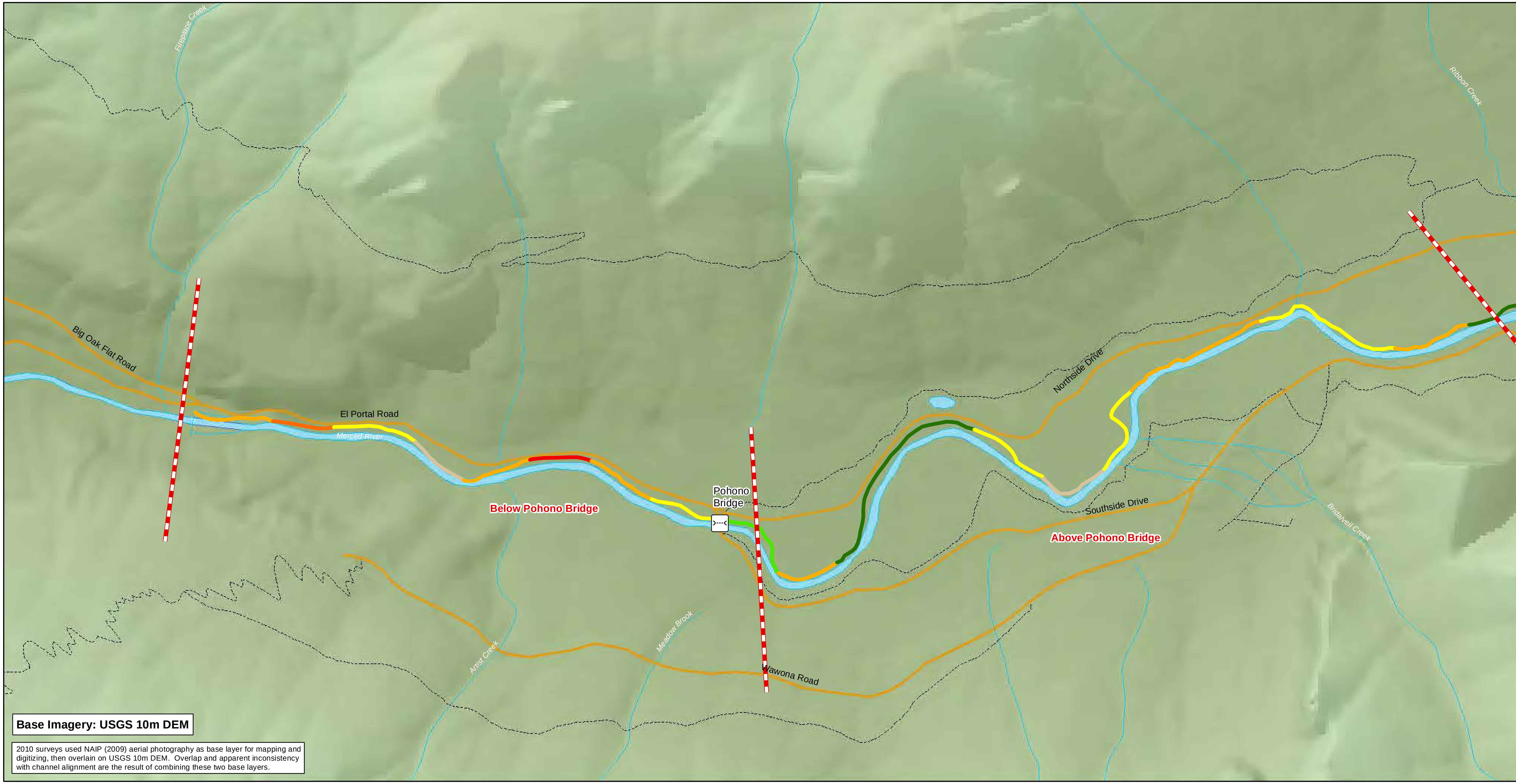
N W E S

0 125 250 500 Meters



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Merced River
Yosemite National Park

Biotic Structure Map Series

Biotic Structure along the Merced River within the Study Area (2010)

Map 3 of 3

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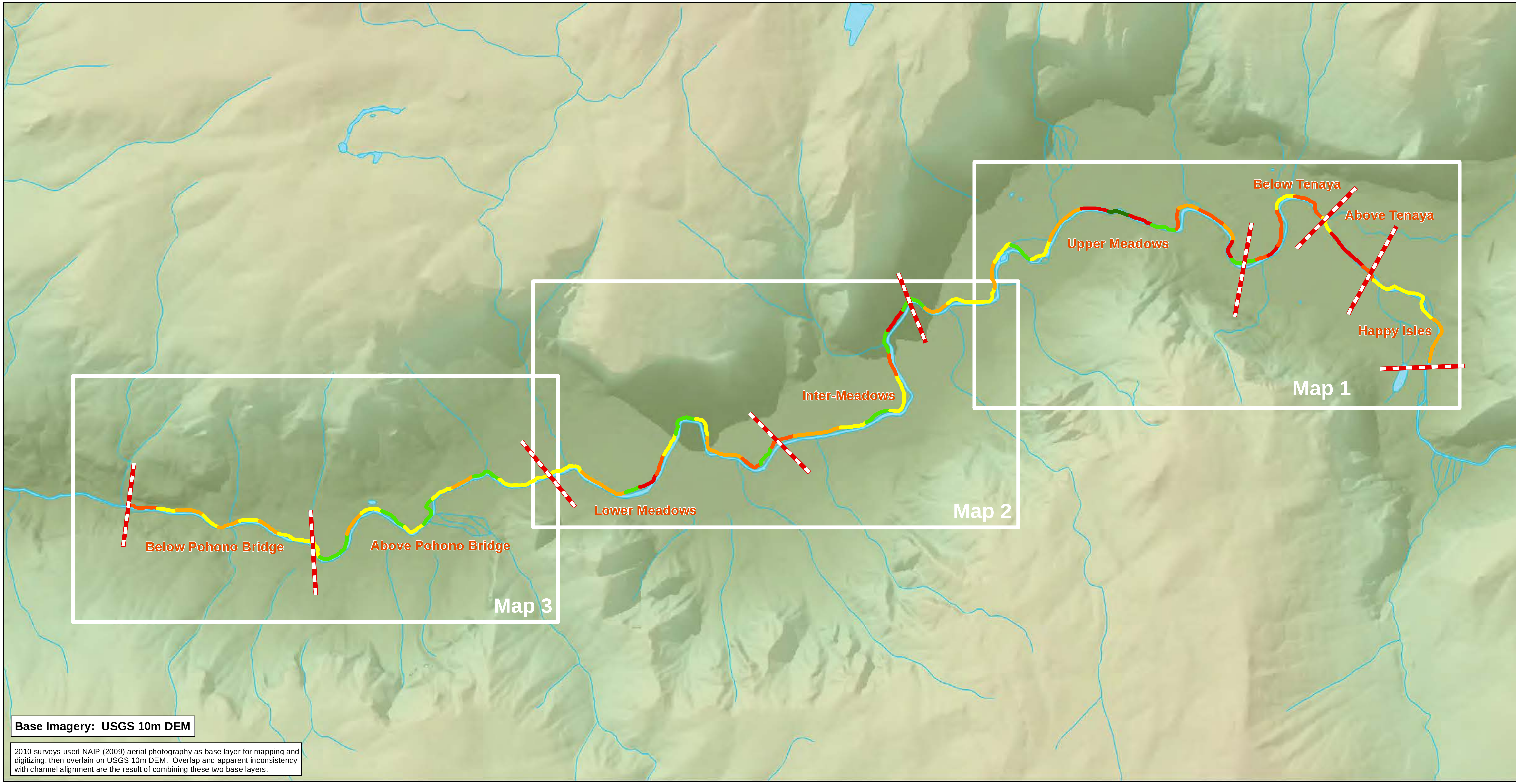

Physical Structure Condition

- >0.951
- 0.851-0.95
- 0.651-0.75
- 0.551-0.65
- 0.451-0.55
- <0.45
- Geomorphic Reach Break
- Stream
- Waterbody

*CRAM data are summarized by AA in Appendix C

Note: The Physical Structure Attribute includes assessments of the number of different types of physical features or surfaces that may provide habitat, and the overall variability in micro- and macro-topographic relief that may affect moisture gradients and/or flow paths within each assessment area.

Merced River
Yosemite National Park

Physical Structure Condition Map Series

Physical Structure Condition along the Merced River within the Study Area (2010)

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Coordinate System:
NAD 1983 UTM Zone 11 meters

N W E S

0 375 750 1,500 Meters

Physical Structure Condition

Physical Structure Condition		
>0.951	Bridge	Geomorphic Reach Break
0.851-0.95	Campground	Primary Rd
0.651-0.75	Picnic Area	Secondary/Local Rd
0.551-0.65	Waterfall	Trail
0.451-0.55		Stream
<0.45		Waterbody

*CRAM data are summarized by AA in Appendix C

Note: The Physical Structure Attribute includes assessments of the number of different types of physical features or surfaces that may provide habitat, and the overall variability in micro- and macro-topographic relief that may affect moisture gradients and/or flow paths within each assessment area.

Merced River
Yosemite National Park

Physical Structure Condition Map Series

Physical Structure Condition along the Merced River within the Study Area (2010)

Map 1 of 3

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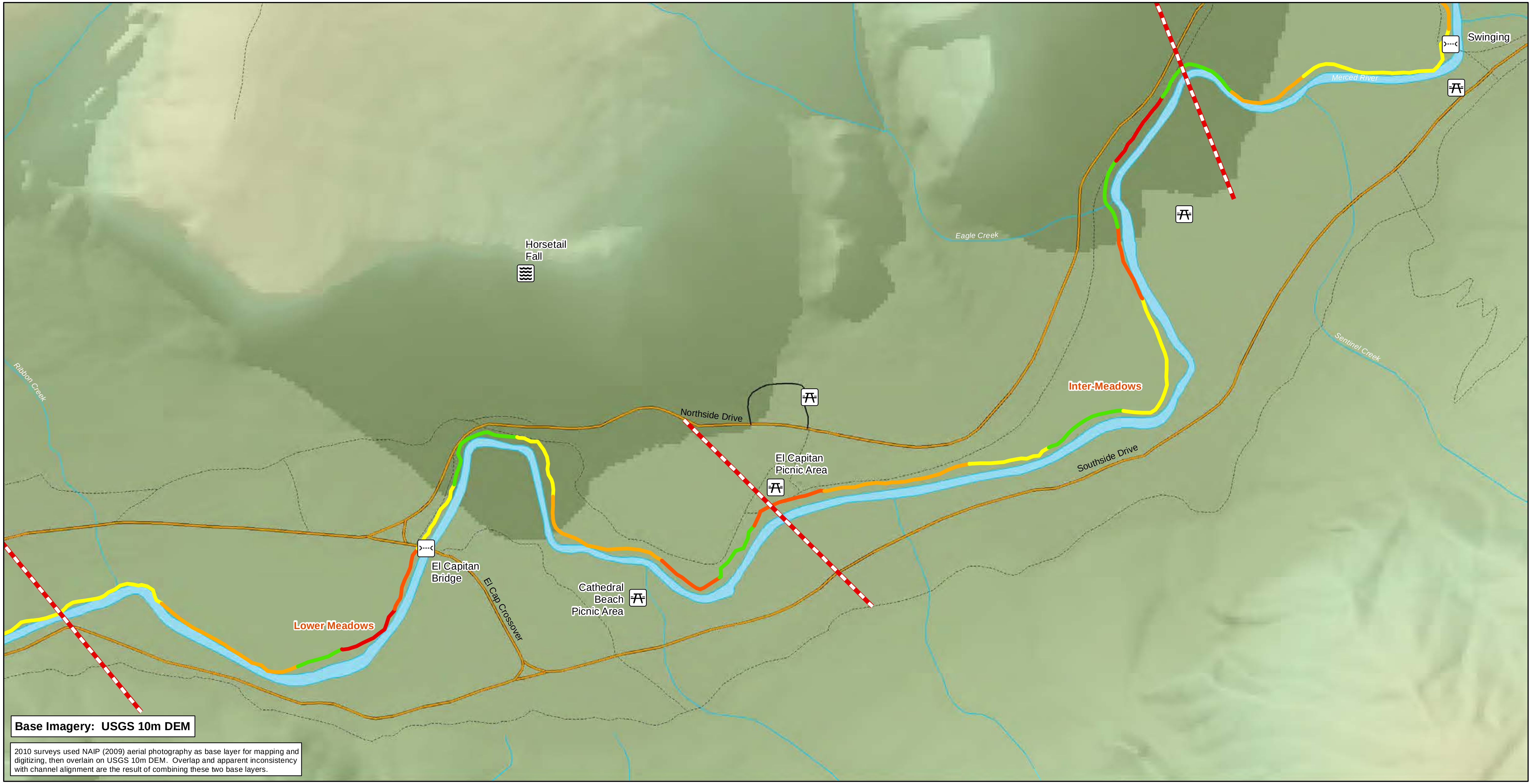
N W E S

0 125 250 500 Meters



Physical Structure Condition

- >0.951
- 0.851-0.95
- 0.651-0.75
- 0.551-0.65
- 0.451-0.55
- <0.45

- Bridge
- Campground
- Picnic Area
- Waterfall

- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

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Note: The Physical Structure Attribute includes assessments of the number of different types of physical features or surfaces that may provide habitat, and the overall variability in micro- and macro-topographic relief that may affect moisture gradients and/or flow paths within each assessment area.

Merced River
Yosemite National Park

Physical Structure Condition Map Series

Physical Structure Condition along the Merced River within the Study Area (2010)

Map 2 of 3

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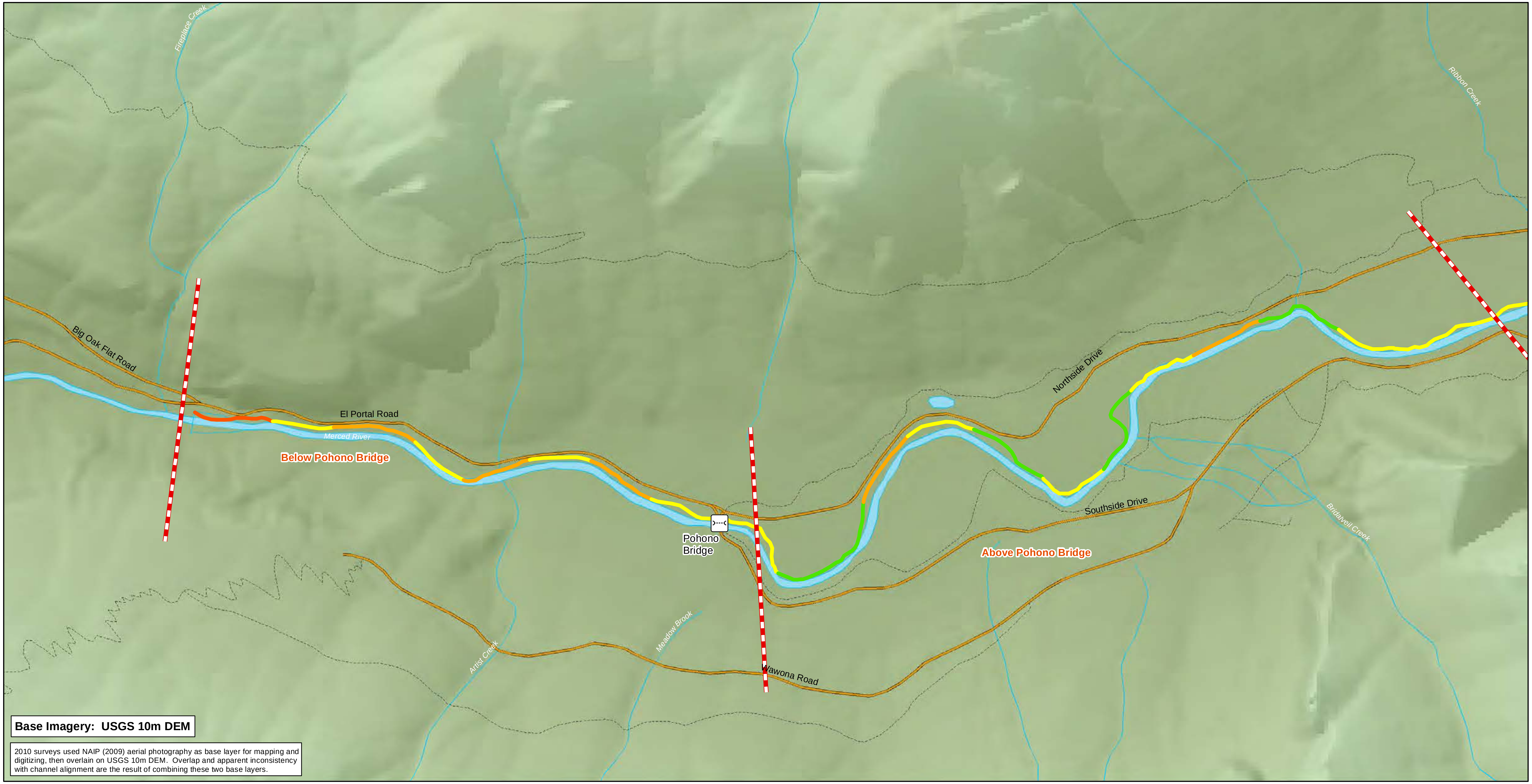
N E S W

0 125 250 500 Meters



Physical Structure Condition

- >0.951
- 0.851-0.95
- 0.651-0.75
- 0.551-0.65
- 0.451-0.55
- <0.45

- Bridge
- Campground
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- Waterfall

- Geomorphic Reach Break
- Primary Rd
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- Trail
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- Waterbody

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Note: The Physical Structure Attribute includes assessments of the number of different types of physical features or surfaces that may provide habitat, and the overall variability in micro- and macro-topographic relief that may affect moisture gradients and/or flow paths within each assessment area.

Merced River
Yosemite National Park

Physical Structure Condition Map Series

Physical Structure Condition along the Merced River within the Study Area (2010)

Map 3 of 3

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Coordinate System:
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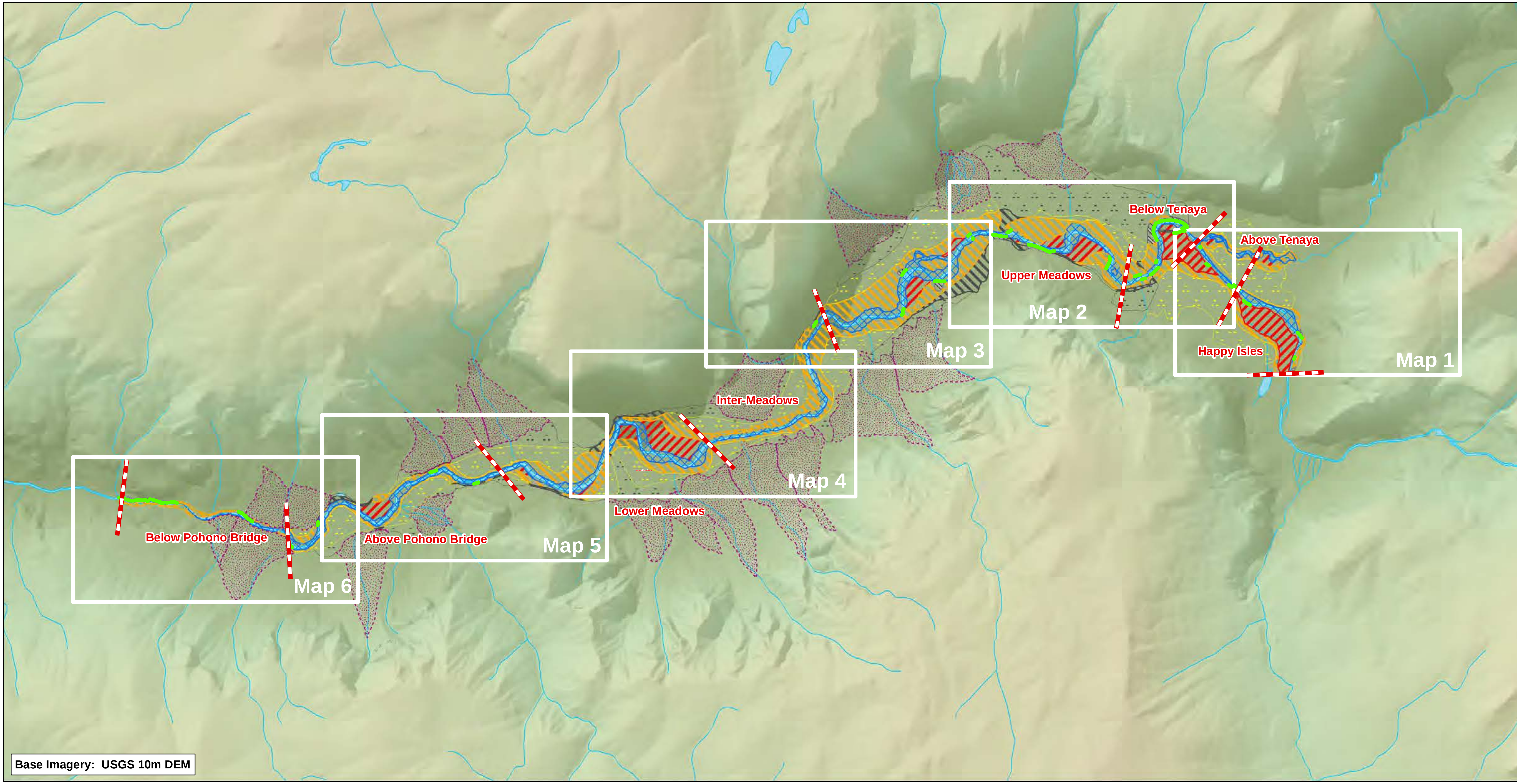
N E S W

0 125 250 500 Meters



Channel Migration Zone

- Alluvial Fan
- Avulsion Hazard Zone
- Disconnected Avulsion Hazard Zone
- Disconnected Erosion Hazard Area
- Disconnected Valley Alluvium
- Erosion Hazard Area
- Historic Migration Zone
- Protected Disconnected Erosion Hazard Area
- Valley Alluvium
- Revetment Location
- Geomorphic Reach Break
- Stream
- Waterbody

2010 surveys used NAIP (2009) aerial photography as base layer for mapping and digitizing, then overlain on USGS 10m DEM. Overlap and apparent inconsistency with channel alignment is the result of combining these two base layers.

Merced River
Yosemite National Park

Channel Migration Zone Map Series

Merced River Channel Migration Zones within Yosemite Valley

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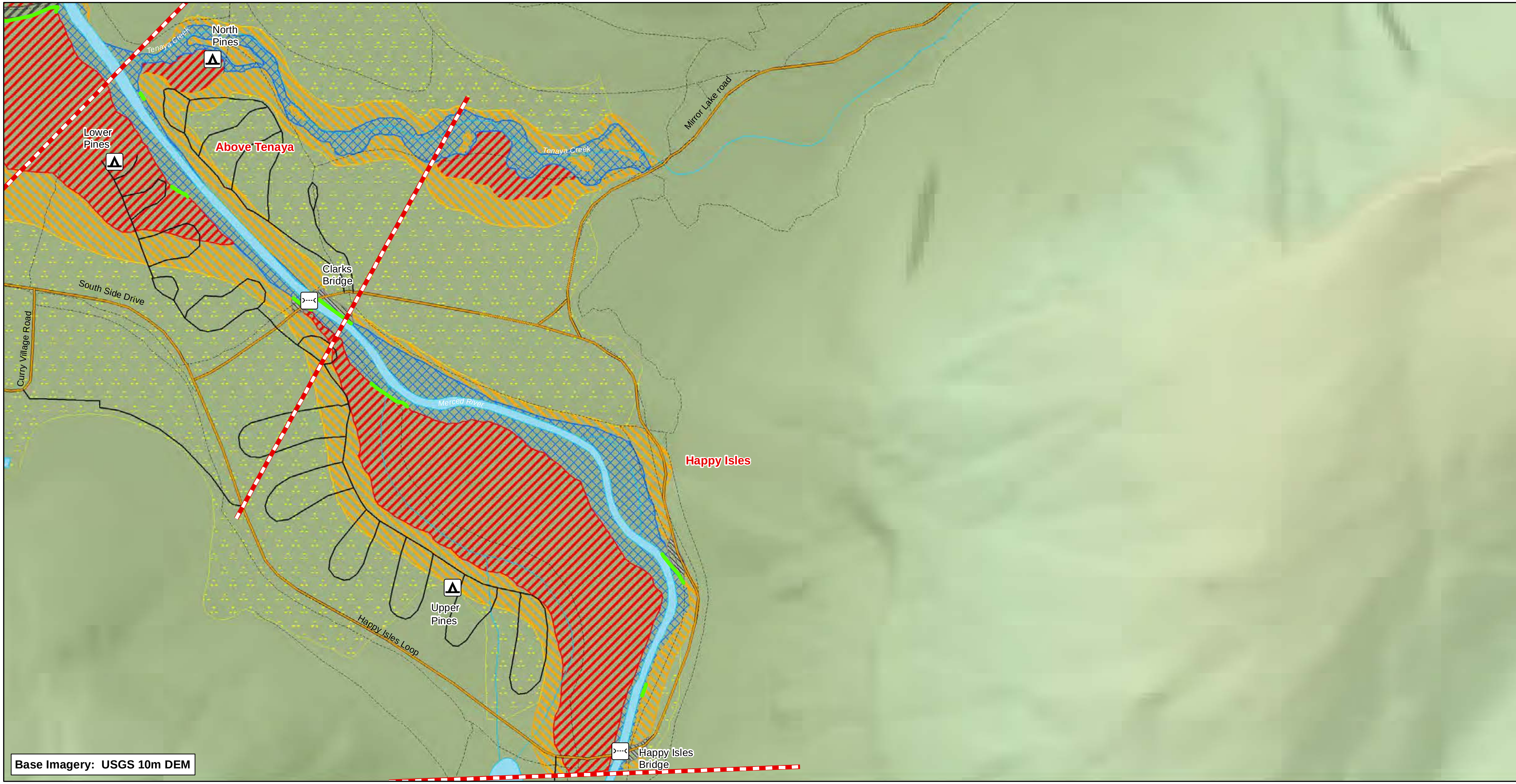
Coordinate System:
NAD 1983 UTM Zone 11 meters

N W E S

0 375 750 1,500 Meters



Channel Migration Zone

- Alluvial Fan
- Avulsion Hazard Zone
- Disconnected Avulsion Hazard Zone
- Disconnected Erosion Hazard Area
- Disconnected Valley Alluvium
- Erosion Hazard Area
- Historic Migration Zone
- Protected Disconnected Erosion Hazard Area
- Valley Alluvium

- Bridge
- Campground
- Picnic Area
- Waterfall

- Revetment Location
- Geomorphic Reach Break
- Primary Rd
- Secondary/Local Rd
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- Stream
- Waterbody

2010 surveys used NAIP (2009) aerial photography as base layer for mapping and digitizing, then overlain on USGS 10m DEM. Overlap and apparent inconsistency with channel alignment is the result of combining these two base layers.

Merced River
Yosemite National Park

Channel Migration Zone Map Series

Merced River Channel Migration Zones within Yosemite Valley

Map 1 of 6

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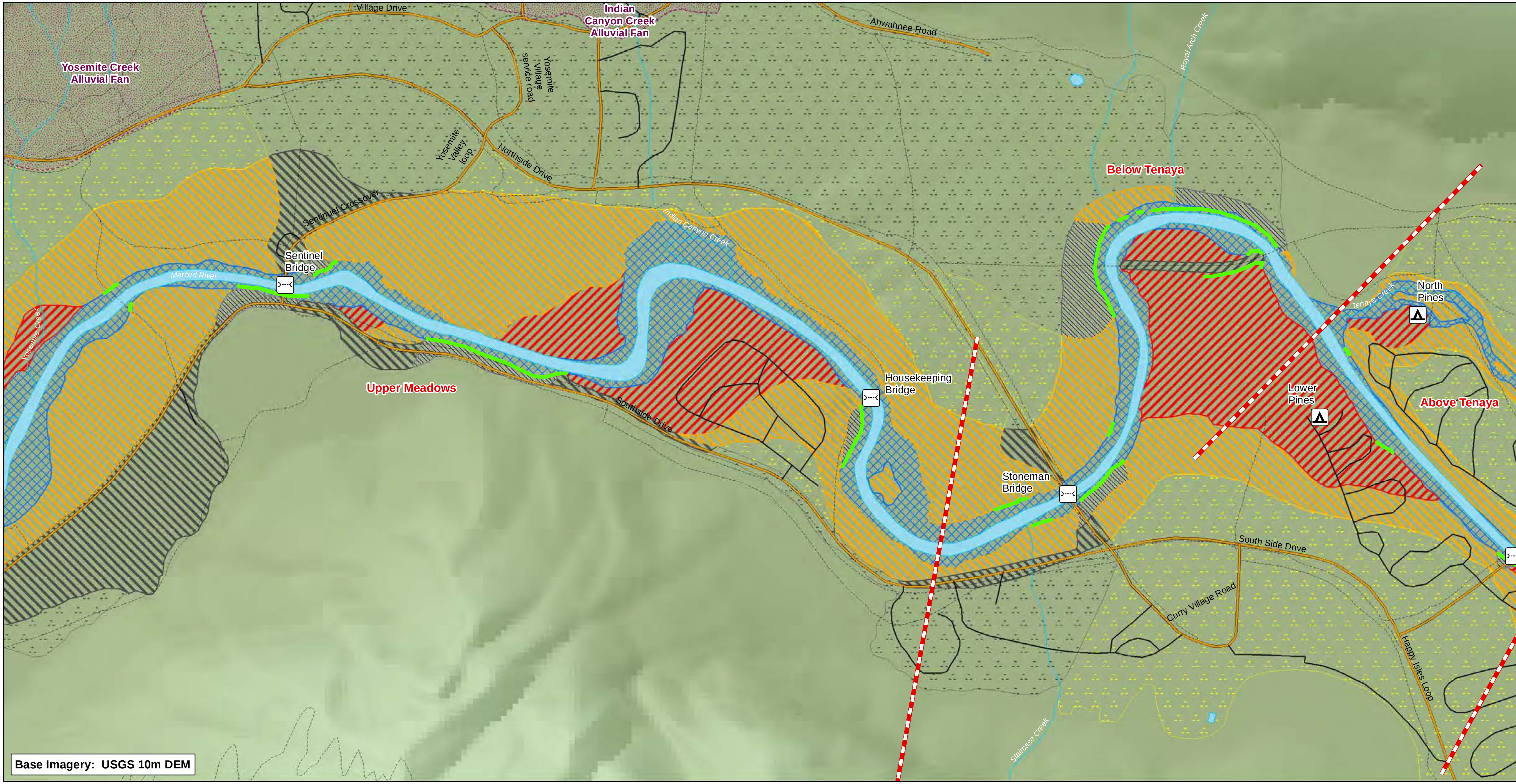
Coordinate System:
NAD 1983 UTM Zone 11 meters

N E S W

0 75 150 300 Meters



Channel Migration Zone

- Alluvial Fan
- Avulsion Hazard Zone
- Disconnected Avulsion Hazard Zone
- Disconnected Erosion Hazard Area
- Disconnected Valley Alluvium
- Erosion Hazard Area
- Historic Migration Zone
- Protected Disconnected Erosion Hazard Area
- Valley Alluvium

- Bridge
- Campground
- Picnic Area
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Merced River
Yosemite National Park

