US Army Corps of Engineers®

Sacramento District
Engineering Division

Yuba River Ecosystem Restoration Feasibility Study

Yuba County, California

Appendix C: Engineering

January 2019

This page intentionally left blank.

Table of Contents

List of Tables

List of Figures

List of Plates

List of Attachments

This page intentionally left blank.

C-1. General

C-1.1. Format and Organization. This document and the associated plates and attachments comprises the Engineering Appendix to the Yuba River Ecosystem Restoration Feasibility Report/Environmental Assessment. This document has been constructed following ER 1110-2-1150 Appendix C - CONTENT OF ENGINEERING APPENDIX TO FEASIBILITY REPORT. Several sections of ER 1110-2-1150 Appendix C are not applicable to this Ecosystem Restoration Study and are thus not addressed, though the headings are still listed; many other sections require only brief explanations. Non-applicable sub-sections are omitted without comment. The sections most relevant to this Study are C-2 Hydraulics and Hydrology, C-6 Civil Design (which features elements of C-4 Geotech and C-7 Structural Design), C-3 Surveying, Mapping, and Other Geospatial Data Requirements (though elements are covered in Section C-6 Civil Design), and C-19 Cost Engineering; plates and attachments are contained following a references section at the end of this Appendix.

This Appendix describes the ecosystem restoration features that are part of the Recommended Plan. Hydrology and Hydraulics modeling that was performed in support of plan selection can be found in Appendix D – Environmental, Attachment 8 Habitat Evaluation Assessment Approach Technical Memorandum.

C-1.2. Study Area. The Yuba River Watershed (Figure C-1-1) encompasses 1,340 square miles on the western slopes of the Sierra Nevada Mountain Range, and is located in portions of Sierra, Placer, Yuba, and Nevada counties (Reynolds *et al*., 1993). The Yuba River is a tributary of the Feather River which, in turn, flows into the Sacramento River near the town of Verona, California. The Yuba River flows through forest, foothill chaparral, and agricultural lands. Levees are absent from most of its course except for near the river’s confluence with the Feather River. At that point, the Yuba River is bounded by setback levees for approximately six miles.

The Recommended Plan area is on the Lower Yuba River, which is bounded by Englebright Dam to the north and Marysville and the confluence with the Feather River to the south.

C-1.3. Project Purpose. The goal of the Yuba River Ecosystem Restoration Feasibility Study (YRERFS) is to explore ecosystem restoration opportunities and identify a National Ecosystem Restoration (NER) within the Yuba River watershed. The identification of an NER plan involves evaluating and comparing the relative benefits and costs of proposed actions through use of the cost effectiveness / incremental cost analysis (CE/ICA) tool. Ecosystem outputs (benefits) for proposed actions were developed through use of a Habitat Evaluation Procedures (HEP) based assessment approach.

Initial alternatives spanned from large structural measures including juvenile fish collection facilities at and upstream of Englebright Dam as part of fish collection and

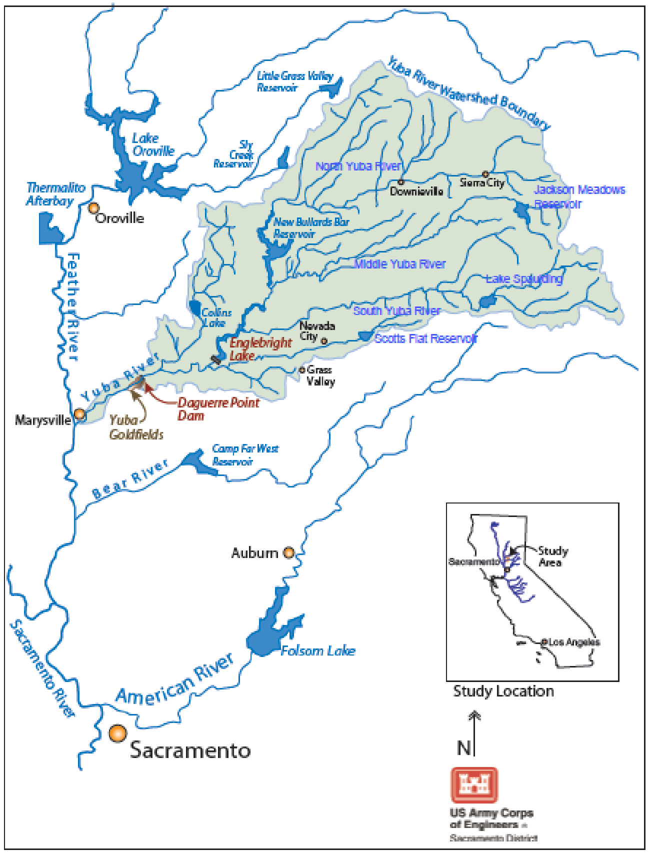


Figure C-1-1. Yuba River Watershed.

transport schemes to habitat restoration measures (e.g. non-mechanical, non-structural floodplain grading, side channel excavation, tree planting) developed by several parties. Through screening phases based on risk, estimated benefits, and cost ranges the final array of alternatives emerged as five habitat restoration increments (groups of measures). It is the engineering and modeling of this final array of alternatives that is detailed in this Appendix. The Recommended Plan consists of the restoration of approximately 180 acres of riverine, floodplain, and riparian habitat through 19 habitat measures, including creation and enhancement of side channels, floodplain lowering to facilitate riparian plantings, backwater creation, and bank scalloping.

C-1.4. Habitat Measure Background. For the Yuba River Ecosystem Restoration (YRER) Feasibility Study, preliminarily measures were compiled from several source documents including the Central Valley Recovery Plan (NMFS 2014), Yuba River Ecosystem Restoration Section 905(b) Analysis (Corps 2014), Habitat Expansion Plan (DWR and PG&E 2010), Habitat Expansion for Spring- run Chinook Salmon and Steelhead (RMT 2009), Daguerre Alley Habitat Enhancement Measures (cbec 2014), Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach (cbec et al. 2010), and Rehabilitation Planning from Parks Bar to Marysville (cbec 2013). Additional preliminary measures were suggested at the YRER planning Charrette held in Marysville, California from September 22 – 25, 2015.

Some of the source documents (including the Charrette) presented general, non-site specific measures, as well as site-specific measures. In addition, several of the preliminarily identified measures were redundant among source documents. Thus, prior to identifying those measures that will be subjected to the screening process to determine which measures will be carried forward for inclusion in alternative plan formulation, it is necessary to review the measures and compile a consolidated list.

One of the first steps in the development of a consolidated list of ecosystem restoration measures included distinguishing conceptual representations from actions. Several of the preliminarily identified measures addressed management plans or policies, general land use considerations, regulations and studies. A few of the measures addressed infrastructure modifications to alleviate stressors to indicator species, but were not directly associated with habitat enhancement (e.g., fish screens). Redundancy was minimized by not individually listing general (non-site specific) measures when the general concept was included in site- specific measures.

In Yuba River Ecosystem Restoration Feasibility Study Habitat Measures (HDR 2016) a list of measures was compiled and numbered for reference for use by USACE and YCWA in the planning process. Progressive screening eliminated measures for various reasons (see Main Report Chapter 3). The Recommended Plan consists of 19 measures, each of which may have more than one action (e.g. floodplain lowering, riparian planting) at the measure site. To provide context for the remainder of this Appendix, these 19 measures are described in narrative form in Section C-1.5.

C-1.5. Habitat Measures That Comprise the Recommended Plan. The habitat measures listed below comprise the Recommended Plan. The measure identification numbers from HDR (2016) are retained throughout this document to remain consistent with screening performed during the planning process and with the Main Report. These identification numbers are smaller upstream and increase with progression downstream on the Lower Yuba River, but have no other qualitative, quantitative, ranking etc. significance- they are only identifiers. Plates IN-1 thru IN-4 show the habitat measures in the Recommended Plan and geographic features referenced in measure narratives, along with proposed staging sites and access/haul routes, which are discussed in subsequent sections of this Appendix.

Measure 19. Upper Gilt Edge Bar floodplain lowering and riparian planting. Upper Gilt Edge Bar sits relatively high above the bankfull channel, with a shallow water table less than 7 feet from the ground surface only present in a narrow band along the channel margins, and with a limited area in the 7 to 10 feet range of depth to water table on the floodplain below the higher terraces. Floodplain areas in the 7 to 10 feet range would be lowered to facilitate more frequent inundation with planting along the margins. Planting of cottonwood or other native woody riparian species could increase structural diversity in this area over time (cbec 2013).

Measure 20. Bank scalloping at Upper Gilt Edge Bar. Measure 20 would occur along the channel edge of Upper Gilt Edge Bar, where the bank is 8-15 feet high, and the edge of the channel is relatively monotonous with little habitat complexity (cbec 2013). Small scallops would be excavated into the tall and steep banks to increase local topographic diversity and wetted edge. These scallops/alcoves would be excavated to create an inundated alcove at all discharges, with the steep slopes surrounding the alcoves feathered to at least a 10:1 slope to provide additional shallow inundated areas with desirable depth/velocity combinations. Initially, these scallops/alcoves would provide year-round rearing habitat to juvenile salmonids. Over time it is expected that fine sediment may deposit in the scallops creating nursery sites where natural woody vegetation recruitment/establishment could occur. The scallops would further facilitate natural recruitment of riparian vegetation, due to shallow access to the water table, and the fine texture of deposited sediments. In addition, LWM would be placed within, and protruding from the scallops. Yuba County Water Agency (YCWA 2016) defined LWM pieces as both: (1) a log with a target size of 18 feet or greater in length with an average diameter of 24 inches or greater, with attached root wad; and (2) smaller LWM pieces (minimum thickness of 10 inches diameter at breast height (dbh)) with crowns attached. Pending local availability of suitable LWM pieces with root wads or tree crowns attached, such pieces would be used preferentially. A minimum of seven pieces of LWM with root wads could be placed at each location that is identified for LWM placement, and an additional three pieces of LWM with attached crowns could be set in between the other pieces. The definition of LWM described in this TM is consistent with the mitigation plan developed by YCWA (2016) and California Department of Fish and Wildlife (CDFW), U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS).

Measure 21. Backwater at Upper Gilt Edge Bar. Measure 21 would enhance a backwater area and increase the extent and species richness of existing riparian vegetation. Excavation of sediment in the 7 to 10 foot range would occur to allow for backwater inundation at base flows, and potential excavation/lowering of the surrounding area to allow for inundation in a typical 99% (1/1.01) ACE to 50% (1/2) ACE flood. Riparian woody species may be planted to promote species richness and structural diversity. Additional fine material could be introduced to the upper 3 feet of the soil column in excavated areas to increase soil capillarity and the amount of soil moisture available to herbaceous riparian vegetation. LWM would be placed within the backwater to provide aquatic structure.

Measure 22. Floodplain lowering and riparian planting near River Mile 17. The unnamed bar located on the north side of the lower Yuba River near River Mile (RM) 17 provides an opportunity to plant riparian vegetation in areas where the water table is less than 7 feet from the ground surface. The site also could be enhanced by grading/lowering areas where the depth to water is between 7 to 10 feet, which would increase lateral connectivity and provide for additional opportunity to plant riparian vegetation to increase riparian structure and species diversity.

Measure 24. Lower Gilt Edge Bar enhancement. Floodplain areas in the 7 to 10 feet depth-to-water table range would be lowered to facilitate more frequent inundation and riparian vegetation planting. An existing swale feature (at upstream end of Lower Gilt Edge Bar) could be lowered and connected to the channel to become inundated at about 3,000 cfs. In the lower Yuba River, swale morphological units (MUs) typically activate around 3,000 cfs and provide habitat with depths in the 1 to 1.5 foot range and velocities in the 0.75 to 1 foot per second range between 3,000 and 5,000 cfs (G. Pasternack, pers. comm., as cited in cbec (2013)). An additional enhancement would be construction of a patchwork floodplain network surrounding the enhanced groundwater-fed swale to encourage fine sediment deposition and potential riparian recruitment, as well as provide edgewater refugia at flows above baseflow.

Measure 26. Riparian Planting at Hidden Island. This measure would be located on the alluvial bar located on the northern side of the lower Yuba River downstream of Lower Gilt Edge Bar. The area would be planted with native hardwoods in areas where the maximum depth to the water table is less than 7 feet. It was previously suggested (cbec et al., 2010) that lowering the existing high flow side channel would allow connectivity at base flow levels. However, additional consideration (G. Pasternack, pers. comm. 2016) has resulted in not including side channel lowering or floodplain lowering at this site due to concerns regarding the potential for the main channel to redirect its course and cut off the southern portion of Hidden Island. Consequently, for the purposes of this TM, this measure only includes the features of riparian planting where the depth to water table is less than 7 feet.

Measure 28. First Island bank complexity. First Island has large expanses of floodplain and high floodplain, and a side channel on river left (south side) provides spawning and rearing habitat. The Yuba Accord River Management Team (RMT) Monitoring and Evaluation Program Interim Draft Report (2013) found that the main channel adjacent to First Island was heavily utilized for salmon spawning in 2009 and 2010, with some salmon redds occurring within the side channel itself. This area may provide immediate benefit to emerging salmonid fry if allowed access to larger expanses of shallow habitat with riparian cover. cbec (2013) suggested the possibility of installing a floodplain patchwork of engineered log jams (ELJ)s, particularly along the apex of First Island just above bankfull elevation, although no specific placement was described. The intended purpose was to encourage sediment deposition and riparian vegetation recruitment. For purposes of this TM, direct planting of riparian vegetation was substituted for ELJ placement.

Measure 29. Silica Bar channel stabilization and ELJ placement. Rock/sediment could be deposited along the left bank of Silica Bar, coupled with placement of ELJs to aid river constriction at this location. ELJ technology includes a wide range of instream and floodplain structures designed to replicate the geomorphic and ecologic functions of natural accumulations of woody material (Abbe et al., 1997, 2003). Generally, ELJs have a pre-determined structure consisting of large key pieces anchoring a matrix of other structural components including stacked logs, racked logs, and piles (Abbe et al., 2002). Distinct types of ELJs have been classified based on the presence or absence of key members, source and recruitment mechanism of the key members, ELJ architecture (i.e., log arrangement), geomorphic effects, and patterns of vegetation on or adjacent to the ELJ (Abbe et al., 1993). However, for preliminary planning purposes associated with this TM, the definition of an ELJ is restricted to the assumptions that are presented in the design criteria – specifically, pieces of LWM that are 25 feet in length and 2 feet in diameter.

Measure 30. Silica Bar floodplain enhancement. Large wood would be placed along the margins of the downstream terminus of the existing side channel/backwater that is surrounded by an existing stand of diverse, mature, native riparian vegetation, in areas that would not disrupt existing riparian vegetation along the banks of the side channel/backwater area. Floodplain elevations less than 7 feet at Silica Bar would be planted with riparian vegetation. Floodplain areas in the 7 to 10 foot depth to water table range would be lowered to facilitate more frequent inundation and riparian vegetation planting. If needed, fine sediment would be incorporated into the upper 3 feet of the soil column, and the floodplain surface would be planted with native riparian woody vegetation.

Measure 32. Bar A enhancement. Located on river right just downstream of First Island, this site (referred to as North Silica Bar (RMT 2009)) would be enhanced by lowering floodplain surfaces for riparian vegetation planting and more frequent inundation between 3,000 and 5,000 cfs. Although cbec (2013) suggested that LWM placement and bank scalloping along the steeper bank downstream could increase wetted area and add complexity, these features were not included in this TM because this area was included with riparian planting.

Measure 33. North Silica Bar channel stabilization and ELJ placement. Rock/sediment could be deposited along the left bank of Silica Bar, coupled with placement of ELJs to aid river constriction at this location. Measure 33 would be about 1.9 acres in size.

Measure 34. North Silica Bar side channel (bar opposite of Silica Bar side channel). North Silica Bar provides opportunity to lower floodplain surfaces for riparian vegetation planting and more frequent inundation between 3,000 and 5,000 cfs. A groundwater-fed pond sits elevated above the channel and only currently connects above approximately 7,500 cfs (cbec 2013). A side channel that activates above 3,000 cfs and connects to the low lying area downstream may provide beneficial off-channel habitat with established riparian vegetation already present. This measure would create an anabranching side channel in an existing swale within a stand of relatively dense riparian vegetation that presently includes willows and cottonwoods. The approximate length of the side channel would be 4,600 feet, and the potential area about 10.5 acres.

Measure 46. Bar C floodplain and backwater enhancement. Immediately downstream of the Daguerre High Flow Channel's downstream confluence with the main channel is a large expanse of floodplain with depth-to-water table exceeding 7 to10 feet in the center of "Bar C". A large backwater area with shallow groundwater and relatively extensive riparian vegetation is also currently present. Two historical channel alignments are present that floodplain grading could enhance to inundate at 3,000 cfs to function as a swale habitat with adjacent floodplain lowering. Riparian vegetation would be planted on each side of the enhanced swale/side channel, extending a minimum of about 40 feet from the wetted edge of the channel. Bar C also exhibits a large expanse characterized by 0 to 7 feet depth to water table, and additional areas on the high floodplain in the 7 to 10 feet depth range. It is assumed that the features at this site include riparian vegetation planting in areas within 7 feet of the water table. Floodplain grading in areas from 10 to 7 feet of the water table down to 7 feet of the water table also would be conducted, following by riparian planting in the newly graded areas. The upper portion of the site, immediately downstream of the Daguerre High Flow Channel, has been very geomorphically dynamic. Longevity of enhancements here for specific functions may be short, and the downstream area may yield longer term benefits. The upstream and downstream portion of Bar C also could be enhanced by placement of ELJs in a patchwork configuration along the enhanced swale. In addition, LWM would be placed in the backwater area at the downstream end to increase structural and habitat complexity in the area.

Measure 47. Yuba Goldfields Terminus side channel. Create a side-channel in the bar referred to as “Bar C”. The side channel would be created within a stand of riparian vegetation, extending into a current backwater habitat located at the downstream corner of the Yuba Goldfields. Note that this side channel construction would occur on a different alignment than that indicated in Measure 46. Floodplain lowering would occur on the north side of the side channel (to the extent necessary) to plant riparian vegetation in areas of Bar C that are adjacent to the north side of the channel - extending about 40 feet from the wetted edge of the channel. Boulder structures for hydraulic maintenance may be placed at the inflow section. The side channel is about 5,000 feet in length, and the potential area is about 208,000 square feet (4.8 acres) at 40 feet wide.

Measure 48. Narrow Bar side channel. Measure 48 would create an anabranching side-channel in Narrow Bar (also referred to as Bar D). An existing swale connects across the downstream end of the bar with relatively extensive riparian vegetation, and could be extended to connect further upstream. A side channel would be located north of the main channel, following a historical channel path, and would split to form a second side channel extending in a south-west direction through the middle of the bar. Existing riparian vegetation would border the created side-channels. Boulders for hydraulic maintenance may be placed at the inflow. Approximate length is 5,500 feet, and potential area is 391,265 square feet (about 9 acres at 5,500 feet long x average width of 71 feet).

Measure 49. Bar D floodplain riparian vegetation planting. Bar D exhibits a large expanse of shallow groundwater within 0 to 7 feet of the ground surface, and additional areas on the high floodplain in the 7 to 10 feet depth range. It is assumed that the features at this site include riparian vegetation planting in areas within 7 feet of the water table. Floodplain grading in areas from 10 to 7 feet of the water table down to 7 feet of the water table also could be conducted, following by riparian planting in the newly graded areas. Additionally, floodplain grading along the main channel could be implemented to increase inundation duration and frequency at 3,000 cfs. Large expanses of moderately shallow groundwater to facilitate riparian recruitment and the potential enhancement of the existing swale could be augmented by placement of ELJs in a patchwork configuration.

Measure 50. Narrow Bar floodplain lowering, riparian vegetation planting and ELJ placement. This measure could involve lowering the floodplain to medial bar, planting riparian vegetation, and adding ELJs within an area of about 4 acres.

Measure 51. Narrow Bar deep backwater area. Located on the west side of Narrow Bar near RM 6.5, this measure would involve the creation of a wide, deep backwater area extending from the lower end of the Narrow Bar side channel to the lower Yuba River. The terminus of the side channel described in Measure 48 would flow into the upper extent of the backwater area.

Measure 52. Lower Yuba River backwater area. This measure could involve excavation to develop a backwater area of about 1 acre on the right bank of the lower Yuba River near RM 6.5.

Measure 53. Bar E riparian vegetation planting. Bar E exhibits a large expanse characterized by depth-to-water table of 7 to 10 ft, or greater range. From 1999 to 2008, aggradation of up to 9 feet has occurred in the historical channel that now functions as a swale activating between 3,000 and 5,000 cfs, while the main channel has incised by up to 6 feet (cbec 2013). The existing swale is located at the downstream end with riparian vegetation along the levee toe just north of the diversion channel. Planting in the downstream portion of this bar surrounding a historical channel alignment may be beneficial to enhance species and structural diversity. A diversion channel is maintained across this bar, and floodplain grading is not suggested due to this constraint. Therefore, riparian planting would occur in areas of Bar E where the depth-to-water is less than 7 feet. This site also may be a good candidate location for placement of LWM in the swale/backwater downstream from the diversion point across the upstream portion of this bar.

Measure 54. Island B riparian vegetation planting. Island B mostly is characterized by depth-to-water table in the 0 to 7 feet depth range, and as of 2009, inundates on the lower portion at 5,000 cfs. Riparian species and structural diversity could be improved by planting along the upstream portion of this island. This island also may benefit from ELJ placement in a patchwork configuration, however, as this reach is confined by levees, increases in water surface elevation may be more pronounced than at other enhancement locations.

C-2. Hydrology and Hydraulics

Hydrologic and Hydraulic modeling associated with habitat benefit calculations is described in Appendix D – Environmental, Attachment 8 Habitat Evaluation Assessment Approach Technical Memorandum. This section presents hydrology and hydraulic information pertinent to the Recommended Plan.

In accordance with SMART Planning principles, design modeling of the habitat measures was not performed for feasibility level design; such design modeling would be time-consuming and expensive (relative to SMART Planning timelines and budgets), likely requiring multiple scenarios of sequential geomorphic change simulation to be executed. Such a level of design is appropriate for Preconstruction Engineering and Design (PED) toward generation plans and specifications. In lieu of design modeling, a geomorphic assessment of potential damages and associated adaptive management and maintenance costs, or habitat benefit reductions was performed (see Section C-6 Civil Design) to inform feasibility level (Class III) cost estimates.

C-2.1. Lower Yuba River Hydrology. The final array of alternatives are located just upstream from the Yuba River near Marysville gage (Gage Number 114121000). There is very little contributing drainage area between the proposed alternatives and the gage. Therefore, this gage reflects the flow conditions at each of the proposed restoration sites. Flows on the Lower Yuba River are highly influenced by upstream reservoir regulation for flood management, hydropower, and water supply purposes. As a result, flows measured at the gage prior to 1972 are not considered representative of the current hydrologic conditions with the reach. Annual peak flows measured from Water Years 1970 through 2016 (45 years of record) at the Yuba River near Marysville gage have ranged from 673 cfs in water year 1977 to 161,000 cfs in water year 1997. The Sacramento District USACE conducted a hydrology study of the Central Valley in 2015 for the California Department of Water Resources. The study, titled "Central Valley Hydrology Study, 29, November 2015", presented Annual Chance of Exceedance (ACE) estimates for peak flows measured at the USGS Yuba River near Marysville Gage. The estimates were made using reservoir simulations of rare floods and the results were presented for a range of flood magnitudes from 10% (1/10) ACE to 0.002 (1/500) ACE. Table 1 presents these results in tabular format. These flows are considered suitable for evaluation of the ecosystem restoration alternatives presented in this report.

Table C-2-1. Peak Discharges and Associated Annual Chances of Exceedance.

Annual Chance of Exceedance	Peak Discharge (CFS)
10% (1/10)	71,700
2% (1/50)	112,000
1% (1/100)	178,000
0.5% (1/200)	212,000
0.2% (1/500)	282,000

C-2.2. Hydrology and Hydraulic Information Used in Habitat Measure Siting and Designs.

As noted in C-1.4 Habitat Measure Background, initial concepts for the habitat measures that comprise the recommended plan came from a number of sources. This section is intended to provide background on the hydrology and hydraulic information used in source documents for the design of the habitat measures in the Recommended Plan.

Although the Lower Yuba River is dynamic in nature and subject to changes in geomorphology, all measures in the recommended plan are sited on persistent landforms in the Yuba River (e.g. Upper Gilt Edge Bar, Parks Bar, Lower Gilt Edge Bar, First Island, Hidden Island that have persisted through the current regulated flow regime (post 1970, see cbec et al. 2010, HDR 2016). The Siting of the habitat measures in the Selected Plan came from three primary references that included morphologic analyses, modeling, and expert judgement to choose restoration locations.

The Yuba Accord River Management Team (RMT) (which includes Yuba County Water Agency (YCWA), California Department of Fish and Game (CDFG), National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), the South Yuba River Citizens League (SYRCL), the Bay Institute, Friends of the River, Trout Unlimited, PG&E, and Department of Water Resources (DWR), with the collaboration of the Pacific States Marine Fisheries Commission (PSMFC) and University of California at Davis (UC Davis)) published siting of side channel restoration locations in RMT (2009) based upon morphological analyses utilizing historical aerial photography for channel alignments, site visits, and expert judgment.

cbec, inc., South Yuba River Citizens League, and McBain & Trush, Inc. utilized flow frequency analyses for the current regulated flow regime (1970-2009) and morphologic analyses based on aerial photography from 1952-2009 and a site visit for proposed bank scalloping, backwater creation, riparian planting, floodplain enhancement (including boulder and woody debris) siting in cbec et al. (2010).

Wyrick and Pasternack (2012) conducted a thorough geomorphic assessment of the Lower Yuba River using digital elevation models and detailed 2D hydrodynamic modeling that was extensively referenced in the hydrologic and geomorphic analysis to support rehabilitation planning by cbec (2013). This report built upon cbec et al. (2010) through use of detailed 2D modeling results and the geomorphic characteristics of the Lower Yuba River to recommend habitat measure sites (including depth to baseflow groundwater assessments to inform floodplain lowering sites/elevations for subsequent riparian planting).

HDR (2016) reviewed several references that recommended restoration activities for the Lower Yuba River including RMT (2009), cbec et al. (2010) and cbec (2013) to generate a list of potential restoration activities and recommend further activities on previously analyzed persistent landforms for USACE and YCWA as part of the USACE Planning Process.

The habitat measures in the Recommended Plan come from three primary sources, Table C-2-2 lists habitat measure locations, descriptions, and source documents and measure references within those documents.

C-2.3. SRH2D Modeling. As mentioned in Section C-2.2, detailed hydrodynamic modeling for performed to inform Wyrick and Pasternack (2012) and cbec 2013, two of the primary references for the Habitat Measure designs herein; this modeling was performed using the USACE-Approved SRH-2D v. 2.0 or 2.1 for 2D modeling created by Dr. Yong Lai of the U.S. Bureau of Reclamation (files and information exist at http://www.usbr.gov/pmts/sediment/model/srh2d/index.html) Additionally, the design criteria used to convert the narrative descriptions in Section C-1.5 to GIS polygons for use in Civil Design and Cost Engineering are based on SRH2D modeling Results. Baker (2011) describes the calibration and validation procedure used for the Lower Yuba River SRH2D model. Technical Memorandum 7-10 Instream Flow Downstream of Englebright Dam (YCWA 2013) describes the lower Yuba River SRD2H hydrodynamic modeling and validation in detail.

US Army Engineer District Sacramento technical staff reviewed the SRH2D modeling documentation and obtained copies of modeling files and results (including post-processed results such as calculated shear stress rasters that were used ultimately used in the Geomorphic Cost-Risk Assessment, Section C-15). Following review, the project Technical Lead, Hydraulic Analysis PDT member and Chief, and Hydrology and Hydraulics Branch Chief concluded that use SRH2D modeling results in habitat measure design and design criteria were suitable for use. Thus, the narrative descriptions in Section C-1.5 and the Design Criteria in Section C-6 and Attachment CV-A were adopted and GIS polygons were generated (see Section C-3 and Attachment CV-B)

Excerpts from Section 2.6 of YCWA (2013) are presented below to provide context for the Lower Yuba River Model validation; a table of SRH2D validation data, parameters, and inputs is contained in Attachment HH-A):

> **"2D Model Outputs**
>
> The SRH2D v2.1 model produces output at all computational nodes, which are irregularly- spaced. The variables that are provided include water surface elevation, depth, velocity magnitude, velocity x- and y- components, Froude number, and shear stress. To have a uniform approach to presenting, analyzing, and applying hydraulics, SRH2D v2.1 model outputs are interpolated to a raster with 3 ft by 3 ft cells that covers the wetted area for each discharge. The procedure for converting

raw model output files into rasters for each variable clipped to the water's edge is explained step-by-step in Pasternack (2011).

Hydraulic Model Validation

Extensive hydraulic model validation was performed for unvegetated model simulations for an order of magnitude of flow range (i.e., ~530 – 6,400 cfs), which is the widest range of flows tested among all 2D modeling studies done previously on the study area. Validation was done according to the procedures explained in Pasternack (2011). Tests were done on mass conservation, WSE, depth, velocity magnitude, and velocity direction. A full suite of tests on the 2D hydraulic model suite was reported by Barker (2011). A key test involved computing the coefficient of determination (r^2) between observed and predicted values. Another meaningful model performance test involved computing the median absolute error.

A sampling of the validation results provides a reasonable characterization of performance quality. Mass conservation between specified input flow and computed output flows was within 1 percent. From cross-sectional surveys yielding 199 observations, predicted versus observed depths yielded a correlation (*r*) of 0.81, which is on par with what is commonly reported. Using the Lagrangian particle tracking data, surface velocity magnitude testing yielded a predicted vs. observed *r* of 0.89, which is significantly higher (better) than commonly reported. Median unsigned velocity magnitude error was 16 percent, which is less than commonly reported. Also using the Lagrangian particle tracking data, velocity direction testing yielding a predicted versus observed *r* of 0.89. Median direction error was 4 percent, with 61 percent of deviations within 5 degrees and 86 percent of deviations within 10 degrees. Compared with previous 2D model studies done in the study area, the SRH2D v2.1 analyses were the most comprehensive in terms of number of tests and number of observations, and the results yielded the highest performance in terms of mass conservation, depth, velocity magnitude, and velocity direction.

For WSE, the SRH2D v2.1 model can only be as accurate locally as the bed elevation variation arising from the presence of cobble substrate throughout most of the river. This means that if a bed elevation measurement is made on the top of a cobble versus in the space between cobbles, then the model's WSE will be different between those two locations simply because of bed topography. Therefore, the benchmark for model performance for WSE is a combination of the WSE measurement error (i.e., ~0.15 - 0.2-ft) and the bed elevation uncertainty due to measurement method accuracy and bed substrate variability (i.e., ~0.25 - 0.35-ft). These errors are not uniform, but are statistically distributed with uncertainty. Therefore, WSE performance will also be statistically distributed with uncertainty. There is no single constant WSE deviation value that can be correctly stated as the acceptable threshold for model performance. Note that the highest quality topographic survey recognized by the USACE has an accuracy of 0.5-ft.

As an example of WSE performance, drawing one of the datasets tested, 197 observations at 880 cfs yielded a mean signed deviation of -1.8 mm. For unsigned deviations (i.e., absolute value of a deviation), 27 percent were within 3.1 cm (0.1-ft), 49 percent of deviations within 7.62 cm (0.25-ft), 70 percent within 15.25 cm (0.5-ft), and 94 percent within 30.5 cm (1-ft). The vast majority of checks for the combined errors of both observational uncertainty and topographic uncertainty were as good as or better than the accuracy of the highest quality USACE topographic survey, with more than half being better than that standard. WSE performance in the model was put through very high scrutiny compared to previous 2D model studies in the study area. For a river of this size and topographic variability, WSE model performance was good. Overall, the SRH2D v2.1 model met or exceeded all common standards of 2D model performance and was put through the most rigorous battery of tests reported for a river in California."

C-2.4. Geomorphic Assessment. Attachment HH-B is a geomorphic assessment based on the three primary measure sources noted in Section C-2.2 and those referenced elsewhere throughout this Appendix and its attachments. Attachment HH-B is summarized in the following subsections.

C-2.4.1. Increment 2 (Parks Bar Reach). Increment 2 starts at the top of Parks Bar Reach at Route 20 bridge, includes Upper Gilt Edge Bar and Parks Bar. Increment 2 includes two bars, Upper Gilt Edge Bar (Measures 19, 20 and 21 – floodplain lowering, riparian planting, bank scalloping and backwater area) on the Left just downstream of the bridge, and Parks Bar (Measure 22 – floodplain lowering and riparian planting) just downstream from that on the Right. The cbec (2013) report starts at Parks Bar Reach. No change from 1970 to 2009 (cbec 2013), bars are in the same place. Previously, 1958 channel shows Parks bar was the main channel location (in part – imagery is cut off in cbec (2013) analysis) though the present alignment is quite similar to 1947 and 1952, possibly additional flow in partial side channel on the left bank across from Parks Bar, minor multi-channel configuration upstream of the bridge, but the design can generally be implemented with some assurance of lower risk of changes here according to the imagery from 1998 – 2017, largely the same every flyover.

Analysis by Wyrick and Pasternack (2015) shows a short section of avulsion, though I don't see this from the imagery, except that sometimes there is flow across the top of the LB bar on the left side of the patch of vegetation just downstream from the bridge. The main flow is generally tight against the RB. Most of the area outside the main channels is assigned "no detectable change," "overbank storage" or "vegetated overbank storage," with small interspersed sections of "overbank scour" on the bar area, and downcutting and bank migration in the main channel areas (Wyrick and Pasternack, 2015). "In-channel fill" and very small sections of "bar emergence" are noted along channel margins (Wyrick and Pasternack, 2015). The bars are definitely active, with little vegetation on them – Measures might fill in, might scour, but overall risk of erosion or burial is low.

Table C-2-2. Recommended Plan Measure Descriptions Source References.

Persistent Landform	Measure Number	TSP Increment	Measure Description	Acres	Source		Source Identifier		Source Figure
Upper Gilt Edge Bar	19	2	Upper Gilt Edge Bar structural complexity	10.6	cbec 2013	;	Site 1	;	Figure 29
	20	2	Bank scalloping at Upper Gilt Edge Bar	0.6	cbec et al. 2010	;	Project 3	;	Figure 5-1
	21		Backwater at Upper Gilt Edge Bar	1.0	cbec et al. 2010	;	Project 4	;	Figure 5-2
Parks Bar	22	2	Floodplain lowering and riparian planting near River Mile 17	11.2	cbec 2013	;	Site 2	;	Figure 29
					HDR 2016	;		;	Figure 4
Lower Gilt Edge Bar	24	3a	Lower Gilt Edge Bar enhancement	11.9	cbec 2013	;	Site 3	;	Figure 29
Hidden Island	26	3a	Riparian Planting at Hidden Island	2.3	cbec et al. 2010	;	Project 6	;	Figure 5-5
First Island	28	3a	First Island bank complexity	6.3	cbec 2013	;	Site 5	;	Figure 29
Silica Bar	29	3a	Silica Bar channel stabilization and ELJ placement	1.6	HDR 2016	;		;	Figure 5
	30	3a	Silica Bar floodplain enhancement (lowering, planting)	5.1	RMT 2009	;	Site 3, Site 4	;	Figure 5
					cbec et al. 2010	;	Project 8	;	Figure 5-7
North Silica Bar/Bar A	32	3a	RMT 2009 had sidechannel creation, we don't (same for 30)	16.8	RMT 2009	;	Site 3, Site 4	;	Figure 5
			Bar A enhancement		cbec 2013	;	Site 6	;	Figure 29
	33	3a	North Silica Bar channel stabilization and ELJ placement	1.9	HDR 2016	;		;	Figure 5
	34	3a	Side Channel	10.5	RMT 2009	;	Site 3, Site 4	;	Figure 5
			North Silica Bar side channel (bar opposite of Silica Bar)		cbec 2013	;	Site 6	;	Figure 29
Bar C	46	5a	Bar C floodplain and backwater enhancement	39.9	cbec 2013	;	Site 15	;	Figure 31
	47	5a	Yuba Goldfields Terminus side channel	9.5	RMT 2009	;	Site 9	;	Figure 10
Narrow Bar/Bar D	48	5b	Narrow Bar side channel	9.2	RMT 2009	;	Site 8	;	Figure 9
					cbec 2013	;	Site 16	;	Figure 31
	49	5b	Bar D floodplain riparian vegetation planting	28	cbec 2013	;	Site 16	;	Figure 31
	50	5b	Narrow Bar floodplain lowering, riparian vegetation planting and ELJ placement	4.4	HDR 2016	;		;	Figure 10
	51	5b	Narrow Bar deep backwater area	1.9	HDR 2016	;		;	Figure 10
	52	5b	Lower Yuba River backwater area	1	HDR 2016	;		;	Figure 10
Bar E	53	5b	Bar E riparian vegetation planting	2.4	cbec 2013	;	Site 17	;	Figure 31
Island B	54	5b	Island B Riparian Vegitation Planting	2.5	cbec 2013	;	Site 18	;	Figure 31

C-2.4.2. Increment 3a (Parks Bar Reach). Increment 3a is also within Parks Bar Reach, with the downstream portion beginning to get into mine tailings influence. Two areas examined for scale - Lower Gilt Bar, Hidden Island, First Island shown first, Silica Bar and Bar A shown second. While more dynamic, this reach maintains a relatively consistent multi-channel bar system, shown by the number of lines of trees marking former (and current) channels. Measures include riparian planting, side channel, floodplain lowering and channel stabilization. Lower Gilt Edge Bar, Hidden Island and First Islands – this channel really doesn't move appreciably from 1998 to 2017 on GE imagery, thought the size and shape of First Island changes somewhat, and Hidden Island is currently connected to the bar on the RB by a minor side channel. Multiple tree lines show this channel shifts relatively often, so may reasonably be expected to become a medial bar (or island) again. Riparian plantings planned here should be relatively stable, as flow will likely tend to split to one side or the other, forming a temporary side channel in the remaining open bar area. First Island revegetation should also be relatively stable, though this bar also experiences expansion and contraction periodically, so vegetation at the upstream end might be more likely to experience scour.

The cbec (2013) report shows greater movement in the preceding decades, with the channel occupying multiple locations throughout the entire valley width, maintaining a single thread (with the exception of Hidden Island) in the upstream portion, but going through obvious adjustment in the downstream portion with First Island following expansion of tailing mounds shown in 1947 imagery with '52 channel alignment, and apparent channelization and heavy adjustment from in the 50's and 60's where the channel appears to have regained a relatively persistent single thread in the 80's, though the extent and location of First Island has continued to shift somewhat through this period, though has remained relatively stable since the 1980's.

Wyrick and Pasternack (2015) show both Hidden Island and First Island areas between 1999 and 2008 as "island storage" and "vegetated island storage" which is appropriate here. Adjustment of multiple channels and single thread channel are also shown in the narrow range we can see from the imagery, with Lower Gilt Edge bar showing "no detectable change" for most of this area, and the bar upslope from Hidden Island designated "overbank storage" and "vegetated storage" (Wyrick and Pasternack, 2015). The channel in the downstream portion appears relatively constant, as do the two channels as they enter the frame at the upstream end. The location of both channels and associated bar formations (the downstream end of First island is between the north and south channels in all three images) shift considerably, particularly the location where a single thread is resumed. From 1998 to 2009, the main channel on the RB has moved south, though the general configuration is similar. Note treelines in 2009 to the north in that section show the location of the channel and small medial bar present in 1998. From 2009 to 2017 the junction of the multiple channel system has moved downstream roughly 1000 feet and both north and south channels have migrated south.

C-2.4.3. Increment 5a (Hallwood Reach). Increment 5a is located within Hallwood Reach, starting at the approximate (assumed) top of Hallwood Reach, covering the entirety of Bar C. Measures 46 and 47 include floodplain lowering, riparian planting, backwater enhancement, single side channel and an anabranching side channel. This bar has seen several channel alignments shown in the aerial history, with portions of the mainstem shifting from left to right bank and back a few times between the 50’s and the 90’s, with greatest activity in the upstream portion of the bar just downstream from the Daguerre High Flow Channel. Side channel proposed as part of Measure 46 is designed to reoccupy the 1993 alignment between two visible existing tree lines marking the banks of this alignment. This area is likelier to scour with possible reoccupation of one or more of the former alignments, particularly with floodplain lowering/disturbance activities planned along both sides of this feature, though former alignments should be more persistent with a new side channel if existing riparian treelines are preserved. Fill may be more likely due to splitting flow into three branches here, spreading out transport energy, though if constructed well and stabilized, vegetation might hold alignments even if buried in sediment, as long as deposition is shallow and vegetation is at least partially established.

The downstream end of Bar C has held a much more persistent alignment, where the bar is clearly an active surface but should be at lower risk of damage to the presence of established vegetation, particularly if main channel, backwater and swale side channel are well stabilized. Most of the bar surface is shown as “vegetated overbank” or “overbank storage” between 1999-2008, so fill is the most likely process to occur here (Wyrick and Pasternack, 2015). Bar areas in the vicinity of Measure 47 may be either filled or scoured out if channel shift is significant, but this isn't likely. If historically unstable channels shift into planted areas, this may scour out vegetation or fill as described above.

Most of the bar surface is shown as “vegetated overbank" or “overbank storage”, showing some likelihood of dominant fill processes, though the side channel proposed for the end of the Yuba Goldfields Terminus should keep the downstream end of Bar C from filling if well maintained against the left bank with good transport capacity (Wyrick and Pasternack, 2015).

C-2.4.4. Increment 5b (Hallwood Reach). Increment 5b is also located within Hallwood Reach, including Bar D, Narrow Bar, Bar E and Island B, including Measures 48, 49 and 50-54, including an anabranching side channel in a former swale, floodplain lowering, riparian planting, ELJ placement, two backwaters and LWM.

Historical aerial analysis in cbec (2013) shows significant shifting of number and location of channels at Narrow Bar (Bar D), with multiple channels in '64, single in '75, multiple in '86, and single after '98. Wyrick and Pasternack (2015) indicates the upper portion of Bar D as a “no discernible change” area, and while that's a relatively short period geomorphically speaking, the pattern persisted through the next 10-year period, through 2017, experiencing a 13 year event within the hydrologic regime of the period between 2008 and 2017.

With regard to installing an anabranching channel pattern at Bar D, the north channel may fill and the middle channel may shift location, though boulders to set grade in some areas should help. However, splitting flow into more than two channels increases risk of deposition by reducing transport capacity, and possibly avulsion or increased scour if one or more channels joins the others. Floodplain lowering with planting is relatively limited in area and confined to mid-bar areas, so may remain relatively stable if flow tends to occupy former locations, though the configuration shown for the mid-bar channel appears to transect apparent tree lines that mark former channel locations at the downstream end of the bar. If planting doesn't establish quickly and the side channel avulses, damages could be greater, though riparian planting covers most of the bar surface – if vegetation establishes quickly, likelihood of shifting channel locations may be reduced.

Some of the harder materials proposed in this Increment – stone, large wood – may be more susceptible to scour, though splitting flow into multiple channels may reduce transport capacity enough to offset concentrated turbulent scour around these structures. If structures are nonetheless scoured or undercut, the configuration could unravel, or simply be limited to one or more structures with function preserved. As long as side and back channels are maintained, deep backwater area is not likely to fill. Backwater at Lower Yuba River near RM6.5 appears well vegetated, with some scour noted by Wyrick and Pasternack (2015) but otherwise classed as “vegetated overbank storage” between 1999-2008, making fill more likely dominant in this area.

In the area of Bar E, the back channel area that filled in between 1999-2008 is proposed to be stabilized with riparian plantings and LWM. Even though this area is recently filled, the configuration of the main channel is unlikely to resume this sharply curved side channel location - this appears to be an artifact left over from the mainstem shift from left bank to right bank in the '80's, and is more likely to persist.
Island B appears relatively persistent through the imagery record, with possible adjustment in bar extent, but low probability of changing appreciably considering the persistent location of this feature.

C-2.4.5. Qualitative Damage Risk Assessment Methods and Results.
Consequences of channel change in this study were roughly categorized by assessing channel change where Measures are proposed and assigning a qualitative damage probability category (e.g., very low – low – medium – high) that could be incurred from anticipated changes under a similar hydrologic regime over the next 10-50 years.

Detailed categorical inputs for qualitative damage probability and severity analysis was conducted for each Measure and component parts (where relevant) in Increments 2, 3a, 5a and 5b, to enable evaluation based on materials used, degree of disturbance to sediment deposits and location within each complex of morphological features, also summarized in the Measures Matrix. For example, riparian planting is considered as a separate treatment from floodplain lowering, though floodplain lowering includes similar planting design. This is due to the effect of excavation disturbing surface sediment deposits for the first few years, potentially decreasing the shear required to mobilize those sediments, particularly if a formerly existing armor layer has been removed and finer sediments lay below. Similarly, structural measures (boulders, large wood) are considered separately from associated backwater or side channels, considering that an engineered log jam, large woody material or riprap have differing critical shear resistance, themselves differ from native cobble and gravel material, and may increase local scour or deposition patterns.

For time-lumped analysis of potential damage, the sources noted above were assessed for the periods of record or analysis, combined with the dominant processes noted for each reach defined by cbec (2013), the specific areas and types of change noted by Wyrick and Pasternack (2015), the type and location of measure to be implemented, and professional judgment used to assign damage category, probability, and severity should the event or anticipated change occur. Increment-specific assumptions and thought processes are described, with appropriate imagery and mapping records, in report sections below, and summarized in short, targeted notes in Table C-2-3.

C-2.4.6. Quantitative Damage Cost-Risk Assessment. The results of the geomorphic analysis and qualitative risk assessment were coupled with SRH2D modeling results to generate a quantitative cost-risk assessment for adaptive management, operation, maintenance, repair, replacement, and rehabilitation, and outyear damage estimates in dollars; that assessment is in Section C-15 Operation and Maintenance.

Table C-2-3. Qualitative Geomorphic Risk Assessment Results

Measure Number	TSP Increment	W&P 2012 Reach	cbec (2013) dominant processes	Measure Description / subtype	Feature or location	Acres	Damage category	Damage probability	Damage severity	Percent Area Rec. Plan	Processes description and notes
19	2	Parks Bar	Scour & Fill, overbank	floodplain lowering	Upper Gilt Edge (UGE) Bar	8.1	scour or fill	medium	medium	4.5%	avulsed at top of UGE Bar 1999-2008, in channel fill, some local scour - if channel moves entirely, lowered area may scour out or fill in beyond depth to water table tolerance for plantings
19	2	Parks Bar	Scour & Fill, overbank	riparian planting	Upper Gilt Edge Bar	2.5	scour or fill	medium	low to medium	1.4%	avulsed at top of UGE Bar 1999-2008, in channel fill, some local scour - if channel moves entirely, could either scour out or bury vegetation, damage varies with degree of establishment of veg
20	2	Parks Bar	Scour & Fill, overbank	bank scalloping	Upper Gilt Edge Bar	0.3	scour or fill	low	high	0.1%	more structural measure, and located on bar edge more vulnerable to scour or burial but has feedback mechanisms designed in to limit damages
20	2	Parks Bar	Scour & Fill, overbank	riparian planting	Upper Gilt Edge Bar	0.4	scour or fill	low	low to medium	0.2%	structural elements will more likely protect vegetation, damage varies with degree of establishment of veg
21	2	Parks Bar	Scour & Fill, overbank	backwater	Upper Gilt Edge Bar	0.3	scour	medium	low	0.2%	ok if backwater scours in this location, channel has been moving south here the last 10-20 years, but good native riparian buffer
21	2	Parks Bar	Scour & Fill, overbank	riparian planting	Upper Gilt Edge Bar	0.6	scour	low	low to medium	0.3%	as long as existing vegetation not disturbed too much, plantings should also do well, damage varies with degree of establishment of veg
22	2	Parks Bar	Scour & Fill, overbank	floodplain lowering	Parks Bar, upstream	5.9	scour	very low	medium	3.3%	not likely to erode, bank erosion may occur, scour and possible avulsion to the north RB behind planned treatment - may still preserve treatment though functional channel area may shift and occupy lowered areas, leaving new deposits without vegetation, damage may vary with degree of veg establishment
22	2	Parks Bar	Scour & Fill, overbank	floodplain lowering	Parks Bar, downstream		scour	medium	medium	included in 3.3%	noted as a local scour area in 2009, could scour out and reoccupy former alignment in lowered area
22	2	Parks Bar	Scour & Fill, overbank	riparian planting	Parks Bar, upstream	5.2	scour	very low	low to medium	2.9%	vegetation not likely to scour out here considering morphologic record, damage varies with degree of establishment
22	2	Parks Bar	Scour & Fill, overbank	riparian planting	Parks Bar, downstream		scour	medium	low to medium	included in 2.9%	noted as a local scour area in 2009, could scour out vegetation, damage varies with degree of establishment
24	3a	Parks Bar	Scour & Fill, overbank	floodplain lowering	Lower Gilt Edge Bar	6.2	scour or fill	very low	low to medium	3.5%	no change or overbank storage area between 1998-2009, damage may vary with degree of veg establishment
24	3a	Parks Bar	Scour & Fill, overbank	riparian planting	Lower Gilt Edge Bar	5.0	scour or fill	very low	low to medium	2.8%	vegetated overbank storage area between 1998-2009, damage varies with degree of establishment
24	3a	Parks Bar	Scour & Fill, overbank	side channel in swale	Lower Gilt Edge Bar	0.8	fill	low	low	0.4%	better likelihood of staying in place, not filling, if linear plantings follow former channel tree lines
26	3a	Parks Bar	Scour & Fill, overbank	riparian planting in swale	Hidden Island	2.3	scour	medium	low to medium	1.3%	possible reoccupation of swale, scour of vegetation, damage varies by degree of establishment of veg
28	3a	Parks Bar	Scour & Fill, overbank	riparian/habitat complexity	First Island	6.3	scour	very low	low	3.5%	bar location adjustment possible, but not by much
29	3a	Parks Bar	Scour & Fill, overbank	channel stabilization and ELJs ("gravel")	Silica Bar	1.6	scour	medium	high	0.9%	channel location and downstream end of first island moves frequently, LB side channel is moving south, possibly unstable area with new deposits
29	3a	Parks Bar	Scour & Fill, overbank	LWM	Silica Bar	NA	scour	medium	high	NA	channel location and downstream end of first island moves frequently, LB side channel is moving south, damage to new structures and lowered/vegetated floodplain may vary with degree of establishment of veg
29	3a	Parks Bar	Scour & Fill, overbank	riparian planting	Silica Bar	NA	scour	medium	low to medium	NA	though channel location and downstream end of first island moves frequently, LB side channel is currently moving south, IF structural measures succeed, plantings are less likely to erode, damage varies with degree of establishment
30	3a	Parks Bar	Scour & Fill, overbank	floodplain lowering	Silica Bar	1.6	scour	medium	medium	0.9%	existing downstream terminus has moved ~1000' downstream, much of the design area may be in the current main channel or emergent medial bar now, not much if any LB bar present in downstream portion of Silica Bar treatment area - all recent deposits, possibly unstable
30	3a	Parks Bar	Scour & Fill, overbank	riparian planting	Silica Bar	3.5	scour	medium	low to medium	2.0%	existing downstream terminus has moved ~1000' downstream, much of the design area may be in the current main channel or emergent medial bar now, not much if any LB bar present in downstream portion of Silica Bar treatment area - all recent deposits, possibly unstable, though damage varies with degree of establishment of veg
32	3a	Parks Bar	Scour & Fill, overbank	floodplain lowering	Bar A (North Sillica Bar)	5.2	fill	low	low	2.9%	numerous lines of vegetation marking former side channels, combined with reconnecting these, this vegetation is probably low risk and low damage from intermittent fill and overbank storage
32	3a	Parks Bar	Scour & Fill, overbank	riparian planting	Bar A (North Sillica Bar)	11.6	fill	low	low to medium	6.5%	not likely to be affected except if back channel shifts, though damage varies by degree of establishment of veg
33	3a	Parks Bar	Scour & Fill, overbank	channel stabilization and ELJs ("gravel")	Bar A (North Sillica Bar)	1.9	scour or fill	medium	low	1.0%	possible rock/sediment placement with wood, possible scour or fill if channel continues to migrate south (fill) or reoccupies 1998 alignment to RB (north), upstream end is a scour area per W&P between 1999-2008, Bar A historically highly unstable from mine tailings influence per cbec

Table C-2-3 Continued. Qualitative Geomorphic Risk Assessment Results

Measure Number	TSP Increment	W&P 2012 Reach	cbec (2013) dominant processes	Measure Description / subtype	Feature or location	Acres	Damage category	Damage probability	Damage severity	Percent Area Rec. Plan	Processes description and notes
34	3a	Parks Bar	Scour & Fill, overbank	anabranching side channel in swale and former alignment	Bar A (North Sillica Bar)	10.5	scour or fill	medium	medium	5.9%	steeper side channel might scour, though as a vegetated and overbank storage area, sediment likely to continue through with possible channel filling - might even out risks, monitoring will tell. Also former channel alignment from 70's to far N with good native vegetation
46	5a	Hallwood	Fill, veg overbank	floodplain lowering	Bar C - upstream end	13.0	scour or fill	high	high	7.3%	likelier to scour considering multiple channel alignments downstream from the Daguerre High Flow Channel and possible reoccupation of one or more alignments, this area has been split and resplit in multiple locations throughout historical record. Fill possibly more likely due to splitting flow into three branches here spreading out transport energy, though if constructed well and stabilized, vegetation might hold alignments even if covered in sediment, as long as its shallow
46	5a	Hallwood	Fill, veg overbank	floodplain lowering	Bar C - downstream end		fill or scour	very low	low	included in 7.3%	relatively long-lived alignment, clearly an active surface but should be low risk of damage to established vegetation, particularly if main channel, backwater and swale side channel are well stabilized. Most of the bar surface is shown as vegetated overbank or overbank storage, fill is the most likely. Lowering and planting associated with Measure 47 is low risk, medium damage, as it may be filled or scoured out if channel shift is significant, but this isn't as likely
46	5a	Hallwood	Fill, veg overbank	riparian planting	Bar C - upstream end	16.6	scour or fill	high	low to medium	9.3%	If historically unstable channels shift into planted areas, may scour out vegetation or fill as described above, damage varies with degree of establishment of veg
46	5a	Hallwood	Fill, veg overbank	riparian planting	Bar C - downstream end		fill or scour	very low	low to medium	included in 9.3%	damage varies with degree of establishment of veg
46	5a	Hallwood	Fill, veg overbank	backwater enhancement (side channel)	Bar C - downstream end	10.3	fill	very low	medium	5.8%	unlikely to fill at the bottom end if Yuba Goldfields Terminus side channel is maintained against the left bank leading into it to keep sediment from depositing. Most of the bar surface is shown as vegetated overbank or overbank storage
47	5a	Hallwood	Fill, veg overbank	side channel in swale	Yuba Goldfields Terminus	4.8	scour or fill	medium	high	2.7%	if constructed in former alignment (as shown) with minimal damage to existing visible treelines, this side channel may still be vulnerable to avulsion due to adjacent land disturbance by floodplain lowering activities - on both sides at the upstream end of Bar C (high damage probability) and especially on the right side at the downstream end (low to medium probability). narrow bands of revegetated bar surface shown at the margins of the side channel may hold once established
47	5a	Hallwood	Fill, veg overbank	riparian planting	Yuba Goldfields Terminus	4.7	scour or fill	low	low to medium	2.6%	damage varies with degree of establishment of veg
48	5b	Hallwood	Fill, veg overbank	anabranching side channel in swale	Narrow Bar (Bar D)	9.2	scour or fill	medium	high	5.1%	the North channel may fill, middle channel may shift location, boulders should help. However, splitting flow into more than two channels increases risk of damage and amount of damage if flow abandons one or more channels and concentrates into the others or avulses to a new location - historical record shows multiple channels in '64, single in '75, multiple in '86, single after '98. shown as no change from 98-2008, though that's a relatively short period geomorphically
49	5b	Hallwood	Fill, veg overbank	floodplain lowering	Narrow Bar (Bar D, upstream portion)	6.9	scour or fill	low	low	3.9%	lowering with planting is relatively limited in area and confined to mid-bar areas. If planting doesn't establish quickly and side channel avulses, damages could be greater, though riparian planting covers most of the bar surface, so overall bar veg damage should be lower even with shifting channel locations if vegetation establishes well
49	5b	Hallwood	Fill, veg overbank	riparian planting	Narrow Bar (Bar D, upstream portion)	21.1	scour or fill	low	low to medium	11.8%	damage varies with degree of establishment of veg
50	5b	Hallwood	Fill, veg overbank	floodplain lowering	Narrow Bar (Bar D)	0.8	scour	low	low	0.4%	some potential for scour around ELJ structures, much less so away from them
50	5b	Hallwood	Fill, veg overbank	riparian planting	Narrow Bar (Bar D)	3.7	scour	low	low to medium	2.1%	Damage varies with degree of establishment of veg
50	5b	Hallwood	Fill, veg overbank	ELJ placement	Narrow Bar (Bar D, middle portion)	NA	scour	medium	medium	?	if structures are scoured and undercut, the configuration could unravel or be limited to one or more structures - particularly vulnerable if side channels avulse
51	5b	Hallwood	Fill, veg overbank	deep backwater	Narrow Bar (Bar D, lower portion)	1.9	fill	low	medium	1.1%	unlikely to fill if side channel is maintained
52	5b	Hallwood	Fill, veg overbank	backwater	Lower Yuba River nr RM6.5	1.0	fill	low	medium	0.6%	this area is well vegetated with some scour noted but classed as vegetated overbank storage, so fill is more likely
53	5b	Hallwood	Fill, veg overbank	riparian planting, LWM	Bar E	2.4	scour	very low	low	1.4%	Even though this area is recently filled, the configuration of the main channel is unlikely to resume this sharply curved side channel location - this appears to be an artifact left over from the mainstem shift from left bank to right bank in the '80's
54	5b	Hallwood	Fill, veg overbank	riparian planting	Island B	2.5	scour or fill	very low	low	1.4%	possible adjustment in bar extent, but low probability considering the stable location of this feature

C-2.5. Anticipated Frequency of Induced Flooding.

2.5.1. General. Implementation of the Recommended Plan would not affect the primary drivers of hydrology and hydraulics in the watershed; effects would be localized in nature. Inflows and outflows in the lower Yuba River would not be affected by the types of proposed actions. Localized modifications to hydrology and hydraulics could result from project actions, including direct modifications of topography and installation of riparian and hydraulic roughness features. The Proposed Plan includes modifications to terrain that involve the excavation and reshaping of terrain to create complex habitat features (i.e. construction of side channels, backwaters, and floodplain lowering). These modifications are designed to affect habitat at low to normal flow (below bankfull) conditions. Under these normal conditions, these modifications would result in additional channel capacity. During normal flood conditions, the Lower Yuba River flows into the readily accessible floodplain; during these conditions, project features would be inundated. Project features would not affect the ability of the river to access high floodplain nor would it affect the hydrology of the watershed and therefore would not result in significant effects to this resource.

Project features also include the installation of hydraulic roughness features, including planting of riparian vegetation and installation of woody material and boulders. Installation of woody materials and boulders would be limited and focused on improving and/or maintaining the hydraulic stability of constructed features. Boulders and woody material placements would not be constructed at a scale that would affect the hydrologic or hydraulic conditions of the Lower Yuba River.

The Proposed Plan includes planting of 136 acres of riparian vegetation which could affect the conveyance of flood flows through the Lower Yuba River. Potential impacts to flood flow conveyance from the planting of vegetation would be offset through the increase to channel capacity resulting from the excavation of material (on the order of 700,000 cubic yards) from topographic modification actions.

2.5.2. Climate Change. Attachment HH-C contains an ECB 2016-25 compliant climate change assessment for the Recommended Plan along the Lower Yuba River. The assessment concludes the following projected impacts of climate change are likely to affect the Sacramento River and San Joaquin River watersheds:

- Increased air temperatures
- Reduced snow water equivalent
- Earlier spring snowmelt
- More frequent and intense atmospheric river storms
- Chronic long duration hydrological drought

The effects of these climate changes on the habitat measures is discussed below.

2.5.2.1. Increased Air Temperatures. Increased air temperatures could cause increases in water temperatures in the recommended plan area, reducing the temperature suitability of parts of the lower Yuba River. However, given that the Lower Yuba River is one of few that has temperature suitability at the present time, reductions in Recommended Plan long-term benefits may be offset by the increased scarcity of temperature suitable environments throughout Northern California.

2.5.2.2. Reduced Snow Water Equivalent. Because the Recommended Plan is in a flow regulated environment and designs are based on regulated base flows, reduced snow water equivalent is not expected to have significant effects on long-term project performance.

2.5.2.3. Earlier Spring Snowmelt. Because the Recommended Plan is in a flow regulated environment and designs are based on regulated base flows, reduced snow water equivalent is not expected to have significant effects on long-term project performance. There may be some reductions in performance for fish habitat due to shifted periods and durations of inundation in constructed shallow water habitats.

2.5.2.4. More Frequent and Intense Atmospheric River Storms. Increased extreme hydrologic events could all features of the Recommended Plan. However, the features of the recommended plan are most vulnerable to extreme hydrology in the first 10 to 20 years of establishment, a time during which Adaptive Management and OMRR&R activities could mitigate climate change-induced changes.

2.5.2.5. Chronic Long Duration Hydrological Drought. Because the Recommended Plan is in a flow regulated environment and designs are based on regulated base flows, reduced snow water equivalent is not expected to have significant effects on long-term project performance. However, chronic drought during the vegetation establishment period could increase Adaptive Management costs and/or OMRR&R costs.

2.6. Sea Level Rise. Since this project is located at least 60 ft above sea level, sea level rise is not likely to impact the project area. Therefore, analysis required by ER 1100-2-8162, Incorporating Sea Level Change in Civil Works Programs was not conducted. Omission of this analysis is considered an extremely low risk.

C-2.7. Water Quality. Existing conditions and potential project effects on Water Quality are discussed in the Effects Analysis section of the main report. Water Quality concerns associated with the Recommended Plan include increases in turbidity due to induced erosion and temporary increases in suspended soil/sediment during construction; however, the primary water quality concern in the Lower Yuba River is mercury and mercury methylation. As of 3 October 2017, the Lower Yuba River is 303(d) listed for Mercury with TMDL development targeted for 2027; Copper is being considered for placement on the CWA section 303(d) List (https://www.waterboards.ca.gov/water_issues/programs/tmdl/2014_16state_ir_reports/category5_report.shtml). Project activities are not anticipated to cause elevated mercury concentrations beyond background levels.

2.7.1 Water Quality Criteria. Specific water quality criteria for the project will be imposed by the State of California and the Regional Water Quality Control Board. These criteria are not currently known. It is assumed that they will specify acute and chronic above background concentrations for constituents of interest that will be applied at the boundary of an allowable mixing zone. USACE will obtain and comply with a 401 Water Quality Certificate from the Central Valley Regional Water Quality Control Board.

2.7.2. Adaptive Monitoring Strategy. An adaptive water quality monitoring strategy is recommended. Water quality sampling would be conducted along a routine schedule suitable to the State of California and the Regional Water Quality Control Board. The majority of this routine monitoring would center about turbidity because of its ability to provide rapid feedback on current conditions. Trigger values will be established that, if exceeded, signify that water quality impacts are possible. In response, water quality monitoring would be increased in spatial and temporal density to determine the validity of the concern. Response strategies will modification of construction activities to alleviate water quality concerns and implementation of additional best management practices. Construction activity modifications could range from changing equipment operation (location or patterns) to temporarily shifting the location of construction to ceasing construction activities until a solution is identified and implemented.

2.7.3 Establishing Background/Pre-Construction Conditions. Some water quality criteria will likely be issued as above ambient or background conditions. This focuses water quality impacts on activities associated with the construction operation rather than other actions or activities within the watershed. The challenge is establishing reliable background/pre-construction water quality conditions.

If construction is limited to operation in only one location at a time, continuous river flow allows water quality monitoring just upstream of the construction site to define background water quality conditions. Continuously adjusting background concentrations to temporally match downstream water quality data collection allows provides the best option for separating impacts associated with construction operations from other factors impacting water quality. Background monitoring locations can be in close proximity to the construction operation and still represent ambient conditions. These same procedures can be used if multiple construction operations occur simultaneously and their locations are sufficiently distant that upstream impacts do not reach the downstream location or water quality standards are applied on a site-by-site basis.

Establishing ambient conditions is much more complicated and if water quality standards are applied across all construction activities and multiple construction sites are sufficiently close as to see cumulative impacts. Background sampling upstream of the most upstream construction activities can be effective if there are no significant non-construction sources between construction sites. For example, an isolated storm in a tributary watershed could lead to highly turbid discharges entirely unrelated to construction.

If simultaneous construction activities will be conducted at multiple locations and water quality criteria are applied to the entire project reach, establishing background/ambient conditions becomes much more complicated. In this case, a water quality sampling effort will be required in the year before construction begins to establish background conditions. This effort should, to the extent possible, coincide with the window of construction in ensuing years and establish background conditions for the range of flows expected during construction. This data collection effort will require careful design in involved extensive data collection.

2.7.4. Water Quality Monitoring Strategy. This section describes anticipated water quality monitoring strategies. The restoration plan consists of multiple measures, mostly aggregated into a few locations modest distances apart. For the purpose of outlining a general water quality monitoring strategy, it is assumed that each aggregate of measures in a similar location will be monitored separately. Aggregating measures for monitoring purposes allows monitoring stations to remain in place for longer periods of time and should improve the quality of the monitoring program.

Water quality monitoring at each location will consist of an upstream and downstream location. The upstream location will establish background or ambient conditions. The downstream location will provide data to evaluate water quality impacts from construction operations.

2.7.4.1. Sample Collection/Water Quality Measurement Locations. The Yuba River ranges between 200 and 300 feet wide in most areas of the project. Depths range from very shallow (less than 1 foot) in some side channel areas during low flows to over 10 feet deep in the thalweg during higher flow conditions. Since construction is expected to occur during low flow conditions, water depths are expected to be mostly 5 ft or less.

Water quality variations across the channel are expected to be minimal under normal conditions, especially upstream of construction. In those cases, as single sample or measurement in the thalweg of the channel about mid-depth should be adequate to characterize most water quality parameters.

Variations across the channel may be significant downstream of construction and, in some cases, upstream. For those conditions, a single sample or measurement may be inadequate, and a more complicated sampling scheme required. The river cross-section should be segmented into areas. Ideally, each area would represent an equivalent fraction of total flow. But, this is likely unrealistic for the Yuba River since the majority of the flow is likely in the main channel. When this is the case, velocity must be measured at each sample location to facilitate computing a flow-weighted average concentration. Analyzing this number of samples on a frequent (e.g. daily) basis quickly becomes prohibitive, plus the results are not available within a time frame to be useful. Thus, the use of turbidity as a surrogate measurement is recommended with enough concurrent samples collected to correlate turbidity to suspended sediment concentration and other constituents of concern such as total metals and methyl mercury.

Ideally, water quality sampling can be automated with turbidity sensors, data loggers, and automatic samplers. These tool reduce the overall cost of compliance and usually produce more reliable results. Direct measure constituents, e.g. turbidity, can be monitored on a more frequent basis without increasing costs for personnel or equipment.

2.7.4.2. Sampling Frequency. Water quality parameters of interest would be measured at hourly intervals and data retrieved from dataloggers once daily under normal conditions and to establish background conditions. Sampling and measurement frequency should be increased gradually during times of elevated concern, starting with 2 times per day and increasing as needed. The majority of this data collection is expected to be electronic.

Some physical samples will be required to measure other constituents of concern. Under routine conditions, 5 samples per week will be sent for laboratory analysis to measure total metals and methyl mercury in addition to other standard water quality tests such as suspended solids. It should be assumed that there will be times of exceedances when more frequent sampling is required. For planning purpose, it is assumed that an additional 10 samples per month will be used for these purposes. Sampling constituents and frequency will comply with the 401 Certification.

Water quality conditions are expected to return to normal rapidly after construction ceases, so monitoring beyond the end of construction should not be necessary.

2.7.4.3 Sampling Duration. It is assumed that the water quality monitoring will be required for 7 months per year for three years at each construction site across a total construction duration of 4 years. Background sampling will occur at each construction site the year prior to construction.

2.7.5. Best Management Practices and Controls. Potential characterization methods and controls to mitigate water quality impacts with respect to mercury or other fine-grained-sediment-associated contaminants are discussed in Sections C-9 Hazardous and Toxic Materials, C-10 Construction Procedures and Water Control Plan, and C-21 Special Studies of this Appendix, and in the Effects Analysis section of the Main Report.

2.7.6 Long Term Water Quality Benefits. Overall, the long term impacts of the Recommended Plan are expected to provide a higher quality riverine system and improve most water quality parameters. The restored vegetated riparian areas would improve long-term water quality by providing shade that would help moderate stream temperatures and light penetration; and providing root structure and woody material that would help stabilize stream banks, moderate stream velocities, reduce channelization, and reduce erosion and suspended sediments. Long-term water quality concerns thus focus on ensuring that increased methylation of mercury is not induced by project activities.

C-3. Surveying, Mapping, and Other Geospatial Data Requirements

Existing mapping data was sufficient for a baseline of FWOP conditions and a basis for FWP conditions for the habitat measures in the Recommended Plan.

3.1. Civil Design Quantities/Areas. Yuba River Ecosystem Restoration Study Feasibility Study Habitat Measures" (YCWA 2016b) details the habitat features and provided the basis for their polygon representation in GIS (see also Section C-1.5). Section 6.1 and subsections summarizes habitat measure design criteria that were used to bootstrap habitat feature descriptions into polygons suitable for GIS analyses and modeling coverages (full detail is contained in Attachment CV-A). Habitat features were created by HDR and mosaicked into existing topographic data by both HDR (in support of YCWA) and Sacramento District staff.

Attachment CV-B describes the GIS files and manipulations used in the generation of excavation and grading quantities. These quantities were used in Civil Design and Cost Engineering calculations.

3.2. Other Civil and Cost Engineering. Non-quantity-related aspects of Civil Design and Cost Engineering siting and other distance calculations were made using Google Earth Pro v. 7.1.5.1557. Section CV-6.5.and subsections discuss staging area, access route, and haul route determinations that were used for cost, environmental, and real estate purposes.

C-3.2. GIS Modeling and Data Processing for Plan Selection. GIS was utilized for benefit calculations to generate outputs for CE/ICA analyses that informed Plan Selection. Main Report Appendix D – Environmental, Attachment 8 describes the modeling coverages, roughness values, and workflow from with-project coverage generation to hydraulic modeling inputs and results to benefit calculations. Attachments GIS-A through GIS-C to this Appendix describe the GIS processes and post-processing performed for benefit calculations.

C-4. Geotechnical

C-4.1.1. Site Geology. The major physiographic feature within the project vicinity is the Sierra Nevada Range, which is about 400 miles long and runs south-southeast to north-northwest in the eastern portion of California. The Sierra Nevada crest forms the eastern limit of the Yuba and Bear River Basins and trends north-northwest. Drainage within the Yuba and Bear River Basins is west to southwest from the Sierra Crest to the adjacent floor of the Sacramento Valley. To the east of the basins, down faulting of the eastern Sierra face has affected drainage evolution by creating channels that now have their headwaters facing east.

Uplifting and tilting of the Sierra Block reorganized drainage networks and initiated a period of sustained channel incision, and many of the modern river channels have elevations below Tertiary-age river channels. The ancestral (Tertiary Period) Yuba River had cut about 1,000 feet below a surface defined by San Juan, Washington, and Harmony ridges. These ancestral deep channels drained north-northwest across the strike of the modern drainages. The south branch of the ancestral Yuba River flowed north from Gold Run to Badger Hill, then southwest to Smartsville and Marysville. The ancestral channels were filled first by very coarse, boulder material rich in gold, followed by finer gravel and sand deposits, also rich in gold. These Tertiary gravel deposits are the source of the gold extensively mined in the late 1800s.

The modern Yuba and Bear River Basins drain the northwestern Sierra Nevada via a series of deep canyons separated by high, steep-sided ridges and a parallel drainage network. The parallel drainage network results in narrow ridges between small tributaries, small tributary watersheds, and low tributary sediment loads under natural conditions; prehistoric debris fans at tributary junctions were not common. Stratigraphic evidence indicates the presence of stepped, Quaternary Period terraces similar to piedmont channels flowing out of the Sierra Nevada, but these terraces were generally buried by debris and sediment associated with mining activities. Downcutting, as noted specifically in the Bear River, through the relatively soft Paleozoic metamorphic rock (Shoofly Complex) has created a deep, v-shaped canyon where short, steep-sided tributary drainages are typical. Distinctive v-shaped inner gorge areas are common in all of the major drainages in the vicinity of the projects (YCWA 2014).

C-4.1.2. Hydraulic Mining Impacts. The study area has been heavily impacted by past hydraulic mining. Extensive hydraulic mining occurred in the Yuba River watershed from 1852 until the enactment of the Caminetti Act 1893 that severely limited its use. In hydraulic mining, water cannons shot high-pressure flows out to wash away hillsides (see Figure 8.). The material that was dislodged was then sluiced to expose the gold.

Figure C-4-1. Hydraulic Mining Water Cannon

Gilbert (1917), as cited in Yoshiyama *et al*. (2001), estimated that "…during the period 1849-1909, 684 million cubic yards of gravel and debris due to hydraulic mining were washed into the Yuba River system – more than triple the volume of earth excavated during the construction of the Panama Canal. According to Major William W. Harts of the California Debris Commission, "The low water plane of the Yuba River at Marysville was raised 15 feet between the years 1849 and 1881. Between the years 1881 and 1905 there was an additional raise of three feet, making a total raise in the low water plane of 18 feet (the actual fill in the main channel being 26 feet). The depth of fill of mining debris in the Yuba River averaged from 7 1/2 feet at Marysville to 26 feet at Daguerre Point and 84 feet at Smartsville. A short distance east from Marysville, the bed of the Yuba River was 13 feet above the level of the surrounding farms." The quantity of material lodged in the river due to mining has been variously estimated, but it seems safe to say that there are now (1905) upwards of 333,000,000 cubic yards in the bed of the lower Yuba River. This debris field is still mined for residual gold deposits and gravel. Hydraulic mining in the Yuba River accounted for 40 percent of all the mining debris that washed into the Central Valley (Mount 1995).

Hydraulic mining resulted in torrents of sediment being transported downslope to the valley and caused rapid aggradation and exacerbation of flooding along Central Valley Rivers, including the lower Yuba River (James and Singer 2008). Two major debris dams (i.e., Daguerre Point Dam (DPD) in 1906 and Englebright Dam in 1941) were constructed on the Yuba River to prevent the continued movement of sediment into the Feather and Sacramento rivers, and ultimately the San Francisco Bay-Delta.