Channel Migration Zone Map Series

Merced River Channel Migration Zones within Yosemite Valley

Map 2 of 6

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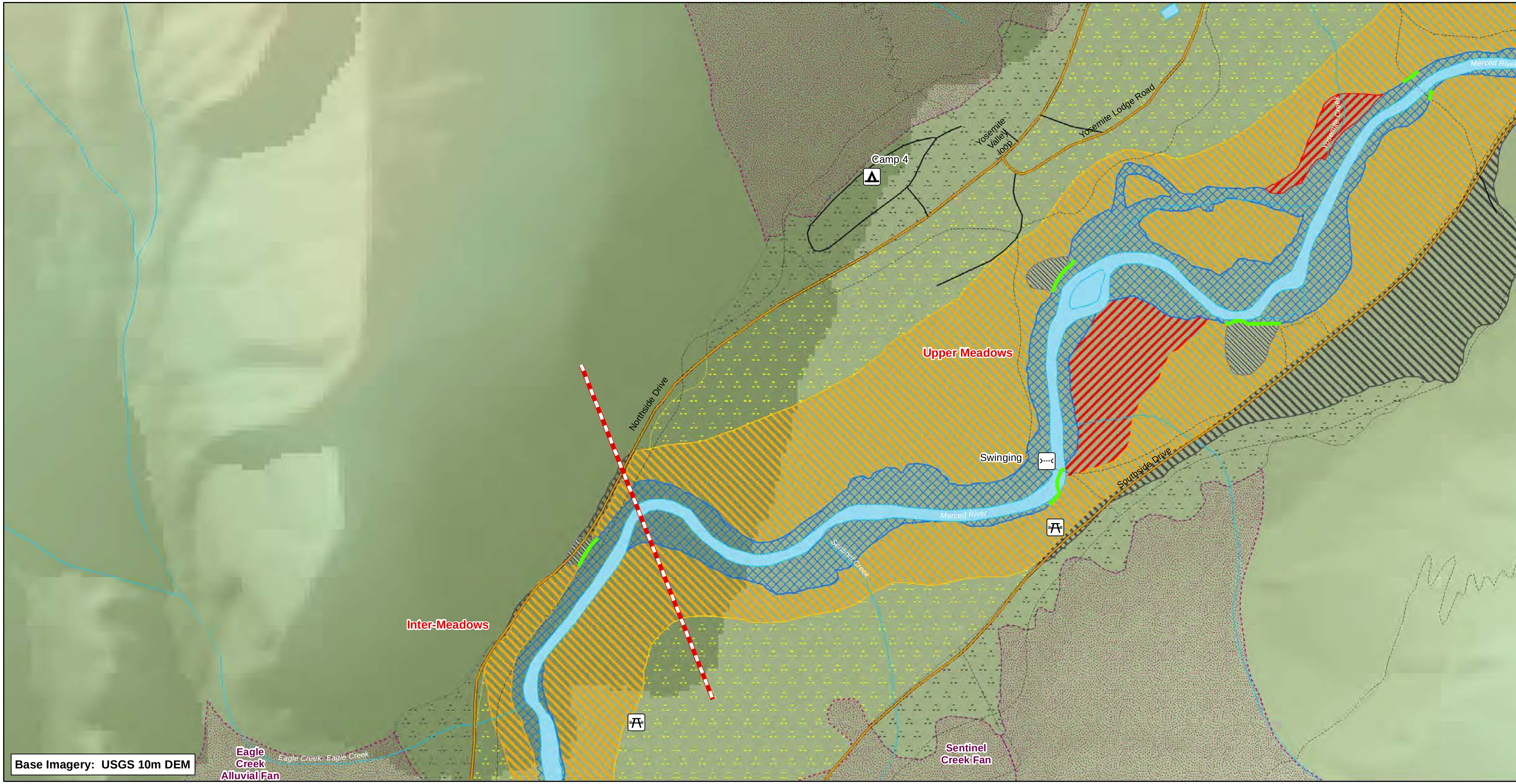
Coordinate System:
NAD 1983 UTM Zone 11 meters

0 75 150 300 Meters



Channel Migration Zone

- Alluvial Fan
- Avulsion Hazard Zone
- Disconnected Avulsion Hazard Zone
- Disconnected Erosion Hazard Area
- Disconnected Valley Alluvium
- Erosion Hazard Area
- Historic Migration Zone
- Protected Disconnected Erosion Hazard Area
- Valley Alluvium

- Bridge
- Campground
- Picnic Area
- Waterfall

- Revetment Location
- Geomorphic Reach Break
- Primary Rd
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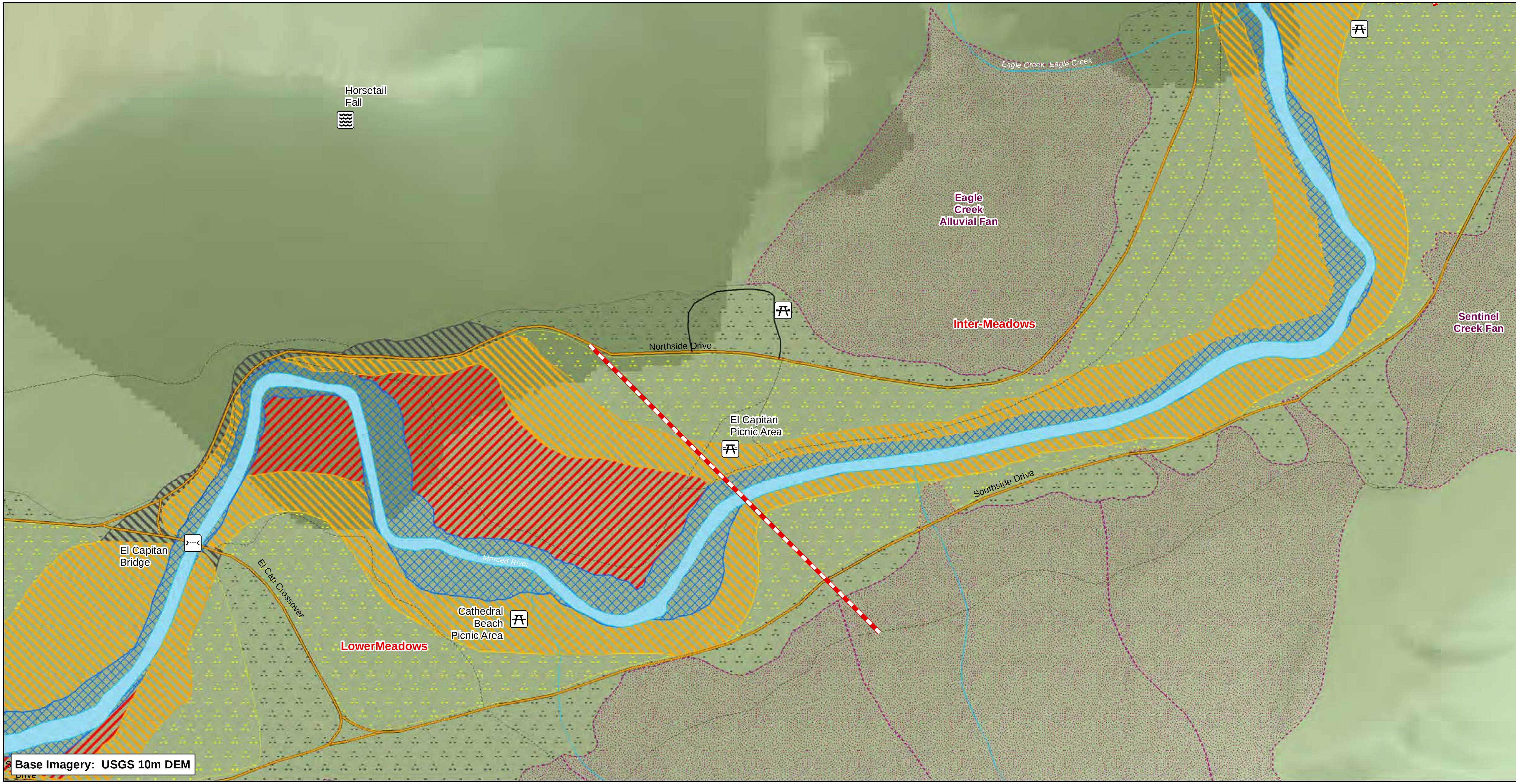

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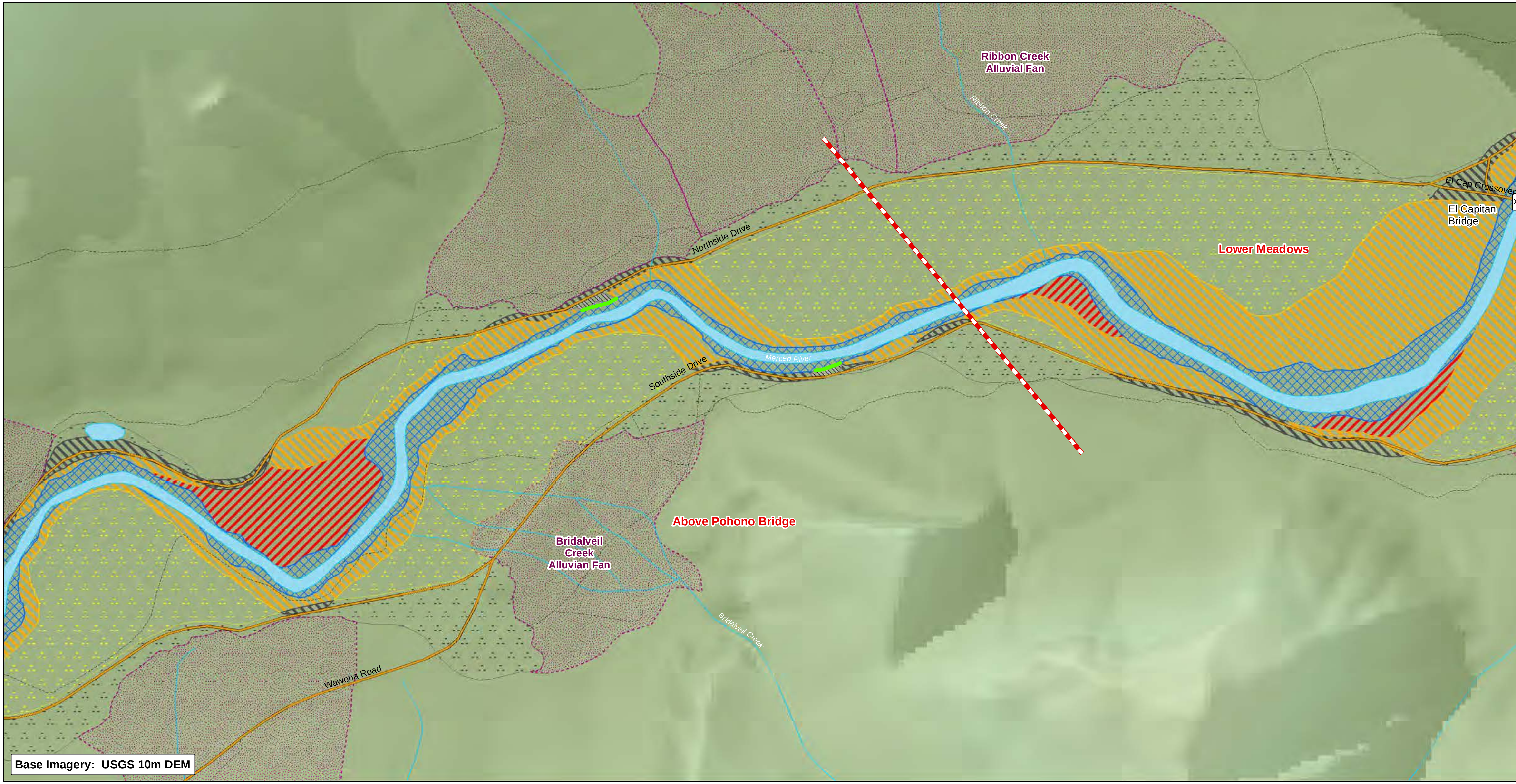

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Channel Migration Zone Map Series

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Map 5 of 6

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Map 6 of 6

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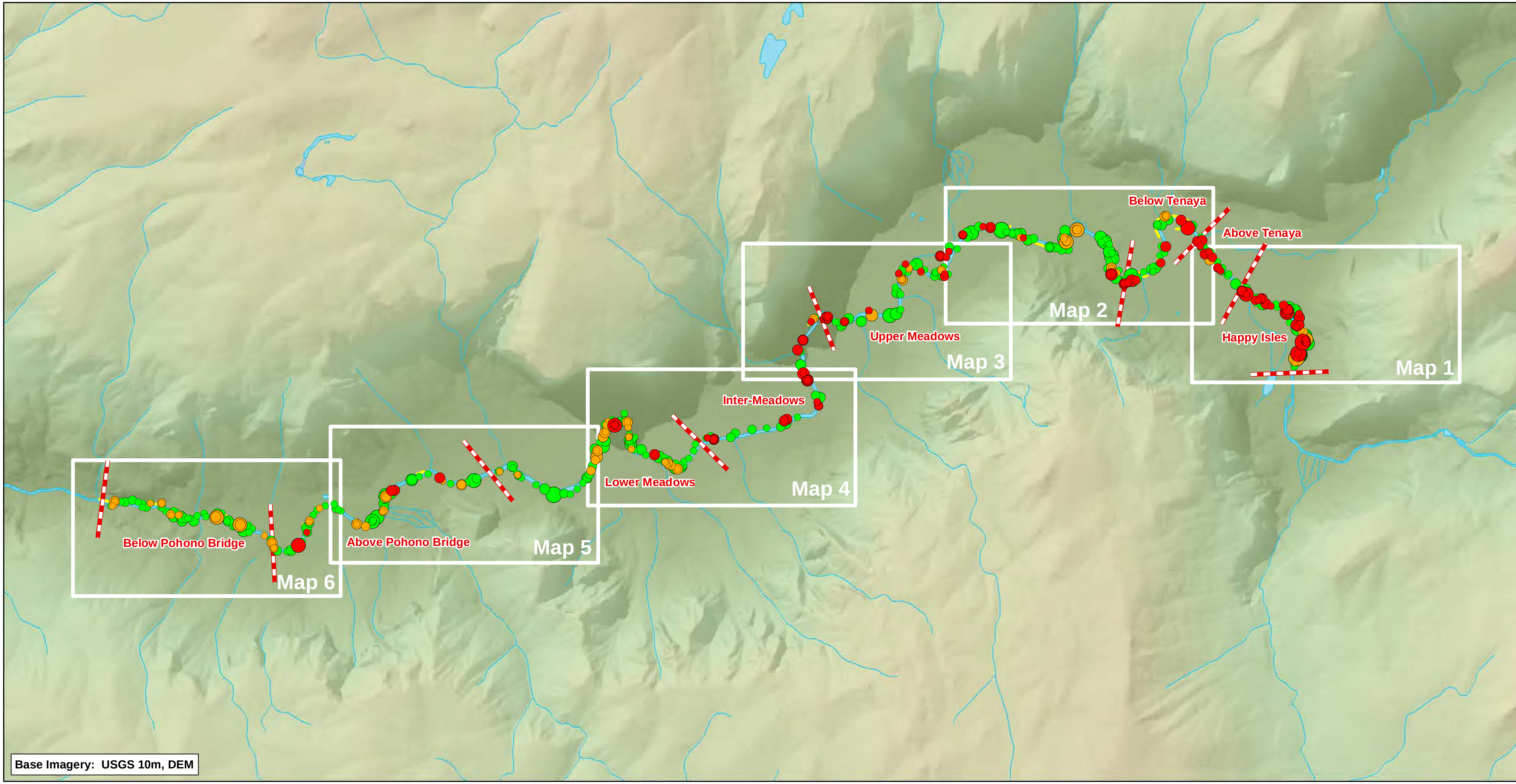

Single Piece DBH	Touching 1 (2) DBH	>3 Pieces (Jam) DBH
0.2 - 0.5	0.2 - 0.5	0.2 - 0.5
0.5 - 0.75	0.5 - 0.75	0.5 - 0.75
0.75 - 1.0	0.75 - 1.0	0.75 - 1.0
1.0 - 1.25	1.0 - 1.25	1.0 - 1.25
1.25 - 1.5	1.25 - 1.5	1.25 - 1.5
> 2	> 2	> 2

- Geomorphic Reach Break
- Revetment Location
- Stream
- Waterbody

Merced River
Yosemite National Park

Large Woody Debris Map Series

Distribution of Merced River Large Woody Debris within Yosemite Valley

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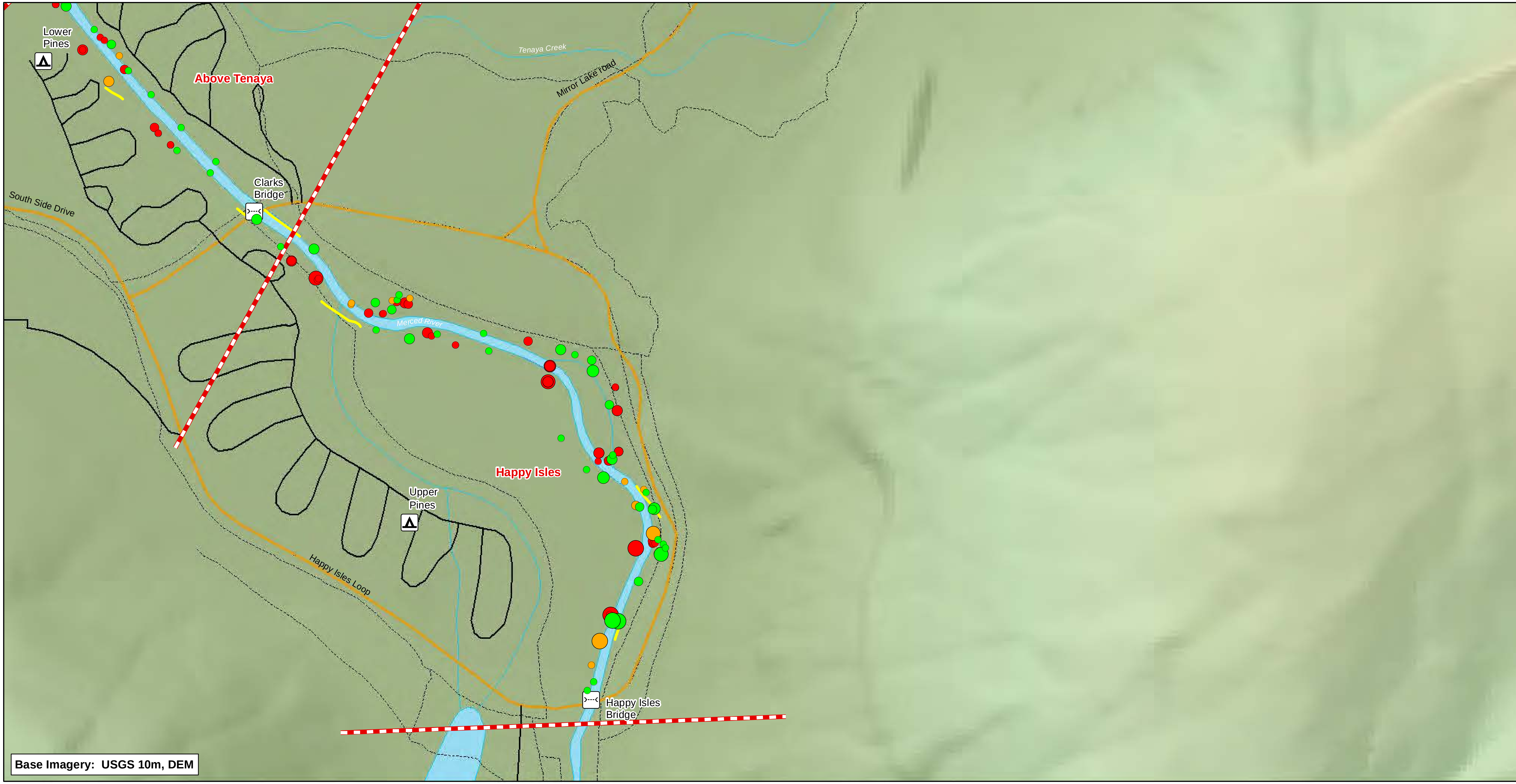

Single Piece DBH	Touching 1 (2) DBH	>3 Pieces (Jam) DBH
0.2 - 0.5	0.2 - 0.5	0.2 - 0.5
0.5 - 0.75	0.5 - 0.75	0.5 - 0.75
0.75 - 1.0	0.75 - 1.0	0.75 - 1.0
1.0 - 1.25	1.0 - 1.25	1.0 - 1.25
1.25 - 1.5	1.25 - 1.5	1.25 - 1.5
> 2	> 2	> 2

- Bridge
- Campground
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- Waterfall

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Merced River
Yosemite National Park

Large Woody Debris Map Series

Distribution of Merced River Large Woody Debris within Yosemite Valley

Map 1 of 6

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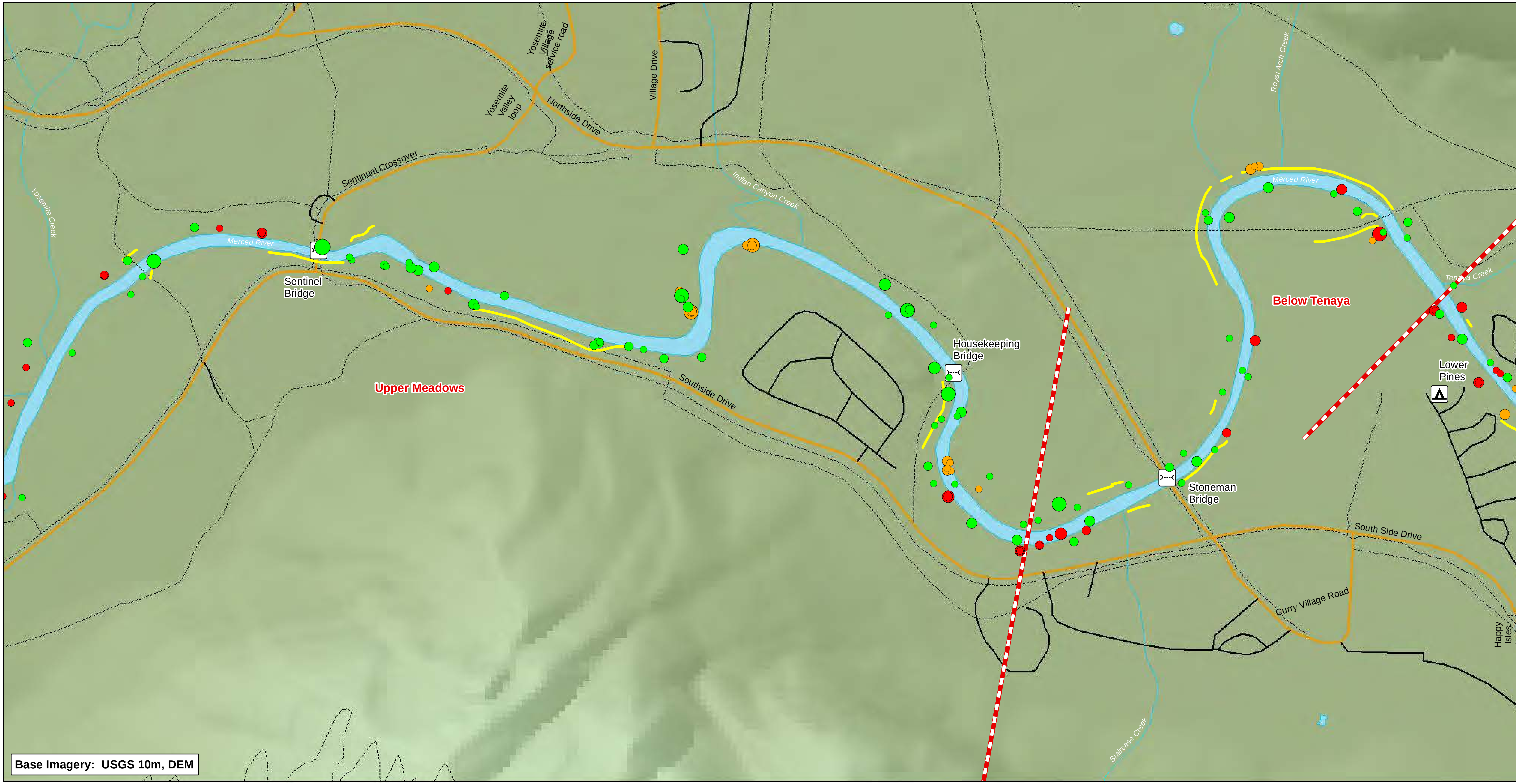

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0.5 - 0.75	0.5 - 0.75	0.5 - 0.75
0.75 - 1.0	0.75 - 1.0	0.75 - 1.0
1.0 - 1.25	1.0 - 1.25	1.0 - 1.25
1.25 - 1.5	1.25 - 1.5	1.25 - 1.5
> 2	> 2	> 2

Bridge
Campground
Picnic Area
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Geomorphic Reach Break
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Primary Rd
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Merced River
Yosemite National Park

Large Woody Debris Map Series

Distribution of Merced River
Large Woody Debris
within Yosemite Valley

Map 2 of 6

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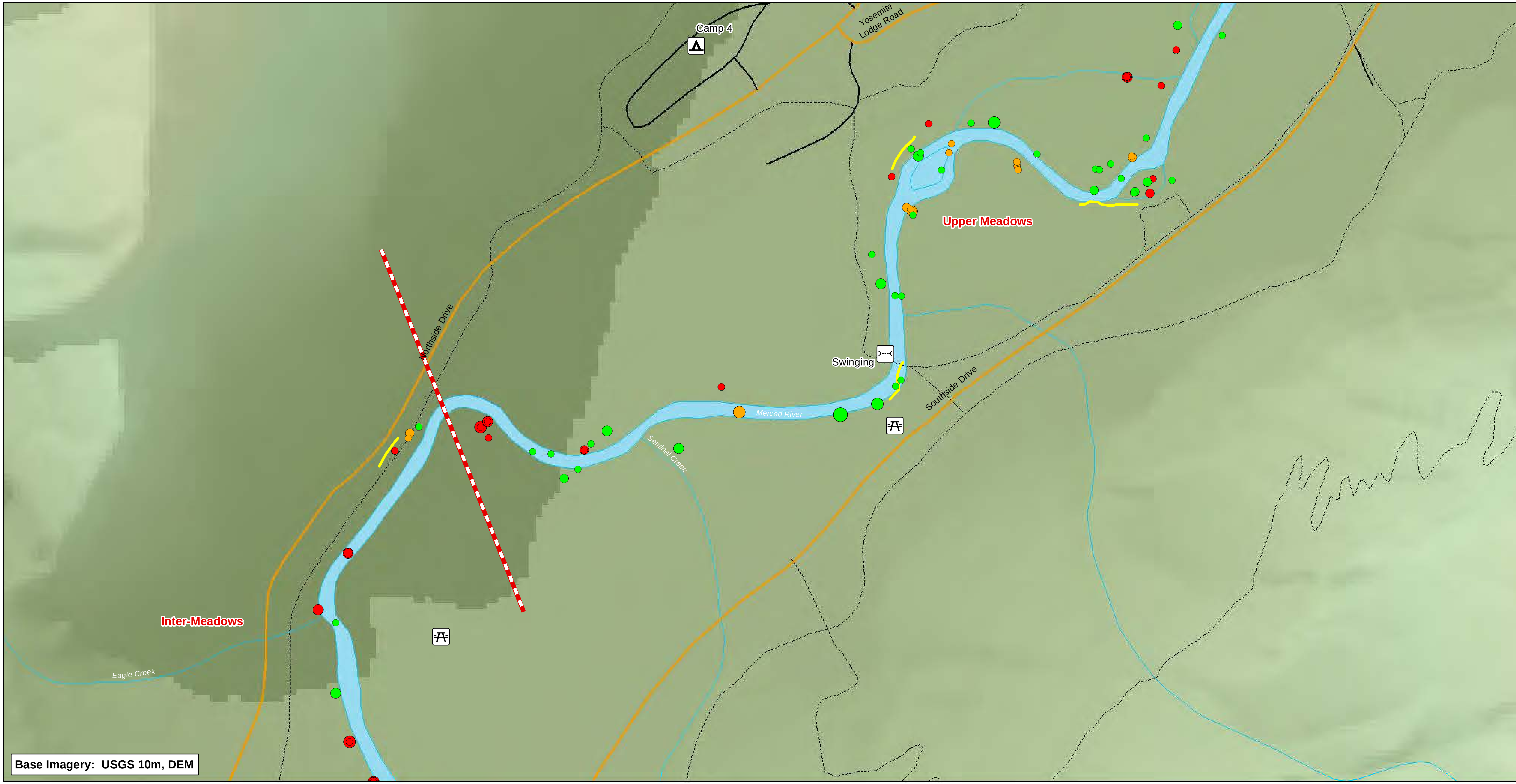

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0.5 - 0.75	0.5 - 0.75	0.5 - 0.75
0.75 - 1.0	0.75 - 1.0	0.75 - 1.0
1.0 - 1.25	1.0 - 1.25	1.0 - 1.25
1.25 - 1.5	1.25 - 1.5	1.25 - 1.5
> 2	> 2	> 2

Bridge
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Merced River
Yosemite National Park

Large Woody Debris Map Series

Distribution of Merced River Large Woody Debris within Yosemite Valley

Map 3 of 6

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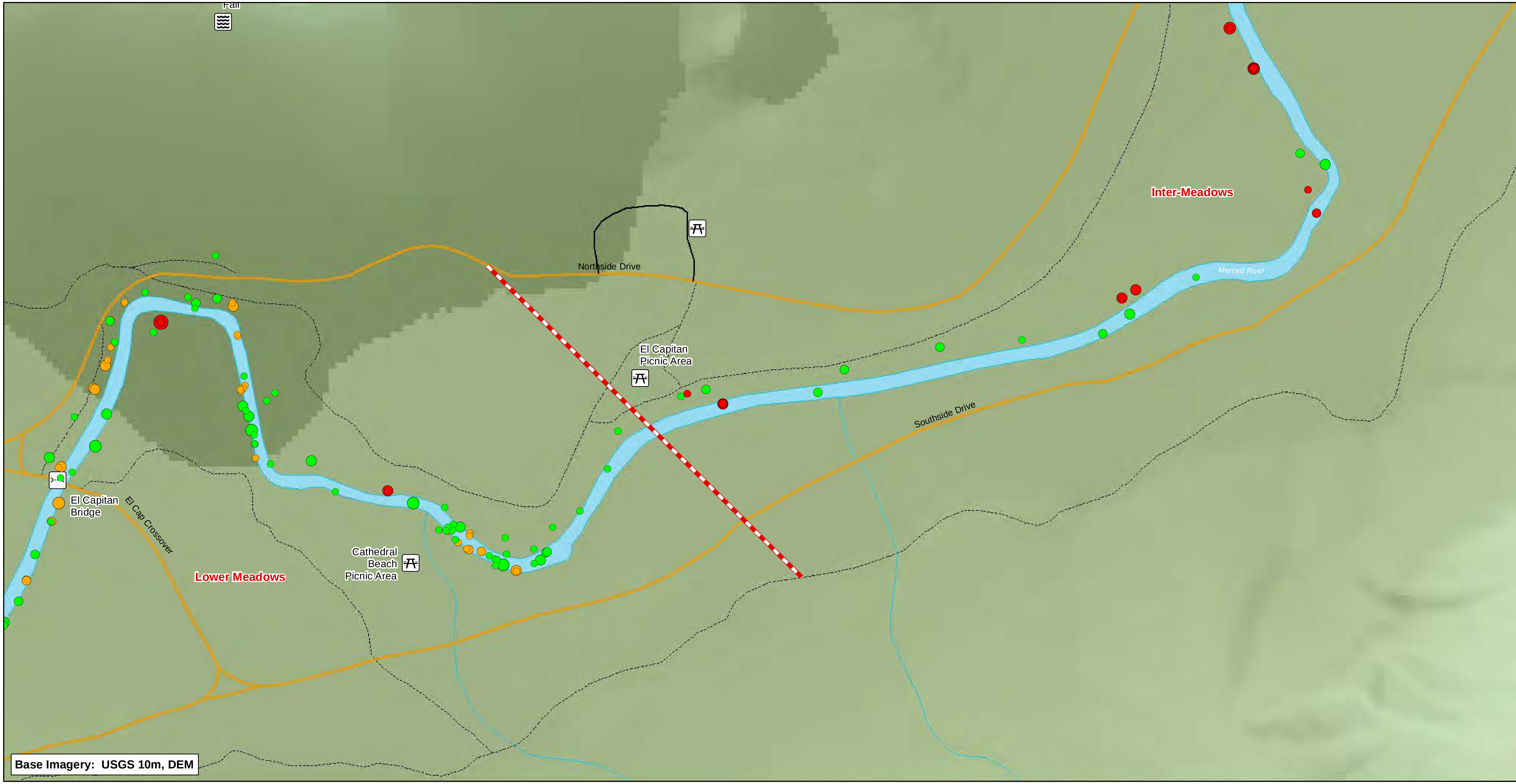

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0.75 - 1.0	0.75 - 1.0	0.75 - 1.0
1.0 - 1.25	1.0 - 1.25	1.0 - 1.25
1.25 - 1.5	1.25 - 1.5	1.25 - 1.5
> 2	> 2	> 2

Bridge
Campground
Picnic Area
Waterfall

Geomorphic Reach Break
Revetment Location
Primary Rd
Secondary/Local Rd
Trail
Stream
Waterbody

Merced River
Yosemite National Park

Large Woody Debris Map Series

Distribution of Merced River Large Woody Debris within Yosemite Valley

Map 4 of 6

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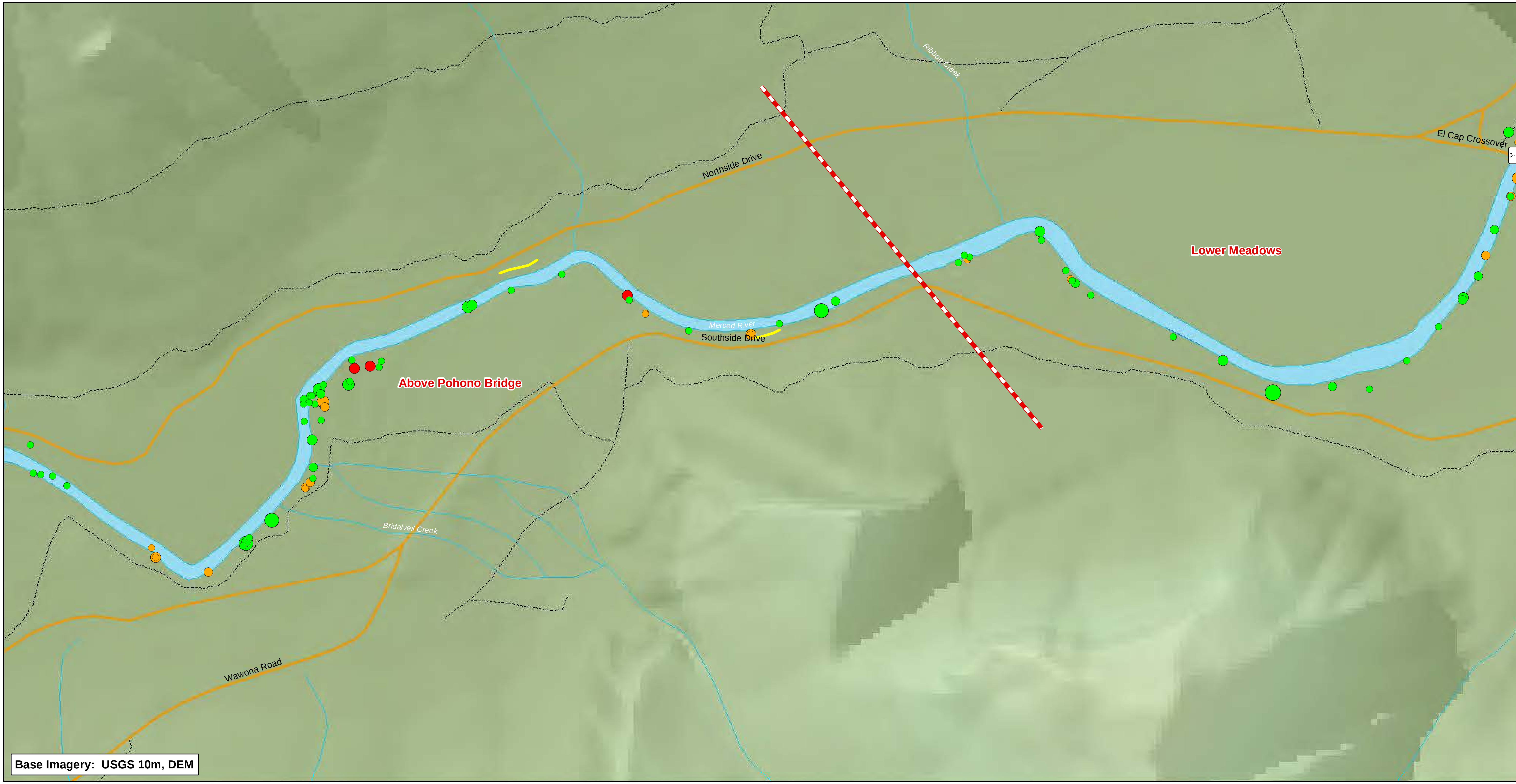

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0.75 - 1.0	0.75 - 1.0	0.75 - 1.0
1.0 - 1.25	1.0 - 1.25	1.0 - 1.25
1.25 - 1.5	1.25 - 1.5	1.25 - 1.5
> 2	> 2	> 2

Bridge
Campground
Picnic Area
Waterfall

Geomorphic Reach Break
Revetment Location
Primary Rd
Secondary/Local Rd
Trail
Stream
Waterbody

Merced River
Yosemite National Park

Large Woody Debris Map Series

Distribution of Merced River Large Woody Debris within Yosemite Valley

Map 5 of 6

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N S W E

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0.75 - 1.0	0.75 - 1.0	0.75 - 1.0
1.0 - 1.25	1.0 - 1.25	1.0 - 1.25
1.25 - 1.5	1.25 - 1.5	1.25 - 1.5
> 2	> 2	> 2

Bridge
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Yosemite National Park

Large Woody Debris Map Series

Distribution of Merced River Large Woody Debris within Yosemite Valley

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N, E, S, W

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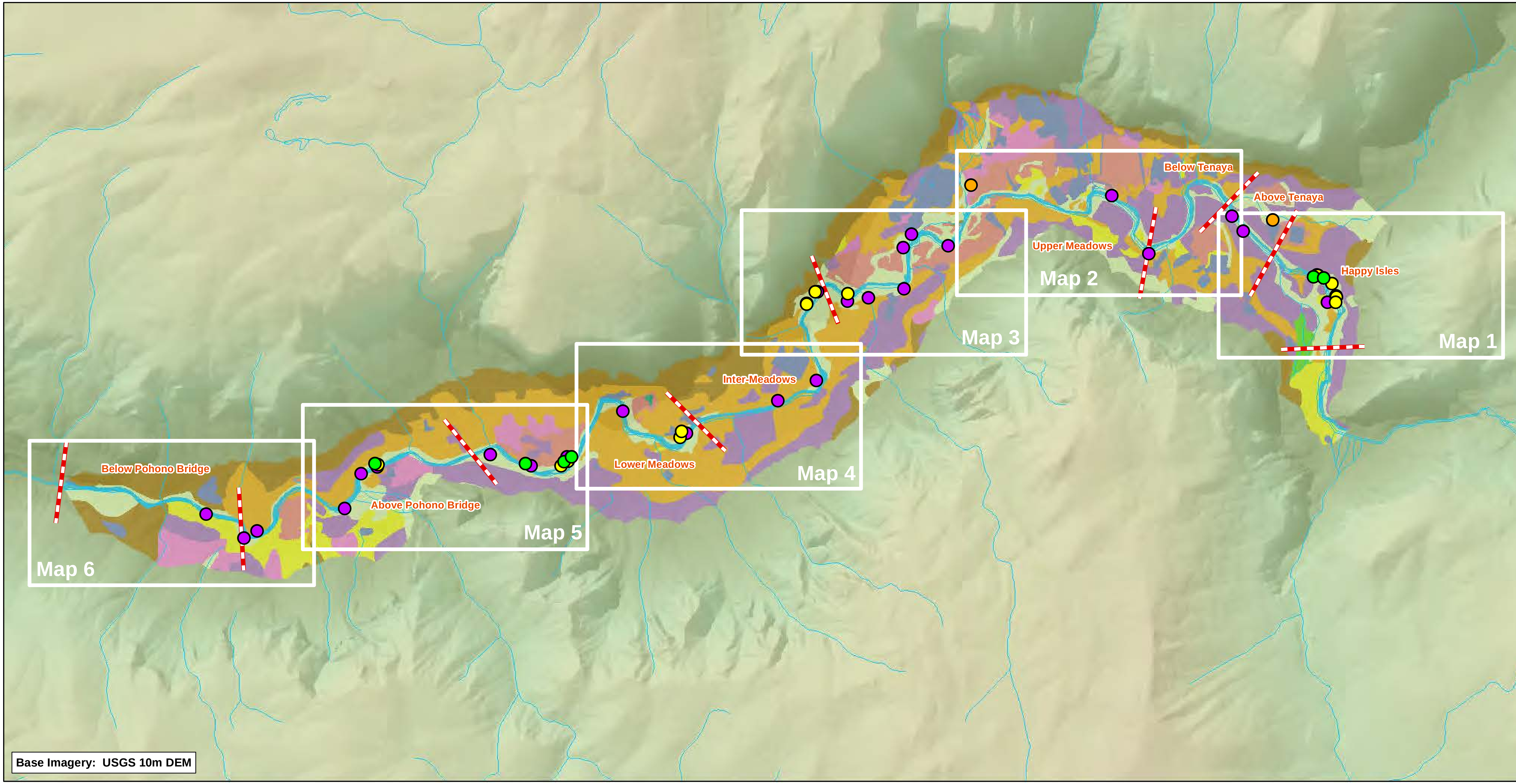

Wildlife Habitat Relationship Types

- Black Oak Woodland
- Fresh Emergent Wetland
- Lacustrine
- Montane Hardwood
- Montane Hardwood Conifer
- Montane Riparian
- Ponderosa Pine
- Riverine
- Sierra Mixed Conifer
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- Bat Observation
- July 2010, Amphibian/Reptile Observation
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Merced River
Yosemite National Park

Wildlife Habitat Relationships Map Series

Wildlife Habitat Relationship Types along the Merced River (data from Espinoza et al. [2010])

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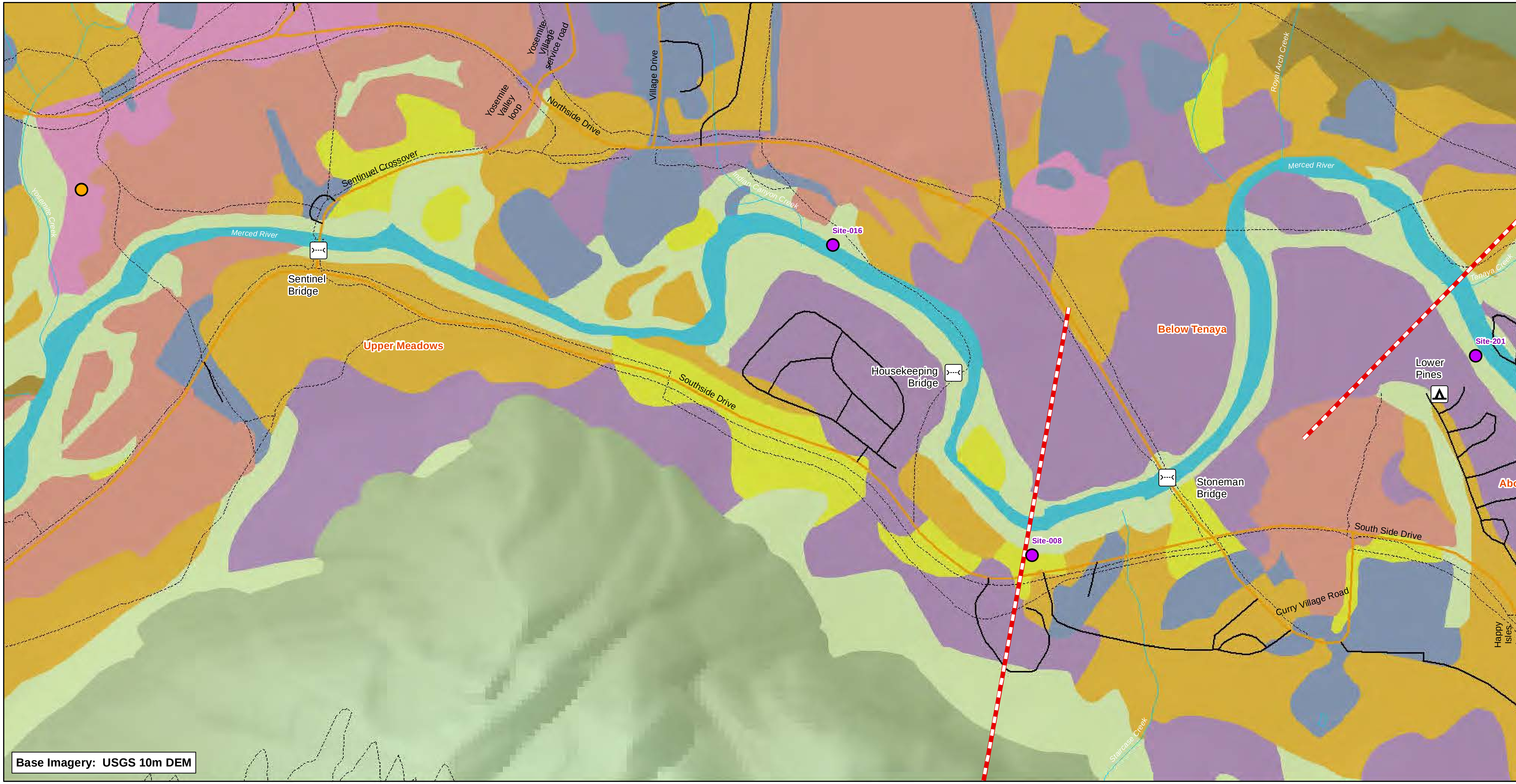

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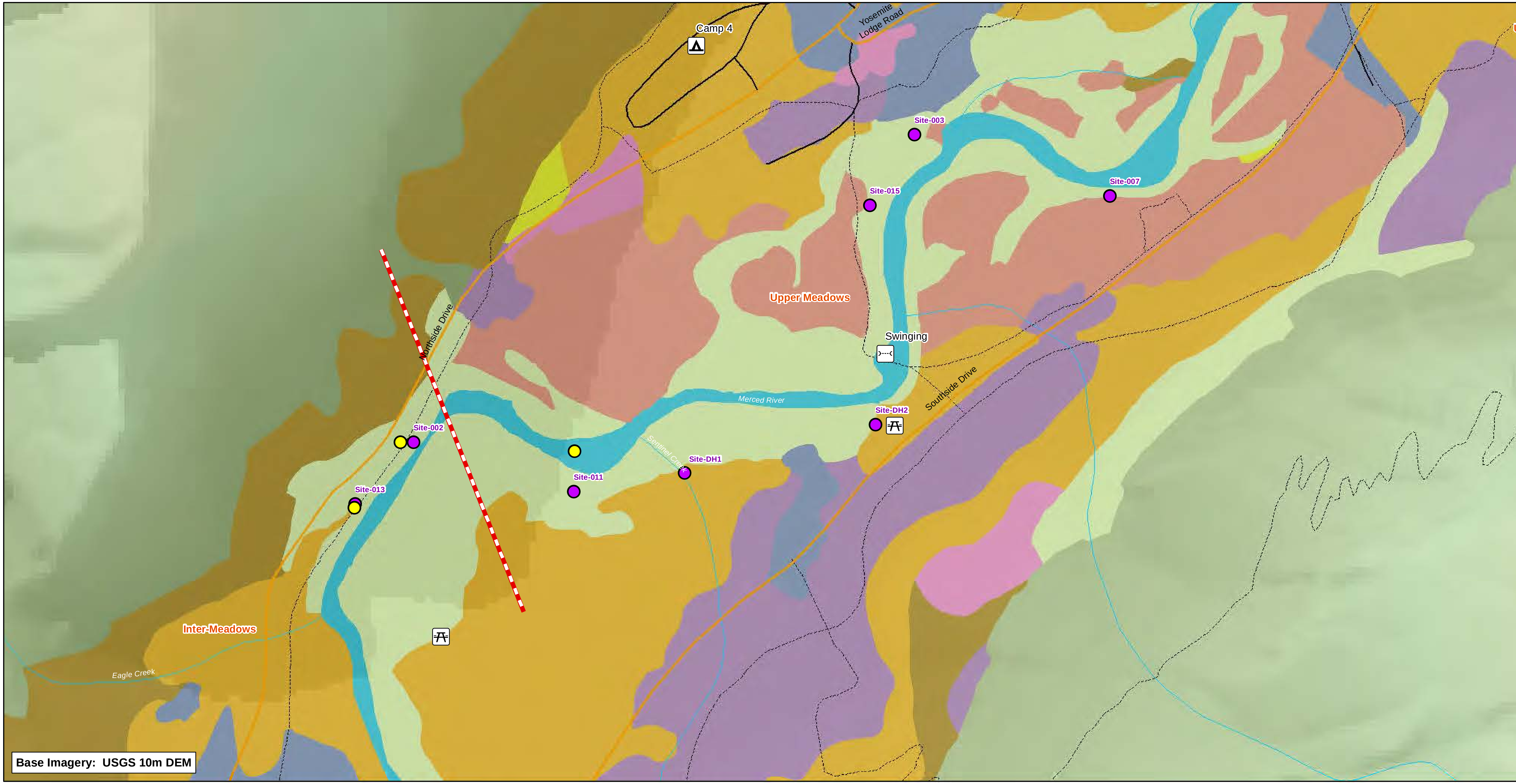

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Wildlife Habitat Relationship Types

Black Oak Woodland	Urban	Bridge	Geomorphic Reach Break
Fresh Emergent Wetland	Wet Meadow	Campground	Primary Rd
Lacustrine	Bat Observation	Picnic Area	Secondary/Local Rd
Montane Hardwood	July 2010, Amphibian/Reptile Observation	Waterfall	Trail
Montane Hardwood Conifer	September 2010, Amphibian/Reptile Observation		Stream
Montane Riparian	NPA Survey Site Location		
Ponderosa Pine			
Riverine			
Sierra Mixed Conifer			

Merced River
Yosemite National Park

Wildlife Habitat Relationships Map Series

Wildlife Habitat Relationship Types along the Merced River (data from Espinoza et al. [2010])

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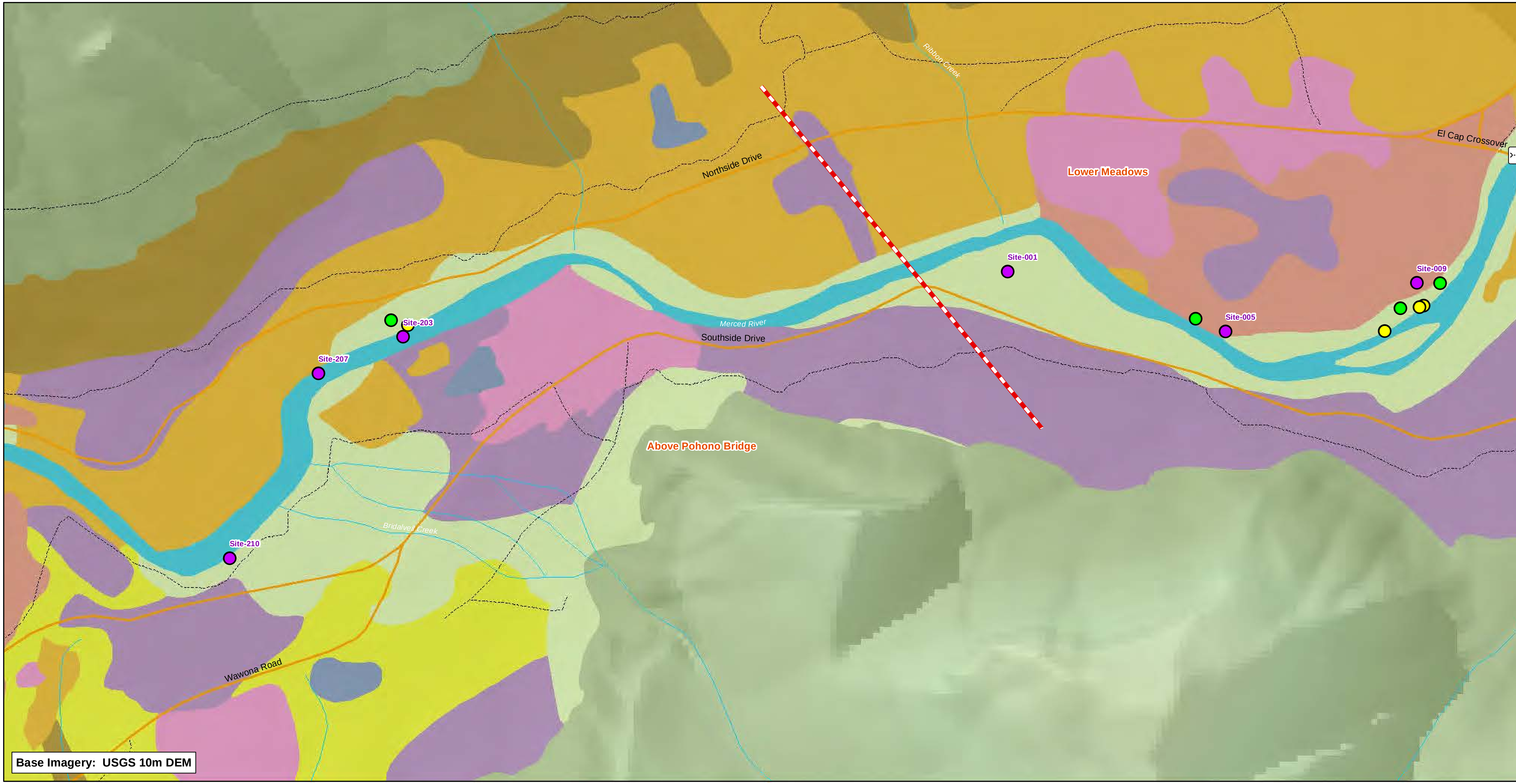

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Merced River
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Wildlife Habitat Relationships Map Series

Wildlife Habitat Relationship Types along the Merced River (data from Espinoza et al. [2010])

Map 5 of 6

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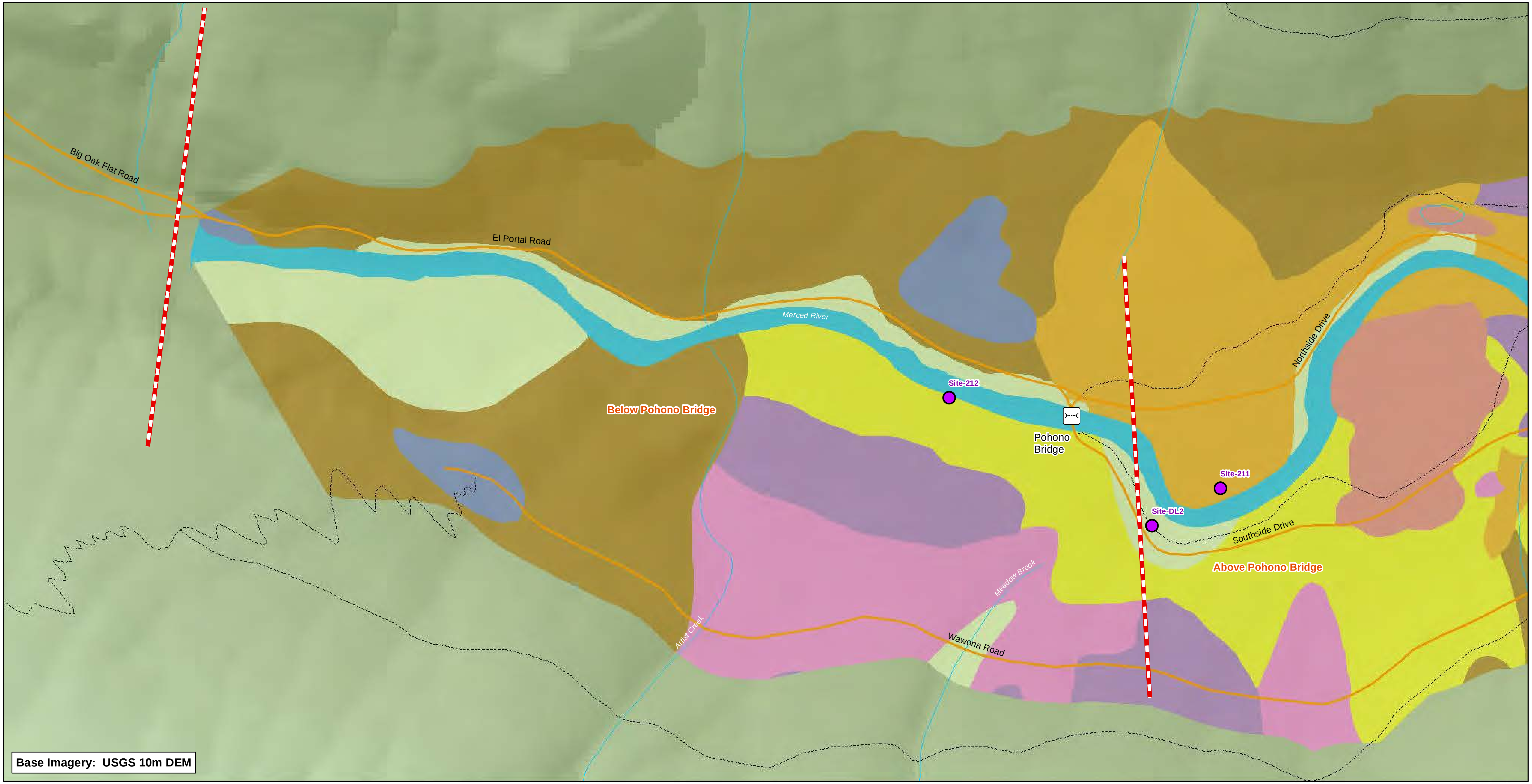

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Merced River
Yosemite National Park

Wildlife Habitat Relationships Map Series

Wildlife Habitat Relationship Types along the Merced River (data from Espinoza et al. [2010])

Map 6 of 6

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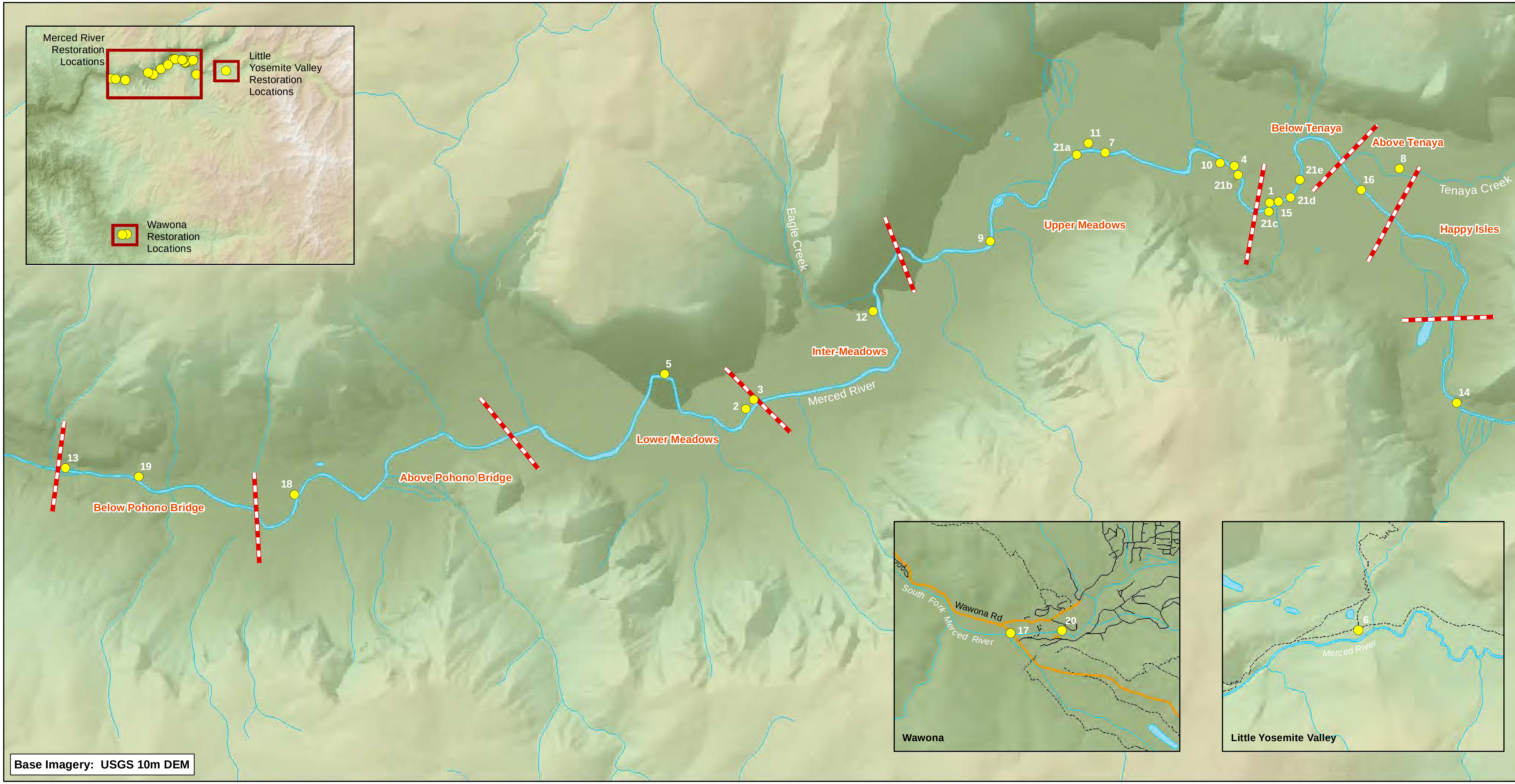

1 - Lower River Campground Restoration, 1991-1994
2 - El Capitan Picnic Area Dumpsite Restoration, 1991-1995
3 - El Capitan Picnic Area Restoration, 1992-1994
4 - Lower River Housekeeping Camp Restoration, 1992
5 - Devil's Elbow Restoration, 1993-1995
6 - Little Yosemite Valley Restoration, 1993-1994
7 - Sentinel Bridge Restoration, 1994-1995
8 - North Pines Group Camp Restoration, 1994-1995
9 - Swinging Bridge Restoration, 1994-1995
10 - Housekeeping Camp Restoration, 1995
11 - Cooks Meadow Restoration, 1998-2005
12 - Eagle Creek Restoration, 2002
13 - Cascades Diversion Dam Removal, 2003-2004
14 - Happy Isles Dam Removal, 2004-2006
15 - Riverbank Restoration below Stoneman Bridge, 2006
16 - Riverbank Restoration below Clark's Bridge, 2006
17 - South Fork Bridge Restoration, 2006
18 - Valley View Pullout Revegetation, 2007
19 - El Portal Road Rehabilitation at The Narrows, 2008
20 - Wawona Utility Crossing, 2010
21a - Yosemite Valley Abandoned Utilities Removal, 2010
21b - Yosemite Valley Abandoned Utilities Removal, 2010
21c - Yosemite Valley Abandoned Utilities Removal, 2010
21d - Yosemite Valley Abandoned Utilities Removal, 2010
21e - Yosemite Valley Abandoned Utilities Removal, 2010
Geomorphic Reach Break
Restoration Location

Merced River
Yosemite National Park

Restoration Location Map

Locations of Merced River
Restoration Projects 1991-2010

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N W E S
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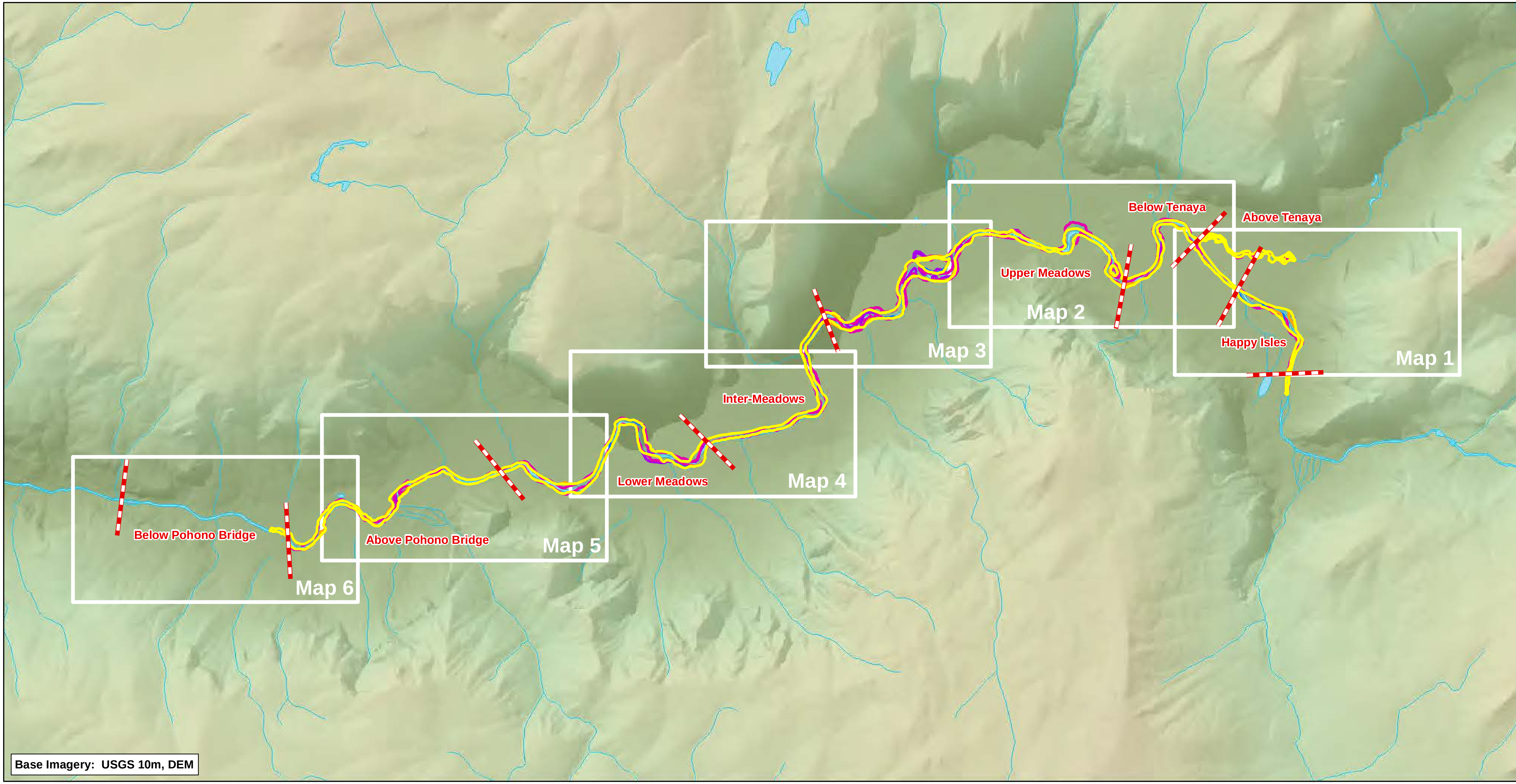

Historic Channel Alignments

2009 Channel	Geomorphic Reach
2005 Channel	Stream
1987 Channel	Waterbody
1944 Channel	
1934 Channel	

Note: Where the channel lines overlap only the latest year is visible.