The Yuba Goldfields, located from approximately 8 to 16 miles upstream of Marysville, are dominated by approximately 20,000 acres of dredger tailings that were reworked from hydraulic mine waste. Dredging of gold from the hydraulic waste in the Goldfields began in 1902, and by 1910, 15 dredges were operating in the lower Yuba River. The area has been dredged and re-dredged intermittently throughout the years, and dredging continues today See Plates G-1 through G-5 for spatial and temporal changes in the area.

Before the advent of Hydraulic Mining, tidal effect was felt up the Feather River to Nicolaus, 19 miles below Marysville, or about 175 miles from San Francisco by river. The Feather River was navigable to Oroville, about 141 miles from the mouth of the Sacramento River and the Sacramento River itself was navigable to Red Bluff, about 250 miles from the mouth of that river. Mining debris, however, ruined navigation on the Feather River many years ago and it is not being navigated now. The Sacramento River to Colusa is now very difficult at times to navigate. Along with deleterious effects downstream due to hydraulic mining, mercury was used to process gold deposits. According to the US Geological Survey, hundreds of pounds of liquid mercury were added to the typical sluice box for Gold extraction. Gold sank to the bottom of the sluice, while sand and gravel passed over the high-density Mercury/Gold, allowing gold to separate and sink to the bottom. In the Sierra Nevada, up to 9 million pounds of mercury were lost in this manner to the environment (Churchill 2000).

C-4.2. Groundwater Setting. The high permeability of Lower Yuba River sediments and the neighboring goldfields creates a dynamic groundwater relationship that has been described by many (e.g. California Department of Water Resources 1999). Excavation of side channels, creation of backwaters, placement of boulders and large woody material is not anticipated to alter the groundwater regime of the Lower Yuba River in any significant way, be it flow or quality. Any unforeseen groundwater considerations will be addressed through the appropriate permits as part of environmental compliance activities.

C-4.3. Grain Size, Excavatability, Construction Techniques. The coarse grained cobble, gravel and sand have been mined by local companies for many years with common heavy equipment; some silty clay lenses have been encountered in past sediment coring upstream of DPD (Alpers *et al*., 2016), which should also be excavatable with this equipment. 13 cubic yard trucks will likely be used for transport of excavated material to placement sites. Heavy blade grader and water trucks will be utilized to maintain haul roads and staging areas. Planting activities will utilize heavy loaders equipped with stingers for placement of cuttings. Culverted crossings using spawning-sized gravel will be used to access bars when swales or side-channels must be crossed. A detailed discussion of excavation and construction techniques is contained in C-10 Construction Techniques and Water Control Plan.

C-4.4. Potential Borrow Sites and Disposal Sites. Borrow volumes are expected to be extremely small and any necessary borrow can be supplied by nearby excavation associated with this project. Multiple potential placement/disposal sites for excavated material are present in the project area on both the north and south sides of the river, including the Teichert Hallwood Facility, Western Aggregates, and Butte Sand and Gravel; C-19 Cost Estimates discusses assumptions about utilization of these facilities and haul distance assumptions. Placement/disposal of excavated material will likely require characterization of the material (see C-4.5. Summary of Additional Exploration, Testing, and Analysis and C-9. Hazardous and Toxic Materials).

C-4.5. Summary of Additional Exploration, Testing, and Analysis.

C-4.5.1. Groundwater Water/Baseflow Elevation. Given the coarse nature of the soils in and adjacent to the streambed, it is likely that the groundwater table is tied directly to the stage of the Yuba River. Thus, the baseflow of the river represents groundwater contributions from other sources and establishes the minimum water level expected. This level is likely the river stage associated with about 800 cfs.

Prior to excavation or sampling activities, the depth to groundwater must be determined by piezometer, monitoring well, or small-scale exploratory excavation. This elevation will be crucial in the design phase to ensure the water depths in the ecosystem restoration design provide the desired habitat. Much like the hydrologic analysis of Yuba River flows, it will be important to evaluate water surface elevation variations. However, instead of peak flows, the primary concern for this analysis is low flow frequency (see C-6.1 Habitat Measure Design Criteria).

C-4.5.2. Topography/Bathymetry. Accurate cross-sections at regular intervals (e.g. 100 ft) for project design. Surveys will be required at all 14 identified areas to obtain accurate measurements of existing surface elevations above and below the water level. These areas range from 0.5 acres to over 70 acres in size and the surveying requirements are generally proportional to area.

C-4.5.3. Soil/Sediment Characterization. Many of the ecosystem restoration measures require excavation above and/or below the water line. Characterization of the soils and sediment to be excavated is important to support the design of the excavation activities. Further, sufficient samples must be analyzed for chemical constituents, in particular total and methyl mercury, to allay any concerns about contamination that might limit the reuse of the excavated sediments.

The coring strategy for soil/sediment characterization at each habitat measure (or group of measures) is shown in Attachment GT-A Table 1. These cores will be collected with a Vibracore coring system using 4-inch aluminum tubes if possible, though in some locations a backhoe with auger attachment maybe be necessary; in some cases, a hybrid approach of minor excavation to fine gravel/sand followed by Vibracoring may be necessary. The auger or tubes will be penetrated to 10 feet below the surface with an elevation established for each location using surveying equipment. Auger samples or tubes will be sealed and returned to the laboratory for sample extraction and preparation. Samples are expected to be composited over 2 ft intervals unless conditions within the core or other additional information suggest differently. This would yield 155 samples. Physical analyses would be collected on all of them. Twelve (12) samples would be identified for full bulk sediment chemistry. Attachment GT-A Table 2 lists the specific physical and chemical analyses to be performed.

C-4.6. Seismicity. The projects are in an area of low to moderate seismicity, with most seismic activity concentrated east and southeast of the project areas near Lake Tahoe and to the northwest of the project areas, south of Lake Oroville. Expected seismic shaking intensities within the project area from these nearby faults are considered to be low.

A number of north-to-northwest trending faults cross the project area, most of which are associated with the Foothills Fault System. Among the more significant faults are the Grass Valley Fault, the Melones Fault Zone, the Big Bend/Wolf Creek Fault Zone, the Giant Gap Fault, and the Camel Peak Fault Zone. None of the mapped faults within the project areas has been active in Quaternary time. A portion of the Giant Gap fault south of the projects is designated as having been active in Quaternary time. The nearest active fault (defined by the California Geological Survey as movement within the past 11,400 years) is the Cleveland Hill Fault located to the northwest of the projects near Lake Oroville; that fault had recorded movement in 1975. Other active faults are located to the east and southeast of the projects near Lake Tahoe (YCWA 2014).

C-5. Environmental Engineering

As this is a proposed ecosystem restoration project, several aspects of environmental engineering are necessarily incorporated into each aspect of the project, including:

- Use of environmentally renewable materials,
- Design of positive environmental attributes into the project,
- Inclusion of environmentally beneficial operations and management for the project,
- Consideration of indirect environmental costs and benefits,
- Integration of environmental sensitivity into all aspects of the project;

Details of the items on this list are contained in C-6. Civil Design and the Appendix D - Environmental.

Beneficial uses of excavated material during construction, adaptive management, and Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) is a project goal for both environmental and cost purposes. Several gravel mining operations are in the vicinity of the project site, beneficial use of excavated material will be maximized to the extent practicable considering coordination with potential placement sites and the physical/chemical characterization on the material (see 9. Toxic and Hazardous Materials for further details of potential constraints).

Any issues or concerns noted in the Environmental Review Guide for Operations (ERGO) will be addressed through the Environmental Assessment herein, all applicable clean air, water, and other permits, and through the compliance with the California Environmental Quality Act.

C-6. Civil Design.

C-6.1. Habitat Measure Design Criteria. In order to translate the written descriptions of measures (Section C-1.5) and the varying degrees of detail in source references (Section C-2.5) into a modified terrain model that will be used in the hydraulic analysis for benefit calculation (Appendix D – Attachment 8) and Plan Selection (Main Report, Chapter 3), design criteria for each habitat feature type were developed to fill in gaps. These design criteria were used for the full development of habitat measure polygons in GIS for mosaicking into existing terrain coverages for quantity calculations. Attachment CV-A is a Technical Memorandum (USACE and YCWA (2016)) describing the design intent, strategy, and specifics for each habitat measure type; information relevant to final GIS polygon designs and associated quantity calculations (i.e. civil design considerations) is summarized below, details regarding the ecological basis for these design can be referred to in Attachment CV-A.

These criteria are not suggested to be final for purposes of Plans and Specifications. While the design criteria below are adequate for the feasibility level design and benefit calculation purposes, they will serve only as a starting point for Preconstruction Engineering and Design purposes. Final designs will go through thorough, site-specific feature design to maximize sustainability and thus long-term ecological function.

The overall strategy for development and application of design for habitat restoration measures is summarized below:

1. Identify major features of the proposed habitat restoration measures on the lower Yuba River
2. Develop design criteria, including minimum performance and general guidelines, for each major feature type
    a. Define design intent
    b. Define design strategy
    c. Define specific design parameters based on reasonable performance goals
3. Develop a modified GIS-based terrain layer to be used in conjunction with hydraulic modeling to simulate habitat conditions resulting from implementation of the proposed habitat restoration measures.
    a. Using YRERFS Habitat Measures Technical Memorandum (YCWA and Corps 2016)
    b. Applying design criteria to fill in gaps where appropriate and ensure a minimum level of performance

The major feature types included in the design criteria include side channels, floodplain grading, structural complexity features, and vegetative planting. These features were selected because they are anticipated to have the greatest effect on ecosystem output.

C-6.1.1. Side Channels. Side Channel designs are applicable to the creation of new, or enhancement of existing side channels. The following design criteria also will be applied as appropriate to features such as bank scalloping, backwaters, and/or any habitat feature with a similar design intent.

The operative design strategy is to provide side channel habitat particularly during the critical oversummer (June through September) rearing period (see Attachment CV-A exceedance Figures 1-4 and baseflow definitions, below). The following subsections detail design parameters that were incorporated into the measure descriptions from Section C-1.5 to generate polygons in GIS for design quantity and benefit calculations.

C-6.1.1.1. Base Flow Condition Parameters. Base flow condition parameters for GIS polygon design were 730 cfs above Daguerre Point Dam and 530 cfs below the Dam. Attachment CV-A contains further details of base flow derivation.

C-6.1.1.2. Entrance and Exit parameters. Side channel exit and entrance parameters were adapted from Hoopa Valley Tribe *et al*. (2011):

- Side channel entrance angle should be less than or equal to 40 degrees.
- To avoid sedimentation, either: (1) place the side-channel entrance at a location in the channel that is not transporting (and depositing) sediment; or (2) design the side-channel entrance such that it transports any coarse sediment that may enter the side-channel from the mainstem (Hoopa Valley Tribe *et al*., 2011).
- The side channel should not convey more than 15% of the baseflow to preserve sediment transport capacity in the main channel.
- The side channel entrance (i.e., approximate upper 1/3 of the side-channel) should not contain an abundance of added hydraulic roughness elements in order to retain sediment transport competency.
- In the downstream 2/3 of the side channel where roughness no longer has hydraulic effect on the coarse sediment competency of the entrance, additional roughness via structural elements (e.g., large woody material (LWM), engineered log jams (ELJs), boulders) and vegetation plantings can be encouraged.

C-6.1.1.3. Footprint. Side-channel footprint (width, length) were based on descriptions of the proposed measures presented in the YRERFS Habitat Measures Technical Memorandum (YCWA and USACE 2016) and on previously prepared reports (RMT 2009; DWR and PG&E 2010; cbec 2013; NMFS 2014; cbec 2014):

- Area: Polygons for project footprints were developed and documented in the YRERFS Habitat Measures Technical Memorandum (YCWA and Corps 2016).
- Depth: Side-channels will be created to a water depth of 0.5 ft associated with the base flow conditions. The ecological reasoning for this depth for different fish species and life stages is detailed in Attachment CV-A.
- Shore slope: Side channel walls will slope at 3:1 (H:V) from the base flow condition to a design depth (0.5 ft). A 3:1 slope was selected due to relative stability. Steep side slope walls may be preferred to prevent spawning in areas prone to dewatering.

C-6.1.2. Floodplain Grading. The design intent floodplain grading is to create additional inundated habitat, increase the frequency and duration of inundation, and enhance access to groundwater for establishment of riparian vegetation. The design criteria for floodplain grading are were also applied as appropriate to backwater creation.

The design strategy for floodplain grading is to base the design elevation on a standardized elevation corresponding to a target flow for each habitat/hydrologic zone, or (HZ). Using existing polygons to define upper limits of floodplain grading, polygons based on a depth-to-water table of 7 to 10 feet (floodplain grading/lowering/excavation) were defined based on depth to groundwater modeling results (cbec 2013).

C-6.1.2.1. Flow Related Target Elevations. The flow-related target elevations used were 2,000 cfs through the Study reach. See Attachment CV-A for a detailed discussion of frequency and duration of inundation rationales.

C-6.1.2.2. Floodplain Grading Footprints. Floodplain grading footprints (width, length) will be based on descriptions of the proposed measures presented in the YRERFS Habitat Measures Technical Memorandum (YCWA and Corps 2016) and on previously prepared reports (RMT 2009; DWR and PG&E 2010; cbec 2013; NMFS 2014; cbec 2014):

- Area: Polygons for project footprints were developed and documented in YRERFS Habitat Measures Technical Memorandum (YCWA and Corps 2016).
- Depth: Floodplain grading would be conducted with the goal of providing water depths associated with 50 – 100% of juvenile spring-run Chinook salmon optimal water depth suitability (i.e., depths ranging from about 0.5 to 3.3 ft) approximately 80% of the time during the over-summer juvenile rearing period (June through September).
- Slope: Slope of floodplain grading features will generally follow a linear extrapolation between the waterside and landside limits of the grading area.

C-6.1.3. Vegetative Planting. Vegetative plantings are intended to enhancing existing or create new riparian vegetation. Conduct riparian vegetation planting corresponding to design elevations based on standardized flow conditions for each habitat/hydrologic zone, or (HZ). Use existing polygons to define areas for riparian vegetation planting. Identify planting locations based on a depth-to-water table of less than 7 feet at each location. Dormant hardwood cuttings will be planted to depth of groundwater during the late fall. The depth-to-groundwater must be known, cuttings must be properly prepared, and the selected implementation methods must be able to reach groundwater at each selected location (SYRCL 2013).

C-6.1.3.1. Native Species Planting Composition. A combination of four native species will be planted, including: Fremont cottonwood (*Populus fremontii*), Gooddings black willow (*Salix gooddingii*), red willow (*S. laevigata*), and arroyo willow (*S. lasiolepis*). The planting design is intended to promote hardwood structure (i.e., forest and large wood production) while also providing species and structural diversity. Although arroyo willow is not a tree-type willow, it is included in the design to create structural diversity known to support neotropical bird habitat (RHJV 2004). Furthermore, arroyo willow is under-represented on the lower Yuba River compared to other shrubby willows (WSI 2012; SYRCL 2013).

C-6.1.3.2. Donor Trees. Donor trees will be selected from existing riparian areas along the lower Yuba River or surrounding areas if deemed suitable by an arborist. Multiple cuttings will be taken from red willow and arroyo willow shrubs, but single cuttings will be taken from the other tree species. If red willow donor tree availability becomes limited, Gooding's willow will be substituted.

C-6.1.3.3. Cuttings Size. Cuttings will be from branches or stems harvested from donor trees, and prepared as cuttings that are about 7 feet in length. Cuttings will be less than 2 inches diameter at the base.

C-6.1.3.4. Planting Design. It is recommended that revegetation should not cover more than 50% of a constructed surface. Revegetating with patchy stands ensures that existing monotypic vegetation will be replaced with a desirable species composition and structural diversity on some surfaces, while leaving other portions of the constructed surface exposed for natural plant recruitment (Hoopa Valley Tribe *et al*., 2011). Cuttings will be brought to stinger planting locations in the following combination: 6 cottonwoods and 2 of each willow species. Cuttings planted by stinger should be less than 2 inches in diameter and straight.
Each planting location will receive two cuttings of the same species, resulting in 12 cuttings per pod. Placing two cuttings per location is a common approach to increase success rate where some proportion of cuttings fail to root and thrive regardless of planting conditions (Hoag 2009). Initially, planting density will be 1,500 cuttings per acre. If further analyses of previously conducted pilot programs indicates relatively high (e.g., 75%) survivorship, then planting density could be reduced from 1,500 cuttings an acre to 1,000 cuttings an acre, resulting in a lower cost per acre for implementation (SYRCL 2013). Attachment CV-A contains further details on riparian planting designs and design derivations.

C-6.1.3.5 Footprint. Riparian vegetation planting footprint will be based on descriptions of the proposed measures presented in the YRERFS Habitat Measures Technical Memorandum (YCWA and Corps 2016) and on previously prepared reports (RMT 2009; DWR and PG&E 2010; cbec 2013; NMFS 2014; cbec 2014):

- Area: Polygons for project footprints were developed and documented in YRERFS Habitat Measures Technical Memorandum (YCWA and Corps 2016).

- Depth: Depth to groundwater has been estimated by Wyrick and Pasternack (2012) and by cbec *et al*. (2010). Available information will be reviewed and modified, if necessary, to estimate depth to groundwater at the various identified riparian vegetation planting locations. Literature reviews will be conducted to identify inundation frequencies and timing to maximize cutting survival, and to provide benefit to rearing juvenile anadromous salmonids.

Riparian planting will occur in areas adjacent to all side-channel footprint descriptions associated with the proposed measures presented in the YRERFS Habitat Measures Technical Memorandum (YCWA and Corps 2016).

C-6.1.4. Structural Complexity Features. Structural complexity features are designed to enhance physical structure only. Structural complexity features of the Recommended Plan consist of large woody material, engineered log jams, and large boulders. Attachment CV-A contains further details on the design of structural complexity features.

C-6.2. Quantity Calculations. Habitat measure polygons were developed from measure descriptions (Section C-1.5) and design criteria (Section C-6.1). These polygons were mosaicked into existing topography through a procedure detailed in Attachment CV-B. The mosaicking procedure described in Attachment CV-B allowed for quantification of habitat measure surface areas (for planting calculations/costs) and quantity takeoffs (QTOs) necessary for construction; these surface areas, QTO volumes, and the average depth of excavation across each Habitat Measure are shown in Table CV-B-1.

C-6.3. Construction Staging Areas, Access Routes, Haul Routes. Staging sites and access/haul routes were chosen based on the availability of existing roads, route efficiency to public haul roads (for sites with excavation), minimization of affected real estate parcels, and practicality based on site-specific topography.

C-6.3.1. Staging Sites. Staging sites and access/haul routes were chosen based on the availability of existing roads, route efficiency to public haul roads (for sites with excavation), minimization of affected real estate parcels, and practicality based on site-specific topography. Plates INT-1 thru 5 show proposed access routes and staging sites for each habitat measure in the recommended plan. Staging sites were sized from half an acre to an acre to minimize impacts to the surrounding environment while still providing an adequate and safe worksite. Table C-6-1 lists the Staging Site IDs (hereafter referred to interchangeably as “Site 1”, “Site 5”, etc), the associated habitat increment from the TPS (see Main Report Chapter 3), the geographic feature name, area of staging site, and associated habitat measure numbers (see C-1.5), and reference Plates.

Table C-6-1. Staging Site Information for Recommended Plan Habitat Measures.

Staging Area ID	TSP Increment	Locations	Area (Acres)	Associated Measures	Reference Plate
S-1	2	Upper Gilt Edge Bar	0.63	19,20,21	IN-1
S-2		Unnamed Bar	0.51	22	
S-3	3a	Lower Gilt Edge Bar	0.66	24	IN-2
S-4		Hidden Island	0.53	26	
S-5		First Island & Silica Bar	0.82	28,29,30	
S-6		Bar A	0.84	32,33,34	
S-7	5a	Bar C	0.89	46,47	IN-3
S-8	5b	Narrow Bar & Mile 6.5	0.75	48,49,50,51,52	IN-4
S-9		Island B & Bar E	0.74	53,54	

C-6.3.2. Access Routes. Access/haul routes beyond public roads will all require some level of improvement; access road improvement has been cost-estimated for each unique staging site. From each staging site, roads will be built out on gravel bars for work site access and hauling. A full-time grader (blade), water truck, and crew of laborers is allotted for each staging site's access roads. Plates IN-1 thru 5 also show proposed access routes to each staging site. Some staging site share portions of the same access route. Table C-6-2 shows access routes to each staging site, route length, and the junction to public haul roads to potential excavated material placement sites.

Table C-6-2. Access Routes to Staging Sites.

Staging Area ID	Length (mi.)	Proposed Access Route	Significant Improv-ment	Culverted Gravel Crossing to Work Site	Junction to Public Haul Road(s)
S-1	2.31 to Site 5	Hammonton Rd./New Truck Road	no	no	Hwy 20 to northside placement sites
S-3				no	
S-5				yes	
S-2	0.29	Unnamed gated Road	yes (lower)	no	Hwy 20 to northside placement sites
S-4	1.29	SRI Sand and Gravel Access Roads	no	yes	Hwy 20 to northside placement sites
S-6	1.09				
S-7	1.14	Desilva Gates Access Road	no	yes	Simpson Rd. to Dantoni Rd. to Hammonton-Smartville Rd. to southside placement sites
S-8	0.56	Farm Road	no	yes	Hammonton Rd. to Hwy 20, north- or south-side placement sites
S-9	1.53	Farm Road	no	yes	Dantoni Rd. to Simpson Rd. to Hwy 20 to northside placement sites or Dantoni Rd. Hammonton-Smartville Rd. to southside placement sites

C-6.3.3. Excavated Material Haul Routes. Several aggregate companies have large sites in the project vicinity on both the north and south sides of the Lower Yuba River. Conservative assumptions to these hypothetical placement sites were made to ensure adequate authorized costs for the project (i.e. optimal routes were purposefully not chosen). Table C-6-3XX shows the excavation volume associated with each staging site, the assumed haul distance to each staging site's assumed placement site, and a general location of the assumed placement sites.

Table C-6-3. Assumed Haul Route Distances and Volumes for Each Staging Site.

Staging ID	Staging Location Relative to River	Staging Site Excavation Volume (CY)	Assumed Distance to Placement Site (mi.)	Assumed Placement Site Location relative to River, Project Area
S-1	South	26,150	13.0	(North, Western)
S-2	North	15,300	11.3	(North, Western)
S-3	South	30,400	13.7	(North, Western)
S-4	North	0	NA	
S-5	South	3,500	14.6	(North, Western)
S-6	North	234,400	9.8	(North, Western)
S-7	South	284,800	6.2	(South, Southwestern)
S-8	North	188,400	12.8	(North, Eastern)
S-9	South	0	NA	

C-6.4. Real Estate. The land surrounding the Lower Yuba River in the Yuba Goldfields are owned by multiple property owners, including Bureau of Land Management, U.S. Army Corps of Engineers, and Western Aggregate. There are both cost and schedule risks associated with the acquisition of

- Rights of Entry for potential site characterization (see C-10 for sampling strategies)
- land parcels
- mineral rights associated with land parcels (potentially a party other than the land owner)
- easement rights for access/haul routes.

These cost and schedule risks were discussed in depth at the Cost and Schedule Risk Assessment meeting associated with the generation of Class 3 Cost Estimates (see Section C-19).

Parcel maps with Recommended Plan habitat measures overlaid are show in Plates CV-1 thru CV-6.

C-6.5. Relocations. The Recommended Plan will not require any known utility and/or facility relocations.

C-7. Structural Requirements.

There are no structural or mechanical elements of this Ecosystem Restoration project.

C-8. Electrical and Mechanical Requirements.

No utility relocations are identified for the Tentatively Selected Plan. Electrical and Mechanical Requirements will thus be limited to construction activities. Construction activities are predominately excavation and hauling of coarse grained or cobble sized river and bar soils/sediments, placement of large woody material and boulders, and grading activities. Should local beneficial uses of material based on separation be identified in subsequent design or PED, additional electricity for separation technologies may be required if on-site separation is deemed most efficient. Separation activities would be ongoing, heavy load actives that would require coordination with local electricity providers. Power poles are available for residential and industrial use sporadically use through the study area.

C-9. Hazardous and Toxic Materials.

A Phase I Environmental Site Assessment was performed in conformance with the scope and limitations of ASTM Practice E 1527-13 for the Yuba River Ecosystem Restoration Project. This assessment has revealed no Recognized Environmental Conditions in connection with the project site (see Attachment ENV-A). As discussed in Sections C-4.2.1. Study Area and C-2.4. Water Quality, elemental mercury (Hg2+, CASRN 7439-97-6) and methylmercury (MeHg; CASRN 22967-92-6) are known contaminants of concern in Lower Yuba River; methylmercury is of particular concern because it is bioaccumulative, biomagnifiable through the foodchain, and toxic to humans
(https://cfpub.epa.gov/ncea/iris/iris_documents/documents/subst/0073_summary.pdf).

The potential for the release of contaminants will be addressed through characterization and controls; however, no concentrations of any material are anticipated at levels that would be classified as Hazardous or acutely Toxic. Chronic mercury concentration in the water column (freshwater criteria 0.77 ug/L) could be concern depending on local bulk sediment concentrations.

Section C-4.5 describes the proposed site characterization sampling strategy for each site of ecosystem restoration construction, Attachment GT-A lists bulk soil/sediment chemistry and other tests to determine contaminant levels at proposed restoration sites. Any parcels that have toxicants at hazardous levels will not be acquired as part of this Ecosystem Restoration Project; parcels that have toxicants at levels that are above general landfill allowable levels may be deemed uneconomical for acquisition. In either case, habitat restoration feature would be re-sited or omitted from the project.

Section C-10. Construction Procedures and Water Control Plan discusses some potential controls and Best Management Practices (BMPs) to mitigate risks from unanticipated contaminant releases during construction.

Contaminant concentrations that may be environmentally relevant will be addressed through characterization, monitoring and adaptive controls through the 401 Certification process. Section C-2.4 Water Quality describes an anticipated water quality monitoring strategy that will be part of 401 compliance. C-21 Special Studies puts forth possible means of mitigating hazardous and toxic materials that are encountered unexpectedly.

C-10. Construction Procedures and Water Control Plan

C-10.1. General Construction Procedures. For each proposed staging site, S-1 thru S-9 (see Plates IN-1 thru 4, and Section C-6 Civil Design), the list below outlines the sequencing, construction procedures, and associated equipment.

1. Construct Staging Area.
Build Staging area (clear and grub, fencing, site BMPs for SWPPP).

Equipment: Medium Excavator (45,000 to 72,000 lbs), Grader (blade) and Water Truck, Roller, Gravel Trucks, crews for fencing and BMP installation.

2. Construct, Improve, Maintain Site Access Roads.
Develop off-road access to river-bar/worksite. Once constructed, the same equipment will maintain haul/access roads, staging sites, and on-bar construction sites continuously during construction operations.

Equipment: Grader (blade) and Water Truck, Roller, Gravel Trucks, (Medium Excavator in the case of culverted crossings or road washouts).

3. Temporary Culvert crossings filled with clean spawning size gravel will be used for site access during initial construction and for establishment work, monitoring, and adaptive management.

4. Import self-elevating water tank trailer ~12,000 gal to worksite for long-term road maintenance and dust control.

Equipment: Semi-truck, 12,000 gal self-elevating water tank.

5. Side Channel Excavation.
A large (~165,000 lb) excavator will begin excavation near the entrance or exit of a planned side channel, leaving material at the end as a natural coffer dam and leaving crossing points for access to outward bar locations for planting. The large excavator will cut an 8-10’ wide swath to about the water table (i.e. dry excavation) moving backwards (inward toward the center of the bar), loading directly into trucks at an assumed rate of 5 minutes per truck.

6. Following behind the large excavator, a medium (~70,000 lb) excavator will excavate to design depth. This material will be placed to adjacent to the bank of the side channel

and any captured groundwater will allowed to percolate into the gravel/sand bar. This procedure will also be used for backwater construction and bank scalloping.

7. Floodplain lowering will be performed by self-elevating (paddlewheel) scrapers, moving material into the unexcavated side-channel large excavator footprint to be loaded into trucks per bullet 5. Since floodplain lowering excavation volumes are much smaller than side channel volumes, paddlewheel excavators will similarly collect material placed adjacent to side channels by medium excavators (bullet 6) and place that material in the large excavator footprint for loading to haul trucks.

7. 11-13 cy highway dump trucks will be used to haul over off-road access to public paved roads to placement/disposal sites. Five sites around the North and South sides of the Lower Yuba River are being considered for placement/disposal. Worst-case hauling distances were assumed to facilitate conservative cost/effects distances. The number of haul trucks for each construction site where excavation is to take place is calculated by the assumed round-trip time to the placement/disposal site divided by the 5 minute assumed loading time.

8. Plantings will occur at about 1500 stinger sites per acre. Following marking (crews of one biologist and two laborers), cutting (crews of laborers and a foreman), and soaking of cuttings, cuttings will be wrapped in wet blankets and carried by flatbed to the excavator for stinger installation. A medium (~45,000 to 72,000) excavator with stinger attachment will clear holes for hand-dropping 1 cutting per stinger site.

10.2. Water Control Plan and Best Management Practices.

Water control during ecosystem restoration construction will be accomplished through use of best management practices (BMPs). Best management practices will be utilized in all phases of construction to minimize water quality impacts. Silt fences will be used liberally to impede and filter runoff from all construction sites. Though not expected based on the coarse-grained nature of haul roads and construction sites, detention ponds should be used where feasible if turbidity-inducing runoff is possible. Disturbed erodible areas will be revegetated as quickly as possible to minimize the areas subject to excessive erosion during storm events. Construction equipment will be kept out of wet or inundated areas except when essential to the operation.

SWPPP BMPs and other erosion and sediment control BMPs will be employed on any new access roads and in staging and construction areas for both grading/lowing/excavation phase and planting phases of the project. Floodplain lowering and grading activities may include “inside out” excavations to limit erosion and transport of sediments during construction. Side channel excavations may similarly utilize middle out construction to allow endpiece sediments to act as natural coffer dams for the bulk of the excavation. Cofferdams, curtains, or sheet pile may also be employed to control erosion and other sediment releases during excavation. Any water discharge, temporary storage, or land application will be performed in accordance with all appropriate laws and regulations, including a CWA Section 401 permit; these permits are highly site-specific in nature and will be obtained in Preconstruction, Engineering, and Design (PED). Restoration feature-specific water control considerations are discussed below.

C-10.2.1. Floodplain Lowering. Floodplain lowering activities will occur in areas that are dry during low-flow periods. Since most of these areas consist primarily of cobble, gravel, and some sand, construction should have little impact on water quality until the surface elevation reaches the ground water table. Further, large-grained material is less likely to contain high concentrations of the metals of interest, or any anthropogenic chemical since these constituents typically adsorb or absorb to fine grain and/or organic material. A low berm will be left between excavated areas and the river to avoid unnecessary water exchange until interior excavation is complete.

C-10.2.2. Riparian Planting. Riparian planting will be completed with mechanized equipment. Water quality impacts may result from traffic in areas where surface soils composed of non-coarse-grained particles subject to saturation or inundation. Traffic in these areas will be avoided where possible and minimized where traffic is essential.

C-10.2.3. Side Channels. Constructing new side channels could potentially pose a significant risk to impair water quality because significant excavation will occur below water. Channel excavation will first be completed between end caps to avoid water exchange. Once excavation is complete except for the end caps, water in the channel will be allowed to clarify. Excavation of the downstream end cap will occur first, followed by excavation of the upstream end cap to allow flow through the channel. An initial flushing of residual soft solids is expected, but should be short lived.

C-10.2.4. Backwater Areas. Backwater areas are mostly existing low-laying areas near small tributary confluences. Consequently, they provide the most challenging water control/water quality management strategies. Ideally, these areas would be constructed during low-flow periods without substantial rainfall. Since that may not always be possible, managing the construction will be particularly important to protect water quality. Like other areas being excavated below water level, berms will be left along the perimeter of the area adjacent to the river. Tributaries flowing through the area will be temporarily rerouted to avoid the construction site when possible.

C-11. Initial Reservoir Filling and Surveillance Plan

Initial Reservoir Filling and Surveillance Plan Flood Emergency Plans for Areas Downstream of Corps Dams is not a relevant aspect of this ecosystem restoration study.

C-12. Flood Emergency Plans for Areas Downstream of Corps Dams

Flood Emergency Plans for Areas Downstream of Corps Dams is not a relevant aspect of this ecosystem restoration study.

C-13. Environmental Objective and Requirements.

This information is provided in the main body of the report. No mitigation is expected for this proposed ecosystem restoration project. An Environmental Site Assessment Phase 1 did not identify any potential concerns.

C-14. Reservoir Clearing

Reservoir clearing is not a relevant aspect of this ecosystem restoration study.

C-15. Operation and Maintenance

The Recommended Plan consists solely of non-structural habitat measures within a dynamic river environment. Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) costs for habitat measures in a dynamic river system are potentially significant. In order to evaluate OMRR&R costs, an overall quantitative cost-risk assessment that combines Adaptive Management time frames must be performed. To determine the cost-risk to habitat benefits in the planning horizon beyond the Adaptive Management and OMRR&R periods, an analysis that accounts for those time periods must also be performed.

An integrated cost-risk assessment that determines estimated Adaptive Management, OMRR&R, and post-intervention benefit damage costs is therefore presented in this section.

C-15.1. Quantitative Cost-Risk Assessment for Project Lifecycle Damages. Risks to the performance of the LYR emanate from several external drivers that affect the management measures proposed for restoration. Floodplain Lowering and Riparian Planting are the predominant measures, accounting for 76% of total restored acreage in the project area (47.6 acres and 88.5 acres, respectively). Additional measures include side channels, backchannel, engineered logjams (ELJ), large woody material (LWM), boulder and gravel placement. While there are vectors that affect the performance of these features, risks to overall project objectives from suboptimal performance of these features are relatively low and, hence, were not considered as part of the quantitative assessment of risk and associated cost. (Note: side channel performance may be an exception on a case-by-case basis and will be addressed separately in the refinement of risk assessment during PED).

The main vectors for cost-risk associated with floodplain lowering (FPL) or riparian planting (RP) include 1) damage from flood event associated sedimentation processes, 2) mortality due to drought, and 3) a host of factors leading to stress or mortality of the vegetation including disease, mold, browsing, etc. This analysis focuses on the first vector. It is recognized that the other vectors warrant consideration, and it is suggested that a more detailed assessment during PED be undertaken to incorporate drought related risks using the same methodology as employed for flooding. Similarly, further consideration should be given to the other vectors for stress and mortality to vegetation with the express purpose of identifying monitoring needs, decision criteria, and contingency plans to be incorporated in the adaptive management plan at PED. The remainder of this section describes the analysis undertaken to assess the first vector. Individual Measures were assessed within each increment in the attached Matrix, with probability of damage qualitatively assessed, i.e., broad characterization of overall stability or persistence of channel morphology from previous studies, flood records at the USGS Marysville Gage and aerial imagery were used to assign very low, low, medium or high probability categories for each Measure in each Increment. The qualitative probability approach used for this assessment is described in a separate memorandum. Results from this qualitative assessment informed a quantitative assessment of cost-risk wherein measures were assessed categorically to enable a more rapid quantitative assessment for Feasibility level analysis. Cost-risks were calculated separately for each Measure category (e.g. floodplain lowering [FPL] and riparian planting [RP]) as a proportion of the total acreage in each Measure category. Refinement of the risk analysis and associated cost estimates during PED could build upon both qualitative and quantitative approaches.

The quantitative assessment is based on a characterization of risk as a product of the probability of an adverse outcome (P) times the consequences (C) of that outcome; stated mathematically risk = P * C. The method applied is generally consistent with the USACE procedure for calculating expected annual damages (EAD) from floods. For FPL and RP on the Yuba, one would expect the susceptibility to damage to decrease over time as the floodplain vegetation matures, the channel adjusts to the project, and the bed armors. Thus, a decreasing risk over time it is anticipated due to lower consequences, and the risk relation should be expressed as: risk = P * C(t), where t is time. Thought of in another way, there is a family of damage functions that vary over time and consequences are integrated over time (preferably applying a discount rate as you do so) to get equivalent annual damages.

Corps' policy limits cost-shared monitoring to a maximum of ten years post construction, or until the project is determined to be successful. Assuming success will not be established sooner, ten years is used as the timeframe for assessing shared costs. Monitoring and AM beyond 10 years will likely be needed, so risks have been calculated through year 50, but monitoring costs beyond year 10, and any AM costs after success is determined, will be 100% non-federal OMRR&R costs. For nonstructural habitat measures, OMRR&R will be required for only 10 years after success is determined, so any OMRR&R beyond that point will be voluntary.

For the quantitative cost-risk assessment, damage or failure was based upon an assessment of critical shear stress thresholds for riparian plantings and bio technical stabilization measures. Recognizing that susceptibility decreases over time, thresholds were set that represent failure or damages likely to be incurred by live stake plantings in the first 2 years, the next 3 years, and after year 5 of the Adaptive Management phase. These ranges correspond to vegetation resistance when newly installed, establishing, and established (in the first 10 years of AM activities). The time frames and thresholds were used as a basis for ascribing probabilities, and contributed to the consequence portion of the calculation as described below.

Model results of five representative flows (with associated probability) were utilized for assessment of shear stress within the project reach. The percent area of each Measure type associated with each shear stress threshold was estimated for each modeled flow using shear stress maps that included Measure overlays. The overall proportion of each Measure within each of the shear stress bands provided a basis for estimating the consequences, while the flow generating that particular shear stress band provided a basis for assessing the probability (based on its recurrence interval). For example, for RP Measures at 15,000 cfs (approximately the 2.0 year recurrence flood), 35% of treated area was the within 0.5 to 1.0 psf shear stress band, 15% was between 1 and 5 psf, and 0% above 5 psf. For 42,000 cfs (4.5 year event), corresponding bands accounted for 60%, 35%, and 5%, respectively, with an additional 0% estimated at an extreme threshold shear stress number. A simple spreadsheet was developed for calculating overall risk. Probability was calculated using standard methods for assessing flood frequency of an event of specific magnitude, with adjustment the span of the associated year time period. The probability of exceedance for an event in any one year was based upon the analyses presented by Wyrick and Pasternack (2012) using data for the period from 1970 through 2010 (i.e. post regulation). An alternative flood frequency analysis based upon an analysis of the full period of record using current reservoir water control criteria was also employed. The latter analysis as the benefit of offering longer time series, but may not be representatives of conventional conditions if nonstationary exists. Table C-15-1 provides a summary of the flows and associated probabilities.

Table C-15-1. Flows and associated probabilities.

Return Interval at Marysville	Discharge (cfs) based on W&P 2012	Discharge (cfs) based on POR w/ current operations	Probability of exceedance in any single year	Probability of exceedance in any two year period	Probability of exceedance in any three year period	Probability of exceedance in any five year period
1.2	4,000	13,000	0.83	0.97	1.00	1.00
2	15,000	28,000	0.50	0.75	0.88	0.97
4.5	42,000	57,000	0.22	0.39	0.53	0.71
12.5	84,000	100,000	0.08	0.15	0.22	0.34
50	168,000	170,000	0.02	0.04	0.06	0.10

An assumed cost of replacement/repair per acre for each of the treatment methods is incorporated within the spreadsheet model. For the feasibility analysis, replacement cost for Riparian planting is $41,000/ac and for floodplain lowering is $60,000/ac. The total number of acres for each treatment (88.5 and 47.6 acres, respectively) is used in calculation of damages by multiplying with the percent of area for which each shear stress threshold is exceeded (see Table C-15-2). Additional analyses were subsequently undertaken to assess damage probabilities in years 10 to 20 and 20 to 50.

Table C-15-2. Percent of area for each treatment type for which each shear stress threshold is exceeded at each of the modeled flows.

Shear Stress Threshold (psf)	% of FPL Area Threshold Exceeded for Given Flow				
	4k	15k	42k	84k	168k
0.5	0%	30%	80%	100%	100%
1	0%	15%	20%	95%	100%
5	0%	0%	0%	3%	5%

Shear Stress Threshold (psf)	% of RP Area Threshold Exceeded for Given Flow				
	4k	15k	42k	84k	168k
0.5	5%	35%	60%	95%	100%
1	0%	15%	35%	95%	100%
5	0%	0%	5%	10%	60%

Estimated damage probability for each year range (e.g., 0-2, 2-5, 5-10…) was next expressed as a probability-damage function. These are shown in Figure C-15-1 in terms of probability of Damages in $M; annual damages at or above each shear threshold value is shown in $M per exceedance probability. Integrating the area under each of these curves yields a total dollar amount within each timeframe. The resultant values, shown in Tables C-15-3 and C-15-4, can be summed to determine an expected AM or OMRR&R cost over any timeframe (e.g. the ten years of shared AM cost). An alternative computation was also made by applying annual exceedance probabilities.

Refinement of these estimates will occur during PED. Refinements will be based upon improved designs and cost estimates as well as refinement of the overall AM plan, which would better address critical uncertainties, and associated monitoring, decision criteria and contingent plans. Other adjustments might include assumptions regarding the extent to which affected areas are repaired or adjusted. For example, it might be reasonable to assume that total replacement will occur if damages are incurred in the first 2 years, 80% replacement may occur in the next 3 years, and 50% replacement or repair in years five through 10. Given that an area damaged by a flood may be revegetated by natural recruitment to some extent, an additional year of monitoring may be the selected action rather than replanting in that year, to assess the capacity of the site for natural recovery. Actions after the first 10 years are considered OMRR&R, and assumes full repair for extreme events.

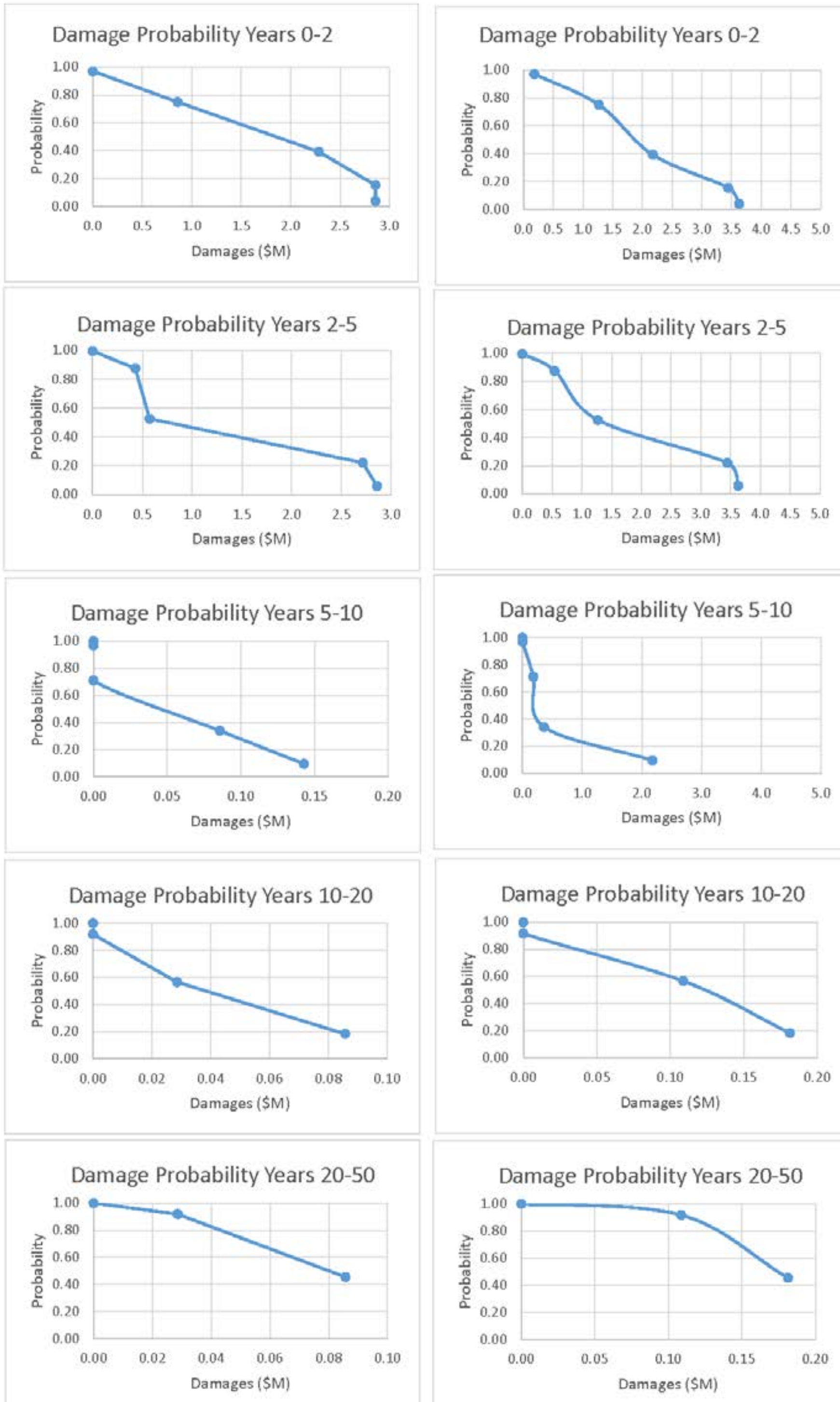


Figure C-15-1. Damage-probability functions for each time period for Floodplain Lowering (left column) and Riparian Planting (right column).

Table C-15-3. Calculated risks associated with Floodplain Lowering.

Exceed Prob. Any Year	Damage ($m) yr 0-2	Probability of Being Exceeded	Period Risk ($M)	Annual Risk ($M)
0.83	0.000	0.97	0.737	0.141
0.50	0.857	0.75	0.815	0.440
0.22	2.285	0.39	0.156	0.360
0.08	2.856	0.15	0.000	0.171
0.02	2.856	0.04	**1.71**	**1.11**
0.83	0.000	1.00	0.401	0.285
0.50	0.428	0.88	0.100	0.051
0.22	0.571	0.53	0.800	0.321
0.08	2.713	0.22	0.020	0.007
0.02	2.856	0.06	**1.32**	**0.66**
0.83	0.000	1.00	0.000	0.000
0.50	0.000	0.97	0.000	0.000
0.22	0.000	0.71	0.045	0.013
0.08	0.086	0.34	0.012	0.003
0.02	0.143	0.10	**0.06**	**0.02**
		10 yr FPL AM/OMRR&R Total	**$3.09**	**$3.01**
	yr 10-20			
0.83	0.000	1.00	0.000	0.000
0.50	0.000	1.00	0.000	0.000
0.22	0.000	0.92	0.021	0.004
0.08	0.029	0.57	0.021	0.003
0.02	0.086	0.18	**0.043**	**0.007**
		10-20 yr FPL AM/OMRR&R Total	**$0.043**	**$0.071**
	yr 20-50			
0.83	0.000	1.00	0.000	0.000
0.50	0.000	1.00	0.000	0.000
0.22	0.000	1.00	0.027	0.004
0.08	0.029	0.92	0.039	0.003
0.02	0.086	0.45	**0.067**	**0.007**
		20-50 yr FPL AM/OMRR&R Total	**$0.067**	**$0.214**

Table C-15-4. Calculated risks associated with Riparian Planting.

Exceed Prob.	Damage ($m)	Probability of	Period	Annual
Any Year	yr 0-2	Being Exceeded	Risk ($M)	Risk ($M)
0.83	0.181	0.97	0.937	0.239
0.50	1.270	0.75	0.518	0.482
0.22	2.177	0.3916	0.346	0.394
0.08	3.446	0.1536	0.018	0.212
0.02	3.628	0.04	**1.82**	**1.33**
	yr 2-5			
0.83	0.000	1.00	0.51	0.36
0.50	0.544	0.88	0.51	0.26
0.22	1.270	0.53	0.81	0.33
0.08	3.446	0.22	0.03	0.01
0.02	3.628	0.06	**1.85**	**0.96**
	yr 5-10			
0.83	0.000	1.00	0.000	0.000
0.50	0.000	0.97	0.152	0.065
0.22	0.181	0.71	0.095	0.027
0.08	0.363	0.34	0.396	0.091
0.02	2.177	0.10	**0.64**	**0.18**
		10 yr Riparian Planting AM total	**$4.32**	**$4.51**
	yr 10-20			
0.83	0.000	1.00	0.000	0.000
0.50	0.000	1.00	0.000	0.000
0.22	0.000	0.92	0.081	0.016
0.08	0.109	0.57	0.027	0.004
0.02	0.181	0.18	**0.108**	**0.020**
		10-20 yr Riparian Planting OMRR&R total	**$0.108**	**$0.200**
	yr 20-50			
0.83	0.000	1.00	0.000	0.000
0.50	0.000	1.00	0.000	0.000
0.22	0.000	1.00	0.104	0.016
0.08	0.109	0.92	0.050	0.004
0.02	0.181	0.45	**0.154**	**0.020**
		20-50 yr Riparian Planting total	**$0.154**	**$0.599**

C-15.2 Cost-Risk Assessment Results. As the Annual method of computing damages is more conservative on the whole, those damages are used for feasibility level cost estimates. The estimated cost results from the Cost-Risk Assessment are:

- Adaptive Management: $7,520,000 over the assumed 10 year period (post-construction years 1 to 10, without contingency or escalation)

- Repair, Replacement, Rehabilitation: $271,000 over the 10 year period (post-construction years 11 to 20 without escalation)

- Damages post Adaptive Management and OMRR&R: $813,000 (post-construction years 21 to 50, at the discretion of the sponsor, without escalation).

These costs were used in Section C-19 Engineering and the Environmental sections of the Main Report.

C-15.3. General Operation and Maintenance Requirements. Operation and Maintenance requirements for the Recommended Plan will likely consist of litter control and maintaining site controls and access capabilities (for monitoring, etc). Based on twice quarterly visits from a two person crew, O&M annual costs are conservatively estimated to be $15,000/yr for site access and encroachment prevention for post-construction years 1 to 20 (the M&AM and RR&R period), and $5,000/yr for encroachment prevention post-construction years 21 to 50 (the remainder of the period of analysis).

C-16. Access Roads

Please see Civil Design section C-6.3 for a discussion of access roads.

C-17. Corrosion Mitigation

Coatings and/or cathodic protection will be included in the design as required for materials which are installed in water or soil.

C-18. Project Security

This ecosystem restoration project, consisting only of side channel excavations, floodplain lowering, installation of large woody material and engineered logjams (see 6-Civil Design for full detail) is not anticipated to require a security plan.

C-19. Cost Estimates

In developing the feasibility level cost estimates for the Selected Plan, the Cost Engineering team utilized a construction methodology incorporating the estimating software MII 4.3 (MCASES Version 4.5.51209) and generated costs at a Class 3 level. Project costs were based on the generation of crews and equipment necessary for the construction or the Selected Plan within MII; Section C-6 Civil Design and Section C-10 Construction Procedures and Water Control Plan discuss the bulk of these project aspects that are integrated into MII.

The estimates follow the Civil Works Work Breakdown Structure (CWWBS) code of accounts. Featured codes represented in these estimates are 01- Lands and Damages, 06-Fish and Wildlife Facilities (with separate line items for Construction, Post Construction Monitoring, and Adaptive Management), 30-Plannning Engineering and Design and 31-Construction Management. The 30 and 31 accounts include costs associated with USACE staffing on the project. The amounts are based on historical data adjusted based upon the nature of the features of work (detailed in C-19.6).

C-19.1. Key Assumptions

a. Estimate – Quantities were developed GIS PDT members and reviewed by Civil Design based on representative samples of the work. The quantities where then provided to Cost Engineering as a basis for developing the estimate. Production was estimated based on the following assumptions

   - 1 month per year staging
   - 1 month per year “dry” excavation/site work, 4 months per year “in-water” work
   - 10 hrs/day
   - 26 workdays/month (6 days/week)
   - 11 cy haul trucks
   - 12 trucks/hour (5 minute load time)
   - 12 miles on average to representative disposal site (though site specific distances were calculated for each staging site)
   - 30 seconds per stinger site
   - marking and collection cost estimates for riparian plantings were generated based crew-based work across the project vicinity.

b. Haul Distances – Haul Distances were assumed to be a site 20 miles and 25 minutes from the excavation site on average. See sections C-4.2, C-5, and C-21 Special Studies for a discussion on the potential for near-site beneficial use of excavated material, which could decrease haul costs significantly. Beneficial uses were captured as an opportunity in the CSRA.

   Note that additional site characterization test and associated costs have been included in the estimate to facilitate realization of beneficial use opportunities.

c. Real Estate – Due to significant uncertainties regarding real estate costs and mineral rights, a composite 28% contingency was used for 01 Land and Damages.

d. Quantity Uncertainty – Quantities may vary depending on uncertainties inherent in design and morphological changes in the river system between feasibility and construction and uncertainty in hydraulic modeling results. This uncertainty has been captured in the CRSA.

e. Project Schedule – 2 years of PED were assumed beginning with authorization in FY19, with 4 seasons of construction following (see C-20 Schedule for Design and Construction for details).

f. Planning, Engineering & Design Costs – A Planning, Engineering, and Design (30 Account) percentage of 16.5% was used in lieu of the usual 27.5% assumption. This reduced percentage is based on the fact that this project is ecological in nature, thus reduced costs for engineering and design are expected relative to conventional construction projects. The 30 Account estimate accounts for approximately 13 Full Time Equivalent staff members for each year of design/procurement activities which is consistent with the anticipated team composition.

g. Construction Management – A Construction Management (31 Account) percentage of 5% was used in lieu of the usual 14.5% assumption. This reduced percentage is based on the fact that this project is ecological in nature, thus reduced costs are expected relative to conventional construction projects. The 31 Account estimate accounts for approximately 5 Full Time Equivalent staff members for each year of construction activities which is consistent with the anticipated team composition.

h. Constructability – Section C-10.1 details assumed construction methods. Shapability and constructability are considered to be low risk due to the gravel/cobble nature of site materials. Construction sequencing was assumed such that riparian plantings were evenly distributed across the 4 seasons of construction to the maximum extent practicable to alleviate risks regarding donor tree supply availability.

i. Site Characterization and Monitoring during Construction Costs. A site characterization strategy and associated sampling costs were obtained from the Engineer Research and Development Center's Environmental Laboratory. A similar strategy, equipment list, and sampling costs were obtained for environmental compliance monitoring during construction (see Section C-10). Labor costs for sampling and maintenance were distributed over the 4 years of construction for each staging site. These costs were entered directly as a 30 Account line item for each staging site.

C-19.2. Review. Feasibility Level Cost Estimates (Class 3) underwent District Quality Control by the Sacramento District. A District Quality Control certificate was signed by the Cost Engineering Support Branch's Branch Chief. Agency Technical Review and Cost and Schedule Risk Assessments were performed by the USACE Cost DX, Walla Walla, WA.

C-19.3. Cost Uncertainties. There are inherent uncertainties in the costs at the feasibility level of design as the result of lacking detailed design, plans or specifications. These discrepancies are reflected in the contingency acquired through the Cost and Schedule Risk Analysis (CSRA).

An initial Abbreviated Cost Risk Analysis (ACRA) was performed for the project during the TSP phase. The risk analysis process involved dividing project costs into typical risk elements and placing them into a Risk Register, then identifying the risks/concerns relative to those risk elements, and then justifying the likelihood of the risk occurring and the impact if the risk occurs. A Risk Matrix utilizing weighted likelihood/impacts is used to establish the cost contingency for each risk element (work feature) for use in alternatives comparisons. Risk analysis results are intended to provide project leadership with contingency information in order to support decision making and risk management as the project progresses from planning through implementation. The initial contingency value based on the post-ATR ACRA was 48% at the Class 4 (5-10% quality of project definition) level.

Cost and Schedule Risk Analysis was held 17 October 2018 with the project manager and PDT members that was led by Walla Walla Cost DX personnel. The meeting primarily focused on risk factor identification through discussions based on risks material excavation and hauling, multiple potential impacts to schedule (timing and amounts of funding, RE considerations, environmental and permitting uncertainties) and ecosystem restoration projects in general. The meeting encompassed risk factor assessment and quantification which resulted in revisions to the estimate. Project risks were identified and documented leading to the development of a risk register spreadsheet. Following the analysis the draft risk register was forwarded to the PDT for review.

The qualitative impacts of each risk element on costs and schedule were analyzed in order to generate quantitative cost-growth models for various project facets in a "Crystal Ball" analysis. The resulting product models reflects the risk register parameters as developed by the team.

Contingency is an amount added to an estimate and/or schedule allowing for items, conditions or events for which the occurrence or impact is uncertain. It is probable these uncertainties will result in the additional costs being incurred or additional time being required. Based on CSRA results, a contingency for the Recommended Plan of 25% was found to be necessary to achieve 80% confidence the stated project cost would not be exceeded.

C-19.4. Total Project Cost Summary. Total Project Cost Summary Sheets were developed for construction at each staging site (see C-1.5 and C-6). This reflects the independent development of the cost estimates for each staging site and the sequencing of construction activities in different seasons (see C-20 for details). Midpoints of construction were entered for each Site's respective TPCS spreadsheet independently to most accurately reflect escalation costs based on the assumed project schedule.

Monitoring and Adaptive Management costs were entered into two respective 06 Account line items in the Site 1 TPCS spreadsheet for succinctness. Attachment CE-A shows the overall Recommended Plan. Table C-19-1 summarizes the first and fully funded costs of the Recommended Plan; Sections C-6 and C-15 detail the development of Adaptive Management, OMRR&R, and post-OMRR&R estimated damages (that can be voluntarily repaired by non-Federal Sponsors).

Table C-19-1. Summary of Costs (in $1000s).

Cost Account or Element	First Cost	Fully Funded Cost
01 Lands and Damages	$9,060	$10,002
06 Construction	$58,491	$64,514
06 Monitoring post Construction	$2,384	$3,236
06 Adaptive Management	$9,400	$13,047
30 PED (incl. Compliance Monitoring)	$14,364	$16,584
31 Construction Management	$3,396	$3,926
Total (incl. items not shown)	$97,219	$111,444

Total Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) costs were estimated to be $150,000 (O&M) and $271,000 (RR&R) for post construction years 10 to 20, or about $42,000 per year (actual costs will vary slightly based on annualization). Post OMRR&R total damages through the remainder of the planning horizon (i.e. years 20 to 50) were estimated at $813,000 (see Section C-15).

C-20. Schedule for Design and Construction

The construction schedule is assumed for cost engineering purposes to be 4 seasons/years. A 4 month window for in-water work was assumed and a one month window for "dry" only excavations was assumed preceding that. A two month planting window was assumed. Three years of excavation, grading, and planting activities were assumed, planting activities only were assumed for the 4th season. Proposed construction was sequenced such that riparian plantings were evenly distributed across the 4 seasons of construction to the maximum extent practicable to alleviate risks regarding donor tree supply availability.

Construction for each staging site (see C-1.5 and C-6) was scheduled in either one season or across multiple seasons depending on

- excavation quantities (large-scale were sequenced in early years)
- planting quantities
- interrelation between excavation and plantings
- interrelation between haul routes and disposal sites (e.g. one active north-side and one active south-side site per year w.r.t the Lower Yuba River.

Following the assumptions above, the first year of construction was assumed to have the largest quantity of excavation. Due to the use of multiple haul trucks for excavations and excavation site and placement site heavy equipment activities, the 1st year of construction was the conservative year used for air quality modeling purposes (see Appendix D for air quality modeling discussion and results).

Attachment CE-B shows the proposed construction schedule for the Recommended Plan.

C-21. Special Studies

Post feasibility hydraulic design, hydraulic modeling or physical modeling should be considered during PED to resolve resiliency and operation and maintenance questions for the proposed ecosystem restoration for events of various Annual Chance of Exceedances. This may include, for example, lifecycle modeling of plantings in the study area (trees may fall but become woody debris) and sequential geomorphic change modeling scenarios to evaluate multiple series of events of varying ACEs. PED modeling efforts will include surveys of water surface profile/profiles for model validation; this will also allow for comparisons to survey data from feasibility SRH2D modeling efforts so that aggradation/degradation trends can be evaluated.

Freshwater acute and chronic water quality criteria are published for total mercury, but only secondary values exist for methylmercury. Thorough characterization of material to be excavated/graded will be necessary prior to excavation activities, and additional bioassays or environmental risk assessments may be necessary to determine what contaminant release levels are ecologically significant for methylmercury in light of other ambient constituent concentrations in the system, e.g. total organic carbon.

If beneficial use of excavated material is problematic based on total mercury levels or other unanticipated contamination at small scales, study of separation or other innovative techniques to allow for beneficial use of the majority of excavated material would be desirable from both environmental and cost perspectives.

C-22. Plates, Figures, and Drawings

Figures have been embedded in line with text in this Appendix. Plates for the Introduction Section (IN-1 through IN-4), Geotechnical Engineering (GT-1 through GT-5), and Civil Design (CV-1 through CV-6) follow the References section of this Appendix. Attachments for Hydraulics and Hydrology (HH-A through HH-C), Civil Design (CV-A through D, including associated figures and tables, e.g. Table CV-B-1), Cost Engineering (CE-A and CE-B), Geotechnical Engineering (GT-A), GIS (GIS-A through C), and Environmental Engineering (ENV-A) follow plates at the end of this Appendix.

C-23. Data Management.

In accordance with South Pacific Division Policy, this project utilized ProjectWise for both engineering data management and data management for other disciplines. During the feasibility study, electronic data was compiled and maintained in project folders for each discipline involved on the server. This data is backed up regularly by USACE's data manager (ACE-IT). The project information will be available for the next phase of the project. Basic Output from SRH2D modeling is too voluminous to be included with this Appendix, but it is retained on ProjectWise as part of the project file so that it can be made available to reviewers upon request.

C-24. Use of Metric System Measurements.

In accordance with SMART Planning Principles, British Units were predominantly used on this project due to the substantial existing body of available work on the watershed's use of British Units. Surveys and existing GIS and modeling work have been performed using British Units, conversion of these to metric units would be prohibitively time consuming and costly. It is anticipated that future chemical and sediment characterization work will utilize SI units (e.g. mg/L, mg/kg, kg/m^3).

References

Abbe, T.B., D.R. Montgomery, K. Fetherston, and E.M. McClure. 1993. A Process-based Classification of Woody Debris in a Fluvial Network: Preliminary Analysis of the Queets River, WA. EOS, Transactions of the American Geophysical Union 73(43):296.

Abbe, T. B., D.R. Montgomery, and C. Petroff. 1997. Design of Stable In-channel Wood Debris Structures for Bank Protection and Habitat Restoration: An Example from the Cowlitz River, WA. Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision, 1997 S.S.Y. Wang, E.J. Langendoen and F.D. Shields, Jr. (eds.) ISBN 0-937099- 05-8.

Abbe, T., G. Pess, D. R. Montgomery, and K. L. Fetherston. 2002. Chapter 17 – Integrating Engineered Log Jam Technology into River Rehabilitation. In Restoration of Puget Sound Rivers. Edited by Montgomery, D. R., S. Bolton, D. B. Booth, and L. Wall.

Abbe T.B., Brooks A.P., and D. R. Montgomery. 2003. Wood in River Rehabilitation and Management. In The Ecology and Management of Wood in World Rivers. S. Gregory K, Boyer A Grunell (eds). AFS Symposium 37: Bethesda, Maryland; 367–389.

Alpers, C.N., et al. 2016. Prediction of fish and sediment mercury in streams using landscape variables and historical mining. Science of the Total Environment, 571, 364-379.

cbec, inc. (cbec), South Yuba River Citizens League, and McBain & Trush. 2010. Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River. November 2010. Prepared for the USFWS with Funding Provided by the Anadromous Fish Restoration Program.

cbec. 2013. Hydrologic and Geomorphic Analysis to Support Rehabilitation Planning for the Lower Yuba River from Parks Bar to Marysville. Prepared for the South Yuba River Citizens League with Funding Provided by the Anadromous Fish Restoration Program.

Churchill, R.K. 2000. Contributions of mercury to California's environment from mercury and gold mining activities; Insights from the historical record. *In*: Extended abstracts for the U.S. EPA sponsored meeting, Assessing and Managing Mercury from Historic and Current Mining Activities, November 28-30, 2000, San Francisco, Calif., p. 33-36 and S35-S48.

Hunerlach, M.P., C. N. Alpers, M. Marvin-DiPasquale, et al. 2001. Geochemistry of Mercury and other Trace Elements in Fluvial Tailings Upstream of Daguerre Point Dam, Yuba River, California, August 2001

Pasternack, G. B. 2010. Personal Communication. October 2016.

Reynolds, F. L., T. J. Mills, R. Benthin. 1993. Restoring Central Valley Streams: A Plan For Action. California Department of Fish and Game. California Department of Fish and Game.

U.S. Army Corps of Engineers (USACE). 1999. ENGINEERING AND DESIGN FOR CIVIL WORKS PROJECTS. ER 1110-2-1150.

USACE. 2012. ENGINEERING WITHIN THE PLANNING MODERNIZATION PARADIGM. ECB 2012-18.

Wyrick, J. R. and G. Pasternack. G. B. 2012. Landforms of the Lower Yuba River. Prepared for the Yuba Accord River Management Team as part of the Lower Yuba River Monitoring and Evaluation Program.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 2001. Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California. Contributions to the Biology of Central Valley Salmonids. Fish Bulletin 179, Volume 1.

Yuba Accord River Management Team (RMT). 2009. Appendix M of the Habitat Expansion Agreement for Central Valley Spring-Run Chinook Salmon and California Central Valley Steelhead Final Habitat Expansion Plan Habitat - Expansion for Spring-Run Chinook Salmon and Steelhead in the Lower Yuba River Prepared for the HEA Steering Committee by Members of the Yuba Accord River Management Team.

Yuba Accord River Management Team (RMT). 2013. Aquatic Resources of the Lower Yuba River – Past, Present & Future, Yuba Accord Monitoring and Evaluation Program, Draft Interim Report. April 2013.

Yuba County Water Agency (YCWA). 2007. Yuba River Development Project FERC Project No. 2246. Final Fisheries Agreement. Retrieved from <http://www.yubaaccordrmt.com/Yuba%20Accord%20Documents/Forms/AllItems.aspx?RootFolder=%2fYuba%20Accord%20Documents%2fYuba%20Accord%20Documents&FolderCTID=&View=%7bB86CA5B0%2d7D95%2d45E5%2dA951%2d795AB3A3A8AF%7d>

YCWA. 2012a. Yuba River Development Project FERC Project No. 2246. Technical Memorandum 2-2. Water Balance /Operations Model. November 2012.

YCWA. 2012b. Yuba River Development Project FERC Project No. 2246. Water Balance /Operations Model. YRDP 1.19.2 Base Case. http://www.ycwa-relicensing.com/Modeling%20Information/Forms/AllItems.aspx?RootFolder=%2fModeling%20Information%2fOperations%20Model&FolderCTID=&View=%7b768D86D7%2dFC78%2d434C%2dB1DD%2d57D0A189345F%7d.

YCWA. 2013. Technical Memorandum 7-10 - Instream Flow Downstream of Englebright Dam. Yuba River Development Project FERC Project No. 2246. September 2013.

Yuba County Water Agency (YCWA). 2014. Cultural Resources Inventory, National Register of Historic Places Evaluations, and Finding of Effect for the Yuba River Development Project Relicensing, Nevada, Yuba, and Sierra Counties, California. Yuba River Development Project. FERC Project No. 2246.

YCWA. 2016a. Draft Mitigation Plan for February 8, 2015 Minimum Instream Flow Deviation Event. April 15, 2016.

YCWA. 2016b. Yuba River Ecosystem Restoration Feasibility Study: Habitat Measures. October 2016.

Engineering Plates

Engineering Attachments

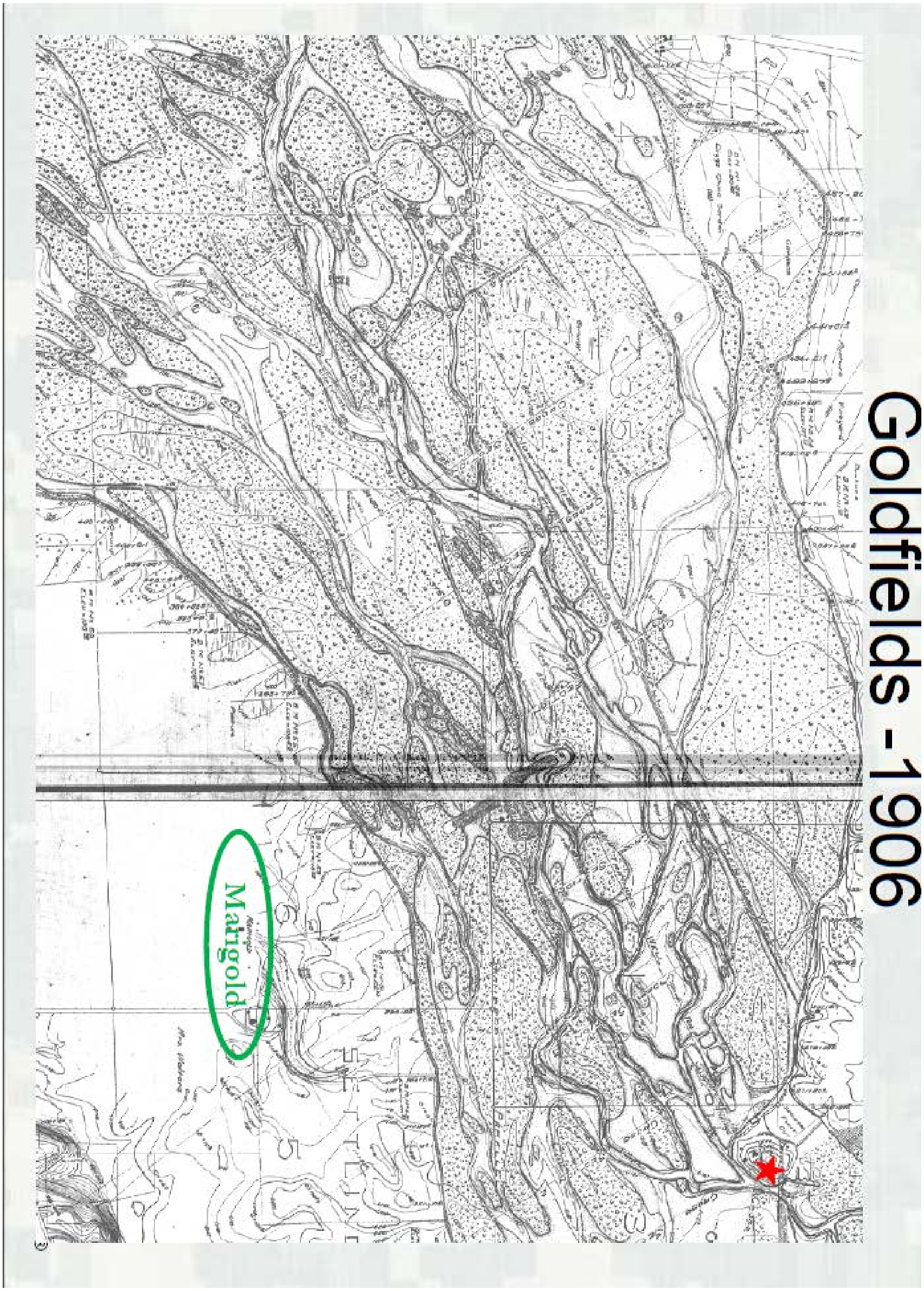


Plate GT-1 Goldfields 1906

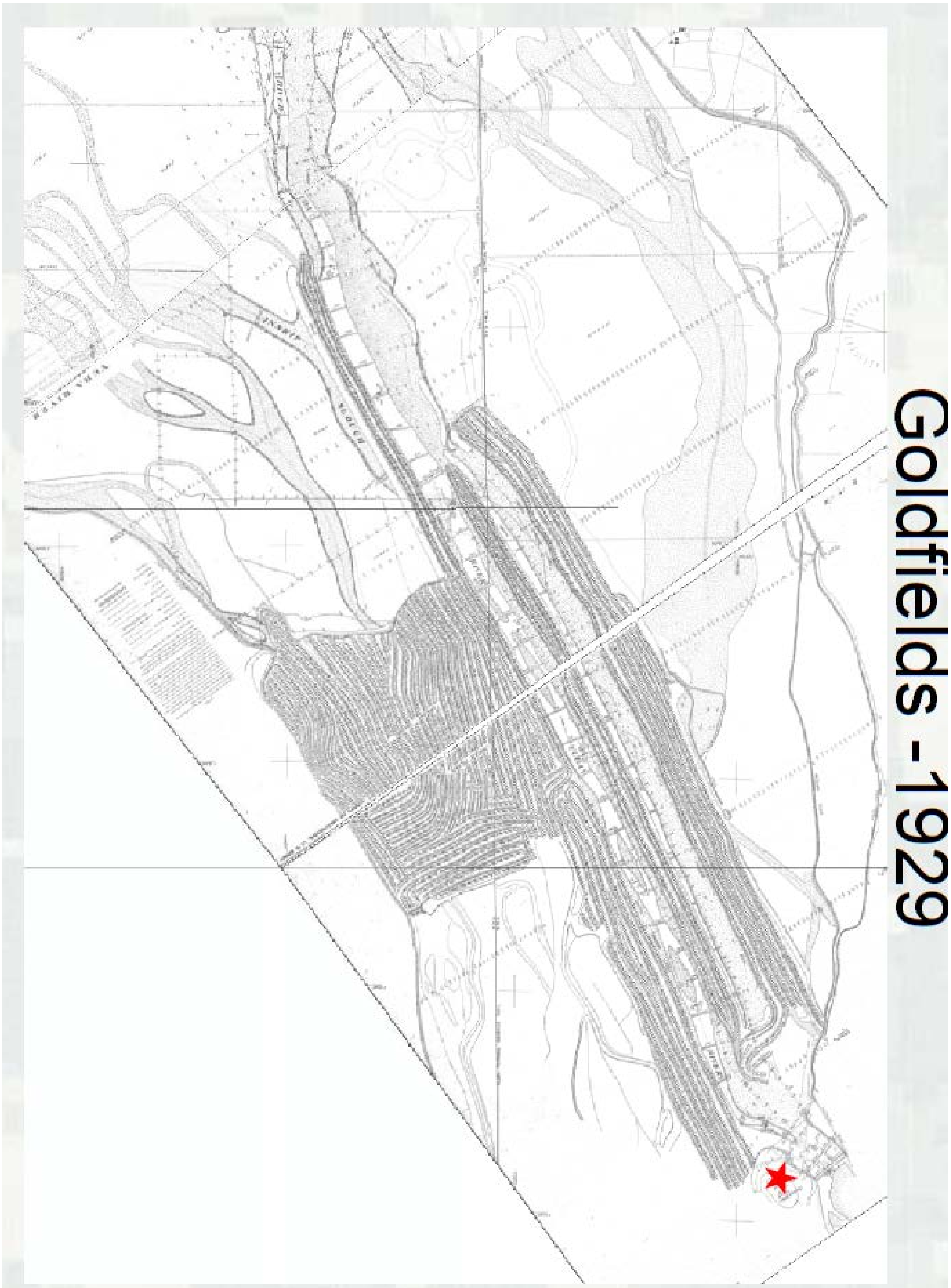


Plate GT-2 Goldfields 1929

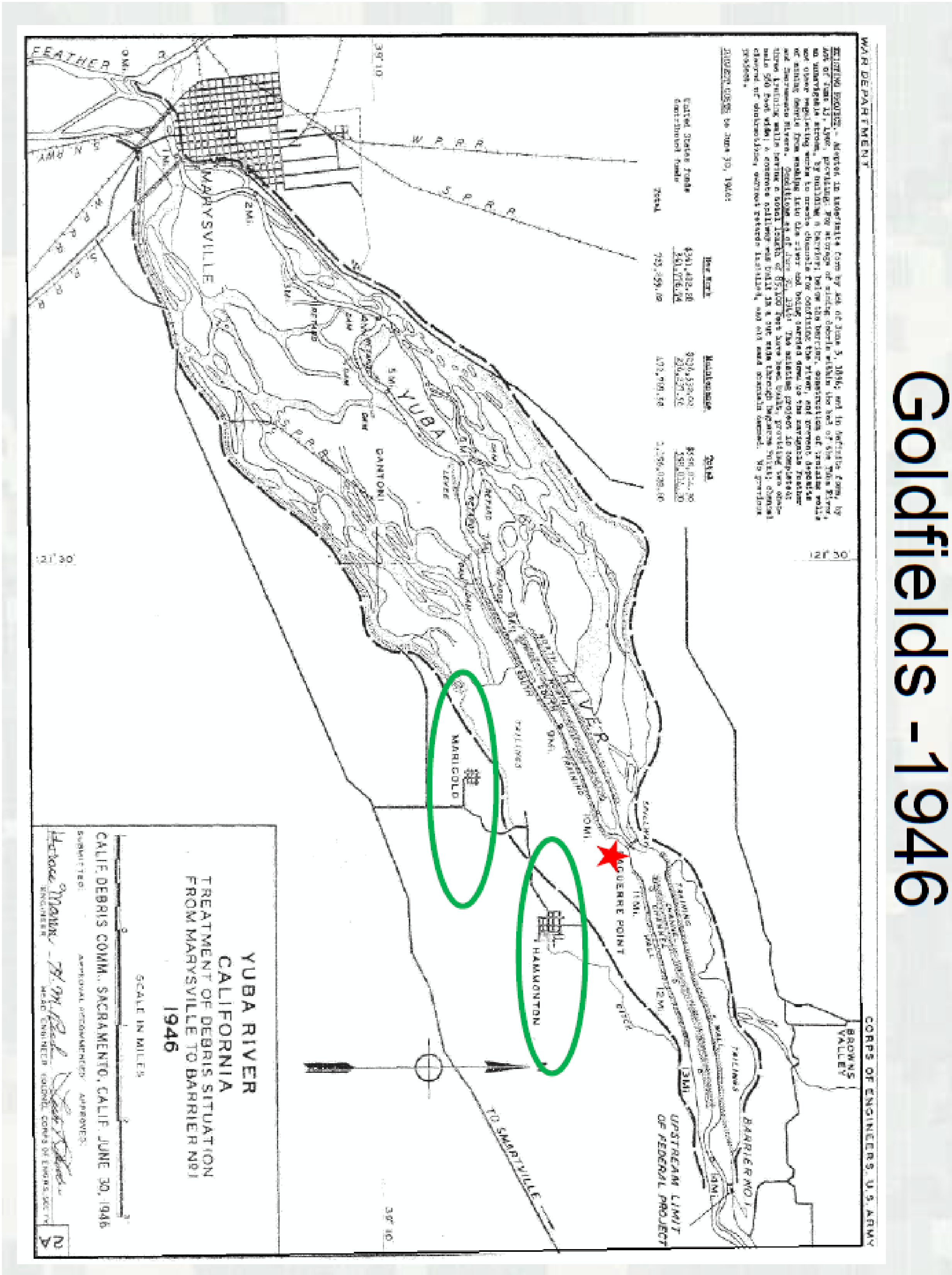


Plate GT-3 Goldfields 1946

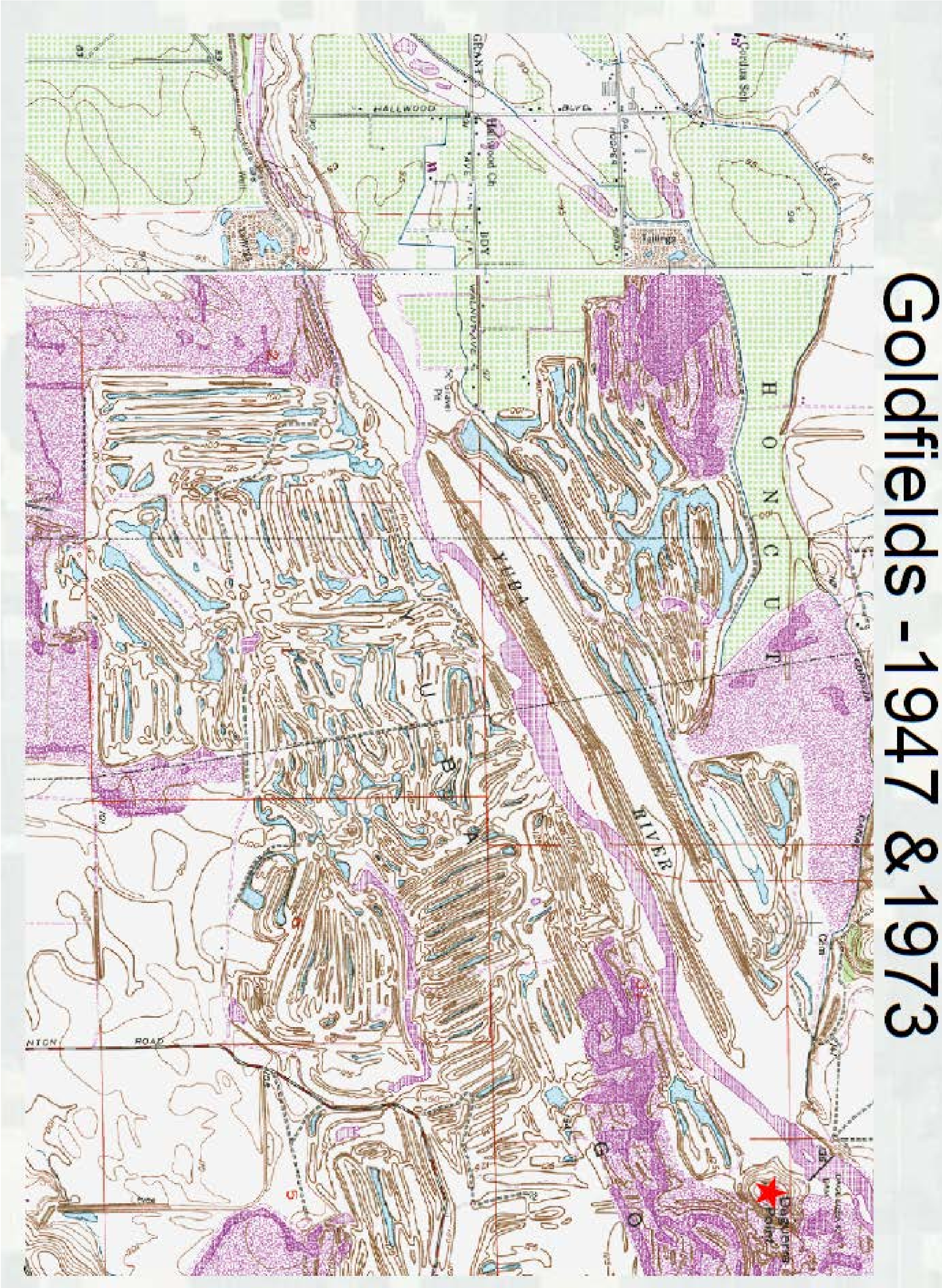
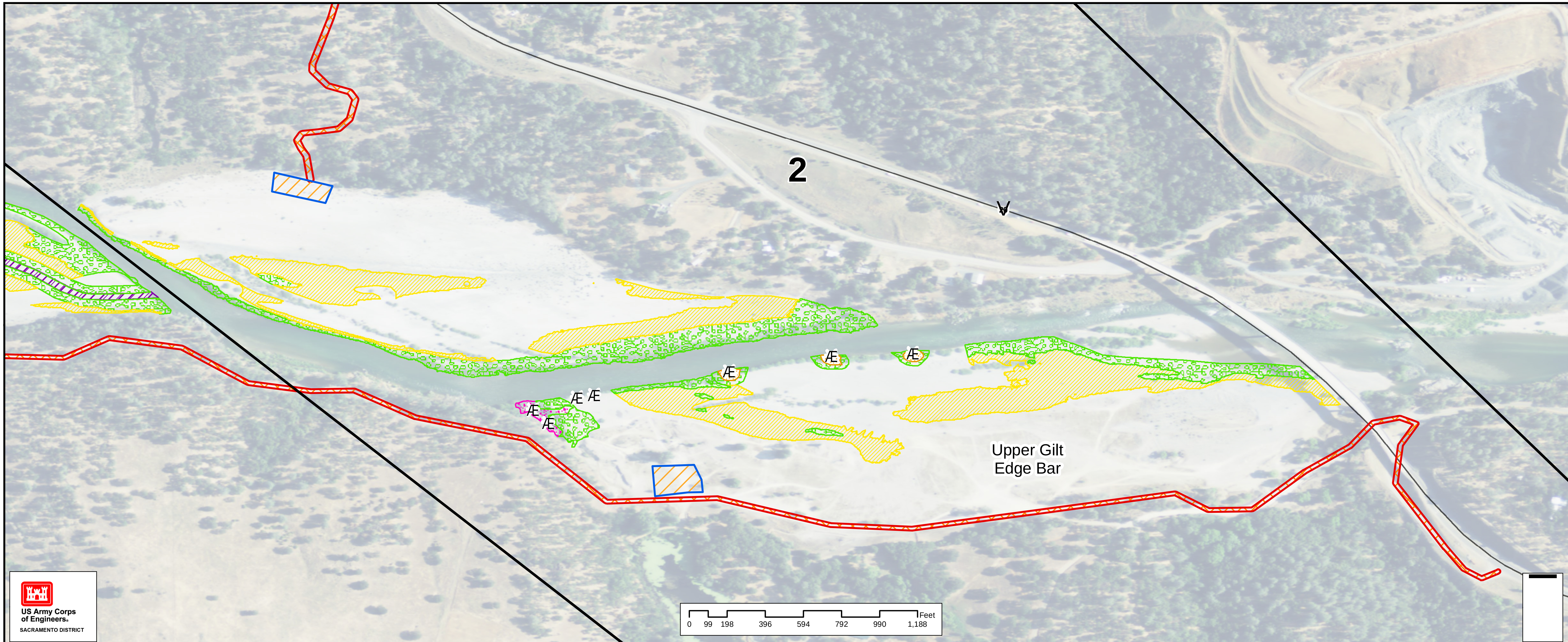


Plate GT-4 Goldfields 1947 & 1973 (Purple)

Plate GT-5 Goldfields 2005

Plates IN-1 through IN-4.

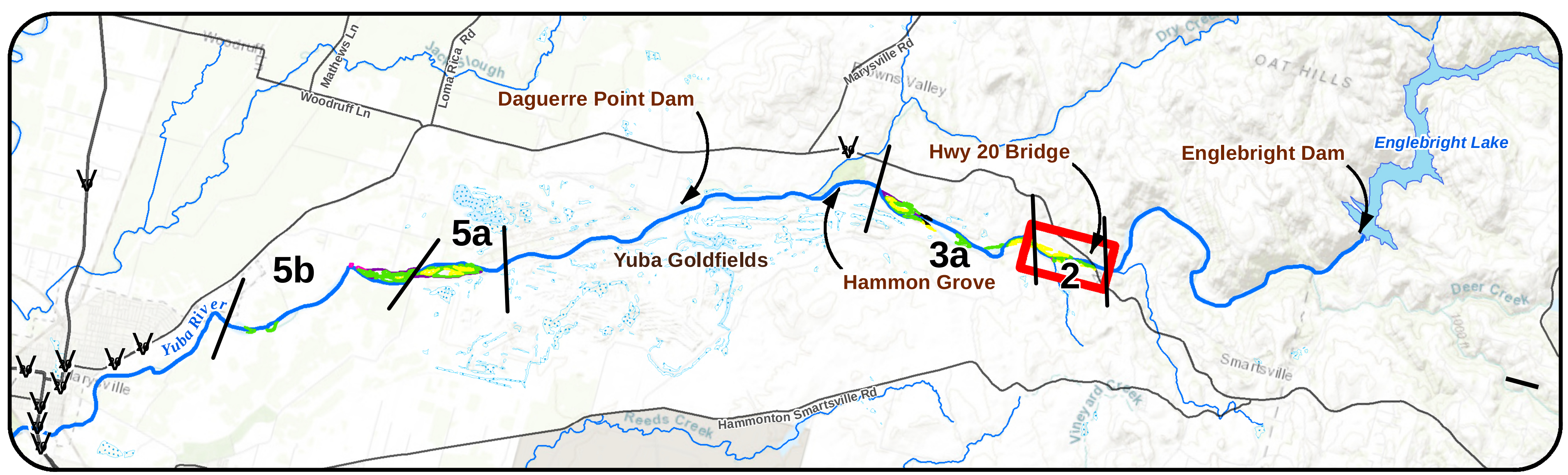


RECOMMENDED PLAN

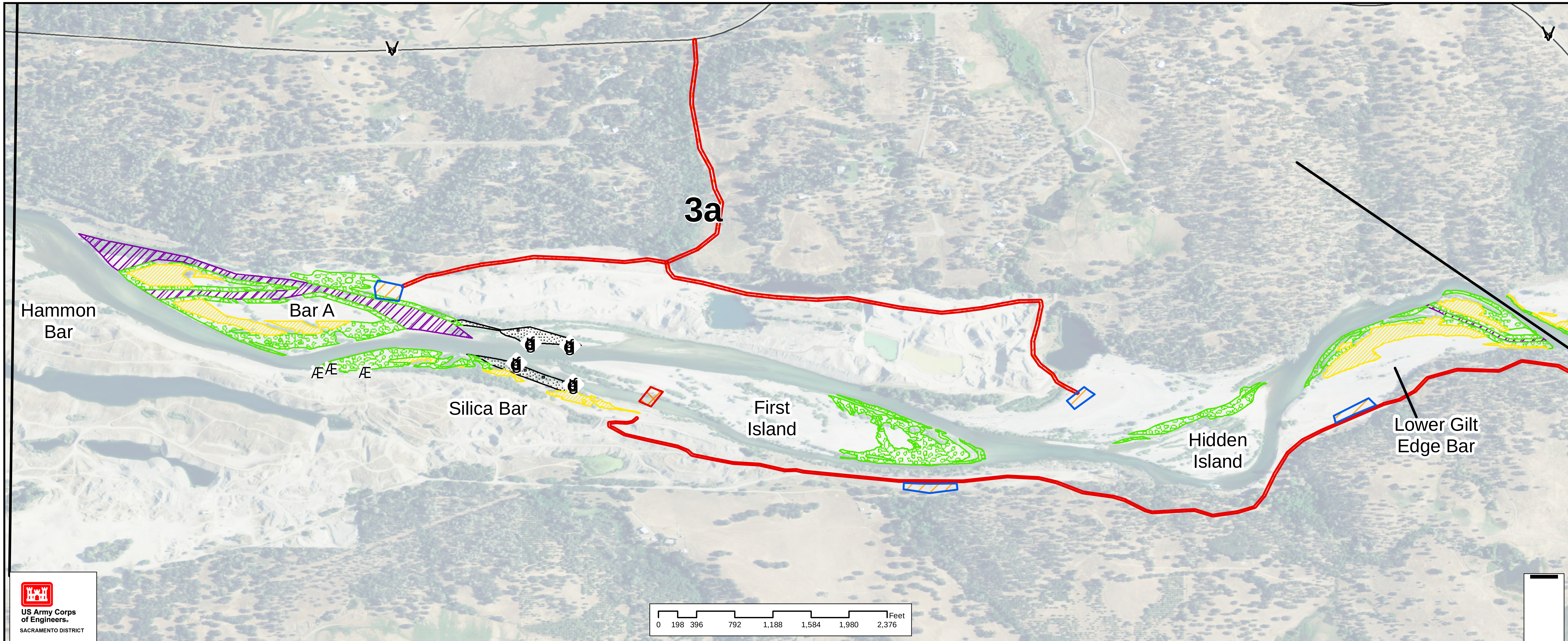
Yuba River Ecosystem Restoration Feasibility Study

Legend

- Backwater Area
- Bank Scalloping
- Floodplain Lowering
- Gravel
- Riparian Planting
- Side Channel
- Staging Areas
- Access Routes
- Ü Boulder
- Engineered Log Jam
- Æ Large Woody Material



GCS_WGS_1984

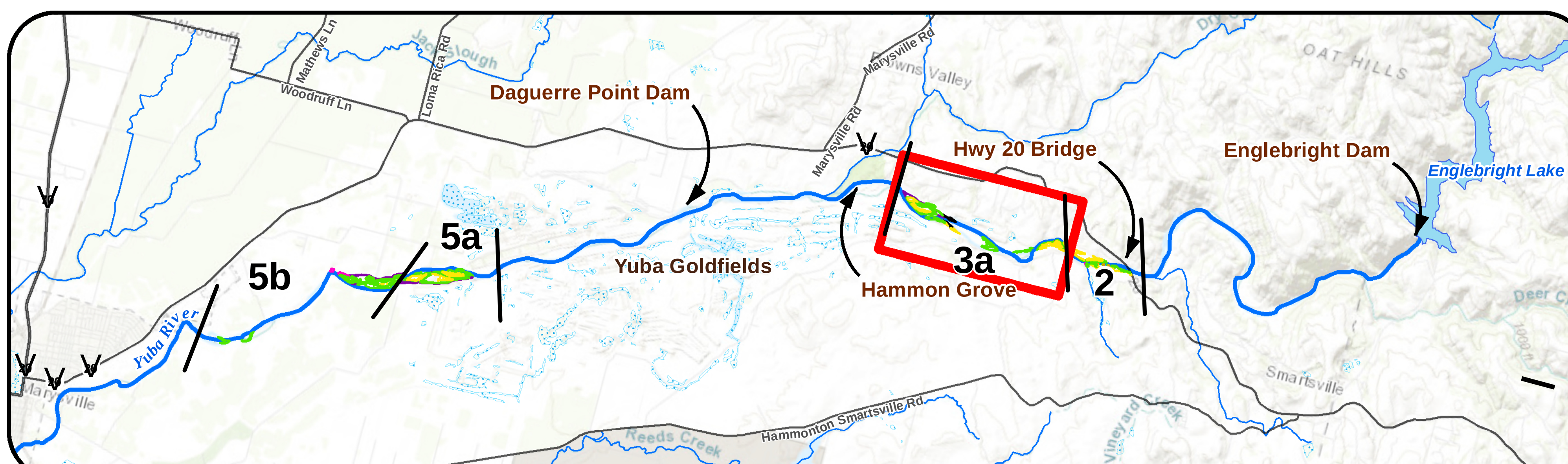


RECOMMENDED PLAN

Yuba River Ecosystem Restoration Feasibility Study

Legend

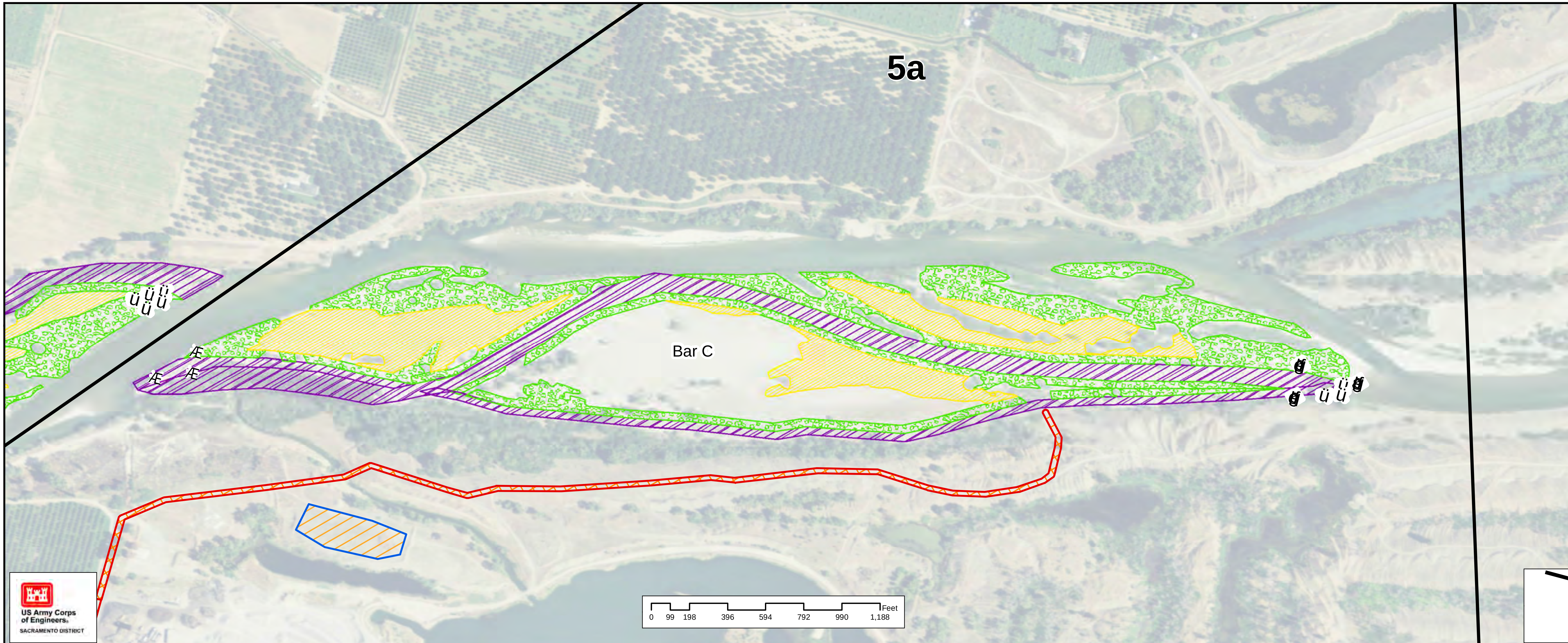
- Backwater Area
- Bank Scalloping
- Floodplain Lowering
- Gravel
- Riparian Planting
- Side Channel
- Staging Areas
- Access Routes
- ü Boulder
- Engineered Log Jam
- Æ Large Woody Material



GCS_WGS_1984

Path: \\COE-SPKNV001SAC.spk.ds.usace.army.mil\EGIS_GEOMATICS\CivilWorks\YubaRiver_CA\EcosystemRestorationProject\gis\Projects\RecommendedPlan\YRER_3a_RecommendedPlan_11X17.mxd

Date Saved: 9/26/2018 1:47:39 PM

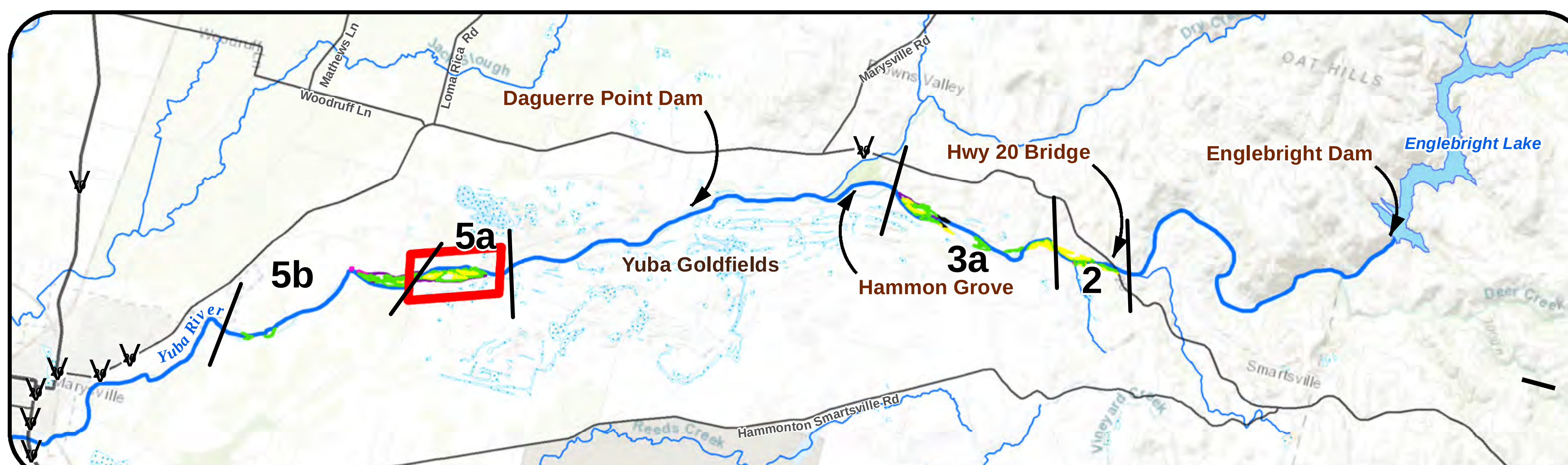


RECOMMENDED PLAN

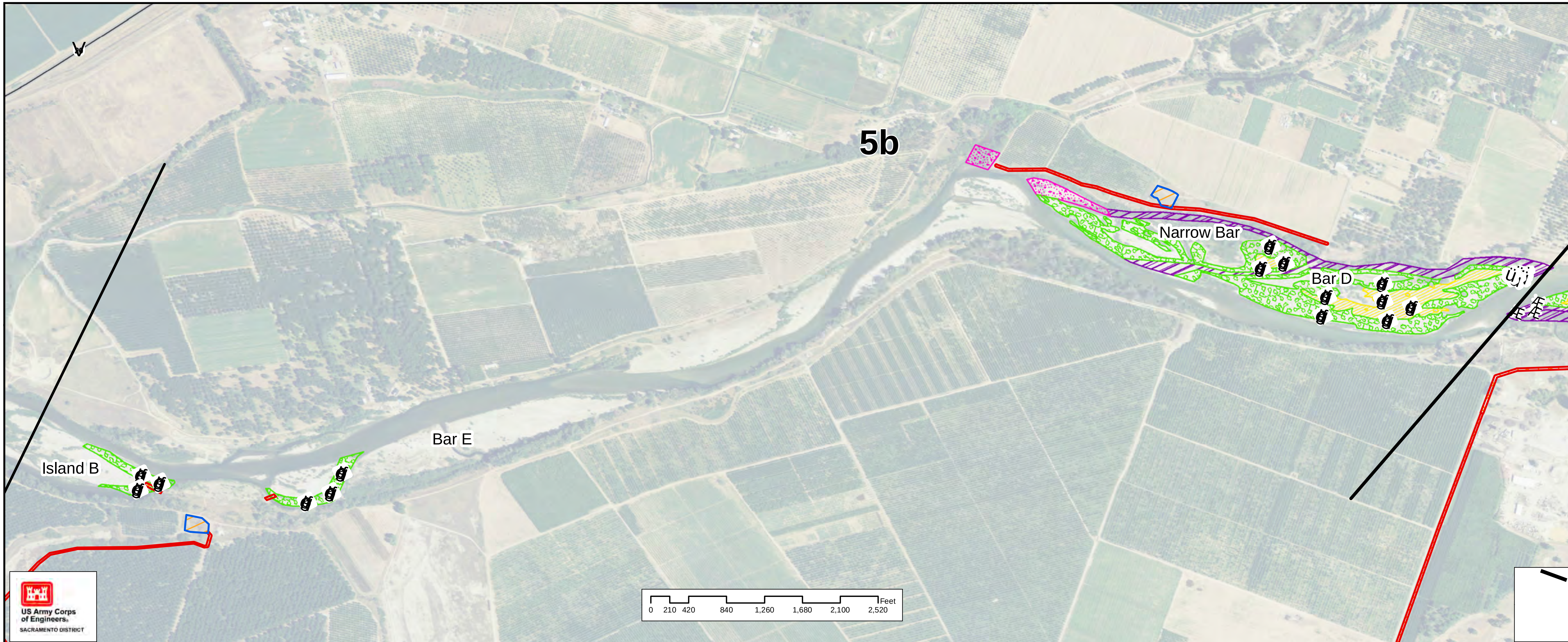
Yuba River Ecosystem Restoration Feasibility Study

Legend

Backwater Area	Staging Areas
Bank Scalloping	Access Routes
Floodplain Lowering	ü Boulder
Gravel	ǥ Engineered Log Jam
Riparian Planting	Æ Large Woody Material
Side Channel	



GCS_WGS_1984

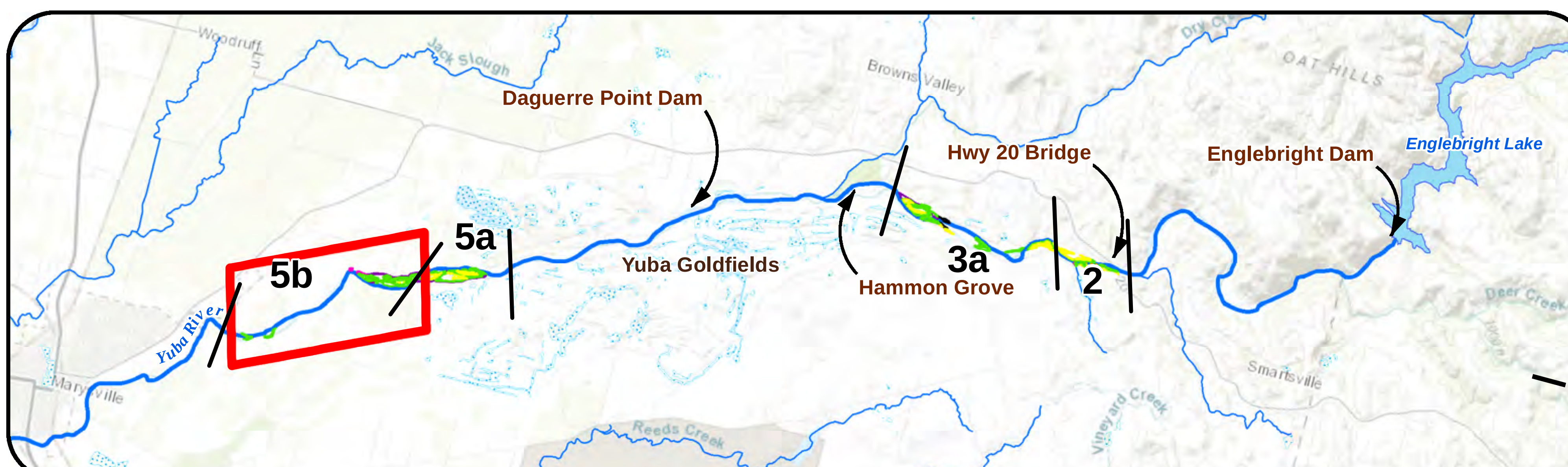


RECOMMENDED PLAN

Yuba River Ecosystem Restoration Feasibility Study

Legend

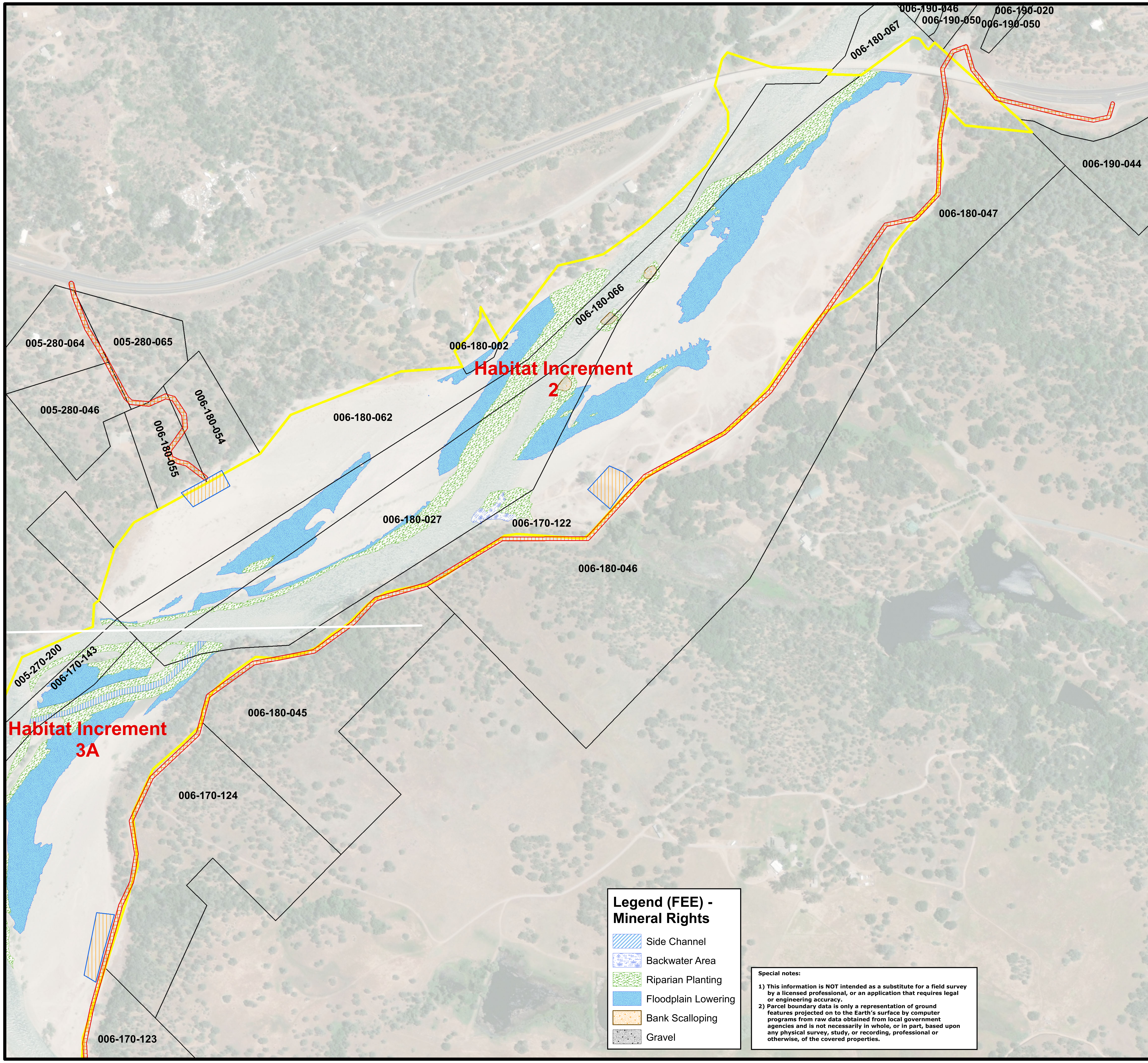
- Backwater Area
- Bank Scalloping
- Floodplain Lowering
- Gravel
- Riparian Planting
- Side Channel
- Staging Areas
- Access Routes
- Ü Boulder
- Engineered Log Jam
- Æ Large Woody Material



GCS_WGS_1984

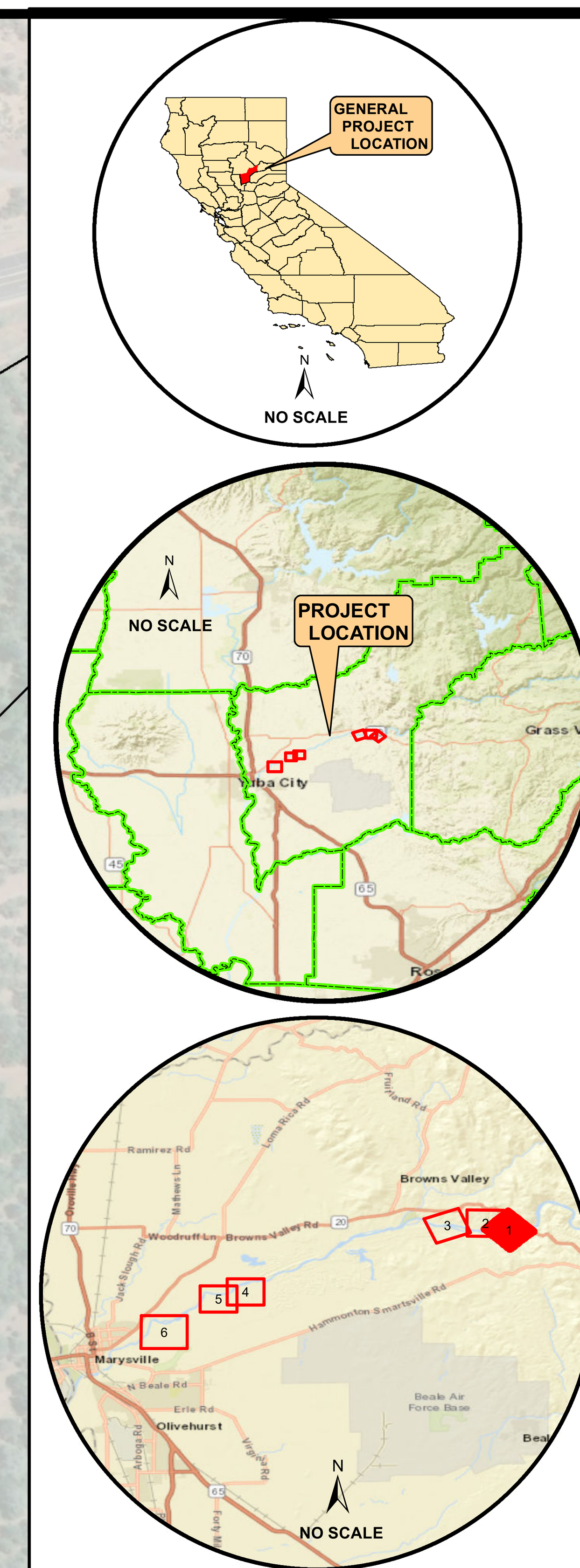
Plates CV-1 through CV-6.

CORPS OF ENGINEERS U.S. ARMY



Special notes:

1) This information is NOT intended as a substitute for a field survey by a licensed professional, or an application that requires legal or engineering accuracy.
2) Parcel boundary data is only a representation of ground features projected on to the Earth's surface by computer programs from raw data obtained from local government agencies and is not necessarily in whole, or in part, based upon any physical survey, study, or recording, professional or otherwise, of the covered properties.



METADATA

Townships\Ranges: 00S,0011E of the Mount Diablo Baseline & Meridian.

1:2,400
1 inch = 200 feet
Feet
0 200 400 600 800

Coordinate System: NAD 1983 2011 StatePlane California II FIPS 0402 Ft US
Projection: Lambert Conformal Conic
Datum: NAD 1983 2011
Units: Foot US

ACQUISITION AUTHORIZATION

FINAL
As Applicable

PROJECT MAP

DEPARTMENT OF THE ARMY
USING SERVICE U.S. ARMY

LOCATION OF PROJECT

STATE CALIFORNIA
COUNTY YUBA COUNTY
DIVISION SOUTH PACIFIC DIVISION (SPD)
DISTRICT SACRAMENTO (SPK)
ARMY AREA 6TH ARMY
13 Miles N.E. OF YUBA CITY
43 Miles N. OF SACRAMENTO

TRANSPORTATION FACILITIES

FEDERAL ROADS US HWY 5
STATE ROADS STATE HWY 70/99
AIRPORTS SACRAMENTO INT. AIRPORT

ACQUISITION

TOTAL ACRES ACQUIRED See T.A.R.
FEE See T.A.R.
PUBLIC DOMAIN { WITHDRAWN See T.A.R. / USE PERMIT
USE PERMIT (Other than P.D.)
TRANSFER { WITHDRAWN / USE PERMIT
LEASE NONE
EASEMENT RESERVED IN FEE DISPOSAL
LESSER INTERESTS { EASEMENT / PERMIT / LICENSE

DISPOSAL

TOTAL ACRES DISPOSED NO AREA
SOLD
PUBLIC DOMAIN { WITHDRAWN / USE PERMIT
USE PERMIT (Other than P.D.)
TRANSFERRED { FEE
LEASES TERMINATED
LESSER INTERESTS TERM
REASSIGNED
ACRES TO

LEGEND

EXCEPT FOR SPECIAL SYMBOLS SHOWN BELOW, MAP SYMBOLS ARE STANDARD IN U.S. ARMY FIELD MANUAL, FM 21-31, TOPOGRAPHIC SYMBOLS, DATED DECEMBER 1968.

STAGING
TWAE
HAUL ROUTE
FOOTPRINT
PARCEL
DISPOSAL SITE

REAL ESTATE OWNERSHIP MAPS 2017

DEPARTMENT OF THE ARMY
OFFICE OF THE SACRAMENTO DISTRICT ENGINEER
SOUTH PACIFIC DIVISION

CARTOGRAPHER J. HENRIKSEN
CARTO TECH.
CHECKED BY
SUBMITTED BY STEVE J. CAREY, LEAD, CADASTRAL TEAM
RECOMMENDED BY JAMES M. OLIVER, CHIEF, GEOMATICS SECTION

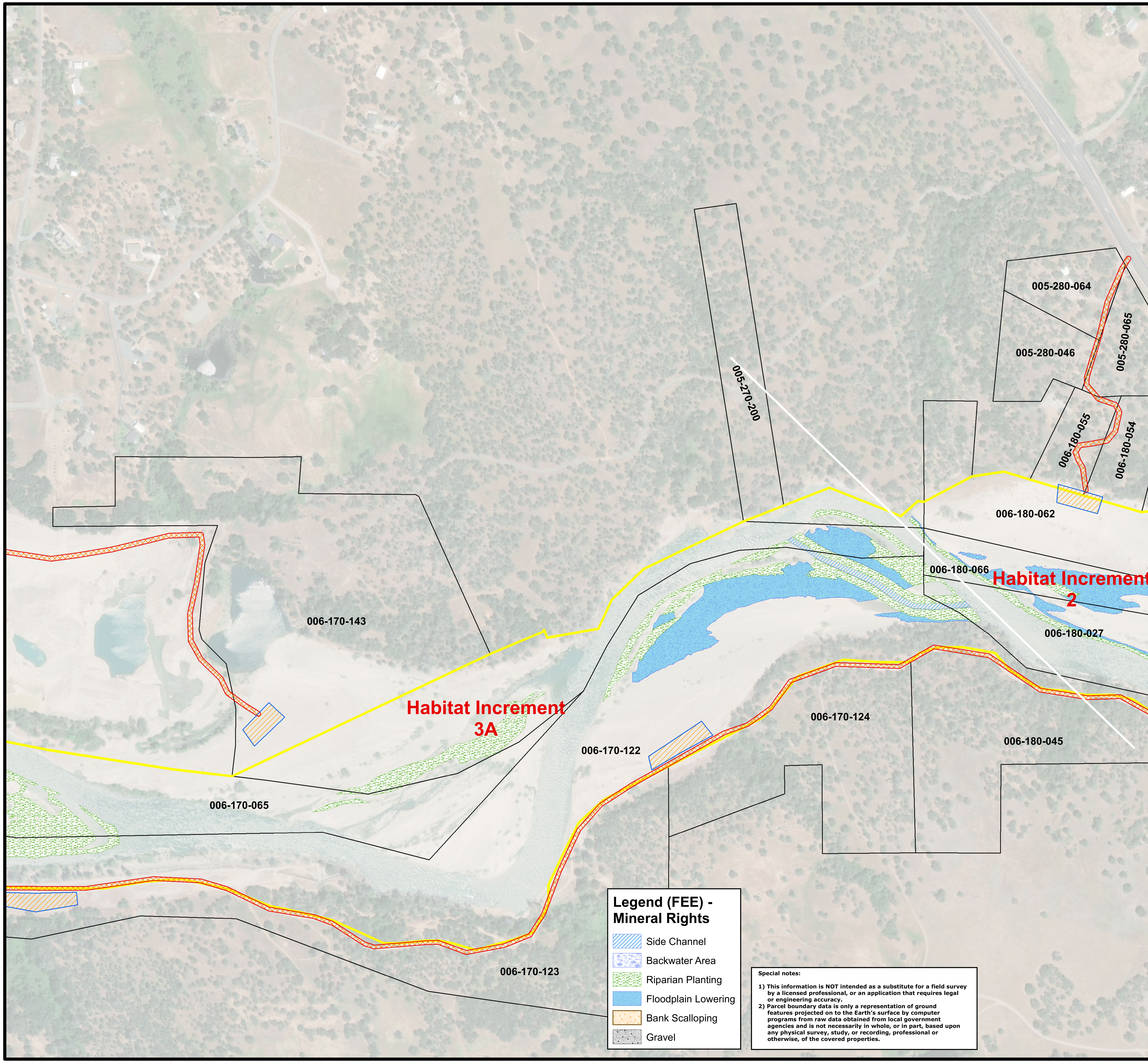
YUBA COUNTY CALIFORNIA
ENGINEERING GEOMATICS SECTION - CADASTRAL TEAM
YUBA RIVER ECOSYSTEM RESTORATION FEASIBILITY STUDY
HABITAT INCREMENTS 2, 3A, 5A & 5B

APPROVED BY DIANE M. SIMPSON, CHIEF, REAL ESTATE DIVISION DATE

OFFICE, CHIEF OF ENGINEERS, WASHINGTON 25, D.C.
REMIS CODE:
REMIS UNIQUE ID:
INSTALLATION OR PROJECT NO.

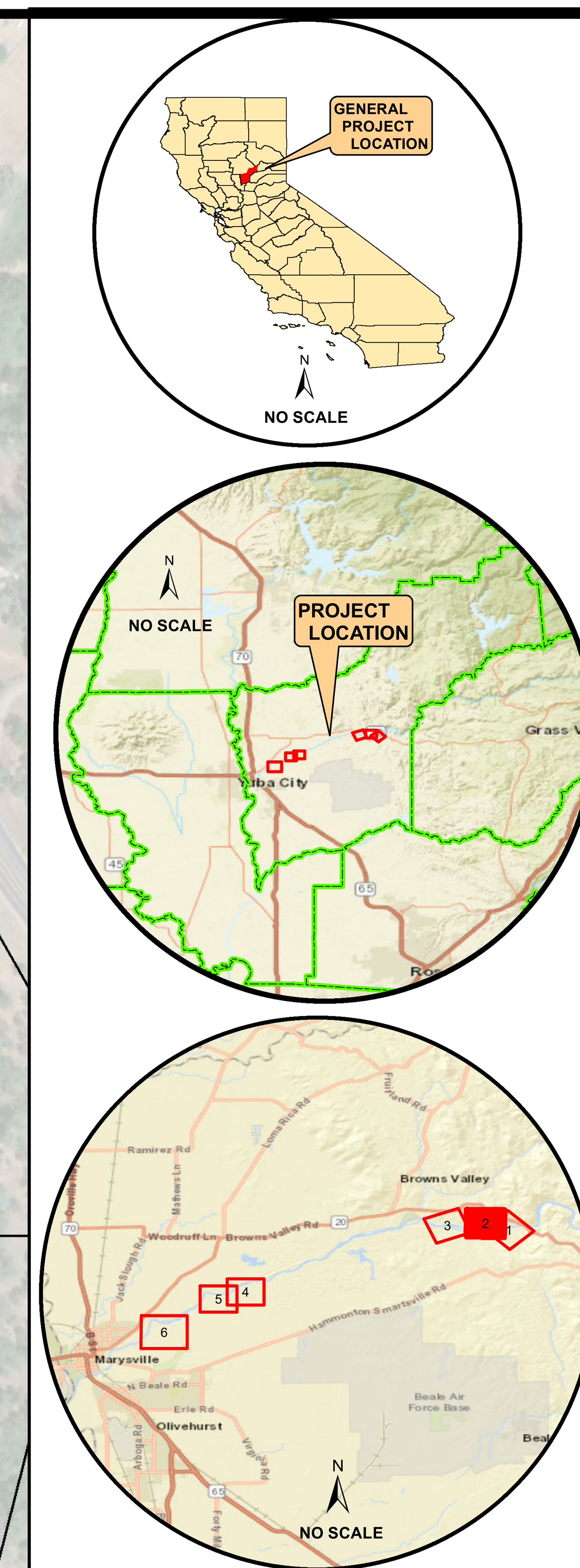
Date Saved: 8/16/2018 4:23:13 PM
This sheet originally formatted to ARCH_E1, 30"X42".
SHEET 01 OF 07 DRAWING NO.

(Ver. DEC 16, 2016) ER 405-1-200 Eng_Form 1456A, Oct 81



Special notes:

1) This information is NOT intended as a substitute for a field survey by a licensed professional, or an application that requires legal or engineering accuracy.
2) Parcel boundary data is only a representation of ground features projected on to the Earth's surface by computer programs from raw data obtained from local government agencies and is not necessarily in whole, or in part, based upon any physical survey, study, or recording, professional or otherwise, of the covered properties.



METADATA

Townships\Ranges:
00S,0011E
of the Mount Diablo Baseline & Meridian.

N

1:2,400
1 inch = 200 feet

Feet
0 200 400 600 800

Coordinate System:
NAD 1983 2011 StatePlane California II FIPS 0402 Ft US
Projection: Lambert Conformal Conic
Datum: NAD 1983 2011
Units: Foot US

ACQUISITION AUTHORIZATION

FINAL
As Applicable

PROJECT MAP

DEPARTMENT OF THE ARMY
USING SERVICE U.S. ARMY

LOCATION OF PROJECT

STATE CALIFORNIA
COUNTY YUBA COUNTY
DIVISION SOUTH PACIFIC DIVSION (SPD)
DISTRICT SACRAMENTO (SPK)
ARMY AREA 6TH ARMY
13 Miles N.E. OF YUBA CITY
43 Miles N. OF SACRAMENTO

TRANSPORTATION FACILITIES

FEDERAL ROADS US HWY 5
STATE ROADS STATE HWY 70/99
AIRPORTS SACRAMENTO INT. AIRPORT

ACQUISITION

TOTAL ACRES ACQUIRED See T.A.R.
FEE See T.A.R.
PUBLIC DOMAIN (WITHDRAWN See T.A.R. / USE PERMIT)
USE PERMIT (Other than P.D.)
TRANSFER (WITHDRAWN / USE PERMIT)
LEASE NONE
EASEMENT RESERVED IN FEE DISPOSAL
LESSER INTERESTS (EASEMENT / PERMIT / LICENSE)

DISPOSAL

TOTAL ACRES DISPOSED NO AREA
SOLD
PUBLIC DOMAIN (WITHDRAWN / USE PERMIT)
USE PERMIT (Other than P.D.)
TRANSFERRED (FEE)
LEASES TERMINATED
LESSER INTERESTS TERM
REASSIGNED
ACRES TO

LEGEND

EXCEPT FOR SPECIAL SYMBOLS SHOWN BELOW, MAP SYMBOLS ARE STANDARD IN U.S. ARMY FIELD MANUAL, FM 21-31, TOPOGRAPHIC SYMBOLS, DATED DECEMBER 1968.

- STAGING
- TWAE
- HAUL ROUTE
- FOOTPRINT
- PARCEL
- DISPOSAL SITE

REAL ESTATE OWNERSHIP MAPS 2017

DEPARTMENT OF THE ARMY
OFFICE OF THE SACRAMENTO DISTRICT ENGINEER
SOUTH PACIFIC DIVSION

CARTOGRAPHER *J. HENRIKSEN*
CARTO TECH.
CHECKED BY

YUBA COUNTY — CALIFORNIA
ENGINEERING GEOMATICS SECTION - CADASTRAL TEAM

YUBA RIVER ECOSYSTEM RESTORATION FEASIBILITY STUDY

HABITAT INCREMENTS 2, 3A, 5A & 5B

SUBMITTED BY
STEVE J. CAREY
LEAD, CADASTRAL TEAM

RECOMMENDED BY
JAMES M. OLIVER
CHIEF, GEOMATICS SECTION

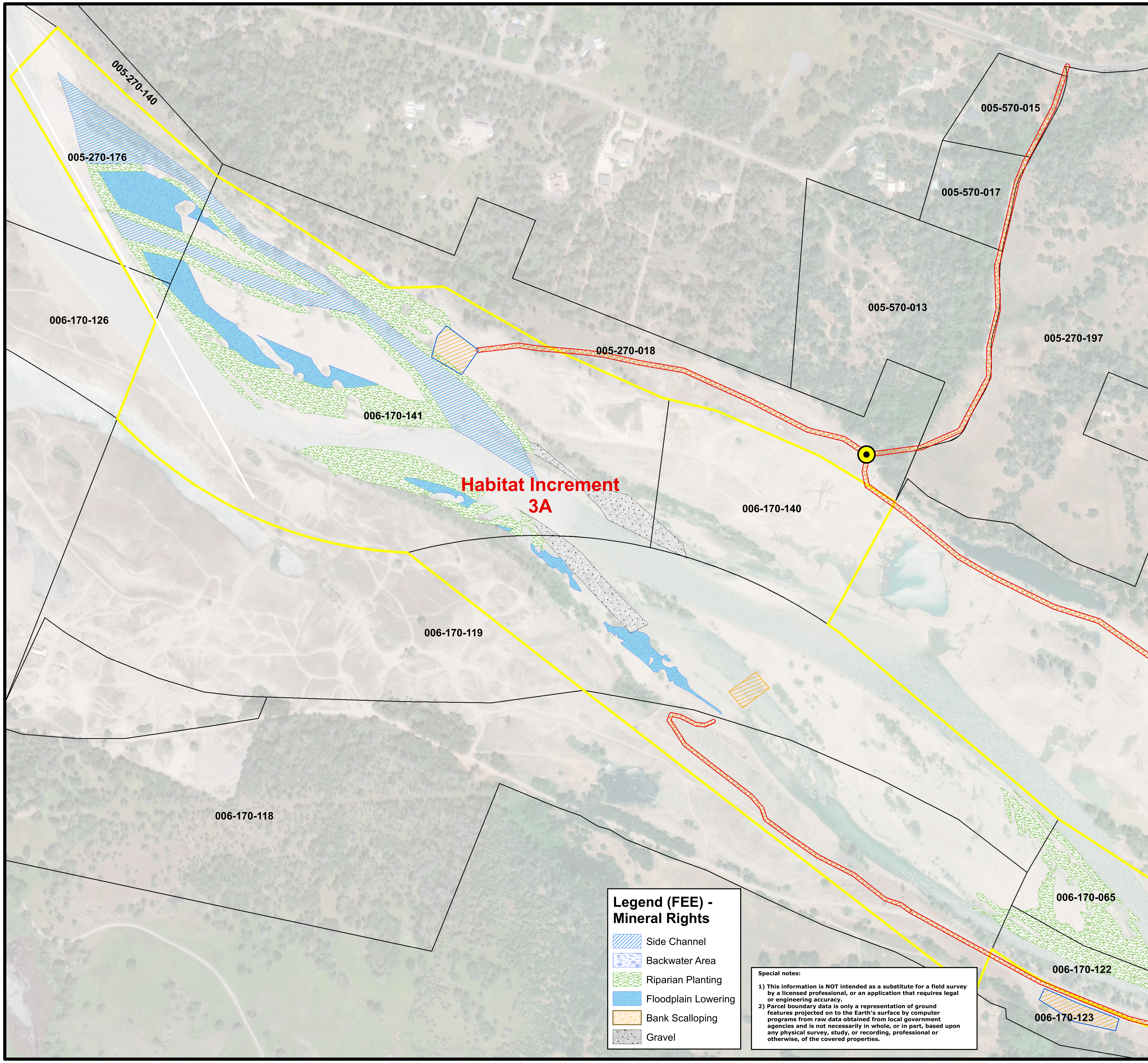
APPROVED BY ______ DATE ______
DIANE M. SIMPSON
CHIEF, REAL ESTATE DIVISION

OFFICE, CHIEF OF ENGINEERS, WASHINGTON 25, D.C.
REMIS CODE:
REMIS UNIQUE ID:
INSTALLATION OR PROJECT NO.

Date Saved: 8/16/2018 4:23:13 PM
This sheet originally formatted to ARCH_E1, 30"X42".

SHEET 02 OF 07
DRAWING NO.

CORPS OF ENGINEERS U.S. ARMY



Path: \\COE-SPKNV001SAC.spk.ds.usace.army.mil\EGIS_GEOMATICS\SPK_Team_Data\Organizations\CESPK-ED\EDS\EDS-G\012-Cadastral\Unit\GIS_PROJECTS\CIVIL\3_SPK\Yuba_Goldfields\Projects\Eco_Restorations_2017\20180816_YRER-FS.mxd

GENERAL PROJECT LOCATION
NO SCALE
PROJECT LOCATION
NO SCALE

FINAL
As Applicable

PROJECT MAP

DEPARTMENT OF THE ARMY
USING SERVICE U.S. ARMY

LOCATION OF PROJECT

STATE CALIFORNIA
COUNTY YUBA COUNTY
DIVISION SOUTH PACIFIC DIVISION (SPD)
DISTRICT SACRAMENTO (SPK)
ARMY AREA 6TH ARMY
13 Miles N.E. OF YUBA CITY
43 Miles N. OF SACRAMENTO

TRANSPORTATION FACILITIES

FEDERAL ROADS US HWY 5
STATE ROADS STATE HWY 70/99
AIRPORTS SACRAMENTO INT. AIRPORT

ACQUISITION

TOTAL ACRES ACQUIRED See T.A.R.
FEE See T.A.R.
PUBLIC DOMAIN WITHDRAWN See T.A.R.; USE PERMIT
USE PERMIT (Other than P.D.)
TRANSFER WITHDRAWN; USE PERMIT
LEASE NONE
EASEMENT RESERVED IN FEE DISPOSAL
LESSER INTERESTS EASEMENT; PERMIT; LICENSE

DISPOSAL

TOTAL ACRES DISPOSED NO AREA
SOLD
PUBLIC DOMAIN WITHDRAWN; USE PERMIT
USE PERMIT (Other than P.D.)
TRANSFERRED FEE
LEASES TERMINATED
LESSER INTERESTS TERM
REASSIGNED
ACRES TO

METADATA
Townships\Ranges:
00S,0011E
of the Mount Diablo Baseline & Meridian.

N
1:2,400
1 inch = 200 feet
Feet
0 200 400 600 800

Coordinate System:
NAD 1983 2011 StatePlane California II FIPS 0402 Ft US
Projection: Lambert Conformal Conic
Datum: NAD 1983 2011
Units: Foot US

ACQUISITION AUTHORIZATION

LEGEND

EXCEPT FOR SPECIAL SYMBOLS SHOWN BELOW, MAP SYMBOLS ARE STANDARD IN U.S. ARMY FIELD MANUAL, FM 21-31, TOPOGRAPHIC SYMBOLS, DATED DECEMBER 1968.

- STAGING
- TWAE
- HAUL ROUTE
- FOOTPRINT
- PARCEL
- DISPOSAL SITE

REAL ESTATE OWNERSHIP MAPS 2017

DEPARTMENT OF THE ARMY
OFFICE OF THE SACRAMENTO DISTRICT ENGINEER
SOUTH PACIFIC DIVISION

CARTOGRAPHER J. HENRIKSEN
CARTO TECH.
CHECKED BY
SUBMITTED BY STEVE J. CAREY, LEAD, CADASTRAL TEAM
RECOMMENDED BY JAMES M. OLIVER, CHIEF, GEOMATICS SECTION

YUBA COUNTY CALIFORNIA
ENGINEERING GEOMATICS SECTION - CADASTRAL TEAM
YUBA RIVER ECOSYSTEM RESTORATION FEASIBILITY STUDY
HABITAT INCREMENTS 2, 3A, 5A & 5B

APPROVED BY DIANE M. SIMPSON, CHIEF, REAL ESTATE DIVISION DATE

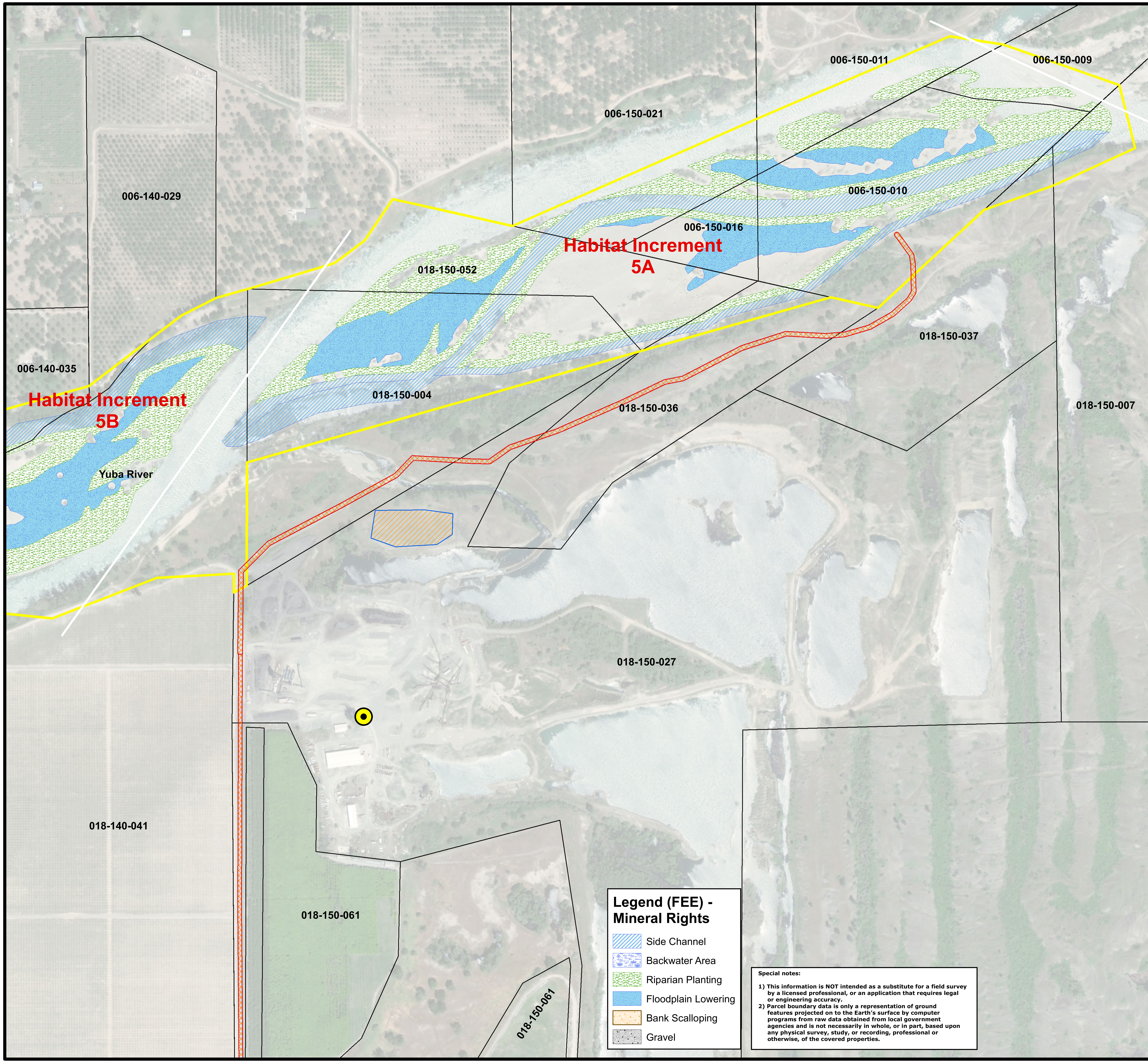
OFFICE, CHIEF OF ENGINEERS, WASHINGTON 25, D.C.
REMIS CODE:
REMIS UNIQUE ID:
INSTALLATION OR PROJECT NO.

Date Saved: 8/16/2018 4:23:13 PM
This sheet originally formatted to ARCH_E1, 30"X42".
SHEET 03 OF 07 DRAWING NO.

(Ver. DEC 16, 2016) ER 405-1-200 Eng_Form 1456A, Oct 81

CORPS OF ENGINEERS

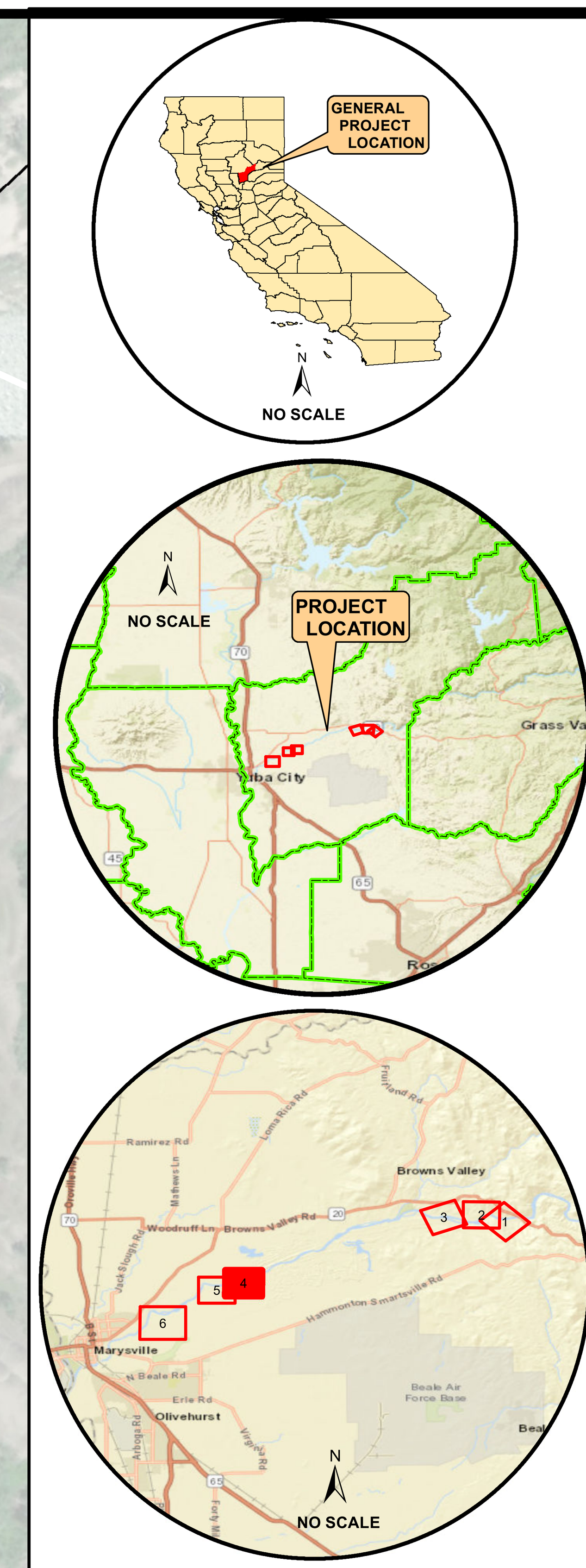
U.S. ARMY



Special notes:

1) This information is NOT intended as a substitute for a field survey by a licensed professional, or an application that requires legal or engineering accuracy.
2) Parcel boundary data is only a representation of ground features projected on to the Earth's surface by computer programs from raw data obtained from local government agencies and is not necessarily in whole, or in part, based upon any physical survey, study, or recording, professional or otherwise, of the covered properties.

Path: \\COE-SPKNV001SAC.spk.ds.usace.army.mil\EGIS_GEOMATICS\SPK_Team_Data\Organizations\CESPK-ED\ED\EDS-G\012-Cadastral\Unit\GIS_PROJECTS\CIVIL\3_SPK\Yuba_Goldfields\Projects\Eco_Restorations_2017\20180816_YRER-FS.mxd



METADATA
Townships\Ranges:
00S,0011E
of the Mount Diablo Baseline & Meridian.

N

1:2,400
1 inch = 200 feet

Feet
0 200 400 600 800

Coordinate System:
NAD 1983 2011 StatePlane California II FIPS 0402 Ft US
Projection: Lambert Conformal Conic
Datum: NAD 1983 2011
Units: Foot US

ACQUISITION AUTHORIZATION

FINAL
As Applicable

PROJECT MAP

DEPARTMENT OF THE: ARMY
USING SERVICE: U.S. ARMY

LOCATION OF PROJECT

STATE: CALIFORNIA
COUNTY: YUBA COUNTY
DIVISION: SOUTH PACIFIC DIVISION (SPD)
DISTRICT: SACRAMENTO (SPK)
ARMY AREA: 6TH ARMY
13 Miles N.E. OF YUBA CITY
43 Miles N. OF SACRAMENTO

TRANSPORTATION FACILITIES

FEDERAL ROADS: US HWY 5
STATE ROADS: STATE HWY 70/99
AIRPORTS: SACRAMENTO INT. AIRPORT

ACQUISITION

TOTAL ACRES ACQUIRED: See T.A.R.
FEE: See T.A.R.
PUBLIC DOMAIN (WITHDRAWN / USE PERMIT): See T.A.R.
USE PERMIT (Other than P.D.)
TRANSFER (WITHDRAWN / USE PERMIT)
LEASE: NONE
EASEMENT RESERVED IN FEE DISPOSAL
LESSER INTERESTS (EASEMENT / PERMIT / LICENSE)

DISPOSAL

TOTAL ACRES DISPOSED: NO AREA
SOLD
PUBLIC DOMAIN (WITHDRAWN / USE PERMIT)
USE PERMIT (Other than P.D.)
TRANSFERRED (FEE)
LEASES TERMINATED
LESSER INTERESTS TERM
REASSIGNED
ACRES TO

LEGEND

EXCEPT FOR SPECIAL SYMBOLS SHOWN BELOW, MAP SYMBOLS ARE STANDARD IN U.S. ARMY FIELD MANUAL, FM 21-31, TOPOGRAPHIC SYMBOLS, DATED DECEMBER 1968.

- STAGING
- TWAE
- HAUL ROUTE
- FOOTPRINT
- PARCEL
- DISPOSAL SITE

REAL ESTATE OWNERSHIP MAPS 2017

DEPARTMENT OF THE ARMY
OFFICE OF THE SACRAMENTO DISTRICT ENGINEER
SOUTH PACIFIC DIVSION

CARTOGRAPHER: J. HENRIKSEN
CARTO TECH.
CHECKED BY

SUBMITTED BY
STEVE J. CAREY
LEAD, CADASTRAL TEAM

RECOMMENDED BY
JAMES M. OLIVER
CHIEF, GEOMATICS SECTION

YUBA COUNTY — CALIFORNIA

ENGINEERING GEOMATICS SECTION - CADASTRAL TEAM

YUBA RIVER ECOSYSTEM RESTORATION FEASIBILITY STUDY
HABITAT INCREMENTS 2, 3A, 5A & 5B

APPROVED BY: DIANE M. SIMPSON, CHIEF, REAL ESTATE DIVISION — DATE

OFFICE, CHIEF OF ENGINEERS, WASHINGTON 25, D.C.
REMIS CODE:
REMIS UNIQUE ID:
INSTALLATION OR PROJECT NO.

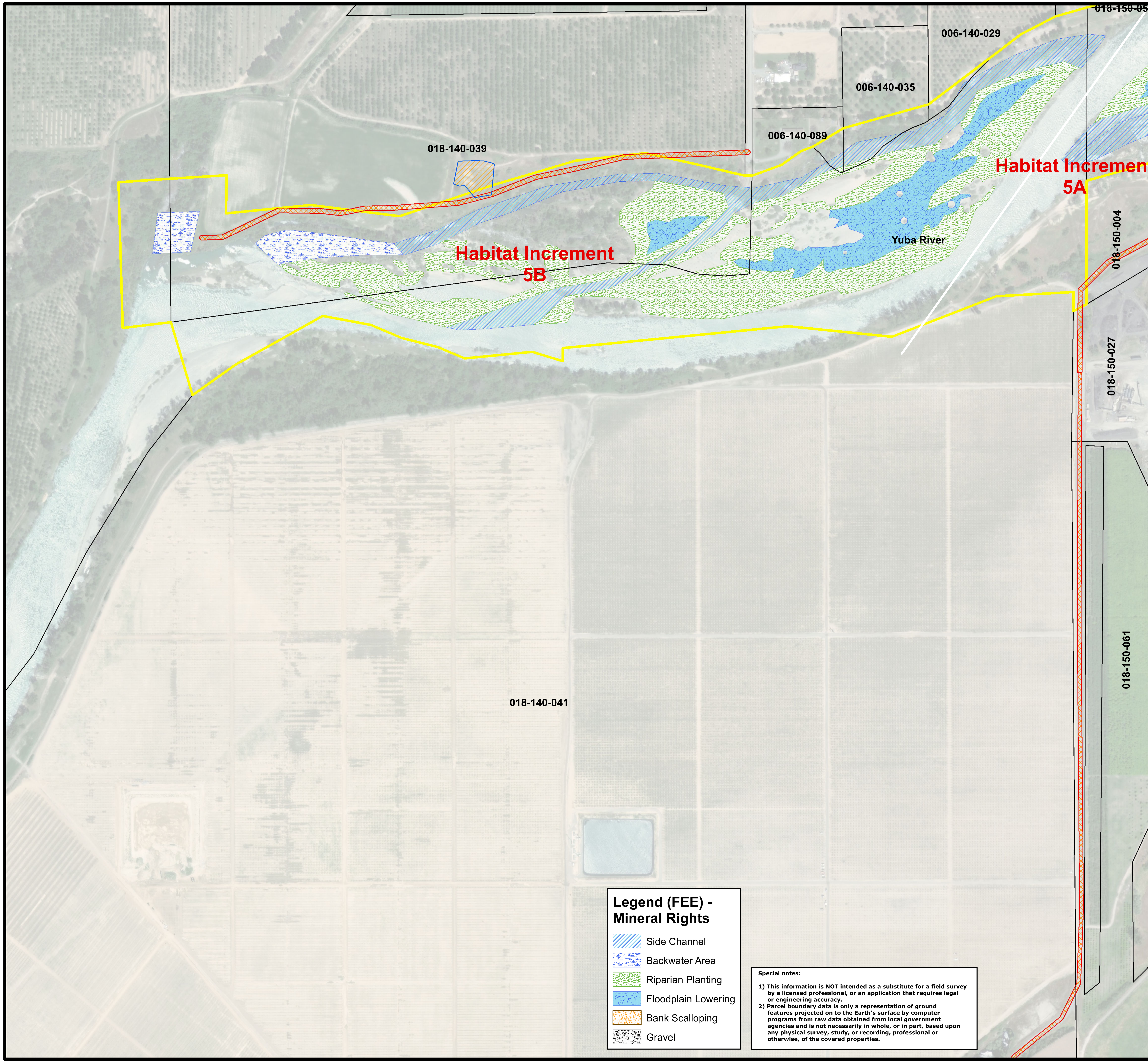
Date Saved: 8/16/2018 4:23:13 PM
This sheet originally formatted to ARCH_E1, 30"X42".

SHEET 04 OF 07
DRAWING NO.