Merced River
Yosemite National Park

Historical Channels Map Series

Historical Channel Alignments for the Merced River

Index

Cardno ENTRIX
2300 Clayton Road
Concord, CA 94520
ph (925) 935-9920
fx (925) 935-5368
www.cardnoentrix.com

Coordinate System:
NAD 1983 UTM Zone 11 meters

0 375 750 1,500 Meters

Historic Channel Alignments

- 2009 Channel
- 2005 Channel
- 1987 Channel
- 1944 Channel
- 1934 Channel

- Bridge
- Campground
- Picnic Area
- Waterfall

- Geomorphic Reach
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

Note: Where the channel lines overlap only the latest year is visible.

Merced River
Yosemite National Park

Historical Channels Map Series

Historical Channel Alignments for the Merced River

Map 1 of 6

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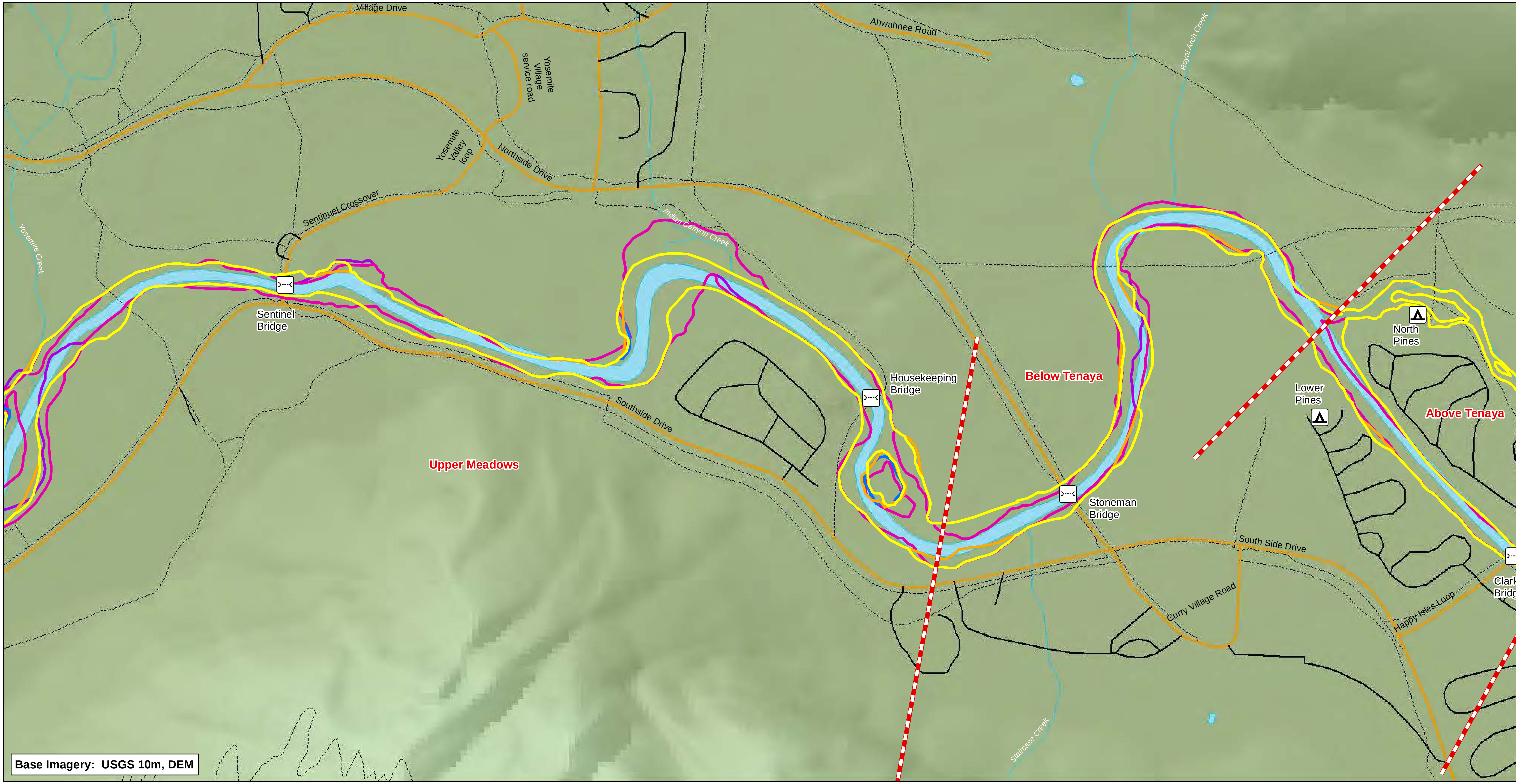
N S E W

0 75 150 300 Meters



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Merced River
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Historical Channels Map Series

Historical Channel Alignments for the Merced River

Map 2 of 6

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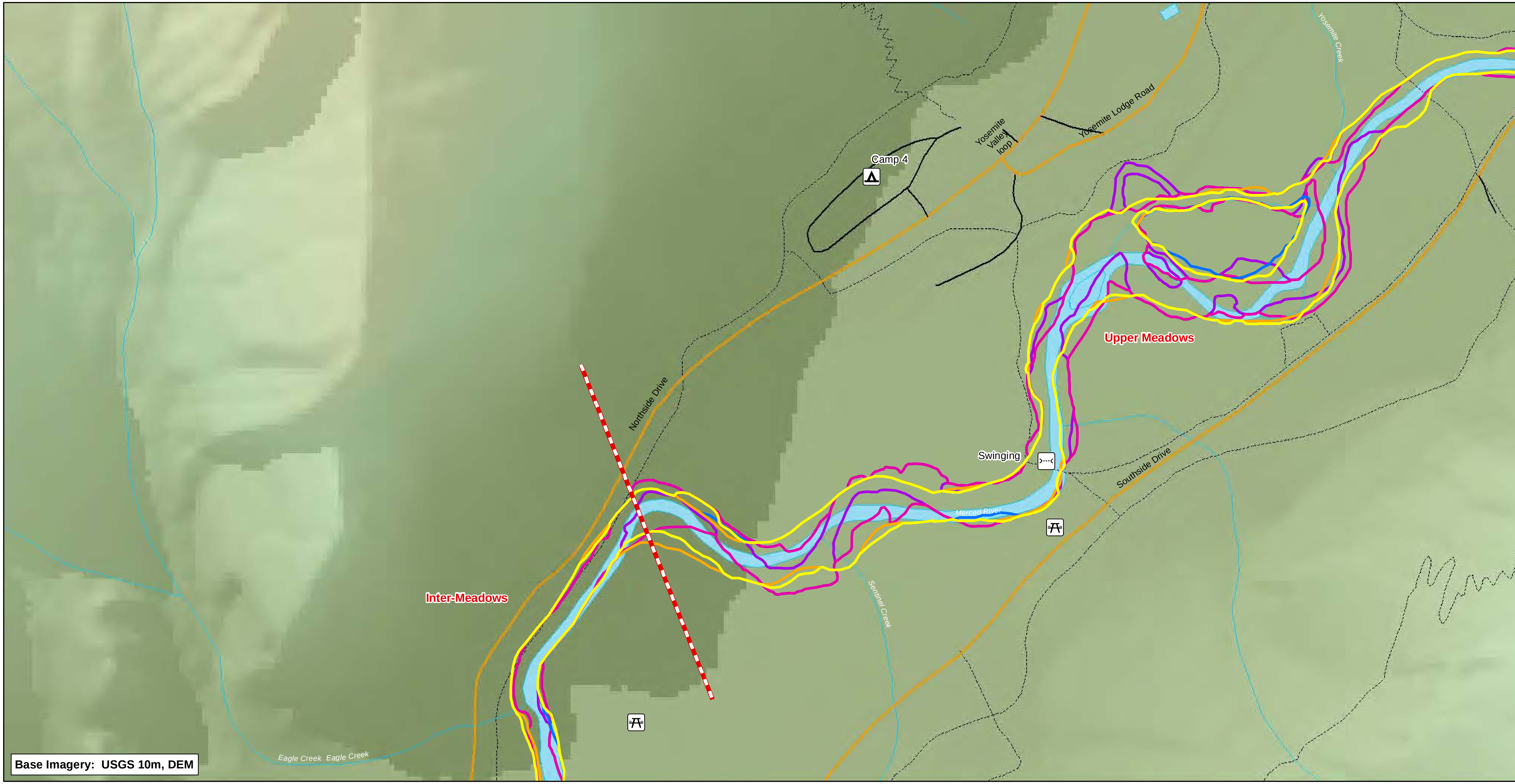

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Historical Channels Map Series

Historical Channel Alignments for the Merced River

Map 3 of 6

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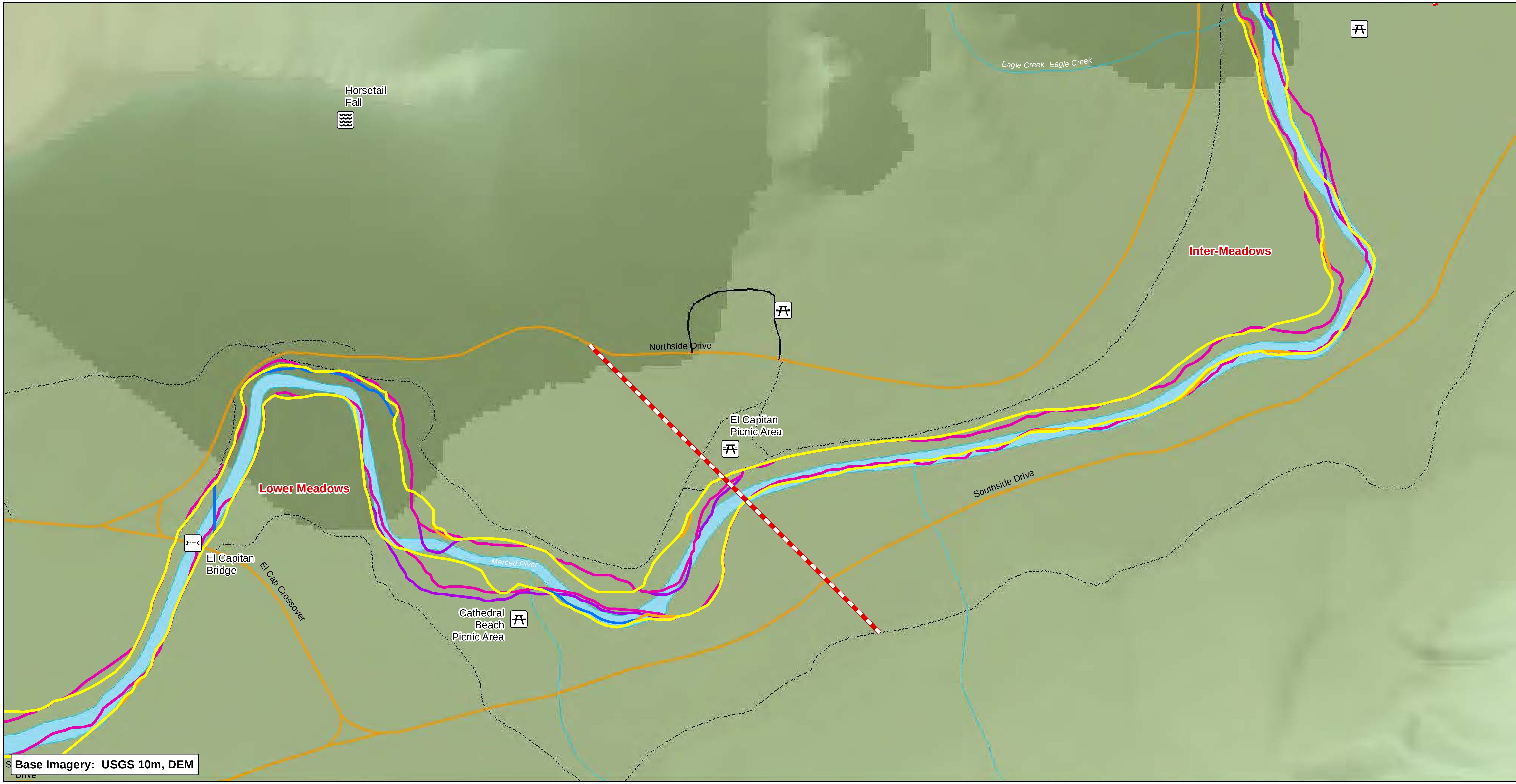

Historic Channel Alignments

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- Geomorphic Reach
- Primary Rd
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- Trail
- Stream
- Waterbody

Note: Where the channel lines overlap only the latest year is visible.

Merced River
Yosemite National Park

Historical Channels Map Series

Historical Channel Alignments for the Merced River

Map 4 of 6

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Coordinate System:
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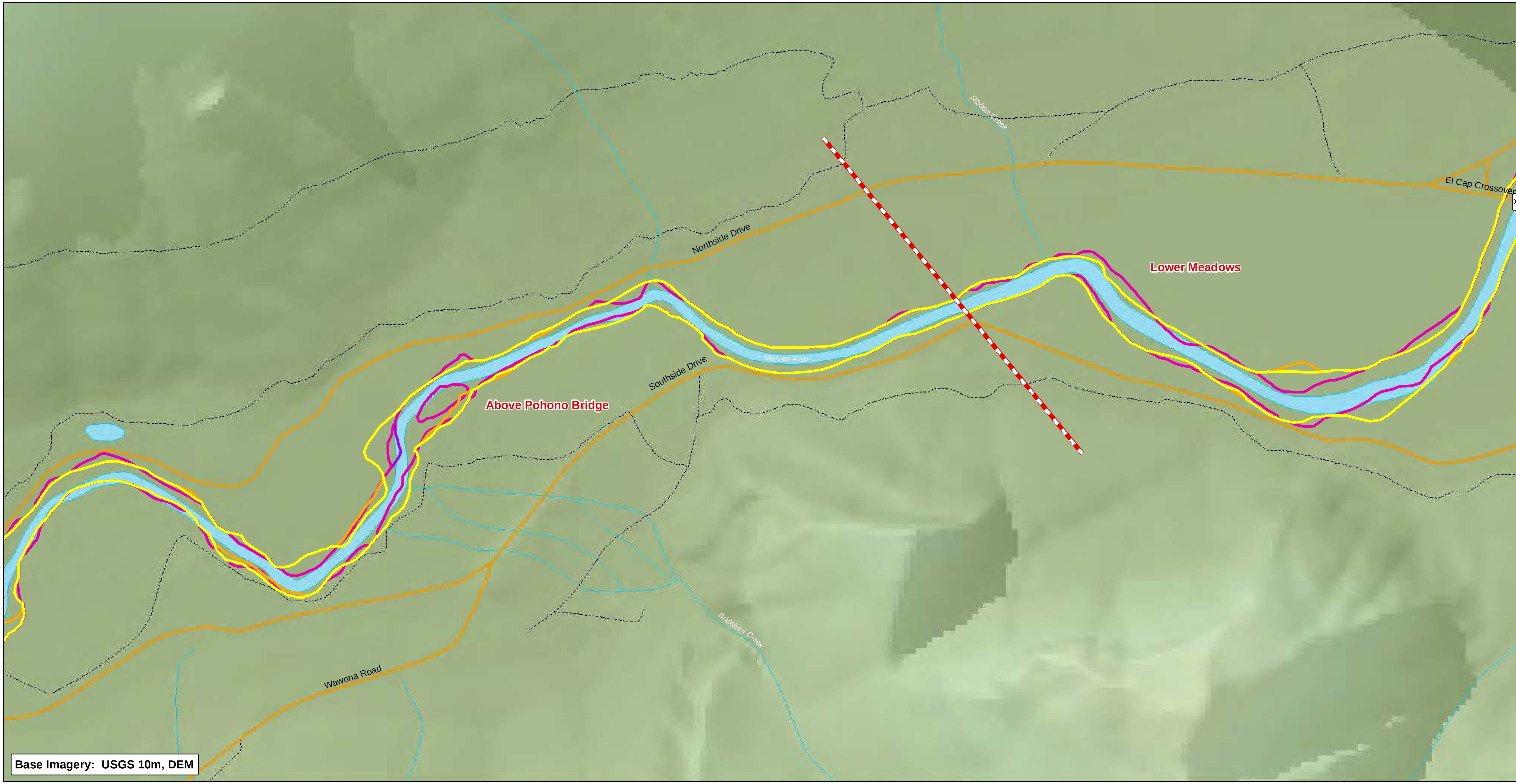
N S E W

0 75 150 300 Meters



Historic Channel Alignments

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- 2005 Channel
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- 1934 Channel

- Bridge
- Campground
- Picnic Area
- Waterfall

- Geomorphic Reach
- Primary Rd
- Secondary/Local Rd
- Trail
- Stream
- Waterbody

Note: Where the channel lines overlap only the latest year is visible.

Merced River
Yosemite National Park

Historical Channels Map Series

Historical Channel Alignments for the Merced River

Map 5 of 6

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Coordinate System:
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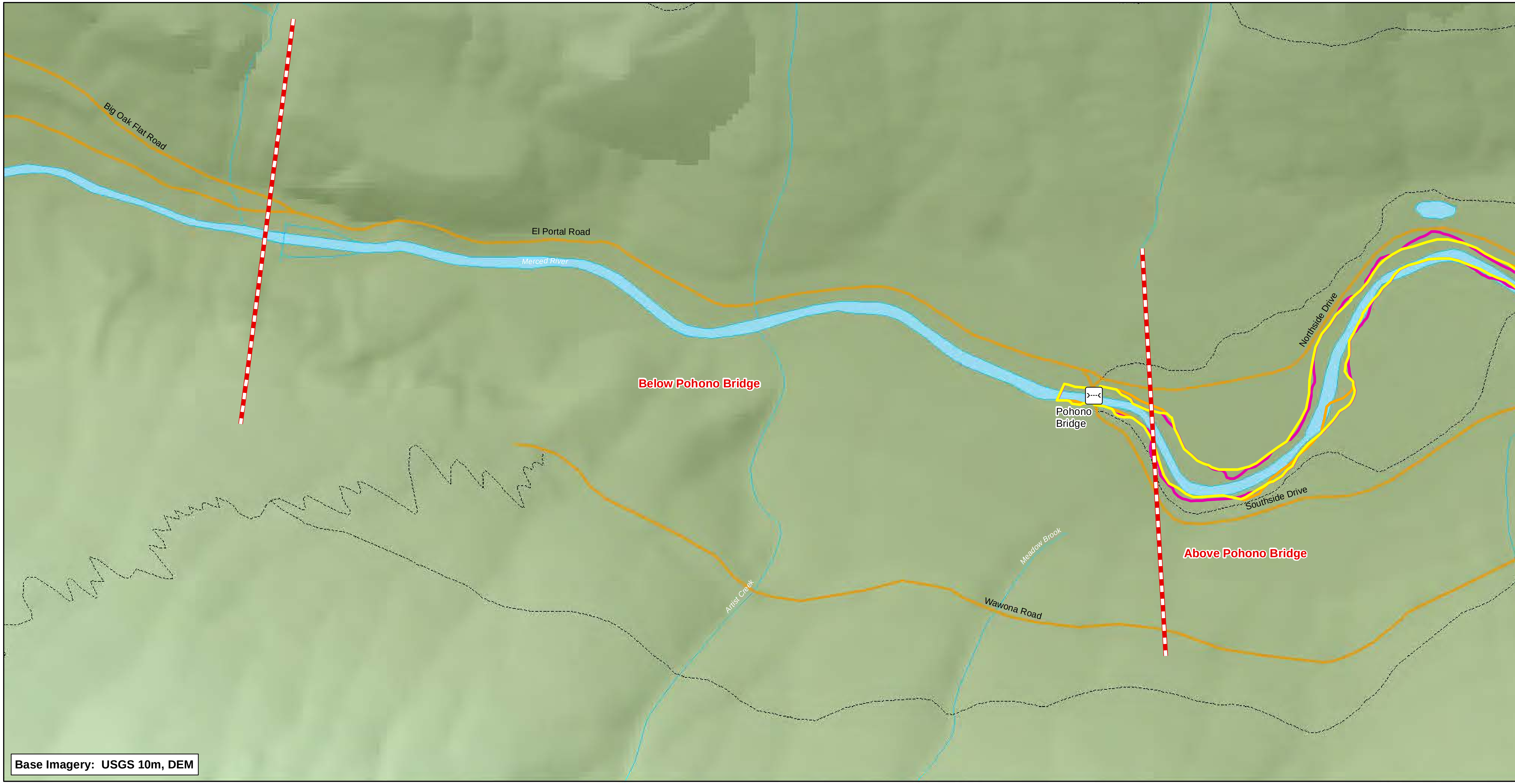
N W E S

0 75 150 300 Meters



Historic Channel Alignments

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- Geomorphic Reach
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- Waterbody

Note: Where the channel lines overlap only the latest year is visible.

Merced River
Yosemite National Park

Historical Channels Map Series

Historical Channel Alignments for the Merced River

Map 6 of 6

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N W E S

0 75 150 300 Meters

Appendix B

Broad Vegetation Category

Table B-1: Vegetation Categories

Vegetation	1992 Vegetation Community	1997 Vegetation Community	2010 Vegetation Community
Bare (including Oxbow and Cutoff Channels)	Bare	Sparsely Vegetated Undifferentiated	Bare
	Developed Open Area - Sparse Vegetation	Sparsely Vegetated Riverine Flat	
	Watered Lawn	Sparsely Vegetated to Non-vegetated Exposed Rock	
	Oxbow and Cutoff Channels	Urban/Developed	
Oaks and Conifers	Canyon Live Oak	Canyon Live Oak Forest Alliance	Canyon Live Oak Forest Alliance
	CA Black Oak Woodland	Canyon Live Oak/Whiteleaf Manzanita Forest Association	Canyon Live Oak - Whiteleaf Manzanita Forest
	CA Black Oak Woodland with Encroaching Conifers	Canyon Live Oak-California Laurel Forest Association	California Black Oak Forest Alliance
	Pygmy CA Black Oak Woodland	California Black Oak Forest Alliance	Incense Cedar Forest Alliance
	Developed Ponderosa Pine Forest	California Black Oak/(Bracken Fern) Forest Mapping Unit	Ponderosa Pine - Incense Cedar Forest Alliance
	White Fir - Douglas Fir Forest	Ponderosa Pine Woodland Alliance	Douglas Fir Forest Alliance
	Dense Mixed Coniferous Forest	Ponderosa Pine-Incense-cedar Forest Alliance	Douglas Fir - White Fir - Incense Cedar Forest
	Sparse Ponderosa Pine Scrub	Douglas-fir-(White Fir-Incense-cedar-Ponderosa Pine) Forest Mapping Unit	Douglas Fir - Ponderosa Pine - Incense Cedar Forest
	North Facing Mixed Conifer - Canyon Live Oak Talus	Ponderosa Pine-Incense-cedar-(California Black Oak-Canyon Live Oak)	Ponderosa Pine - Douglas Fir - Canyon Live Oak Forest
	South Facing Mixed Conifer - Canyon Live Oak Talus Forest	Canyon Live Oak-(Ponderosa Pine-Incense-cedar) Forest Superassociation	California Black Oak - Douglas Fir Forrest
	Impacted Mixed Riparian - Conifer Corridor Forest	Douglas-fir-Canyon Live Oak Forest Association	Ponderosa Pine - Incense Cedar - California Black Oak Forest
	Mixed Riparian - Conifer Corridor Forest	California Black Oak-Incense-cedar Forest Association	California Black Oak - Ponderosa Pine Forest
	Developed Open Ponderosa Pine - CA Black Oak		California Black Oak - Incense Cedar Forest
	Open Ponderosa Pine - CA Black Oak Woodland		
Alder (including with Bigleaf Maple and Conifers)	White Alder Riparian Forest	White Alder & Bigleaf Maple Forest Superalliance	White Alder Forest
	Big Leaf Maple Riparian Forest		Incense Cedar - White Alder Forest

Table B-1: Vegetation Categories

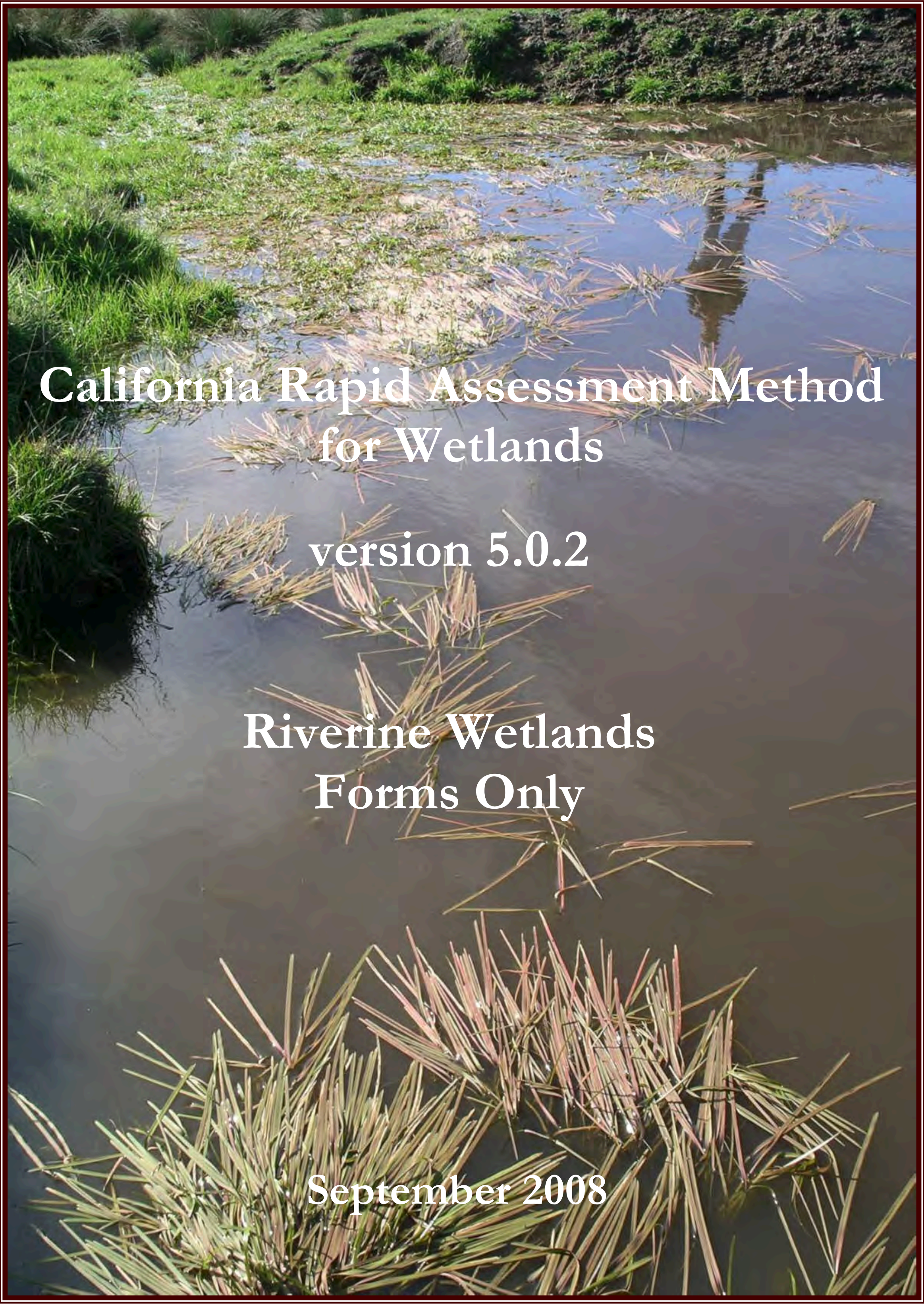
Vegetation	1992 Vegetation Community	1997 Vegetation Community	2010 Vegetation Community
Meadow	Dogbane Meadow	Intermittently to Seasonally Flooded Meadow	Creeping Bent Grassland
	Grass - Sedge Meadow	Semi-permanently to Permanently Flooded Meadow	Dogbane Meadow
	Grass Meadow		Wooly Sedge Meadow
	Carex senta Wet Meadow Border		Blue Wild Rye Herbaceous Alliance
	Carex vesicaria Wet Meadow		Blue Wild Rye - Creeping Bent Herbaceous Alliance
	Mixed Low Meadow		Blue Wild Rye - Mugwort Herbaceous Alliance
			Panicled Bulrush Herbaceous Alliance
Cottonwood (including mixed)	Dense Black Cottonwood - Willow Riparian Forest	Black Cottonwood Temporarily Flooded Forest Alliance	Black Cottonwood Temporarily Flooded Forest Alliance
Willow Riparian	Sandbar Willow Riparian Woodland	Willow spp. Riparian Shrubland Mapping Unit	Shining Willow Riparian Scrub
			Dusky Willow Riparian Scrub

Appendix C

CRAM Attributes, Metrics, and Data Sheets

C.1 California Rapid Assessment Method for Wetlands Manual

Version 5—Riverine Wetlands Forms Only



California Rapid Assessment Method for Wetlands

version 5.0.2

Riverine Wetlands Forms Only

September 2008

Basic Information Sheet: Riverine Wetlands

Your Name:	
CRAM Site ID:	
Assessment Area Name:	
Date (m/d/y):	
Assessment Team Members for This AA	

Average Bankfull Width:

Approximate Length of AA (10 times bankfull width, min 100 m, max 200 m)**:**

Wetland Sub-type:

□ Confined □ Non-confined

AA Category:

□ Restoration □ Mitigation □ Impacted □ Other

Did the river/stream have flowing water at the time of the assessment? □ yes □ no

What is the apparent hydrologic flow regime of the reach you are assessing?

The hydrologic flow regime of a stream describes the frequency with which the channel conducts water. *Perennial* streams conduct water all year long, whereas *ephemeral* streams conduct water only during and immediately following precipitation events. *Intermittent* streams are dry for part of the year, but conduct water for periods longer than ephemeral streams, as a function of watershed size and water source.

□ perennial □ ephemeral □ intermittent

Photo Identification Numbers and Description:

	Photo ID No.	**Description**	**Latitude**	**Longitude**	**Datum**
1		North			
2		South			
3		East			
4		West			
5					
6					

Comments:

Scoring Sheet: Riverine Wetlands

AA Name:				**(m/d/y)**			
Attributes and Metrics		**Scores**		**Comments**			
Buffer and Landscape Context							
Landscape Connectivity (D)							
Buffer submetric A: Percent of AA with Buffer							
Buffer submetric B: Average Buffer Width							
Buffer submetric C: Buffer Condition							
$D + [C \times (A \times B)^{1/2}]^{1/2}$ = **Attribute Score**		Raw	Final	Final Attribute Score = (Raw Score/24)100			
Hydrology							
Water Source							
Hydroperiod or Channel Stability							
Hydrologic Connectivity							
Attribute Score		Raw	Final	Final Attribute Score = (Raw Score/36)100			
Physical Structure							
Structural Patch Richness							
Topographic Complexity							
Attribute Score		Raw	Final	Final Attribute Score = (Raw Score/24)100			
Biotic Structure							
Plant Community submetric A: Number of Plant Layers							
Plant Community submetric B: Number of Co-dominant species							
Plant Community submetric C: Percent Invasion							
Plant Community Metric (*average of submetrics A-C*)							
Horizontal Interspersion and Zonation							
Vertical Biotic Structure							
Attribute Score		Raw	Final	Final Attribute Score = (Raw Score/36)100			
Overall AA Score				**Average of Final Attribute Scores**			

Worksheet 1: Landscape Connectivity Metric for Riverine Wetlands.

Lengths of Non-buffer Segments For Distance of 500 m Upstream of AA		**Lengths of Non-buffer Segments For Distance of 500 m Downstream of AA**	
Segment No.	Length (m)	Segment No.	Length (m)
1		1	
2		2	
3		3	
4		4	
5		5	
Upstream Total Length		Downstream Total Length	

Worksheet 2: Calculating average buffer width of AA.

Line	**Buffer Width (m)**
A	
B	
C	
D	
E	
F	
G	
H	
Average Buffer Width	

Worksheet 3: Assessing Hydroperiod for Riverine Wetlands.

Condition	Field Indicators (check all existing conditions)
Indicators of Channel Equilibrium	☐ The channel (or multiple channels in braided systems) has a well-defined bankfull contour that clearly demarcates an obvious active floodplain in the cross-sectional profile of the channel throughout most of the AA. ☐ Perennial riparian vegetation is abundant and well established along the bankfull contour, but not below it. ☐ There is leaf litter, thatch, or wrack in most pools. ☐ The channel contains embedded woody debris of the size and amount consistent with what is naturally available in the riparian area. ☐ There is little or no active undercutting or burial of riparian vegetation. ☐ There are no mid-channel bars and/or point bars densely vegetated with perennial vegetation. ☐ Channel bars consist of well-sorted bed material. ☐ There are channel pools, the bed is not planar, and the spacing between pools tends to be regular. ☐ The larger bed material supports abundant mosses or periphyton.
Indicators of Active Degradation	☐ The channel is characterized by deeply undercut banks with exposed living roots of trees or shrubs. ☐ There are abundant bank slides or slumps, or the lower banks are uniformly scoured and not vegetated. ☐ Riparian vegetation is declining in stature or vigor, or many riparian trees and shrubs along the banks are leaning or falling into the channel. ☐ An obvious historical floodplain has recently been abandoned, as indicated by the age structure of its riparian vegetation. ☐ The channel bed appears scoured to bedrock or dense clay. ☐ Recently active flow pathways appear to have coalesced into one channel (i.e. a previously braided system is no longer braided). ☐ The channel has one or more nick points indicating headward erosion of the bed.
Indicators of Active Aggradation	☐ There is an active floodplain with fresh splays of coarse sediment. ☐ There are partially buried living tree trunks or shrubs along the banks. ☐ The bed is planar overall; it lacks well-defined channel pools, or they are uncommon and irregularly spaced. ☐ There are partially buried, or sediment-choked, culverts. ☐ Perennial terrestrial or riparian vegetation is encroaching into the channel or onto channel bars below the bankfull contour. ☐ There are avulsion channels on the floodplain or adjacent valley floor.