(Ver. DEC 16, 2016) ER 405-1-200 Eng_Form 1456A, Oct 81

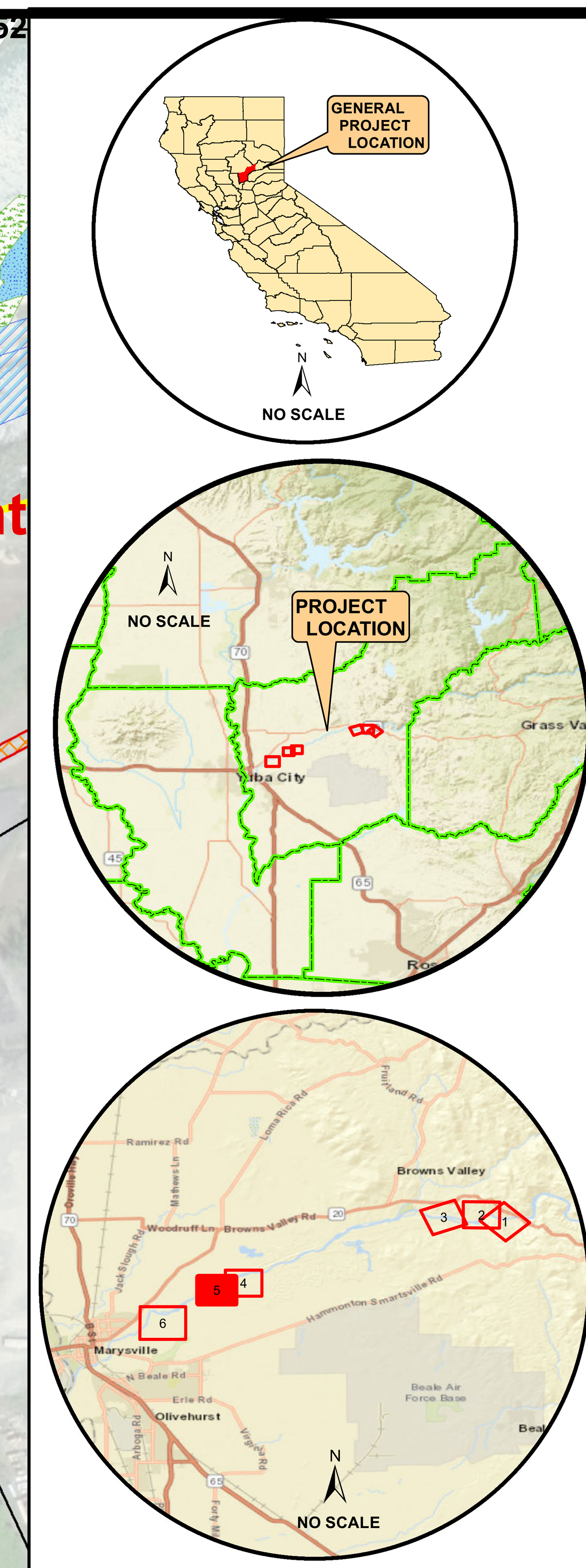
CORPS OF ENGINEERS

U.S. ARMY



Special notes:

1) This information is NOT intended as a substitute for a field survey by a licensed professional, or an application that requires legal or engineering accuracy.
2) Parcel boundary data is only a representation of ground features projected on to the Earth's surface by computer programs from raw data obtained from local government agencies and is not necessarily in whole, or in part, based upon any physical survey, study, or recording, professional or otherwise, of the covered properties.



METADATA

Townships\Ranges:
00S,0011E
of the Mount Diablo Baseline & Meridian.

N

1:2,400
1 inch = 200 feet

Feet
0 200 400 600 800

Coordinate System:
NAD 1983 2011 StatePlane California II FIPS 0402 Ft US
Projection: Lambert Conformal Conic
Datum: NAD 1983 2011
Units: Foot US

ACQUISITION AUTHORIZATION

FINAL
As Applicable

PROJECT MAP

DEPARTMENT OF THE ARMY
USING SERVICE U.S. ARMY

LOCATION OF PROJECT

STATE CALIFORNIA
COUNTY YUBA COUNTY
DIVISION SOUTH PACIFIC DIVSION (SPD)
DISTRICT SACRAMENTO (SPK)
ARMY AREA 6TH ARMY
13 Miles N.E. OF YUBA CITY
43 Miles N. OF SACRAMENTO

TRANSPORTATION FACILITIES

FEDERAL ROADS US HWY 5
STATE ROADS STATE HWY 70/99
AIRPORTS SACRAMENTO INT. AIRPORT

ACQUISITION

TOTAL ACRES ACQUIRED See T.A.R.
FEE See T.A.R.
PUBLIC DOMAIN (WITHDRAWN See T.A.R. / USE PERMIT)
USE PERMIT (Other than P.D.)
TRANSFER (WITHDRAWN / USE PERMIT)
LEASE NONE
EASEMENT RESERVED IN FEE DISPOSAL
LESSER INTERESTS (EASEMENT / PERMIT / LICENSE)

DISPOSAL

TOTAL ACRES DISPOSED NO AREA
SOLD
PUBLIC DOMAIN (WITHDRAWN / USE PERMIT)
USE PERMIT (Other than P.D.)
TRANSFERRED (FEE)
LEASES TERMINATED
LESSER INTERESTS TERM
REASSIGNED
ACRES TO

LEGEND

EXCEPT FOR SPECIAL SYMBOLS SHOWN BELOW, MAP SYMBOLS ARE STANDARD IN U.S. ARMY FIELD MANUAL, FM 21-31, TOPOGRAPHIC SYMBOLS, DATED DECEMBER 1968.

STAGING
TWAE
HAUL ROUTE
FOOTPRINT
PARCEL
DISPOSAL SITE

REAL ESTATE OWNERSHIP MAPS 2017

DEPARTMENT OF THE ARMY
OFFICE OF THE SACRAMENTO DISTRICT ENGINEER
SOUTH PACIFIC DIVSION

CARTOGRAPHER *J. HENRIKSEN*
CARTO TECH.
CHECKED BY

SUBMITTED BY
STEVE J. CAREY
LEAD, CADASTRAL TEAM

RECOMMENDED BY
JAMES M. OLIVER
CHIEF, GEOMATICS SECTION

YUBA COUNTY CALIFORNIA

ENGINEERING GEOMATICS SECTION - CADASTRAL TEAM

YUBA RIVER ECOSYSTEM RESTORATION FEASIBILITY STUDY

HABITAT INCREMENTS 2, 3A, 5A & 5B

APPROVED BY ______ DATE ______
DIANE M. SIMPSON
CHIEF, REAL ESTATE DIVISION

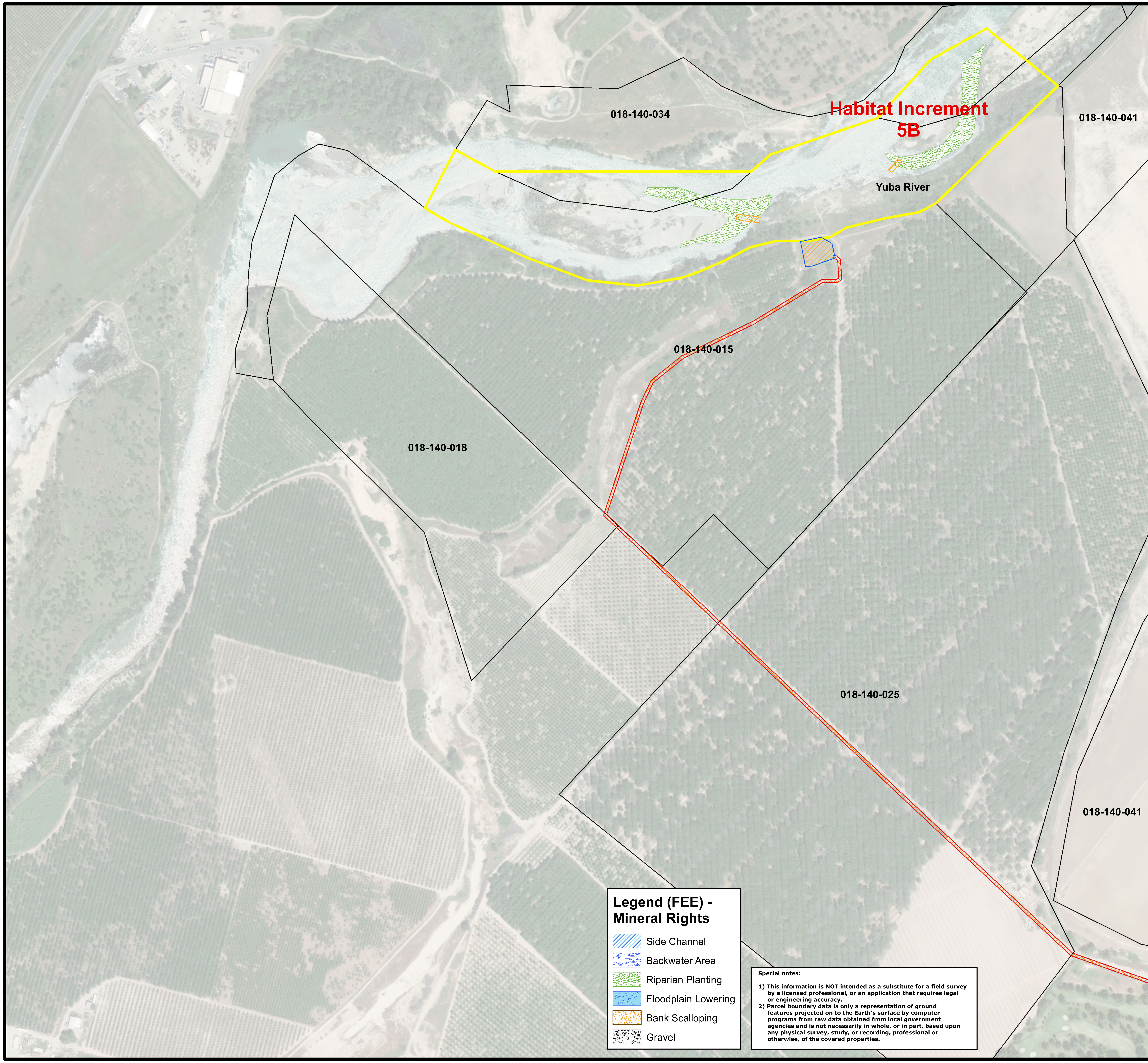
OFFICE, CHIEF OF ENGINEERS, WASHINGTON 25, D.C.
REMIS CODE:
REMIS UNIQUE ID:
INSTALLATION OR PROJECT NO.

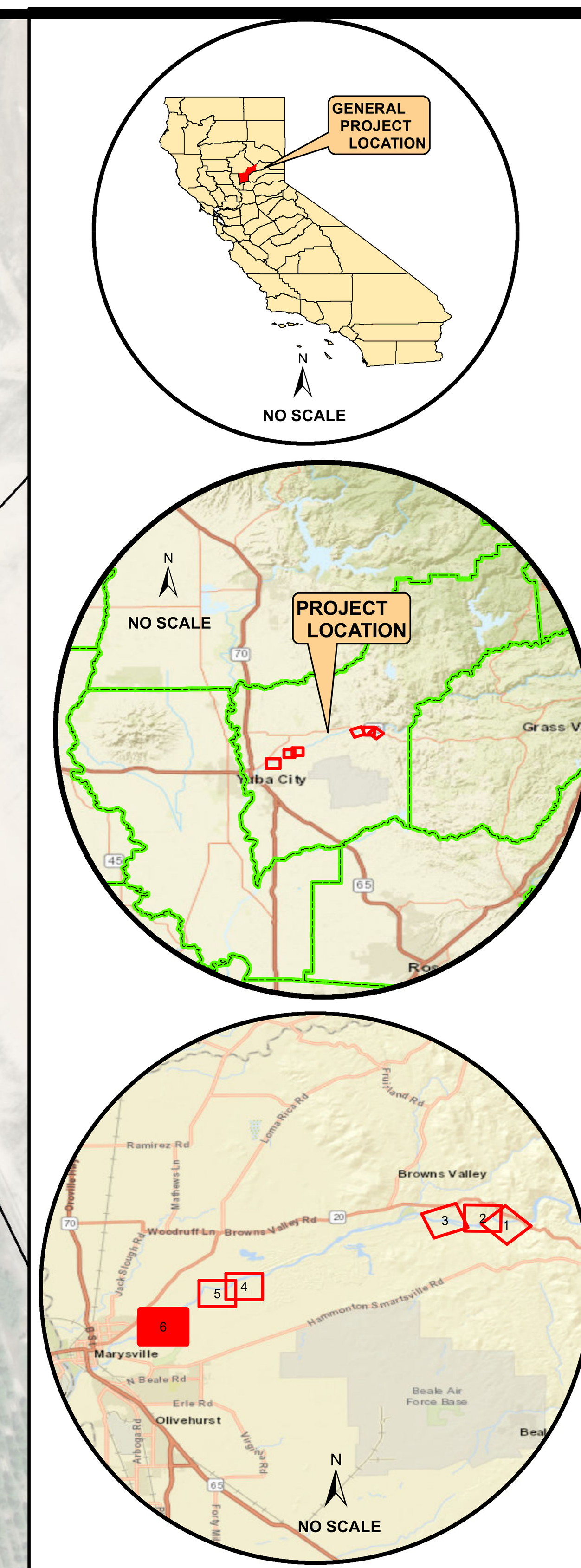
Date Saved: 8/16/2018 4:23:13 PM
This sheet originally formatted to ARCH_E1, 30"X42".

SHEET 05 OF 07
DRAWING NO.

(Ver. DEC 16, 2016) ER 405-1-200 Eng_Form 1456A, Oct 81

CORPS OF ENGINEERS — U.S. ARMY





METADATA

Townships\Ranges:
00S,0011E
of the Mount Diablo Baseline & Meridian.

N

1:3,000
1 inch = 250 feet

Feet
0 200 400 600 800

Coordinate System:
NAD 1983 2011 StatePlane California II FIPS 0402 Ft US
Projection: Lambert Conformal Conic
Datum: NAD 1983 2011
Units: Foot US

ACQUISITION AUTHORIZATION

FINAL
As Applicable

PROJECT MAP

DEPARTMENT OF THE ARMY
USING SERVICE U.S. ARMY

LOCATION OF PROJECT

STATE CALIFORNIA
COUNTY YUBA COUNTY
DIVISION SOUTH PACIFIC DIVISION (SPD)
DISTRICT SACRAMENTO (SPK)
ARMY AREA 6TH ARMY
13 Miles N.E. OF YUBA CITY
43 Miles N. OF SACRAMENTO

TRANSPORTATION FACILITIES

FEDERAL ROADS US HWY 5
STATE ROADS STATE HWY 70/99
AIRPORTS SACRAMENTO INT. AIRPORT

ACQUISITION

TOTAL ACRES ACQUIRED See T.A.R.
FEE See T.A.R.
PUBLIC DOMAIN WITHDRAWN See T.A.R. / USE PERMIT
USE PERMIT (Other than P.D.)
TRANSFER WITHDRAWN / USE PERMIT
LEASE NONE
EASEMENT RESERVED IN FEE DISPOSAL
LESSER INTERESTS EASEMENT / PERMIT / LICENSE

DISPOSAL

TOTAL ACRES DISPOSED NO AREA
SOLD
PUBLIC DOMAIN WITHDRAWN / USE PERMIT
USE PERMIT (Other than P.D.)
TRANSFERRED FEE
LEASES TERMINATED
LESSER INTERESTS TERM
REASSIGNED
ACRES TO

LEGEND

EXCEPT FOR SPECIAL SYMBOLS SHOWN BELOW, MAP SYMBOLS ARE STANDARD IN U.S. ARMY FIELD MANUAL, FM 21-31, TOPOGRAPHIC SYMBOLS, DATED DECEMBER 1968.

- STAGING
- TWAE
- HAUL ROUTE
- FOOTPRINT
- PARCEL
- DISPOSAL SITE

REAL ESTATE OWNERSHIP MAPS 2017

DEPARTMENT OF THE ARMY
OFFICE OF THE SACRAMENTO DISTRICT ENGINEER
SOUTH PACIFIC DIVSION

CARTOGRAPHER J. HENRIKSEN
CARTO TECH.
CHECKED BY

SUBMITTED BY
STEVE J. CAREY
LEAD, CADASTRAL TEAM

YUBA COUNTY — CALIFORNIA
ENGINEERING GEOMATICS SECTION - CADASTRAL TEAM

YUBA RIVER ECOSYSTEM RESTORATION FEASIBILITY STUDY

HABITAT INCREMENTS 2, 3A, 5A & 5B

RECOMMENDED BY
JAMES M. OLIVER
CHIEF, GEOMATICS SECTION

APPROVED BY ______ DATE ______
DIANE M. SIMPSON
CHIEF, REAL ESTATE DIVISION

OFFICE, CHIEF OF ENGINEERS, WASHINGTON 25, D.C.
REMIS CODE:
REMIS UNIQUE ID:
INSTALLATION OR PROJECT NO.

Date Saved: 8/16/2018 4:23:13 PM
This sheet originally formatted to ARCH_E1, 30"X42".

SHEET 06 OF 07
DRAWING NO.

(Ver. DEC 16, 2016) ER 405-1-200 Eng_Form 1456A, Oct 81

Attachment HH-A. SRH2D Modeling Information.

#	Attribute	RMT 2D Model
1	Aerial extent	Entire river, except the "Narrows Reach", which is from the junction of Deer Creek to the onset of gravel at Blue Point Mine.
2	Years of data collection	EDR was mapped in 2005 and 2007 and Timbuctoo Bend was mapped in June-December 2006.From highway 20 down, most bathymetry was mapped in late August to early September 2008, with some high-flow data collection in March and May 2009 as well as small additional near-bank and near-DPD gaps mapped in November 2009. Ground-based topographic surveys were done in November 2008 and November 2009. Lidar of the terrestrial river corridor was flown on September 21, 2008.
3	Bathymetric Resolution	EDR: Within the 880 cfs inundation area, points were collected along longitudinal lines, cross-sections, and on ~5'x5' grids, yielding an average grid point spacing of one point every 4.5 ft. (54.3 pts/100m^2) TBR: Within the 880 cfs inundation area, points were collected along longitudinal lines, cross-sections, and on ~10'x10' grids, yielding an average grid point spacing of one point every 6.2 ft. (28 pts/100m^2) All other reaches: Within the 880 cfs inundation area points were collected along longitudinal lines, some cross-sections, some localized grids. The average grid point spacing is one point every 4.2 ft. (59.8 pts/100m^2)
4	Topographic Resolution	EDR: Outside the 880 cfs inundation area, points were collected with a combination of grid-based ground-based reflectorless laser scanning of canyon walls and total station surveys of accessible ground, yielding an average grid point spacing of one point every 5.9 ft. (31.3 pts/100m^2) TBR: Outside the 880 cfs inundation area, points were collected on a grid, yielding an average grid point spacing of one point every 9.7 ft. (11.4 pts/100m^2) All other reaches: Outside the 880 cfs inundation area, points were mostly collected with lidar, yielding an average grid point spacing of one point every 1.4 ft. (554 pts/100m^2)
5	Bathymetric Accuracy	EDR: comparison of overlapping echosounder and total station survey points yielded observed differences of 0.2-0.3'. TBR: comparison of overlapping echosounder and total station survey points yielded observed differences of 0.2-0.3'. All other reaches: comparison of overlapping echosounder and total station survey points at one site yielded observed differences of 50% within 0.5', 75% within 0.6', and 94% within 1'. Comparison of boat-based water edge shots versus RTK GPS surveyed water's edge shots yielded observed differences of 75% within 0.1', 91% within 0.2', and 99% within 0.5'.
6	Topographic Accuracy	EDR: regular total station control point checks yielded accuracies of 0.03-0.06'. TBR: regular total station control point checks yielded accuracies of 0.03-0.06'. All other reaches: compared against 8,769 ground-based RTK GPS observations of elevation along flat surfaces, 54% of LIDAR points were within 0.1' , 86% were within

		0.2', and virtually all of the data were within 0.5'. Regular total station control point checks yielded accuracies of 0.03-0.06'. RTK GPS observations had vertical precisions of 0.06'. Comparison of lidar water edge points versus the same for RTK GPS yielded observed differences of 30% within 0.1', 57% within 0.2', and 92% within 0.5'.
7	Computational Mesh Resolution	EDR: 3' internodal spacing for all Q TBR: For Q<5,000 cfs, 3' internodal spacing. As flow goes overbank, cell size increases to 6'. For flows >21,100 cfs, different mesh has 10' internodal spacing. HR: For flows 0-1300 cfs, 5' internodal spacing. For flows 1300-7500 cfs, 5' internodal spacing. For flows >10,000, 10' internodal spacing. DGR: For flows 0-1300 cfs, 5' internodal spacing. For flows 1300-7500 cfs, 5' internodal spacing. For flows >10,000, 10' internodal spacing. FR: For flows 0-1300 cfs, 5' internodal spacing. For flows 1300-7500 cfs, 5' internodal spacing. For flows >10,000, 10' internodal spacing.
8	Discharge Range of Model	EDR: 700 to 110,400 cfs All else: 300 to 110,400 cfs (only 300-5,000 cfs used for relicensing instream habitat study)
9	Downstream WSE data/model source	EDR: Some WSE observations combined with slope-based translation of the Smartville gage WSE data to the end of the reach TBR: Direct observation of WSE at a limited number of flows <~12,000 cfs. For higher flows the downstream WSE was taken as the upstream WSE from the HR model at that flow. HR: Continuous direct observation of WSE at flows <~22,000 cfs. For higher flows the downstream WSE was taken as the upstream WSE from the HR model at that flow. DGR: Reach ends exactly at Marysville gaging station, so the WSE data is of the highest quality and abundance. Continuous WSE data for all flows ~500 - 110,400 cfs. FR: Continuous direct observation of WSE at flows <~22,000 cfs. For higher flows the downstream WSE was set to yield an upstream WSE equal to that at the Marysville gage.
10	River roughness specification	Because the scientific literature reports no consistent variation of Manning's n as a function of stage-dependent relative roughness (i.e., roughness/depth), a constant value was used for all unvegetated sediment as follows: 0.032 for EDR (a deeper bedrock canyon), 0.03 for TBR (based on preliminary testing in 2008-2009 prior to adoption by RMT), and 0.04 for the rest of the LYR (based on validation testing of 0.03, 0.04, and 0.05 as possible options). For vegetated terrain, the Casas et al. (2010) algorithm was used to obtain a spatially distributed, flow-dependent surface roughness for each model cell on the basis of the ratio of local canopy height to flow depth.
11	Eddy viscosity specification	Parabolic turbulence closure with an eddy velocity that scales with depth, shear velocity, and a coefficient (e_0) that can be selected between ~0.05 to 0.8 based on expert knowledge and local data indicators. Q<10,000 cfs: $e_0 = 0.6$ Q>=10,000 cfs: $e_0 = 0.1$
12	Hydraulic Validation Range	Point observations of WSE were primarily collected at 880 cfs, with some observations during higher flows, but not systematically analyzed. Velocity observations were collected for flows ranging from 530-5,010 cfs. Cross-sectional validation data collected at 800 cfs above DPD and 540 cfs below DPD.
13	Mass Conservation	0.001 to 1.98 %

	(Calculated vs Given Q)	
14a	WSE prediction accuracy	At 880 cfs there are 197 observations. Mean raw deviation is -0.006'. 27% of deviations within 0.1', 49% of deviations within 0.25', 70% within 0.5', 94% within 1'.
14b	Depth prediction accuracy	From cross-sectional surveys, predicted vs observed depths yielded a correlation (r) of 0.81.
15	Velocity magnitude prediction accuracy	5780 observations yielding a scatter plot correlation (r) of 0.887. Median error of 16%. Percent error metrics include all velocities (including V <3ft/s, which tends to have high error percents) yielding a rigorous standard of reporting.
16	Velocity direction prediction accuracy	5780 observations yielding a scatter plot correlation (r) of 0.892. Median error of 4%. Mean error of 6%. 61% of deviations within 5 deg and 86% of deviations within 10 deg.
17	Application of Univariate HSC	Yes
18	Application of Adjacent Velocity HSC	Feasible given the HSCs.
19	Substrate data extent	Whole river within 5000 cfs wetted area, except the Narrows Reach.
20	Substrate data resolution	Visual classification of sediment facies with 7 bins sized to match visual feasibility and biological functions (silt/clay (<0.0625 mm), sand (0.0625-2 mm), fine gravel (2-32 mm), medium gravel/small cobble (32-90 mm), cobble (90-128 mm), large cobble (128-256 mm), boulder (>256 mm)). Goal was to capture differences at ~10m x10m resolution.
21	Substrate data accuracy	Tested PSMFC fisheries biologists consisting of 9 individuals with fourteen 5-gallon buckets of material drawn from the river and complete pebble counts of each bucket. Performance was evaluated using 2 metrics. First, people were graded for their ability to properly detect the presence and absence of size classes. Some observers scored a perfect 100%, some were in the high 90s.Those scoring <85% did not participate in the real field surveys. Second, observers were graded on their ability to estimate the amount of each size class to the nearest 10%. The top scorer got a 98% score, some were in the 80s, some were in the 70s, and the bottom performers scoring below that did not participate in the real field surveys. After reviewing the test performance, the remaining participants were tested again, but the second test results have not been analyzed.
22	Riparian vegetation data extent	EDR and TBR: vegetation polygons within ~150,000 cfs domain. All other reaches: Lidar-derived vegetation pixels within ~150,000 cfs domain, except for downstream of the Goldfields where the levees are shorter and the domain is only to the back of the levees. Vegetation data includes height, likely vegetation association type, and many other variables.
23	Riparian vegetation data resolution	EDR and TBR: hand-drawn using 2006 color aerial imagery with 2' pixel resolution. All other reaches: 1-m vegetation pixels.
24	Riparian vegetation data accuracy	Vegetation association and structural variables tested and reported, but no direct comparison of canopy height prediction or presence/absence.

25	bed-element cover data extent	Whole river within 5000 cfs wetted area, except the Narrows Reach.
26	bed-element cover data resolution	Goal was to capture differences at ~10m x10m resolution.
27	bed-element cover data accuracy	See substrate testing.
28	nonbed-element cover data extent	Whole river within alluvial valley, except the Narrows Reach. Cannot see any such features hidden under tree canopy or completely underwater.
29	nonbed-element cover data resolution	2' aerial imagery above highway 20 bridge and 1' aerial imagery below it.
30	nonbed-element cover data accuracy	Accuracy not formally assessed

Attachment HH-B: Geomorphic Assessment

Geomorphic and Hydrologic Assessment of the Lower Yuba River in Support of Restoration Measures Cost-Risk Analysis for Alternative 5, Tentatively Selected Plan: US Army Corps of Engineers Sacramento District Yuba River Ecosystem Restoration Feasibility Study

Prepared by

Sarah Miller and Craig Fischenich PhD, P.E.

Environmental Laboratory, Ecological Resources Branch
US Army Engineer Research and Development Center
Vicksburg MS

Contents

Figures

Tables

Introduction

This document summarizes assessment of hydrologic and geomorphic information and methods as partial justification and support for Cost-Risk assessment assumptions to inform Adaptive Management and OMRR&R for Yuba River Ecosystem Restoration Feasibility Study, Lower Yuba River (LYR) between Englebright Dam and Marysville, CA (Figures 1 and 2). Analysis focuses on the Tentatively Selected Plan (TSP), Alternative 5, which includes four sub-reaches of the LYR (Habitat Increments), with selected restoration or management measures (Measures). USACE-determined Habitat Increments 2, 3a, 5a and 5b, comprise Alternative 5 (see Table 6, Yuba River Ecosystem Restoration Draft Feasibility Study. Yuba County, California, Appendix C: Draft Engineering Appendix, Dec 2017: "OMRR&R cost assumptions based on risk-informed tool").

Figure 1. Location map, Lower Yuba River below Englebright Dam to Dry Creek Confluence, showing significant locations referred to in reference materials and USACE design documents.

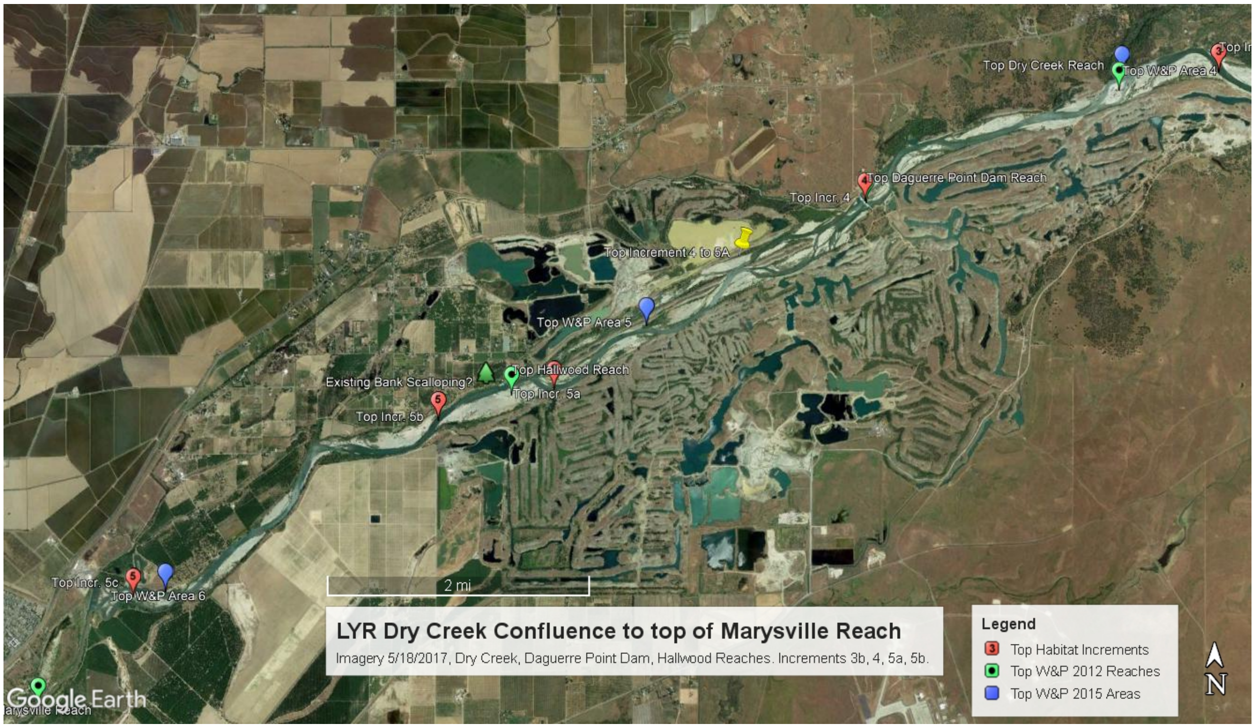


Figure 2. Location map, Lower Yuba River below Englebright Dam, Dry Creek Confluence to top of Marysville Reach, upstream from Marysville, showing significant locations referred to in reference materials and USACE design documents.

Data Sources

Existing data sources were used in this analysis, cross-referenced where needed to improve consistency or comparability, including locations of reaches or sub-reaches within the LYR project reach (see Figures 1 and 2). Approximate locations of the tops of eight Reaches described by Wyrick and Pasternack (2012) are based on narrative descriptions referring to baseflow thalweg river miles, landmarks such as bridges or tributary confluences, and descriptions of emergent features such as slope breaks, confining geology or topography or sediment changes. The date of these landmark designations is not specified, but appears to be between 2006 and 2009, considering references to gage data, bathymetric surveys, hydrodynamic modeling and other analyses of similar vintage that appear to have been used in part for delineation. A cbec (2013) report provides an overview map using these same Reaches, with rough designation of boundaries, focusing on the lower five reaches for their hydrologic and geomorphic analyses: Parks Bar, Dry Creek, DPD, Hallwood and Marysville. USACE-defined Increments 2 and 3a fall within Parks Bar Reach; Increments 5a and 5b fall within Hallwood Reach (see Figures 1 and 2).

Detailed assessment conducted by Wyrick and Pasternack (2015) concentrated on the period between 1999 and 2008, and the cbec (2013) assessment included the photo record from the 1940's, though at a less resolved scale of assessment focusing on location of the mainstem and significant side or back channels.

**Special Note regarding dates for imagery analysis: the 2009 configuration of LYR channel is considered present alignment for design and assessment purposes. USACE LYR Feasibility Study Habitat Increments and Measures are shown over 2009 imagery, flown 6/5/2009. The cbec (2013) report considers 2009 as the endpoint from 1940's imagery in geomorphic analysis. Wyrick and Pasternack (2015) topographic change process (TCP) analysis considers the period 1999 – 2008.

As noted, Wyrick and Pasternack (2012 and 2015), cbec (2013) and USACE SPK (2017) use 2009 imagery to set final or "current" location of the main channel, aerial extent of Measures and for calculations of quantities of cuts, fills and required construction materials. Comparing design plans on 6/5/2009 imagery with the best match current imagery from Google Earth, usually 10/9/2017, with apparently similar flow, has great utility in enabling a validation exercise for anticipated effects on planned Measures, using previous data and analyses as the predictive template. Reference to differences in channel alignment or feature configuration in our analysis include comparison to these more recent images, incorporating observed gross morphological changes into our assumptions for inherent geomorphic stability and lumped damage probability, to enable a more conservative evaluation of actual likelihood of channel changes that may impact Increments and Measures. In other words, the assumption of Wyrick and Pasternack of a representative hydrologic regime resulting in gross geomorphic topographic change processes (TCPs) for a period of time is assumed to apply to the 2008-2017 period similarly to 1999-2008, once difference being that the largest intervening event in the earlier epoch has a 7 year return period; the largest intervening event in the latter epoch has a 13 year return period. A full evaluation and comparison of the hydrologic regime between these two periods would be warranted during PED, though was not pursued herein at the feasibility stage.

For the purposes of this study, Google Earth best match for current imagery is 10/9/2017 (though 5/18/2017 is clearer), because October flow level appears closer to that shown in 2009. As described in further sections below, this imagery offers an excellent opportunity to compare predicted or assumed levels of change or impacts to proposed Measures, through assessment of channel processes and hydrologic events in the pre-2009 period of record, in the context of an actual test period of comparison between imagery and other data analyses end-points (2008, 2009) with the present (2017). As Wyrick and Pasternack (2015) characterized the time period of their analysis (they define as an "epoch") as a "hydrologically heterogeneous period" that includes an instantaneous peak flood of 53,000 cfs recorded at the USGS Marysville gage, we can consider the 2009 to 2017 period similarly representing a hydrologically heterogeneous period that includes a large documented event (87,100 cfs in January, 2017), and shows resulting response of reaches assessed.

**Special Note regarding Flood Frequency Analysis: Flood recurrence and selected flows discussed or assessed in referenced reports are all cross-referenced to the flood frequency curve for annual peaks 1970-2010WY, USGS Marysville gage, presented in Wyrick and Pasternack (2012), presumably based on a log-Pearson Type III transformation per USGS Bulletin 17B, an industry standard method for use primarily in unregulated stream and river systems (Table 1). Importantly, as noted in Draft Feasibility Study Appendix C (USACE SPK 2017), Section C-2.1 Hydrology, the LYR has been a regulated system since the early 1970's, and should not be expected to hold to the same assumptions regarding the shape of a flood frequency distribution of an unregulated system. Specifically, regulation tends to increase the recurrence interval of small flood events and decrease the recurrence interval of large flood events. In other words, smaller floods will happen more often and larger floods will happen less often. The Central Valley Hydrology Study (2015) was conducted to correct for these effects. The resulting shift in flood frequency for the purposes of restoration and flood related damages is most relevant at the top end of the curve, i.e., for large events (see Table 1).

Table 1. on page C-2-1 of Appendix C (USACE SPK 2017) shows exceedance probability for five events from the 10 year flood (10% probability of exceedance in any given year) to the 500 year event (0.2% probability of exceedance in any given year). Reservoir regulation clearly damps the higher end of the flood frequency distribution, increasing the recurrence interval (decreasing the exceedance probability, or annual chance of exceedance, or ACE), with greater impacts on recurrence interval the more extreme the high flows. The 10 year regulated flow (10% ACE) is about 3% lower than the unregulated flow magnitude, whereas the post-regulation flood of record, 161,000 cfs is a 40 year event using the log-Pearson Type III distribution, the regulated 40 year event would be about 116,000 cfs, nearly 40% lower.

Using pre-regulated flow recurrence intervals and associated exceedance probabilities in damage probability estimates will tend to over-predict the size of an event of selected likelihood, thereby overestimating potential associated costs to repair or replace damaged measures over a selected period of time or the life of the project. At the feasibility study stage, this approach will yield a conservative estimate of anticipated damages and associated costs, particularly for rarer but more damaging large events. The result is a higher projected set of costs at this stage. Refining this analysis at PED stage using updated reservoir release models to better represent this regulated system will decrease the predicted probability of high flow events occurring during M&AM, OMRR&R and full project lifespan, with concomitant reduction in associated costs to address damages likely to occur.

Discharge Recurrence and Historical Placement

Flood recurrence and exceedance probability of selected flows cross-walk are based on flood frequency curve for annual peaks 1970-2010WY, USGS Marysville gage, downstream from all sites (presented in Wyrick and Pasternack, 2012). Influential, important and/or reported flows:

- Modeled shear raster overlay flows (described below)
- “flood” and “bankfull” flows based on Wyrick and Pasternack (2012)
- USGS gaged flows representing largest preceding flows for 1999, 2008-9 and 2017 imagery
- Modeled flows from sediment mobility studies using critical dimensionless shear stress (YCWA 2013, provided by Pasternack)
- Standard set of RI as presented in table with Figure 4 (Wyrick and Pasternack 2012)

Table 1. Significant flow events recorded at Marysville Gage, USGS 11421000, 1970-2010 WY, flood frequency generated by Wyrick and Pasternack (2012). Gold cells represent largest intervening events in cbec (2013) areal imagery analysis, pink cells represent shear stress raster maps modeled for impacts to Increments and Measures, blue cells represent morphologically significant flows documented by Wyrick and Pasternack (2012) to represent in-channel and out of channel (floodplain) elevations, cells in italics represent select modeled high flows in this reservoir regulated system for comparison.

RI (yrs) at Marysville	Discharge (cfs)	Source or significance of Q	Notes
500	385729	Wyrick and Pasternack 2012 Table w Figure 4, p 19	
500	*305,000*	*Central Valley Hydrology Study (2015)*	*Simulated reservoir high flow*
200	287324	Wyrick and Pasternack 2012 Table w Figure 4, p 19	
100	223917	Wyrick and Pasternack 2012 Table w Figure 4, p 19	
200	*212,000*	*Central Valley Hydrology Study (2015)*	*Simulated reservoir high flow*

RI (yrs) at Marysville	Discharge (cfs)	Source or significance of Q	Notes
60	180000	USGS Marysville gage, 22 Dec 1964	largest event prior to 1970 imagery, cbec (2013) table 2 (flood of record)
100	*178,000*	*Central Valley Hydrology Study (2015)*	*Simulated reservoir high flow*
50	169397	Wyrick and Pasternack 2012 Table w Figure 4, p 19	
40	161000	USGS Marysville gage, 2 Jan 1997	largest event prior to 1999 imagery, cbec (2013) table 2
50	*112,000*	*Central Valley Hydrology Study (2015)*	*Simulated reservoir high flow*
20	111000	USGS Marysville gage, 19 Feb 1986	largest event prior to 1986 imagery, cbec (2013) table 2, close to 20, might be 21, can't determine that close
20	110400	overbank model run YCWA 2013 part 1	this run not included in YCWA 2013 sediment mobility analysis
20	110016	Wyrick and Pasternack 2012 Table w Figure 4, p 19	
13	87100	USGS Marysville gage, 9 Jan 2017	largest event prior to 2017 imagery, cbec (2013) table 2
12	84400	Shear Raster Flow, RI from Graph Wyrick and Pasternack 2012 p 19	highest sed mobility flow included in YCWA 2013, highest shear raster overlay with designs
12	84400	overbank model run YCWA 2013 part 1	
10	73980	Wyrick and Pasternack 2012 Table w Figure 4, p 19	
10	*71,700*	*Central Valley Hydrology Study (2015)*	*Simulated reservoir high flow*
7	53000	USGS Marysville gage, 19 May 2005	largest event prior to 2008 and 2009 imagery, cbec (2013) table 2
5	44980	Wyrick and Pasternack 2012 Table w Figure 4, p 19	
4.5	42200	Shear Raster Flow	
4.5	42200	overbank model run YCWA 2013 part 1	
	30000	overbank model run YCWA 2013 part 1	RI not relevant for analysis
2.5	21100	Wyrick and Pasternack 2012 flood Q, fills floodplain, calculated form reported 40% exceedance probability	
	21100	overbank model run YCWA 2013 part 1	RI not relevant for analysis
2	16464	Wyrick and Pasternack 2012 Table w Figure 4, p 19	
1.9	15000	Shear Raster Flow	
	15000	overbank model run YCWA 2013 part 1	RI not relevant for analysis
	10000	overbank model run YCWA 2013 part 1	RI not relevant for analysis

RI (yrs) at Marysville	Discharge (cfs)	Source or significance of Q	Notes
1.4	7500	Shear Raster Flow	
	7500	overbank model run YCWA 2013 part 1	RI not relevant for analysis
1.25	5612	Wyrick and Pasternack 2012 Table w Figure 4, p 19	
1.22	5000	Wyrick and Pasternack 2012 bankfull Q, calculated form reported 82% exceedance probability	
	5000	within bankfull model run YCWA 2013 part 1	RI not relevant for analysis
1.2	4000	Shear Raster Flow	
1.11	3106	Wyrick and Pasternack 2012 ~3000 cfs significant geomorphic slope break at banks and swales	
	3000	within bankfull model run YCWA 2013 part 1	
1.1	2500	Shear Raster Flow	
1.05	1877	Wyrick and Pasternack 2012 Table w Figure 4, p 19	
1.05	1700	Shear Raster Flow	too close to 1877 to distinguish RI effectively
	1300	within bankfull model run YCWA 2013 part 1	RI not relevant for analysis
	930	within bankfull model run YCWA 2013 part 1	RI not relevant for analysis
1.01	800	Shear Raster Flow	
1.01	702	Wyrick and Pasternack 2012 Table w Figure 4, p 19	
	700	within bankfull model run YCWA 2013 part 1	RI not relevant for analysis

Imagery Analysis and Interpretation Methods

To begin our analysis, we oriented around the historical period starting with construction of the Englebright Dam in 1941, which was followed by construction of New Bullards Dam in 1970, marking the beginning of a regulated flow era for LYR, generally speaking. From this time period, we constructed a qualitative estimate of the likelihood of channel change that might impact Measures in each Habitat Increment included in Alternative 5 (see attached Measures Matrix). This assessment was made by evaluating a combination of imagery in cbec (2013), figures in Wyrick and Pasternack (2015) and the aerial record on Google Earth, augmented by additional reports and documented geomorphic analyses.

We can see channel adjustments in response to previous mining activities and dam construction are clearly still in progress, though evidence of localized dynamic equilibrium can be noted from the aerial record and inferred by location of some hard points (e.g., bedrock, levees, infrastructure) to some extent. cbec (2013) reports the image date, estimated flow at the time of the flight, and the largest intervening peak flood, implicitly assumed to have the greatest gross morphological effect or change when comparing the previous image to the next available image, as shown in the qualitative assessment of these aerial images in their assessment. We also note that the flood of record at Marysville gage (USGS 11421000), 180,000 cfs (about a 60 year return event, see Table 1), occurred in 1964, prior to construction of New Bullards Dam, and thus prior to present-day regulation of the LYR relevant to the TSP.

Subsequent peak discharges of interest for the period between dam construction and more detailed analysis of the period 1999-2008 (see flood frequency Special Note above) include 49,300 cfs (6 year return) recorded in 1974, 64,900 cfs (8 year return) recorded in 1981, and 111,000 cfs (20 year return) recorded in 1986. Peak flow recorded in 1997 was 161,000 cfs (about a 40 year return event), and in 2005 was 53,000 cfs (about a 7 year return event). Analysis by cbec (2013) using aerial imagery from the 1940's to 2009 shows longer historical trends from Parks Bar Reach down through Marysville Reach, extending into the pre-regulated period.

Comparing Google Earth imagery from 1993 or 1998 through 2017 for the same reaches shows the 20 year trend; combining this with the detailed TCP analysis from 1999-2008 (Wyrick and Pasternack 2015, below) suggests areas may be most likely to adjust, and in what way (generally, scour or fill processes), during that time period.

Wyrick and Pasternack's (2015) analysis was presented in a series of area maps numbered 1-6; these areas are noted herein for comparison. Specific types of topographic change are discussed in interpretation of amounts and types of morphological adjustment that might be expected under the hydrologic regime that included a peak flow of 53,000 cfs (7 year return event). USACE SPK (2017) Habitat Increment boundaries are noted on each map reproduced in associated figures.

Modeled shear stress (in psf) overlay maps for eight selected flows with approximate RI in years – 1.01, 1.05, 1.2, 1.4, ~2, 4.5 and 12 (800 cfs, 1,700 cfs, 2,500 cfs, 4,000 cfs, 7,500 cfs, 15,000 cfs, 42,200 cfs, 84400 cfs, respectively) – with Habitat Measures, all Increments (2, 3a, 5a, 5b). Importantly, the 12 year modeled event is similar to the 13 year event (87,100 cfs) occurring in January 2017 (prior to flight dates). Likewise, the 7 year event recorded in 2005 (53,000 cfs), constituting the largest event between 1999 and 2008 assessed in Wyrick and Pasternack (2015) TCP analysis, is similar enough in size to the 42,200 cfs shear stress modeled event to allow qualitative effects between 1998 and 2009 imagery (and 2009 to 2017 imagery) to be compared with detailed geomorphic analysis and anticipated effects of similar shear values to be compared using modeled shear stress values.

Description and General Geomorphic Assessment of Habitat Increments

Parks Bar Reach – Increment 2

Increment 2 starts at the top of Parks Bar Reach at Route 20 bridge, includes Upper Gilt Edge Bar and Parks Bar. Increment 2 includes two bars, Upper Gilt Edge Bar (Measures 19, 20 and 21 – floodplain lowering, riparian planting, bank scalloping and backwater area) on the Left just downstream of the bridge, and Parks Bar (Measure 22 – floodplain lowering and riparian planting) just downstream from that on the Right. Thecbec (2013) report starts at Parks Bar Reach.

No change from 1970 to 2009 (cbec 2013), bars are in the same place. Previously, 1958 channel shows Parks bar was the main channel location (in part – imagery is cut off in cbec (2013) analysis) though the present alignment is quite similar to 1947 and 1952, possibly additional flow in partial side channel on the left bank across from Parks Bar, minor multi-channel configuration upstream of the bridge, but the design can generally be implemented with some assurance of lower risk of changes here according to the imagery from 1998 – 2017, largely the same every flyover.

Analysis by Wyrick and Pasternack (2015) shows a short section of avulsion, though I don't see this from the imagery, except that sometimes there is flow across the top of the LB bar on the left side of the patch of vegetation just downstream from the bridge. The main flow is generally tight against the RB. Most of the area outside the main channels is assigned "no detectable change," "overbank storage" or "vegetated overbank storage," with small interspersed sections of "overbank scour" on the bar area, and downcutting and bank migration in the main channel areas (Wyrick and Pasternack, 2015). "In-channel fill" and very small sections of "bar emergence" are noted along channel margins (Wyrick and Pasternack, 2015). The bars are definitely active, with little vegetation on them – Measures might fill in, might scour, but overall risk of erosion or burial is low.

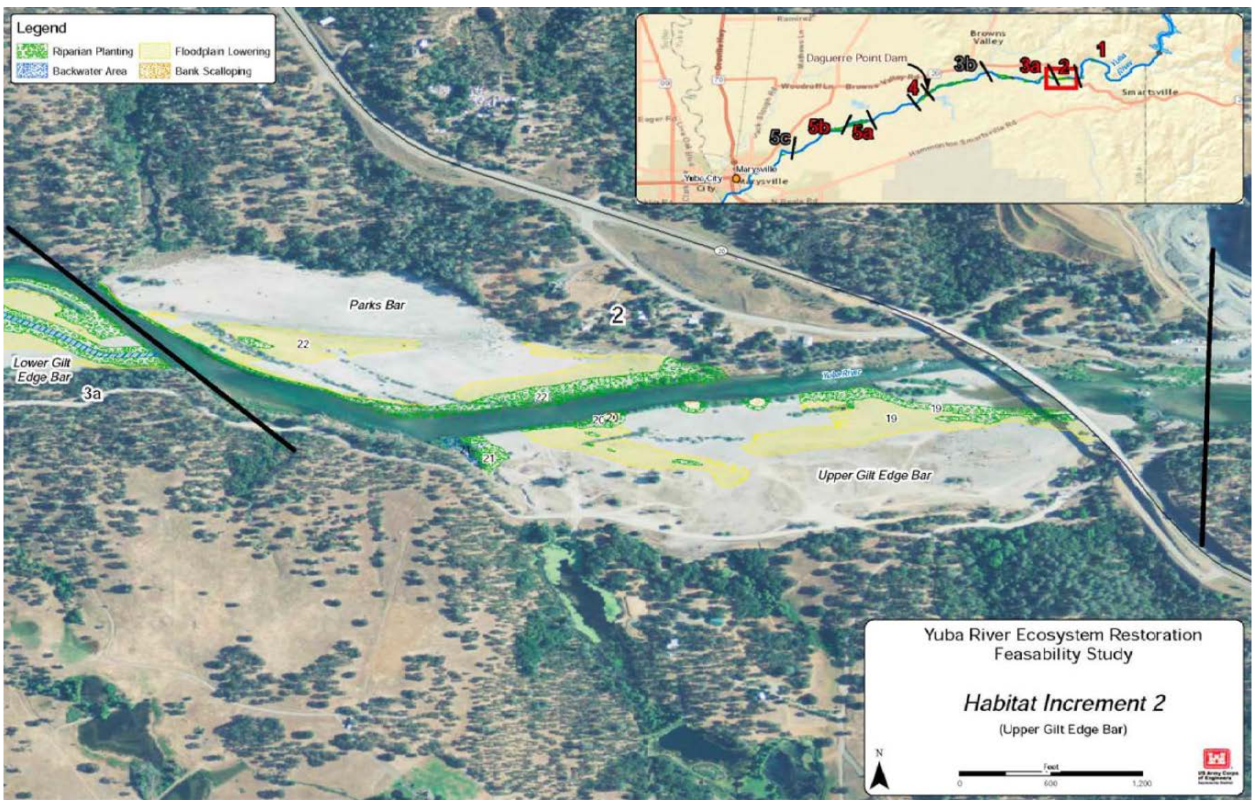


Figure 3. USACE 2017 design drawings, Habitat Increment 2, 2009 Imagery.

Figure 4. Google Earth imagery 1998, USACE 2017 Habitat Increment 2.

Figure 5. Google Earth imagery 2009, USACE 2017 Habitat Increment 2

Figure 6. Google Earth imagery 2017, USACE 2017 Habitat Increment 2.

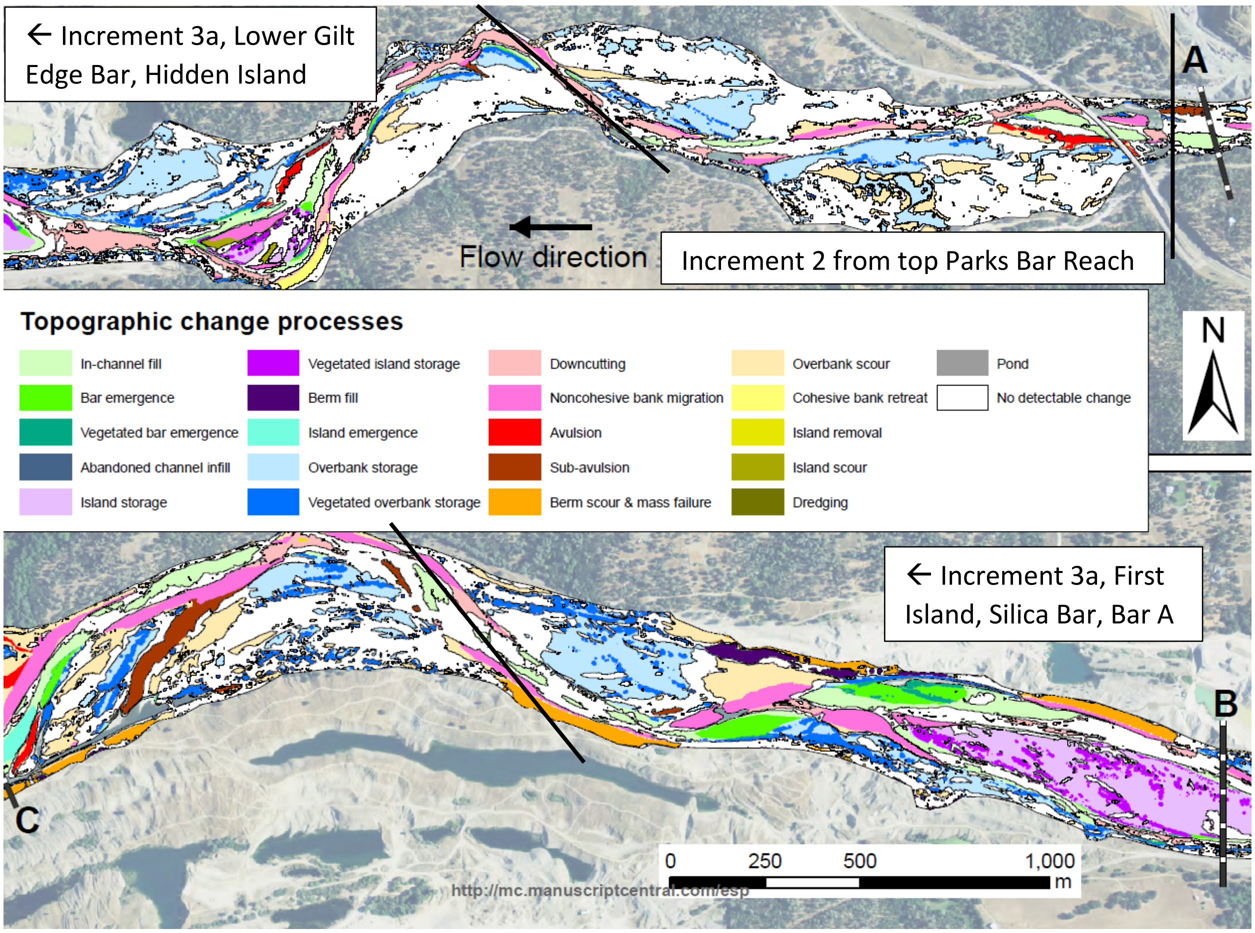


Figure 7. Wyrick and Pasternack, 2015, TCP area 2, orientation adjusted to match design. Habitat Increments labeled and boundaries marked with black solid lines.

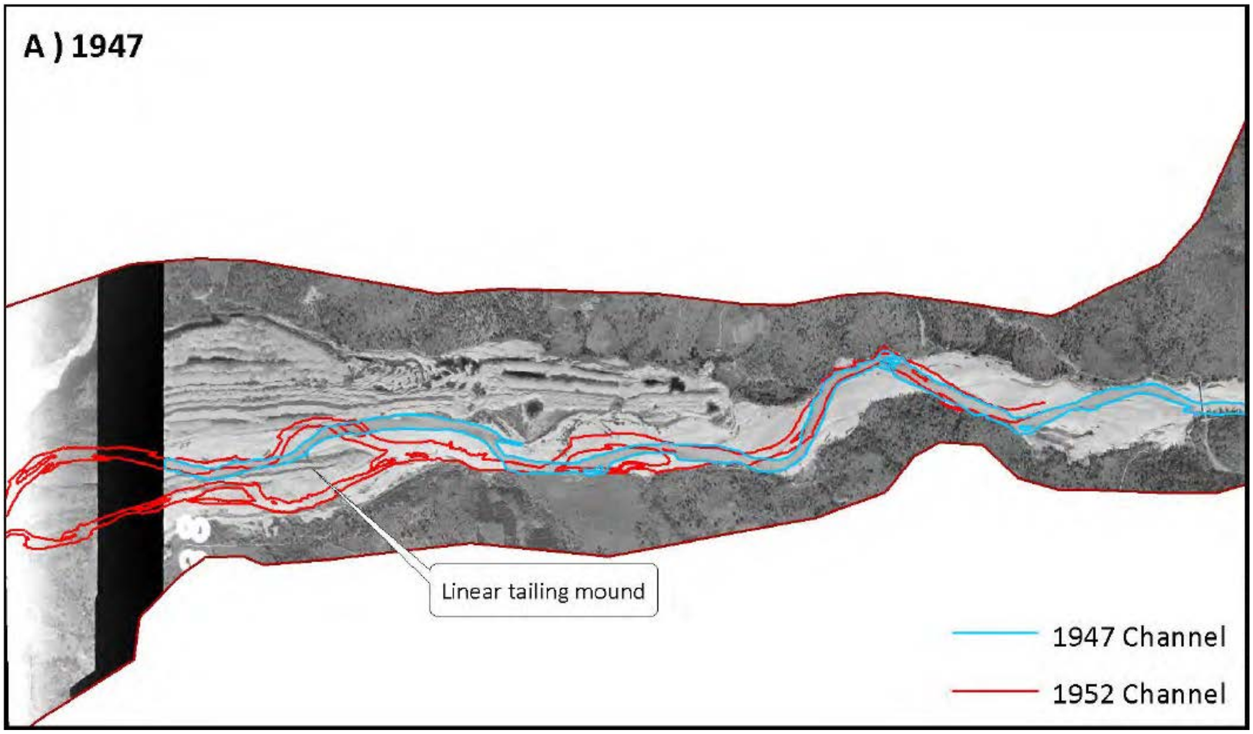


Figure 8. cbec (2013) aerial series plot A, Parks Bar Reach.

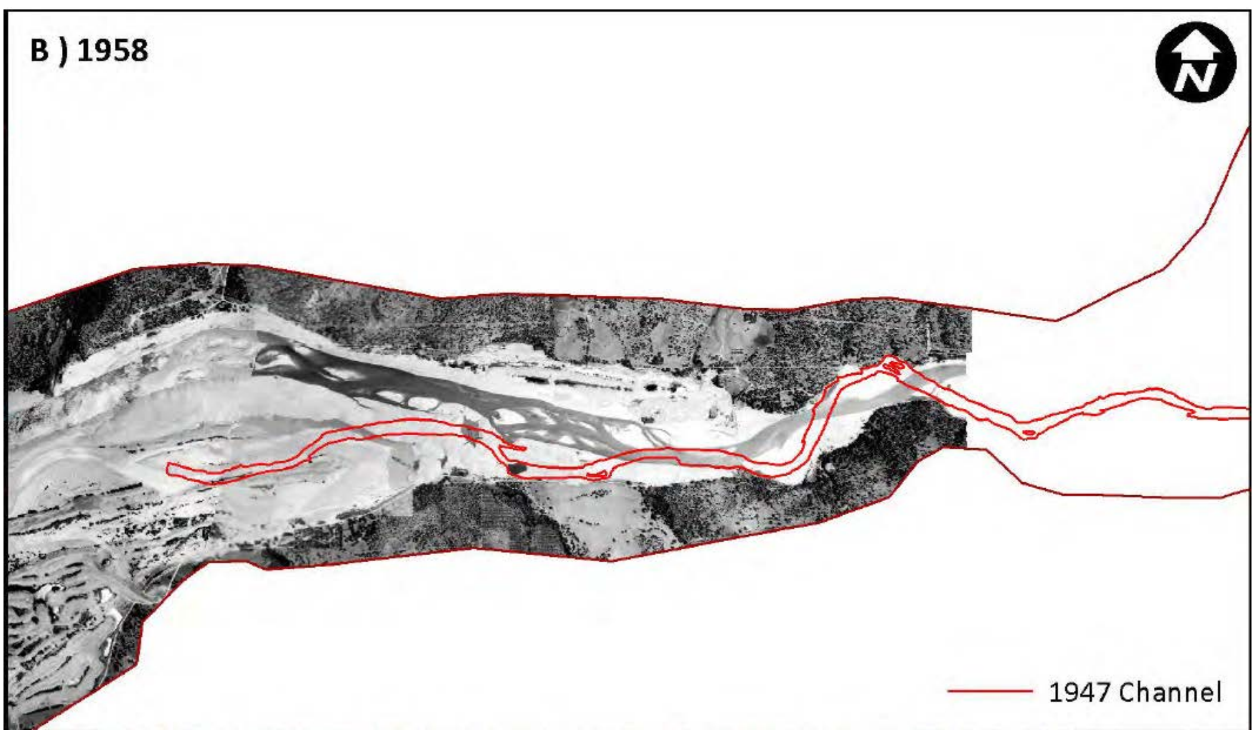


Figure 9. cbec (2013) aerial series plot B, Parks Bar Reach.

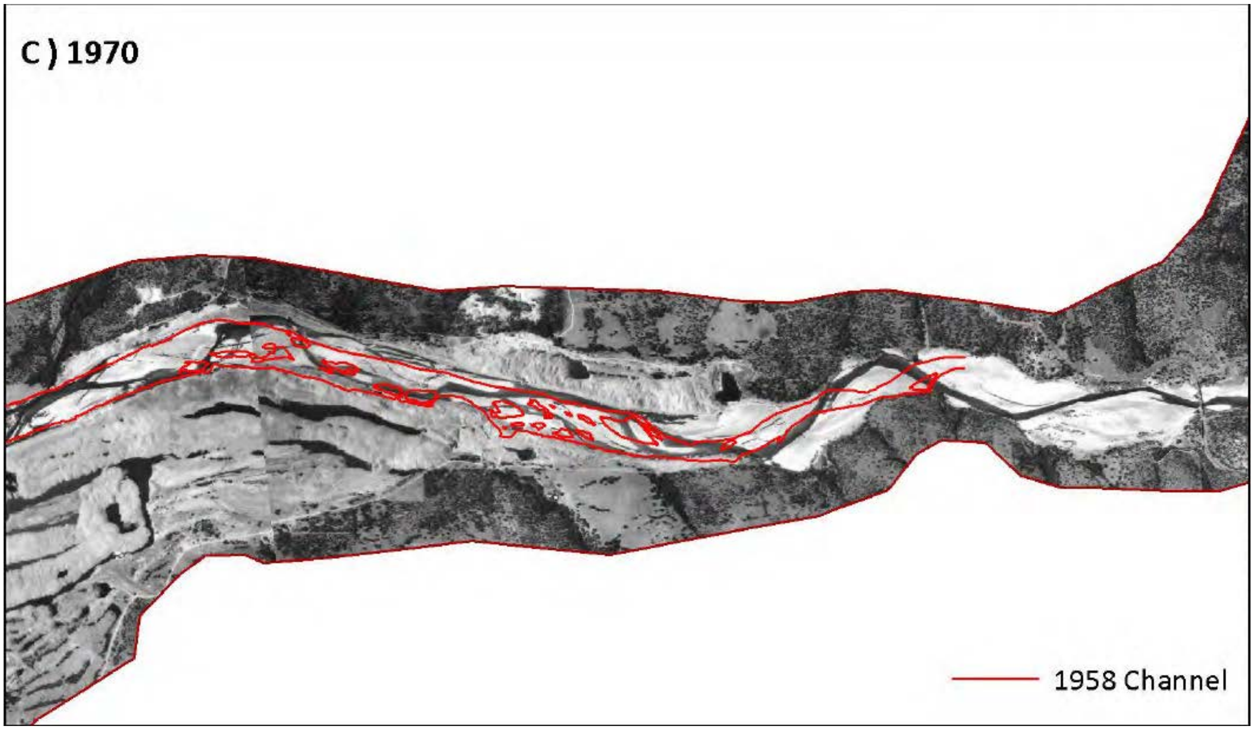


Figure 10. cbec (2013) aerial series plot C, Parks Bar Reach.

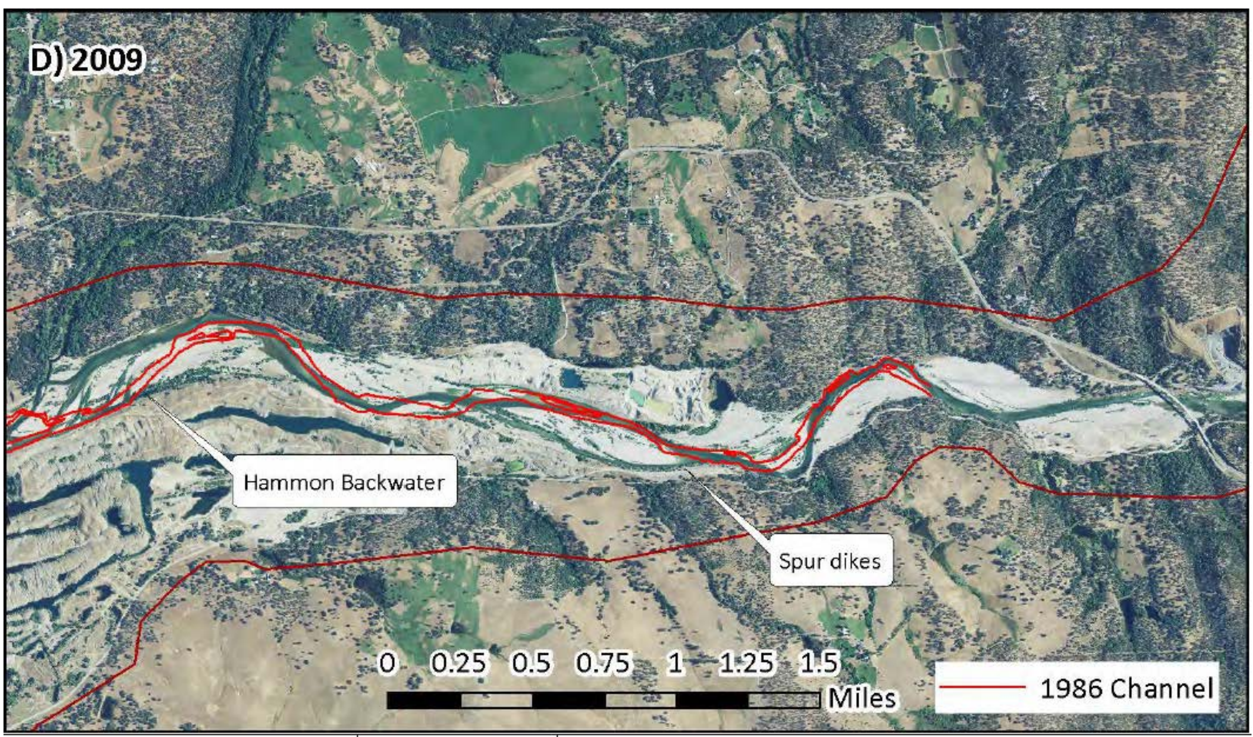


Figure 11. cbec (2013) aerial series plot D, Parks Bar Reach.

Notes: 1947, 1958 and 1970 aerials from James (2012). 2009 aerial from the National Ag Imagery Program (NAIP). Channel alignments from James (2012).	cbec	*Hydrologic and Geomorphic Analysis to Support Rehabilitation Planning* **Geomorphic evolution at Parks Bar Reach**		
		Project No. 13-1003	Created By: AMS	**Figure 4**

Parks Bar Reach – Increment 3a

Increment 3a is also within Parks Bar Reach, with the downstream portion beginning to get into mine tailings influence. Two areas examined for scale - Lower Gilt Bar, Hidden Island, First Island shown first, Silica Bar and Bar A shown second. While more dynamic, this reach maintains a relatively consistent multi-channel bar system, shown by the number of lines of trees marking former (and current) channels. Measures include riparian planting, side channel, floodplain lowering and channel stabilization. Lower Gilt Edge Bar, Hidden Island and First Islands – this channel really doesn't move appreciably from 1998 to 2017 on GE imagery, thought the size and shape of First Island changes somewhat, and Hidden Island is currently connected to the bar on the RB by a minor side channel. Multiple tree lines show this channel shifts relatively often, so may reasonably be expected to become a medial bar (or island) again. Riparian plantings planned here should be relatively stable, as flow will likely tend to split to one side or the other, forming a temporary side channel in the remaining open bar area. First Island revegetation should also be relatively stable, though this bar also experiences expansion and contraction periodically, so vegetation at the upstream end might be more likely to experience scour.

The cbec (2013) report shows greater movement in the preceding decades, with the channel occupying multiple locations throughout the entire valley width, maintaining a single thread (with the exception of Hidden Island) in the upstream portion, but going through obvious adjustment in the downstream portion with First Island following expansion of tailing mounds shown in 1947 imagery with '52 channel alignment, and apparent channelization and heavy adjustment from in the 50's and 60's where the channel appears to have regained a relatively persistent single thread in the 80's, though the extent and location of First Island has continued to shift somewhat through this period, though has remained relatively stable since the 1980's.

Wyrick and Pasternack (2015) show both Hidden Island and First Island areas between 1999 and 2008 as "island storage" and "vegetated island storage" which is appropriate here. Adjustment of multiple channels and single thread channel are also shown in the narrow range we can see from the imagery, with Lower Gilt Edge bar showing "no detectable change" for most of this area, and the bar upslope from Hidden Island designated "overbank storage" and "vegetated storage" (Wyrick and Pasternack, 2015).

The channel in the downstream portion appears relatively constant, as do the two channels as they enter the frame at the upstream end. The location of both channels and associated bar formations (the downstream end of First island is between the north and south channels in all three images) shift considerably, particularly the location where a single thread is resumed. From 1998 to 2009, the main channel on the RB has moved south, though the general configuration is similar. Note treelines in 2009 to the north in that section show the location of the channel and small medial bar present in 1998. From 2009 to 2017 the junction of the multiple channel system has moved downstream roughly 1000 feet and both north and south channels have migrated south.

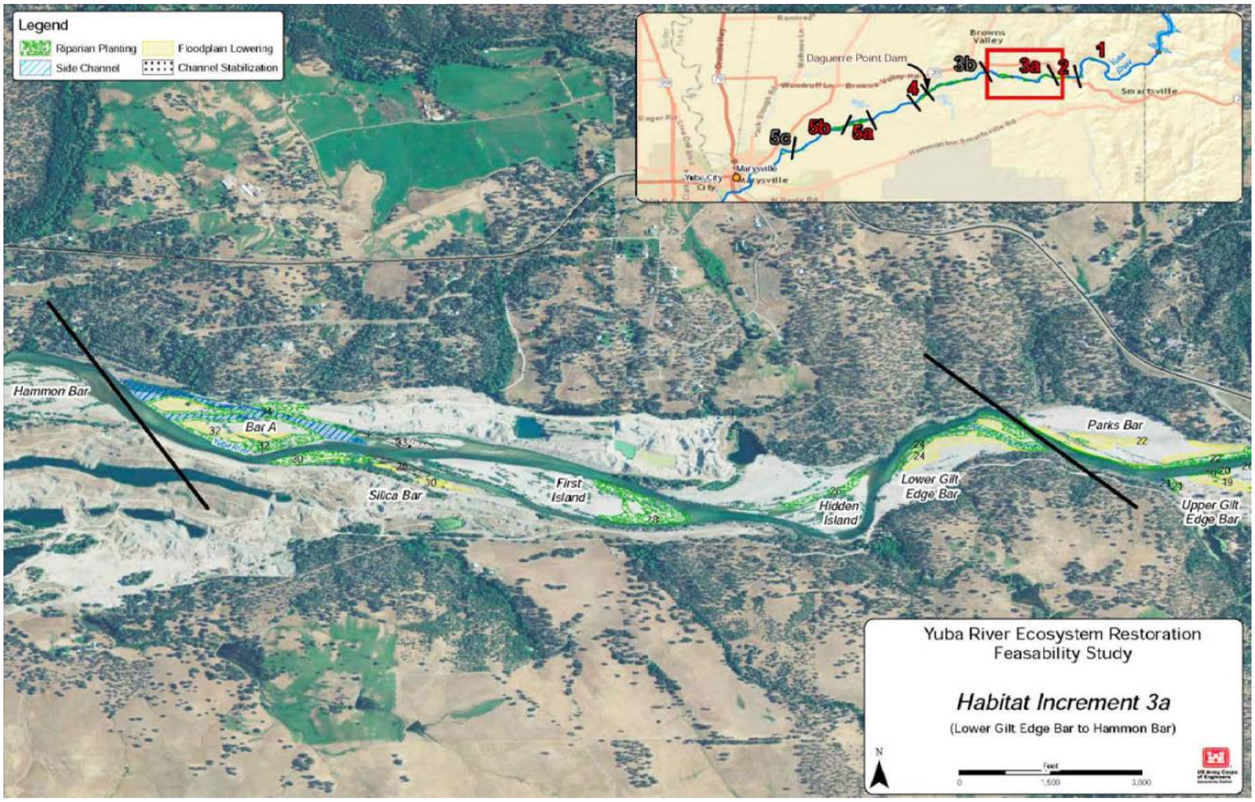


Figure 12. USACE 2017 design drawings, Habitat Increment 3a, 2009 Imagery.

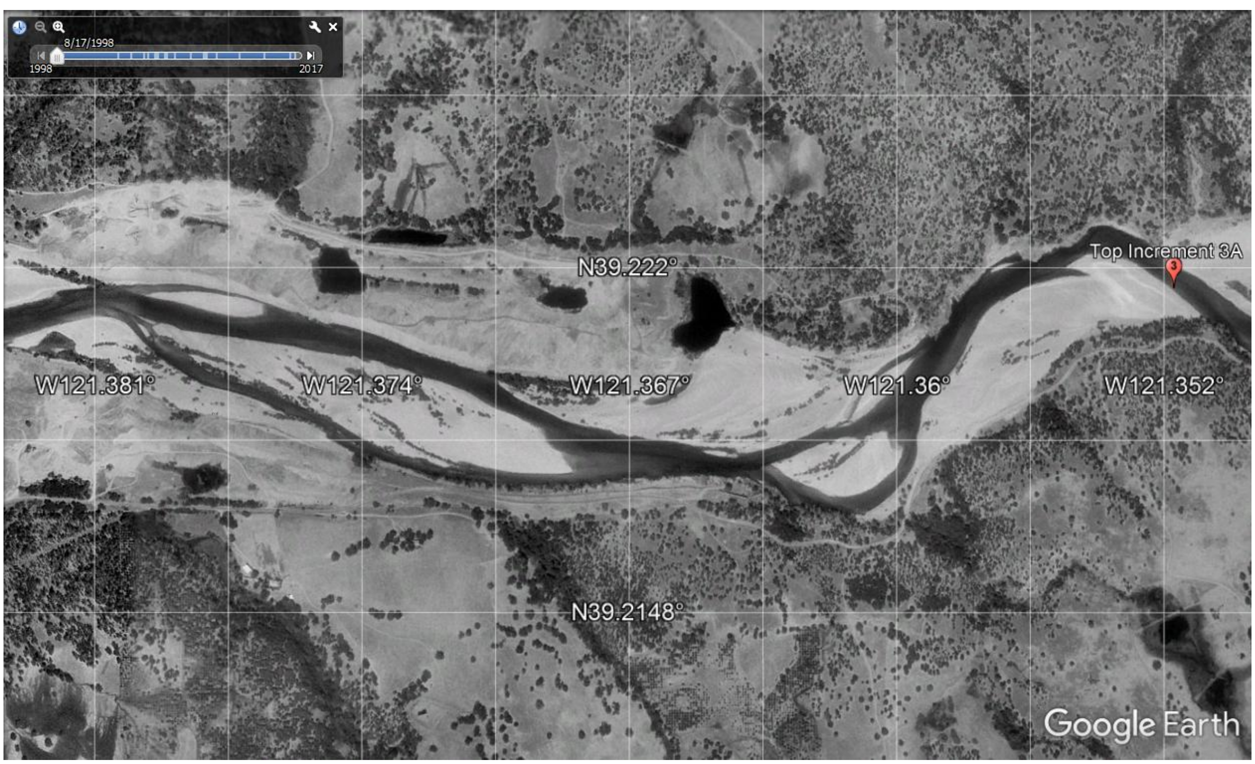


Figure 13. Google Earth imagery 1998, USACE 2017 Habitat Increment 3a.