Worksheet 4: Entrenchment Ratio Calculation for Riverine Wetlands.

The following 5 steps should be conducted for each of 3 cross-sections located in the AA at the approximate mid-points along straight riffles or glides, away from deep pools or meander bends.				
Steps	**Replicate Cross-sections** ⟶	**1**	**2**	**3**
1 Estimate bankfull width.	This is a critical step requiring familiarity with field indicators of the bankfull contour. Estimate or measure the distance between the right and left bankfull contours.			
2: Estimate max. bankfull depth.	Imagine a level line between the right and left bankfull contours; estimate or measure the height of the line above the thalweg (the deepest part of the channel).			
3: Estimate flood prone depth.	Double the estimate of maximum bankfull depth from Step 2.			
4: Estimate flood prone width.	Imagine a level line having a height equal to the flood prone depth from Step 3; note where the line intercepts the right and left banks; estimate or measure the length of this line.			
5: Calculate entrenchment ratio.	Divide the flood prone width (Step 4) by the bankfull width (Step 1).			
6: Calculate average entrenchment ratio.	Calculate the average results for Step 5 for all 3 replicate cross-sections.			

Worksheet 5a: Structural Patch Type for Non-confined Riverine Wetlands.

Identify each type of patch that is observed in the AA.

Structural Patch Type	**Check for presence**
Secondary channels on floodplains or along shorelines	
Swales on floodplain or along shoreline	
Pannes or pools on floodplain	
Vegetated islands (mostly above high-water)	
Pools or depressions in channels (wet or dry channels)	
Riffles or rapids (wet channel) or planar bed (dry channel)	
Point bars and in-channel bars	
Debris jams	
Abundant wrackline or organic debris in channel, on floodplain, or across depressional wetland plain	
Plant hummocks and/or sediment mounds	
Bank slumps or undercut banks in channels or along shoreline	
Variegated, convoluted, or crenulated foreshore (instead of broadly arcuate or mostly straight)	
Standing snags (at least 3 m tall)	
Filamentous macroalgae or algal mats	
Cobble and/or Boulders	
Submerged vegetation	
Total Possible	**16**
No. Observed Patch Types	

Worksheet 5b: Structural Patch Type for Confined Riverine Wetlands.

Identify each type of patch that is observed in the AA.

Structural Patch Type	Check for presence
Pools or depressions in channels (wet or dry channels)	
Riffles or rapids (wet channel) or planar bed (dry channel)	
Point bars and in-channel bars	
Debris jams	
Abundant wrackline or organic debris in channel, on floodplain, or across depressional wetland plain	
Plant hummocks and/or sediment mounds	
Bank slumps or undercut banks in channels or along shoreline	
Variegated, convoluted, or crenulated foreshore (instead of broadly arcuate or mostly straight)	
Standing snags (at least 3 m tall)	
Filamentous macroalgae or algal mats	
Cobble and/or Boulders	
Total Possible	**11**
No. Observed Patch Types	

Worksheet 6a: Plant Community Metric –

Co-dominant Species Richness for Non-confined Riverine Wetlands.

Note: A dominant species represents ≥10% *relative* cover. Count species only once when calculating any Plant Community sub-metric.

Floating or Canopy-forming	Invasive?	Short	Invasive?
Medium	**Invasive?**	**Tall**	**Invasive?**
Very Tall	**Invasive?**		
		Total number of co-dominant species for all layers combined	
		Percent Invasion	

Worksheet 6b: Plant Community Metric –

Co-dominant Species Richness for Confined Riverine Wetlands.

Note: A dominant species represents ≥10% *relative* cover. Count species only once when calculating any Plant Community sub-metric.

Short	Invasive?	Medium	Invasive?
Tall	**Invasive?**	**Very Tall**	**Invasive?**
		Total number of co-dominants for all layers combined	
		Percent Invasion	

Worksheet 7: Wetland disturbances and conversions.

Has a major disturbance occurred at this wetland?	Yes	No		
If yes, was it a flood, fire, landslide, or other?	flood	fire	landslide	other
If yes, then how severe is the disturbance?	likely to affect site next 5 or more years	likely to affect site next 3-5 years	likely to affect site next 1-2 years	
Has this wetland been converted from another type? If yes, then what was the previous type?	depressional	vernal pool	vernal pool system	
	non-confined riverine	confined riverine	seasonal estuarine	
	perennial saline estuarine	perennial non-saline estuarine	wet meadow	
	lacustrine	seep or spring	playa	

Worksheet 8: Stressor Checklist.

HYDROLOGY ATTRIBUTE (WITHIN 50 M OF AA)	**Present and likely to have negative effect on AA**	**Significant negative effect on AA**
Point Source (PS) discharges (POTW, other non-stormwater discharge)		
Non-point Source (Non-PS) discharges (urban runoff, farm drainage)		
Flow diversions or unnatural inflows		
Dams (reservoirs, detention basins, recharge basins)		
Flow obstructions (culverts, paved stream crossings)		
Weir/drop structure, tide gates		
Dredged inlet/channel		
Engineered channel (riprap, armored channel bank, bed)		
Dike/levees		
Groundwater extraction		
Ditches (borrow, agricultural drainage, mosquito control, etc.)		
Actively managed hydrology		
Comments		

PHYSICAL STRUCTURE ATTRIBUTE (WITHIN 50 M OF AA)	**Present and likely to have negative effect on AA**	**Significant negative effect on AA**
Filling or dumping of sediment or soils **(N/A for restoration areas)**		
Grading/ compaction **(N/A for restoration areas)**		
Plowing/Discing **(N/A for restoration areas)**		
Resource extraction (sediment, gravel, oil and/or gas)		
Vegetation management		
Excessive sediment or organic debris from watershed		
Excessive runoff from watershed		
Nutrient impaired (PS or Non-PS pollution)		
Heavy metal impaired (PS or Non-PS pollution)		
Pesticides or trace organics impaired (PS or Non-PS pollution)		
Bacteria and pathogens impaired (PS or Non-PS pollution)		
Trash or refuse		
Comments		

BIOTIC STRUCTURE ATTRIBUTE (WITHIN 50 M OF AA)	Present and likely to have negative effect on AA	Significant negative effect on AA
Mowing, grazing, excessive herbivory (within AA)		
Excessive human visitation		
Predation and habitat destruction by non-native vertebrates (e.g., *Virginia opossum* and domestic predators, such as feral pets)		
Tree cutting/sapling removal		
Removal of woody debris		
Treatment of non-native and nuisance plant species		
Pesticide application or vector control		
Biological resource extraction or stocking (fisheries, aquaculture)		
Excessive organic debris in matrix (for vernal pools)		
Lack of vegetation management to conserve natural resources		
Lack of treatment of invasive plants adjacent to AA or buffer		
Comments		

BUFFER AND LANDSCAPE CONTEXT ATTRIBUTE (WITHIN 500 M OF AA)	Present and likely to have negative effect on AA	Significant negative effect on AA
Urban residential		
Industrial/commercial		
Military training/Air traffic		
Dams (or other major flow regulation or disruption)		
Dryland farming		
Intensive row-crop agriculture		
Orchards/nurseries		
Commercial feedlots		
Dairies		
Ranching (enclosed livestock grazing or horse paddock or feedlot)		
Transportation corridor		
Rangeland (livestock rangeland also managed for native vegetation)		
Sports fields and urban parklands (golf courses, soccer fields, etc.)		
Passive recreation (bird-watching, hiking, etc.)		
Active recreation (off-road vehicles, mountain biking, hunting, fishing)		
Physical resource extraction (rock, sediment, oil/gas)		
Biological resource extraction (aquaculture, commercial fisheries)		
Comments		

C.2 California Rapid Assessment Method Overview and Datasheets

The alternative descriptions of condition for assessing the CRAM attributes and metrics are summarized below.

Table C-1: CRAM Datasheet Overview

Attributes	Metrics	Assessment Description	Alternative Descriptions of Condition
Buffer and Landscape Context	Landscape Connectivity	*On an aerial photo, estimate length of non-buffer segments (>10 feet in width) that interrupt longitudinal connectivity of riparian corridor 500 m upstream and downstream of AA.*	A. Total non-buffer length is <100 m (both upstream and downstream of AA). B. Total non-buffer length is <100 m in one direction and between 100-200 m in the other direction. C. Total non-buffer length is between 100-200 m in both directions. D. Combined total non-buffer length is >200 m in either direction.
	Buffer:		
	Percent of Assessment Area with Buffer	*On an aerial photo, estimate total percentage of wetland perimeter that adjoins land cover types that usually provide buffer functions (e.g., trails, parks). Examples are provided in the manual.*	Buffer % of AA perimeter: A. 75-100% B. 50-74% C. 25-49% D. 0-24%
	Average Buffer Width	*On aerial photo, draw lines 250 m in length perpendicular to the AA and estimate the width of the buffer (4 lines for one-sided riverine AAs and 8 for two-sided riverine AAs).*	Average buffer width: A. 190-250 m B. 130-189 m C. 65-129 m D. 0-64 m
	Buffer Condition	*Assess condition of buffer in the field.*	A. Buffer is dominated by native vegetation, has undisturbed soils, and is apparently subject to little or no human visitation. B. Buffer has an intermediate mix of native and non-native vegetation, but mostly undisturbed soils and is apparently subject to little or no human visitation. C. Buffer has substantial amounts of non-native vegetation and there is at least a moderate degree of soil disturbance/compaction, and/or there is evidence of at least moderate-intensity human visitation. D. Buffer has barren ground and/or highly compacted or otherwise disturbed soils, and/or there is evidence of very intense human visitation.

Table C-1: CRAM Datasheet Overview

Attributes		Metrics	Assessment Description	Alternative Descriptions of Condition
Hydrology		Water Source	*Assess water sources that affect the extent, duration, and frequency of saturated or ponded conditions. Focus is on dry season conditions.*	A. No indication that dry season conditions are substantially controlled by artificial water sources. B. No large point sources or dams control the overall hydrology. C. Sources that affect the dry season conditions are substantially controlled by known diversions or other withdrawals; or substantial artificial hydrology (e.g., developed or irrigated ag lands) comprise more than 20% of the immediate drainage basin. D. Natural freshwater sources that affect dry season conditions have been eliminated based on: impoundment of all possible wet season inflows, diversion of all dry-season inflow, and predominance of xeric vegetation.
		Hydroperiod or Channel Stability	*Assess recent changes in hydroperiod, flow regime, or sediment regime and the degree to which these changes affect channel stability. Specific indicators are listed in the manual.*	A. Most of channel is characterized by equilibrium conditions, with little evidence of aggradation or degradation. B. Most of channel is characterized by some aggradation or degradation, none of which is severe. C. Evidence of severe aggradation or degradation over most of channel length or the channel is artificially hardened through less than ½ of the reach. D. Channel is concrete or otherwise artificially hardened through most of the reach.
		Hydrologic Connectivity	*Calculate entrenchment ratio.*	Entrenchment ratio (non-confined riverine wetlands): A. >2.2 B. 1.9-2.2 C. 1.5-1.8 D. <1.5
Structure	Physical	Structural Patch Richness	*Identify number of different obvious types of physical surfaces or features that may provide habitat for species. Specific examples are provided in the manual.*	Number of structural patches (non-confined riverine wetlands): A. ≥12 B. 9-11 C. 6-8 D. ≤5

Table C-1: CRAM Datasheet Overview

Attributes		Metrics	Assessment Description	Alternative Descriptions of Condition
		Topographic Complexity	*Assess the overall variability in physical patches and topographic features. Illustrations are provided in the manual for guidance.*	A. At least 2 benches or breaks in slope above the channel bottom, excluding the thalweg; each with abundant micro-topographic complexity. B. At least 2 benches or breaks as above, but lacking abundant micro-topographic complexity. C. Single bench or obvious break in slope, which may or may not have abundant micro-topographic complexity. D. Lacks obvious breaks in slope or bench. Cross-section is a single, uniform slope, with or without micro-topographic complexity.
	Biotic	Plant Community:		
		Number of Plant Layers Present	*Based on current height of species, not potential height at maturity. Illustrations are provided in the manual for guidance.*	Non-confined riverine wetlands: A. 4-5 B. 3 C. 1-2 D. 0
		Number of Co-Dominant Species	*Species must account for at least 10% of relative cover within the AA.*	Non-confined riverine wetlands: A. ≥12 B. 9-11 C. 6-8 D. 0-5
		Percent Invasion	*Number of invasive co-dominant species relative to total number of co-dominant species.*	Non-confined riverine wetlands: A. 0-15% B. 16-30% C. 31-45% D. 46-100%
		Horizontal Interspersion or Zonation	*Assess the number of distinct plant “zones” (monocultures/ multi-species associations) and the amount of edge between them. Illustrations are provided in the manual for guidance.*	Degree of plan-view interspersion: A. High B. Moderate C. Low D. None
		Vertical Biotic Structure	*Assess degree of overlap among plant layers.*	A. >50% supports abundant overlap of plant layers. B. >50% supports at least moderate overlap of plant layers. C. 25-50% supports at least moderate overlap of plant layers or 3 plant layers are well represented but there is little to no overlap. D. <25% supports moderate overlap of plant layers or 2 layers are well represented but with little overlap; or it is sparsely vegetated.

C.3 CRAM Summary Score Figures for Study Reach

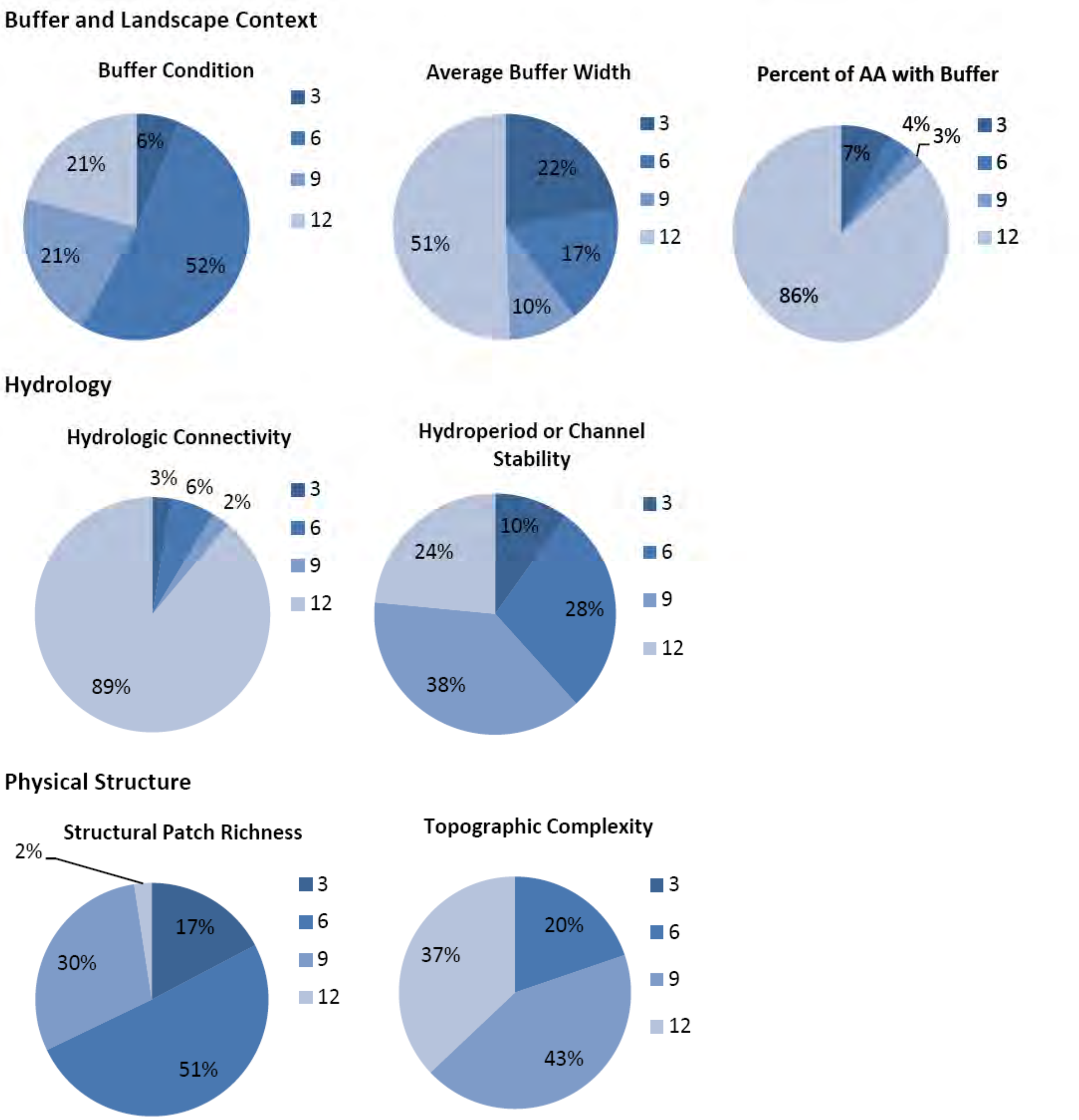
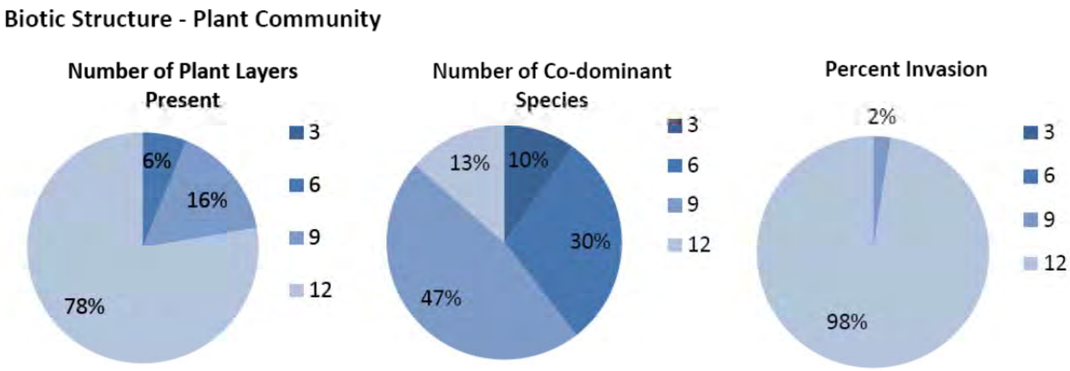


Figure C.3-1 Proportion of California Rapid Assessment Method Metric Scores along the Merced River within the Study Area.



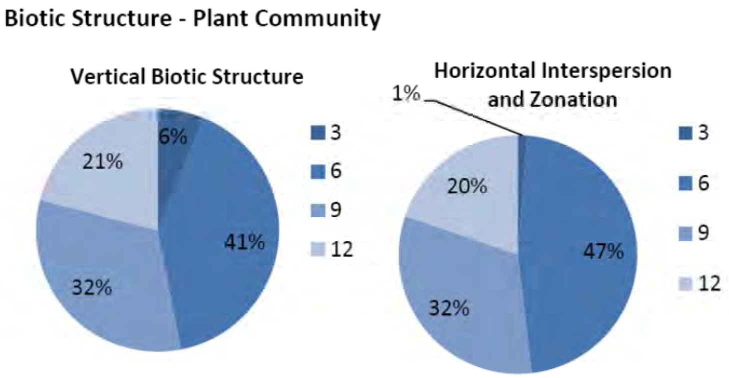


Figure C.3-1 Proportion of California Rapid Assessment Method Metric Scores along the Merced River within the Study Area, continued.

C.4 CRAM Summary Scores by Geomorphic Reach

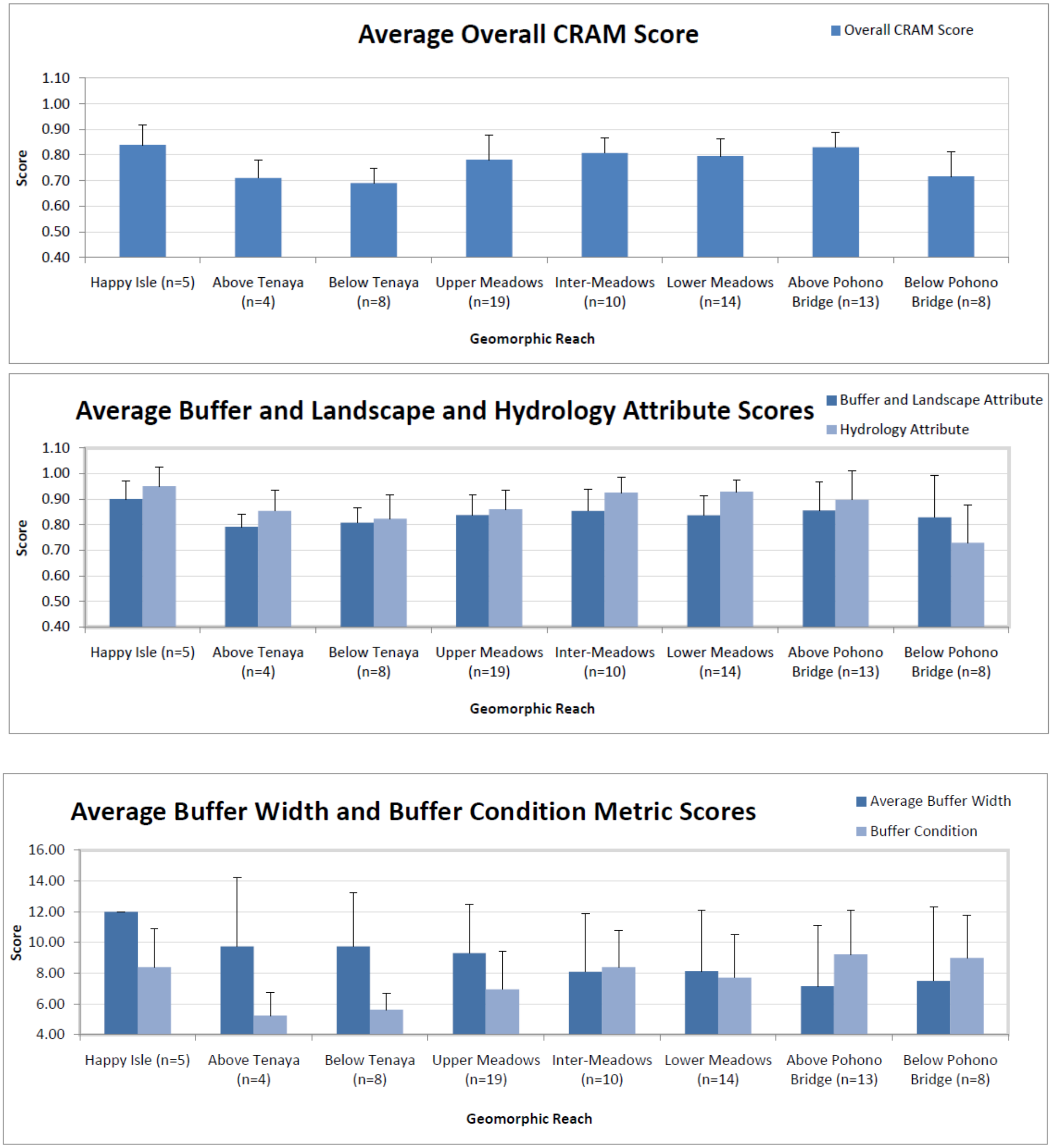
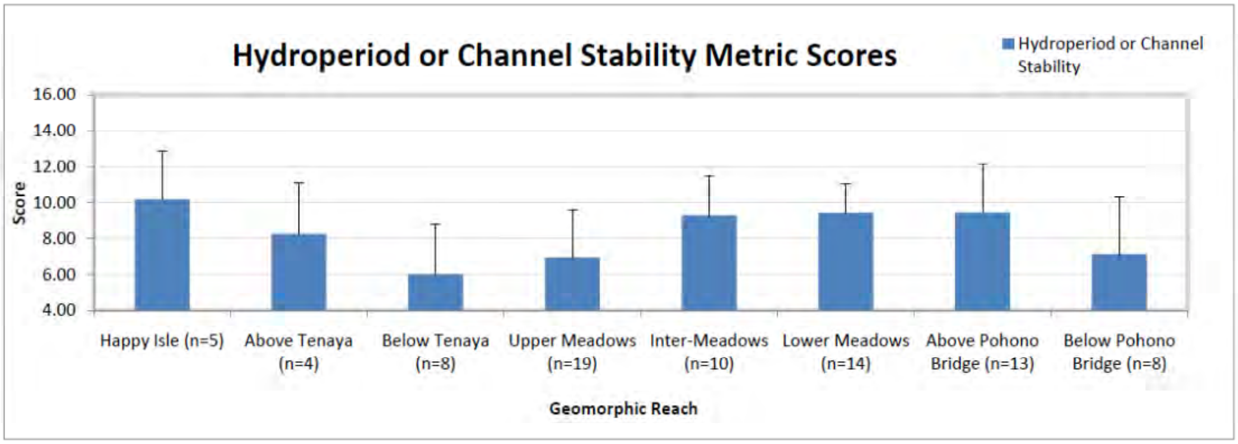
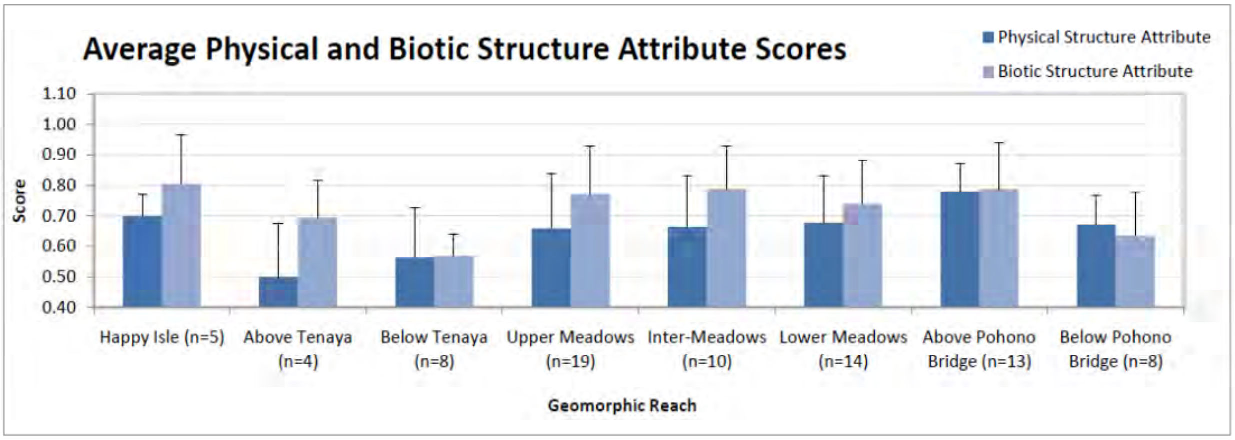


Figure C.4-1 Summary of California Rapid Assessment Method Overall, Attribute, and Metric Scores by Geomorphic Reach (Average and Standard Deviation)





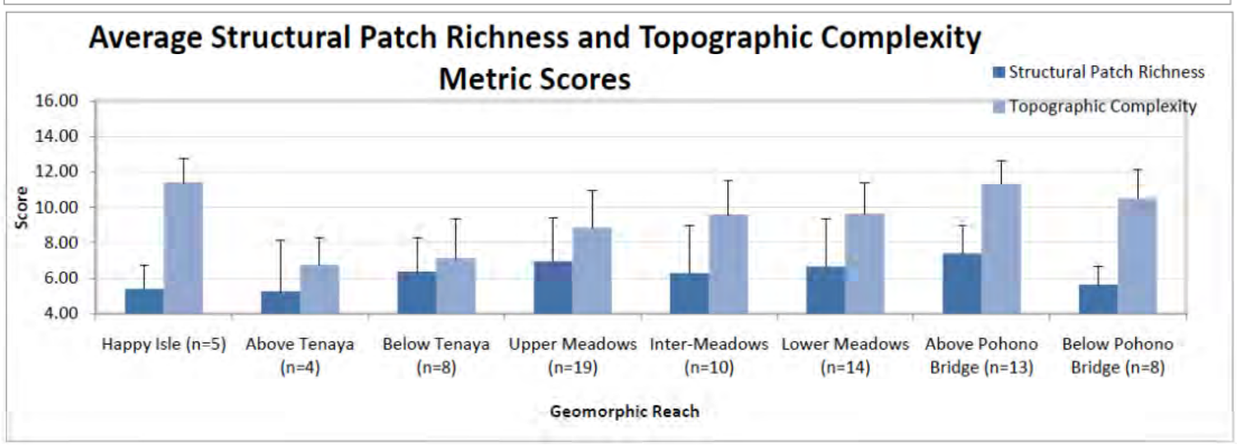


Figure C.4-1 Summary of California Rapid Assessment Method Overall, Attribute, and Metric Scores by Geomorphic Reach (Average and Standard Deviation) (continued).

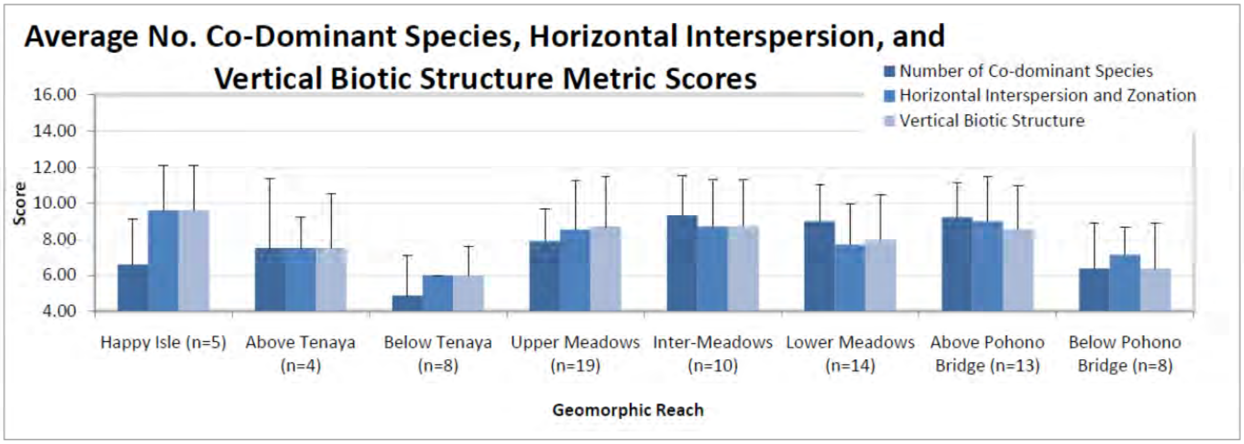


Figure C.4-1 Summary of California Rapid Assessment Method Overall, Attribute, and Metric Scores by Geomorphic Reach (Average and Standard Deviation) (continued).

C.5 CRAM Summary Table for Study Reach

Table C-5 Trends in Attribute Condition within Assessment Areas with Comparatively Higher, Moderate, and Lower Overall California Rapid Assessment Method Scores.

CRAM Metric	Proportion with 'A' or 'B' Ranking1 (%)				Proportion with 'D' Ranking1 (%)		
	"Higher" Overall CRAM Scores	"Moderate" Overall CRAM Scores	"Lower" Overall CRAM Scores		"Higher" Overall CRAM Scores	"Moderate" Overall CRAM Scores	"Lower" Overall CRAM Scores
Buffer and Landscape Context							
Landscape Connectivity	100	100	100		0	0	0
Percent of Assessment Area with Buffer	94	91	76		0	6	18
Average Buffer Width	82	60	41		6	23	35
Buffer Condition	88	32	24		0	4	18
Hydrology							
Water Source	100	100	100		0	0	0
Hydroperiod or Channel Stability	82	64	35		0	0	47
Hydrologic Connectivity	100	91	82		0	0	12
Physical Structure							
Structural Patch Richness	53	36	0		0	11	53
Topographic Complexity	100	91	29		0	0	0
Plant Community and Biotic Structure							
Number of Plant Layers Present	100	94	88		0	0	0
Percent Invasive	100	100	100		0	0	0
Number of Co-Dominant Species	76	68	24		0	6	29
Horizontal Interspersion or Zonation	100	51	6		0	0	6
Vertical Biotic Structure	94	51	18		0	4	18

1Higher: The AAs with overall CRAM scores in the top 20th percentile (greater than or equal to 0.87) (n=17)
Lower: The AAs with overall CRAM scores in the lowest 20th percentile (less than or equal to 0.70) (n=17)
Moderate: The AAs with overall CRAM scores between 0.701 to 0.869 (n=47)

C.6 CRAM Summary Table Geomorphic Reach

Table C-6 Summary of Riparian Corridor Vegetation and California Rapid Assessment Methods Results by Geomorphic Reach.