Figure 14. Google Earth imagery 2009, USACE 2017 Habitat Increment 3a.

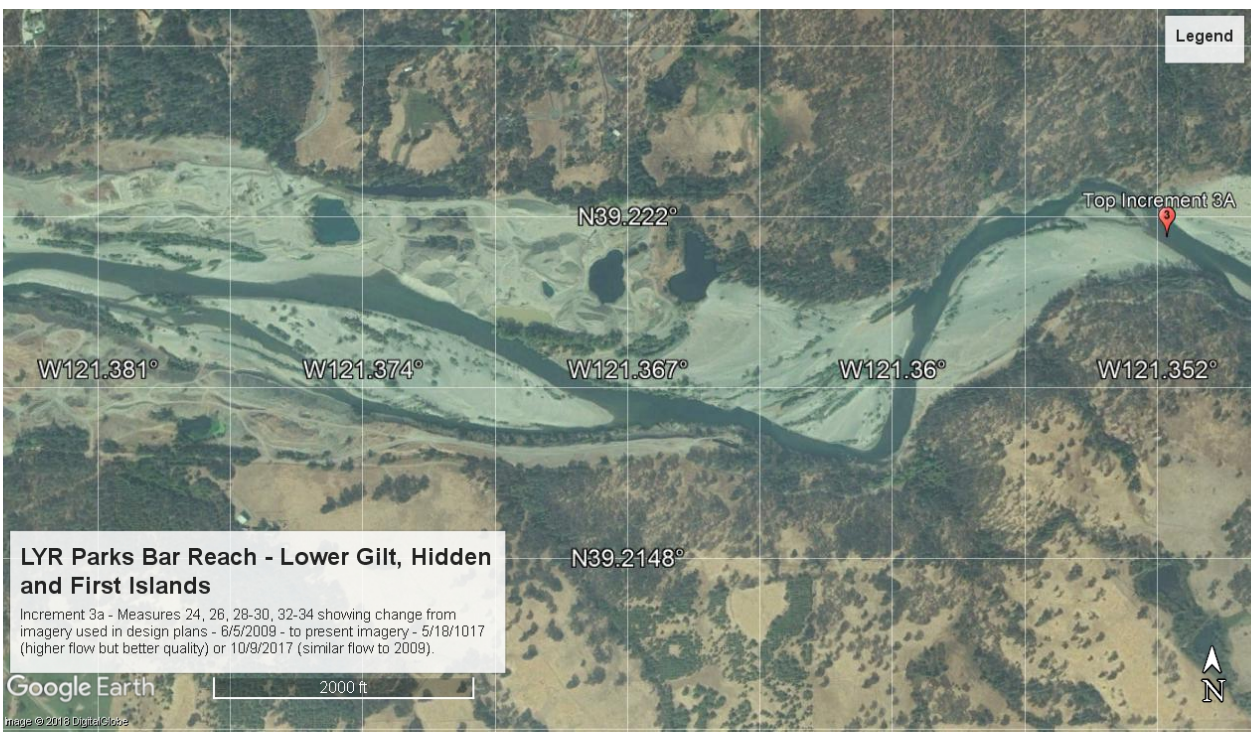


Figure 15. Google Earth imagery 2017, USACE 2017 Habitat Increment 3a.

Figure 16. Google Earth imagery 1998, USACE 2017 Habitat Increment 3a.

Figure 17. Google Earth imagery 2009, USACE 2017 Habitat Increment 3a.

Figure 18. Google Earth imagery 2017, USACE 2017 Habitat Increment 3a.

Hallwood Reach – Increment 5a

Increment 5a is located within Hallwood Reach, starting at the approximate (assumed) top of Hallwood Reach, covering the entirety of Bar C. Measures 46 and 47 include floodplain lowering, riparian planting, backwater enhancement, single side channel and an anabranching side channel. This bar has seen several channel alignments shown in the aerial history, with portions of the mainstem shifting from left to right bank and back a few times between the 50's and the 90's, with greatest activity in the upstream portion of the bar just downstream from the Daguerre High Flow Channel. Side channel proposed as part of Measure 46 is designed to reoccupy the 1993 alignment between two visible existing tree lines marking the banks of this alignment. This area is likelier to scour with possible reoccupation of one or more of the former alignments, particularly with floodplain lowering/disturbance activities planned along both sides of this feature, though former alignments should be more persistent with a new side channel if existing riparian treelines are preserved. Fill may be more likely due to splitting flow into three branches here, spreading out transport energy, though if constructed well and stabilized, vegetation might hold alignments even if buried in sediment, as long as deposition is shallow and vegetation is at least partially established.

The downstream end of Bar C has held a much more persistent alignment, where the bar is clearly an active surface but should be at lower risk of damage to the presence of established vegetation, particularly if main channel, backwater and swale side channel are well stabilized. Most of the bar surface is shown as “vegetated overbank” or “overbank storage” between 1999-2008, so fill is the most likely process to occur here (Wyrick and Pasternack, 2015). Bar areas in the vicinity of Measure 47 may be either filled or scoured out if channel shift is significant, but this isn't likely. If historically unstable channels shift into planted areas, this may scour out vegetation or fill as described above.

Most of the bar surface is shown as “vegetated overbank" or “overbank storage”, showing some likelihood of dominant fill processes, though the side channel proposed for the end of the Yuba Goldfields Terminus should keep the downstream end of Bar C from filling if well maintained against the left bank with good transport capacity (Wyrick and Pasternack, 2015).

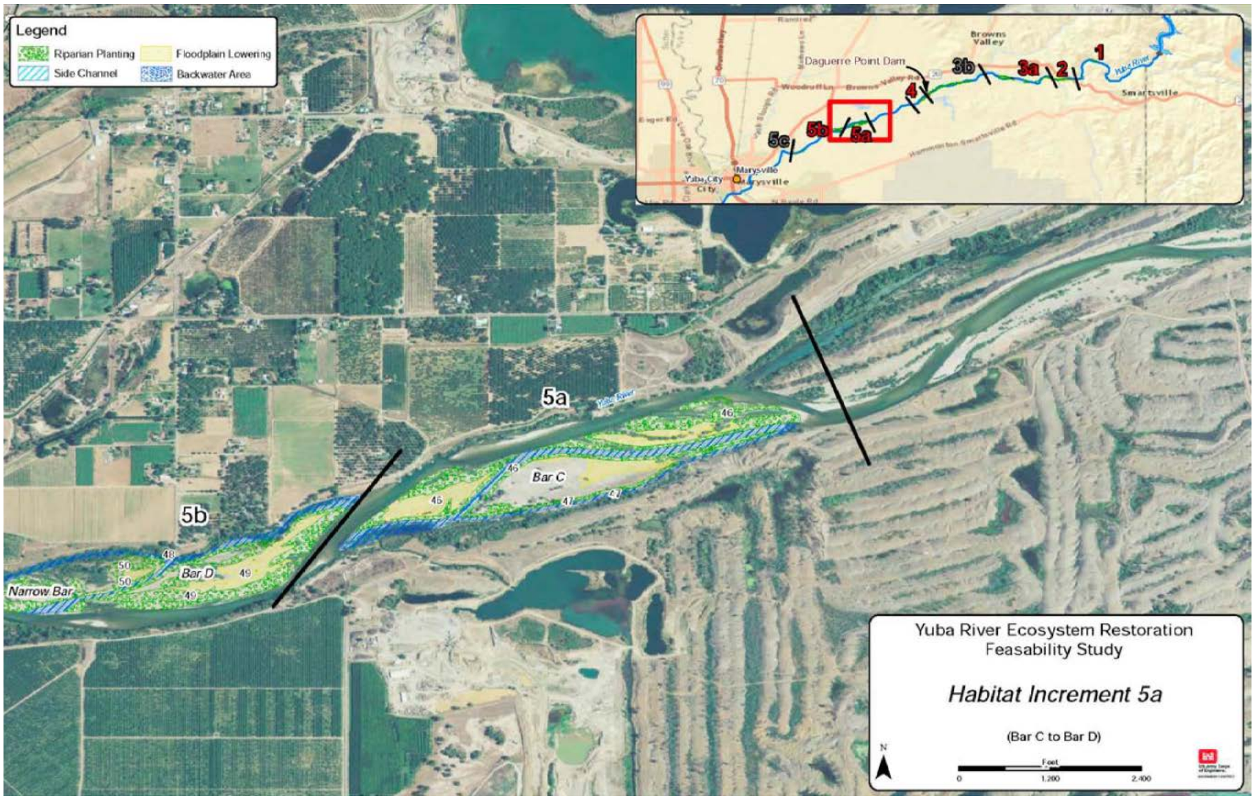


Figure 19. USACE 2017 design drawings, Habitat Increment 5a, 2009 Imagery.

Figure 20. Google Earth imagery 1993, USACE 2017 Habitat Increment 5a.

Figure 21. Google Earth imagery 2009, USACE 2017 Habitat Increment 5a.

Figure 22. Google Earth imagery 2017, USACE 2017 Habitat Increment 5a.

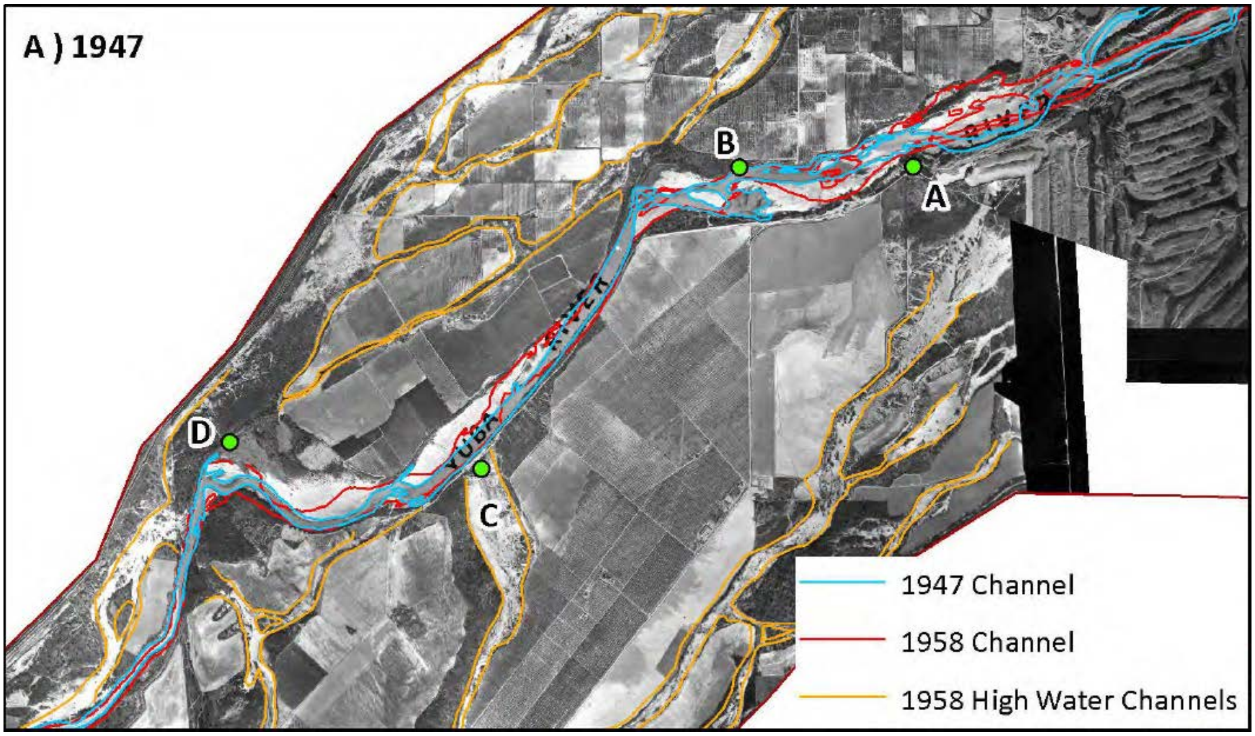


Figure 23. cbec (2013) aerial series plot A, Hallwood Reach.

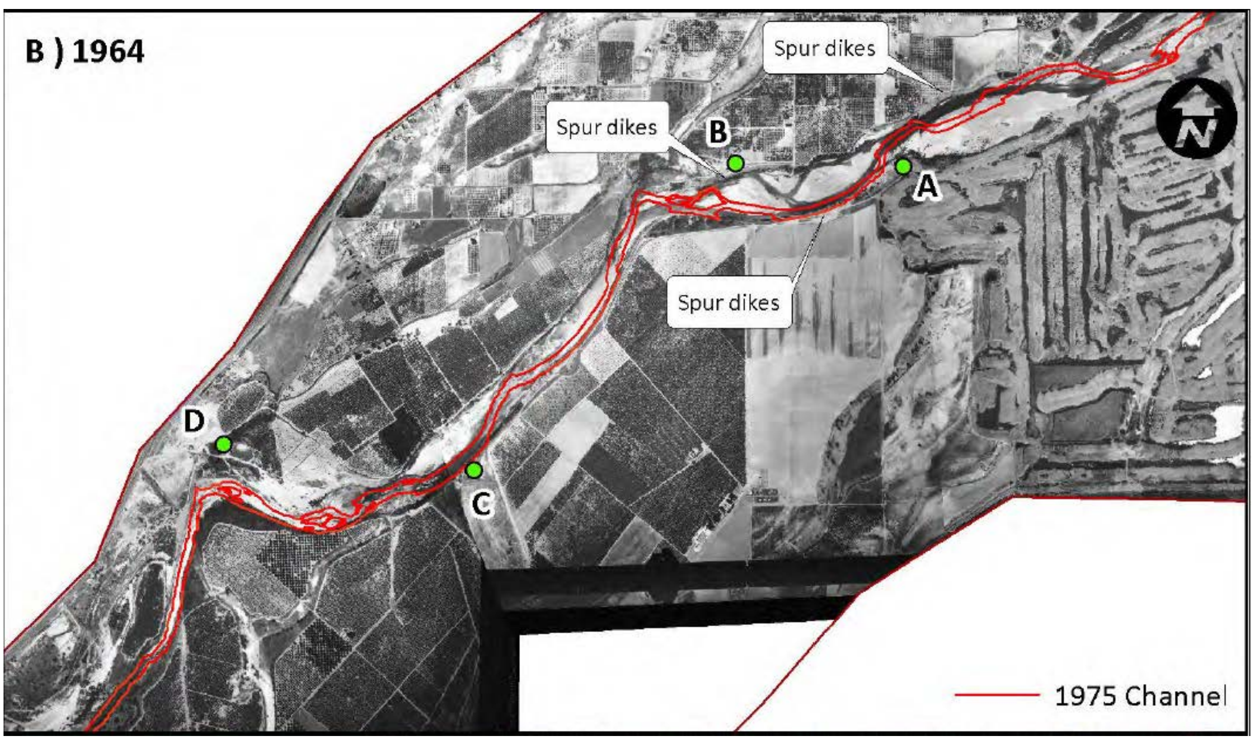


Figure 24. cbec (2013) aerial series plot B, Hallwood Reach.

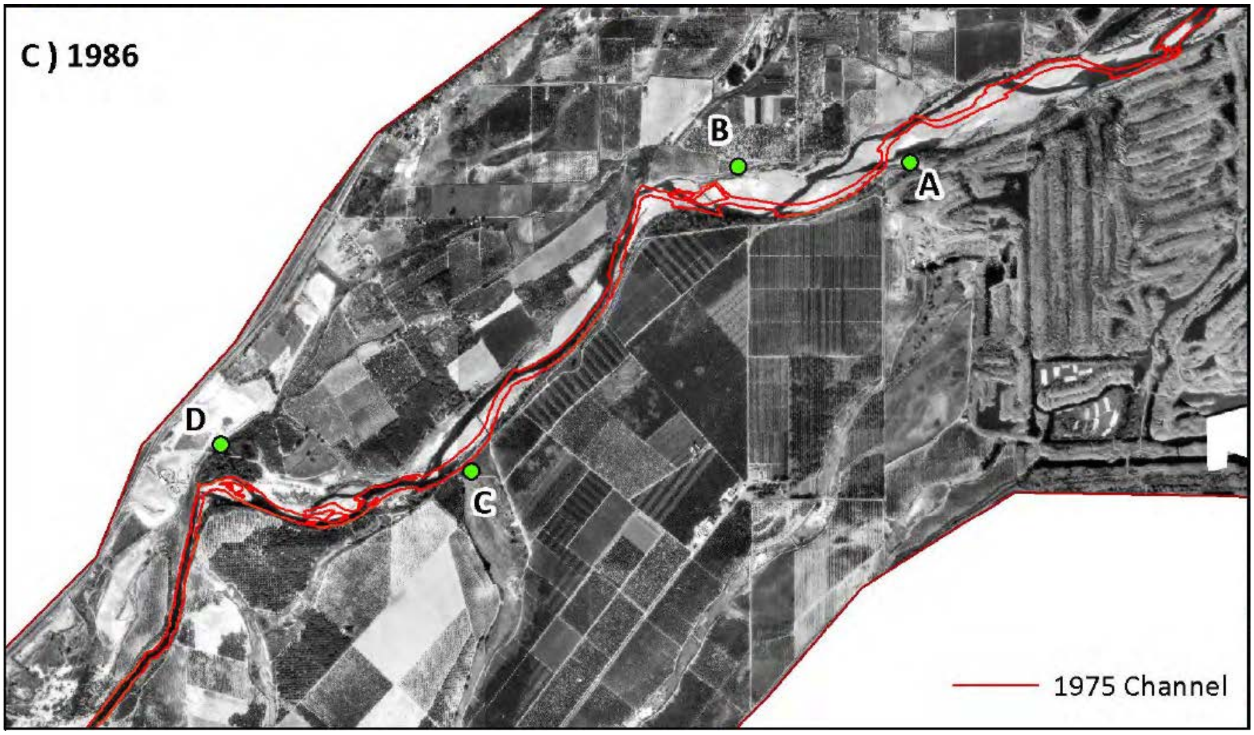


Figure 25. cbec (2013) aerial series plot C, Hallwood Reach.

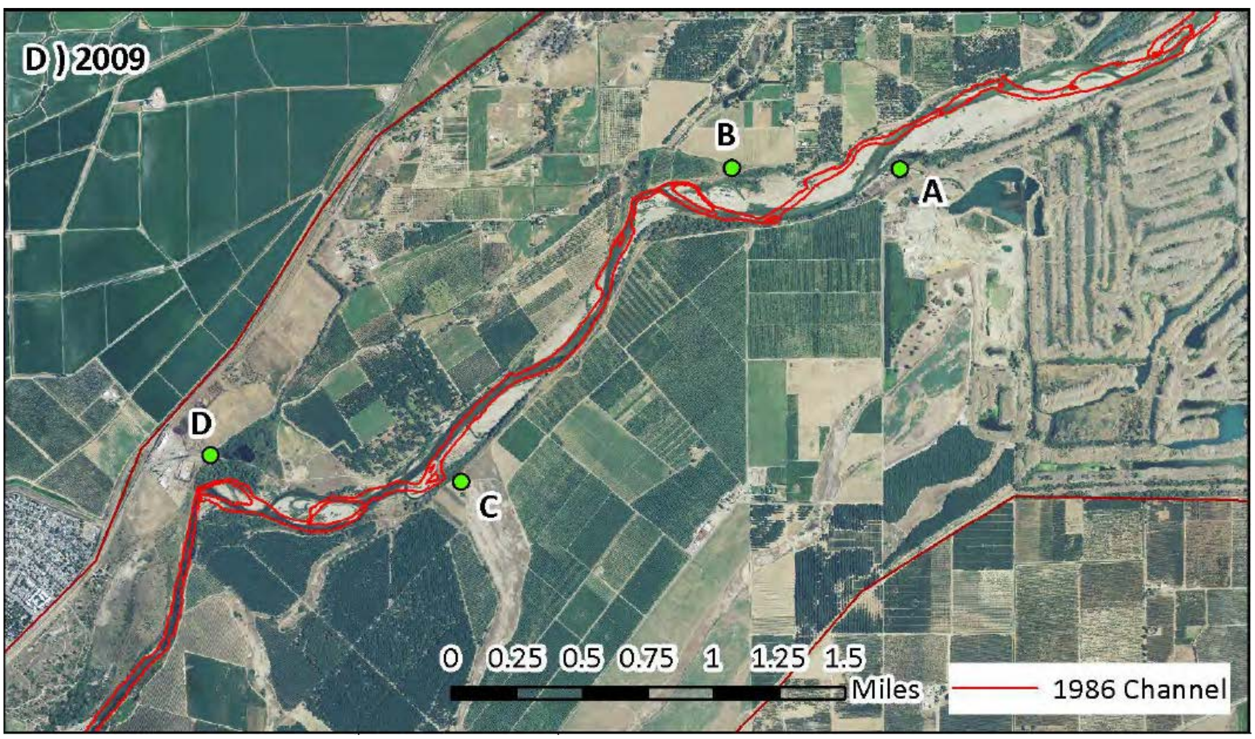


Figure 26. cbec (2013) aerial series plot D, Hallwood Reach.

Notes: 1947, 1964 and 1986 aerials from James (2012). 2009 aerial from the National Ag Imagery Program (NAIP). Channel alignments from James (2012).	cbec	*Hydrologic and Geomorphic Analysis to Support Rehabilitation Planning* **Geomorphic evolution at Hallwood Reach**		
		Project No. 13-1003	Created By: AMS	**Figure 8**

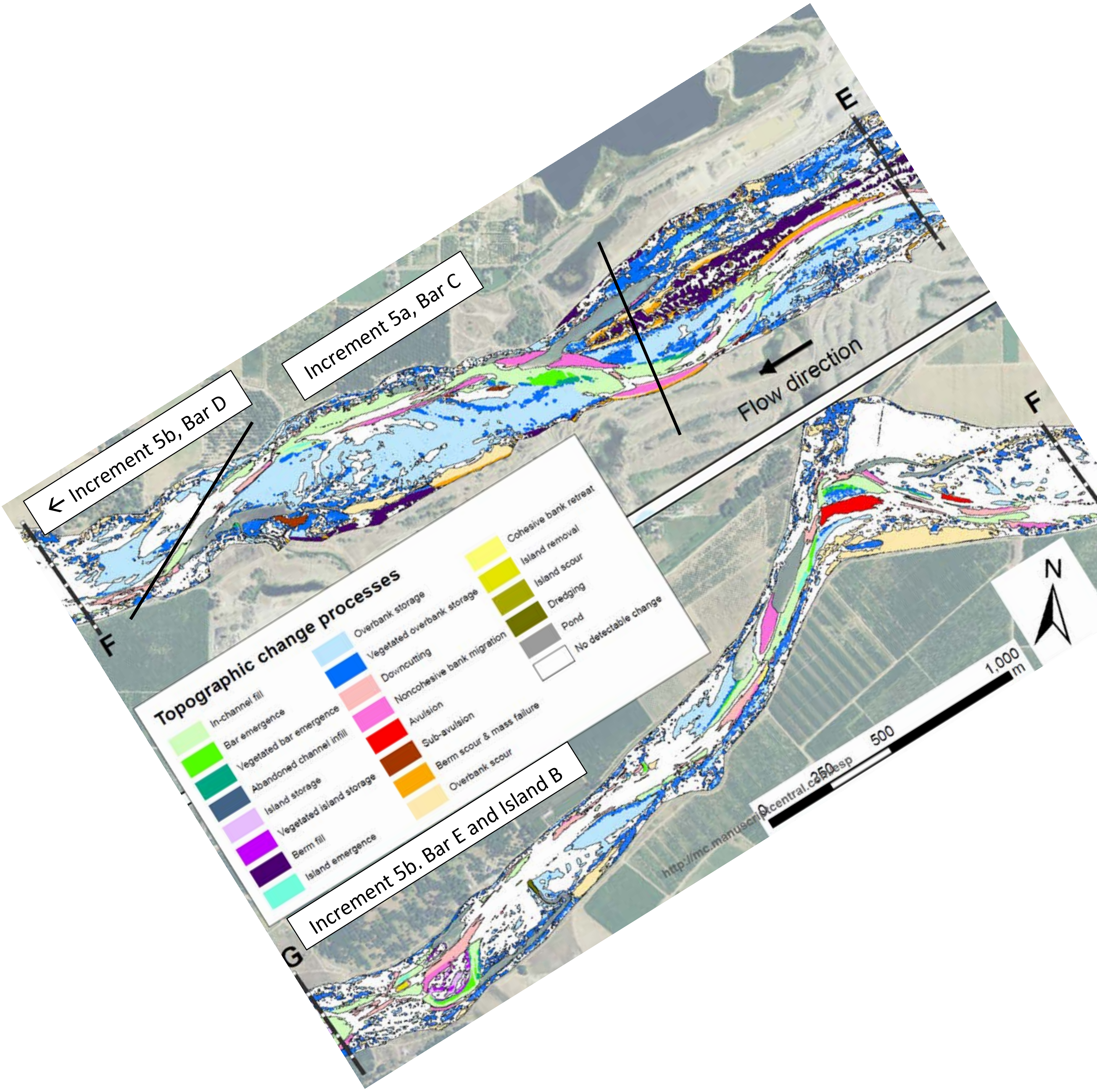


Figure 27. Wyrick and Pasternack, 2015, TCP area 5, orientation adjusted to match design. Habitat Increments labeled and boundaries marked with black solid lines.

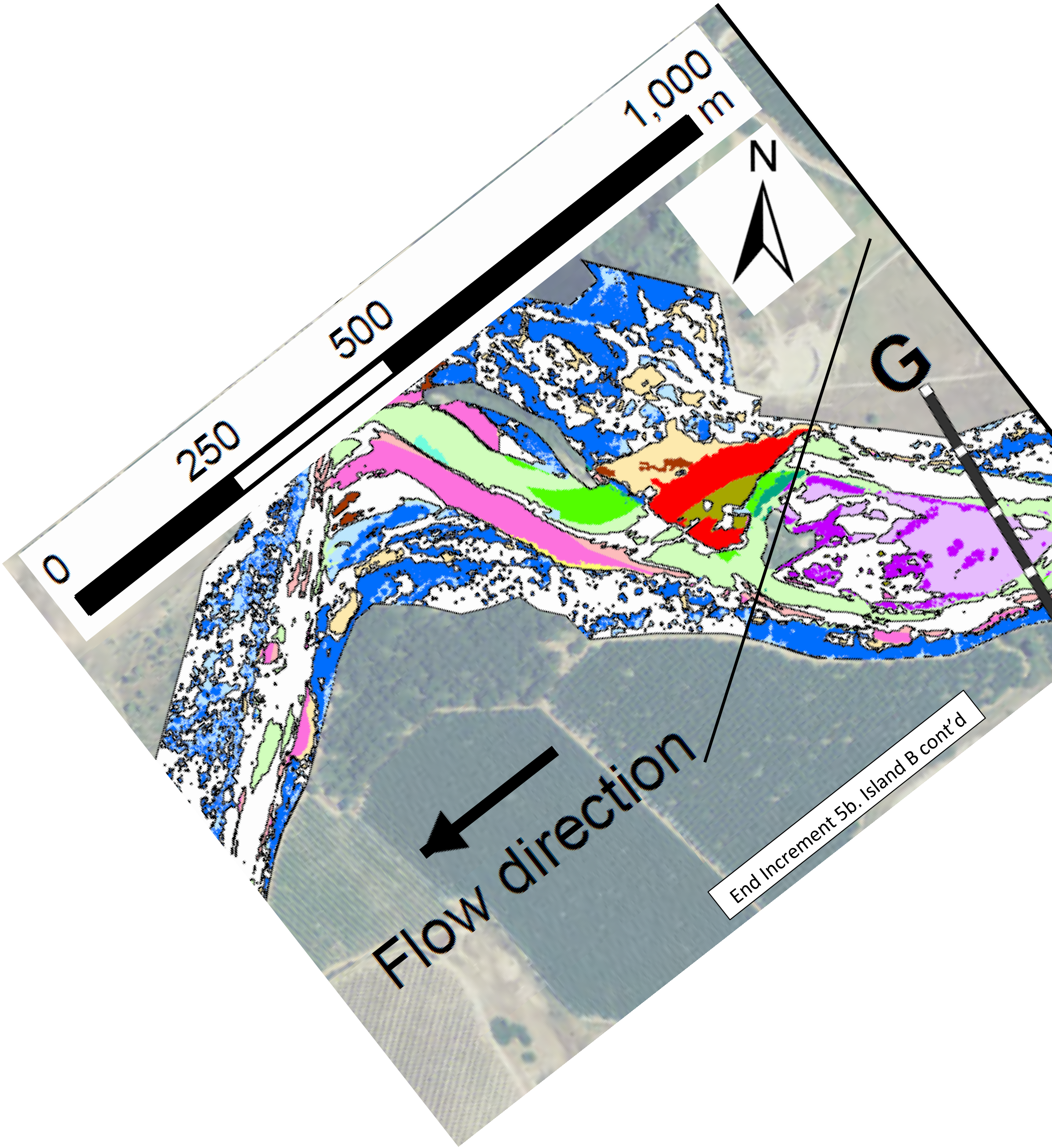


Figure 28. Wyrick and Pasternack, 2015, TCP area 5, orientation adjusted to match design. Habitat Increments labeled and boundaries marked with black solid lines.

Hallwood Reach – Increment 5b

Increment 5b is also located within Hallwood Reach, including Bar D, Narrow Bar, Bar E and Island B, including Measures 48, 49 and 50-54, including an anabranching side channel in a former swale, floodplain lowering, riparian planting, ELJ placement, two backwaters and LWM.

Historical aerial analysis in cbec (2013) shows significant shifting of number and location of channels at Narrow Bar (Bar D), with multiple channels in '64, single in '75, multiple in '86, and single after '98. Wyrick and Pasternack (2015) indicates the upper portion of Bar D as a "no discernible change" area, and while that's a relatively short period geomorphically speaking, the pattern persisted through the next 10-year period, through 2017, experiencing a 13 year event within the hydrologic regime of the period between 2008 and 2017.

With regard to installing an anabranching channel pattern at Bar D, the North channel may fill and the middle channel may shift location, though boulders to set grade in some areas should help. However, splitting flow into more than two channels increases risk of deposition by reducing transport capacity, and possibly avulsion or increased scour if one or more channels joins the others. Floodplain lowering with planting is relatively limited in area and confined to mid-bar areas, so may remain relatively stable if flow tends to occupy former locations, though the configuration shown for the mid-bar channel appears to transect apparent tree lines that mark former channel locations at the downstream end of the bar. If planting doesn't establish quickly and the side channel avulses, damages could be greater, though riparian planting covers most of the bar surface – if vegetation establishes quickly, likelihood of shifting channel locations may be reduced.

Some of the harder materials proposed in this Increment – stone, large wood – may be more susceptible to scour, though splitting flow into multiple channels may reduce transport capacity enough to offset concentrated turbulent scour around these structures. If structures are nonetheless scoured or undercut, the configuration could unravel, or simply be limited to one or more structures with function preserved. As long as side and back channels are maintained, deep backwater area is not likely to fill. Backwater at Lower Yuba River nr RM6.5 appears well vegetated, with some scour noted by Wyrick and Pasternack (2015) but otherwise classed as "vegetated overbank storage" between 1999-2008, making fill more likely dominant in this area.

In the area of Bar E, the back channel area that filled in between 1999-2008 is proposed to be stabilized with riparian plantings and LWM. Even though this area is recently filled, the configuration of the main channel is unlikely to resume this sharply curved side channel location - this appears to be an artifact left over from the mainstem shift from left bank to right bank in the '80's, and is more likely to persist.

Island B appears relatively persistent through the imagery record, with possible adjustment in bar extent, but low probability of changing appreciably considering the persistent location of this feature.

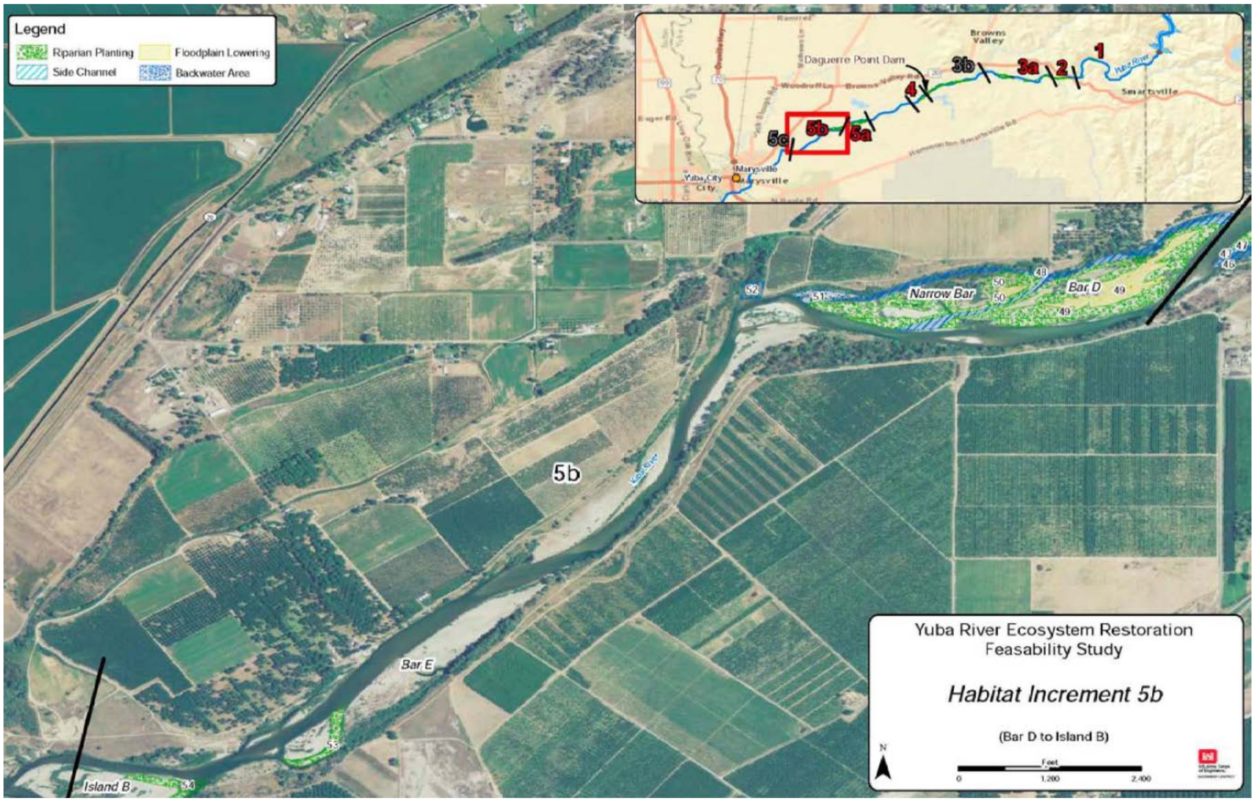


Figure 29. USACE 2017 design drawings, Habitat Increment 5b, 2009 Imagery.

Figure 30. Google Earth imagery 1998, USACE 2017 Habitat Increment 5b.

Figure 31. Google Earth imagery 2009, USACE 2017 Habitat Increment 5b.

Figure 32. Google Earth imagery 2017, USACE 2017 Habitat Increment 5b.

Damage, Probability and Risk Considerations

Risk is defined herein as the product of the probability of damage, loss, or any other adverse outcome caused by external or internal vulnerabilities, and the consequences of the outcome. By analyzing previous studies and the aerial imagery record, we can make some assumptions regarding the probability of an adverse outcome caused by channel change over the management timescale – that is, if the previous hydrologic regime and boundary conditions can be assumed to persist for the design life of the project, we can reasonably expect (or assume) similar types of channel change within a management timeframe (on the order of a few decades).

The amount of "damage" that various channel change processes would likely cause relative to the stated objective is a function of several factors, including the nature of the change (i.e. scour or fill), its severity and scale, the timing of the event (seasonally and relative to other events), antecedent conditions, and importantly, the susceptibility of various Measures to the type of change – e.g., deposition may result in minimal damage to a lowered, vegetated floodplain if the floodplain vegetation is not adversely affected, depending on materials used, or if deposition is within the 7-10 foot water table depth per most floodplain lowering designs specifying lowering to within 7 feet of water table in sections currently at 7-10 feet within water table. Alternatively, scour in those areas might also have low effect if vegetation is established, of if new vegetation colonizes reduced areas as long as the water table is still within the 0-7 foot design range. Replanting might be likelier to survive and increased roughness should encourage future sediment deposition as vegetation matures.

Drought can cause adverse outcomes in the absence of channel change, providing another vector for risk. Probability of droughts can be obtained from assessing the meteorological record (assuming stationarity) or using climate models. Similar to flood-induced channel changes, the consequences of drought are a function of the type of Measure employed and site conditions. The combination of these assessments should enable some assignment of rough risk categories resulting from each or both process types, cutting/scouring/degradation ("scour") or deposition/fill/aggradation ("fill"), in specific areas (i.e., location of each Measure) within each Habitat Increment.

Qualitative Damage Risk Assessment Methods and Results

Consequences of channel change in this study were roughly categorized by assessing channel change where Measures are proposed and assigning a qualitative damage probability category (e.g., very low – low – medium – high) that could be incurred from anticipated changes under a similar hydrologic regime over the next 10-50 years. Results of this assessment are presented in the attached Excel spreadsheet as a Measures Matrix.

**Special note on damage probability: only impacts from flood events were assessed here – impacts from browse, drought, disease, vandalism or other hazards should be included for a more complete assessment of total risk.

Detailed categorical inputs for qualitative damage probability and severity analysis was conducted for each Measure and component parts (where relevant) in Increments 2, 3a, 5a and 5b, to enable evaluation based on materials used, degree of disturbance to sediment deposits and location within each complex of morphological features, also summarized in the Measures Matrix. For example, riparian planting is considered as a separate treatment from floodplain lowering, though floodplain lowering includes similar planting design. This is due to the effect of excavation disturbing surface sediment deposits for the first few years, potentially decreasing the shear required to mobilize those sediments, particularly if a formerly existing armor layer has been removed and finer sediments lay below. Similarly, structural measures (boulders, large wood) are considered separately from associated backwater or side channels, considering that an engineered log jam, large woody material or riprap have differing critical shear resistance, themselves differ from native cobble and gravel material, and may increase local scour or deposition patterns.

For time-lumped analysis of potential damage, the sources noted above were assessed for the periods of record or analysis, combined with the dominant processes noted for each reach defined by cbec (2013), the specific areas and types of change noted by Wyrick and Pasternack (2015), the type and location of measure to be implemented, and professional judgment used to assign damage category, probability, and severity should the event or anticipated change occur. Increment-specific assumptions and thought processes are described, with appropriate imagery and mapping records, in report sections below, and summarized in short, targeted notes in the Measures Matrix.

Attachment HH-C: Climate Change Assessment

Climate Change Impacts on Inland Hydrology in the Feather - Yuba River Watershed Yuba River Ecosystem Restoration Project

Overview:

Introduction: ECB No. 2016-25 requires Corps planning studies to provide a qualitative description of climate change impacts to inland hydrology. The objective of ECB 2016-25 is to enhance USACE climate preparedness and resilience and reduce vulnerabilities by incorporating relevant information about climate change impacts in hydrologic analyses for new and existing USACE projects. The purpose of this section is to meet the requirements as set forth in the ECB. The purpose of this section is to apply the qualitative analysis guidance required in ECB 2016-25 to inland hydrology of the Sacramento River Valley including the Yuba River Watershed, and facilitate the incorporation of climate change impacts on hydrologic analyses in plans and designs for the Yuba River Ecosystem Restoration Project (See Figure 1). Up to the present time, USACE projects and operations have generally proven to be robust in the face of natural climate variability over their operating life spans. However recent scientific evidence shows, that in some geographic locations and for some impacts relevant to USACE operations, climate change is shifting the climatological baseline about which natural climate variability occurs and the range of the variability may be changing as well (USACE 2015, USGCRP 2014). Climate change information for hydrologic analyses includes direct changes to hydrology through changes in temperature, precipitation, evaporation rates, and other climate variables, as well as dependent basin responses to climate drivers, such as sedimentation loadings.

Two phases are required to conduct the qualitative analysis required by the ECB (Figure 1). The analysis includes consideration of both past (observed) changes as well as potential future (projected) changes to relevant hydrologic inputs. The qualitative approach on its own will not produce binding numerical outputs or alter the numerical results of the calculations made for other, non-climate aspects of the required hydrologic analyses. However, the qualitative analysis can inform the decision process related to future without project conditions, formulation and evaluation of the performance of alternative plans, and other decisions related to project planning, engineering, operation, and maintenance. Some examples of how a qualitative assessment may affect a project design include considering whether the project could be modified in the future, whether a strategy should be considered to accommodate projected future conditions, or whether one project alternative can be judged to reduce vulnerabilities or enhance resilience more than the others.

At the time of this study, the methods for incorporating climate change into the planning process are still developing. Additional guidance documents will be published in the future to support quantitative analyses of climate threats and impacts, including the detection of trends, attribution of these trends to climate change, and projections of future trends.

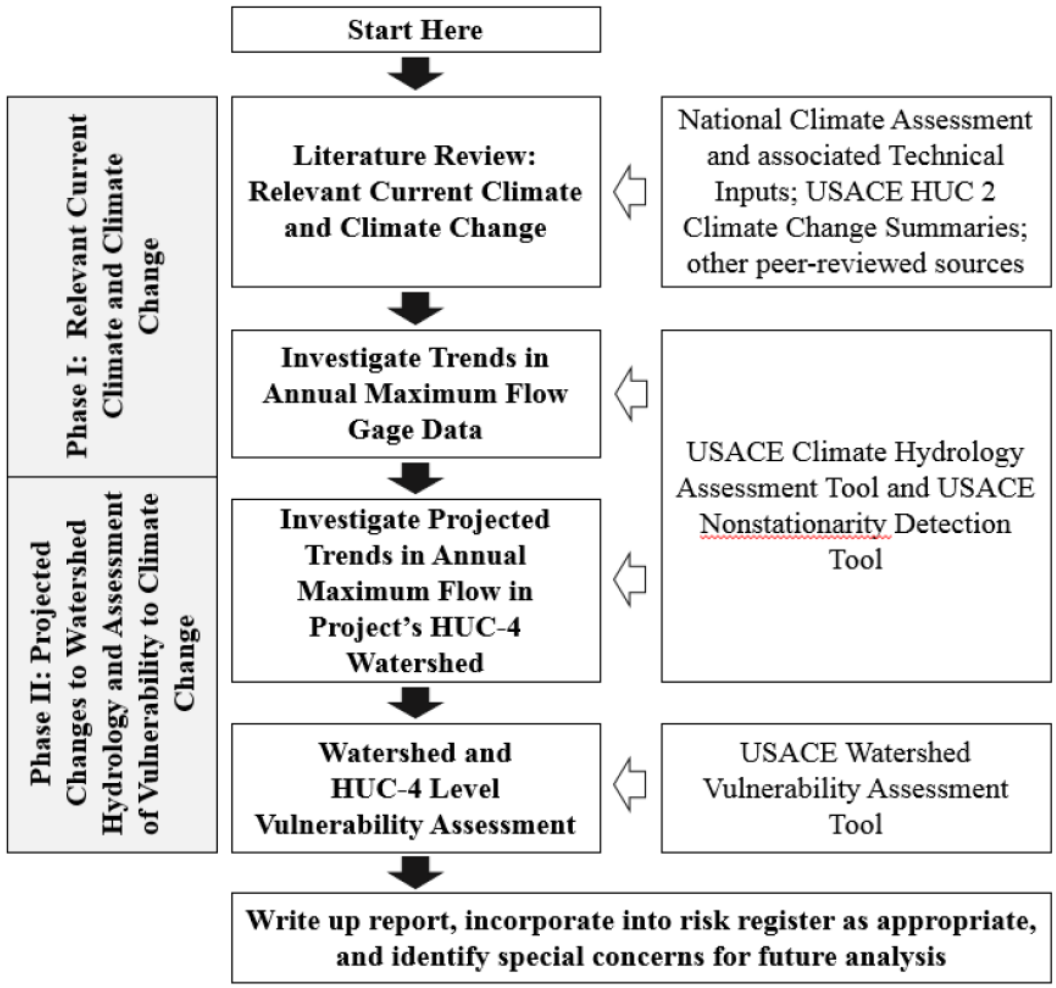


Figure 1 Flow Chart describing the qualitative climate change assessment to be used in Hydrology studies for Corps projects. From ECB 2016-25, Attachment B.

Project Description:

The principal features of the Yuba River Ecosystem Restoration Project (YRERP) include restoration of approximately 43 acres of aquatic habitat including side channels, backwater areas, bank scallops, and channel stabilization. These features will provide shallow, low velocity, rearing habitat and refugia for juvenile anadromous salmonids and potentially increase benthic macroinvertebrate producing habitat. Engineered log jams (ELJs) and placement of boulders and large woody material have been incorporated in the YRERP at strategic locations. ELJs and boulders will be placed at actively eroding banks or sites with high velocities and shear stresses. These features will promote bank stabilization, add structural complexity, provide velocity refuge for juvenile fish, and modify local hydraulics and sediment transport.

YRERP also includes about 136 acres of riparian habitat restoration consisting of floodplain lowering and grading and riparian vegetation plantings, which will increase the quantity and quality of riparian habitat in the river corridor. The YRERP addresses fragmentation of habitat by targeting areas adjacent to existing vegetation that have been unable to initiate revegetation through natural processes due to substrate composition and depth to groundwater. Floodplain lowering reconnects the river to its floodplain and makes planting feasible where it was not previously due to excessive groundwater depths. Four native species will be planted to provide species and structural diversity, including arroyo willow which is known to support neotropical bird habitat (RHJV 2004). When the restored riparian habitat is inundated by high flows, it will also function as aquatic habitat, providing additional feeding habitat and refugia for juvenile fish.

To various degrees, the YRERP addresses all of the objectives of the feasibility study. Longitudinal river connectivity would be increased by improving approximately five river miles of aquatic habitat, improving refuge, rearing, and food production options for migrating fish along the lower Yuba River. The YRERP will also reduce gaps between areas of suitable aquatic habitat, including other restoration projects such as the Hallwood Side Channel and Floodplain Restoration Project and the Hammon Bar Restoration Project.

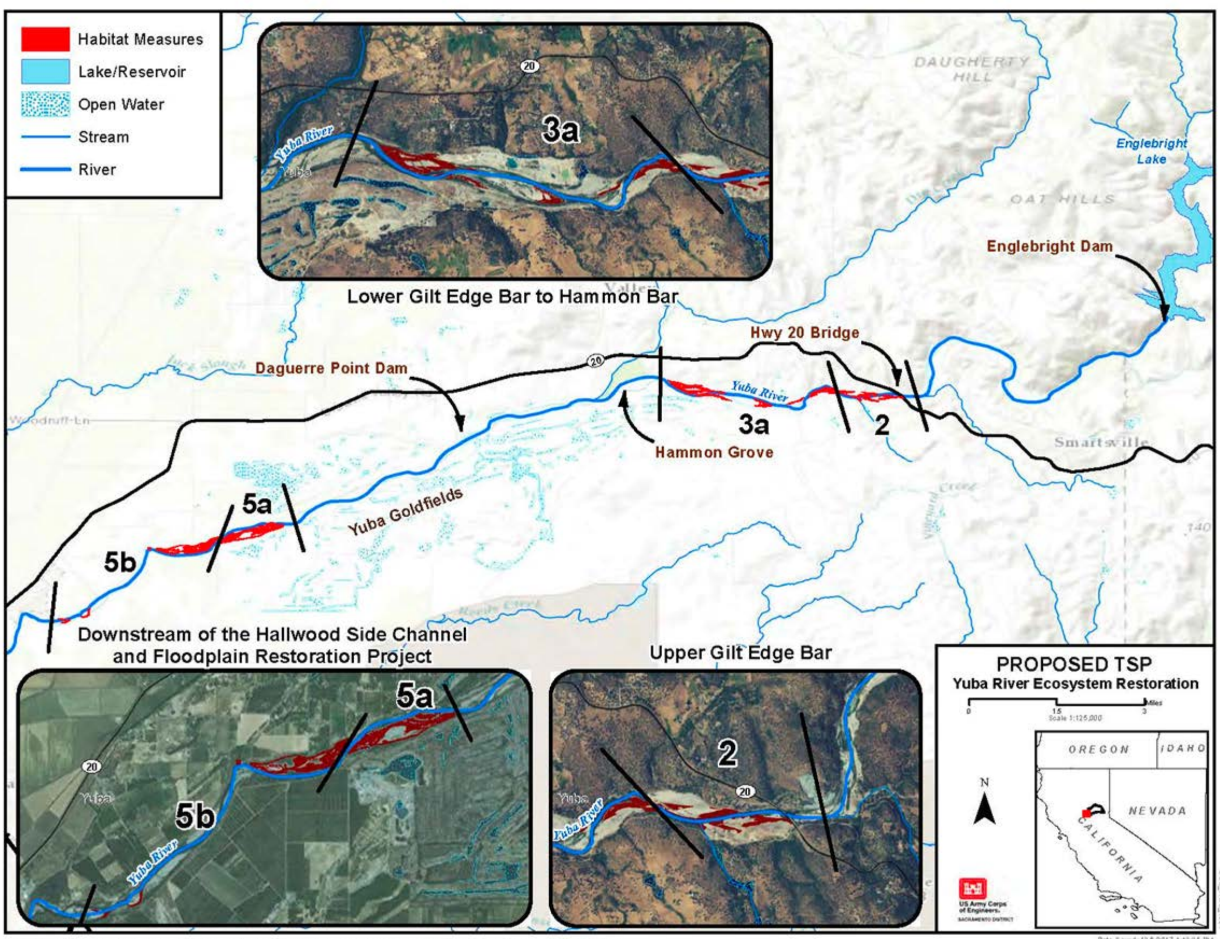


Figure 2 Yuba River Ecosystem Restoration Project tentatively selected plan

Successful restoration could depend on one or more of the following variables, some of which will likely be impacted by climate change.

- Hydrology/water management
- Suspended sediment
- Fresh water plant communities

The hydrology of the Yuba River Watershed is regulated by numerous Federal, State and local water projects including diversions and dams.

Literature Synthesis:

Projected changes in future climate contain significant uncertainties related to our understanding and modeling of the earth's systems, as well as our ability to forecast future development and greenhouse gas emission pathways. There are also a great deal of uncertainties associated with simulating changes at a local scale and at a time-step relevant to hydrologic analysis (USACE 2015, USGRP 2014).

USACE Climate Preparedness and Resilience Community of Practice Literature Review:

A 2015 USACE climate literature report synthesizes literature for HUC-2 Region 18 (California Region; Figure 4), focusing on the identification and detection of climate trends (USACE 2015). The approach at USACE is to consider the questions in need of climate change information at the geospatial scale where the driving climate models retain the climate change signal. As of 2015, USACE judged that the regional, sub-continental climate signals projected by the driving climate models were coherent and useful at the scale of the 2-digit HUC and that confidence in the driving climate model outputs declines below the level of a reasonable trade-off between precision and accuracy for areas smaller than the watershed scale of the 4-digit HUC.

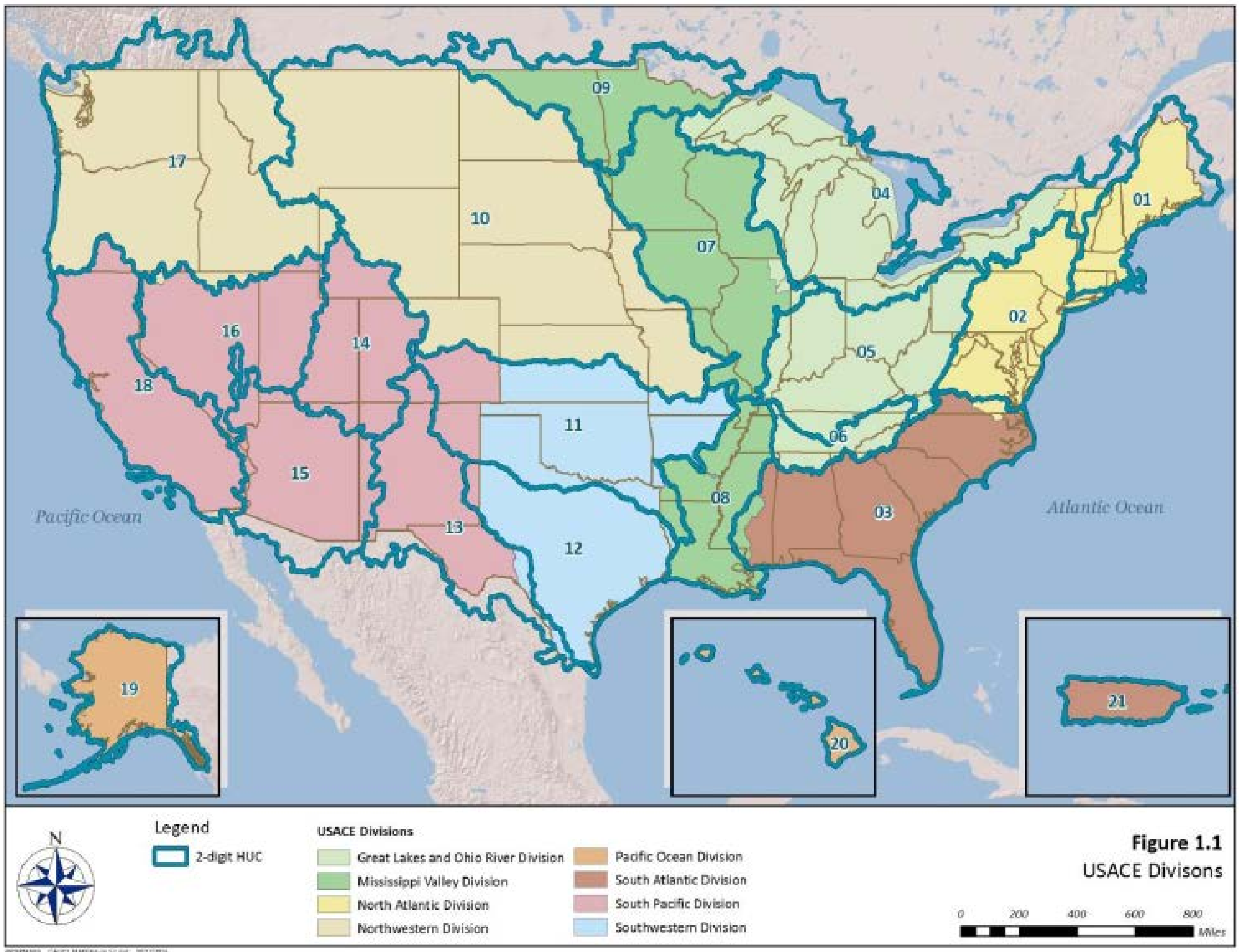


Figure 3: HUC-2 Region for USACE Literature Synthesis (USACE 2015)

Key findings of the USACE literature review are listed below. Figure 3 summarizes the key variables identified in the report and variables for which consensus exists about current or projected trends.

- In general, there appears to be an increasing trend in both minimum and maximum historical temperatures in the California Region with relatively strong consensus in the literature.
- Strong consensus exists in the literature that projected mean, minimum, maximum, and extreme temperatures in the study region show an increasing trend over the next century.
- No consistent trend has been identified in the region's historical precipitation data, with little consensus across the literature.
- Large variability exists, spatially, and across model projections, for future precipitation trends within the California Region. There is little consensus across the literature as to how precipitation trends will change, although many studies recognize this variability.

- Despite the low consensus in precipitation trends, extreme precipitation events are projected to increase in intensity.
- Literature on observed streamflow trends in the California Region have very low consensus. The majority of studies suggest that no statistically significant trends have been identified in the region's streamflow data for the latter half of the 20th century, although advances in the timing of spring runoff and reductions in April 1 SWE were observed.

The USACE literature synthesis also summarizes potential climate impacts by line of business. For the ecosystem restoration line of business in the California Region, the report lists the following impacts:

- Increased ambient air temperatures and heat wave days will result in increased water temperatures. This may lead to water quality concerns, particularly for the dissolved oxygen levels, which are an important water quality parameter for aquatic life. Increased air temperatures are associated with the growth of nuisance algal blooms and influence wildlife and supporting food supplies.
- Increased storm intensities and frequencies may pose complications to planning for ecosystem needs and lead to variation in flows. This may be particularly true during dry years, when water demands for conflicting uses may outweigh water supply.

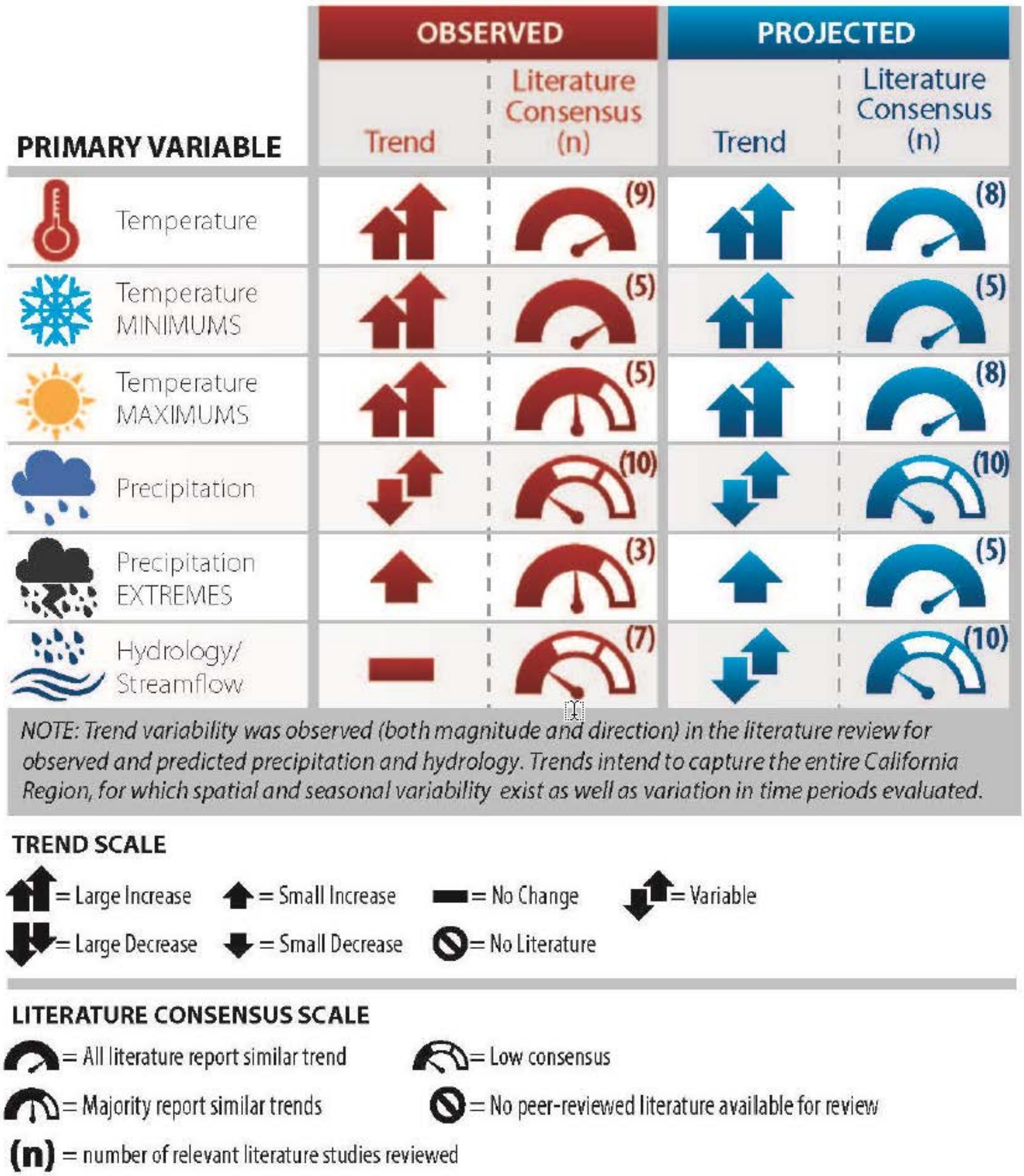


Figure 4. Summary of USACE Literature Synthesis (USACE 2015)

USACE Sacramento District Project Climate Assessments:

The Sacramento District (SPK) has completed climate assessments for specific projects in the Sacramento and San Joaquin River Basins. The literature review from those assessments is included in this section below.

Recent surface observations of temperature and precipitation in the southwest United States including the Central Valley of California indicate a significant warming trend starting about 1970 (NOAA, 2013, Goodrich, 2007). This recent warming trend is especially noticeable in the minimum temperatures during the interval from 1990 to about 2005. This warming is in addition to more general warming trends from about 1890 to the present. The reasons cited among scientists include natural multi-decadal oscillations, increased greenhouse gases in the atmosphere, land use changes, and urban heat island effects (NOAA, 2013; Levi, 2008; Barnett et al. 2008; Das et al., 2011). Current reported temperature trends and future climate projections indicate warmer winter temperatures and some changes in precipitation in the Central Valley, and this leads to an increased risk of flooding from large storms (CH2M Hill 2014, NOAA 2013).

Projected changes in future climate contain significant uncertainties related to our understanding and modeling of the earth's systems, as well as our ability to forecast future development and greenhouse gas emission pathways. There are also a great deal of uncertainties associated with simulating changes at a local scale and at a time-step relevant to hydrologic analysis. Climate models suggest the projected temperature signal is strong and temporally consistent. It has been projected that air temperatures will increase by over 3 degrees Fahrenheit by the middle of the current century. All projections are consistent in the direction of the temperature change, but vary in terms of other hydrometeorological variables (precipitation, streamflow, seasonality, variability, extremes etc.). For example, annual precipitation projections are not directionally consistent. Multi-decadal variability complicates period precipitation analysis. Regional trends indicate that it is more likely for the upper Sacramento Valley to experience equal or greater precipitation. Extreme precipitation is likely to increase (Das et al., 2013; NOAA, 2013; CH2M HILL, 2014).

Simulations with global climatic models (GCMs) are mostly consistent in predicting that future climate change will cause a general increase in air temperatures in California during the critical months when the most precipitation falls. November through March is the period when the most significant and damaging storms hit this region. The Yuba River, which flows through Englebright Dam, has many high elevation mountains with peaks ranging from 5,000 to 11,000 feet above sea level. Significant portions of these watersheds are covered in snowpack during the winter months. As temperatures warm during the century, it is expected that the snowpack line (demarcation between bare ground and snowpack-covered ground) will recede to higher elevations, and a greater percentage of the drainage area of individual watersheds will incur rainfall, as opposed to snowfall (DWR 2017,USACE, 2015, USGRP 2014, NOAA 2013). This trend is expected to cause significant increases in runoff volume in the high elevation watersheds for large storms. Another impact of warmer air temperatures on the seasonality of flooding in the study area is that the spring snowpack will melt earlier, thus increasing reservoir inflows at a time when spring storms still threaten the region and empty space is still required to attenuate flood inflows. In other words, flood control operations at reservoirs could become more difficult in the spring months. The snowpack typically begins to melt in late March or early April. With the projected increase in temperatures during the coming decades, the snowpack will begin to melt earlier in the year (i.e. early to mid-March or sooner). This will overlap the time in which large atmospheric river storms normally hit the region. Therefore, more rain on snow events are likely to occur. Additionally, more of the watershed will be exposed to rainfall runoff processes because the snowlines on average will be higher than during the base period. The trend towards earlier spring snowmelt has already been observed in the Sierra Nevada Mountains over the last century (DWR 2017, USACE 2015, USGRP, 2014, NOAA 2013).

With less certainty than above, some global climate models indicate that future conditions may increase the amount of moisture in the storms, since warmer air holds more moisture than cold air. When air cools, condensation occurs, which causes precipitation. It is possible that due to increasing temperatures, atmospheric rivers will have higher precipitation depths in the future because the warmer air can hold more moisture than cooler air, and this will lead to an increase in the size of runoff peaks and volumes. The largest storms that typically impact the west coast of the United States are termed "pineapple express" or more recently "atmospheric rivers" by meteorologists. This type of event occurs when a long plume of saturated air moves northeastward from the low-latitudes of the Pacific Ocean and mixes with cold dense air moving southward from the arctic. The mixing of cold and warm air causes a storm front. As these very moist storms move eastward over the Sierra Mountain Range, the air is pushed to higher elevations where more cooling occurs, thus increasing condensation and precipitation. Historically, the largest and most damaging floods in the Central Valley of California are caused by atmospheric rivers (USACE 2015, USGRP 2014, CH2M HILL 2014, NOAA 2013).

Climate projections (CMIP5) consistent with the most recent Intergovernmental Panel on Climate Change (IPCC) Assessment Report 5 (AR5) are available to evaluate future, projected climate (Taylor et al., 2012). Three on-going, DWR-supported research studies were initiated in 2013, which apply CMIP5 data to hydrologic analysis. These include the Climate Variability Sensitivity Study (completed by the Corps in 2014) which evaluated the effects of increasing temperature only (not precipitation) on flood runoff on selected watersheds in the San Joaquin River Valley. The results from this study indicate that warmer temperatures would reduce the volume of the antecedent snowpack and increase the storm runoff due to more precipitation falling as rain and larger portions of the watersheds contributing runoff. The other two include the Atmospheric River Study (led by Scripps Institute of Oceanography/USGS) investigating indices and future projections of the major flood-producing atmospheric processes, and the Watershed Sensitivity Study (led by UC Davis) investigating the atmospheric and watershed conditions that contribute to the extreme flows on several Central Valley watersheds. This study shows that annual runoff and event runoff will occur earlier in the season as a result of increasing temperatures and declining snowpack. The California Department of Natural Resources (DWR) has invested millions of dollars to study climate impacts on the flood control system in the Central Valley. Results were recently published in the *Draft 2017 CVFPP Update– Climate Change Analysis Technical Memorandum* dated March 2017. The results are based on downscaled outputs from a subset of the Coupled Model Intercomparison Project – Phase 5 (CMIP5) global climatic models, which DWR has determined are most suitable for modeling climate change on the west coast of California. The downscaled results are fed into a calibrated variable infiltration capacity (VIC) rainfall runoff model of the Sacramento and San Joaquin River watersheds. The DWR analysis relies upon existing, available climate projections and hydrologic modeling to represent a range of potential future changes to unregulated flow volumes due to climate change. The draft results provided by DWR have projections of volume change for 1-day and 3-day durations at many index points throughout the Sacramento River, including the American River Watershed. DWR results indicate the potential for an increase in 1-day and 3-day streamflow peaks within the study area.

Major Studies:

Climate assessments are in progress or have been completed by organizations with water management responsibilities in the Sacramento and San Joaquin River watersheds (Table 1).

Table 1. Climate Change Studies and Assessments Applicable to HUC 1802 and 1804 Regions

Study Name and Organization	**Purpose**	**Climate Models/Scenarios**	**Status/Results**
Climate Variability Sensitivity Study (CVSS) (USACE 2014)	Evaluation of the effects of increasing temperature only (not precipitation) on flood runoff on selected watersheds in the San Joaquin River Valley. Uses curves developed for CVHS below.	TBD	Results indicate that warmer temperatures would reduce the volume of the antecedent snowpack and increase the storm runoff due to more precipitation falling as rain and larger portions of the watersheds contributing runoff.
Central Valley Hydrology Study (CVHS) USACE (date?)	Development of flow-frequency relationships at two hundred locations in the Central Valley using historical flow data and rainfall-runoff watershed models	TBD	
West-Wide Climate Risk Assessment for the Sacramento and San Joaquin Basins Climate Impact Assessment (Bureau of Reclamation 2014)	Reconnaissance-level assessment of climate risk to water supplies and related resources	TBD	
Draft 2017 CVFPP Update – Climate Change Analysis Technical Memorandum (DWR 2017)		TBD	
Scripps Atmospheric River Studies and UC Davis Watershed Sensitivity Study (Scripps – ongoing; UC Davis unknown)	Scripps/USGS: Investigation of indices and future projections of the major flood-producing atmospheric processes. UC Davis: Investigation of the atmospheric and watershed conditions that contribute to the extreme flows on several Central Valley watersheds.	TBD	This study shows that annual runoff and event runoff will occur earlier in the season as a result of increasing temperatures and declining snowpack

Phase I Trends in Observed Records:

Historical Precipitation and Temperature Data

Historical temperature, precipitation, and drought index data for 1895-2018 are available from NOAA National Centers for Environmental Information (Figure 4 - Figure 9). California Climate Division 2 represents Sacramento Drainage (HUC 1802) which includes the Yuba River Watershed (NOAA NCEI 2018).

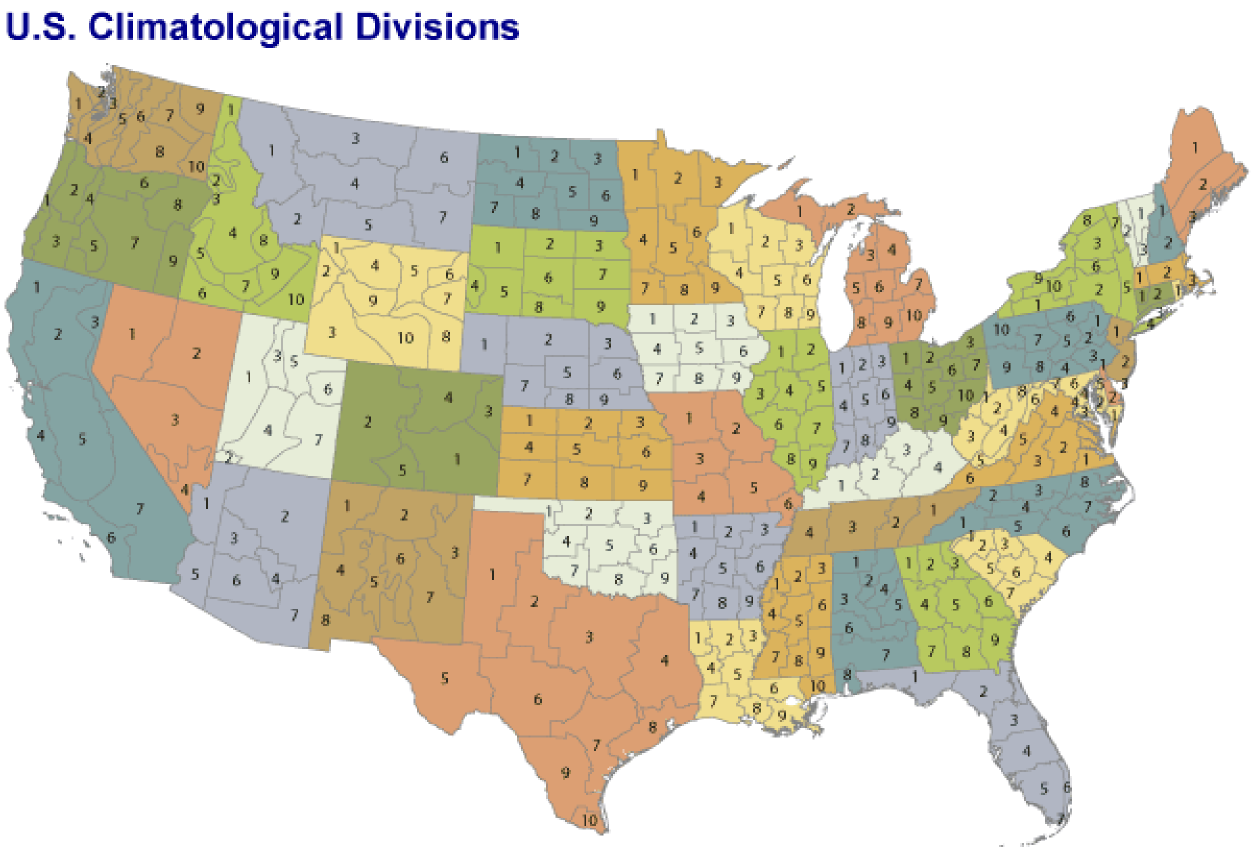


Figure 4 US Climatological Divisions (NOAA NCEI 2018)

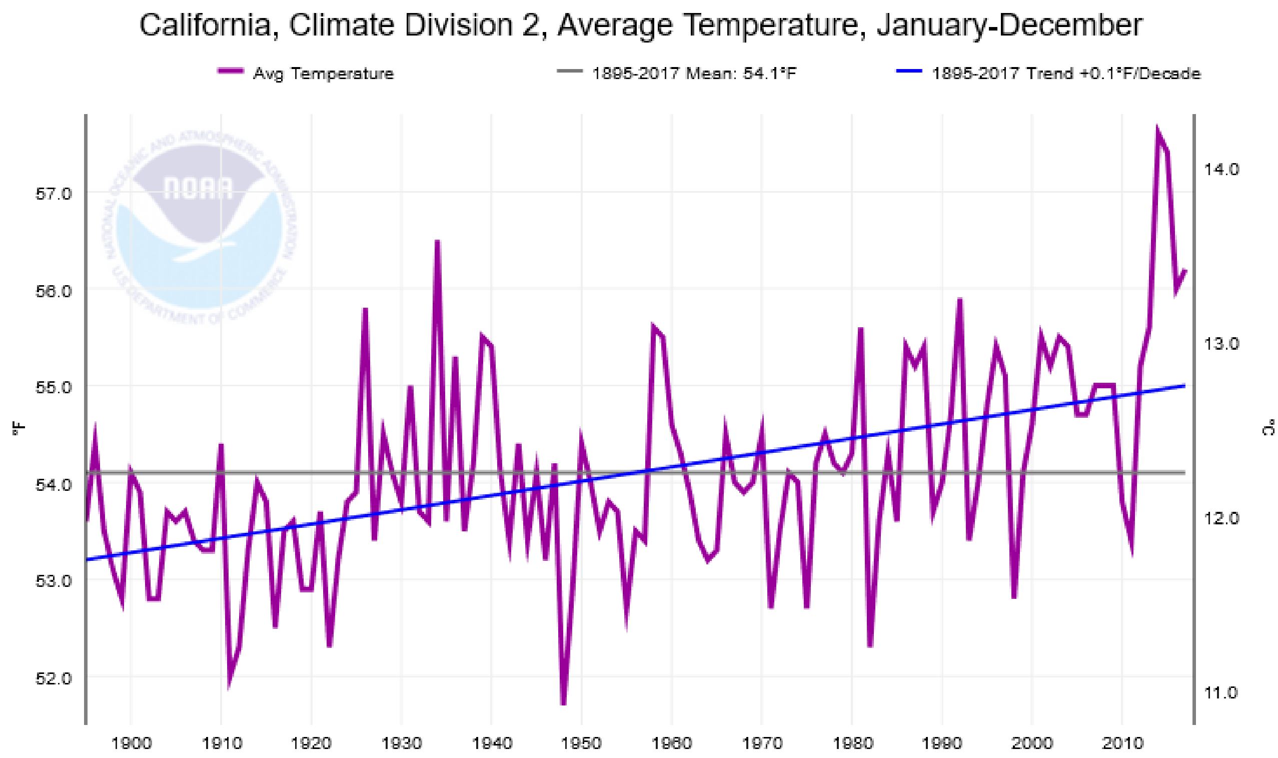


Figure 5: Average Annual Temperature for Sacramento HUC 1802 Watershed

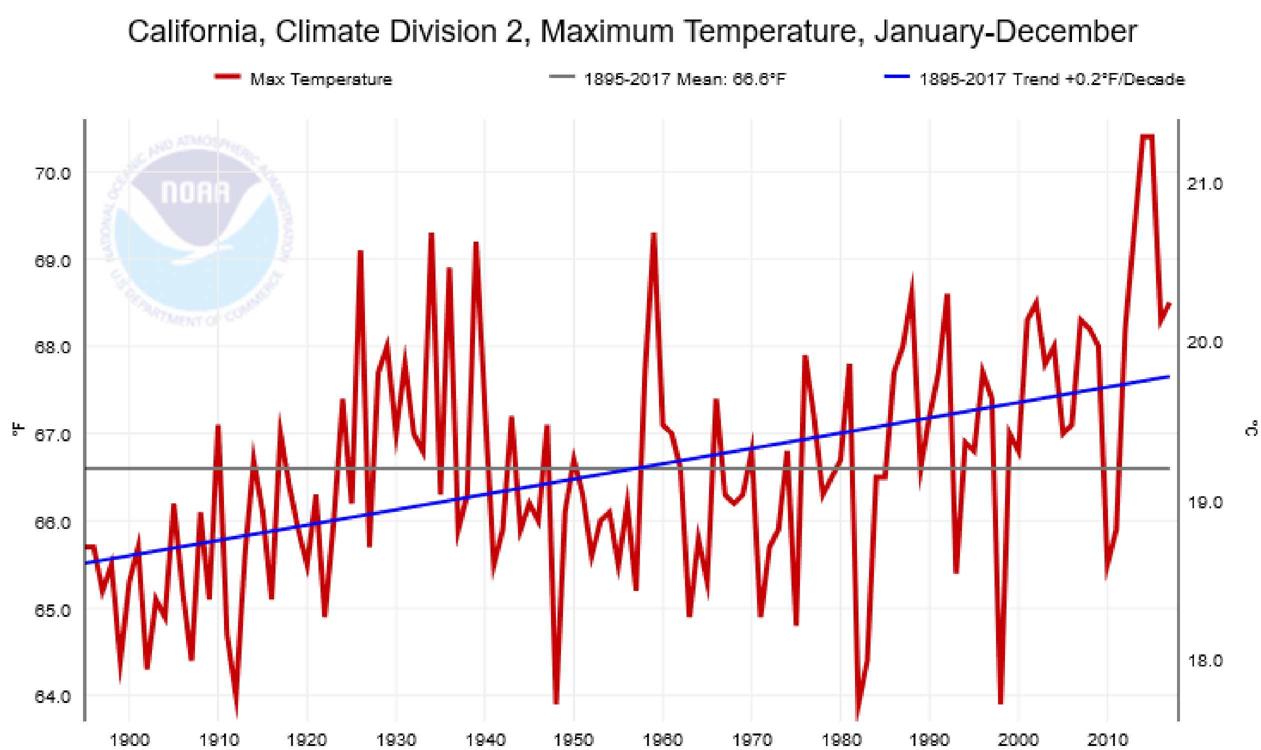


Figure 6: Annual Maximum Temperature for the Sacramento Watershed.

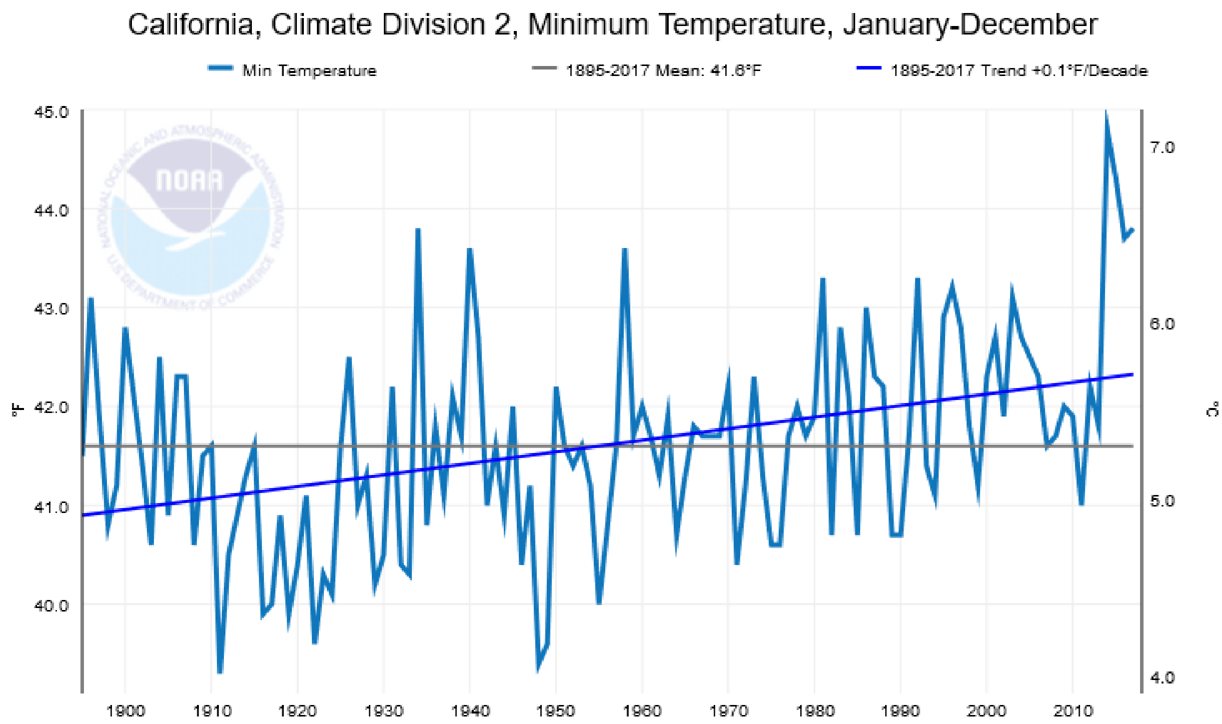


Figure 7: Annual Minimum Temperature for Sacramento Watershed.

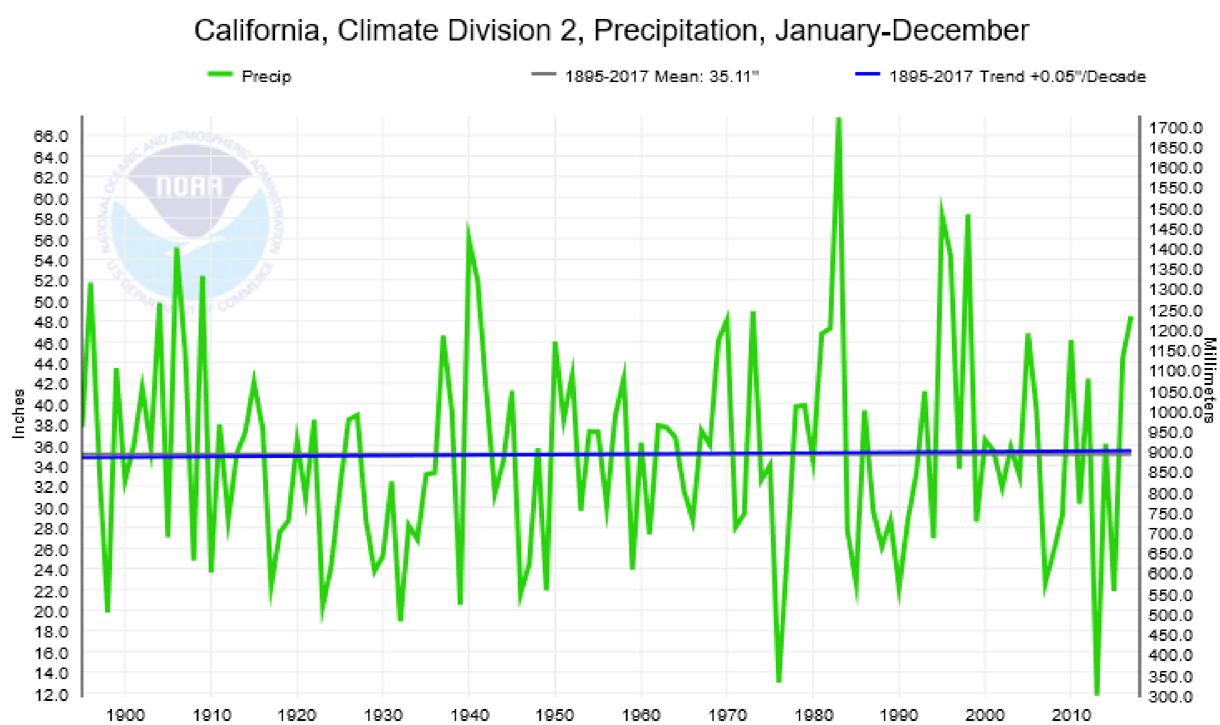


Figure 8: Annual Precipitation in the Sacramento Watershed.

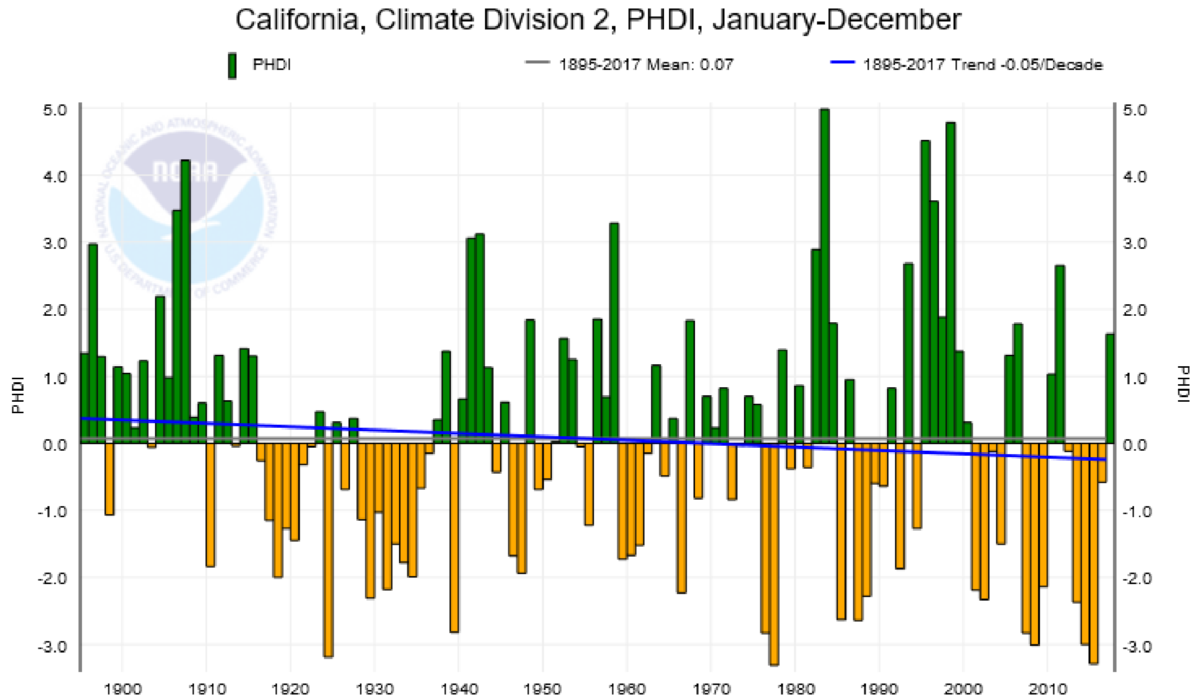


Figure 9: Palmer Hydrologic Drought Index (PHDI) for the Sacramento Watershed.

Annual Maximum Flow Data: Climate Hydrology Assessment and Non-Stationarity Detection Tools

Changes in hydrologic processes can occur either abruptly (e.g., through construction of a dam) or gradually (e.g., through watershed development over time) depending on the characteristics of the nonstationarity factors affecting physical processes. Engineering Technical Letter (ETL) 1100-2-3 provides guidance on detecting abrupt and slowly varying changes in annual maximum discharge records that could impact future without-project-condition.

Monotonic trend analysis can be conducted after the change point detection tests have been applied. The change point detection tests divide the record into a series of statistically homogenous subsets. If no abrupt changes were detected, the presence of monotonic trends should be examined using the entire record. Tests for monotonic patterns indicate whether the statistical properties within subsets of data are relatively constant, increasing or decreasing, and provide the user with insight into whether or not the trends exhibited within the dataset are likely to persist. If trends are detected within the identified subsets of flow data, the user should apply engineering judgment when using methods that rely on the stationarity assumption (USACE 2017).

For this assessment, no exploratory data analysis or trend analysis was undertaken because the relevant flow gages are primarily measuring regulated flows.

Phase II Future Climate Scenarios:

Projected changes in future climate contain significant uncertainties due to limitations in our understanding and modeling of the earth's systems, estimated projections of future development and greenhouse gas emission pathways. Uncertainties are also associated with hydrologic modeling, and translating global climate model outputs to a temporal and spatial scale applicable to hydrologic analysis.

The Corps Climate Hydrology Assessment Tool was used to examine projected trends in watershed hydrology for HUC 1802 to support the qualitative assessment. As expected, there is considerable and consistent spread in the projected annual maximum monthly flows (Figure 10). The overall projected trend in mean projected annual maximum monthly flows (Figure 11) increases over time and this trend is statistically significant (p-value <0.0001), suggesting that there may be potential for an increase in flood risk in the future relative to the current time. The tool uses climate data projected by global circulation models translated using a Variable Infiltration Capacity (VIC) model developed for the entire United States. The VIC model does not capture regulatory impacts. The assessment tool facilitates an overall assessment of probable projected trends in climate changed hydrology, but does not provide much insight into the magnitude of these trends. The VIC model is not calibrated to historical values at a study specific scale thus it may not replicate exact historic streamflow within a high degree of accuracy and this adds to the uncertainty with the projected climate changed hydrology.

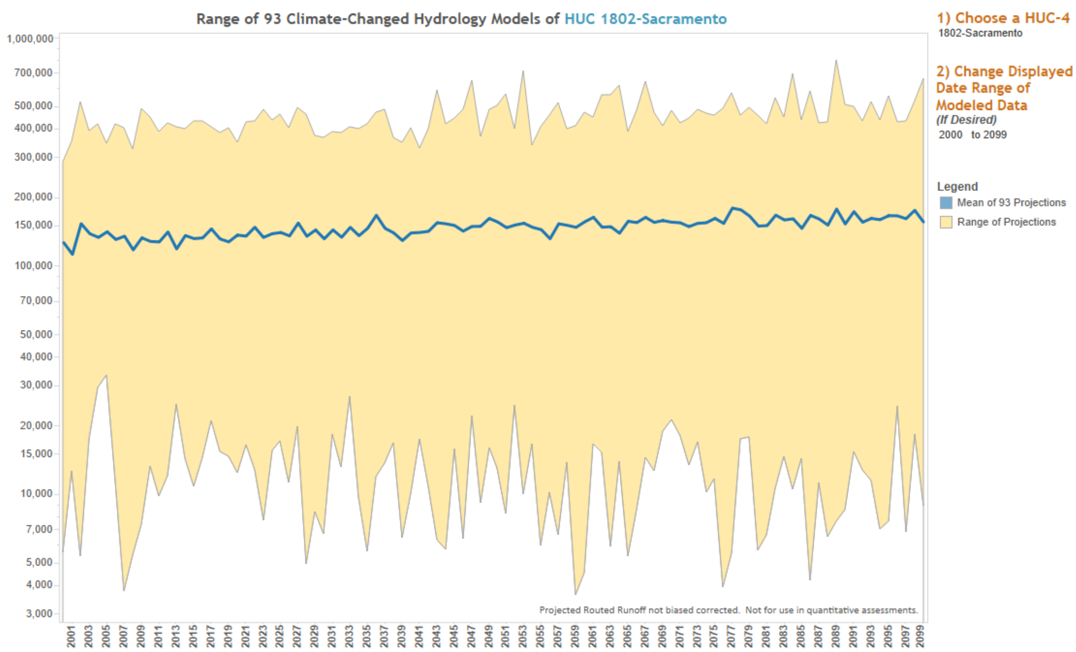


Figure 10: Range of 92 Climate-Altered Hydrology Model Projections of Annual Maximum Monthly Average Flow in HUC 1802 Sacramento.

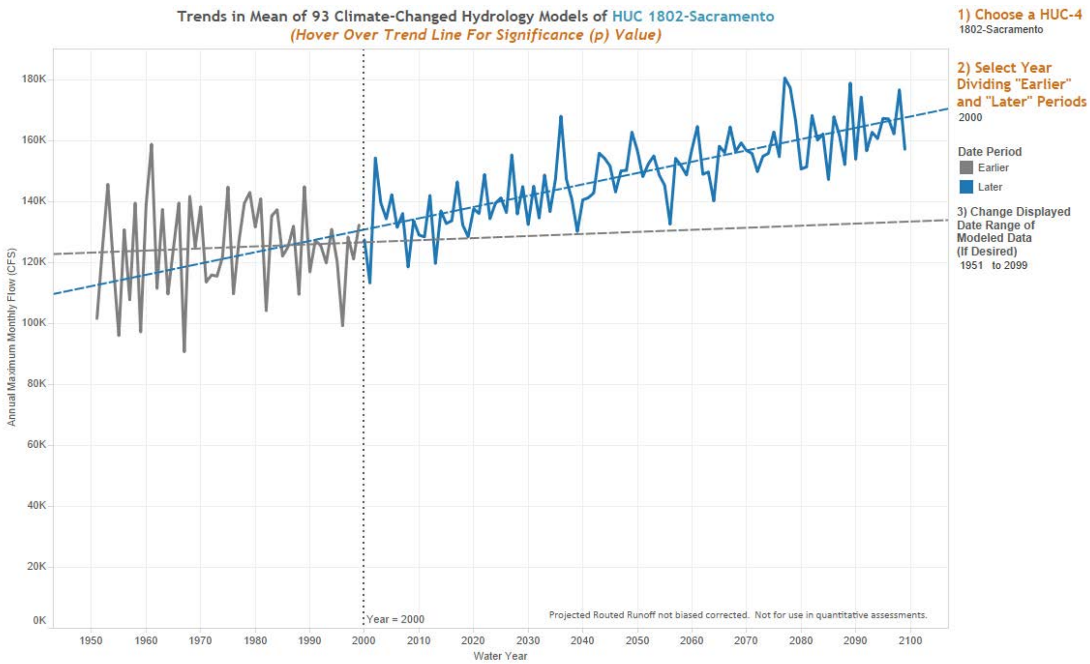


Figure 11: Projected Trend in Annual Maximum Flow for HUC-1802 Sacramento.
Dotted line indicates year 2000, gray dashed line indicates present trend from 1950 to 2000 and the blue dashed line indicates projected climate-altered trend in streamflow after 2000 to 2100.

Vulnerability Assessment Tool

The U.S. Army Corps of Engineers Vulnerability Assessment Tool (USACE 2016b) was used to examine the vulnerability of the HUC 1802 (Sacramento River) watersheds to climate change for the project's authorized business line of ecosystem restoration. Like the Climate Hydrology Assessment Tool, this tool uses climate data projected by GCMs translated into runoff using a VIC model, and the vulnerability assessment for inland Hydrology is only qualitative at this time. The vulnerability assessment is run for two time epochs centered on the years 2050 and 2085 and two subsets of GCM model based projected, climate changed hydrology: 1) a Dry subset of traces which is based on the driest 50% of downscaled CMIP 5 projections and a Wet subset of traces which is based on the Wettest 50% of model projections. Results from the Wet and Dry subsets of traces, as well as the two epochs of time are displayed in order to reveal some of the uncertainties associated with how projected, climate changed variables are computed. The Wet subset includes the projections that are above the median value for the given epoch and the Dry subset includes only those projections that are less than the median for that epoch (USACE 2016 b). The time epochs are as follows:

- 2035-2064 (centered on 2050)
- 2070-2099 (centered on 2085)
- 1950-1999 (base period)

The base period uses modeled flows generated from the GCM outputs from the base period (1950-1999). Because the base period simulations are based on historical climate data, they are not split into two different subsets. The dry projection could be wetter than the base epoch. A major strength of the VA Tool is that through the calculation of five scenario-epoch combinations, USACE project teams can consider the range of possibilities reflective of the inherent uncertainties of climate projections. The results for the Sacramento River watershed are relative to those of the other 201 watersheds in the United States.

This vulnerability assessment tool uses 27 different variables (indicators) and eight business lines to develop vulnerability scores specific to each of the 202 HUC-4 watersheds in the United States for each of the business lines. Indicators reflect stressors related to climate, demographic changes, ecological changes, and other factors relevant to particular business lines. Nine of these indicators are relevant to the ecosystem restoration line of business (Table 2). A subjective weight can be used to give more weight to indicators that are more relevant to the issues affecting the vulnerability of a given business line. The least relevant/important indicator is assigned an importance weight of 1, while all other indicators are assigned an importance weight relative to that (e.g., an indicator that is considered 50% more relevant/important is given an importance weight of 1.5).

Table 2: Ecosystem Restoration Indicators and Default Importance Weights

Indicator Short Name	Indicator Description	Default Importance Weight
568L_FLOOD _MAGNIFICATION	Change in flood runoff: Ratio of indicator 571L (monthly runoff exceeded 10% of the time, excluding upstream freshwater inputs) to 571L in base period.	1
700C_LOW_FLOW _REDUCTION	Change in low runoff: ratio of indicator 570C (monthly runoff exceeded 90% of the time, including upstream freshwater inputs) to 570C in base period.	1
65L_MEAN _ANNUAL_RUNOFF	Mean runoff: average annual runoff, excluding upstream freshwater inputs (local).	1.3
156_SEDIMENT	The ratio of the change in the sediment load in the future to the present load due to change in future precipitation.	1.5
568C_FLOOD _MAGNIFICATION	Change in flood runoff: ratio of indicator 571C (monthly runoff exceeded 10% of the time, including upstream freshwater inputs) to 571C in base period.	1.5
221C_MONTHLY _COV	Measure of short-term variability in the region's hydrology: 75th percentile of annual ratios of the standard deviation of monthly runoff to the mean of monthly runoff. Includes upstream freshwater inputs (cumulative).	1.75
277_RUNOFF _PRECIP	Median of: deviation of runoff from monthly mean times average monthly runoff divided by deviation of precipitation from monthly mean times average monthly precipitation (elasticity indicator).	1.75

297_MACROINVERTEBRATE	The sum (ranging from 0-100) of scores for six metrics that characterize macroinvertebrate assemblages: taxonomic richness, taxonomic composition, taxonomic diversity, feeding groups, habits, pollution tolerance.	2
8_AT_RISK _FRESHWATER _PLANT	Percentage of wetland and riparian plant communities that are at risk of extinction, based on remaining number and condition, remaining acreage, threat severity, etc.	2

The tool provides an indication of how vulnerable a given HUC-4 watershed is to the potential impacts of climate change relative to the other 201 HUC-4 watersheds in the United States. The business lines are the prisms for the evaluation of vulnerability in a given watershed. The VA tool gives assessments using two scenarios (wet and dry) for two of three epochs assessed within the tool, 2035-2064 (centered on 2050) and 2070-2099 (centered on 2085). The remaining epoch (base period) covers the current time and uses modeled flows generated from the GCM outputs from the base period (1950-1999).

Within each of the future epochs the GCM projections are divided into two equal sized groups. The group with the lower cumulative runoff projections is used to compute values for the dry scenario and the group with the higher runoff projections is used to compute values for the wet scenario. These are all equally likely projections of the future and the dry projection could be wetter than the base epoch. For the Sacramento River Watershed (HUC 1802), this tool shows that the area is highly vulnerable to increased flood risk during the twenty-first century for all wet and dry projected scenarios when compared to the other 201 HUC-4 watersheds in the nation. The assessment was carried out using the national standard settings (ORness set to 0.7, all 202 HUC-4 watersheds are considered, Analysis type is set to “Each” and vulnerability threshold is set at 20%).

Results Based on National Standard Settings:

The results for each HUC-4 watershed provide an indication of how vulnerable the watershed is to potential impacts of climate change relative to the other 201 HUC-4 watersheds in the United States. For the Sacramento River Watershed (HUC 1802), this tool shows that the ecosystem restoration line of business is vulnerable to climate change for three scenarios/epoch combinations (2050 wet, 2085 wet and dry) compared to the other 201 HUC-4 watersheds in the nation (Table 3, Figure 12). The indicator contributing the highest amount to the WOWA score under both scenarios is the at risk freshwater plants indicator which accounts for more than one third of the scores. The second largest contributor to the WOWA scores is 221C monthly covariance of stream flow (indicates the variability of streamflow) which accounts for more than one quarter of the scores. The third most important indicator is 277 which indicates changes in the amount of runoff from a given storm event accounts for 10 to 15 percent of the scores. These last two indicators are directly related to the higher snow levels and increased moisture that could be associated with atmospheric river events under projected future conditions.

The Sacramento River Basin HUC-4 watershed is not as vulnerable relative to the other HUC-4 watersheds (i.e. the vulnerability score is not in the highest 20% of HUC-4 watershed vulnerability scores) during the 2050 epoch especially in the dry subset of model runs, but over time becomes more vulnerable (relative to the other watersheds) as monthly runoff decreases and freshwater plants become more susceptible to dryness and heat.

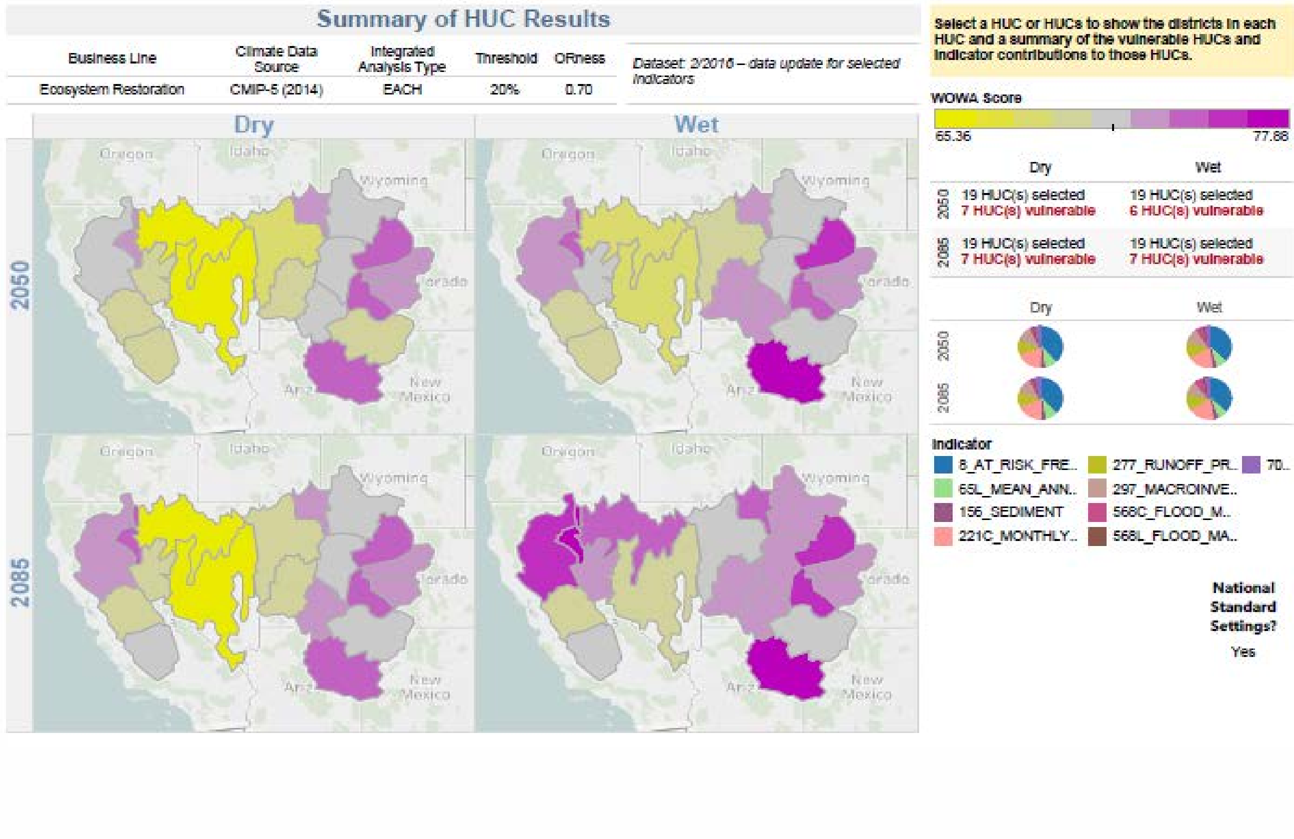


Figure 12: Summary of Vulnerability to the Ecosystem Restoration Business Line in the Sacramento River HUC-4 Watershed. The watershed is not vulnerable relative to other watersheds during the 2050 epoch but becomes vulnerable in this business line relative to the other watersheds during the 2085 epoch. The dominant indicator appears to be the presence of at risk freshwater plant communities.

Table 3 WOWA Scores and Contributions for HUC-4 Watershed 1802 Sacramento River

Business Line	**Ecosystem Restoration**									
Epoch and Scenario	Base Period		Dry 2050		Wet 2050		Dry 2085		Wet 2085	
Indicator	Raw WOWA	% WOWA	Raw WOWA	% WOWA	Raw WOWA	% WOWA	Raw WOWA	% WOWA	Raw WOWA	% WOWA
8_AT_RISK_FRESHWATER_PLANT	27.22	0.40	27.22	0.38	27.31	0.37	27.32	0.37	27.39	0.36
700C_LOW_FLOW_REDUCTION	2.67	0.04	2.83	0.04	2.82	0.04	3.74	0.05	2.84	0.04
65L_MEAN_ANNUAL_RUNOFF	3.67	0.05	3.72	0.05	2.15	0.03	2.86	0.04	2.15	0.03
568L_FLOOD_MAGNIFICATION	0.79	0.01	0.85	0.01	1.10	0.02	0.87	0.01	1.60	0.02
568C_FLOOD_MAGNIFICATION	1.54	0.02	2.16	0.03	6.08	0.08	2.20	0.03	6.84	0.09
297_MACROINVERTEBRATE	5.64	0.08	5.64	0.08	4.36	0.06	5.66	0.08	4.37	0.06
277_RUNOFF_PRECIP	8.78	0.13	9.66	0.14	9.81	0.13	10.02	0.14	10.08	0.13
221C_MONTHLY_COV	15.97	0.23	17.83	0.25	17.85	0.24	18.78	0.26	18.98	0.25
156_SEDIMENT	2.01	0.03	1.55	0.02	1.55	0.02	1.55	0.02	1.20	0.02
Total WOWA	68.29	1.00	71.46	1.00	73.04	1.00	73.01	1.00	75.44	1.00

Notes: 1). Results from US Army Corps of Engineers, CRRL, Watershed Vulnerability Assessment Tool on 25 Apr 2017. 2). Total WOWA scores can range from 0 to 100 and scores are relative to the other HUC-4 Watersheds in the US.

Conclusions:

Both observations and downscaled climate model outputs indicate that the climate in the Sacramento Valley of California will be warmer and possibly wetter than the present one. The likelihood of large floods will increase due to increases in moisture content of the storms and snow lines receding to higher elevations, leading to more precipitation falling as rain and more basin exposure for runoff to occur A review of the literature indicates that the following projected impacts of climate change are likely to affect the Sacramento River and San Joaquin River watersheds:

- Increased air temperatures
- Reduced snow water equivalent
- Earlier spring snowmelt
- More frequent and intense atmospheric river storms
- Chronic long duration hydrological drought

VIC model results indicate a significant increase in runoff in the Sacramento River HUC-4 Watershed as a result of warmer and wetter conditions projected in the downscaled CMIP-5 climate model outputs for California. Additionally, droughts could become more severe and overall annual runoff could decrease so that operations involving ecosystem restoration become more vulnerable. The study team should be aware that changing climate conditions could impact both the water levels in and near the project and the water quality conditions in the Yuba River. The project should be designed to accommodate both severe droughts and a variety of hydrological runoff and water management scenarios.

References

USACE, Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects: ECB No. 2016-25 Dated September 2016.

USACE, Climate Hydrology Assessment Tool (ECB 2016-25), http://corpsmapu.usace.army.mil/cm_apex/f?p=313 dated November 2016.

USACE, Nonstationarity Detection Tool (NSD), http://corpsmapu.usace.army.mil/cm_apex/f?p=257 dated November 2016.

USACE, Vulnerability Assessment (VA) Tool, https://maps.crrel.usace.army.mil/apex/f?p=201 dated November 2016.

CH2M HILL , Preliminary Climate Change Analysis for the CVFPP - Phase IIA, CH2M HILL Technical Memorandum. Dated September 25, 2014.

Barnett, T.P., D.W. Pierce, H. Hidalgo, C. Bonfils, B. Santer, T. Das, G. Bala, A. Wood, T. Nozawa, A. Mirin, D. Cayan and M. Dettinger. 2008. Human-induced changes in the hydrology of the western United States. Science, 316, 1080-1083.

NOAA, NOAA Technical Report NESDIS 142-5: Regional Climate Trends and Scenarios for the U. S. National Climate Assessment: Part 5 Climate of the Southwest U.S. Washington D.C. dated January 2013.

Dettinger M.D., Ralph F.M., Hughes M., Das T., Neiman P., Cox D., Estes G., Reynolds D., Hartman R., Cayan D.R., and Jones L. 2011a. Design and quantification of an extreme winter storm scenario for emergency preparedness and planning exercises in California. Natural Hazards, doi: 10.1007/s11069-011-9894-5.

Dettinger, M.D., Ralph F.M., Das T., Neiman P.J., and Cayan D.R. 2011b. Atmospheric Rivers, Floods and the Water Resources of California. Water 3 (2), 445-478.

Das T., Maurer E.P., Pierce D.W., Dettinger M.D., and Cayan D.R. 2013. Increases in Flood Magnitudes in California under Warming Climates. Journal of Hydrology. http://dx.doi.org/10.1016/j.jhydrol.2013.07.042.

Das T., Dettinger M.D., Cayan D.R., and Hidalgo H.G. 2011a. Potential increase in floods in Californian Sierra Nevada under future climate projections. Climatic Change, doi: 10.1007/s10584-011-0298-z.

Das, T., D.W. Pierce, D.R. Cayan, J.A. Vano, and D.P. Lettenmaier. 2011b. The Importance of Warm Season Warming to Western U.S. Streamflow Changes. Geophys. Res. Lett., DOI: 10.1029/2011GL049660.

Taylor, Karl E., Ronald J. Stouffer, Gerald A. Meehl. 2012. An Overview of CMIP5 and the Experiment Design. Bull. Amer. Meteor. Soc., 93, 485–498.

Goodridge, J., Persistence in California Weather Patterns, unpublished, Dated July 28, 2007.

National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI), Climate at a Glance: Divisional Time Series, published February 2018, retrieved on March 13, 2018 from http://www.ncdc.noaa.gov/cag/

National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI), US Climate Divisions, retrieved on March 13, 2018 from https://www.ncdc.noaa.gov/monitoring-references/maps/us-climate-divisions.php

USACE (SPK). 2015. Central Valley Climate Variability Sensitivity Study, USACE, Sacramento District (SPK).

U.S. Bureau of Reclamation (US BoR). 2014. West-Wide Climate Risk Assessment for the Sacramento and San Joaquin Basins. Downloaded 18 March 2018. https://www.usbr.gov/watersmart/wcra/docs/ssjbia/ssjbia.pdf

Attachment GT-A. Site Characterization Strategy and Physical and Chemical Testing.

Table 1. Site Characterization Sampling Strategy for Recommended Plan Habitat Measures.	
19	About 10 acres of lowering the surface and riparian planting. • 3 cores (10 ft deep) • 2 ft samples yields 15 total samples • GSD, moisture content for all; Atterberg limit, organic content, and Hg for all "sediment" (assume 5 samples) • Full bulk chemistry for 1 selected sample
20	~ 3 acres • 2 cores (10 ft deep) • 2 ft samples yields 10 total samples • GSD, moisture content for all; Atterberg limit, organic content, and Hg for all "sediment" (assume 4 samples) • Full bulk chemistry for 1 selected sample
21	~0.5 acres • 1 core (10 ft deep) • 2 ft samples yields 5 total samples • GSD, moisture content for all; Atterberg limit, organic content, and Hg for all "sediment" (assume 2 samples) • Full bulk chemistry for 1 selected sample
22	~ 4 acres in east area; similar area on west end of bar; extensive planting along water edge • 3 cores (10 ft deep); 1 in each main area, but one along the bank because it will likely be more fine materials • 2 ft samples yields 15 total samples • GSD, moisture content for all; Atterberg limit, organic content, and Hg for all "sediment" (assume 5 samples) • Full bulk chemistry for 2 selected samples (one near bank)
24	~ 12 acres • 3 cores (10 ft deep) • 2 ft samples yields 15 total samples • GSD, moisture content for all; Atterberg limit, organic content, and Hg for all "sediment" (assume 5 samples) • Full bulk chemistry for 1 selected sample
26	~ 12 acres • 3 cores (10 ft deep) • 2 ft samples yields 15 total samples • GSD, moisture content for all; Atterberg limit, organic content, and Hg for all "sediment" (assume 5 samples) Full bulk chemistry for 1 selected sample

28	~ 12 acres • 3 cores (10 ft deep) • 2 ft samples yields 15 total samples • GSD, moisture content for all; Atterberg limit, organic content, and Hg for all “sediment” (assume 5 samples) Full bulk chemistry for 1 selected sample
29	No excavation, but 1 core recommended in case the ELJ requires driving piles for support • 1 core (10 ft deep) • 2 ft samples yields 5 total samples • GSD, moisture content for all; Atterberg limit, organic content, and Hg for all “sediment” (assume 2 samples) • Full bulk chemistry for 1 selected sample
30	~3 acres, long and thin • 2 cores (10 ft deep) • 2 ft samples yields 10 total samples • GSD, moisture content for all; Atterberg limit, organic content, and Hg for all “sediment” (assume 4 samples) • Full bulk chemistry for 1 selected sample
32, 33, 34	20 – 30 acres of excavation including several channels; still, given the homogeneity that seem to be present: • 3 cores (10 ft deep) • 2 ft samples yields 15 total samples • GSD, moisture content for all; Atterberg limit, organic content, and Hg for all “sediment” (assume 5 samples) • Full bulk chemistry for 1 selected sample
46, 47	~50 acres of restoration including several channels: • 5 cores (10 ft deep); 1 in each “channel” alignment and 3 in other areas. • 2 ft samples yields 20 total samples • GSD, moisture content for all; Atterberg limit, organic content, and Hg for all “sediment” (assume 5 samples) • Full bulk chemistry for 1 selected sample
48, 49, 50, 51	~60 acres of restoration including several channels • 7 cores (10 ft deep); 3 in the “channel” alignments and 4 in other areas. • 2 ft samples yields 35 total samples • GSD, moisture content for all; Atterberg limit, organic content, and Hg for all “sediment” (assume 7 samples) • Full bulk chemistry for 2 selected samples

52	~1 acre • 1 core (10 ft deep) • 2 ft samples yields 5 total samples • GSD, moisture content for all; Atterberg limit, organic content, and Hg for all “sediment” (assume 2 samples) • Full bulk chemistry for 1 selected sample
53,54	~2.5 acres each • 1 core (10 ft deep) • 2 ft samples yields 5 total samples • GSD, moisture content for all; Atterberg limit, organic content, and Hg for all “sediment” (assume 2 samples) Full bulk chemistry for 1 selected sample

Table 2. Physical and Chemical Testing
Physical Analyses:
Grain Size (includes sieve and hydrometer)
Moisture content
Organic carbon
Atterberg Limits
Volatile Solids/Organic Content
Total Physical
Chemistry:
TAL Metals (includes Total Hg)
Methyl Hg
PCB Arochlors
Pesticides
PCB Congeners
PAHs
Total Chemistry

Attachments GIS A through GIS C: GIS Modeling Processes

YRERFS GIS WORKFLOW AND MODELING PROCESS

Presenter Name

Presenter Title

SPK Sacramento

7/12/2017

US Army Corps of Engineers
BUILDING STRONG®

YRERFS Juvenile Steelhead Habitat Determination

BUILDING STRONG®

Original Data Sets

- tree_object_classification (Riparian Scrub/ Riparian Forest)
- AllCobbles_5000
- LYRriprapHBD
- LYRbedrock

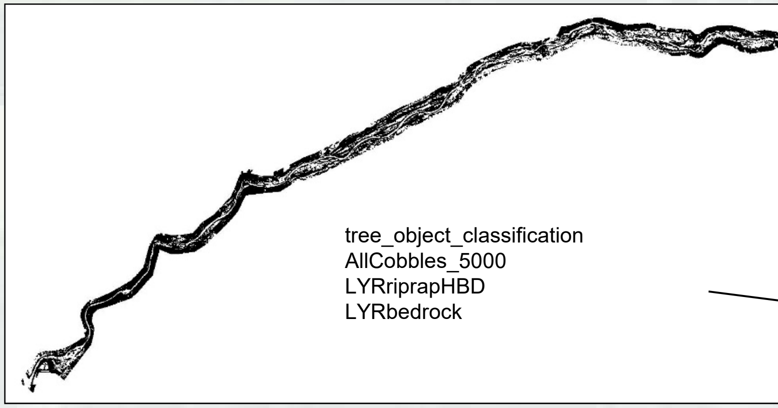
Data provided by HDR
Originally WSI Vegetation analysis, 2010

Create Cover Raster

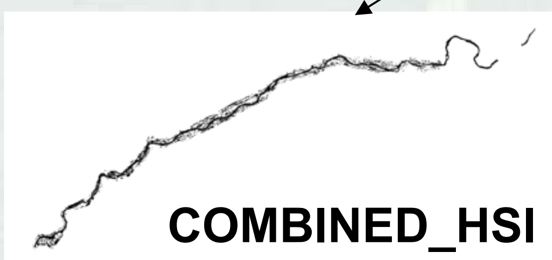
WITHOUT PROJECT CONDITIONS (FWOP)						
Note: the following additional data layers were provided by the RMT for calculating WUA for these cover versions: LYR_Bedrock_boulder_cover.shp, LYR_riprap_HBD.shp, cobble_5k,lrgcobb_5k, Boulder_5000 and LYR5000_streamwood.shp.	Method	Process	Output	Cell Size	Format	Value
CREATE "AllCobbles_5000"—Combine "cobble_5k" and "lrgcobb_5k" rasters by doing an addition function. Each pixel contains a percentage of the pixel that contains cobble, so by adding the two cobble size classes together a total percentage of area within the pixel that's cobble was calculated.	MATH	cobble_5k+lrgcobb_5k=AllCobbles_5000	AllCobbles_5000	3x3	Float32	%Cobble
CREATE "LYRriprapHBD"—Converted the file "LYR_riprap_HBD.shp" containing polygons to a raster format with 3ft x 3ft pixels.	Feature to Raster	LYR_riprap_HBD.shp to LYRriprapHBD	LYRriprapHBD	3x3	Float32	1=RipRap
CREATE "LYRbedrock"—Converted the file "LYR_Bedrock_boulder_cover.shp" containing polygons to a raster format with 3ft x 3 ft pixels.	Feature to Raster	LYR_Bedrock_boulder_cover.shp to LYRbedrock	LYRbedrock	3x3	Float32	1=Bedrock
CREATE "LYR_Boulder_presence"—For a given pixel within the raster "Boulder_5000" that was greater than 9 the output pixel would be 1; otherwise it was zero.	Raster Reclass	boulder_5k to LYR_Boulder_presence	LYR_Boulder_presence	3x3	Float32	1=Boulder
Cover Version – Steelhead (O. mykiss) juvenile Note: The following additional data sources were used: "LYR_veg_only_dissolve", "LYR5000_wettedarea_dissolved.shp", "LYR_streamwood.shp".	Method	Process		Cell Size	Format	Value
CALCULATE SHSI—If AllCobbles_5000 is less than 30% of a given pixel then the SHSI is .3; otherwise it's .5.	Raster Calc	AllCobbles_5000 <30=.3 and >30=.5	SHSI_AllCobbles_5000	3x3	Float32	<30=.3 >30=.5
CALCULATE LYR_hardcover_OMYjuv_HSI—For a given pixel if the sum of "LYRriprapHBD", "LYRbedrock" and "LYR_Boulder_presence" is greater than zero then the output pixel value is .5; otherwise .3.	Mosaic/Raster Calc	LYRriprapHBD+LYRbedrock+LYR_Boulder_presence	LYR_hardcover_OMYjuv_HSI	3x3	Float32	1=.5
CALCULATE LYR_veg_ OMYjuv_HSI—Polygons representing areas of vegetation taller than 2' were buffered by 3 feet and assigned a value of 1. Areas within the 5000 cfs wetted area that were not within the 3 foot buffered vegetation polygons were assigned a value of .3.	Raster Calc	HeightClass=3ftBuffTree=1 and Shrub=.3	LYR_veg__OMYjuv_HSI	3x3	Float32	Tree=1 Shrub=.3
CALCULATE LYR_SW_ OMYjuv_HSI—Polygons representing areas of streamwood were buffered by 6 feet and assigned a value of 1. Areas within the 5000 cfs wetted area that were not within the 3 foot buffered vegetation polygons were assigned a value of .3.	Feature to Raster	6ftBuffSW=1	LYR_SW__OMYjuv_HSI	3x3	Float32	SW=1
CALCULATE COMBINED HSI—Overlaying the SHSI, hardcover HSI, streamwood HSI and vegetation HSI rasters and looking at one pixel location at a time the output for that pixel location was whichever of the four inputs had the highest value.	Mosaic	SHSI+ hardcover HIS+streamwood HIS+vegetation	COMBINED_HSI	3x3	Float32	Heighest

Data provided by HDR
Originally WSI Vegetation analysis, 2010

Create Cover Raster



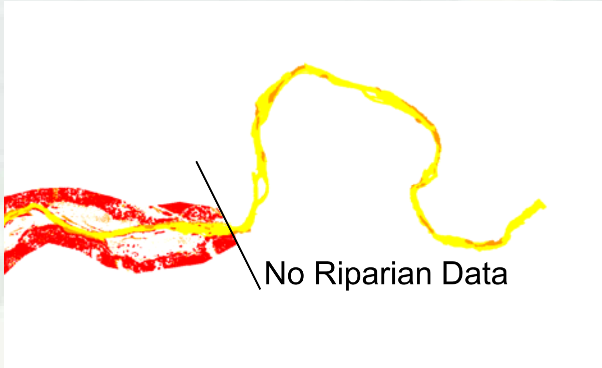
LYR_SW__OMYjuv_HSI
LYR_veg__OMYjuv_HSI
LYR_hardcover_OMYjuv_HSI
SHSI_AllCobbles_5000



Create Cover Raster

MODIFY COVER RASTER FOR FWOP

- Cover Raster missing data at Timbuctoo Bend
- Modify Cover Raster(Raster's Measures Feature to Raster)
  - Side Channel
  - Back Water
  - Riparian Planting
  - Floodplain Lowering
- Assign Habitat Units to Measures Raster's
  - .3 - Side Channel
  - .3 - Back Water
  - .5 - Riparian Planting
  - .5 - Floodplain Lowering
- Mosaic to Existing Riverine Cover Raster



Build Raster for missing data at Timbuctoo Bend

Feature to Raster

- BackWaterCoverRaster
- LoweringCoverRaster
- SideChannelCoverRaster
- PlantingCoverRaster

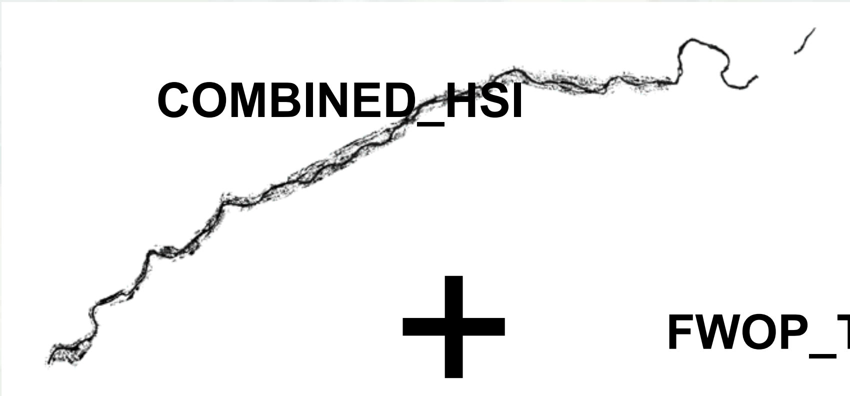
Cover (reclass by table)	
Cover_class	SI value
boulder/riprap	0.5
cobble	0.5
none	0.3
riparian vegetation	1
stream wood	1

Reclassify Rasters

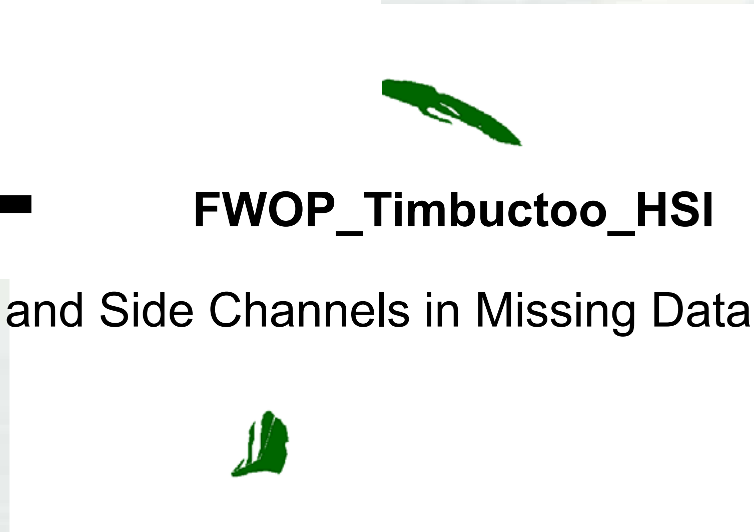
- FWOP_BackWater_HSI
- FWOP_Lowering_HSI
- FWOP_Planting_HSI
- FWOP_SideChannel_HSI

FWOP_Timbuctoo_HSI

Cover (reclass by table)	
Cover_class	SI value
boulder/riprap	0.5
cobble	0.5
none	**0.3**
riparian vegetation	1
stream wood	1



+



(Back Water and Side Channels in Missing Data Area at Timbuctoo Bend)

=

*Only areas within FWP footprint added to FWOP (existing) conditions

BUILDING STRONG®

Create FWOP Cover Raster

MODIFY COVER RASTER FOR FWP

- Create project condition (Raster's Measures Feature to Raster)
    - Side Channel
    - Back Water
    - Riparian Planting
    - Floodplain Lowering
- Assign Habitat Units to Measures Raster's
    - .5 - Side Channel
    - .5 - Back Water
    - 1 - Riparian Planting
    - 1 - Floodplain Lowering
- Mosaic to Existing Riverine Cover Raster

Build Raster for missing data at Timbuctoo Bend

Feature to Raster

BackWaterCoverRaster
LoweringCoverRaster
SideChannelCoverRaster
PlantingCoverRaster

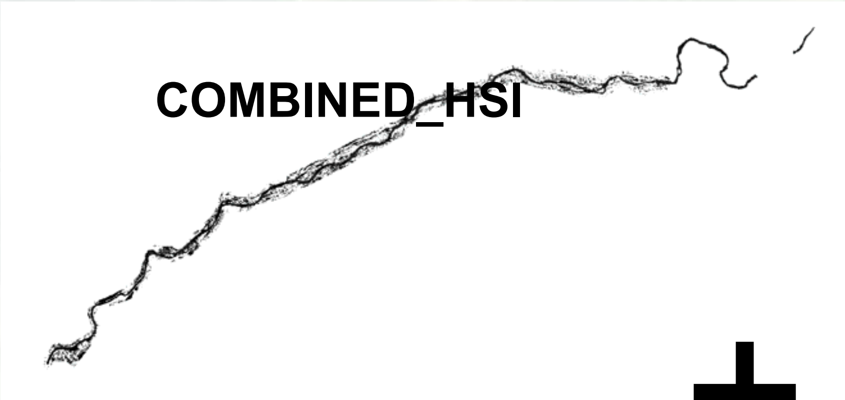
Cover (reclass by table)	
Cover_class	SI value
boulder/riprap	0.5
cobble	**0.5**
none	0.3
riparian vegetation	1
stream wood	1

Reclassify Rasters

FWP_BackWater_HSI
FWP_Lowering_HSI
FWP_Planting_HSI
FWP_SideChannel_HSI

FWOP_Timbuctoo_HSI

Cover (reclass by table)	
Cover_class	SI value
boulder/riprap	0.5
cobble	0.5
none	0.3
riparian vegetation	1
stream wood	1

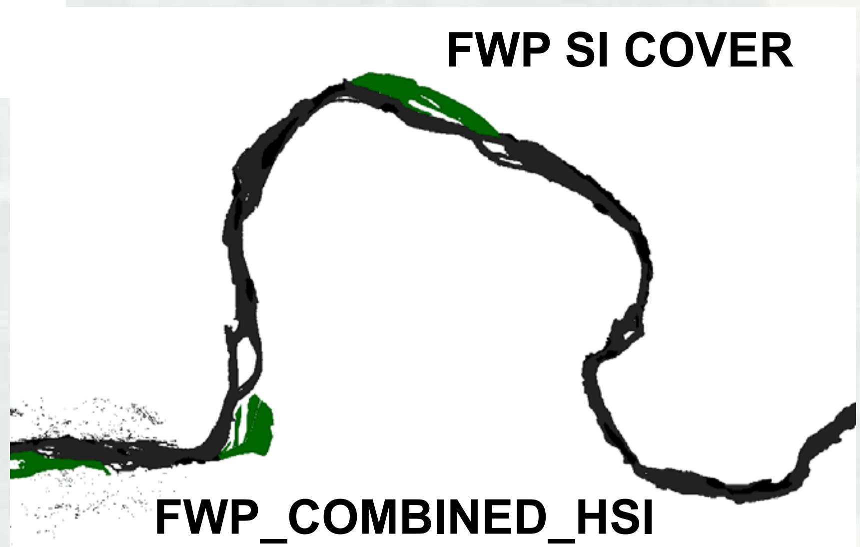


+

Habitat Values of .5 added to Back Water and Side Channel areas in order to Represent Cobble Cover in FWP conditions.

+

=



Habitat Values of 1 added to Floodplain Lowering and Riparian Planting areas in order to Represent Cobble Cover in FWP conditions.

Create FWP Cover Raster

Raster Reclass Depth

Depth (feet)	Suitability Index Value
0.4	0
0.5	0.45
1.6	0.9
2	0.98
2.2	1
2.5	1
3	0.94
3.5	0.84
5.5	0.32
6.5	0.17
8	0.07
9.5	0.04
10.5	0.03
13.5	0.03
15	0.04
15.1	0

1 - Table to Table in ArcGIS (Excel to ASCII Table) with Range whole number (*100)= (100 200 : 300 where fromVal toVal : HSC)
2 - Depth/Velocity*100 in Raster Calculator
3 - Reclass by ASCII Table
4 - Copy Raster To Float32
5 - DepthReclass/VelocityReclass/100 in Raster Calc

=DepthWith750SI, DepthWithOut750SI DepthWith1850SI, DepthWithOut1850SI, DepthWith5000SI, DepthWithOut5000SI

Raster Reclass Velocity

Velocity (feet/second)	Suitability Index Value
0.00	1.00
0.10	1.00
0.20	0.99
0.30	0.98
0.40	0.97
0.50	0.96
0.60	0.94
0.70	0.92
0.80	0.89
0.90	0.87
1.00	0.84
1.10	0.81
1.20	0.78
1.30	0.74
1.40	0.71
1.50	0.67
1.60	0.63
1.70	0.60
1.80	0.56
1.90	0.52
2.00	0.48
2.10	0.45
2.20	0.41
2.30	0.38
2.40	0.34
2.50	0.31
2.55	0.30
4.00	0.00

=VelocityWith750SI, VelocityWith1850SI, VelocityWith5000SI, VelocityWithOut750SI, VelocityWithOut1850SI, VelocityWithOut5000SI

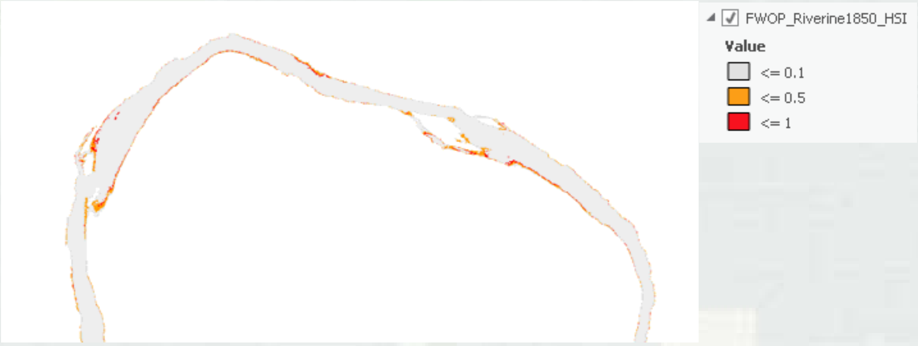
Create Final Cover HSI Raster's

8 CALCULATE CHSI— For each flow for a given pixel the output value for that pixel is the cubic root of the product of the VHSI, DHSI and Combined HSI at that location.

Juvenile Steelhead AKA Riverine FWOP HSI RASTER = $(SI_{depthFWOP} \times SI_{velocityFWOP} \times SI_{coverFWOP})^{1/3}$

Juvenile Steelhead AKA Riverine FWP HSI RASTER = $(SI_{depthFWP} \times SI_{velocityFWP} \times SI_{coverFWP})^{1/3}$

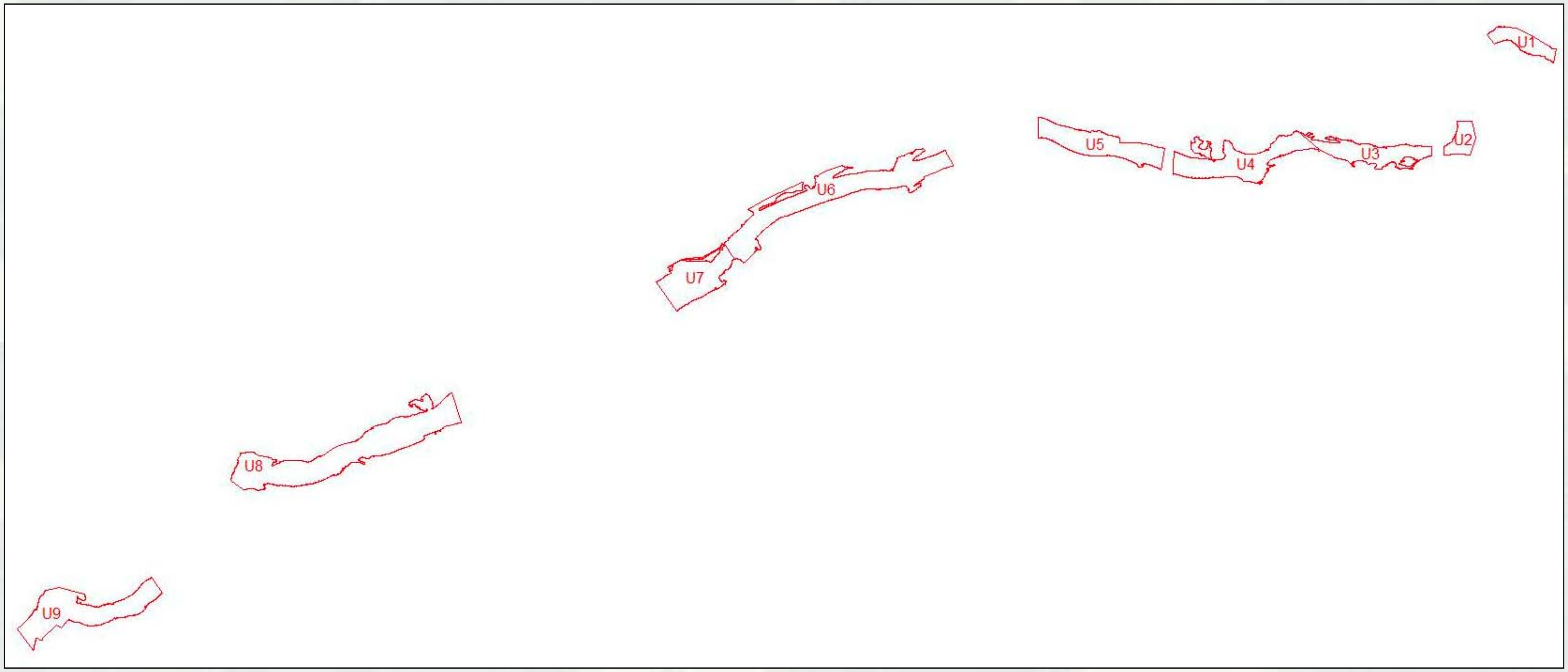
=FWOP_Riverine750_HSI,
FWOP_Riverine1850_HSI,
FWOP_Riverine5000_HSI,



FWP_Riverine750_HSI,
FWP_Riverine1850_HSI,
FWP_Riverine5000_HSI

BUILDING STRONG®

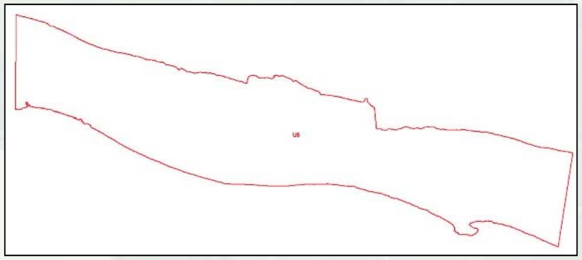
To refine results of the HSI and make it pertinent to the areas where measures are, a new layer was created to clip out the needed features. The layer, ”Units”, has a north-south boundary based on the 84,000 cfs flow boundary and an east west boundary of 500 feet off either end of the widest measure in each measure grouping. There are 9 units total.



(Extract by Mask)

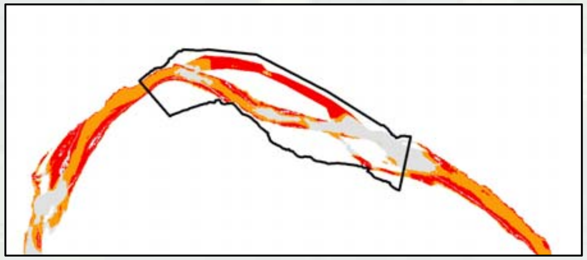
All 9 units were used to clip the FWP and FWOP HSI rasters.

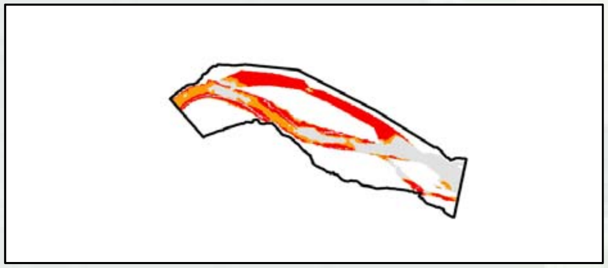
Units



Unit 1

FWOP/FWP_HSI Raster's





Unit 1: 1850 cfs flow boundary clipped out

=FWOP_Riverine750_HSI_U1 through U9,
FWOP_Riverine1850_HSI_U1 through U9,
FWOP_Riverine5000_HSI_U1 through U9,
FWP_Riverine750_HSI_U1 through U9,
FWP_Riverine1850_HSI_U1 through U9,
FWP_Riverine5000_HSI_U1 through U9

X54 By-Units HIS Rasters

U.S.ARMY

BUILDING STRONG®

To calculate actual Habitat Units (end product) need to create a table for each raster. To create a table use the Zonal Statistics tool and input the rasters you want to create a table for.

8 Units Rasters to Table (Zonal Statistics)

9 Add HSI Field

10 Sum from Zonal Statastics *9

11 Add Name Field

```
import arcpy
from arcpy import env
env.workspace = r"D:\USACE Projects\YubaRiverEcosystemRestoration\GDB\Scratch.gdb"
for table in arcpy.ListTables("*"):
 name = table.split(".")[0]
 arcpy.AddField_management(table, "Name", "TEXT")
 arcpy.CalculateField_management(table, "Name", "'" + name + "'", "PYTHON")
```

12 Merge Tables and export to Excel

Contents | Preview | Description

Name	Type
FWP_yr1_Basal_HSI_1850cfs_Unit1	File Geodatabase Table
FWP_yr1_Basal_HSI_1850cfs_Unit2	File Geodatabase Table
FWP_yr1_Basal_HSI_1850cfs_Unit3	File Geodatabase Table
FWP_yr1_Basal_HSI_1850cfs_Unit4	File Geodatabase Table
FWP_yr1_Basal_HSI_1850cfs_Unit5	File Geodatabase Table
FWP_yr1_Basal_HSI_1850cfs_Unit6	File Geodatabase Table
FWP_yr1_Basal_HSI_1850cfs_Unit7	File Geodatabase Table
FWP_yr1_Basal_HSI_1850cfs_Unit8	File Geodatabase Table
FWP_yr1_Basal_HSI_1850cfs_Unit9	File Geodatabase Table
FWP_yr1_Basal_HSI_5000cfs_Unit1	File Geodatabase Table
FWP_yr1_Basal_HSI_5000cfs_Unit2	File Geodatabase Table
FWP_yr1_Basal_HSI_5000cfs_Unit3	File Geodatabase Table
FWP_yr1_Basal_HSI_5000cfs_Unit4	File Geodatabase Table
FWP_yr1_Basal_HSI_5000cfs_Unit5	File Geodatabase Table
FWP_yr1_Basal_HSI_5000cfs_Unit6	File Geodatabase Table
FWP_yr1_Basal_HSI_5000cfs_Unit7	File Geodatabase Table
FWP_yr1_Basal_HSI_5000cfs_Unit8	File Geodatabase Table
FWP_yr1_Basal_HSI_5000cfs_Unit9	File Geodatabase Table
FWP_yr1_Basal_HSI_750cfs_Unit1	File Geodatabase Table
FWP_yr1_Basal_HSI_750cfs_Unit2	File Geodatabase Table
FWP_yr1_Basal_HSI_750cfs_Unit3	File Geodatabase Table
FWP_yr1_Basal_HSI_750cfs_Unit4	File Geodatabase Table
FWP_yr1_Basal_HSI_750cfs_Unit5	File Geodatabase Table
FWP_yr1_Basal_HSI_750cfs_Unit6	File Geodatabase Table
FWP_yr1_Basal_HSI_750cfs_Unit7	File Geodatabase Table
FWP_yr1_Basal_HSI_750cfs_Unit8	File Geodatabase Table
FWP_yr1_Basal_HSI_750cfs_Unit9	File Geodatabase Table

Once the table is created, create a new field in each raster and call it "Habitat Unit" then use the field calculator tool to determine the total ft^2 of for each raster.

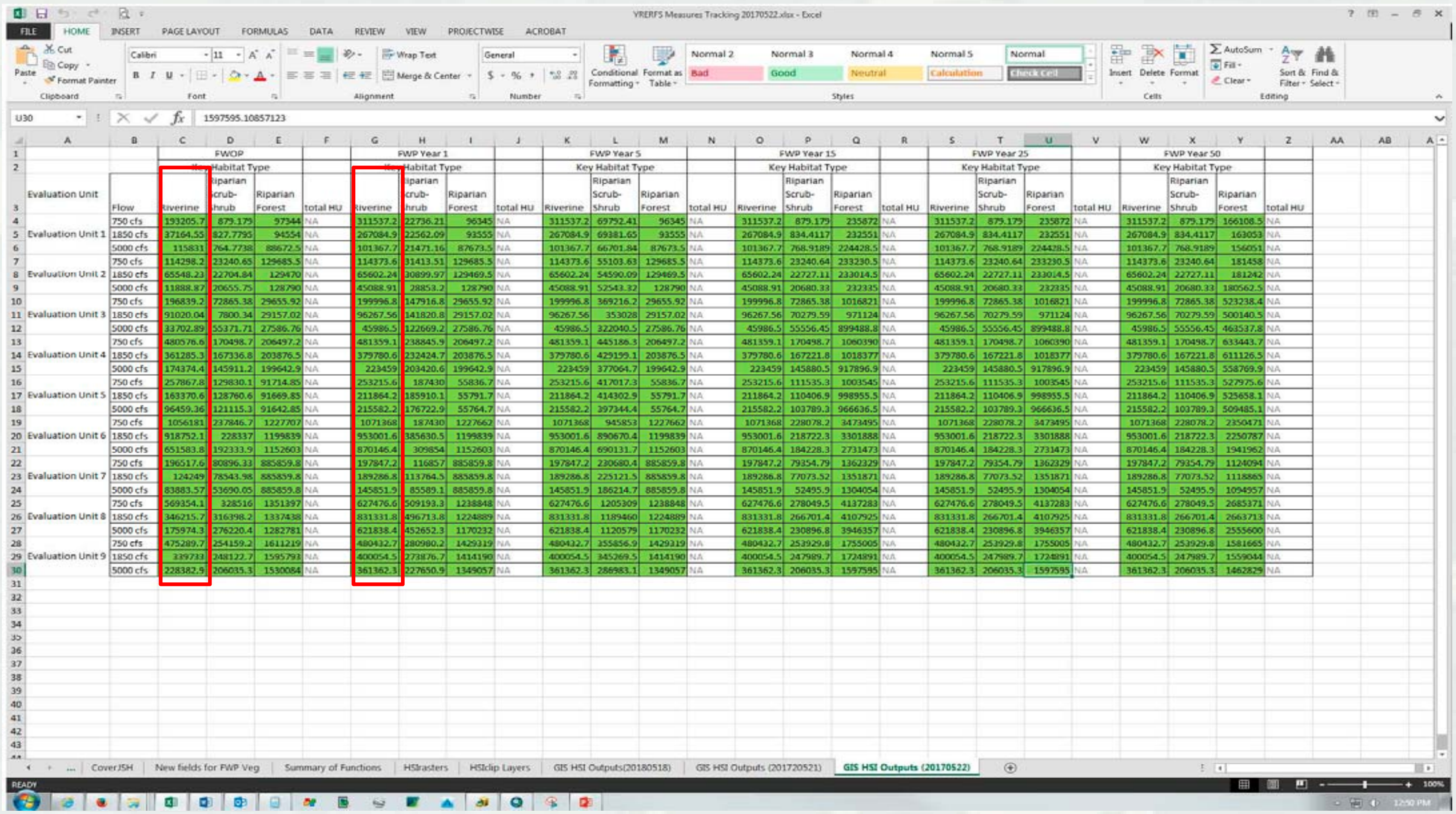
9 CALCULATE WUA— The CHSI rasters for each flow were grouped by hydraulic zone and a sum total of the pixel values for each zone was calculated. The sum total was then multiplied by the surface area of a single pixel (3' x 3' = 9ft2) to get the WUA for each separate hydraulic zone and for each modeled flow.

Contents | Preview | Description

OBJECTID *	reach_ID	ZONE_CODE	COUNT	AREA	SUM	Habitat_Unit
1	U1	1	20790	187110	10395	93555

Use the formula "Sum * 9" where nine is the dimensions of each individual raster cell (3X3) and Sum is the total number of cells.