Geomorphic Reach	Reach Description		California Rapid Assessment Method Attribute and Metric Scores																			
				Buffer and Landscape Context					Hydrology				Physical Structure			Biotic Structure – Plant Community						
	Assessment Areas Included within Reach[1]	Reach Length (km)	OVERALL CRAM SCORE	Buffer Total Score	Landscape Connectivity	Percent of AA with Buffer	Average Buffer Width	Buffer Condition	Hydrology Total	Water Source	Hydroperiod or Channel Stability	Hydrologic Connectivity	Physical Structure Total	Structural Patch Richness	Topographic Complexity	Biotic Structure Totasl Score	Plant Community	Number of Plant Layers Present	Number of Co-dominant Species	Percent Invasion	Horizontal Interspersion and Zonation	Vertical Biotic Structure
Happy Isles																						
	1-5	1	Average	0.84	0.90	12.00	12.00	12.00	8.40	0.95	12.00	10.20	12.00	0.70	5.40	11.40	0.81	11.40	6.60	11.40	9.60	9.60
			Minimum	0.71	0.83	12.00	12.00	12.00	6.00	0.83	12.00	6.00	12.00	0.63	3.00	9.00	0.56	9.00	3.00	9.00	6.00	6.00
			Maximum	0.91	1.00	12.00	12.00	12.00	12.00	1.00	12.00	12.00	12.00	0.75	6.00	12.00	0.97	12.00	9.00	12.00	12.00	12.00
			Std. Dev	0.08	0.07	0.00	0.00	0.00	2.51	0.07	0.00	2.68	0.00	0.07	1.34	1.34	0.16	1.34	2.51	1.34	2.51	2.51
Above Tenaya																						
	6-9	0.73	Average	0.71	0.79	12.00	12.00	9.75	5.25	0.85	10.50	8.25	12.00	0.50	5.25	6.75	0.69	10.50	7.50	12.00	7.50	7.50
			Minimum	0.67	0.75	12.00	12.00	3.00	3.00	0.75	9.00	6.00	12.00	0.38	3.00	6.00	0.56	9.00	3.00	12.00	6.00	6.00
			Maximum	0.81	0.83	12.00	12.00	12.00	6.00	0.92	12.00	12.00	12.00	0.75	9.00	9.00	0.83	12.00	12.00	12.00	9.00	12.00
			Std. Dev.	0.07	0.05	0.00	0.00	4.50	1.50	0.08	1.73	2.87	0.00	0.18	2.87	1.50	0.12	1.73	3.87	0.00	1.73	3.00
Below Tenaya																						
	10-17	1.23	Average	0.69	0.81	12.00	12.00	9.75	5.63	0.82	11.63	6.00	12.00	0.56	6.38	7.13	0.57	8.63	4.88	12.00	6.00	6.00
			Minimum	0.60	0.67	12.00	12.00	3.00	3.00	0.67	9.00	3.00	12.00	0.38	3.00	6.00	0.50	6.00	3.00	12.00	6.00	3.00
			Maximum	0.77	0.83	12.00	12.00	12.00	6.00	0.92	12.00	9.00	12.00	0.88	9.00	12.00	0.72	12.00	9.00	12.00	6.00	9.00

Table C-6 Summary of Riparian Corridor Vegetation and California Rapid Assessment Methods Results by Geomorphic Reach.

Geomorphic Reach	Reach Description		California Rapid Assessment Method Attribute and Metric Scores																			
				Buffer and Landscape Context					Hydrology				Physical Structure			Biotic Structure / Plant Community						
	Assessment Areas Included within Reach[1]	Reach Length (km)	OVERALL CRAM SCORE	Buffer Total Score	Landscape Connectivity	Percent of AA with Buffer	Average Buffer Width	Buffer Condition	Hydrology Total	Water Source	Hydroperiod or Channel Stability	Hydrologic Connectivity	Physical Structure Total	Structural Patch Richness	Topographic Complexity	Biotic Structure Totasl Score	Plant Community	Number of Plant Layers Present	Number of Co-dominant Species	Percent Invasion	Horizontal Interspersion and Zonation	Vertical Biotic Structure
			Std. Dev.	0.06	0.06	0.00	0.00	3.49	1.06	0.09	1.06	2.78	0.00	0.16	1.92	2.23	0.07	2.50	2.23	0.00	0.00	1.60
Upper Meadows																						
	18-36	3.94	Average	0.78	0.84	12.00	11.53	9.32	6.95	0.86	12.00	6.95	12.00	0.66	6.95	8.84	0.77	11.68	7.89	12.00	8.53	8.68
			Minimum	0.56	0.71	12.00	6.00	3.00	3.00	0.75	12.00	3.00	12.00	0.38	3.00	6.00	0.42	9.00	6.00	12.00	3.00	3.00
			Maximum	0.93	1.00	12.00	12.00	12.00	12.00	1.00	12.00	12.00	12.00	1.00	12.00	12.00	1.00	12.00	12.00	12.00	12.00	12.00
			Std. Dev.	0.10	0.08	0.00	1.50	3.15	2.46	0.07	0.00	2.66	0.00	0.18	2.46	2.12	0.16	0.95	1.79	0.00	2.70	2.81
Inter-Meadows																						
	37-46	2.11	Average	0.81	0.85	12.00	11.10	8.10	8.40	0.93	12.00	9.30	12.00	0.66	6.30	9.60	0.79	11.70	9.30	12.00	8.70	8.70
			Minimum	0.72	0.75	12.00	3.00	3.00	6.00	0.83	12.00	6.00	12.00	0.38	3.00	6.00	0.64	9.00	6.00	12.00	6.00	6.00
			Maximum	0.92	1.00	12.00	12.00	12.00	12.00	1.00	12.00	12.00	12.00	0.88	9.00	12.00	1.00	12.00	12.00	12.00	12.00	12.00
			Std. Dev.	0.06	0.08	0.00	2.85	3.75	2.37	0.06	0.00	2.21	0.00	0.17	2.63	1.90	0.14	0.95	2.21	0.00	2.63	2.63
Lower Meadows																						
	47-60	2.41	Average	0.80	0.84	12.00	11.57	8.14	7.71	0.93	12.00	9.43	12.00	0.68	6.64	9.64	0.74	12.00	9.00	12.00	7.71	7.93
			Minimum	0.70	0.75	12.00	6.00	3.00	3.00	0.83	12.00	6.00	12.00	0.38	3.00	6.00	0.61	12.00	6.00	12.00	6.00	6.00
			Maximum	0.90	0.96	12.00	12.00	12.00	12.00	1.00	12.00	12.00	12.00	0.88	12.00	12.00	1.00	12.00	12.00	12.00	12.00	12.00

Table C-6 Summary of Riparian Corridor Vegetation and California Rapid Assessment Methods Results by Geomorphic Reach.

	Reach Description		California Rapid Assessment Method Attribute and Metric Scores																			
				Buffer and Landscape Context					Hydrology				Physical Structure			Biotic Structure / Plant Community						
Geomorphic Reach	Assessment Areas Included within Reach[1]	Reach Length (km)	OVERALL CRAM SCORE	Buffer Total Score	Landscape Connectivity	Percent of AA with Buffer	Average Buffer Width	Buffer Condition	Hydrology Total	Water Source	Hydroperiod or Channel Stability	Hydrologic Connectivity	Physical Structure Total	Structural Patch Richness	Topographic Complexity	Biotic Structure Totasl Score	Plant Community	Number of Plant Layers Present	Number of Co-dominant Species	Percent Invasion	Horizontal Interspersion and Zonation	Vertical Biotic Structure
			Std. Dev.	0.07	0.08	0.00	1.60	3.98	2.81	0.04	0.00	1.60	0.00	0.15	2.68	1.74	0.14	0.00	2.04	0.00	2.27	2.53
Above Pohono Bridge																						
	61-73	2.69	Average	0.83	0.86	12.00	10.62	7.15	9.23	0.90	12.00	9.46	10.85	0.78	7.38	11.31	0.79	11.54	9.23	11.77	9.00	8.54
			Minimum	0.75	0.67	12.00	3.00	3.00	6.00	0.67	12.00	6.00	6.00	0.63	6.00	9.00	0.58	9.00	6.00	9.00	6.00	6.00
			Maximum	0.91	1.00	12.00	12.00	12.00	12.00	1.00	12.00	12.00	12.00	0.88	9.00	12.00	1.00	12.00	12.00	12.00	12.00	12.00
			Std. Dev.	0.06	0.11	0.00	2.90	3.98	2.86	0.11	0.00	2.70	2.30	0.09	1.56	1.32	0.15	1.13	1.92	0.83	2.45	2.40
Below Pohono Bridge																						
	74-81	1.72	Average	0.72	0.83	12.00	7.50	7.50	9.00	0.73	12.00	7.13	7.13	0.67	5.63	10.50	0.64	9.75	6.38	12.00	7.13	6.38
			Minimum	0.60	0.67	12.00	3.00	3.00	6.00	0.50	12.00	3.00	3.00	0.50	3.00	9.00	0.44	6.00	3.00	12.00	6.00	3.00
			Maximum	0.88	1.00	12.00	12.00	12.00	12.00	1.00	12.00	12.00	12.00	0.75	6.00	12.00	0.81	12.00	9.00	12.00	9.00	9.00
			Std. Dev.	0.10	0.16	0.00	4.81	4.81	2.78	0.15	0.00	3.18	3.56	0.09	1.06	1.60	0.14	2.66	2.50	0.00	1.55	2.50

[1] If a geomorphic reach boundary intersected an assessment area, the assessment area was included in the reach in which the largest proportion of the assessment area occurred. If the boundary bisected an assessment area, the assessment area was included in the upstream geomorphic reach. See Appendix A for locations of assessment areas in relation to the geomorphic reach boundaries.

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C.7 CRAM Scores Summary Table

Table C-7 Summary of California Rapid Assessment Method Metric, Attribute, and Overall Scores for each Assessment Area.

AA No.	OVERALL CRAM SCORE	Buffer and Landscape Context					Hydrology				Physical Structure		
		Landscape Connectivity	Percent of AA with Buffer	Average Buffer Width	Buffer Condition	Buffer Score	Water Source	Hydroperiod or Channel Stability	Hydrologic Connectivity	Hydrology Total	Structural Patch Richness	Topographic Complexity	Physical Structure Total
1	0.71	12	12	12	6	0.83	12	6	12	0.83	6	9	0.63
2	0.82	12	12	12	9	0.92	12	12	12	1.00	3	12	0.63
3	0.87	12	12	12	6	0.83	12	12	12	1.00	6	12	0.75
4	0.88	12	12	12	9	0.92	12	12	12	1.00	6	12	0.75
5	0.91	12	12	12	12	1.00	12	9	12	0.92	6	12	0.75
6	0.68	12	12	12	6	0.83	12	6	12	0.83	6	6	0.50
7	0.67	12	12	3	6	0.75	12	9	12	0.92	3	6	0.38
8	0.68	12	12	12	3	0.75	9	6	12	0.75	3	6	0.38
9	0.81	12	12	12	6	0.83	9	12	12	0.92	9	9	0.75
10	0.69	12	12	12	6	0.83	12	6	12	0.83	6	6	0.50
11	0.63	12	12	9	6	0.83	9	3	12	0.67	6	6	0.50
12	0.76	12	12	12	6	0.83	12	9	12	0.92	9	9	0.75
13	0.70	12	12	12	6	0.83	12	3	12	0.75	6	6	0.50
14	0.72	12	12	12	6	0.83	12	9	12	0.92	6	6	0.50
15	0.66	12	12	6	6	0.79	12	9	12	0.92	3	6	0.38
16	0.60	12	12	3	3	0.67	12	3	12	0.75	6	6	0.50
17	0.77	12	12	12	6	0.83	12	6	12	0.83	9	12	0.88
18	0.56	12	12	6	3	0.71	12	3	12	0.75	3	6	0.38
19	0.75	12	12	9	3	0.75	12	6	12	0.83	6	9	0.63

Table C-7 Summary of California Rapid Assessment Method Metric, Attribute, and Overall Scores for each Assessment Area.

AA No.	OVERALL CRAM SCORE	Buffer and Landscape Context					Hydrology				Physical Structure		
		Landscape Connectivity	Percent of AA with Buffer	Average Buffer Width	Buffer Condition	Buffer Score	Water Source	Hydroperiod or Channel Stability	Hydrologic Connectivity	Hydrology Total	Structural Patch Richness	Topographic Complexity	Physical Structure Total
20	0.75	12	12	12	6	0.83	12	12	12	1.00	6	6	0.50
21	0.76	12	12	6	6	0.79	12	6	12	0.83	6	9	0.63
22	0.76	12	12	12	6	0.83	12	6	12	0.83	6	6	0.50
23	0.85	12	12	6	6	0.79	12	6	12	0.83	9	12	0.88
24	0.65	12	6	3	9	0.75	12	3	12	0.75	3	6	0.38
25	0.93	12	12	6	9	0.88	12	6	12	0.83	12	12	1.00
26	0.63	12	9	6	6	0.79	12	3	12	0.75	3	6	0.38
27	0.84	12	12	12	9	0.92	12	6	12	0.83	6	9	0.63
28	0.75	12	12	9	6	0.83	12	9	12	0.92	6	9	0.63
29	0.93	12	12	12	12	1.00	12	12	12	1.00	9	9	0.75
30	0.87	12	12	12	12	1.00	12	6	12	0.83	9	12	0.88
31	0.80	12	12	6	6	0.79	12	6	12	0.83	9	9	0.75
32	0.75	12	12	12	6	0.83	12	9	12	0.92	6	9	0.63
33	0.76	12	12	12	6	0.83	12	9	12	0.92	9	9	0.75
34	0.83	12	12	12	6	0.83	12	9	12	0.92	9	9	0.75
35	0.77	12	12	12	6	0.83	12	6	12	0.83	6	9	0.63
36	0.91	12	12	12	9	0.92	12	9	12	0.92	9	12	0.88
37	0.73	12	3	3	12	0.75	12	6	12	0.83	3	6	0.38
38	0.92	12	12	12	9	0.92	12	9	12	0.92	9	12	0.88
39	0.83	12	12	9	9	0.92	12	9	12	0.92	3	9	0.50

Table C-7 Summary of California Rapid Assessment Method Metric, Attribute, and Overall Scores for each Assessment Area.

AA No.	OVERALL CRAM SCORE	Buffer and Landscape Context					Hydrology				Physical Structure		
		Landscape Connectivity	Percent of AA with Buffer	Average Buffer Width	Buffer Condition	Buffer Score	Water Source	Hydroperiod or Channel Stability	Hydrologic Connectivity	Hydrology Total	Structural Patch Richness	Topographic Complexity	Physical Structure Total
40	0.85	12	12	12	12	1.00	12	12	12	1.00	6	12	0.75
41	0.79	12	12	12	6	0.83	12	9	12	0.92	9	9	0.75
42	0.86	12	12	3	6	0.75	12	12	12	1.00	9	12	0.88
43	0.80	12	12	6	6	0.79	12	9	12	0.92	9	9	0.75
44	0.72	12	12	6	6	0.79	12	6	12	0.83	6	9	0.63
45	0.81	12	12	6	9	0.88	12	9	12	0.92	6	9	0.63
46	0.77	12	12	12	9	0.92	12	12	12	1.00	3	9	0.50
47	0.90	12	12	12	9	0.92	12	12	12	1.00	9	12	0.88
48	0.70	12	12	6	6	0.79	12	9	12	0.92	3	9	0.50
49	0.75	12	12	12	6	0.83	12	9	12	0.92	6	9	0.63
50	0.84	12	12	12	6	0.83	12	9	12	0.92	6	9	0.63
51	0.81	12	12	6	12	0.92	12	9	12	0.92	9	9	0.75
52	0.80	12	12	12	3	0.75	12	9	12	0.92	12	9	0.88
53	0.76	12	12	3	6	0.75	12	9	12	0.92	9	9	0.75
54	0.73	12	12	9	6	0.83	12	9	12	0.92	3	9	0.50
55	0.70	12	12	12	9	0.92	12	9	12	0.92	3	6	0.38
56	0.84	12	12	3	6	0.75	12	9	12	0.92	9	12	0.88

[1] BOLD: significant negative effect on assessment area.

[2] Species with at least 10% cover within each vegetation layer: (1) aquatic vegetation; (2) short (<0.5 m tall); (3) medium (0.5-1.5 m tall); (4) tall (1.5-3.0 m tall); and (5) very tall (>3.0 m).

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Appendix D

Entrenchment Ratio

Appendix D

Entrenchment Ratio Calculation Method

Entrenchment describes the relative degree to which a river channel is incised below the valley floor. The entrenchment ratio was developed for Rosgen's (1994) classification system to quantify the vertical containment of a river and is defined as the ratio of the flood prone width to bankfull width. The general approach for calculating the entrenchment ratio is to:

1. Estimate the bankfull width[1];
2. Estimate the maximum bankfull depth;
3. Estimate flood prone depth[2] as twice the maximum bankfull depth;
4. Estimate flood prone width; and
5. Calculate entrenchment ratio as the flood prone width divided by the bankfull width.

The CRAM guidelines specify that the entrenchment ratio is calculated for three cross-sections in each assessment area (AA). The study area includes 81 AAs spaced at approximately 200 meter (m) intervals (see Section 2.3 for additional CRAM methods). Topographic data were analyzed to estimate the entrenchment ratio at three locations within each AA (e.g., upstream, middle, and downstream portions of each area). The entrenchment ratio for each AA was calculated as the average for the three cross-sectional measurements. The approach for determining the cross-sectional profile and parameters needed for the calculation of the entrenchment ratio are described below. Calculation of the entrenchment ratio for each cross-sectional profile and AA is then described.

Cross-sectional Profiles. Two sources of topographic data were used to develop the channel and floodplain characteristics (cross-sectional profiles) needed to determine the entrenchment ratios within each AA: (1) a Light Detection and Ranging (LiDAR) based digital elevation model (DEM) and (2) field measurements of elevation collected along cross-sectional transects. The DEM was derived from LiDAR observations collected in 2006 that were processed to generate a bare earth model of the ground surface with a grid cell resolution of 1 m. LiDAR observations, however, do not penetrate the water surface. As such, the LiDAR data do not include the topography of the channel bed. Field measurements from 129 cross-sectional transects, surveyed by the National Park Service (NPS) in 2008 and 2009, were utilized to augment the LiDAR data and characterize the portion of the river channel obscured by water on the LiDAR DEM. The NPS cross-sections were merged with data from the LiDAR DEM to create 129 cross-valley profiles of the ground surface. The resulting merged profiles included details of the channel bathymetry from the field measurements and elevations of the valley bottom from the DEM. The

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1 Bankfull width is defined as the width of the channel at the point where overbank flow begins during a flood event.

2 Rosgen (1994) defines flood prone depth as twice the maximum bankfull depth.

number of surveyed cross-sections, however, did not fulfill the required number specified in the CRAM criteria (three per AA) (Collins et. al. 2008a). Additional cross-sectional profiles across the valley bottom were extracted from the DEM at locations required by the CRAM criteria. The additional cross-sections based solely on the DEM were used for determining the bankfull width and flood prone width, but not for measurement of maximum bankfull depth because the profiles were truncated at the water surface elevation. For these cross-sections, bankfull depth was estimated by interpolating along a longitudinal profile of the thalweg elevations from the NPS surveys (see Bankfull Depth below).

Bankfull Width. Bankfull width was calculated independently for three cross sections in each AA. Cross-sections were evaluated to identify the elevation at which overbank flow begins (bankfull stage[3]). The identification of bankfull stage was a key component of the entrenchment ratio calculation because variation of the elevation defined as bankfull stage can translate to large differences in bankfull width and depth for a given cross-section.

Identification of bankfull stage required a critical evaluation of the topographic data to differentiate between the active floodplain and recently abandoned terrace surfaces. The height above water surface (HAWS) map was utilized for graphical evaluation of the terrain to highlight topographic relief between the channel and adjacent features on the floodplain and terrace surfaces (See Section 2.4). Within Yosemite Valley, multiple terrace surfaces occur at elevations above the active floodplain (Milestone 1978). Historical channel changes in the study area included an episode of incision following an effort in 1879 to lower the streambed elevation by blasting boulders in the channel at the El Capitan Moraine. Milestone (1978) estimated that the 1879 blasting lowered the channel bed at the moraine by 1.5 m and that incision extended several kilometers upstream with the magnitude of incision decreasing in the upstream direction. Smillie et al. (1995) noted that the upstream limit of historical incision terminated downstream of Yosemite Lodge. Bankfull stage was identified in the area suspected to be entrenched with disconnected or undeveloped floodplains by the tops of exposed gravel bars and by the lower limit of perennial vegetation (U.S. Forest Service 1999).

Bankfull Depth. At cross-sections which included channel bathymetry from the NPS field surveys, the maximum bankfull depth was determined by measuring down from the bankfull stage to the thalweg elevation. For the cross-sections that were developed using only the DEM data, thalweg elevations were estimated by interpolating along a longitudinal profile of the thalweg elevations from the NPS surveys. The interpolated thalweg elevation was compared to the bankfull stage in order to estimate the maximum bankfull depth for locations lacking in survey data.

Flood Prone Depth. This parameter does not have any physical relation of hydrologic or geomorphic significance, but is defined in a way that attempts to produce consistent results between different individuals. The maximum bankfull depth of the Merced River cross-sections was doubled to determine the flood prone depth.

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[3] Bankfull stage is identified as the elevation of the active floodplain. The active floodplain is the relatively flat surface adjacent to the channel that is created by the present river in the present climate (Leopold, 1994). This definition includes distinct language that differentiates between an active floodplain and a terrace surface. A terrace is an abandoned floodplain formed by the river under a previous set of conditions.

Flood Prone Width. The flood prone depth was summed with the thalweg elevation (from NPS surveys where available or interpolated from the longitudinal profile for cross-sections without channel bathymetry survey data) to estimate the elevation of the flood prone area. The valley width was measured at the elevation of the flood prone depth on each cross-sectional profile.

Entrenchment Ratio Calculation. Entrenchment ratio was calculated for each cross-section by dividing the flood prone width by the bankfull width. The entrenchment ratio for each AA was calculated as the average of the three entrenchment ratio calculations within that area. An illustrated example of the parameters utilized for the entrenchment ratio calculations is presented in Figure 1. The cross-section includes field measurements at NPS cross-section 011A of the channel merged with LiDAR DEM data that extend to the valley walls.

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Appendix E

Yosemite Site History

Appendix E

Yosemite Site History

E.1 El Capitan Dumpsite Restoration, 1991-1995

E.1.1 Introduction

The El Capitan Dump is adjacent to both the Merced River and a former picnic area. At the time, the picnic area was heavily used by visitors and served as the concessionaire's raft take-out and shuttle pickup point. Rafters frequently floated past the marked take-out point and attempted to land their rafts on the steep banks alongside the dump. Hikers and water enthusiasts also accessed the river between exposed dump materials.

Figure 1: Exposed materials at El Capitan Dump.

The historic dump was used between 1880 and the 1960's. Exposed material consisted of metal pieces, glass, and ceramic shards, all of which posed a threat to visitors at the picnic area and had a high potential for being transported into the river (Figure 1). The El Capitan Dump Restoration Project was conducted in 1991 by restoration and archeology staff. The project sought to remove exposed surface materials from the site to mitigate potential hazards.

E.1.2 Restoration

Prior to the dump excavation, restoration staff barricaded the project area and installed temporary interpretive signs to explain ongoing activities to visitors. Park foresters were brought in to fell two diseased ponderosa pines that were growing in the center of the dump site. Resource management staff had decided that the diseased trees would obstruct equipment operation. The foresters used heavy equipment to push the trees down and placed them along the riverbank. Archeologists collected dump deposits that were exposed by uprooting the trees.

Archeologists and restoration staff began the dump excavation on October 23, 1991. They started at the eastern end of the river edge terrace, dug a trench away from the river's edge to define the eastern boundary of the dump deposit. They dug another trench to the east and north to define the northeastern boundary of the project. Due to limited resources and archeological clearance, excavation was limited to a 100 x 150-foot section of the river terrace where the dump deposit was most likely to be eroded by shifting river patterns.

During excavation, resource management staff identified the underlying original soil surface due to its different texture (fine sand versus coarse sand and gravel), color, and absence of dump materials. They used this information to determine the necessary depth of excavation which varied throughout the area. Staff discovered a number of old river cut-off channels as debris was removed from deep and shallow deposits. Dump material was piled along the perimeter of the project area for screening.

Archeologists utilized a portable conveyor belt-driven screenplant to separate soils from dump debris. They separated metal from glass and pottery; metal comprised about 90 percent of the total volume of material removed from the dump. All metal debris was removed from the site and taken to a scrap metal dealer outside of the park. They separated the glass and pottery from the sands and gravels which were removed from the park to be used as backfill. The remaining material was saved for use as construction site sub-grade material in the park. All dumpsite materials were either salvaged or recycled.

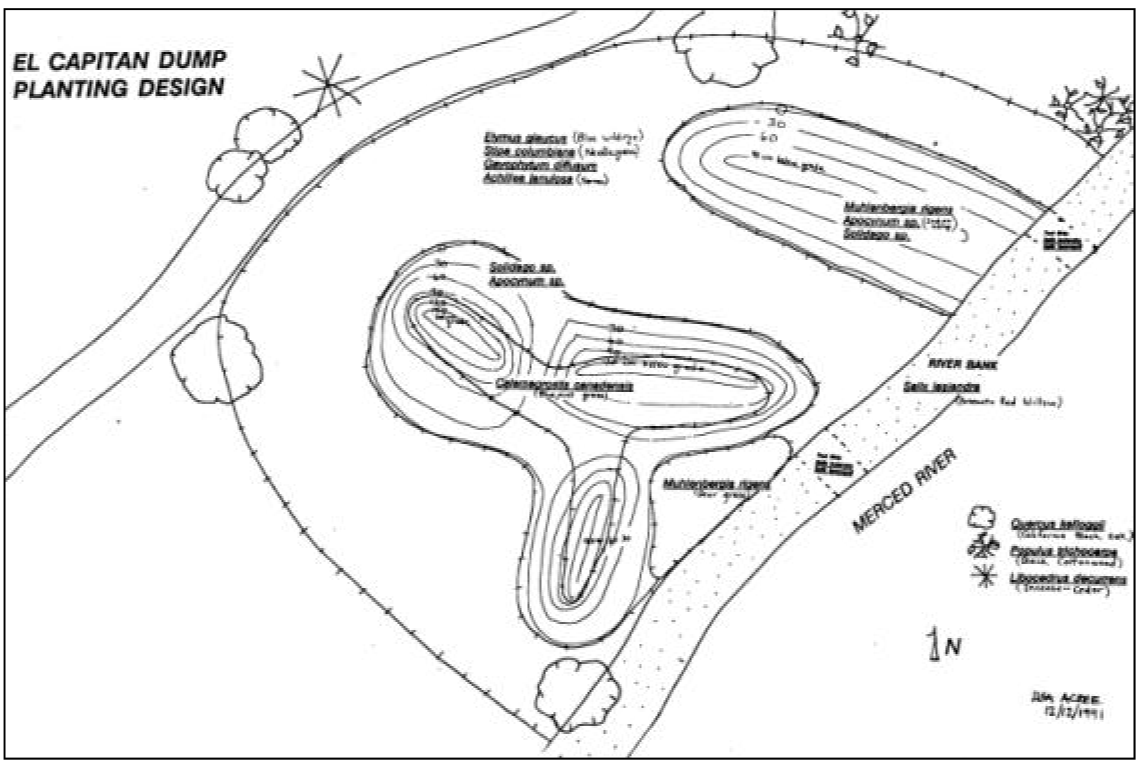

Figure 2: El Capitan Dump Revegetation Plan.

Following dump debris removal, restoration staff recontoured the river terrace edge to achieve a 2: 1 slope. They retained the cut-off channel contours on the terrace and softened the edges of the excavation to blend in with the surrounding topography.

Restoration staff implemented a revegetation plan created by the park botanist (Figure 2). Staff seeded the terrace with eight native species identified as appropriate to the site based on surveys of similar riparian areas in Yosemite Valley. They planted 1100 red willow and 200 black cottonwood cuttings along the riverbank using the excavator (Figure 3). They also planted a small number of willow cuttings in two test strips at opposite ends of the project.

Figure 1: Crew member planting willow and cottonwood cuttings with the aid of the excavator

After planting, the restoration crew installed a split-rail cedar and rope fence to protect the newly planted area. In 1992, a section of the fence was moved and connected to the newly constructed fence surrounding the El Capitan Picnic Area project. In 1994, restoration staff spread additional herbaceous seeds on the terrace and planted willow cuttings on the bank using a hydrodrill. They also monitored for and eradicated exotic plant species through 1995.

E.1.3 Monitoring

Resource management staff installed two permanent river cross sections at the site in 1992. One permanent river cross section established in 1989. Staff surveyed all three in 1994.

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E.2 Lower River Campground Restoration, 1991-1994

E.2.1 Introduction

Lower River Campground was formerly located in Yosemite Valley on the north side of the Merced River downstream of Stoneman Bridge. It is important to note that the campground was closed to camping after the 1997 flood, though it has remained open to the public for day-use purposes. In the spring of 1991, the stretch of riverbank on the south end of the campground immediately downstream of Stoneman Bridge was targeted for restoration due to extensive erosion along the bank.

Figure 1: Riverbank at Lower River Campground before restoration, 1991. Note the displaced riprap in the river channel.

Stoneman Bridge, constructed in 1933, has caused significant changes in channel morphology at this location in the last 60 years. The abutments of the bridge extend into the river channel constricting water flow during high-runoff periods in the winter and spring. Water velocities under the bridge reach unnaturally high levels because of this constriction. Large reverse eddies have formed downstream on both the right and left banks and a deep scour pool has formed immediately downstream of the bridge. The river's excavation of the pool has contributed to the formation of a mid-channel gravel bar roughly 500 feet downstream of the bridge. The presence of this gravel bar forced the thalweg (the deepest channel with highest flow velocities) against the right bank, which caused unnatural bank erosion along the edge of Lower River Campground.

In the late 1950's, park managers placed large riprap boulders along the river to prevent further bank retreat into the campground area. During flooding in the early 1960's, however, the river cut behind the riprap and eroded the bank back even further, negating the function of the riprap (Figure 1). As the river moved into these silty soils, tree roots were exposed and many overstory trees died. As part of Yosemite's hazard tree program, these trees were cut and removed from the bank and river channel. This area has also experienced a high level visitor use which contributed to the lack of understory riparian vegetation and subsequent erosion of the bank.

E.2.2 Restoration

Restoration work began in the spring of 1991 when park maintenance personnel permanently removed 9 campsites from the project area, including all associated campground equipment. Prior to bringing heavy equipment on the site, workers barricaded the area and installed temporary interpretive signs. They also posted informational flyers around the campground to keep visitors informed about project status, as the work was scheduled to begin while the campground was still open. During this time, restoration staff also salvaged sedges, rushes, and small shrubs from around the old campsites and along the riverbank for later replanting in restoration site.

Figure 2: Restoration staff using excavator to remove riprap at Lower River Campground.

In October of 1991, restoration staff used a small excavator to remove all riprap from the channel (Figure 2). On the terrace, they removed the asphalt parking pads, cement curbs, and campground boundary rocks from the nine former campsites. Approximately 230 cubic yards of boulders and 20 cubic yards of asphalt were removed from the site with a loader operated by maintenance personnel. This heavy equipment phase lasted 4 days, from October 7-10.

On October 10th, park foresters removed two hazard trees that were growing on the edge of the river terrace. The trees had been undermined by erosion and threatened to fall into the campground. Equipment operators first dug up the roots of the trees. The trees were felled into the river by simultaneously pulling them with a cable attached to a loader and pushing them with the bucket of the excavator. The root balls of the trees were left attached to the bank with the tree crown extending out into the channel downstream at a 10 degree angle in order to provide aquatic habitat and increase the deposition of organic material into the river.

Following riprap and asphalt removal, restoration staff used the excavator to recontour the bank near the felled trees and decompacted 19,480 square-feet of terrace soils. They set up a rotating sprinkler system for 8 days following the heavy equipment phase to help moisten the dry soils.

They also raked out the remaining ruts and tracks from the heavy equipment to deter the formation of gullies on the bank and tamped displaced bank material back into place using hand tools.

Figure 3: Lower River Campground 1 year after restoration.

Restoration staff then constructed 650 feet of Hetch Hetchy style split-rail cedar fence to enclose the project site and installed "Area Closed” and additional interpretive signs to it for visitors.

Staff planted cottonwood and willow 8-12 inches apart and up to 3 feet deep along the bank. They also planted a small number of larger cottonwood branches 4"-6" in diameter using a power auger. They planted locally salvaged sedge, rush, snowberry, Western azaleas, Western raspberry, currant, gooseberry, and 15 California black oak seedlings on the terrace, as well as spread a small amount of locally collected elderberry seed onto the bare soil (Figure 3). Following the plantings, staff mulched the entire area using woody compost produced by a tub grinder.

The following summer (1992), restoration staff installed a low-pressure watering system and watered the project area twice a month for 8 hours each time to compensate for the six-year drought. They also eradicated exotic plants within the project site to reduce competition with native species.

In 1993, staff added mulch to the west end of the project since few plants had established in the area and ground cover was sparse. In the fall of 1994, workers seeded the area with a variety of herbaceous species and Sierra Club volunteers, under the guidance of restoration staff, hydrodrilled willows on the west end of the project area.

In the winter of 1994, maintenance staff naturalized the stumps that remained from the hazard tree removal by blasting them apart with ammonium nitrate. This was done with the intent to discourage visitors from entering the restoration area to use the stumps.

E.2.3 Monitoring

Two permanent river cross-sections that had already established in 1989 during an initial evaluation of bank erosion were within the boundaries of the project site. Resource management staff surveyed these cross-sections one year after completion of the heavy equipment work. Staff also established 12 photo points prior to project implementation in 1991. The photo points were retaken in 1992, 1993, and 1994, though additional photos of the site have been taken in conjunction with other projects. Below is a photo that was taken in 2008 from river left which includes the 1991 project area (Figure 4).

Figure 4: Former Lower River Campground restoration area, 2008.

E.3 El Capitan Picnic Area Restoration, 1992-1994

The El Capitan Picnic Area was located on a spur road off of Northside Drive, one-half mile east of El Capitan Meadow. The project is located on the outside edge of a meander bend, a river zone highly susceptible to natural erosion processes (Figure 1). The picnic area was a popular site for day-use visitors as well as a raft take-out area used by the concessionaire, both of which lead to trampling of the riverbank vegetation and accelerated erosion rates (Figure 2).

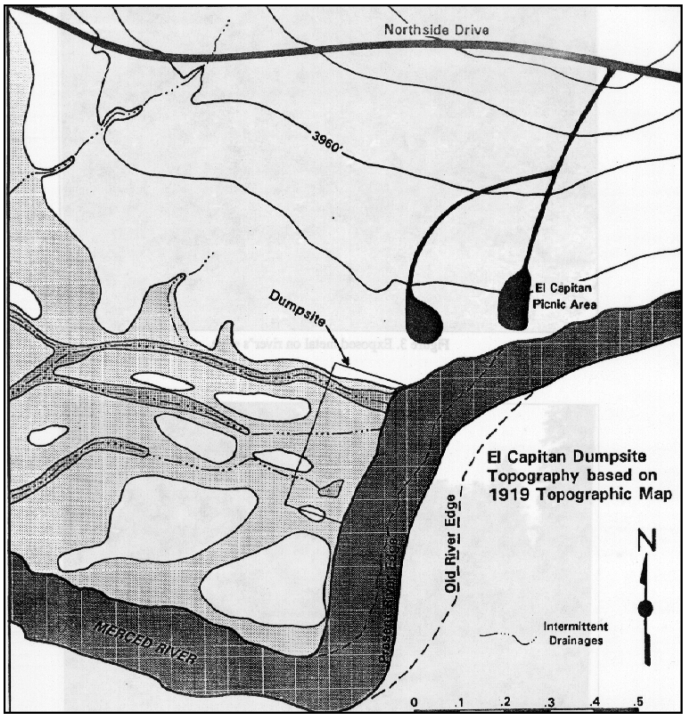

Figure 1: Location of former El Capitan Picnic Area and dumpsite.

Resource management staff considered the restoration of this area to be of high priority because of the site's high visitation rates and susceptibility to erosion. The riverbank slopes are very steep and the soil is fine-grained and non-cohesive. Trampling along the banks caused a decrease in riparian vegetation which consequently accelerated erosion.

In an effort to protect the riverbank, the National Park Service constructed riprap along several hundred feet of bank adjacent to the picnic area. However, this riprap was easily overtopped during annual spring runoff and it provided little bank protection.

E.3.1 Restoration

Figure 2: El Capitan Picnic Area before restoration.

In the summer of 1992, park staff closed the El Capitan Picnic Area. Restoration workers used an excavator to remove 550 cubic yards of riprap from 330 feet of riverbank. The boulders were placed on the terrace above the bank, loaded into dump trucks by a front-end loader, hauled off the site, and stockpiled for future park needs. While removing the boulders, the excavator operator had to carefully work around willow and cottonwood trees growing amongst the riprap. Although the operator did not remove boulders directly from the base of the trees, two cottonwood trees fell during the riprap removal process. Several large, isolated boulders were left in the river channel.

After the riprap was removed, restoration staff used the excavator to recontour a 5-foot deep gully that had formed upriver of the old raft take-out site. They then removed approximately 325 tons of asphalt and road base from the former parking area using the excavator, a front-end loader, and a dump truck.

The crew decompacted approximately 84,200 square feet of river terrace using the excavator and grader. They then used the excavator to grade top soil and organic materials onto the former road and parking areas. The excavator operator worked around established trees and shrubs, but some raspberry bushes and grasses were covered over by the grading process. All the furrows created during the decompaction were graded over.

Figure 3: Post and cable fencing at the El Capitan Picnic Area restoration site.

Staff installed a post and cable fence and connected it to the EI Capitan Dump project fence. They also moved Valley Loop Trail signs to direct hikers along the fenced perimeter (Figure 3).

In the fall of 1992 and spring of 1993, restoration crews and volunteers planted willow and cottonwood cuttings along 630 feet of the riverbank using the hydrodrill. They also brush layered cuttings along the bank at the former raft take-out site. After plantings were completed, they mulched the entire project area.

In the spring of 1993, minor gullies had developed on the riverbank at the old raft take-out. The crew recontoured the soil and re-planted these gullies with horizontal cuttings. Additional mulch was added to the riverbank and the terrace above this area. Figure 4 shows the re-establishment of vegetation on the riverbank after restoration.

Figure 4: El Capitan Picnic Area after restoration.

They irrigated willow and cottonwood plantings in September of 1993 and June of 1994 to supplement below-average precipitation levels.

In the spring of 1994, the restoration crew used a bulldozer equipped with ripping tines to decompacted the two parking areas located adjacent to Northside Drive. The decompaction zone totaled 16,000 square-feet, to a depth of 6-8 inches. The crew then recontoured the site using McLeods and metal rakes. The crew also raked native seeds into the soil and spread five truckloads of mulch across the old parking areas. The crew placed large boulders along Northside Drive to prevent cars from entering the project site. Maintenance staff designated and constructed replacement picnic area in a more appropriate location. A trail was defined through the area to allow access to the Valley Loop Trail from the new picnic area.

E.3.2 Monitoring

Resource management staff installed 11 photo points and two permanent river cross sections at the site in 1992. One permanent river cross section established in 1989. Staff surveyed all three cross sections in 1994. They also established 11 photo point locations.

E.4 Lower River Housekeeping Camp Restoration, 1992

E.4.1 Introduction

This project was located adjacent to the Lower River Campground along the right bank of the Merced River. The project area encompassed approximately 1000 feet of riverbank and terrace which began at Housekeeping Bridge and extended downstream to the lower end of Housekeeping Camp. It is important to note that the campground was closed to camping after the 1997 flood, though it has remained open to the public for day-use purposes.

Due to its close proximity to the campgrounds, Housekeeping Bridge, and Yosemite Village, this stretch of river was very popular as a day-use destination for visitors. A paved trail which provided easy access from Yosemite Village ran along the top of the bank for approximately 100 feet, and encouraged visitor use in the riparian zone. Both the bank and terrace experienced heavy trampling and erosion.

This stretch of the river was not only subjected to heavy day use by visitors, but its channel morphology has also been affected by Housekeeping Bridge. In the mid 1900's, the National Park Service stabilized this section of the bank with riprap boulders ranging in size from 30 pounds to several tons (Figure 1). The boulders helped to prevent further river side-cutting downstream of the bridge, but also created an area that was barren and devoid of riparian vegetation. The boulders on the right bank subsequently deflected the flow of the river and caused cutting on the left bank. The park eventually constructed riprap on the left bank as well, hardening the entire reach below the bridge.

The goal of this project was to remove riprap and reestablish vegetation along the bank.

Figure 1: Riprap and paved path on bank below Housekeeping Bridge prior to restoration.

E.4.2 Restoration

In 1992, restoration staff used two small tractors to rip up 135 cubic yards of asphalt from the paved path to Yosemite Village. At the edge of the bike path where the terrace sloped towards the river, they loaded the buckets of the tractors by hand to prevent the asphalt from falling into the river. The trail was re-established further back onto the terrace, away from the top of the steep riverbank. Restoration workers and volunteer groups prepared the new trail by laying the base course for the asphalt. They excavated a 9-foot wide swath through the trees to an average depth of 4 inches. They placed the soil removed during the installation of the new trail along the site of the old path to improve the soil and supplement the natural seed bank. Approximately 6000 square feet of the terrace area was uncovered during the asphalt removal. Maintenance staff later paved the new trail (Figure 2).

Figure 2: New bike path and fencing.

Restoration staff used an excavator to remove approximately 750 cubic yards of riprap from the bank. They decompacted the entire area using a small tractor and rakes after the removal of heavy equipment. The decompacted terrace and bank area totaled 21,350 square-feet.

Volunteers and restoration workers planted 150 willow cuttings that had been salvaged prior to riprap removal. They planted 80 plants salvaged from the terrace area and leftover plants from the Stoneman Meadow boardwalk construction project. The terrace was also seeded and lightly mulched after planting.

Workers planted willow and cottonwood cuttings along 700 feet of bank using a hydrodrill. Along the 80-foot section of bank directly below the bridge, they brush layered with willow and cottonwood cuttings to provide additional stability to the bank (Figure 3). Workers planted a total of around 3000 willow and 300 cottonwood cuttings throughout the length of the project.

Figure 3: Willow cuttings below Housekeeping Bridge 1 year after restoration.

Restoration workers constructed 1,100 feet of Hetch Hetchy-style cedar split-rail fence to protect the project area (Figure 2). The fence provides river access at a gravel beach 1,000 feet downstream of the bridge and directly across the river from Housekeeping Camp.

E.4.3 Monitoring

In 1992, resource management staff installed two permanent river cross sections below Housekeeping Bridge. A third cross section was established in 1993. Staff also installed 26 photo points in 1992.

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E.5 Devil's Elbow Restoration, 1993-1995

E.5.1 Introduction

Devil's Elbow is a section of the Merced River located just 0.2 miles upstream of El Capitan Crossover Bridge (Figure 1). The site has a long history as a popular picnic area and river access point for visitors. Up until 1984, it served as the main raft take-out location for the concessionaire, resulting in extreme erosion of the bank (Figure 2).

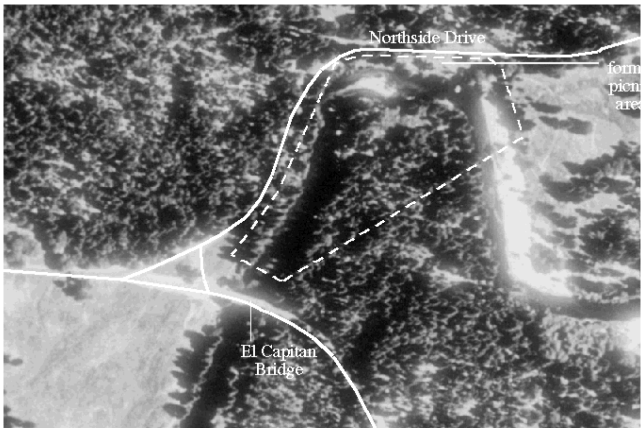

Figure 1: Location of Devil's Elbow.

Figure 2: Riverbank at Devil's Elbow picnic area before restoration.

Within the picnic area, many dead and dying trees on the riverbank had been removed over the years, contributing to erosional problems. A survey of tree stumps in 1992 found that at least 49 trees had been removed, 26 of which were greater than two feet in diameter. Parking turnouts on both sides of the road accommodated up to 35 vehicles at a time.

In 1992, resource management staff proposed restoration of the area to avoid further degradation of the natural and cultural resources present at Devil's Elbow.

E.5.2 Restoration

In the spring of 1993, restoration staff worked with the maintenance division to close the picnic area. Workers removed picnic tables, fire rings and two pit toilets. They placed boulders along the road to prevent cars from parking in the former parking areas. They used heavy equipment to remove the asphalt from the picnic area parking lot on the south side of the road. In 1994, workers removed the asphalt from the north side of the road.

Following the infrastructure removal, restoration workers decompacted 13,000 square-feet of soil using a small tractor fitted with ripping tines. Workers then planted sections of 5- to 7-foot long cottonwood limbs along the bank that had been salvaged from a felled tree near Sentinel Bridge. They used an auger to dig the holes 3-4 feet deep and a posthole digger to deepen the holes to 5 feet. They used the excavator bucket to drive limbs larger than three inches in diameter into the ground. They brush layered willows cuttings along the steeper sections of bank using the excavator. Workers also used the hydrodrill to plant willows vertically between the horizontal brush layering and the cottonwoods.

On the terrace, workers planted 75 California black oak seedlings, 30 canyon live oak seedlings, and raspberry seedlings as well as a spread mixture of native seeds. Volunteers and restoration crews collected mulch and spread it across the terrace. They also collected wood chips from the wood yard and spread them on the bank to provide some protection for the newly planted willows.

Restoration staff constructed 1926 feet of fencing around the site with a river access point at a more resilient sandbar. They installed both zigzag and post and cable style fences.

During the summer of 1994, restoration crews watered all plantings every other week. In 1995, they placed solid double-layer plastic tree shelters around the oak seedlings to prevent browsing and sun damage.

E.5.3 Monitoring

In 1992, resource management staff installed 5 long-term river cross sections and surveyed them again in 1994. They installed 20 photo points in 1993.

E.6 Little Yosemite Valley Restoration, 1993-1994

E.6.1 Introduction

Little Yosemite Valley is located in the Merced River Canyon above Nevada Falls at 6100 feet elevation. Due to its popularity as a wilderness destination, a ranger station and a campground were established at the site in 1972. The section of the John Muir Trail leading to Half Dome through Little Yosemite Valley is also one of the most hiked day-use trails in the Sierra Nevada. The original campground at Little Yosemite Valley had been established less than 100 feet from the river, affecting riparian vegetation through heavy visitor use.

During the summer of 1993, archeologists and restoration staff surveyed the 1.5 acre campground area and determined that heavy visitor use had impacted cultural and natural resources in the area. Figure 1 details the restoration plan for the Little Yosemite Valley campground and vicinity.

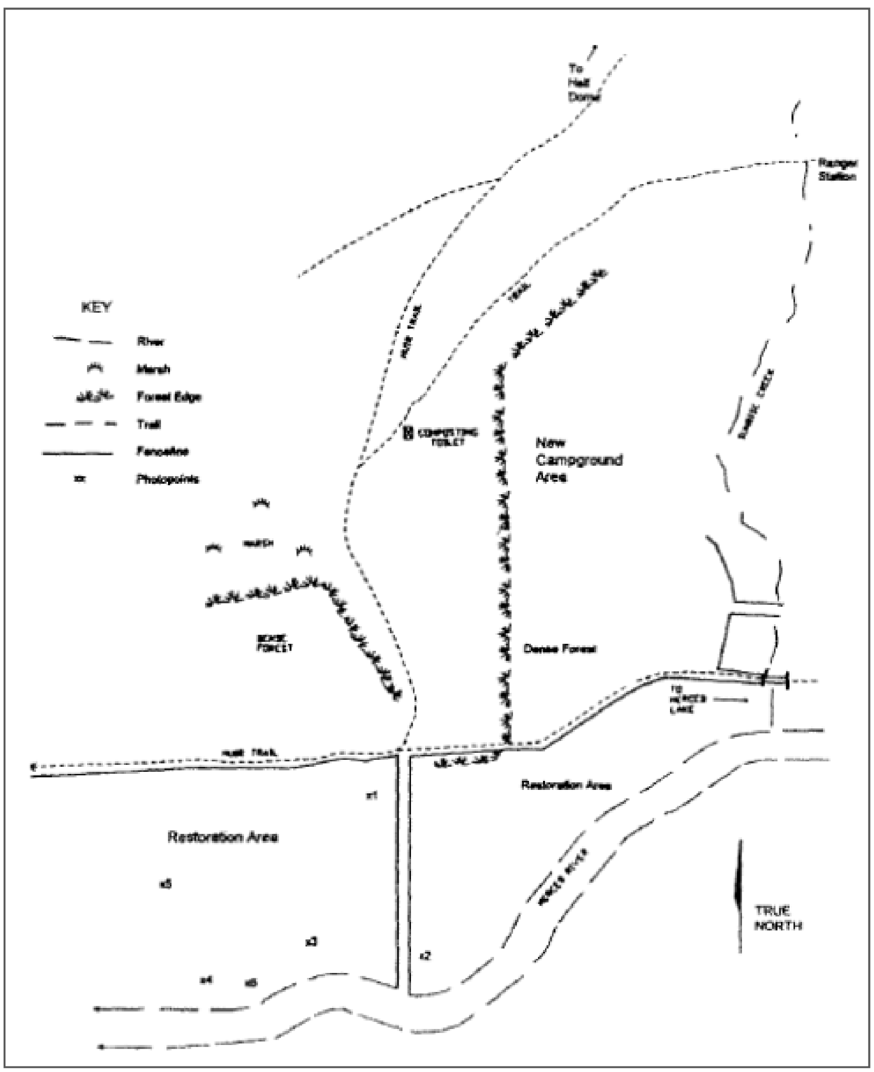

Figure 1: Little Yosemite Valley restoration plan.

E.6.2 Restoration

During the summer of 1993, an interdivisional crew relocated the campground to a more suitable location. They also constructed a composting toilet facility to replace the existing system.

The restoration work leader and 12 Yosemite Conservation Corps (YCC) workers completed the majority of the work in July and August of 1993. The crew camped at the ranger station to minimize the logistics and impact of a separate camp set-up.

The crew eradicated exotic plant species in the project site and in adjacent areas. Then they collected native perennial grass and forb seed from an adjacent burned area to be used on the restoration site. The crew constructed 1950 feet of log and block style fence around the restoration area on the riverbank using salvaged trees that were felled at the new campground location.

The crew decompacted the soils of the former campground by hand using revegetation spades and digging forks. They also naturalized stumps and log ends using axes and mauls.

In September of 1993 and June of 1994, a restoration crew returned to hydrodrill willow and cottonwood cuttings on the riverbank. They also planted a small quantity of aspen and azaleas using the hydrodrill.

E.6.3 Monitoring

A crew member installed 10 photo points of the site in 1993.

E.7 Sentinel Bridge Restoration, 1993-1995

E.7.1 Introduction

In 1987, the Federal Highway Administration and the National Park Service determined that the 1919 Sentinel Bridge needed to be replaced due to failing structural integrity. The old Sentinel Bridge design included two support piers mid- channel in the Merced River. These support piers constricted the river during high flows and caused bank erosion downstream. Engineers worked with resource managers to design a bridge that would cause less impact to the surrounding riparian ecosystem (Figure 1).

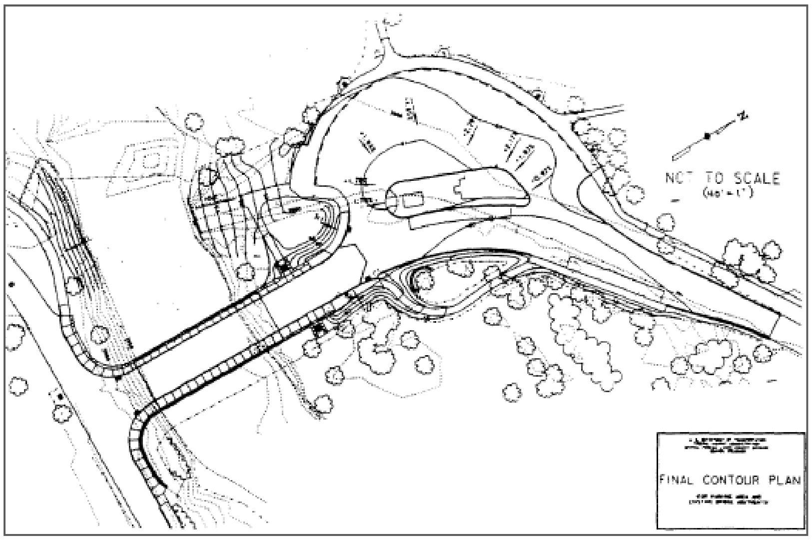

Figure 1: Sentinel Bridge plan.

Construction of the new Sentinel Bridge was completed in the spring of 1994. The bridge is 80 feet upriver from the old one and spans the channel of the river without mid-channel support piers. The restoration goals of this project were to stabilize newly-exposed and recontoured riverbank at the site of the old bridge and to restore native vegetative cover to all sites impacted by construction activities.

E.7.2 Restoration

Prior to construction, the restoration staff worked with Yosemite Association volunteers to salvage vegetation from the site of the new bridge. They salvaged goldenrod *(Solidago canadensis), Carex* spp., *Juncus* spp., milkweed *(Ascelepias speciosa),* and an assortment of grasses from the site of the new bridge.

In 1994, after the bridge was completed, the contractor recontoured the riverbanks and applied sterile rice straw to the fillslopes along the walkway shoulder. Volunteers planted the salvaged vegetation, 50 California black oak seedlings grown from local acorns at the CCC nursery, and 100 sedge plugs *(Carex rostrata)*. Restoration staff constructed 1,000 feet of Hetch Hetchy style split-rail fence to protect the revegetated site.

In the summer of 1994, restoration staff watered the area and eradicated exotic plant species. In the fall, they planted willow and cottonwood cuttings on the north bank using the hydrodrill. They collected, dried, cleaned, scarified, and planted buck lotus seed *(Lotus crassifolius)* in the project site. They also collected and planted deer grass seed *(Muhlenbergia rigens)*. In the summer of 1995, they planted more willow cuttings with the hydrodrill on the right bank, downstream of the bridge. Figure 2 shows the site before and after restoration.

Figure 2: Sentinel Bridge area before and after restoration in 1994 and 1995, respectively.

E.7.3 Monitoring

Park ecologists established 4 vegetation transects to evaluate changes in species frequency and dominance over time and space. They also installed 11 photo points in 1993 and 4 river cross-sections in 1994.

E.8 North Pines Group Camp Restoration, 1994-1995

E.8.1 Introduction

North Pines Group Camp is located at the east end of Yosemite Valley adjacent to Tenaya Creek. The campground experiences intensive visitor use during the summer months and as a result, a section of riverbank between the creek and the campground became denuded of vegetation and heavily eroded (Figure 1).

Figure 1: Denuded Bank of Tenaya Creek at North Pines Group Camp prior to restoration.

It is important to note that North Pines Group Camp was closed to camping after the 1997 flood. The area has remained open to the public for day-use purposes.

Figure 2 details the restoration area at North Pines Group Camp.

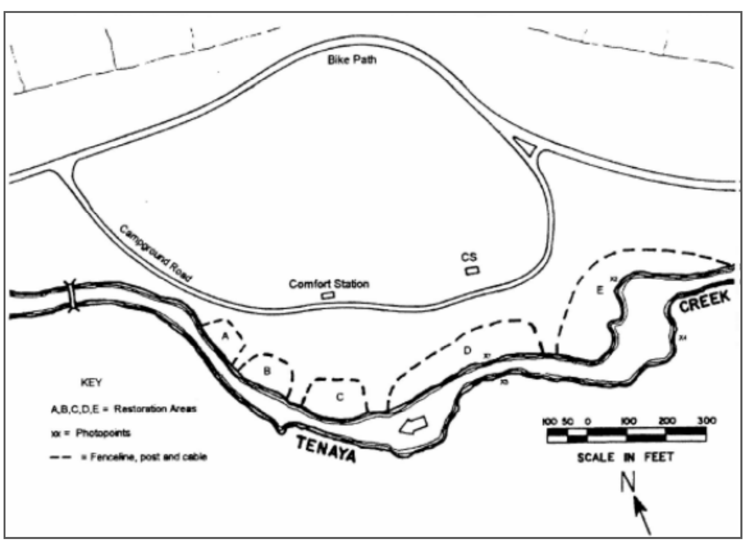

Figure 2: Restoration area map, North Pines Group Camp.

E.8.2 Restoration

In the spring of 1994, restoration workers installed 1970 feet of post and cable fence between the campground and Tenaya Creek which included four creek access areas. A park archeologist screened the soil from eight post-holes within the site and eleven outside the boundaries of the site for cultural artifacts. Workers used a bulldozer to decompact 16,913 square-feet of soil in the fenced areas to a depth of 12-18 inches.

In the fall, restoration crews planted the terrace, banks, and creek zones of the project area. They planted 107 locally collected raspberry cuttings on the terraces. They also planted California black oak seedlings *(Quercus kelloggii)* left over from the Happy Isles restoration project. Restoration workers transplanted 3 species of rush and 3 species of sedge in the creek zones. After planting, workers spread azalea *(Rhododendron occidentalis)* and lotus (*Lotus* spp.) seed on the terrace areas. Then they collected and spread approximately 630 cubic yards of mulch. In the spring of 1995, the restoration staff and volunteers placed boulders along the fence line to delineate a trail and prevent campers from placing their tents too close to the fence.

E.8.3 Monitoring

Resource management staff installed 5 long term monitoring photo points in 1994.

E.9 Swinging Bridge Restoration, 1994-1995

Introduction

The Swinging Bridge project is located on the north side of the river, across from the Swinging Bridge Picnic Area. This section of the river is a very popular day use destination for visitors with a picnic area on river left, a large sand bar and river access area on river right, and a deep pool below Swinging Bridge.

Figure 3: Original Swinging Bridge.

The original Swinging Bridge was built before 1911 as a suspension-style footbridge (Figure 1). After the 1937 flood, the bridge was rebuilt in a different style 300 feet downstream of the former location. The original concrete foundations are still on-site. The current Swinging Bridge has abutments mid-channel which have caused a large scour pool to form downstream, an increase in deposition on the right bank, and erosion of the left bank. The park constructed riprap on the left bank to prevent it from eroding further.

In 1992, resource management personnel designed a plan to rehabilitate the Swinging Bridge Picnic Area on both sides of the river. The proposal included removal of riprap from both banks, relocation of picnic tables away from the riverbank and fencing on the right bank. Resource management staff re-assessed the site in 1994 and decided to focus the work on the left bank. Heavy day use resulted in extensive trampling and a decrease in riparian vegetation on river right; however, the bank on river left remained resilient due to the well-established cottonwood trees growing amongst the riprap. The goal for this project was to reestablish and protect riparian vegetation in order to prevent net stream widening.

E.9.1 Restoration

In 1994 and 1995, staff constructed 1160 feet of Hetch Hetchy style split-rail fence and 45 feet of post and cable fence along the foot path on the right bank upstream from Swinging Bridge. Downstream from the bridge, they installed 150 feet of post and cable fence to encourage visitors to use the sand bar to access the river instead of the steep bank.

Staff manually decompacted the terrace and upper riverbank areas (8250 square feet) with shovels and digging forks, focusing on eliminating informal trails. They collected willow and cottonwood cuttings and planted them along the riverbank using a hydrodrill. Staff directly transplanted sedges and bulrushes along the toe of the bank and sod plugs on the terrace along the decompacted informal trails. After planting, they mulched the terrace and spread seeds of native mugwort, sageword, blue wildrye, needlegrass, and Sierra Lessingia (*lessingia leptoclada*).

E.10 Housekeeping Camp Restoration, 1995

E.10.1 Introduction

Housekeeping Camp is located about one-half mile upstream from Sentinel Bridge and is adjacent to the river for a distance of 1800 feet (0.35 miles). The camp is a popular seasonal lodging area managed by the park concessionaire and is open during the summer months. The Housekeeping Footbridge which spans the Merced River just upstream of the camp has three mid-channel supports with riprap armoring on the downriver side of the supports. Three deep pools have developed immediately downriver of the bridge and a reverse eddy around the left bridge abutment has caused erosion of the riverbank in this area.

Figure 1: Left bank at Housekeeping Camp. Exposed roots in the foreground; riprap boulders in the background.

More than 40 years ago, large boulders were placed on the bank at Housekeeping Camp, but served little purpose because water flowed behind and over the top of them during flood events, causing erosion of the terrace. Approximately two vertical feet of fine fluvial soil had been lost from the terrace surface behind the boulders. Most of the riverbank and terrace along the edge of the camp was devoid of understory vegetation due to trampling (Figure 1).

Due to the continued erosion of the riverbank, resource managers determined that the Housekeeping Camp riverbank was a high priority restoration area. Park managers worked with the concessionaire to implement restoration goals.

The restoration project encompassed 1300 feet of riverbank adjacent to the camp on the left bank of the river. Visitors have access to the river at gravel bars both upstream and downstream of the restoration area.

E.10.2 Restoration

In October of 1995, restoration staff removed 565 cubic yards of riprap revetment boulders from the bank at Housekeeping Camp. They replaced the boulders with large woody debris to provide bank support and increase biomass along the channel. They used the excavator to create 3-foot deep trenches for anchoring the logs. The logs averaged 25 feet in length and 2-4 feet in diameter. Staff placed them at a 10-20 degree angle to the flow of the river in order to deter the formation of back eddies downstream. They crushed smaller or rotten logs and spread the mulch along the terrace.

Restoration crews brush layered willow and cottonwood cuttings randomly along 550 feet of bank. They also planted cuttings near the buried logs and supplemented the brush layers with hydrodrilled cuttings. Three different species of willows comprised 70 percent of the brushlayers and black cottonwood comprised 30 percent Staff used only one species of willow or cottonwood within each brushlayer. Figure 2 shows a section of the project area in 2009, 14 years after restoration.

Figure 2: Riverbank at Housekeeping Camp, 2009.

The restoration crew constructed 1,296 feet of Hetch Hetchy style split-rail fence beginning at Housekeeping Bridge to surround the grove of pine trees along the northwest edge of the camp. The pine trees were included within the project to prevent additional trampling around their roots.

Staff planted rushes, raspberry cuttings, and California black oak and dogwood seedlings across the terrace. Volunteers helped to collect 230 cubic yards of mulch and spread it over the project area.

E.10.3 Monitoring

In 1992, resource management staff established 2 permanent river cross sections below Housekeeping footbridge. They installed a third cross section in 1993. These river cross sections were monitored in 1995 and 1996. They also installed 18 photo points in 1995.

E.11 Cook's Meadow Restoration, 1998-2005

E.11.1 Introduction

Cook's Meadow, located just east of the Yosemite Lodge, is a lower montane wet meadow that is confined to the south by the Merced River, to the west by Yosemite Creek, and to the north and east by major roads. The meadow is approximately 30 acres in size and contains remnants of oxbows that remain inundated throughout the growing season.

The hydrology of Cook's Meadow was significantly altered in the 1800s when settlers drained certain parts of the meadow with ditches and culverts in order to maintain drier land for pastures and agricultural purposes. A road was also built through the center of the meadow, compacting the soil and impeding the flow of surface water across the land. The subsequently drier soils also promoted the proliferation nonnative upland grass species as well as conifer encroachment into the meadow. In later years, paved interpretive trails were established throughout the meadow as well (Figure 1).

Figure 1: Cook's Meadow with paved trails (left and right) and historic roadbed (center), 1993.

The Cook's Meadow Restoration Project aimed to restore two critical elements within the ecosystem by removing unnecessary fill material and improving the existing interpretive trails. The two ecosystem elements - meadow hydrology and native plant species - were determined through the observation of groundwater levels, impounded surface water, distribution and frequency of native wetland species, and distribution and frequency of nonnative species.

E.11.2 Restoration

Before restoration work began in Cook's Meadow, resource management staff recorded the four agricultural ditches due to their association with the Yosemite Valley Historical District and completed a landscape evaluation for the abandoned Sentinel Road. Park archeologists monitored all ground-disturbing activities associated with the project.

The restoration work began in 1998 with the removal of the abandoned Sentinel Road (Figure 2). Restoration staff removed the road material using an excavator, a front-end loader, and dump trucks. They recreated the original landscape contours by removing the coarse sand and gravel fill until the meadow fine silt loam was exposed. The excavated material was salvaged for use as fill in the ditches and outlets.

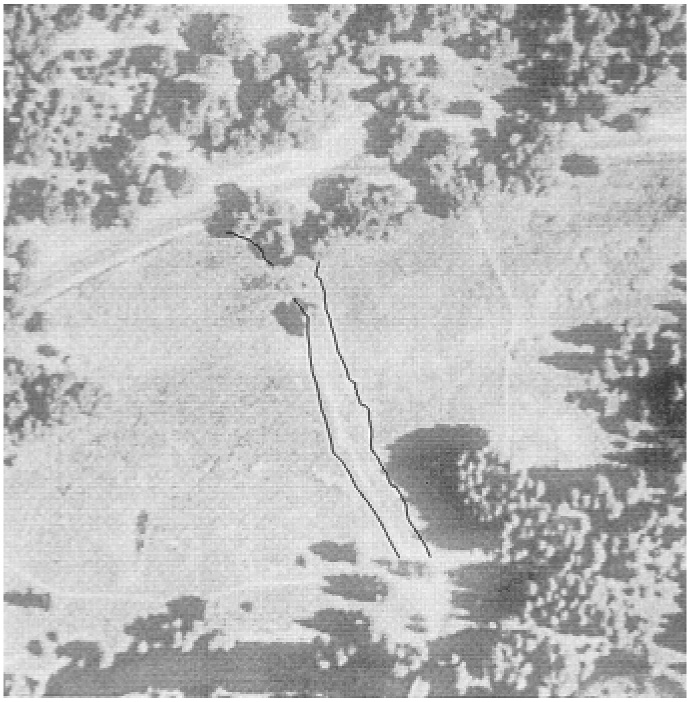

Figure 1: Historic Sentinel Road boundary.