Final Product: after calculating all the habitat units, input values for each Evaluation unit based on flow into the GIS Outputs Table of Values



Evaluation Unit	Flow	FWOP Riverine	FWOP Riparian Scrub-Shrub	FWOP Riparian Forest	FWOP total HU	FWP Year 1 Riverine	FWP Year 1 Riparian Scrub-Shrub	FWP Year 1 Riparian Forest	FWP Year 1 total HU	FWP Year 5 Riverine	FWP Year 5 Riparian Scrub-Shrub	FWP Year 5 Riparian Forest	FWP Year 5 total HU
	750 cfs	193205.7	879.179	97344	NA	311537.2	22736.21	96345	NA	311537.2	69792.41	96345	NA
Evaluation Unit 1	1850 cfs	37164.55	827.7795	94554	NA	267084.9	22562.09	93555	NA	267084.9	69381.65	93555	NA
	5000 cfs	115831	764.7738	88672.5	NA	101367.7	21471.16	87673.5	NA	101367.7	66701.84	87673.5	NA
	750 cfs	114298.2	23240.65	129685.5	NA	114373.6	31413.51	129685.5	NA	114373.6	55103.63	129685.5	NA
Evaluation Unit 2	1850 cfs	65548.23	22704.84	129470	NA	65602.24	30899.97	129469.5	NA	65602.24	54590.09	129469.5	NA
	5000 cfs	11888.87	20655.75	128790	NA	45088.91	28853.2	128790	NA	45088.91	52543.32	128790	NA
	750 cfs	196839.2	72865.38	29655.92	NA	199996.8	147916.8	29655.92	NA	199996.8	369216.2	29655.92	NA
Evaluation Unit 3	1850 cfs	91020.04	7800.34	29157.02	NA	96267.56	141820.8	29157.02	NA	96267.56	353028	29157.02	NA
	5000 cfs	33702.89	55371.71	27586.76	NA	45986.5	122669.2	27586.76	NA	45986.5	322040.5	27586.76	NA
	750 cfs	480576.6	170498.7	206497.2	NA	481359.1	238845.9	206497.2	NA	481359.1	445186.3	206497.2	NA
Evaluation Unit 4	1850 cfs	361285.3	167336.8	203876.5	NA	379780.6	232424.7	203876.5	NA	379780.6	429199.1	203876.5	NA
	5000 cfs	174374.4	145911.2	199642.9	NA	223459	203420.6	199642.9	NA	223459	377064.7	199642.9	NA
	750 cfs	257867.8	129830.1	91714.85	NA	253215.6	187430	55836.7	NA	253215.6	417017.3	55836.7	NA
Evaluation Unit 5	1850 cfs	163370.6	128760.6	91669.85	NA	211864.2	185910.1	55791.7	NA	211864.2	414302.9	55791.7	NA
	5000 cfs	96459.36	121115.3	91642.85	NA	215582.2	176722.9	55764.7	NA	215582.2	397344.4	55764.7	NA
	750 cfs	1056181	237846.7	1227707	NA	1071368	187430	1227662	NA	1071368	945853	1227662	NA
Evaluation Unit 6	1850 cfs	918752.1	228337	1199839	NA	953001.6	385630.5	1199839	NA	953001.6	890670.4	1199839	NA
	5000 cfs	651583.8	192333.9	1152603	NA	870146.4	309854	1152603	NA	870146.4	690131.7	1152603	NA
	750 cfs	196517.6	80896.33	885859.8	NA	197847.2	116857	885859.8	NA	197847.2	230680.4	885859.8	NA
Evaluation Unit 7	1850 cfs	124249	78543.98	885859.8	NA	189286.8	113764.5	885859.8	NA	189286.8	225121.5	885859.8	NA
	5000 cfs	83883.57	53690.05	885859.8	NA	145851.9	85589.1	885859.8	NA	145851.9	186214.7	885859.8	NA
	750 cfs	569354.1	328516	1351397	NA	627476.6	509193.3	1238848	NA	627476.6	1205309	1238848	NA
Evaluation Unit 8	1850 cfs	346215.7	316398.2	1337438	NA	831331.8	496713.8	1224889	NA	831331.8	1189460	1224889	NA
	5000 cfs	175974.3	276220.4	1282781	NA	621838.4	452652.3	1170232	NA	621838.4	1120579	1170232	NA
	750 cfs	475289.7	254159.2	1611219	NA	480432.7	280980.2	1429319	NA	480432.7	355856.9	1429319	NA
Evaluation Unit 9	1850 cfs	339733	248122.7	1595793	NA	400054.5	273876.7	1414190	NA	400054.5	345269.5	1414190	NA
	5000 cfs	228382.9	206035.3	1530084	NA	361362.3	227650.9	1349057	NA	361362.3	286983.1	1349057	NA

Evaluation Unit	Flow	FWP Year 15 Riverine	FWP Year 15 Riparian Scrub-Shrub	FWP Year 15 Riparian Forest	FWP Year 15 total HU	FWP Year 25 Riverine	FWP Year 25 Riparian Scrub-Shrub	FWP Year 25 Riparian Forest	FWP Year 25 total HU	FWP Year 50 Riverine	FWP Year 50 Riparian Scrub-Shrub	FWP Year 50 Riparian Forest	FWP Year 50 total HU
	750 cfs	311537.2	879.179	235872	NA	311537.2	879.179	235872	NA	311537.2	879.179	166108.5	NA
Evaluation Unit 1	1850 cfs	267084.9	834.4117	232551	NA	267084.9	834.4117	232551	NA	267084.9	834.4117	163053	NA
	5000 cfs	101367.7	768.9189	224428.5	NA	101367.7	768.9189	224428.5	NA	101367.7	768.9189	156051	NA
	750 cfs	114373.6	23240.64	233230.5	NA	114373.6	23240.64	233230.5	NA	114373.6	23240.64	181458	NA
Evaluation Unit 2	1850 cfs	65602.24	22727.11	233014.5	NA	65602.24	22727.11	233014.5	NA	65602.24	22727.11	181242	NA
	5000 cfs	45088.91	20680.33	232335	NA	45088.91	20680.33	232335	NA	45088.91	20680.33	180562.5	NA
	750 cfs	199996.8	72865.38	1016821	NA	199996.8	72865.38	1016821	NA	199996.8	72865.38	523238.4	NA
Evaluation Unit 3	1850 cfs	96267.56	70279.59	971124	NA	96267.56	70279.59	971124	NA	96267.56	70279.59	500140.5	NA
	5000 cfs	45986.5	55556.45	899488.8	NA	45986.5	55556.45	899488.8	NA	45986.5	55556.45	463537.8	NA
	750 cfs	481359.1	170498.7	1060390	NA	481359.1	170498.7	1060390	NA	481359.1	170498.7	633443.7	NA
Evaluation Unit 4	1850 cfs	379780.6	167221.8	1018377	NA	379780.6	167221.8	1018377	NA	379780.6	167221.8	611126.5	NA
	5000 cfs	223459	145880.5	917896.9	NA	223459	145880.5	917896.9	NA	223459	145880.5	558769.9	NA
	750 cfs	253215.6	111535.3	1003545	NA	253215.6	111535.3	1003545	NA	253215.6	111535.3	527975.6	NA
Evaluation Unit 5	1850 cfs	211864.2	110406.9	998955.5	NA	211864.2	110406.9	998955.5	NA	211864.2	110406.9	525658.1	NA
	5000 cfs	215582.2	103789.3	966636.5	NA	215582.2	103789.3	966636.5	NA	215582.2	103789.3	509485.1	NA
	750 cfs	1071368	228078.2	3473495	NA	1071368	228078.2	3473495	NA	1071368	228078.2	2350471	NA
Evaluation Unit 6	1850 cfs	953001.6	218722.3	3301888	NA	953001.6	218722.3	3301888	NA	953001.6	218722.3	2250787	NA
	5000 cfs	870146.4	184228.3	2731473	NA	870146.4	184228.3	2731473	NA	870146.4	184228.3	1941962	NA
	750 cfs	197847.2	79354.79	1362329	NA	197847.2	79354.79	1362329	NA	197847.2	79354.79	1124094	NA
Evaluation Unit 7	1850 cfs	189286.8	77073.52	1351871	NA	189286.8	77073.52	1351871	NA	189286.8	77073.52	1118865	NA
	5000 cfs	145851.9	52495.9	1304054	NA	145851.9	52495.9	1304054	NA	145851.9	52495.9	1094957	NA
	750 cfs	627476.6	278049.5	4137283	NA	627476.6	278049.5	4137283	NA	627476.6	278049.5	2685371	NA
Evaluation Unit 8	1850 cfs	831331.8	266701.4	4107925	NA	831331.8	266701.4	4107925	NA	831331.8	266701.4	2663713	NA
	5000 cfs	621838.4	230896.8	3946357	NA	621838.4	230896.8	3946357	NA	621838.4	230896.8	2555600	NA
	750 cfs	480432.7	253929.8	1755005	NA	480432.7	253929.8	1755005	NA	480432.7	253929.8	1581665	NA
Evaluation Unit 9	1850 cfs	400054.5	247989.7	1724891	NA	400054.5	247989.7	1724891	NA	400054.5	247989.7	1559044	NA
	5000 cfs	361362.3	206035.3	1597595	NA	361362.3	206035.3	1597595	NA	361362.3	206035.3	1462829	NA

YRERFS GIS WORKFLOW AND MODELING PROCESS

Presenter Name

Presenter Title

Duty Location

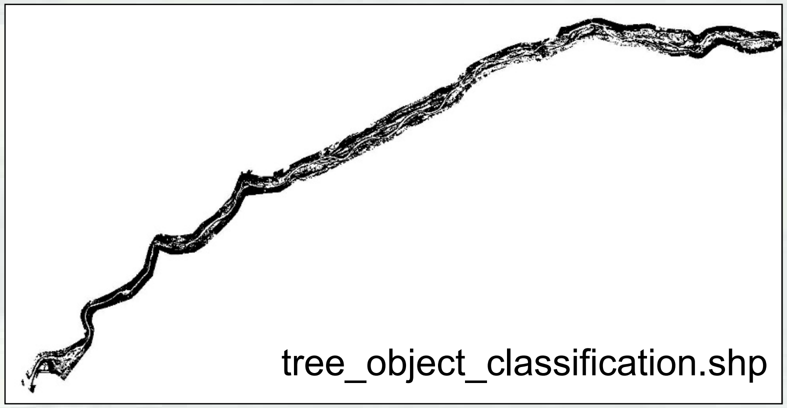
Date of Presentation

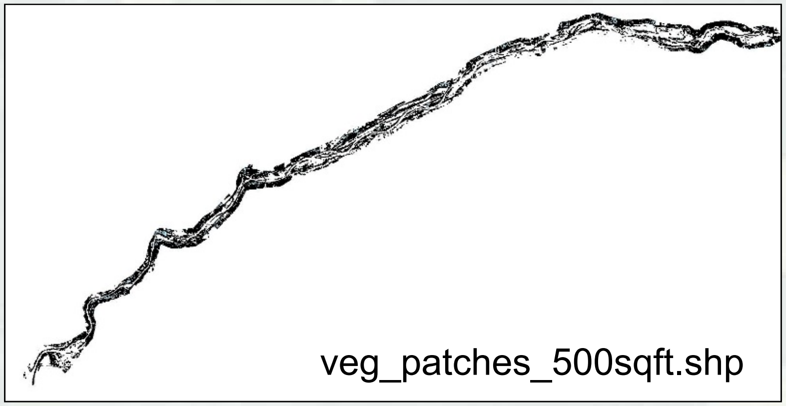
US Army Corps of Engineers
BUILDING STRONG®

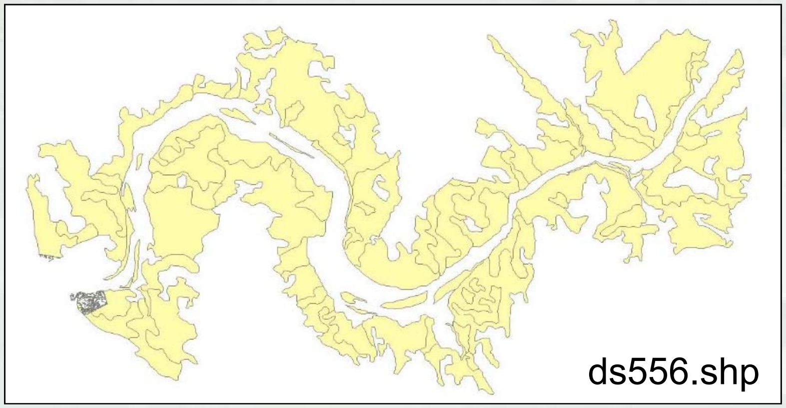
YRERFS Yellow Warbler Riparian Scrub Shrub (RSS) Habitat Determination

Original Data Sets

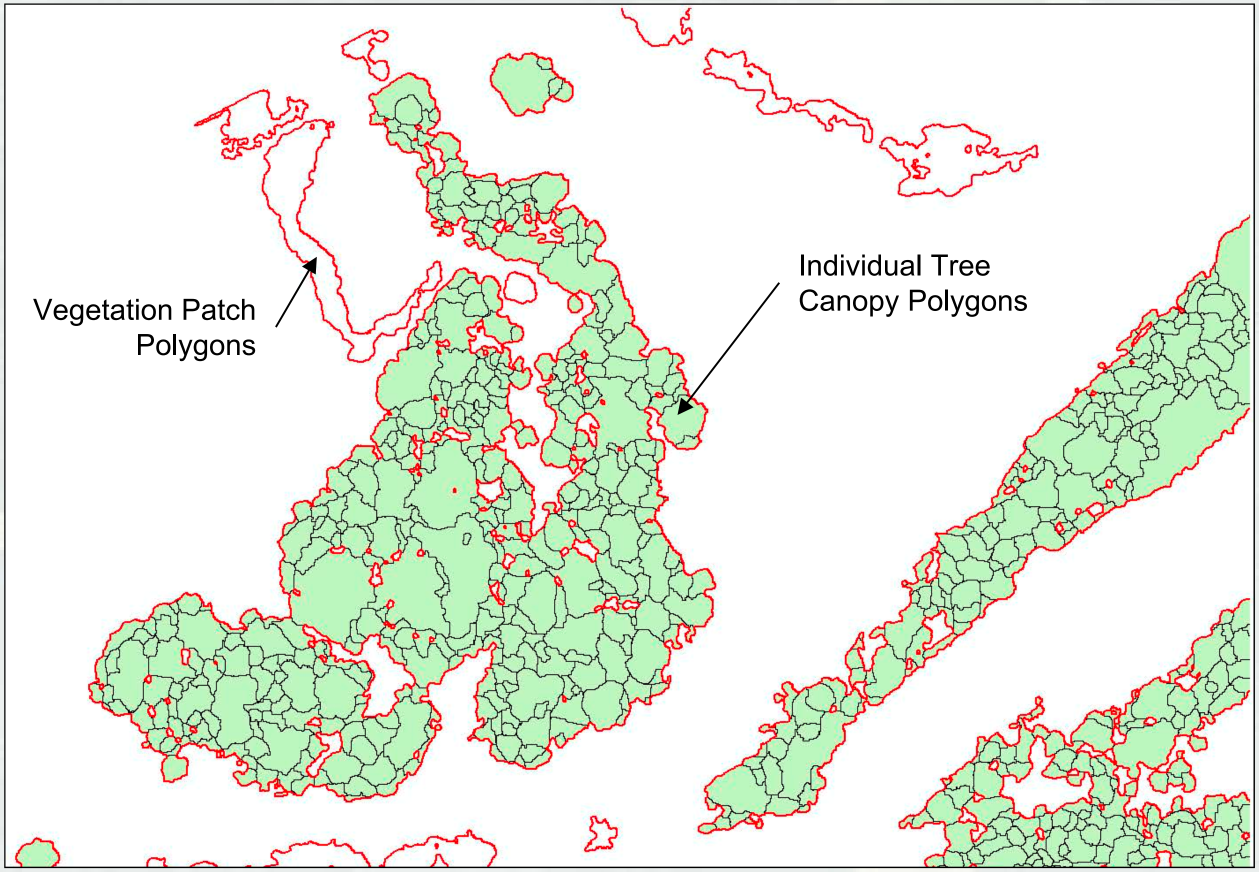
Three datasets were initially used to produce the base data workflow. The tree object classification and vegetation patch datasets were provided by HDR and the third dataset for the area east of HWY 20 came from the Department of Fish and Wildlife web mapping portal.







Prior to conducting an intersect between the layers several new fields were added to the veg patch layer; unique ID, patch area, and canopy type. Canopy type is determined based on the average height of the patch. A height of greater than 16.5 feet was designated Riparian Forest (RF) and 16.5 feet or less was designated Riparian Scrub Shrub (RSS). Similarly new fields of canopy type and canopy area were added to the tree object layer to determine and label each polygon with an RF or RSS designation based on its height. The layers were then intersected so the tree object layer was connected with the veg patch it fell within and given the corresponding unique ID. Since we are dealing with RSS only for Yellow Warbler habitat, the objects designated RSS were queried out as their own layer to conduct the calculations.



RF tree objects intersected with RF veg patches

Three elements needed to determine HSI for Yellow Warbler:

1. % Canopy Cover: percentage of RSS per unit
2. % Hydrophytic Shrub: percentage of hydrophytic shrub area per patch
3. Average Canopy Height: average height of RSS from 0 to 16.5 feet

Percent Hydrophytic

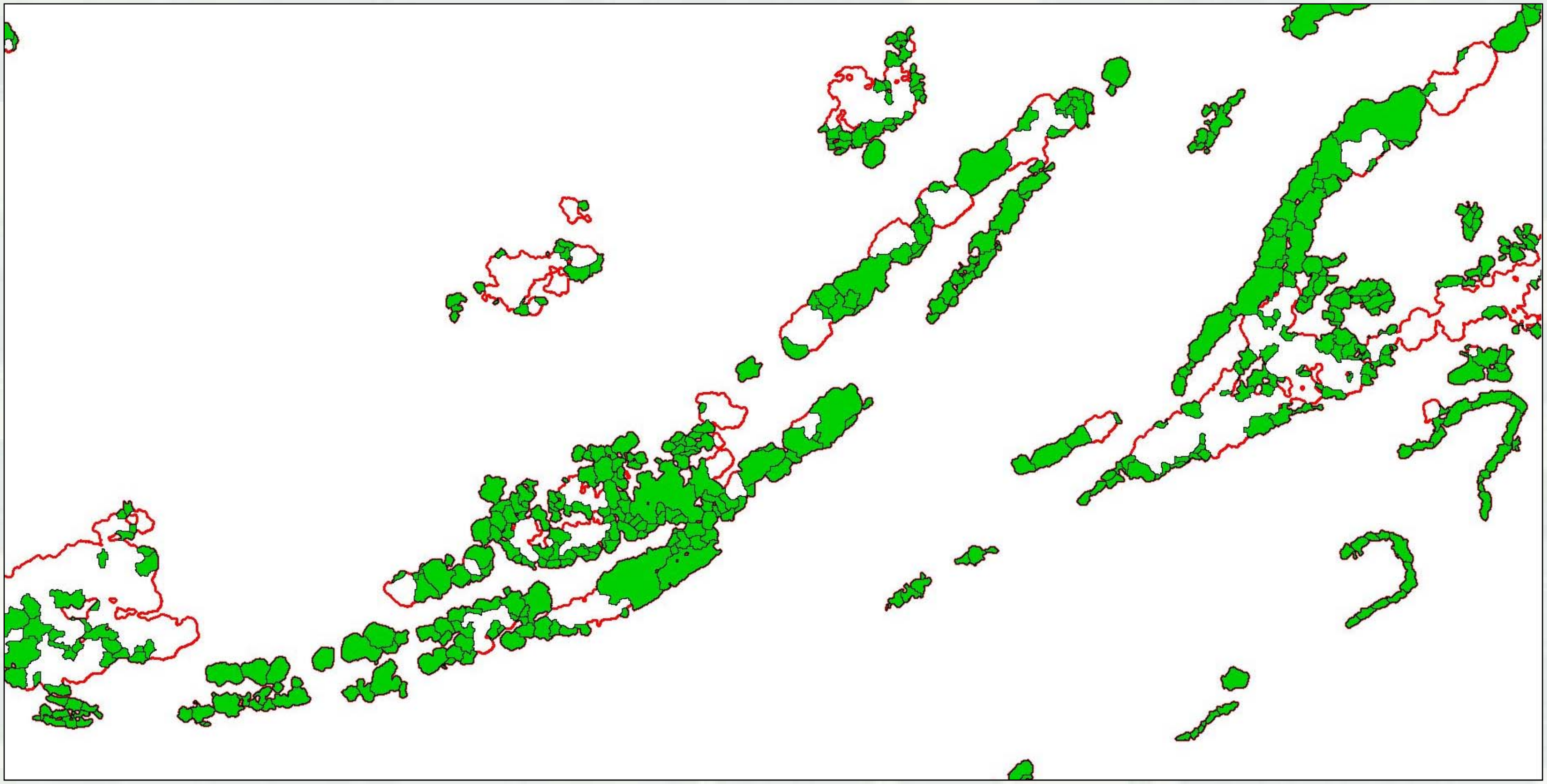
- Sum of the canopy area (sqft) for all hydrophytic RSS within each RSS designated veg patch divided by the total patch area (sqft) for that patch.

Ex:

Patch #1011 has a total patch area of 22,458.99 sqft and the sum of all the hydrophytic shrubs canopy area within that patch is 15,670.99. thus the percentage of hydrophytic shrubs is 69.77%

$$(15670.99/22458.99) * 100 = 69.77\%$$

Percent Hdyro Layer:



Percent hydrophytic resulting table should look similar to the one below after all calculations have been done.

OBJECTI	uniq_patch_ID *	cover_type	veg_canopy_mrh_mean_16_5	Max_nDSM	final_pred	veg_canopy_type	canopy_area	shrub_sum_per_patch	patch_area	perc_hydro_per_patch
1	P1011	hydrophytic	RSS	4.360001	ald	shrub	30	15670.999997	22458.999999	69.776036
2	P1011	hydrophytic	RSS	1.739998	wil	shrub	15	15670.999997	22458.999999	69.776036
3	P1011	hydrophytic	RSS	2.530003	wil	shrub	39	15670.999997	22458.999999	69.776036
4	P1011	hydrophytic	RSS	1.789997	wil	shrub	10	15670.999997	22458.999999	69.776036
5	P1011	hydrophytic	RSS	1.480003	wil	shrub	1	15670.999997	22458.999999	69.776036
6	P1011	hydrophytic	RSS	1.640007	wil	shrub	18	15670.999997	22458.999999	69.776036
7	P1011	hydrophytic	RSS	2.309998	eld	shrub	32	15670.999997	22458.999999	69.776036
8	P1011	hydrophytic	RSS	3.41	wil	shrub	103.000001	15670.999997	22458.999999	69.776036
9	P1011	hydrophytic	RSS	1.82	eld	shrub	29	15670.999997	22458.999999	69.776036
10	P1011	hydrophytic	RSS	1.66	wil	shrub	42	15670.999997	22458.999999	69.776036
11	P1011	hydrophytic	RSS	9.700001	wil	shrub	124.999999	15670.999997	22458.999999	69.776036
12	P1011	hydrophytic	RSS	5.709999	wil	shrub	85	15670.999997	22458.999999	69.776036
13	P1011	hydrophytic	RSS	10.579998	eld	shrub	485	15670.999997	22458.999999	69.776036
14	P1011	hydrophytic	RSS	2.529999	wil	shrub	125.999999	15670.999997	22458.999999	69.776036
15	P1011	hydrophytic	RSS	3.770004	wil	shrub	303	15670.999997	22458.999999	69.776036
16	P1011	hydrophytic	RSS	6.27	wil	shrub	234.999999	15670.999997	22458.999999	69.776036
17	P1011	hydrophytic	RSS	3.540001	wil	shrub	259	15670.999997	22458.999999	69.776036
18	P1011	hydrophytic	RSS	3.830002	ald	shrub	81.999999	15670.999997	22458.999999	69.776036
19	P1011	hydrophytic	RSS	6.340004	wil	shrub	355	15670.999997	22458.999999	69.776036
20	P1011	hydrophytic	RSS	8.5	wil	shrub	277	15670.999997	22458.999999	69.776036
21	P1011	hydrophytic	RSS	7.739998	eld	shrub	510.000001	15670.999997	22458.999999	69.776036
22	P1011	hydrophytic	RSS	12.280006	wil	shrub	1367.999999	15670.999997	22458.999999	69.776036
23	P1011	hydrophytic	RSS	9.900002	wil	shrub	202.000001	15670.999997	22458.999999	69.776036
24	P1011	hydrophytic	RSS	5.110001	wil	shrub	176	15670.999997	22458.999999	69.776036
25	P1011	hydrophytic	RSS	5.41	wil	shrub	296.000001	15670.999997	22458.999999	69.776036
26	P1011	hydrophytic	RSS	11	wil	shrub	125.999999	15670.999997	22458.999999	69.776036
27	P1011	hydrophytic	RSS	2.02	wil	shrub	73	15670.999997	22458.999999	69.776036
28	P1011	hydrophytic	RSS	3.489998	wil	shrub	79	15670.999997	22458.999999	69.776036
29	P1011	hydrophytic	RSS	6.540001	wil	shrub	586.000001	15670.999997	22458.999999	69.776036
30	P1011	hydrophytic	RSS	10.079998	eld	shrub	276	15670.999997	22458.999999	69.776036
31	P1011	hydrophytic	RSS	13.140007	wil	shrub	389	15670.999997	22458.999999	69.776036
32	P1011	hydrophytic	RSS	12.379997	wil	shrub	276	15670.999997	22458.999999	69.776036
33	P1011	hydrophytic	RSS	4.510002	wil	shrub	108	15670.999997	22458.999999	69.776036
34	P1011	hydrophytic	RSS	11.460003	wil	shrub	1029	15670.999997	22458.999999	69.776036
35	P1011	hydrophytic	RSS	9.18	wil	shrub	350	15670.999997	22458.999999	69.776036
36	P1011	hydrophytic	RSS	8.189999	wil	shrub	124	15670.999997	22458.999999	69.776036
37	P1011	hydrophytic	RSS	7.010002	wil	shrub	341	15670.999997	22458.999999	69.776036
38	P1011	hydrophytic	RSS	10.920002	wil	shrub	1069	15670.999997	22458.999999	69.776036
39	P1011	hydrophytic	RSS	8.670002	syc	shrub	94	15670.999997	22458.999999	69.776036
40	P1011	hydrophytic	RSS	11.480003	wil	shrub	676	15670.999997	22458.999999	69.776036

Percent Cover:

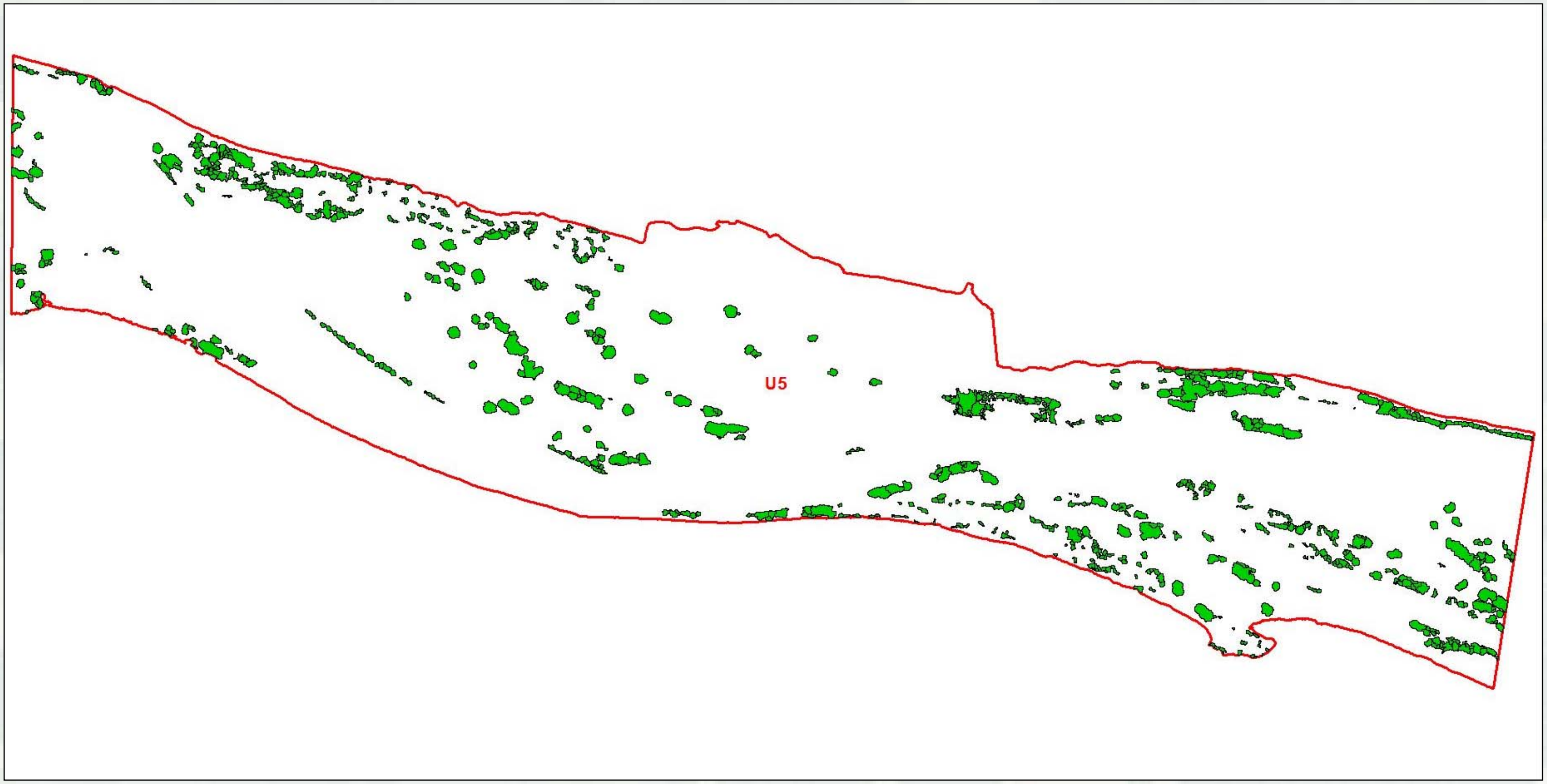
- Sum of the canopy area (sqft) for all RSS within each Unit (1-9) divided by the area (sqft) of that unit.

Ex:

Patch #1460 has an RSS canopy total of 927,406.89 sqft and the Unit (#1) has an area of 5,960,601.90 sqft giving a percent cover total of 15.56%

*(927,406.89/5,960,601.90) * 100 = 15.56%*

Percent Cover Layer:



BUILDING STRONG®

Percent cover resulting table should look similar to the one below after all calculations have been done:

OBJECTID *	uniq_patch_ID *	canopy_area_sqft	FWOP_hab_type	unit_ID	sum_canopyarea_sqft	unit_area_sqft	perc_cover_per_unit
2755	P1460	124.999999	RSS	U1	927406.897374	5960601.9	15.558947
2756	P1460	98.335794	RSS	U1	927406.897374	5960601.9	15.558947
2757	P1460	607.311242	RSS	U1	927406.897374	5960601.9	15.558947
2758	P1460	277.615582	RSS	U1	927406.897374	5960601.9	15.558947
1799	P1461	98	RSS	U1	927406.897374	5960601.9	15.558947
1864	P1461	418	RSS	U1	927406.897374	5960601.9	15.558947
1865	P1461	73.999999	RSS	U1	927406.897374	5960601.9	15.558947
1866	P1461	30	RSS	U1	927406.897374	5960601.9	15.558947
1691	P1462	2	RSS	U1	927406.897374	5960601.9	15.558947
1796	P1462	20.46464	RSS	U1	927406.897374	5960601.9	15.558947
1797	P1462	1	RSS	U1	927406.897374	5960601.9	15.558947
1798	P1462	12	RSS	U1	927406.897374	5960601.9	15.558947
1863	P1462	29.854741	RSS	U1	927406.897374	5960601.9	15.558947
1793	P1463	302	RSS	U1	927406.897374	5960601.9	15.558947
1794	P1463	75.999999	RSS	U1	927406.897374	5960601.9	15.558947
1795	P1463	16	RSS	U1	927406.897374	5960601.9	15.558947
1860	P1463	86.000001	RSS	U1	927406.897374	5960601.9	15.558947
1861	P1463	256	RSS	U1	927406.897374	5960601.9	15.558947
1862	P1463	52	RSS	U1	927406.897374	5960601.9	15.558947
1891	P1464	90.737638	RSS	U1	927406.897374	5960601.9	15.558947
1690	P1465	50	RSS	U1	927406.897374	5960601.9	15.558947
1790	P1465	52	RSS	U1	927406.897374	5960601.9	15.558947
1791	P1465	32	RSS	U1	927406.897374	5960601.9	15.558947
1792	P1465	34	RSS	U1	927406.897374	5960601.9	15.558947
1859	P1465	187	RSS	U1	927406.897374	5960601.9	15.558947
1894	P1465	161	RSS	U1	927406.897374	5960601.9	15.558947
1895	P1465	234.000001	RSS	U1	927406.897374	5960601.9	15.558947
1689	P1466	29	RSS	U1	927406.897374	5960601.9	15.558947
1788	P1466	61	RSS	U1	927406.897374	5960601.9	15.558947
1789	P1466	2	RSS	U1	927406.897374	5960601.9	15.558947
1858	P1466	378	RSS	U1	927406.897374	5960601.9	15.558947
1870	P1466	418.999999	RSS	U1	927406.897374	5960601.9	15.558947
1871	P1466	143	RSS	U1	927406.897374	5960601.9	15.558947
1682	P1467	22	RSS	U1	927406.897374	5960601.9	15.558947
1683	P1467	6	RSS	U1	927406.897374	5960601.9	15.558947
1684	P1467	2	RSS	U1	927406.897374	5960601.9	15.558947
1685	P1467	15	RSS	U1	927406.897374	5960601.9	15.558947
1686	P1467	30	RSS	U1	927406.897374	5960601.9	15.558947
1687	P1467	23	RSS	U1	927406.897374	5960601.9	15.558947
1688	P1467	8	RSS	U1	927406.897374	5960601.9	15.558947

Average Height:

- Within the original *veg_patches_500sqft.shp* there is a column labeled mrh_mean. This layer is based on the values of that column.

  Ex:

  Patch #2 mrh_mean equals 10.0074 feet

Average Height Layer:

BUILDING STRONG®

Average height resulting table should look similar to the one below after all calculations have been done:

OBJECTID *	uniq_patch_ID	veg_canopy_mrh_mean_16_5	patch_area	mrh_MEAN
2	P2	RSS	1173	10.0074
3	P3	RSS	1253.000001	9.2399
4	P4	RSS	873	7.42536
5	P5	RSS	1038	8.65874
6	P6	RSS	602.000001	8.98248
7	P7	RSS	1415	9.4933
8	P8	RSS	1046	8.98746
9	P9	RSS	2637	10.024
10	P10	RSS	2937.999999	10.7309
11	P11	RSS	3212.999999	10.677
12	P12	RSS	3156.000001	11.2352
13	P13	RSS	1000.000001	12.6037
14	P14	RSS	3809.000001	11.5473
15	P15	RSS	2879.000001	12.4995
16	P16	RSS	7968	13.3574
17	P17	RSS	552	9.9786
18	P18	RSS	66963.999995	14.6527
19	P19	RSS	76775.999995	11.3317
20	P20	RSS	589.999999	10.2476
21	P21	RSS	757	8.16641
22	P22	RSS	68674.000002	10.3313
23	P23	RSS	124133.000002	11.5152
24	P24	RSS	785.000001	16.3967
28	P28	RSS	38533	10.3815
29	P29	RSS	580	11.6401
30	P30	RSS	738	7.67482
31	P31	RSS	981	7.87983
32	P32	RSS	519.000001	7.74452
33	P33	RSS	727	6.63634
34	P34	RSS	8059.999998	9.26979
36	P36	RSS	531	2.44963
37	P37	RSS	574	6.64849
38	P38	RSS	2192.000001	9.11792
39	P39	RSS	689.000001	5.18902
40	P40	RSS	601.000001	1.66924
41	P41	RSS	3197.000001	10.7447
42	P42	RSS	715	13.073
43	P43	RSS	2069	16.1482
44	P44	RSS	552	15.5906
45	P45	RSS	707	15.4921

Convert the RSS polygons into future without project (FWOP) rasters based on values under the following column titles in each table:

Percent Hydrophytic

ch_area	perc_hydro_per_patch
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036
458.999999	69.776036

Percent Cover

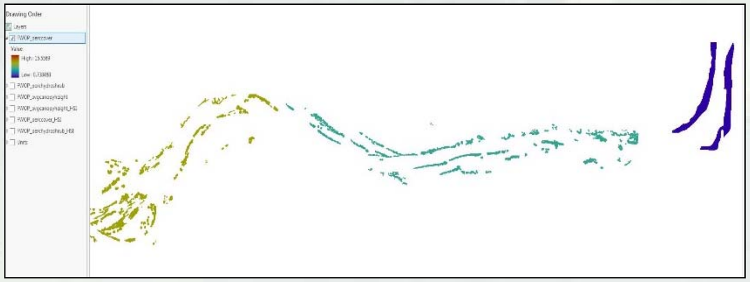
a_sqft	perc_cover_per_unit
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947
5960601.9	15.558947

Average Height

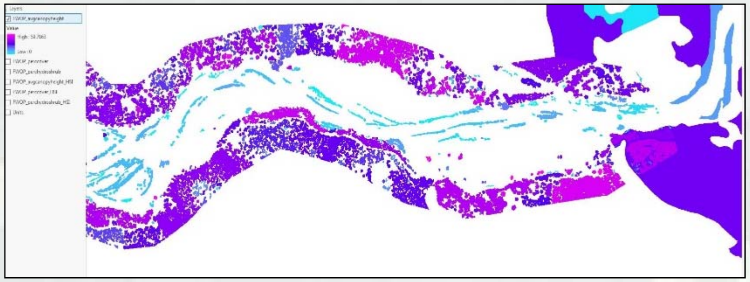
rea	mrh_MEAN
1173	10.0074
00001	9.2399
873	7.42536
1038	8.65874
00001	8.98248
1415	9.4933
1046	8.98746
2637	10.024
99999	10.7309
99999	10.677
00001	11.2352
00001	12.6037
00001	11.5473
00001	12.4995
7968	13.3574
552	9.9786
99995	14.6527
99995	11.3317
99999	10.2476
757	8.16641
00002	10.3313
00002	11.5152
00001	16.3967
38533	10.3815
580	11.6401
738	7.67482
981	7.87983
00001	7.74452
727	6.63634
99998	9.26979
531	2.44963
574	6.64849
00001	9.11792
00001	5.18902
00001	1.66924
00001	10.7447
715	13.073
2069	16.1482
552	15.5906
707	15.4921

RSS FWOP rasters based on values in each table:

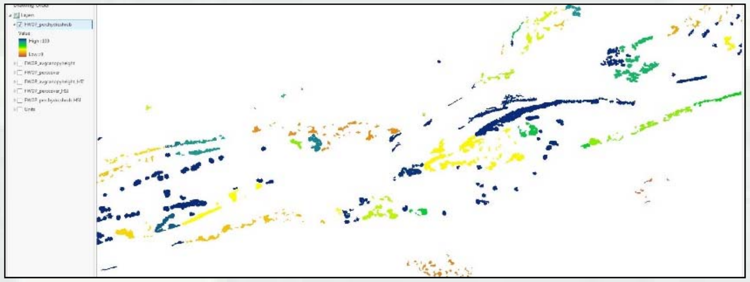
Percent Cover



Average Height



Percent Hydrophytic



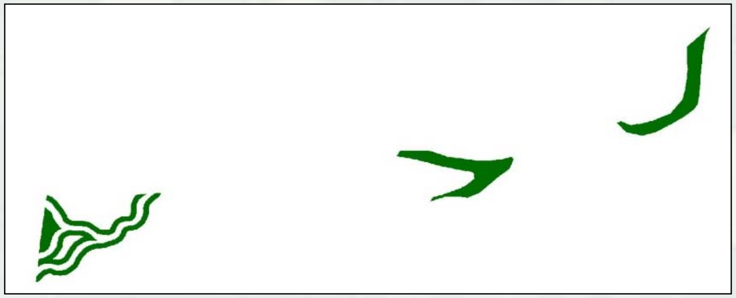
Create a raster of the measures polygon and assign the following values:

	Year 1			
Canopy Type (Riparian Scrub-shrub or Riparian Forest)	% Decidious Shrub Canopy Comprised of Hydrophytic Shrubs (% of hydrophytic shrubs per patch)	Average height of Canopy	% Cover of Shrub canopy (% of polygon area)	Basal Area
RSS	81.3	2	1.5	FWOP
	Year 5			
Canopy Type (Riparian Scrub-shrub or Riparian Forest)	% Decidious Shrub Canopy Comprised of Hydrophytic Shrubs (% of hydrophytic shrubs per patch)	Average height of Canopy	% Cover of Shrub canopy (% of polygon area)	
RSS	81.3	9.6	7.5	FWOP
	Year 15			
Canopy Type (Riparian Scrub-shrub or Riparian Forest)	% Decidious Shrub Canopy Comprised of Hydrophytic Shrubs (% of hydrophytic shrubs per patch)	Average height of Canopy	% Cover of Shrub canopy (% of polygon area)	Basal Area
RF	81.3	25.8	22.5	10.1
	Year 25			
Canopy Type (Riparian Scrub-shrub or Riparian Forest)	% Decidious Shrub Canopy Comprised of Hydrophytic Shrubs (% of hydrophytic shrubs per patch)	Average height of Canopy	% Cover of Shrub canopy by Reach	Basal Area
RF	81.3	37.8	37.5	16.8
	Year 50			
Canopy Type (Riparian Scrub-shrub or Riparian Forest)	% Decidious Shrub Canopy Comprised of Hydrophytic Shrubs (% of hydrophytic shrubs per patch)	Average height of Canopy	% Cover of Shrub canopy by Reach	Basal Area
RF	81.3	49.8	75	33.7

Mosaic: Use *mosaic to new raster* tool to combine the FWOP perc hydro shrub with the measures only raster to create a Future With Project (FWP) raster. Take that raster and copy it to make one for years 1, 5, 15, 25, & 50. *Note: for years 15, 25 & 50 you will see decreased numbers for RSS because the shrubs will have grown above the 16.5 foot shrub height designation*.

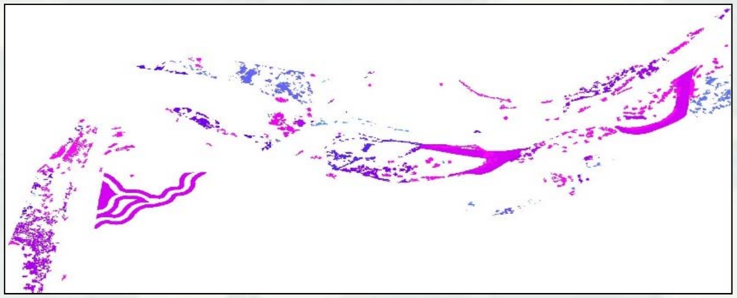
FWOP_perchydroshrub: Values of 0 – 100 percent

+



FWP_yr1_perchydroshrub_measureonly: Value of 81.3%

=



FWP_yr5_perchydroshrub: Values of 0 – 100 percent

Suitability Index (SI) needs to be determined for FWOP, FWP yrs 1, 5, 15, 25, & 50 using the tables below:

Percent Cover

% cover range	Formula
for % cover from 0 to 60%	SI = 0.0167(% Cover)
for % cover from 60 to 80%	SI =1
for % cover from 80 to 100%	SI = -0.05(% Cover) + 5

Average Height

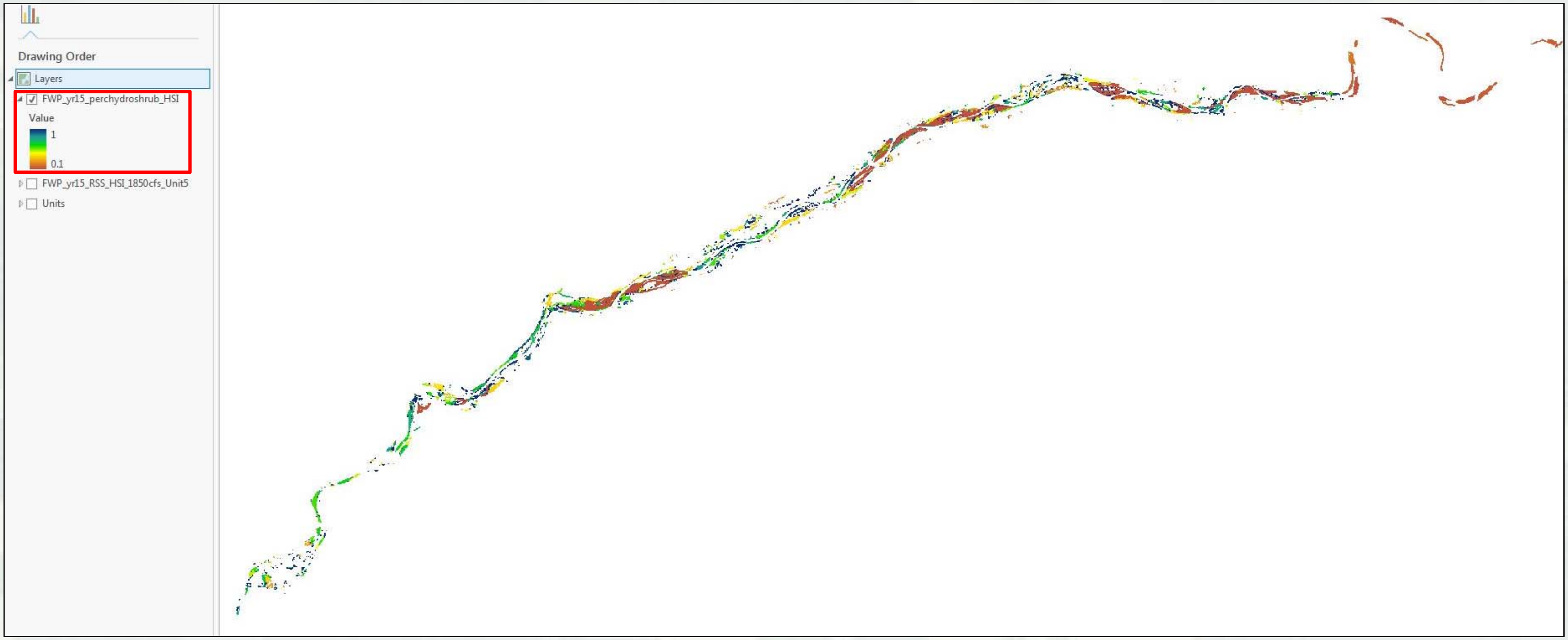
Average Canopy Height (ft)	Formula
for canopy from 0 to 6.56ft	SI = 0.1524 x height
for canopy greater than 6.56ft	SI =1

Percent Hydrophytic

% Hydrophytic Cover	Formula
All values	SI = 0.009(% cover hydro) + 0.1

Ex. A hydrophytic cover with a percentage of 55.86 would yield an SI value of 0.60. (SI = 0.009(55.86) + 0.1)

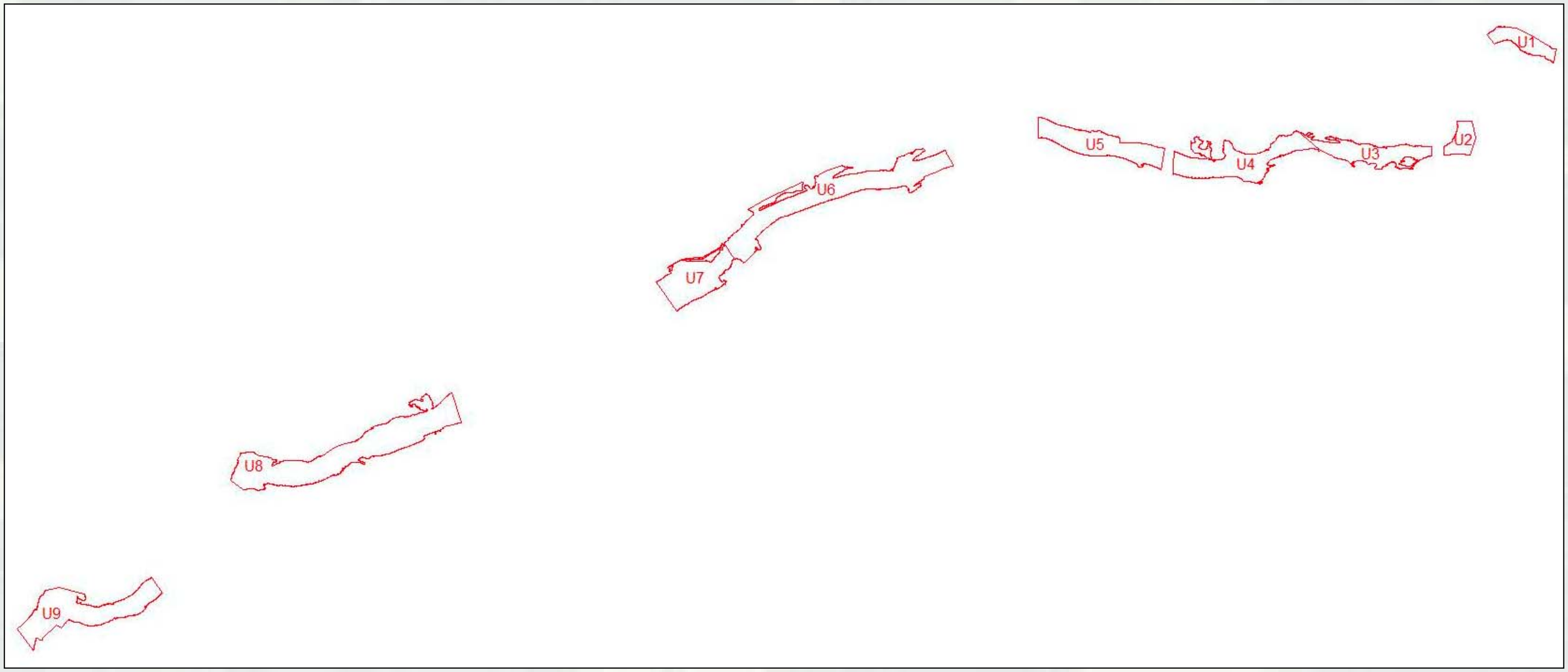
SI values should be between 0 and 1



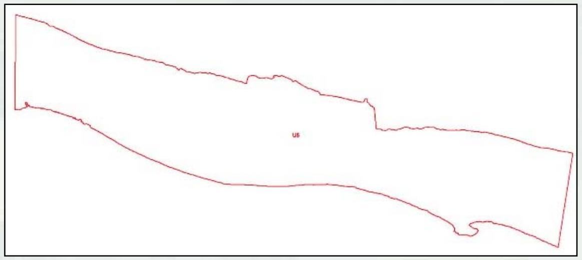
After all SI calculations have been determined those values will be used to determine the HSI values using the following formula:

Yellow Warbler AKA Riparian Scrub Shrub HSI RASTER = $(SI_{\%cover} \times SI_{height} \times SI_{\%hydro})^{1/2}$

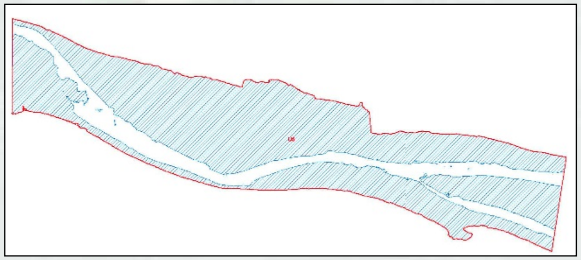
To refine results of the HSI and make it pertinent to the areas where measures are, a new layer was created to clip out the needed features. The layer, ”Units”, has a north-south boundary based on the 84,000 cfs flow boundary and an east west boundary of 500 feet off either end of the widest measure in each measure grouping. There are 9 units total.



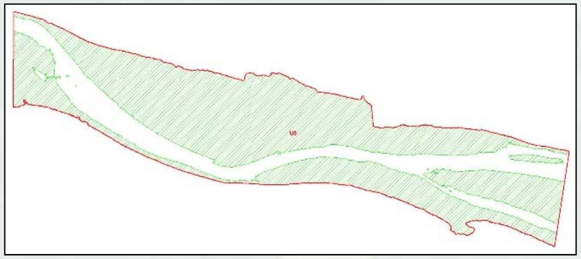
All 9 units were then clipped by three flow boundaries (750, 1850, and 5000 cfs) to get 27 individual polygons that will be used to clip the rasters.



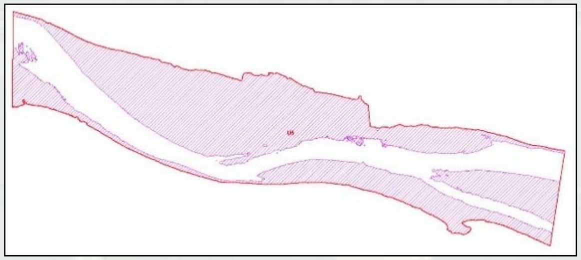
Unit 5



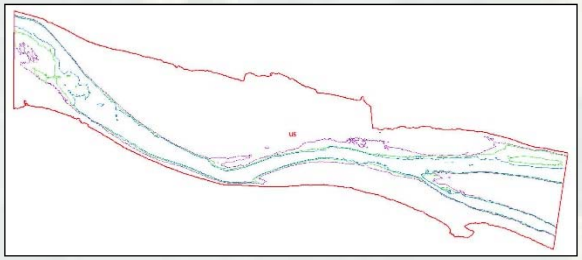
Unit 5: 750 cfs flow boundary clipped out



Unit 5: 1850 cfs flow boundary clipped out

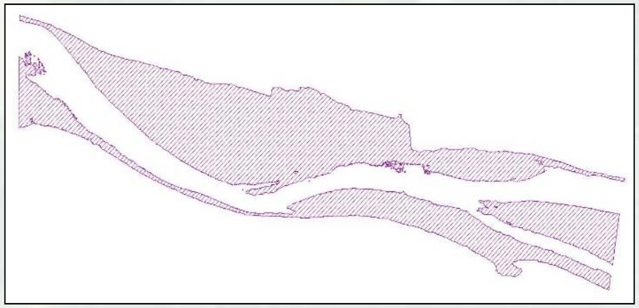


Unit 5: 5000 cfs flow boundary clipped out



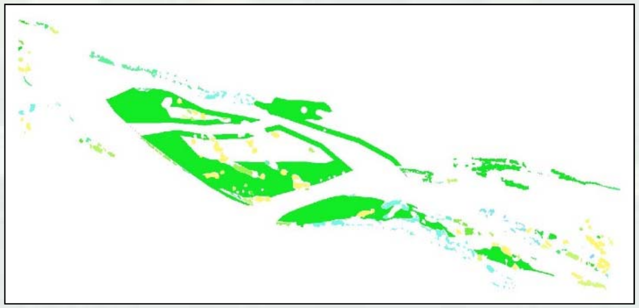
Unit 5: all 3 flows to show the difference between them.

Extract by Mask: to do this you take a unit polygon (unit_5000cfs_unit5 polygon) and use it to mask and HSI raster (FWP_yr25_basalarea_HSI) raster and the resulting output from the process is portions of the input raster bound by the unit mask.



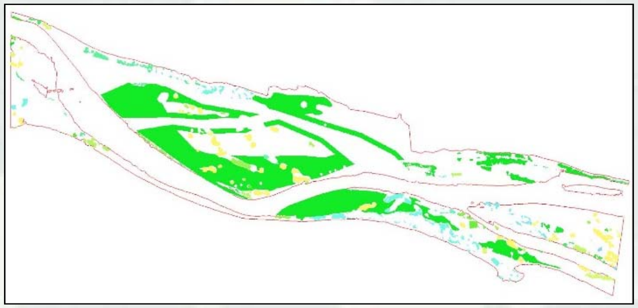
Mask: Unit 5 1850 cfs polygon

+



FWP yr5 RSS HSI raster

=



Result: raster within the bounds of the unit 5 polygon

When done with all the extracts, you will have approximately 162 rasters:

FWP_yr1_RSS_HSI_1850cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_1850cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_1850cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_1850cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_1850cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_1850cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_1850cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_1850cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_1850cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_5000cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_5000cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_5000cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_5000cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_5000cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_5000cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_5000cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_5000cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_5000cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_750cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_750cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_750cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_750cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_750cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_750cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_750cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_750cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr1_RSS_HSI_750cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_1850cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_1850cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_1850cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_1850cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_1850cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_1850cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_1850cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_1850cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_1850cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_5000cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_5000cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_5000cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_5000cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_5000cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_5000cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_5000cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_5000cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_5000cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_750cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_750cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_750cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_750cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_750cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_750cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_750cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_750cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr15_RSS_HSI_750cfs_Unit9	File Geodatabase Raster Dataset

FWP_yr25_RSS_HSI_1850cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_1850cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_1850cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_1850cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_1850cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_1850cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_1850cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_1850cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_1850cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_5000cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_5000cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_5000cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_5000cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_5000cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_5000cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_5000cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_5000cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_5000cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_750cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_750cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_750cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_750cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_750cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_750cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_750cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_750cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr25_RSS_HSI_750cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_1850cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_1850cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_1850cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_1850cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_1850cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_1850cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_1850cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_1850cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_1850cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_5000cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_5000cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_5000cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_5000cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_5000cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_5000cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_5000cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_5000cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_5000cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_750cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_750cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_750cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_750cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_750cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_750cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_750cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_750cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_750cfs_Unit9	File Geodatabase Raster Dataset

FWP_yr5_RSS_HSI_1850cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_1850cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_1850cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_1850cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_1850cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_1850cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_1850cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_1850cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_1850cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_5000cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_5000cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_5000cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_5000cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_5000cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_5000cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_5000cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_5000cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_5000cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_750cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_750cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_750cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_750cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_750cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_750cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_750cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_750cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr5_RSS_HSI_750cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_1850cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_1850cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_1850cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_1850cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_1850cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_1850cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_1850cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_1850cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_1850cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_5000cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_5000cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_5000cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_5000cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_5000cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_5000cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_5000cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_5000cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_5000cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_750cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_750cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_750cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_750cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_750cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_750cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_750cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_750cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr50_RSS_HSI_750cfs_Unit9	File Geodatabase Raster Dataset

To calculate actual Habitat Units (end product) need to create a table for each raster. To create a table use the Zonal Statistics tool and input the rasters you want to create a table for.

Name	Type
FWP_yr25_RSS_HSI_1850cfs_Unit1	File Geodatabase Table
FWP_yr25_RSS_HSI_1850cfs_Unit2	File Geodatabase Table
FWP_yr25_RSS_HSI_1850cfs_Unit3	File Geodatabase Table
FWP_yr25_RSS_HSI_1850cfs_Unit4	File Geodatabase Table
FWP_yr25_RSS_HSI_1850cfs_Unit5	File Geodatabase Table
FWP_yr25_RSS_HSI_1850cfs_Unit6	File Geodatabase Table
FWP_yr25_RSS_HSI_1850cfs_Unit7	File Geodatabase Table
FWP_yr25_RSS_HSI_1850cfs_Unit8	File Geodatabase Table
FWP_yr25_RSS_HSI_1850cfs_Unit9	File Geodatabase Table
FWP_yr25_RSS_HSI_5000cfs_Unit1	File Geodatabase Table
FWP_yr25_RSS_HSI_5000cfs_Unit2	File Geodatabase Table
FWP_yr25_RSS_HSI_5000cfs_Unit3	File Geodatabase Table
FWP_yr25_RSS_HSI_5000cfs_Unit4	File Geodatabase Table
FWP_yr25_RSS_HSI_5000cfs_Unit5	File Geodatabase Table
FWP_yr25_RSS_HSI_5000cfs_Unit6	File Geodatabase Table
FWP_yr25_RSS_HSI_5000cfs_Unit7	File Geodatabase Table
FWP_yr25_RSS_HSI_5000cfs_Unit8	File Geodatabase Table
FWP_yr25_RSS_HSI_5000cfs_Unit9	File Geodatabase Table
FWP_yr25_RSS_HSI_750cfs_Unit1	File Geodatabase Table
FWP_yr25_RSS_HSI_750cfs_Unit2	File Geodatabase Table
FWP_yr25_RSS_HSI_750cfs_Unit3	File Geodatabase Table
FWP_yr25_RSS_HSI_750cfs_Unit4	File Geodatabase Table
FWP_yr25_RSS_HSI_750cfs_Unit5	File Geodatabase Table
FWP_yr25_RSS_HSI_750cfs_Unit6	File Geodatabase Table
FWP_yr25_RSS_HSI_750cfs_Unit7	File Geodatabase Table
FWP_yr25_RSS_HSI_750cfs_Unit8	File Geodatabase Table
FWP_yr25_RSS_HSI_750cfs_Unit9	File Geodatabase Table
FWP_yr5_RSS_HSI_1850cfs_Unit1	File Geodatabase Table
FWP_yr5_RSS_HSI_1850cfs_Unit2	File Geodatabase Table
FWP_yr5_RSS_HSI_1850cfs_Unit3	File Geodatabase Table
FWP_yr5_RSS_HSI_1850cfs_Unit4	File Geodatabase Table
FWP_yr5_RSS_HSI_1850cfs_Unit5	File Geodatabase Table
FWP_yr5_RSS_HSI_1850cfs_Unit6	File Geodatabase Table
FWP_yr5_RSS_HSI_1850cfs_Unit7	File Geodatabase Table
FWP_yr5_RSS_HSI_1850cfs_Unit8	File Geodatabase Table
FWP_yr5_RSS_HSI_1850cfs_Unit9	File Geodatabase Table
FWP_yr5_RSS_HSI_5000cfs_Unit1	File Geodatabase Table
FWP_yr5_RSS_HSI_5000cfs_Unit2	File Geodatabase Table
FWP_yr5_RSS_HSI_5000cfs_Unit3	File Geodatabase Table
FWP_yr5_RSS_HSI_5000cfs_Unit4	File Geodatabase Table
FWP_yr5_RSS_HSI_5000cfs_Unit5	File Geodatabase Table
FWP_yr5_RSS_HSI_5000cfs_Unit6	File Geodatabase Table
FWP_yr5_RSS_HSI_5000cfs_Unit7	File Geodatabase Table
FWP_yr5_RSS_HSI_5000cfs_Unit8	File Geodatabase Table
FWP_yr5_RSS_HSI_5000cfs_Unit9	File Geodatabase Table
FWP_yr5_RSS_HSI_750cfs_Unit1	File Geodatabase Table
FWP_yr5_RSS_HSI_750cfs_Unit2	File Geodatabase Table
FWP_yr5_RSS_HSI_750cfs_Unit3	File Geodatabase Table
FWP_yr5_RSS_HSI_750cfs_Unit4	File Geodatabase Table
FWP_yr5_RSS_HSI_750cfs_Unit5	File Geodatabase Table
FWP_yr5_RSS_HSI_750cfs_Unit6	File Geodatabase Table
FWP_yr5_RSS_HSI_750cfs_Unit7	File Geodatabase Table
FWP_yr5_RSS_HSI_750cfs_Unit8	File Geodatabase Table

Name	Type
FWP_yr1_RSS_HSI_1850cfs_Unit1	File Geodatabase Table
FWP_yr1_RSS_HSI_1850cfs_Unit2	File Geodatabase Table
FWP_yr1_RSS_HSI_1850cfs_Unit3	File Geodatabase Table
FWP_yr1_RSS_HSI_1850cfs_Unit4	File Geodatabase Table
FWP_yr1_RSS_HSI_1850cfs_Unit5	File Geodatabase Table
FWP_yr1_RSS_HSI_1850cfs_Unit6	File Geodatabase Table
FWP_yr1_RSS_HSI_1850cfs_Unit7	File Geodatabase Table
FWP_yr1_RSS_HSI_1850cfs_Unit8	File Geodatabase Table
FWP_yr1_RSS_HSI_1850cfs_Unit9	File Geodatabase Table
FWP_yr1_RSS_HSI_5000cfs_Unit1	File Geodatabase Table
FWP_yr1_RSS_HSI_5000cfs_Unit2	File Geodatabase Table
FWP_yr1_RSS_HSI_5000cfs_Unit3	File Geodatabase Table
FWP_yr1_RSS_HSI_5000cfs_Unit4	File Geodatabase Table
FWP_yr1_RSS_HSI_5000cfs_Unit5	File Geodatabase Table
FWP_yr1_RSS_HSI_5000cfs_Unit6	File Geodatabase Table
FWP_yr1_RSS_HSI_5000cfs_Unit7	File Geodatabase Table
FWP_yr1_RSS_HSI_5000cfs_Unit8	File Geodatabase Table
FWP_yr1_RSS_HSI_5000cfs_Unit9	File Geodatabase Table
FWP_yr1_RSS_HSI_750cfs_Unit1	File Geodatabase Table
FWP_yr1_RSS_HSI_750cfs_Unit2	File Geodatabase Table
FWP_yr1_RSS_HSI_750cfs_Unit3	File Geodatabase Table
FWP_yr1_RSS_HSI_750cfs_Unit4	File Geodatabase Table
FWP_yr1_RSS_HSI_750cfs_Unit5	File Geodatabase Table
FWP_yr1_RSS_HSI_750cfs_Unit6	File Geodatabase Table
FWP_yr1_RSS_HSI_750cfs_Unit7	File Geodatabase Table
FWP_yr1_RSS_HSI_750cfs_Unit8	File Geodatabase Table
FWP_yr1_RSS_HSI_750cfs_Unit9	File Geodatabase Table
FWP_yr15_RSS_HSI_1850cfs_Unit1	File Geodatabase Table
FWP_yr15_RSS_HSI_1850cfs_Unit2	File Geodatabase Table
FWP_yr15_RSS_HSI_1850cfs_Unit3	File Geodatabase Table
FWP_yr15_RSS_HSI_1850cfs_Unit4	File Geodatabase Table
FWP_yr15_RSS_HSI_1850cfs_Unit5	File Geodatabase Table
FWP_yr15_RSS_HSI_1850cfs_Unit6	File Geodatabase Table
FWP_yr15_RSS_HSI_1850cfs_Unit7	File Geodatabase Table
FWP_yr15_RSS_HSI_1850cfs_Unit8	File Geodatabase Table
FWP_yr15_RSS_HSI_1850cfs_Unit9	File Geodatabase Table
FWP_yr15_RSS_HSI_5000cfs_Unit1	File Geodatabase Table
FWP_yr15_RSS_HSI_5000cfs_Unit2	File Geodatabase Table
FWP_yr15_RSS_HSI_5000cfs_Unit3	File Geodatabase Table
FWP_yr15_RSS_HSI_5000cfs_Unit4	File Geodatabase Table
FWP_yr15_RSS_HSI_5000cfs_Unit5	File Geodatabase Table
FWP_yr15_RSS_HSI_5000cfs_Unit6	File Geodatabase Table
FWP_yr15_RSS_HSI_5000cfs_Unit7	File Geodatabase Table
FWP_yr15_RSS_HSI_5000cfs_Unit8	File Geodatabase Table
FWP_yr15_RSS_HSI_5000cfs_Unit9	File Geodatabase Table
FWP_yr15_RSS_HSI_750cfs_Unit1	File Geodatabase Table
FWP_yr15_RSS_HSI_750cfs_Unit2	File Geodatabase Table
FWP_yr15_RSS_HSI_750cfs_Unit3	File Geodatabase Table
FWP_yr15_RSS_HSI_750cfs_Unit4	File Geodatabase Table
FWP_yr15_RSS_HSI_750cfs_Unit5	File Geodatabase Table
FWP_yr15_RSS_HSI_750cfs_Unit6	File Geodatabase Table
FWP_yr15_RSS_HSI_750cfs_Unit7	File Geodatabase Table
FWP_yr15_RSS_HSI_750cfs_Unit8	File Geodatabase Table
FWP_yr15_RSS_HSI_750cfs_Unit9	File Geodatabase Table

Name	Type
FWP_yr5_RSS_HSI_1850cfs_Unit2	File Geodatabase Table
FWP_yr5_RSS_HSI_1850cfs_Unit3	File Geodatabase Table
FWP_yr5_RSS_HSI_1850cfs_Unit4	File Geodatabase Table
FWP_yr5_RSS_HSI_1850cfs_Unit5	File Geodatabase Table
FWP_yr5_RSS_HSI_1850cfs_Unit6	File Geodatabase Table
FWP_yr5_RSS_HSI_1850cfs_Unit7	File Geodatabase Table
FWP_yr5_RSS_HSI_1850cfs_Unit8	File Geodatabase Table
FWP_yr5_RSS_HSI_1850cfs_Unit9	File Geodatabase Table
FWP_yr5_RSS_HSI_5000cfs_Unit1	File Geodatabase Table
FWP_yr5_RSS_HSI_5000cfs_Unit2	File Geodatabase Table
FWP_yr5_RSS_HSI_5000cfs_Unit3	File Geodatabase Table
FWP_yr5_RSS_HSI_5000cfs_Unit4	File Geodatabase Table
FWP_yr5_RSS_HSI_5000cfs_Unit5	File Geodatabase Table
FWP_yr5_RSS_HSI_5000cfs_Unit6	File Geodatabase Table
FWP_yr5_RSS_HSI_5000cfs_Unit7	File Geodatabase Table
FWP_yr5_RSS_HSI_5000cfs_Unit8	File Geodatabase Table
FWP_yr5_RSS_HSI_5000cfs_Unit9	File Geodatabase Table
FWP_yr5_RSS_HSI_750cfs_Unit1	File Geodatabase Table
FWP_yr5_RSS_HSI_750cfs_Unit2	File Geodatabase Table
FWP_yr5_RSS_HSI_750cfs_Unit3	File Geodatabase Table
FWP_yr5_RSS_HSI_750cfs_Unit4	File Geodatabase Table
FWP_yr5_RSS_HSI_750cfs_Unit5	File Geodatabase Table
FWP_yr5_RSS_HSI_750cfs_Unit6	File Geodatabase Table
FWP_yr5_RSS_HSI_750cfs_Unit7	File Geodatabase Table
FWP_yr5_RSS_HSI_750cfs_Unit8	File Geodatabase Table
FWP_yr5_RSS_HSI_750cfs_Unit9	File Geodatabase Table
FWP_yr50_RSS_HSI_1850cfs_Unit1	File Geodatabase Table
FWP_yr50_RSS_HSI_1850cfs_Unit2	File Geodatabase Table
FWP_yr50_RSS_HSI_1850cfs_Unit3	File Geodatabase Table
FWP_yr50_RSS_HSI_1850cfs_Unit4	File Geodatabase Table
FWP_yr50_RSS_HSI_1850cfs_Unit5	File Geodatabase Table
FWP_yr50_RSS_HSI_1850cfs_Unit6	File Geodatabase Table
FWP_yr50_RSS_HSI_1850cfs_Unit7	File Geodatabase Table
FWP_yr50_RSS_HSI_1850cfs_Unit8	File Geodatabase Table
FWP_yr50_RSS_HSI_1850cfs_Unit9	File Geodatabase Table
FWP_yr50_RSS_HSI_5000cfs_Unit1	File Geodatabase Table
FWP_yr50_RSS_HSI_5000cfs_Unit2	File Geodatabase Table
FWP_yr50_RSS_HSI_5000cfs_Unit3	File Geodatabase Table
FWP_yr50_RSS_HSI_5000cfs_Unit4	File Geodatabase Table
FWP_yr50_RSS_HSI_5000cfs_Unit5	File Geodatabase Table
FWP_yr50_RSS_HSI_5000cfs_Unit6	File Geodatabase Table
FWP_yr50_RSS_HSI_5000cfs_Unit7	File Geodatabase Table
FWP_yr50_RSS_HSI_5000cfs_Unit8	File Geodatabase Table
FWP_yr50_RSS_HSI_5000cfs_Unit9	File Geodatabase Table
FWP_yr50_RSS_HSI_750cfs_Unit1	File Geodatabase Table
FWP_yr50_RSS_HSI_750cfs_Unit2	File Geodatabase Table
FWP_yr50_RSS_HSI_750cfs_Unit3	File Geodatabase Table
FWP_yr50_RSS_HSI_750cfs_Unit4	File Geodatabase Table
FWP_yr50_RSS_HSI_750cfs_Unit5	File Geodatabase Table
FWP_yr50_RSS_HSI_750cfs_Unit6	File Geodatabase Table
FWP_yr50_RSS_HSI_750cfs_Unit7	File Geodatabase Table
FWP_yr50_RSS_HSI_750cfs_Unit8	File Geodatabase Table
FWP_yr50_RSS_HSI_750cfs_Unit9	File Geodatabase Table

Once the table is created, create a new field in each raster and call it “Habitat Unit” then use the field calculator tool to determine the total ft^2 of for each raster.

OBJECTID*	reach_ID	ZONE_CODE	COUNT	AREA	SUM	Habitat_Unit
1	U2	1	25387	228483	2525.23400976509	22727.11

Use the formula “Sum * 9” where nine is the dimensions of each individual raster cell (3X3) and Sum is the total number of cells.