In 1998 and 1999, four ditches were altered to reduce surface runoff and extend the inundation period in portions of the meadow. Restoration workers prepared he first three ditches by removing vegetation from the banks, trough, and the outlet into the oxbow. They amended the outlets with a plug of silt loam sloped into the oxbow to improve stability of the ditch fill. The topsoil that had been removed during the ditch preparation and vegetation plug removal was placed back on top of the fill. Staff planted vegetation plugs in the topsoil and used additional loam to fill in the spaces between the plugs. They plugged the fourth ditch, which was much shallower than the others, at the outlet end and installed dikes in intervals along the ditch's length to restrict water flow.

In the fall of 1999, restoration staff constructed a plug to block the outlet located on the riverbank just south of the paved path. They prepared the site by salvaging vegetation from the base and sides of the outlet with an excavator. They then filled it with a solid plug of meadow loam at the edge of the riverbank. They used salvaged fill and loam material from the old Sentinel Road to fill the remaining cavity. After that, they applied topsoil and planted vegetation plugs. Workers planted willow and cottonwood cuttings on the riverbank with a hydrodrill to protect the plug and prevent erosion.

Restoration staff installed two culverts across Sentinel Crossover Road in order to capture a portion of redirected surface flow and increase surface water input from Yosemite Village, Indian Creek drainage, and the Merced River.

In the fall of 2000, staff excavated the paved interpretative trail that crossed the meadow from Sentinel Bridge to Northside Drive parallel to the natural contour of the meadow. They updated the trail by installing a 500-foot boardwalk constructed of a plastic/wood composite. In 2005, they replaced a portion of the paved trail parallel to the Merced River between Sentinel Bridge and the Superintendent's Bridge with a 200-foot long boardwalk (Figure 3). Staff re-established meadow's natural contour and salvaged vegetation was replanted adjacent to each side of the trail. They installed eight interpretive wayside exhibits along the trails to enhance the visitor experience and provide an opportunity to educate the public on the meadow's history.

Figure 2: Interpretive trail before (2000) and after (2006) boardwalk installation.

The project also incorporated aggressive exotic species management techniques to control the proliferation of noxious plants throughout the meadow. Priority species included invasive blackberry (*Rubus discolor*), woolly mullein (*Verbascum thapsus*), and bull thistle (*Cirsium* *vulgare*). The meadow is scanned each year by restoration staff and invasive plant species are eradicated using the appropriate method.

E.11.3 Monitoring

Restoration ecologists initiated several studies surrounding this project that aimed to observe vegetation diversity and meadow hydrology. They designed a vegetation study to monitor plant community changes in the meadow. Surveys were completed before restoration began in 1998, four years later in 2002 and once more in 2005. Botanists categorized observed plant species according to their wetland indicator status.

The park ecologist and hydrologist also developed another study to observe changes in meadow hydrology subsequent to these restoration efforts. They had twenty water table monitoring wells installed throughout the meadow and surrounding area in order to evaluate fluctuations in water table levels. Staff measured and recorded water levels at each well using a portable electrode probe. Monitoring continued through 2007 at weekly to monthly intervals. They also mapped surface inundation utilizing a handheld GPS unit to allow inundation in hectare-days to be calculated and compared for the meadow for each year.

E.12 Eagle Creek Restoration, 2002

E.12.1 Introduction

Eagle Creek originates on the north rim of Yosemite Valley, dropping down to the valley floor between the El Capitan and Three Brothers rock features. It then passes beneath Northside Drive and meets the Merced River about one mile west of Yosemite Lodge.

The short reach of Eagle Creek from Northside Drive down to its confluence with the river was relatively bare of riparian vegetation and exhibited extensive erosion. The area was exposed to frequent day-use traffic, causing ground disturbance and greatly reducing the total coverage of shrubs and herbaceous plants in the understory (Figure 1). The creek bed itself was used as a river access trail during drier portions of the year. The site also contained remnants of infrastructure from the Rocky Point Sewage Treatment Plant which was shut down in 1931. A concrete structure containing an abandoned sewage line spanned the channel of Eagle Creek near its junction with the Merced River, which disrupted the normal flow of the creek.

Figure 1: Confluence of Eagle Creek and the Merced River before restoration, 2002.

E.12.2 Restoration

The goals of the Eagle Creek Restoration project were to remove the concrete structure from the creek bed, plug other abandoned sewer structures, restore and revegetate the denuded riverbank, and redirect and confine visitor access to a more durable location. All of the restoration work was done in 2002.

Early in the year, restoration workers collected local willow cuttings for propagation and salvaged other plants on-site for use on the project. Before restoration work began on the site, crew members surveyed four cross-sections across the Merced River at the confluence of Eagle Creek to establish channel morphology data at the site. Crew members also installed photo points throughout the site. The excavator was used to remove the concrete structure from the creek bed while the sewage line and manhole were left in place and plugged with concrete.

Approximately 60 feet of denuded riverbank were recontoured using an excavator and a bobcat tractor. Excavator operators placed logs and soils on the eroded bank and brush layered willow cuttings to rebuild the bank. Crew members also planted willow cuttings with a hydrodrill at the toe of the bank. Volunteers helped to bury woody debris along the upper portion of the bank and terrace to provide structural support to the newly reconstructed bank. Crew members planted salvaged vegetation throughout the denuded terrace and spread local herbaceous and shrub seeds. Park foresters felled a large incense cedar (*Calocedrus decurrens*) whose roots were entirely exposed on the eroded bank and placed it at the toe of the bank to slow river velocity and create a backwater eddy habitat. Volunteers and crew members then mulched the whole site with local material.

Crew members delineated a new river access trail to redirect visitor use away from the creek bed and riverbank. In order to mitigate trampling and promote the reestablishment of vegetation, 546 feet of fencing was installed on the terrace above the denuded bank.

E.13 Cascades Diversion Dam Removal, 2003-2004

E.13.1 Introduction

The Cascades Diversion Dam, constructed in 1917 to provide hydroelectric power to Yosemite Valley, was located on the Merced River approximately 1.5 miles downstream of Pohono Bridge. In 2001, the dam was identified for removal by the U.S. Bureau of Reclamation due to advanced age and flood damage, and the considerable threat to downstream resources, infrastructure, and human life in the event of sudden failure. The dam was a timber crib construction, 184 feet long and 17 feet high, flanked by 30-foot concrete abutments (Figure 1). The upstream impoundment pool was approximately 1.25 acres in size and stored an estimated 9,600 to 15,000 cubic yards of sediment at the time of removal.

Figure 2: Cascades Dam circa 1924.

E.13.2 Restoration

Prior to construction, park ecologists developed a restoration plan to accompany environmental compliance documents and the engineering design package. The plan included botanical surveys of the project site and reference area which guided the selection of revegetation species and seed collection. The surveys also included landscape position (elevation from bankfull mark) of observed species.

The removal of the dam and much of its associated infrastructure was completed in December of 2003. The project area included the site of the dam itself, upland areas where the dam abutments and screen house were constructed, and the floodplain that was previously impounded and inundated behind the dam. Restoration measures were executed in several stages following the removal of the dam from December 2003 to November 2004. The project was divided into units based on landform and physical characteristics, proximity to the river, and phasing of the project. The four zones - floodplain, revetment, upland and roadside - totaled 1.37 acres (Figure 2).

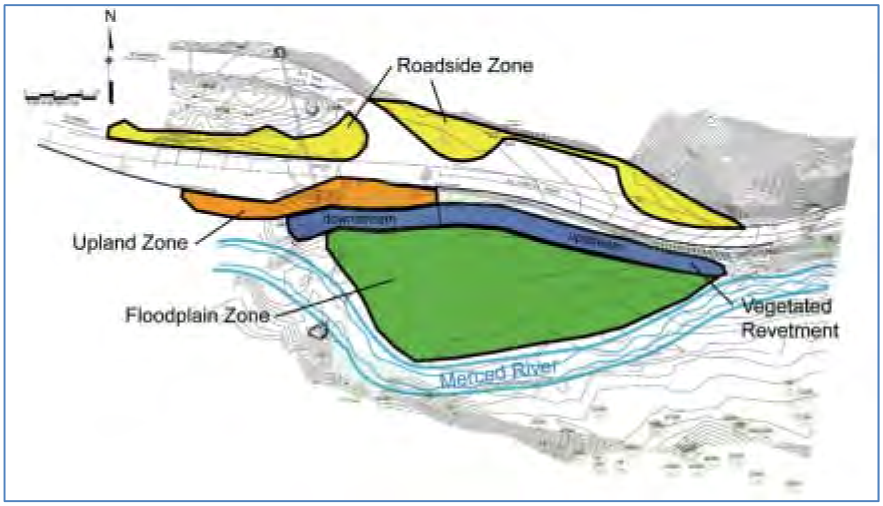

Figure 3: Cascades Dam restoration zones.

The floodplain zone included the entire floodplain along the right bank, between water's edge and the toe of the vegetated revetment. The area consisted primarily of sediments formally impounded behind the dam. During the first year after the dam was removed, a seasonally-flooded side channel formed against the revetment on the right bank and has continued to transport and rework the impounded sediments. Restoration crews planted 100 willow cuttings, 3,500 herbaceous wetland seedlings, 115 shrub seedlings, and broadcast herbaceous wetland seed throughout the floodplain zone.

The contractor constructed the vegetated revetment at the anticipated bank full mark along 137 meters of the right bank. The revetment consists of boulders, smaller rocks, and sediments with riparian vegetation incorporated into it. It was built along the length of the project to protect existing riparian vegetation, newly exposed riverbanks in the former impoundment and dam locations, and to prevent damage to the adjacent El Portal Road. Operators used heavy machinery to position large boulders while restoration crews placed willow and cottonwood cuttings in the gaps between them. They planted approximately 544 cuttings throughout the revetment. Local rock and sediment were used on-site or left in place to be transported by the river; no additional import (or export) of rock, sediment, or soils occurred during this process. The methods used for building the revetment varied slightly between the upstream and downstream ends of the project due to the change in stream gradient and the amount of exposed riverbank between the impoundment pool and the former location of the dam structures downstream (Figure 3).

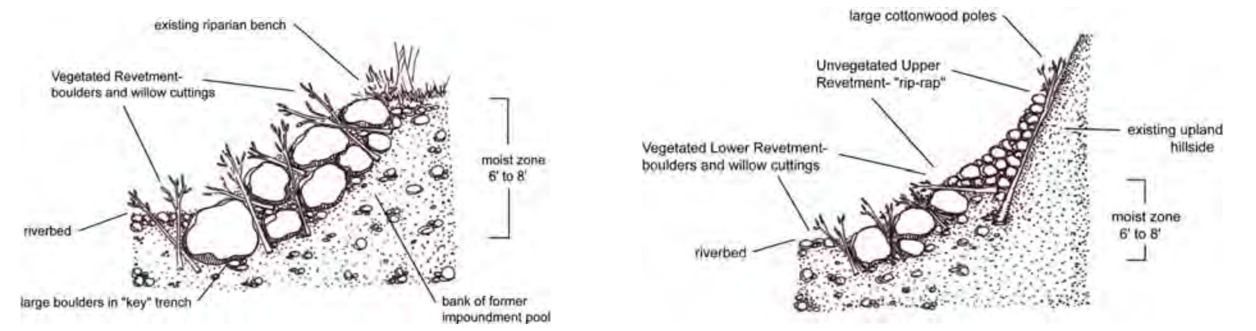

Figure 3: Construction methods used for vegetated revetment.

The upstream segment was one course tall, allowing the cuttings to be inserted throughout the height of the wall. Heavy equipment operators and restoration workers constructed the revetment by placing large boulders within a key trench excavated parallel to the existing riparian bench (bank full mark) on the riverbank. They then placed additional boulders against the foundation in a back slope up the exposed riverbank. Operators constructed the top of the revetment to match the elevation and topography of the edge of the riparian bench. The revetment in this segment was designed to preserve as much on-site vegetation as possible.

The downstream segment of the revetment involved multiple layers of rock. Equipment operators placed additional large boulders and rock above the bioengineered portions to protect upper disturbed slopes. Throughout this segment, restoration workers placed cuttings within the lower 6-8 feet of the revetment. They placed cuttings in every available space. At the top of the first lift, workers installed a layer of sediments and cuttings prior to positioning the second layer of rock. Cuttings were not incorporated into the upper layers in the event that they would not have adequate access to moist soils. Prior to placing the upper layers of rock, workers laid a number of the very largest cottonwood pole cuttings against the soil embankment with their basal ends driven into the ground as deeply as possible.

The upland zone encompassed the slopes above the right bank where the abutments, screen house, and penstock were formally located as well as the newly exposed and bare soils between the revetment and the guard wall of the El Portal Road above. Restoration workers planted 3 pounds of acorns and 900 shrub seedlings, and broadcast native grass, forb, shrub, and tree seed in this area. After planting, they spread duff and leaf litter across the site.

The roadside zone included the disturbed soils along the shoulder of the new road, curbs, ditches, and berms. Here, workers planted 880 shrub seedlings, broadcast grass, forb, and shrub seeds, and covered the area with duff and leaf litter.

E.13.3 Monitoring

Restoration staff monitored the revegetation areas for two years after restoration activities. They established several survey plots and assessed each zone for survival of live plantings and establishment of seeded plants. Progress of vegetation recovery (both planted and naturally-occurring) was also compared to conditions on adjacent reference sites.

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E.14 Happy Isles Dam Removal, 2004-2006

E.14.1 Introduction

Constructed at the mouth of Yosemite Valley in 1910 by the US Army, the Happy Isles Dam was designed to provide reliable drinking water supplies to Yosemite Valley and feed the Happy Isles hydroelectric power plant. In 1919, the NPS removed the old power plant, but continued to draw drinking water from the reservoir until the mid-1980s. The obsolete dam system before removal consisted of a 2.5 foot high wall of rock and concrete crossing 33 feet of channel, two steel-reinforced concrete and iron diversion gates, and 258 feet of 18-inch diameter iron intake pipes below the diversion gate (Figure 1).

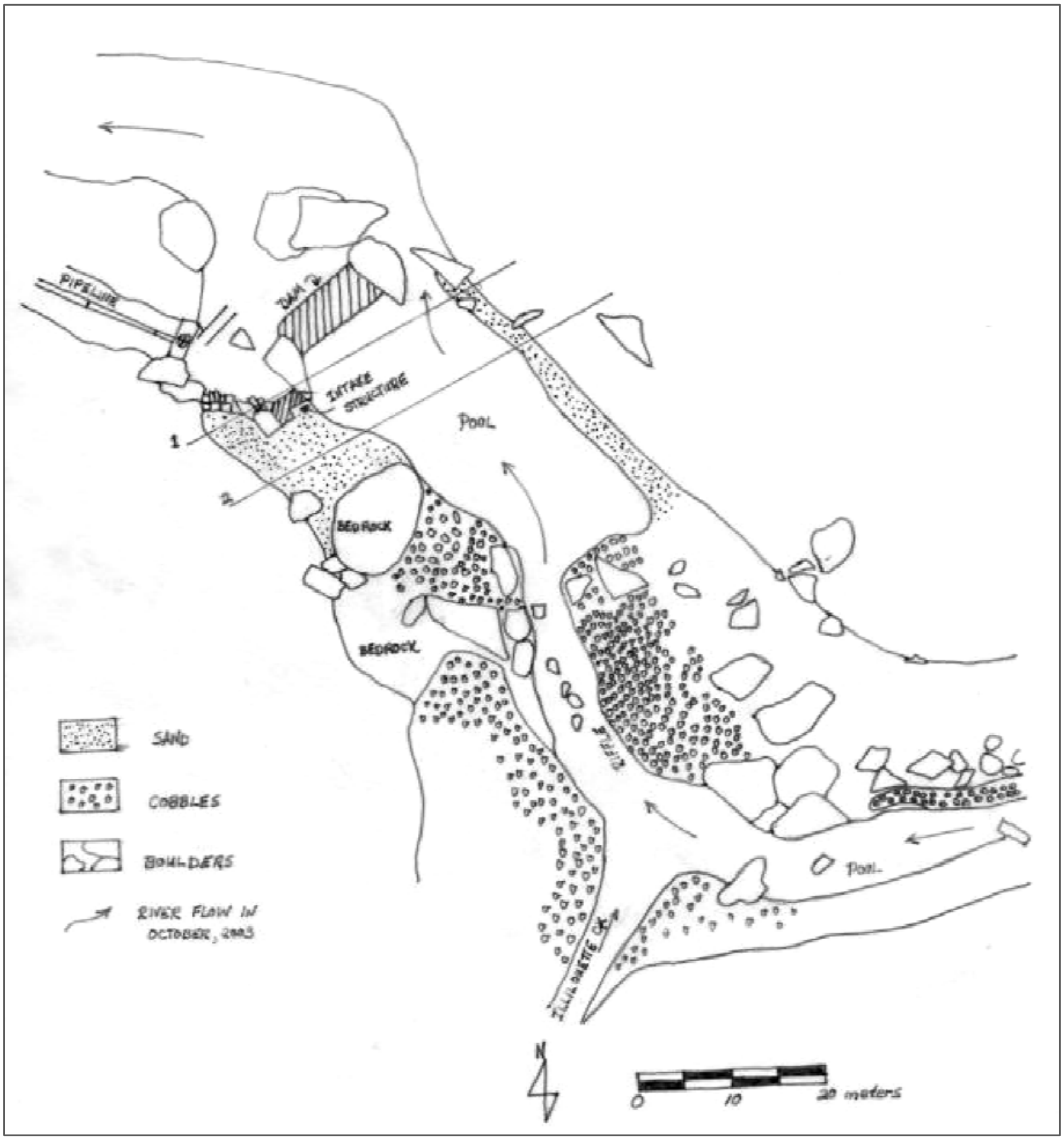

Figure 1: Site map of project area at Happy Isles, including channel survey cross-sections 1 and 2.

The purpose of this project was to restore the free-flowing character and pool-riffle morphology of this reach of the Merced River through the removal of Happy Isles Dam and associated diversion structures. One diversion structure still remains on site; it is recessed from the channel edge and is not slated for removal. This structure is at the head of a corridor created for the pipeline and would create an artificial river channel if removed.

Prior to construction, resource management staff established baseline conditions at the site. Staff mapped the channel and infrastructure using a tape and compass; photographed the site from 5-10 permanent photo points; surveyed 2 river cross-sections (Figure 1); measured water quality components including temperature, dissolved oxygen, and sediment load; and sampled the invertebrate community to determine the health of the local aquatic community.

E.14.2 Restoration

Deconstruction of the dam began in October of 2004 and was completed in November of 2005. Park trail crew staff blasted and removed 37 cubic yards of cement material from the area of the dam (Figure 2). Blasting was accomplished by drilling holes through the structure to determine the thickness of the dam and back filling with explosives sufficient to fracture the dam. One of the intake structures was also blasted and removed by trail crew staff. Approximately 7 cubic yards of concrete and steel were removed with the intake structure. The climbing rungs were also removed from the remaining diversion structure at the head of the pipeline. Stacked rock walls located near the diversion gates were deconstructed and the material positioned in the diversion channel between the removed intake structure and the remaining diversion gate.

Figure 2: Happy Isles Dam before removal (2003) and after (2005).

Given the presence of abundant native riparian vegetation immediately upstream of the project area, direct revegetation efforts were not necessary. The channel sediments were left to be reworked by high-flow periods during spring runoff.

E.15 Riverbank Restoration below Stoneman Bridge, 2006

Figure 33: Eroding bank on river left between Stoneman Bridge and Housekeeping Camp.

Figure 34: Visitors utilizing the raft put-in site at Stoneman Bridge (2005)

In 2006, the reach of river below Stoneman Bridge was selected by for terrace restoration based on the eroded condition of the steep cut bank and exposure to high levels of visitor use (Figure 1). This stretch of river is a popular day use area for guests at Curry Village and Housekeeping Camp, as well as the tenants of the Curry Dorms. Stoneman Bridge serves as the upstream boundary for rafting on the Merced River and is in close proximity to the concessionaire's raft rental area. Consequently, the bridge serves as the most convenient and, therefore, most popular river access site for rafters. The riverbank here is steep and, along with the terrace, lacks understory vegetation cover and exhibits highly compacted soils (Figure 2).

The project area encompassed 1,500 feet of river terrace along the south side of the Merced River from Stoneman Bridge down to the eastern boundary of Housekeeping Camp (Figure 3). Restoration staff constructed split rail fencing along the entire length of the reach (1, 500 feet) and installed two specific river access points: one at the raft put-in directly below the bridge and one farther downstream at a popular river access location for the tenants of Curry Dorms. They also mulched the terrace with local leaf litter to inhibit erosion.

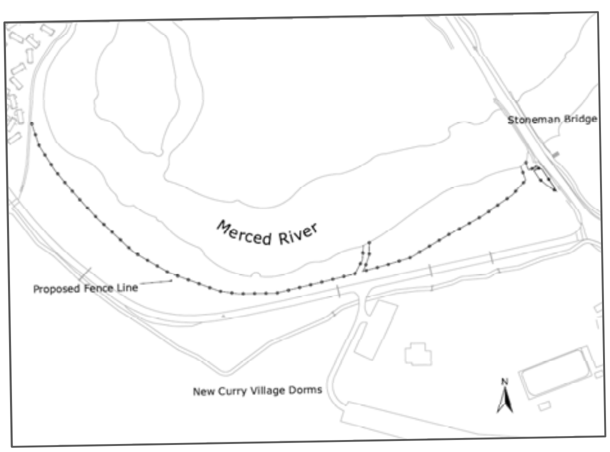

Figure 1: Fencing installed at the site in 2006.

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E.16 Riverbank Restoration below Clark's Bridge (Lower and North Pines Campgrounds), 2006

In 2006, the reach of river below Clark's Bridge at the North Pines and Lower Pines Campgrounds, was targeted for restoration based on the condition of the riverbanks and exposure to high levels of visitor use. The campgrounds are situated opposite each other along approximately 1,750 feet of the Merced River beginning at Clark's Bridge and extending down to the confluence of Tenaya Creek. The banks and terrace on both sides of the river are denuded of most understory vegetation and tree roots are largely exposed (Figure 1).

Figure 1: Exposed tree roots in Lower Pines Campground (river left).

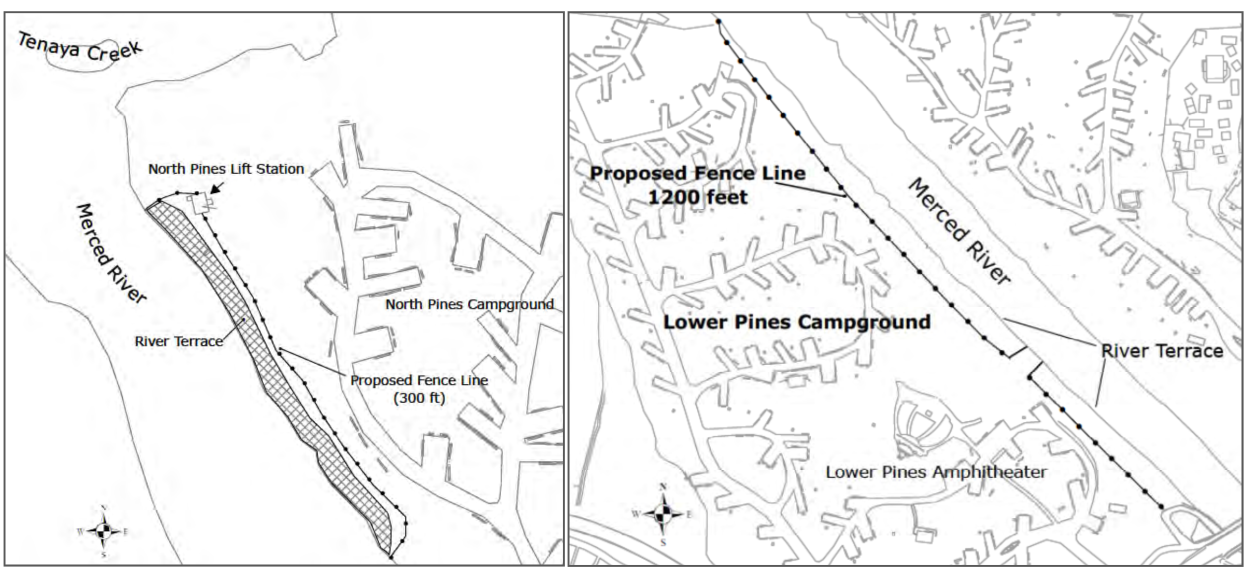


Figure 2: Fencing plans for Lower Pines Campground (left) and North Pines Campground (right).

Restoration staff installed split rail fencing at both sites with the intention of directing visitor use to less sensitive areas and to allow natural reestablishment of riparian vegetation along the banks.

In North Pines Campground, they constructed 300 feet of split rail fencing the bank at the downstream (north) end of the campground (Figure 2).

They constructed two sections of fencing, totaling 1,200 feet, in Lower Pines Campground with a designated river access point between them (Figure 2). Staff also planted the two enclosed areas with herbaceous and shrub seedlings in the more highly denuded zones. Figure3 shows vegetation establishment 2 years after fence installation in Lower Pines Campground.

Figure 3: Vegetation establishment in Lower Pines Campground 2 years after fence installation.

E.17 El Portal Road Rehabilitation at the Narrows, 2008

E.17.1 Introduction

The purpose of this project was to repair portions of the El Portal Road and embankment that were at risk of failure as a result of the damage initially caused by high-water events of the Merced River, including the devastating flood of January 1997. Road rehabilitation occurred along a section of the Merced River canyon called the Narrows, east of the intersection of the El Portal Road and the Big Oak Flat Road.

A mitigation and revegetation plan was necessary for this project due to its close proximity to the Merced River and in order to ensure the replacement of woody riparian vegetation lost during construction activities. The restoration area of the project, bounded on the north by the El Portal Road and on the south by the Merced River corridor, encompassed 2.48 acres and consisted of roughly 1,350 linear feet of stream channel and associated riverbanks.

The road rehabilitation itself included the removal of 250 linear feet of historic guard wall, the reconstruction of historic retaining walls in two locations, and the removal of five canyon live oaks, three California Black Oaks, three ponderosa pines, three black cottonwoods, one bay laurel and several seedlings and brush species. Figure 1 shows a small section of the project before and after construction of the new shoulder and MSE wall.

Figure 1: The Narrows before (left) and after (right) construction.

E.17.2 Restoration

Revegetation of native riparian plant species occurred during and after the road construction. Resource management staff salvaged over 100 willow and 50 cottonwood cuttings at the site prior to construction and stored them in water until planted. Planting took place during the construction of the mechanically stabilized earth (MSE) wall. As the contractor positioned the rip-rap, restoration workers placed willow cuttings into gaps in the rock. The excavator was then used to apply sediment on top of the rip-rap and willow, which was then washed into the gaps of rock using hoses. This was an effective technique used on the Cascade Dam Removal Project downstream of this project. Workers planted an additional 20 willow and 34 cottonwood cuttings in the un-grouted rip-rap at the toe of the slope no higher than 6 feet above of the ordinary high water mark for the Merced River.

Higher along the slope where there is sufficient soil to establish vegetation, workers planted the following species: Big leaf maple (*Acer macrophylla*), Red osier dogwood (*Cornus sericea ssp. Occidentalis*), Spice bush (*Calycanthus occidentalis*), and Short-leaved keckiella (*Keckiella brevifolia*). These species were propagated from seed collected in the area of the construction site to maintain genetic diversity. Workers also broadcast local seed along the road shoulder and in the cut slopes above the road following topsoil placement.

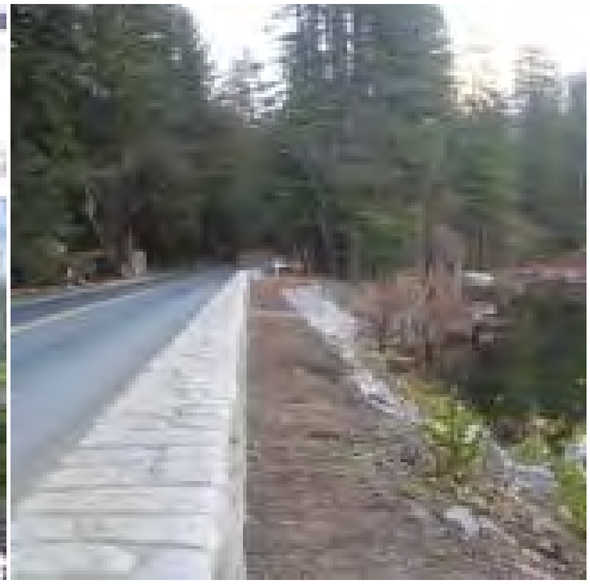
E.17.3 Monitoring

Monitoring is scheduled to occur annually through 2013. The purpose of monitoring is to assess planted material survival and also general plant community recovery. The performance goal is to establish a self-sustaining cover of native species that stabilize soil, trap sediment, provide wildlife habitat, and fulfill other basic functions of riparian ecosystems. More individuals of key species were planted than are expected to survive, which will allow natural processes to select out individuals, as plants crowd out competitors for resources. Natural recruitment was expected both from the seed bank and propagule dispersal.

Two years following the completion of the project, park ecologists have determined that the mitigation planting was a success. The number of woody vegetation stems and clumps, as well as the basal cover and height of these stems and clumps, has increased each year following planting (Figure 2). Survival of planted species is well over 75 percent, with significant volunteer recruitment. No further mitigation efforts are needed and the next monitoring site visit will occur in the late fall or early winter of 2011.

Pre-Construction 11/07

Post-Construction 12/08



Annual Monitoring 11/09

Annual Monitoring 11/10

Figure 1: Vegetation recruitment at the Narrows: pre-construction and 3 years post-construction.

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E.18 Yosemite Valley Abandoned Utilities Removal, 2010

E.18.1 Introduction

In 2010, a significant portion of underground utility lines were permanently abandoned with the completion of Phase 3B of the Integrated Master Utilities Plan for Yosemite Valley. Removal of these lines from sensitive areas such as meadows and the Merced River was identified as a priority by park management.

Several of the utility lines were buried at a very shallow depth below the riverbed and caused pipe dams to form, disrupting the natural flow of the river. The excavation of these lines was accomplished with as minimal impact to water quality and stream bank vegetation as possible. After the lines were removed, park ecologists assessed each bank for impacts and prioritized for additional revegetation and bank stabilization work. Restoration crews used native vegetation to stabilize bank disturbances that occurred during excavation. Excavation of the utility lines included the removal of existing rock revetment and bank material at the utility crossing as well as up to 20 feet upstream and downstream of the lines.

In 2010, the National Park Service and a contractor removed eight utility line crossings from the Merced River, five of which required restoration action in order to stabilize the banks on one or both sides of the river (seven bank locations in all). Figure 1 shows the five general locations requiring restoration action. The site locations that required restoration are described as follows: (1) upstream of Superintendant's Bridge, south side of river; (2) downstream of Housekeeping Bridge, both sides of the river; (3) downstream of Stoneman Bridge, south side of the river; (4) upstream of Stoneman Bridge, south side of the river; and (5) the reach of river at Stoneman Meadow, both sides of the river.

Figure 1: Utility removal restoration locations in Yosemite Valley, 2010.

E.18.2 Restoration

Upstream of Superintendants Bridge, the contractor removed a 6-inch sewer line from the river channel, impacting 20 feet of riverbank on the south side of the river. They removed five cubic yards of rock-boulder revetment during this process. The contractor and resource management staff added 15 cubic yards of screened native soil to the site and recontoured the bank. They established two tiers willow cuttings using a brushlayering method and planted willow pole cuttings with the hydrodrill. Staff also buried woody debris across the upper disturbed terrace to promote bank stabilization and mitigate erosion.

Downstream of Housekeeping Bridge, contractors worked up 20 feet of bank on the south side of the river after removing a 6-inch sewer line and electrical conduit from the river channel. They also removed approximately five cubic yards of rock-boulder revetment. Restoration staff planted 50 willow pole cuttings along the bank after construction. On the north side of the river, 10 feet of bank were also impacted. Restoration staff planted 20 willow pole cuttings in this area. The contractor also removed a lift station from the north side of the river. Restoration staff mulched the entire area.

Downstream of Stoneman Bridge, the contractor removed an 18-inch water line, electrical conduit, and 20 cubic yards of rock-boulder revetment from the river channel, disrupting 40 feet of bank. After construction, restoration staff added 25 cubic yards of screened native soil back to the site, planted 250 willow cuttings using brush layering techniques, planted 100 cuttings with the hydrodrill, and buried woody debris along the upper terrace.

Upstream of Stoneman Bridge on the south side of the river, 30 feet of bank were disturbed during the removal of a 10-inch sewer line and 15 cubic yards of rock-boulder revetment. Restoration staff added approximately 20 cubic yards of screened native soil back to the site. Staff also planted willow cuttings in brushlayers and planted of willow pole cuttings using the hydrodrill.

Near Stoneman Meadow, the contractor removed a 12-inch water line and worked up 20 feet of riverbank on the southeast and northwest sides of the river. On the southeast bank, the contractor removed 10 cubic yards of rock-boulder revetment. Restoration staff added 15 cubic yards of native screened soil to both sides of the river. They also planted salvaged herbaceous seedlings on the banks and mulched the upper terraces with local debris.

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