Final Product: after calculating all the habitat units, input values for each Evaluation unit based on flow into the GIS Outputs Table of Values

		FWOP				FWP Year 1			
		Key Habitat Type				Key Habitat Type			
Evaluation Unit	Flow	Riverine	Riparian Scrub-Shrub	Riparian Forest	total HU	Riverine	Riparian Scrub-Shrub	Riparian Forest	total HU
	750 cfs	193205.7	879.179	97344	NA	311537.2	22736.21	96345	NA
Evaluation Unit 1	1850 cfs	37164.55	827.7795	94554	NA	267084.9	22562.09	93555	NA
	5000 cfs	115831	764.7738	88672.5	NA	101367.7	21471.16	87673.5	NA
	750 cfs	114298.2	23240.65	129685.5	NA	114373.6	31413.51	129685.5	NA
Evaluation Unit 2	1850 cfs	65548.23	22704.84	129470	NA	65602.24	30899.97	129469.5	NA
	5000 cfs	11888.87	20655.75	128790	NA	45088.91	28853.2	128790	NA
	750 cfs	196839.2	72865.38	29655.92	NA	199996.8	147916.8	29655.92	NA
Evaluation Unit 3	1850 cfs	91020.04	7800.34	29157.02	NA	96267.56	141820.8	29157.02	NA
	5000 cfs	33702.89	55371.71	27586.76	NA	45986.5	122669.2	27586.76	NA
	750 cfs	480576.6	170498.7	206497.2	NA	481359.1	238845.9	206497.2	NA
Evaluation Unit 4	1850 cfs	361285.3	167336.8	203876.5	NA	379780.6	232424.7	203876.5	NA
	5000 cfs	174374.4	145911.2	199642.9	NA	223459	203420.6	199642.9	NA
	750 cfs	257867.8	129830.1	91714.85	NA	253215.6	187430	55836.7	NA
Evaluation Unit 5	1850 cfs	163370.6	128760.6	91669.85	NA	211864.2	185910.1	55791.7	NA
	5000 cfs	96459.36	121115.3	91642.85	NA	215582.2	176722.9	55764.7	NA
	750 cfs	1056181	237846.7	1227707	NA	1071368	187430	1227662	NA
Evaluation Unit 6	1850 cfs	918752.1	228337	1199839	NA	953001.6	385630.5	1199839	NA
	5000 cfs	651583.8	192333.9	1152603	NA	870146.4	309854	1152603	NA
	750 cfs	196517.6	80896.33	885859.8	NA	197847.2	116857	885859.8	NA
Evaluation Unit 7	1850 cfs	124249	78543.98	885859.8	NA	189286.8	113764.5	885859.8	NA
	5000 cfs	83883.57	53690.05	885859.8	NA	145851.9	85589.1	885859.8	NA
	750 cfs	569354.1	328516	1351397	NA	627476.6	509193.3	1238848	NA
Evaluation Unit 8	1850 cfs	346215.7	316398.2	1337438	NA	831331.8	496713.8	1224889	NA
	5000 cfs	175974.3	276220.4	1282781	NA	621838.4	452652.3	1170232	NA
	750 cfs	475289.7	254159.2	1611219	NA	480432.7	280980.2	1429319	NA
Evaluation Unit 9	1850 cfs	339733	248122.7	1595793	NA	400054.5	273876.7	1414190	NA
	5000 cfs	228382.9	206035.3	1530084	NA	361362.3	227650.9	1349057	NA

		FWP Year 5				FWP Year 15			
		Key Habitat Type				Key Habitat Type			
Evaluation Unit	Flow	Riverine	Riparian Scrub-Shrub	Riparian Forest	total HU	Riverine	Riparian Scrub-Shrub	Riparian Forest	total HU
	750 cfs	311537.2	69792.41	96345	NA	311537.2	879.179	235872	NA
Evaluation Unit 1	1850 cfs	267084.9	69381.65	93555	NA	267084.9	834.4117	232551	NA
	5000 cfs	101367.7	66701.84	87673.5	NA	101367.7	768.9189	224428.5	NA
	750 cfs	114373.6	55103.63	129685.5	NA	114373.6	23240.64	233230.5	NA
Evaluation Unit 2	1850 cfs	65602.24	54590.09	129469.5	NA	65602.24	22727.11	233014.5	NA
	5000 cfs	45088.91	52543.32	128790	NA	45088.91	20680.33	232335	NA
	750 cfs	199996.8	369216.2	29655.92	NA	199996.8	72865.38	1016821	NA
Evaluation Unit 3	1850 cfs	96267.56	353028	29157.02	NA	96267.56	70279.59	971124	NA
	5000 cfs	45986.5	322040.5	27586.76	NA	45986.5	55556.45	899488.8	NA
	750 cfs	481359.1	445186.3	206497.2	NA	481359.1	170498.7	1060390	NA
Evaluation Unit 4	1850 cfs	379780.6	429199.1	203876.5	NA	379780.6	167221.8	1018377	NA
	5000 cfs	223459	377064.7	199642.9	NA	223459	145880.5	917896.9	NA
	750 cfs	253215.6	417017.3	55836.7	NA	253215.6	111535.3	1003545	NA
Evaluation Unit 5	1850 cfs	211864.2	414302.9	55791.7	NA	211864.2	110406.9	998955.5	NA
	5000 cfs	215582.2	397344.4	55764.7	NA	215582.2	103789.3	966636.5	NA
	750 cfs	1071368	945853	1227662	NA	1071368	228078.2	3473495	NA
Evaluation Unit 6	1850 cfs	953001.6	890670.4	1199839	NA	953001.6	218722.3	3301888	NA
	5000 cfs	870146.4	690131.7	1152603	NA	870146.4	184228.3	2731473	NA
	750 cfs	197847.2	230680.4	885859.8	NA	197847.2	79354.79	1362329	NA
Evaluation Unit 7	1850 cfs	189286.8	225121.5	885859.8	NA	189286.8	77073.52	1351871	NA
	5000 cfs	145851.9	186214.7	885859.8	NA	145851.9	52495.9	1304054	NA
	750 cfs	627476.6	1205309	1238848	NA	627476.6	278049.5	4137283	NA
Evaluation Unit 8	1850 cfs	831331.8	1189460	1224889	NA	831331.8	266701.4	4107925	NA
	5000 cfs	621838.4	1120579	1170232	NA	621838.4	230896.8	3946357	NA
	750 cfs	480432.7	355856.9	1429319	NA	480432.7	253929.8	1755005	NA
Evaluation Unit 9	1850 cfs	400054.5	345269.5	1414190	NA	400054.5	247989.7	1724891	NA
	5000 cfs	361362.3	286983.1	1349057	NA	361362.3	206035.3	1597595	NA

		FWP Year 25				FWP Year 50			
		Key Habitat Type				Key Habitat Type			
Evaluation Unit	Flow	Riverine	Riparian Scrub-Shrub	Riparian Forest	total HU	Riverine	Riparian Scrub-Shrub	Riparian Forest	total HU
	750 cfs	311537.2	879.179	235872	NA	311537.2	879.179	166108.5	NA
Evaluation Unit 1	1850 cfs	267084.9	834.4117	232551	NA	267084.9	834.4117	163053	NA
	5000 cfs	101367.7	768.9189	224428.5	NA	101367.7	768.9189	156051	NA
	750 cfs	114373.6	23240.64	233230.5	NA	114373.6	23240.64	181458	NA
Evaluation Unit 2	1850 cfs	65602.24	22727.11	233014.5	NA	65602.24	22727.11	181242	NA
	5000 cfs	45088.91	20680.33	232335	NA	45088.91	20680.33	180562.5	NA
	750 cfs	199996.8	72865.38	1016821	NA	199996.8	72865.38	523238.4	NA
Evaluation Unit 3	1850 cfs	96267.56	70279.59	971124	NA	96267.56	70279.59	500140.5	NA
	5000 cfs	45986.5	55556.45	899488.8	NA	45986.5	55556.45	463537.8	NA
	750 cfs	481359.1	170498.7	1060390	NA	481359.1	170498.7	633443.7	NA
Evaluation Unit 4	1850 cfs	379780.6	167221.8	1018377	NA	379780.6	167221.8	611126.5	NA
	5000 cfs	223459	145880.5	917896.9	NA	223459	145880.5	558769.9	NA
	750 cfs	253215.6	111535.3	1003545	NA	253215.6	111535.3	527975.6	NA
Evaluation Unit 5	1850 cfs	211864.2	110406.9	998955.5	NA	211864.2	110406.9	525658.1	NA
	5000 cfs	215582.2	103789.3	966636.5	NA	215582.2	103789.3	509485.1	NA
	750 cfs	1071368	228078.2	3473495	NA	1071368	228078.2	2350471	NA
Evaluation Unit 6	1850 cfs	953001.6	218722.3	3301888	NA	953001.6	218722.3	2250787	NA
	5000 cfs	870146.4	184228.3	2731473	NA	870146.4	184228.3	1941962	NA
	750 cfs	197847.2	79354.79	1362329	NA	197847.2	79354.79	1124094	NA
Evaluation Unit 7	1850 cfs	189286.8	77073.52	1351871	NA	189286.8	77073.52	1118865	NA
	5000 cfs	145851.9	52495.9	1304054	NA	145851.9	52495.9	1094957	NA
	750 cfs	627476.6	278049.5	4137283	NA	627476.6	278049.5	2685371	NA
Evaluation Unit 8	1850 cfs	831331.8	266701.4	4107925	NA	831331.8	266701.4	2663713	NA
	5000 cfs	621838.4	230896.8	3946357	NA	621838.4	230896.8	2555600	NA
	750 cfs	480432.7	253929.8	1755005	NA	480432.7	253929.8	1581665	NA
Evaluation Unit 9	1850 cfs	400054.5	247989.7	1724891	NA	400054.5	247989.7	1559044	NA
	5000 cfs	361362.3	206035.3	1597595	NA	361362.3	206035.3	1462829	NA

YRERFS GIS WORKFLOW AND MODELING PROCESS

Presenter Name

Presenter Title

Duty Location

Date of Presentation

U.S.ARMY

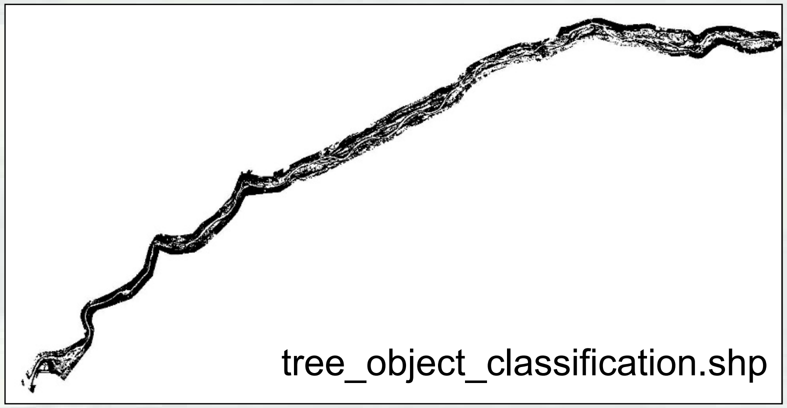
US Army Corps of Engineers
BUILDING STRONG®

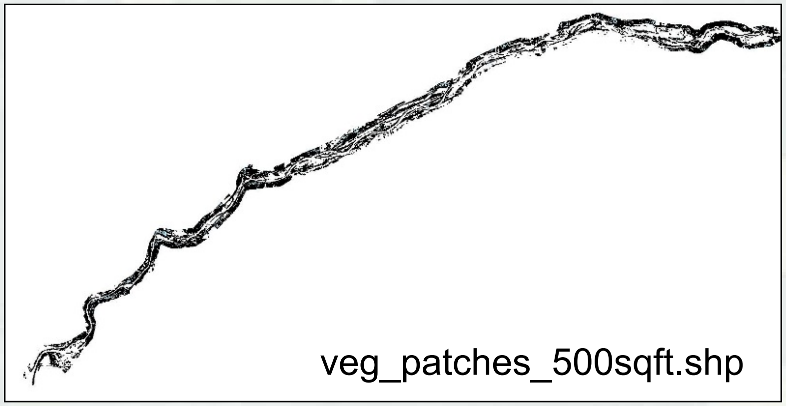
YRERFS Downy Woodpecker Riparian Forest (RF) Habitat Determination

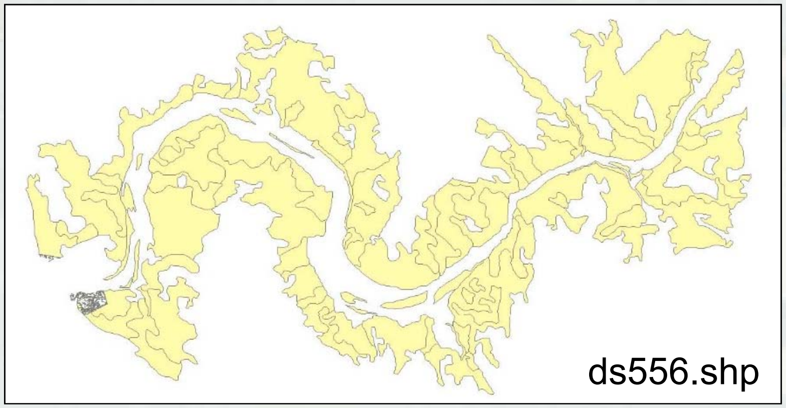
BUILDING STRONG®

Original Data Sets

Three datasets were initially used to produce the base data workflow. The tree object classification and vegetation patch datasets were provided by HDR and the third dataset for the area east of HWY 20 came from the Department of Fish and Wildlife web mapping portal.

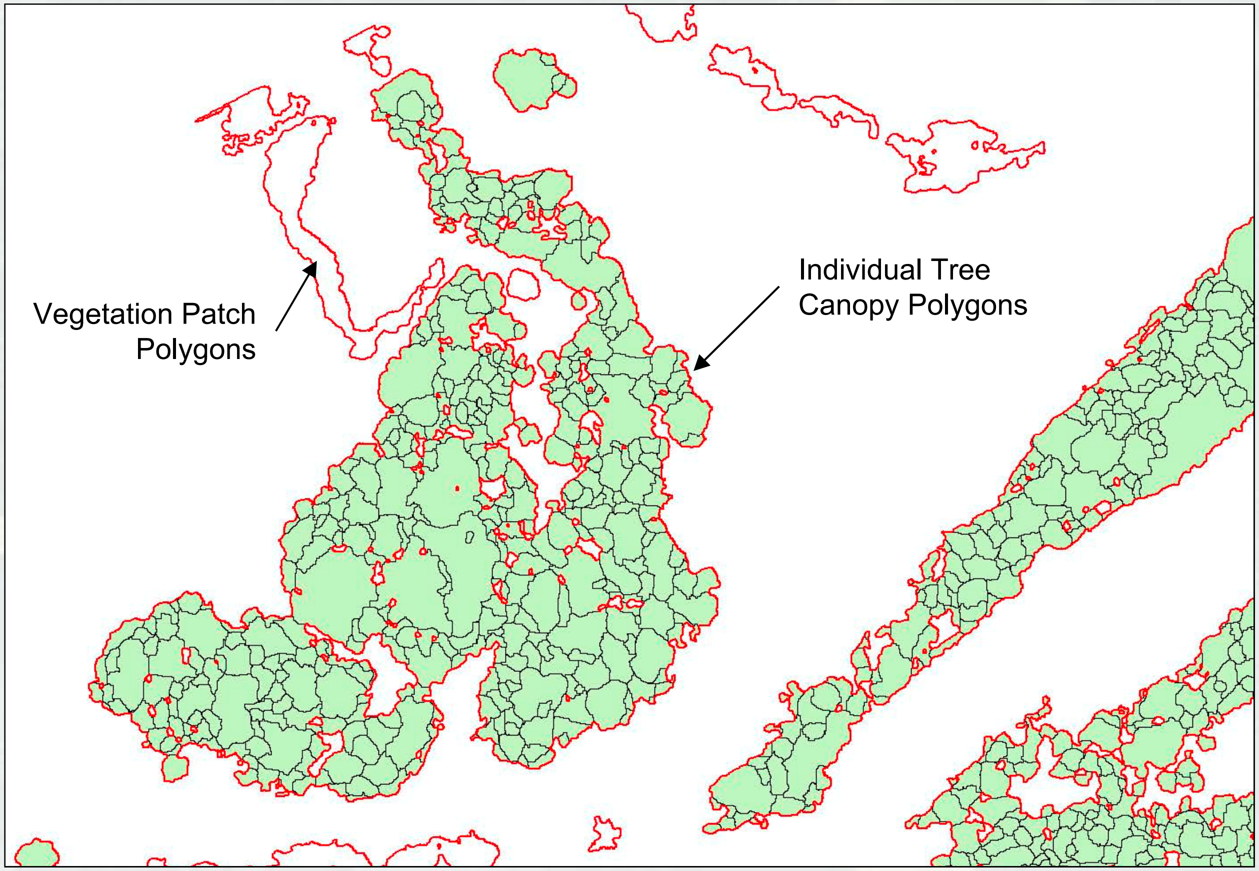






BUILDING STRONG®

Prior to conducting an intersect between the layers several new fields were added to the veg patch layer; unique ID, patch area, and canopy type. Canopy type is determined based on the average height of the patch. A height of greater than 16.5 feet was designated Riparian Forest (RF) and 16.5 feet or less was designated Riparian Scrub Shrub (RSS). Similarly new fields of canopy type and canopy area were added to the tree object layer to determine and label each polygon with an RF or RSS designation based on its height. The layers were then intersected so the tree object layer was connected with the veg patch it fell within and given the corresponding unique ID. Since we are dealing with RF only for Downy Woodpecker habitat, the objects designated RF were queried out as their own layer to conduct the calculations.

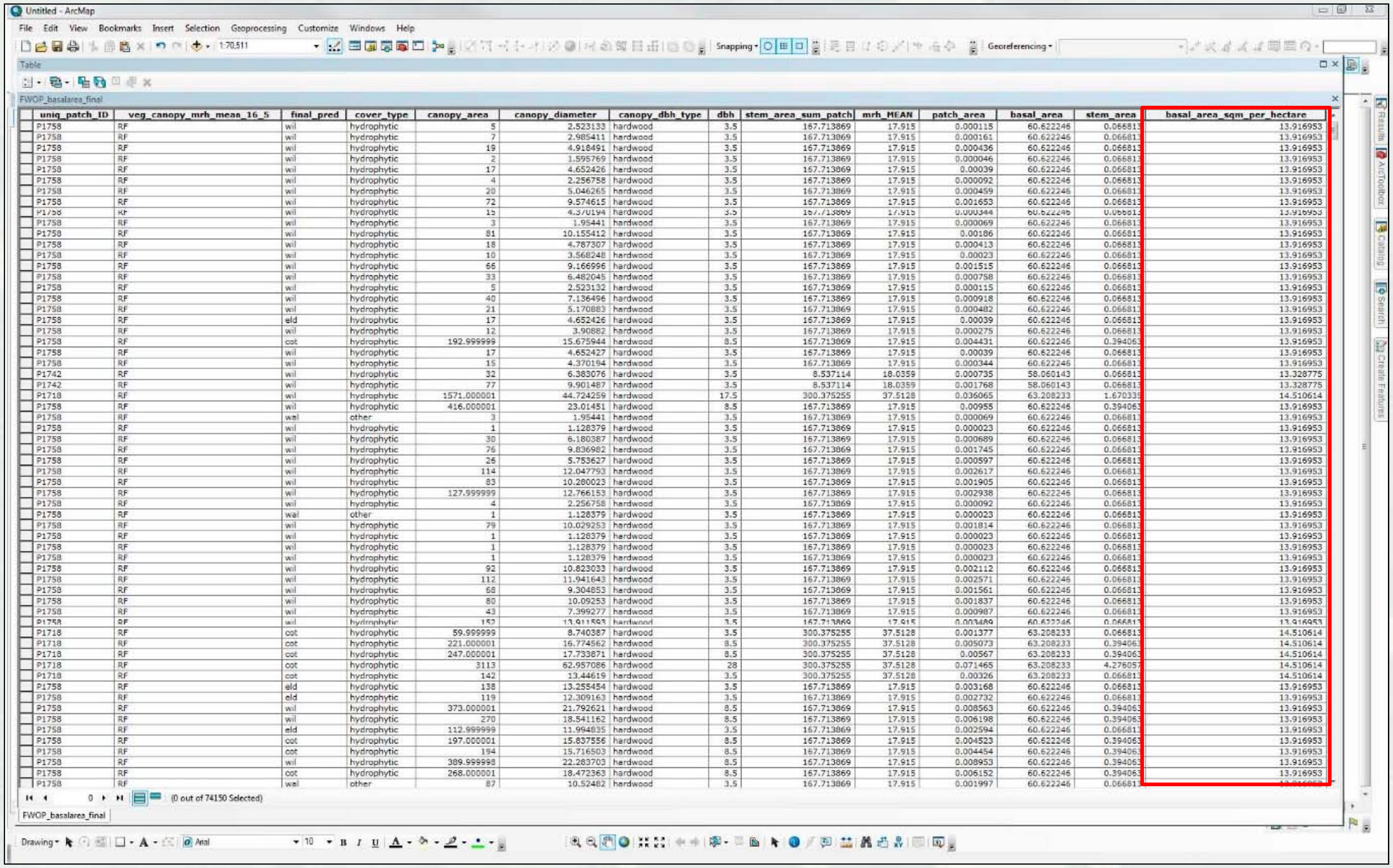


RF tree objects intersected with RF veg patches

A series of calculation need to be conducted within individual fields. Below is the list of steps taken to get to the final output of m^2/hectare: *Underlined phrases are titles for new fields created in the layer table

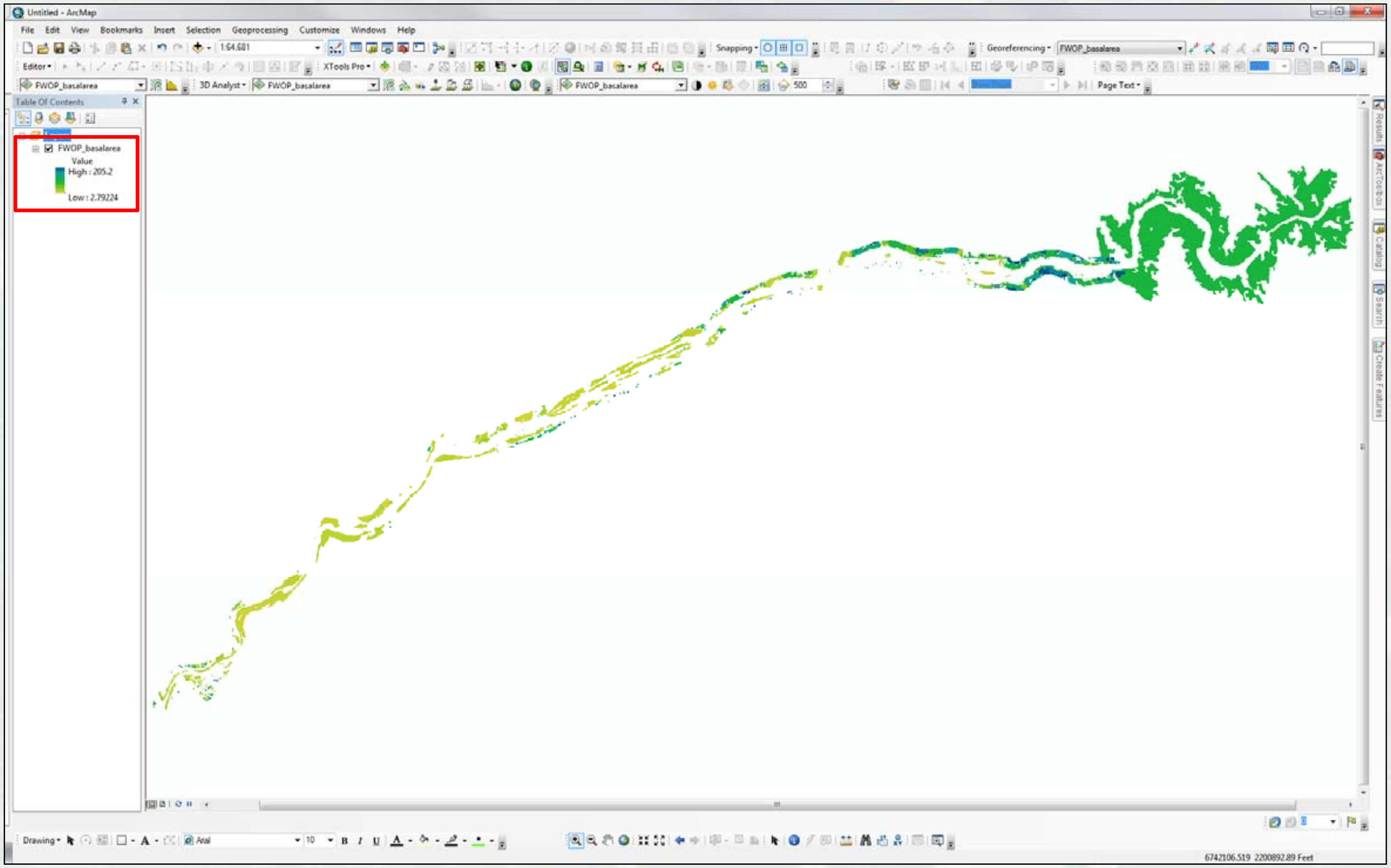
1. Determine canopy area and patch area in ft^2
2. Convert canopy area to canopy diameter using $d=2\sqrt{\frac{A}{\pi}}$
3. Use a cross-walk table to determine dbh based on canopy diameter and canopy dbh type
4. Determine stem area using the equation $\pi\left(\frac{d}{2}\right)^2/144$ where d=DBH
5. Do a dissolve in a separate feature to get the sum of the stem area then join back to the original feature.
6. Convert patch area to acres and divide sum of stem area by patch by patch area to get stem area by patch area in ft^2/acre
7. Convert ft^2/acre to m^2/hectare

Resulting table should look similar to the one below after all calculations have been done.



BUILDING STRONG®

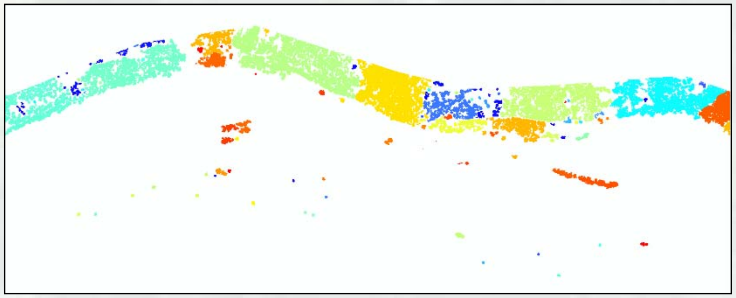
Convert the basal area polygon into a future without project (FWOP) raster based on the (m^2/hectare) field



Create a raster of the measures polygon and assign the following values:

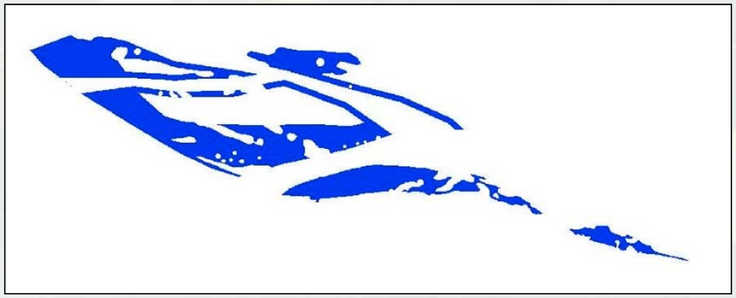
Year 1				
Canopy Type (Riparian Scrub-shrub or Riparian Forest)	% Decidious Shrub Canopy Comprised of Hydrophytic Shrubs (% of hydrophytic shrubs per patch)	Average height of Canopy	% Cover of Shrub canopy (% of polygon area)	Basal Area
RSS	81.3	2	1.5	FWOP
Year 5				
Canopy Type (Riparian Scrub-shrub or Riparian Forest)	% Decidious Shrub Canopy Comprised of Hydrophytic Shrubs (% of hydrophytic shrubs per patch)	Average height of Canopy	% Cover of Shrub canopy (% of polygon area)	Basal Area
RSS	81.3	9.6	7.5	FWOP
Year 15				
Canopy Type (Riparian Scrub-shrub or Riparian Forest)	% Decidious Shrub Canopy Comprised of Hydrophytic Shrubs (% of hydrophytic shrubs per patch)	Average height of Canopy	% Cover of Shrub canopy (% of polygon area)	Basal Area
RF	81.3	25.8	22.5	10.1
Year 25				
Canopy Type (Riparian Scrub-shrub or Riparian Forest)	% Decidious Shrub Canopy Comprised of Hydrophytic Shrubs (% of hydrophytic shrubs per patch)	Average height of Canopy	% Cover of Shrub canopy by Reach	Basal Area
RF	81.3	37.8	37.5	16.8
Year 50				
Canopy Type (Riparian Scrub-shrub or Riparian Forest)	% Decidious Shrub Canopy Comprised of Hydrophytic Shrubs (% of hydrophytic shrubs per patch)	Average height of Canopy	% Cover of Shrub canopy by Reach	Basal Area
RF	81.3	49.8	75	33.7

Mosaic: Use *mosaic to new raster* tool to combine the FWOP basal area raster with the measures only raster to create a Future With Project (FWP) raster. Take that raster and copy it to make one for years 1, 5, 15, 25, & 50. *Note: for years 1 & 5 you will not see riparian forest in the areas of the measures because they are below the 16.5 feet RF designation*.



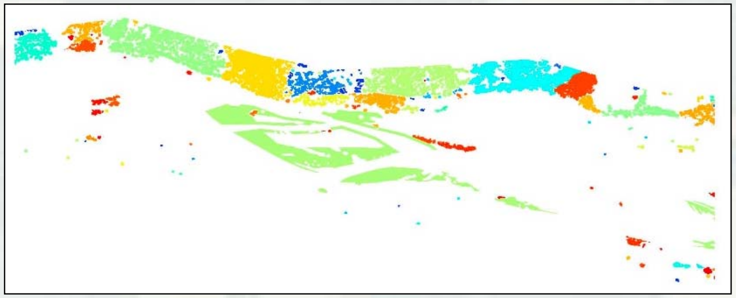
FWOP_basalarea: Values of 2.79 – 205.2 m^2/hectare

+



FWP_basalarea_measureonly: Value of 10.1 m^2/hectare

=



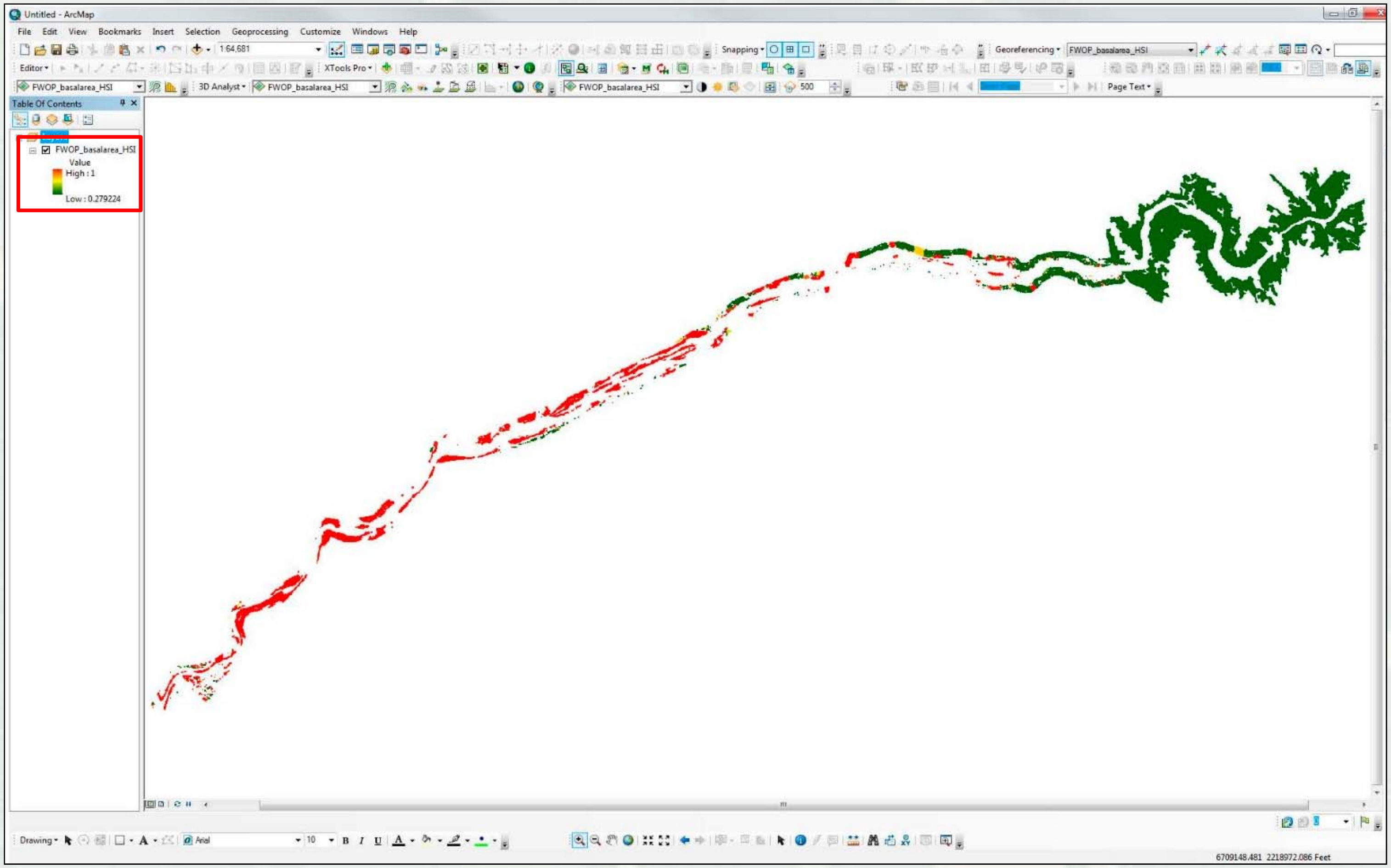
FWP_(yrs1, 5, 15, 25, 50)basalarea_SI: Value of 2.79 - 205.2 m^2/hectare

Suitability Index (SI) needs to be determined for FWOP, FWP yrs 1, 5, 15, 25, & 50 using the table below:

basal area range	Formula
for basal area from 0 to 10 (m2/ hectare)	SI = 0.1 (Basal Area)
for basal area from 10 to 20 (m2/ hectare)	SI =1
for basal area from 20 to 30 (m2/ hectare)	SI = -0.05 (Basal Area) + 2
for basal area greater than 30 (m2/ hectare)	SI = 0.5

Ex. A basal area of 9.2 m^2/hectare would yield an SI of 0.92. (SI = 0.1 * 9.2)

SI values should be between 0 and 1

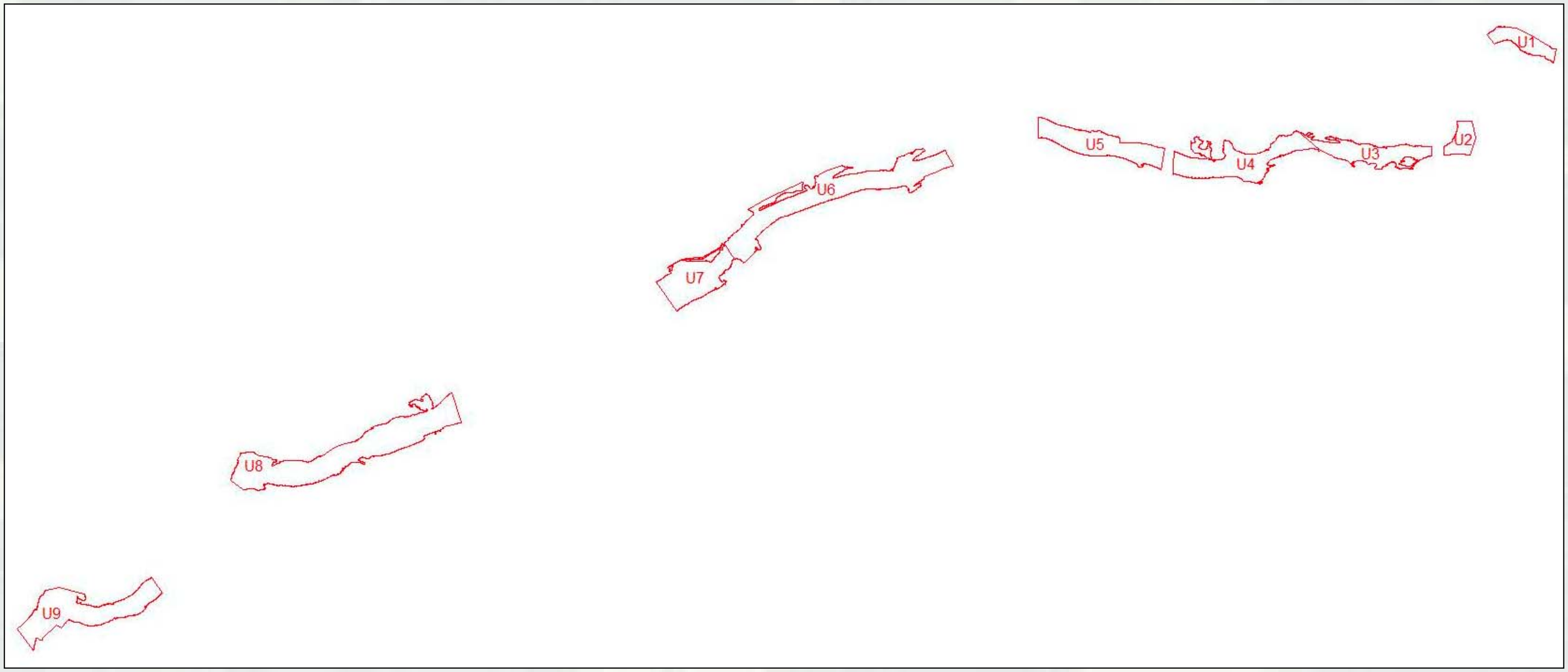


BUILDING STRONG®

After all SI calculations have been determined those values will be used to determine the HSI values using the following formula:

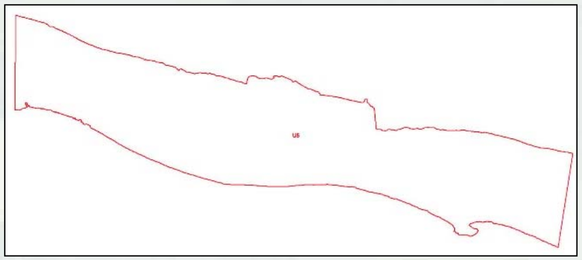
$$\textbf{Riparian Forest HSI} = \textbf{SI}_{\textbf{basal area}}$$

To refine results of the HSI and make it pertinent to the areas where measures are, a new layer was created to clip out the needed features. The layer, "Units", has a north-south boundary based on the 84,000 cfs flow boundary and an east west boundary of 500 feet off either end of the widest measure in each measure grouping. There are 9 units total.

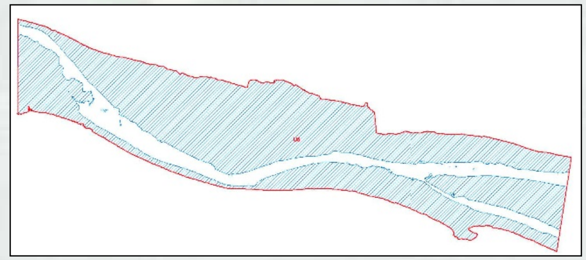


BUILDING STRONG®

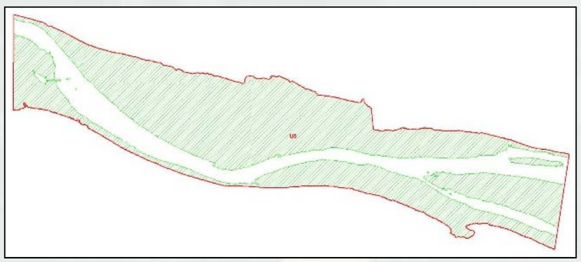
All 9 units were then clipped by three flow boundaries (750, 1850, and 5000 cfs) to get 27 individual polygons that will be used to clip the rasters.



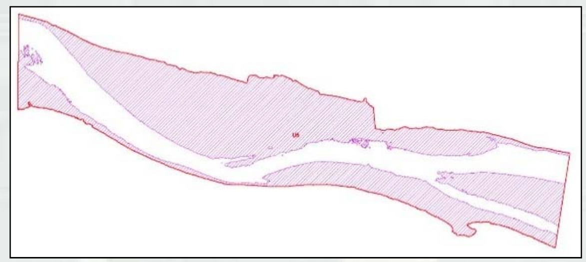
Unit 5



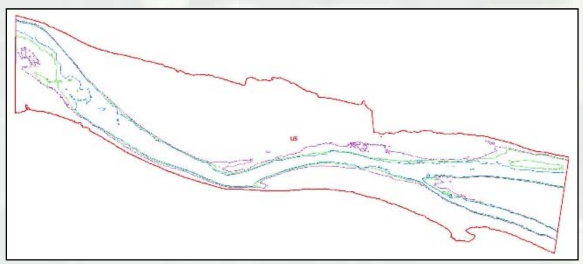
Unit 5: 750 cfs flow boundary clipped out



Unit 5: 1850 cfs flow boundary clipped out

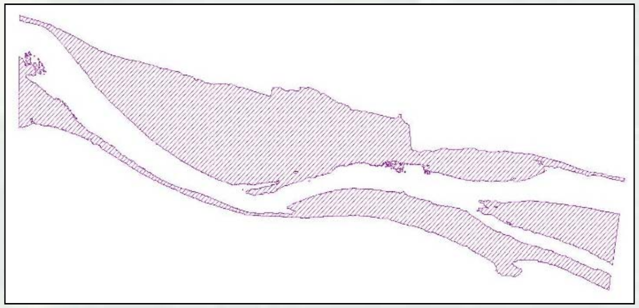


Unit 5: 5000 cfs flow boundary clipped out

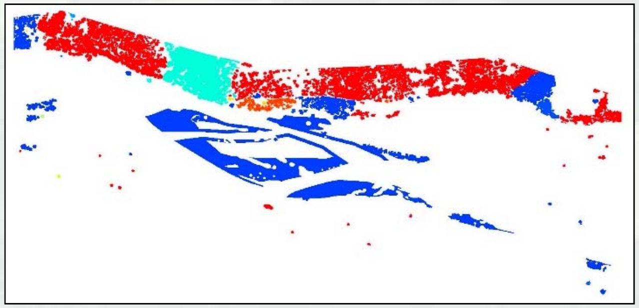


Unit 5: all 3 flows to show the difference between them.

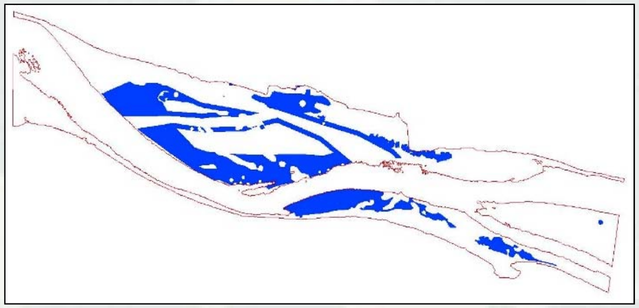
Extract by Mask: to do this you take a unit polygon (unit_5000cfs_unit5 polygon) and use it to mask and HSI raster (FWP_yr25_basalarea_HSI) raster and the resulting output from the process is portions of the input raster bound by the unit mask.



Mask: Unit 5 5000 cfs polygon



FWP yr25 HSI raster



Result: raster within the bounds of the unit 5 polygon

When done with all the extracts, you will have a total of 162 individual rasters

Name	Type
FWOP_Basal_HSI_1850cfs_Unit1	File Geodatabase Raster Dataset
FWOP_Basal_HSI_1850cfs_Unit2	File Geodatabase Raster Dataset
FWOP_Basal_HSI_1850cfs_Unit3	File Geodatabase Raster Dataset
FWOP_Basal_HSI_1850cfs_Unit4	File Geodatabase Raster Dataset
FWOP_Basal_HSI_1850cfs_Unit5	File Geodatabase Raster Dataset
FWOP_Basal_HSI_1850cfs_Unit6	File Geodatabase Raster Dataset
FWOP_Basal_HSI_1850cfs_Unit7	File Geodatabase Raster Dataset
FWOP_Basal_HSI_1850cfs_Unit8	File Geodatabase Raster Dataset
FWOP_Basal_HSI_1850cfs_Unit9	File Geodatabase Raster Dataset
FWOP_Basal_HSI_5000cfs_Unit1	File Geodatabase Raster Dataset
FWOP_Basal_HSI_5000cfs_Unit2	File Geodatabase Raster Dataset
FWOP_Basal_HSI_5000cfs_Unit3	File Geodatabase Raster Dataset
FWOP_Basal_HSI_5000cfs_Unit4	File Geodatabase Raster Dataset
FWOP_Basal_HSI_5000cfs_Unit5	File Geodatabase Raster Dataset
FWOP_Basal_HSI_5000cfs_Unit6	File Geodatabase Raster Dataset
FWOP_Basal_HSI_5000cfs_Unit7	File Geodatabase Raster Dataset
FWOP_Basal_HSI_5000cfs_Unit8	File Geodatabase Raster Dataset
FWOP_Basal_HSI_5000cfs_Unit9	File Geodatabase Raster Dataset
FWOP_Basal_HSI_750cfs_Unit1	File Geodatabase Raster Dataset
FWOP_Basal_HSI_750cfs_Unit2	File Geodatabase Raster Dataset
FWOP_Basal_HSI_750cfs_Unit3	File Geodatabase Raster Dataset
FWOP_Basal_HSI_750cfs_Unit4	File Geodatabase Raster Dataset
FWOP_Basal_HSI_750cfs_Unit5	File Geodatabase Raster Dataset
FWOP_Basal_HSI_750cfs_Unit6	File Geodatabase Raster Dataset
FWOP_Basal_HSI_750cfs_Unit7	File Geodatabase Raster Dataset
FWOP_Basal_HSI_750cfs_Unit8	File Geodatabase Raster Dataset
FWOP_Basal_HSI_750cfs_Unit9	File Geodatabase Raster Dataset
FWOP_basalarea_HSI	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_1850cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_1850cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_1850cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_1850cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_1850cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_1850cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_1850cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_1850cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_1850cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_5000cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_5000cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_5000cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_5000cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_5000cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_5000cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_5000cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_5000cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_5000cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_750cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_750cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_750cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_750cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_750cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_750cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_750cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_750cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr1_Basal_HSI_750cfs_Unit9	File Geodatabase Raster Dataset

Name	Type
FWP_yr15_Basal_HSI_1850cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_1850cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_1850cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_1850cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_1850cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_1850cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_1850cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_1850cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_1850cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_5000cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_5000cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_5000cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_5000cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_5000cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_5000cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_5000cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_5000cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_5000cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_750cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_750cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_750cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_750cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_750cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_750cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_750cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_750cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr15_Basal_HSI_750cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr15_basalarea_HSI	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_1850cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_1850cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_1850cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_1850cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_1850cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_1850cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_1850cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_1850cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_1850cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_5000cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_5000cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_5000cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_5000cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_5000cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_5000cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_5000cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_5000cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_5000cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_750cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_750cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_750cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_750cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_750cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_750cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_750cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_750cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr25_Basal_HSI_750cfs_Unit9	File Geodatabase Raster Dataset

Name	Type
FWP_yr5_Basal_HSI_1850cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_1850cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_1850cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_1850cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_1850cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_1850cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_1850cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_1850cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_1850cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_5000cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_5000cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_5000cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_5000cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_5000cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_5000cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_5000cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_5000cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_5000cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_750cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_750cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_750cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_750cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_750cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_750cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_750cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_750cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr5_Basal_HSI_750cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr5_basalarea_HSI	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_1850cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_1850cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_1850cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_1850cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_1850cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_1850cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_1850cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_1850cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_1850cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_5000cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_5000cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_5000cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_5000cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_5000cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_5000cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_5000cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_5000cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_5000cfs_Unit9	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_750cfs_Unit1	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_750cfs_Unit2	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_750cfs_Unit3	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_750cfs_Unit4	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_750cfs_Unit5	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_750cfs_Unit6	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_750cfs_Unit7	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_750cfs_Unit8	File Geodatabase Raster Dataset
FWP_yr50_Basal_HSI_750cfs_Unit9	File Geodatabase Raster Dataset

To calculate actual Habitat Units (end product) need to create a table for each raster. To create a table use the Zonal Statistics tool and input the rasters you want to create a table for.

Contents | Preview | Description

Name	Type
FWP_yr1_Basal_HSI_1850cfs_Unit1	File Geodatabase Table
FWP_yr1_Basal_HSI_1850cfs_Unit2	File Geodatabase Table
FWP_yr1_Basal_HSI_1850cfs_Unit3	File Geodatabase Table
FWP_yr1_Basal_HSI_1850cfs_Unit4	File Geodatabase Table
FWP_yr1_Basal_HSI_1850cfs_Unit5	File Geodatabase Table
FWP_yr1_Basal_HSI_1850cfs_Unit6	File Geodatabase Table
FWP_yr1_Basal_HSI_1850cfs_Unit7	File Geodatabase Table
FWP_yr1_Basal_HSI_1850cfs_Unit8	File Geodatabase Table
FWP_yr1_Basal_HSI_1850cfs_Unit9	File Geodatabase Table
FWP_yr1_Basal_HSI_5000cfs_Unit1	File Geodatabase Table
FWP_yr1_Basal_HSI_5000cfs_Unit2	File Geodatabase Table
FWP_yr1_Basal_HSI_5000cfs_Unit3	File Geodatabase Table
FWP_yr1_Basal_HSI_5000cfs_Unit4	File Geodatabase Table
FWP_yr1_Basal_HSI_5000cfs_Unit5	File Geodatabase Table
FWP_yr1_Basal_HSI_5000cfs_Unit6	File Geodatabase Table
FWP_yr1_Basal_HSI_5000cfs_Unit7	File Geodatabase Table
FWP_yr1_Basal_HSI_5000cfs_Unit8	File Geodatabase Table
FWP_yr1_Basal_HSI_5000cfs_Unit9	File Geodatabase Table
FWP_yr1_Basal_HSI_750cfs_Unit1	File Geodatabase Table
FWP_yr1_Basal_HSI_750cfs_Unit2	File Geodatabase Table
FWP_yr1_Basal_HSI_750cfs_Unit3	File Geodatabase Table
FWP_yr1_Basal_HSI_750cfs_Unit4	File Geodatabase Table
FWP_yr1_Basal_HSI_750cfs_Unit5	File Geodatabase Table
FWP_yr1_Basal_HSI_750cfs_Unit6	File Geodatabase Table
FWP_yr1_Basal_HSI_750cfs_Unit7	File Geodatabase Table
FWP_yr1_Basal_HSI_750cfs_Unit8	File Geodatabase Table
FWP_yr1_Basal_HSI_750cfs_Unit9	File Geodatabase Table

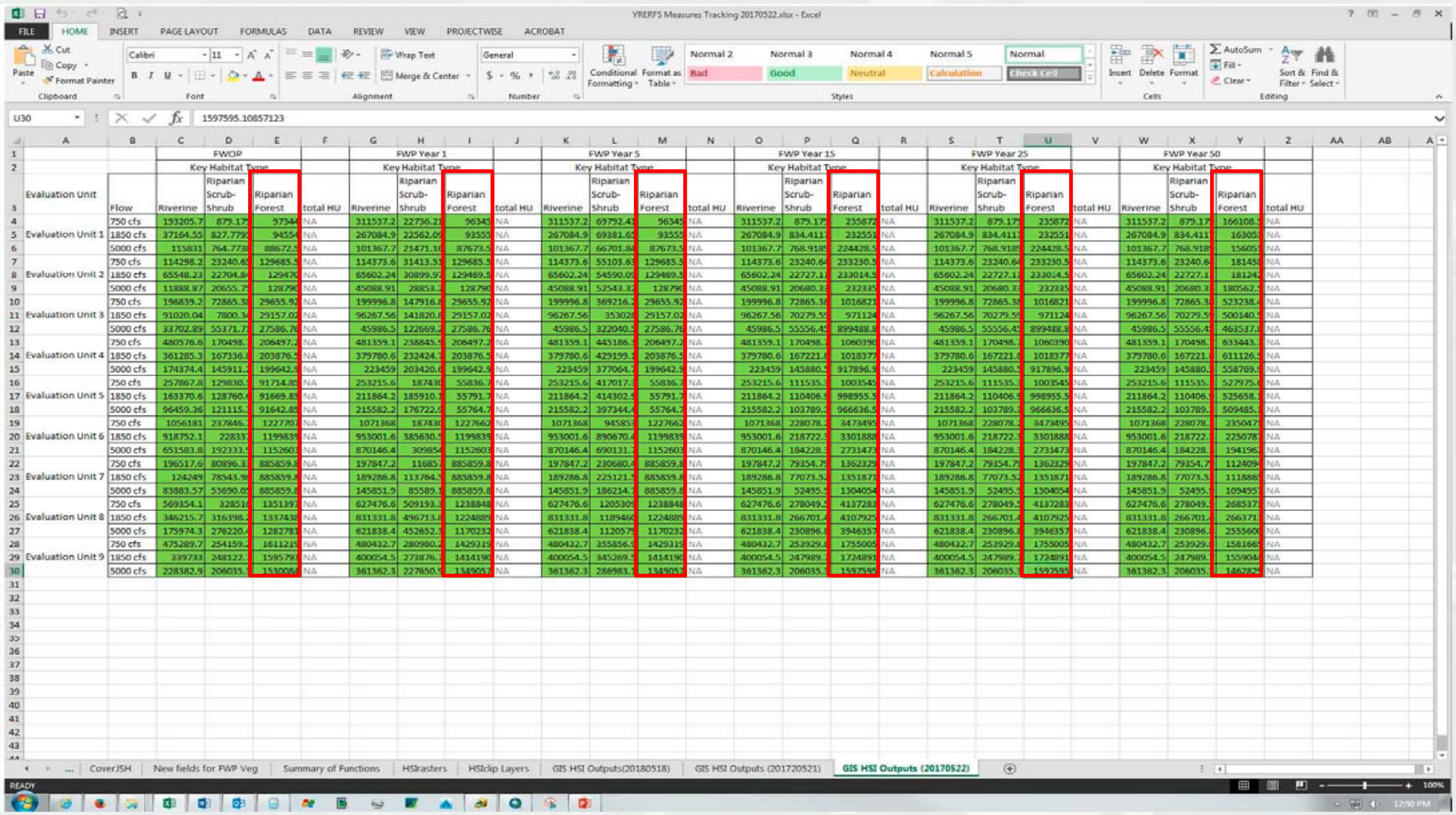
Once the table is created, create a new field in each raster and call it “Habitat Unit” then use the field calculator tool to determine the total ft^2 of for each raster.

Contents | Preview | Description

OBJECTID *	reach_ID	ZONE_CODE	COUNT	AREA	SUM	Habitat_Unit
1	U1	1	20790	187110	10395	93555

Use the formula “Sum * 9” where nine is the dimensions of each individual raster cell (3X3) and Sum is the total number of cells.

Final Product: after calculating all the habitat units, input values for each Evaluation unit based on flow into the GIS Outputs Table of Values



		FWOP				FWP Year 1			
		Key Habitat Type				Key Habitat Type			
Evaluation Unit	Flow	Riverine	Riparian Scrub-Shrub	Riparian Forest	total HU	Riverine	Riparian Scrub-Shrub	Riparian Forest	total HU
	750 cfs	193205.7	879.17	97344	NA	311537.2	22736.21	96345	NA
Evaluation Unit 1	1850 cfs	37164.55	827.779	94554	NA	267084.9	22562.09	93555	NA
	5000 cfs	115831	764.773	88672.5	NA	101367.7	21471.16	87673.5	NA
	750 cfs	114298.2	23240.6	129685.5	NA	114373.6	31413.51	129685.5	NA
Evaluation Unit 2	1850 cfs	65548.23	22704.8	129470	NA	65602.24	30899.97	129469.5	NA
	5000 cfs	11888.87	20655.7	128790	NA	45088.91	28853.2	128790	NA
	750 cfs	196839.2	72865.3	29655.92	NA	199996.8	147916.8	29655.92	NA
Evaluation Unit 3	1850 cfs	91020.04	7800.34	29157.02	NA	96267.56	141820.8	29157.02	NA
	5000 cfs	33702.89	55371.7	27586.76	NA	45986.5	122669.2	27586.76	NA
	750 cfs	480576.6	170498.	206497.2	NA	481359.1	238845.5	206497.2	NA
Evaluation Unit 4	1850 cfs	361285.3	167336.8	203876.5	NA	379780.6	232424.7	203876.5	NA
	5000 cfs	174374.4	145911.2	199642.9	NA	223459	203420.6	199642.9	NA
	750 cfs	257867.8	129830.1	91714.85	NA	253215.6	187430	55836.7	NA
Evaluation Unit 5	1850 cfs	163370.6	128760.6	91669.85	NA	211864.2	185910.1	55791.7	NA
	5000 cfs	96459.36	121115.1	91642.85	NA	215582.2	176722.9	55764.7	NA
	750 cfs	1056181	237846.	1227707	NA	1071368	187430	1227662	NA
Evaluation Unit 6	1850 cfs	918752.1	228337	1199839	NA	953001.6	385630.5	1199839	NA
	5000 cfs	651583.8	192333.5	1152603	NA	870146.4	309854	1152603	NA
	750 cfs	196517.6	80896.33	885859.8	NA	197847.2	116857	885859.8	NA
Evaluation Unit 7	1850 cfs	124249	78543.98	885859.8	NA	189286.8	113764.5	885859.8	NA
	5000 cfs	83883.57	53690.05	885859.8	NA	145851.9	85589.1	885859.8	NA
	750 cfs	569354.1	328516	1351397	NA	627476.6	509193.3	1238848	NA
Evaluation Unit 8	1850 cfs	346215.7	316398.2	1337438	NA	831331.8	496713.8	1224889	NA
	5000 cfs	175974.3	276220.4	1282781	NA	621838.4	452652.3	1170232	NA
	750 cfs	475289.7	254159.2	1611219	NA	480432.7	280980.2	1429319	NA
Evaluation Unit 9	1850 cfs	339733	248122.1	1595793	NA	400054.5	273876.7	1414190	NA
	5000 cfs	228382.9	206035.3	1530084	NA	361362.3	227650.9	1349057	NA

		FWP Year 5				FWP Year 15			
		Key Habitat Type				Key Habitat Type			
Evaluation Unit	Flow	Riverine	Riparian Scrub-Shrub	Riparian Forest	total HU	Riverine	Riparian Scrub-Shrub	Riparian Forest	total HU
	750 cfs	311537.2	69792.41	96345	NA	311537.2	879.175	235872	NA
Evaluation Unit 1	1850 cfs	267084.9	69381.65	93555	NA	267084.9	834.4117	232551	NA
	5000 cfs	101367.7	66701.84	87673.5	NA	101367.7	768.9189	224428.5	NA
	750 cfs	114373.6	55103.63	129685.5	NA	114373.6	23240.64	233230.5	NA
Evaluation Unit 2	1850 cfs	65602.24	54590.09	129469.5	NA	65602.24	22727.11	233014.5	NA
	5000 cfs	45088.91	52543.32	128790	NA	45088.91	20680.33	232335	NA
	750 cfs	199996.8	369216.2	29655.92	NA	199996.8	72865.38	1016821	NA
Evaluation Unit 3	1850 cfs	96267.56	353028	29157.02	NA	96267.56	70279.59	971124	NA
	5000 cfs	45986.5	322040.5	27586.76	NA	45986.5	55556.45	899488.8	NA
	750 cfs	481359.1	445186.3	206497.2	NA	481359.1	170498.7	1060390	NA
Evaluation Unit 4	1850 cfs	379780.6	429199.1	203876.5	NA	379780.6	167221.8	1018377	NA
	5000 cfs	223459	377064.7	199642.9	NA	223459	145880.5	917896.9	NA
	750 cfs	253215.6	417017.3	55836.7	NA	253215.6	111535.3	1003545	NA
Evaluation Unit 5	1850 cfs	211864.2	414302.9	55791.7	NA	211864.2	110406.9	998955.5	NA
	5000 cfs	215582.2	397344.4	55764.7	NA	215582.2	103789.2	966636.5	NA
	750 cfs	1071368	945853	1227662	NA	1071368	228078.2	3473495	NA
Evaluation Unit 6	1850 cfs	953001.6	890670.4	1199839	NA	953001.6	218722.3	3301888	NA
	5000 cfs	870146.4	690131.7	1152603	NA	870146.4	184228.3	2731473	NA
	750 cfs	197847.2	230680.4	885859.8	NA	197847.2	79354.79	1362329	NA
Evaluation Unit 7	1850 cfs	189286.8	225121.5	885859.8	NA	189286.8	77073.52	1351871	NA
	5000 cfs	145851.9	186214.7	885859.8	NA	145851.9	52495.5	1304054	NA
	750 cfs	627476.6	1205309	1238848	NA	627476.6	278049.5	4137283	NA
Evaluation Unit 8	1850 cfs	831331.8	1189460	1224889	NA	831331.8	266701.4	4107925	NA
	5000 cfs	621838.4	1120579	1170232	NA	621838.4	230896.8	3946357	NA
	750 cfs	480432.7	355856.9	1429319	NA	480432.7	253929.8	1755005	NA
Evaluation Unit 9	1850 cfs	400054.5	345269.5	1414190	NA	400054.5	247989.7	1724891	NA
	5000 cfs	361362.3	286983.1	1349057	NA	361362.3	206035.3	1597595	NA

		FWP Year 25				FWP Year 50			
		Key Habitat Type				Key Habitat Type			
Evaluation Unit	Flow	Riverine	Riparian Scrub-Shrub	Riparian Forest	total HU	Riverine	Riparian Scrub-Shrub	Riparian Forest	total HU
	750 cfs	311537.2	879.175	235872	NA	311537.2	879.175	166108.5	NA
Evaluation Unit 1	1850 cfs	267084.9	834.4117	232551	NA	267084.9	834.4117	163059	NA
	5000 cfs	101367.7	768.9189	224428.5	NA	101367.7	768.9189	156051	NA
	750 cfs	114373.6	23240.64	233230.5	NA	114373.6	23240.64	181458	NA
Evaluation Unit 2	1850 cfs	65602.24	22727.11	233014.5	NA	65602.24	22727.11	181242	NA
	5000 cfs	45088.91	20680.33	232335	NA	45088.91	20680.33	180562.5	NA
	750 cfs	199996.8	72865.38	1016821	NA	199996.8	72865.38	523238.4	NA
Evaluation Unit 3	1850 cfs	96267.56	70279.59	971124	NA	96267.56	70279.59	500140.5	NA
	5000 cfs	45986.5	55556.45	899488.8	NA	45986.5	55556.45	463537.8	NA
	750 cfs	481359.1	170498.7	1060390	NA	481359.1	170498.7	633443.1	NA
Evaluation Unit 4	1850 cfs	379780.6	167221.8	1018377	NA	379780.6	167221.8	611126.5	NA
	5000 cfs	223459	145880.5	917896.9	NA	223459	145880.5	558769.5	NA
	750 cfs	253215.6	111535.3	1003545	NA	253215.6	111535.3	527975.4	NA
Evaluation Unit 5	1850 cfs	211864.2	110406.9	998955.5	NA	211864.2	110406.9	525658.3	NA
	5000 cfs	215582.2	103789.2	966636.5	NA	215582.2	103789.2	509485.1	NA
	750 cfs	1071368	228078.2	3473495	NA	1071368	228078.2	2350477	NA
Evaluation Unit 6	1850 cfs	953001.6	218722.3	3301888	NA	953001.6	218722.3	2250782	NA
	5000 cfs	870146.4	184228.3	2731473	NA	870146.4	184228.3	1941962	NA
	750 cfs	197847.2	79354.79	1362329	NA	197847.2	79354.79	1124094	NA
Evaluation Unit 7	1850 cfs	189286.8	77073.52	1351871	NA	189286.8	77073.52	1118885	NA
	5000 cfs	145851.9	52495.5	1304054	NA	145851.9	52495.5	1094957	NA
	750 cfs	627476.6	278049.5	4137283	NA	627476.6	278049.5	2685371	NA
Evaluation Unit 8	1850 cfs	831331.8	266701.4	4107925	NA	831331.8	266701.4	2663711	NA
	5000 cfs	621838.4	230896.8	3946357	NA	621838.4	230896.8	2555600	NA
	750 cfs	480432.7	253929.8	1755005	NA	480432.7	253929.8	1581665	NA
Evaluation Unit 9	1850 cfs	400054.5	247989.7	1724891	NA	400054.5	247989.7	1559049	NA
	5000 cfs	361362.3	206035.3	1597595	NA	361362.3	206035.3	1462829	NA

Civil Design Attachment CV-A

Yuba River Ecosystem Restoration Feasibility Study
DRAFT Design Criteria Technical Memorandum

1.0 INTRODUCTION

The purpose of this technical memorandum (TM) is to document the basis for establishment of design criteria for habitat restoration measures on the lower Yuba River. Design criteria serve as the foundation by which proposed restoration actions were developed to a level of detail necessary to support evaluation of benefits and costs.

2.0 APPLICATION OF DESIGN CRITERIA AND LEVEL OF DESIGN

The purpose of these design criteria is to support the assessment of ecosystem outputs for habitat restoration measures in the lower Yuba River. The HEC-RAS 2D hydraulic model will be used in conjunction with habitat suitability relationships (Habitat Suitability Index models) for representative species. Resulting outputs (habitat units) of habitat quantity and quality will be used to evaluate and compare proposed actions. Design criteria will provide a framework for translating written descriptions of measures into a modified terrain model that will be used in the hydraulic analysis.

In line with SMART planning principles, design criteria and resulting project design will only be developed and applied at a level of detail appropriate to their roles in the planning process. Design criteria will be applied two times throughout the planning process - during evaluation of alternatives and later during a feasibility level analysis of the tentatively selected plan. The differences between benefits and costs of proposed actions are anticipated to be relatively large, which would reduce the need for a high level of detail in design; however, a certain level of design is required to ensure reasonable representative values of ecosystem outputs. Due to the complex nature of habitat restoration measures on the lower Yuba River, features need to be designed and modeled to level of detail sufficient to ensure a minimum amount of function. Furthermore, a feasibility level analysis will be performed using the designs developed for the evaluation of alternatives analysis as a starting point. Therefore, the base level of detail in design should consider efficiencies of supporting a feasibility level analysis.

Given the above considerations, a base level of design criteria will be applied in developing designs for habitat restoration measures on the lower Yuba River that ensures a reasonable representation of habitat output is developed to support an evaluation of alternatives in a CE/ICA analysis. Additional design criteria will be applied during a feasibility level analysis.

As stated above, the essential purpose of design criteria is to provide a framework for translating written descriptions of measures into a modified terrain model that will be used in the hydraulic analysis. The PDT will translate written descriptions of measures as documented in the YRERFS Habitat Measures Technical Memorandum (YCWA and Corps 2016). The descriptions of measures provided in that document will be given primary consideration. Where design details are absent from the original descriptions, the design criteria detailed in this document will be used to fill the gaps.

The overall strategy for development and application of design criteria to evaluate alternatives is summarized below.

4. Identify major features of the proposed habitat restoration measures on the lower Yuba River

5. Develop design criteria, including minimum performance and general guidelines, for each major feature type

   a. Define design intent
   b. Define design strategy
   c. Define specific design parameters based on reasonable performance goals

6. Develop a modified GIS-based terrain layer to be used in conjunction with hydraulic modeling to simulate habitat conditions resulting from implementation of the proposed habitat restoration measures.

   a. Using YRERFS Habitat Measures Technical Memorandum (YCWA and Corps 2016)
   b. Applying design criteria to fill in gaps where appropriate and ensure a minimum level of performance

The major feature types included in the design criteria include side channels, floodplain grading, structural complexity features, and vegetative planting. These features were selected because they are anticipated to have the greatest effect on ecosystem output.

3.0 CRITERIA

3.1 DESIGN FEATURE - SIDE CHANNEL

- Creation of new, or enhancement of existing side channels. The following design criteria also will be applied as appropriate to features such as bank scalloping, backwaters, and/or any habitat feature with a similar design intent.

Design Intent

- Provide additional diverse, complex inundated riverine habitat.

<u>Design Strategy</u>

- Base the design elevation on a standardized base flow condition for each habitat/hydrologic zone, or (HZ). Define a design water depth associated with the base flow condition, and apply that resultant streambed elevation to identified potential side-channel locations. The operative strategy is to provide side channel habitat particularly during the critical oversummer (June through September) rearing period (see exceedance **Figures 1-4** and baseflow definitions, below).

Specific Design Parameters

- Base Flow Condition
  - Upstream of Daguerre Point Dam – 730 cfs. Base flow upstream of Daguerre Point Dam (DPD) corresponding to a Yuba Accord schedule 1, 2, 3 or 4 year that requires a minimum of 700 cfs at the Smartsville Gage from September 1 through April 15. There are no minimum flow requirements at the Smartsville Gage for the remainder of the year, when minimum flow requirements are specified by requirements at the Marysville Gage. A base flow of 730 cfs is provided as a margin of safety.
  - Downstream of Daguerre Point Dam – 530 cfs. Base flow downstream of DPD corresponding to a Yuba Accord schedule 1, 2, or 3 year that requires a minimum of 500 cfs at the Marysville Gage from June through March, mid-June through February, and September through February, respectively. A base flow of 530 cfs is provided as a margin of safety.
- Side-Channel Entrance and Exit (adapted from Hoopa Valley Tribe *et al*., 2011)
  - Side channel entrance angle should be less than or equal to 40 degrees.
  - To avoid sedimentation, either: (1) place the side-channel entrance at a location in the channel that is not transporting (and depositing) sediment; or (2) design the side-channel entrance such that it transports any coarse sediment that may enter the side-channel from the mainstem (Hoopa Valley Tribe *et al*., 2011).
  - The side channel should not convey more than 15% of the baseflow to preserve sediment transport capacity in the main channel.
  - The side channel entrance (i.e., approximate upper 1/3 of the side-channel) should not contain an abundance of added hydraulic roughness elements in order to retain sediment transport competency.
  - In the downstream 2/3 of the side channel where roughness no longer has hydraulic effect on the coarse sediment competency of the entrance, additional roughness via structural elements (e.g., large woody material (LWM), engineered log jams (ELJs), boulders) and vegetation plantings can be encouraged.

Footprint

- Side-channel footprint (width, length) will be based on descriptions of the proposed measures presented in the YRERFS Habitat Measures Technical Memorandum (YCWA and Corps 2016) and on previously prepared reports (RMT 2009; DWR and PG&E 2010; cbec 2013; NMFS 2014; cbec 2014).
- Area: Polygons for project footprints were developed and documented in the YRERFS Habitat Measures Technical Memorandum (YCWA and Corps 2016).

- Depth: Side-channels will be created to a water depth of 0.5 ft associated with the base flow conditions.
    - Steelhead Fry – Water depths of 0.5 ft will provide optimal depth suitability[1] (HSI = 1.0) for fry at the base flow. During the fry rearing period (April through July), flow exceedance probabilities[2] of 50% equate to flows of about 2,350 cfs upstream of Daguerre Point Dam (Smartsville Gage) and about 1,650 cfs downstream of Daguerre Point Dam (Marysville Gage). Using average stage-discharge relationships for slackwater mesohabitat types[3], those flows would provide constructed side-channel water depths of about 1.9 ft and associated HSI of 0.7 upstream of Daguerre Point Dam, and water depths of about 1.8 ft and associated HSI of 0.7 downstream of Daguerre Point Dam (**Figure 5**). Thus, fry rearing habitat would be expected to be 70 - 100% of optimal depth suitability about ½ of the time both upstream and downstream of DPD.
    - Steelhead Juvenile – Water depths of 0.5 ft will provide depth suitability of about 50% of optimal (HSI = 0.5) for juveniles at the base flow. During the over-summer juvenile rearing period (June through September), flow exceedance probabilities of 50% equate to flows of about 1,470 cfs upstream of Daguerre Point Dam (Smartsville Gage) and about 690 cfs downstream of Daguerre Point Dam (Marysville Gage). Using average stage-discharge relationships for slackwater mesohabitat types, those flows would provide constructed side-channel water depths of about 1.3 ft and associated HSI of 0.8 upstream of Daguerre Point Dam, and water depths of about 0.7 ft and associated HSI of 0.6 downstream of Daguerre Point Dam (**Figure 6**). Thus, juvenile rearing habitat would be expected to be 50 - 80% of optimal depth suitability about ½ of the time upstream of DPD, and 50 – 60% of optimal depth suitability about ½ of the time downstream of DPD.
    - Spring-run Chinook Salmon Fry – Water depths of 0.5 ft will provide optimal depth suitability (HSI = 1.0) for fry at the base flow. During the fry rearing period (mid-November through mid-February), flow exceedance probabilities of 50% equate to flows of about 915 cfs upstream of Daguerre Point Dam (Smartsville Gage) and about 905 cfs downstream of Daguerre Point Dam (Marysville Gage). Using average stage-discharge relationships for slackwater mesohabitat types, those flows would provide constructed side-channel water depths of about 0.7 ft and associated optimal HSI of 1.0 upstream of Daguerre Point Dam, and water depths of about 1.0 ft and associated optimal HSI of 1.0 downstream of Daguerre Point Dam (**Figure 7**). Thus, fry rearing habitat would be expected to be 100% of optimal depth suitability about ½ of the time.
        - Spring-run Chinook Salmon Juveniles – Water depths of 0.5 ft will provide depth suitability of about 50% of optimal (HSI = 0.5) for juveniles at the base flow. During the over-summer juvenile rearing period (June through

[1] Water depth suitabilities obtained from YRDP Relicensing Participants HSCs (YRDP TM 7-10 (YCWA 2013)).

[2] Based upon flow exceedance analyses over the 41-year period of record of daily flows derived through the YRDP daily flow model.

[3] Juvenile Chinook salmon were primarily observed in slackwater and slow glide habitat types during snorkel surveys in the lower Yuba River (RMT 2013).

September), flow exceedance probabilities of 50% equate to flows of about 1,470 cfs upstream of Daguerre Point Dam (Smartsville Gage) and about 690 cfs downstream of Daguerre Point Dam (Marysville Gage). Using average stage-discharge relationships for slackwater mesohabitat types, those flows would provide constructed side-channel water depths of about 1.3 ft and associated HSI of 0.9 upstream of Daguerre Point Dam, and water depths of about 0.7 ft and associated HSI of 0.6 downstream of Daguerre Point Dam (**Figure 8**). Thus, juvenile rearing habitat would be expected to be 50 - 90% of optimal depth suitability about ½ of the time upstream of DPD, and 50 – 60% of optimal depth suitability about ½ of the time downstream of DPD.

- Shore slope: Side channel walls will slope at 3:1 (H:V) from the base flow condition to a design depth (0.5 ft). A 3:1 slope was selected due to relative stability. Steep side slope walls may be preferred to prevent spawning in areas prone to dewatering.

3.2 Design Feature – Floodplain Grading

- Creation of new or improvement of existing floodplain connectivity. These design criteria will also be applied as appropriate to backwater creation, bench lowering, terracing, set back of berms (floodplain expansion), and/or any habitat feature with a similar design intent.

Design Intent

- Create additional inundated habitat, increase the frequency and duration of inundation, and enhance access to groundwater for establishment of riparian vegetation.

Design Strategy

- Base the design elevation on a standardized elevation corresponding to a target flow for each habitat/hydrologic zone, or (HZ). Use existing polygons to define upper limits of floodplain grading. Identify grading locations within polygons based on a depth-to-water table of 7 to 10 feet (floodplain grading/lowering/excavation) or greater than 10 feet (terracing) at each location. Extrapolate a graded slope between base flow conditions and upper limits of grading. Floodplain grading features will need to be developed subsequent to side-channel features, because side-channel features would result in localized modifications to water surface elevations associated with standardized target flow conditions.

- Define a streambed elevation for a water depth associated with the target flow condition, and apply that resultant streambed elevation to identified potential floodplain grading locations. Design strategy for YRERFS planning purposes includes riparian vegetation planting for grading of surfaces characterized under the existing condition as a 7 to 10 ft depth to water table.

Specific Design Parameters

- Flow-Related Target Elevations
  - Upstream of Daguerre Point Dam – 2,000 cfs.
  - Downstream of Daguerre Point Dam – 2,000 cfs.
- Frequency of Inundation
  - A frequency of inundation of 67% (2 in 3 years) is considered to be highly supportive of salmon populations (Reedy 2016) due to increased functionality of shallow off-channel rearing habitat, and increased growth associated with refugia habitat and provision of food availability. Floodplain grading and associated riparian vegetation planting are primarily designed to provide benefit to juvenile anadromous salmonids during the spring rearing and growth period.

    Grading floodplain surfaces (e.g., bench and bar lowering) to flow-related target elevations would increase the frequency of inundation, thereby: (1) increasing the functionality of lower Yuba River in-channel bench and bar areas by providing shallow off-channel rearing habitat and refugia for juvenile anadromous salmonids; (2) providing additional growth opportunities due to more suitable water velocities; and (3) potentially increasing benthic macroinvertebrate producing habitat. The primary habitat benefit is to provide increased riparian vegetation and subsequent woody material recruitment to riverine habitats. Additional benefits may be provided by promoting riparian vegetation recruitment, instream object and over-hanging cover, and allochthonous food sources.
- Duration of Inundation
  - A 21-day duration of inundation is considered to be the minimum duration necessary to establish trophic productivity, and to provide benefits to juvenile anadromous salmonid rearing habitat functionality through provision of increased food resources and increased off-channel rearing habitat (Reedy 2016). Studies on the lower American River - a system analogous to the lower Yuba River, have shown that floodplain invertebrate densities approach main channel densities after 2 to 4 weeks of inundation (J. Merz, pers. comm., as cited in cbec 2013). In Central Valley lowland river floodplains, studies have shown increased juvenile salmonid growth rates as a result of at least 21 days on the floodplain (Jeffres *et al*., 2008; Sommer *et al*., 2001, 2002). During this time period, phytoplankton and zooplankton life cycles produce valuable food resources in relatively slow moving, shallow water with temperatures typically warmer than the main river channel (Sommer *et al*., 2004). An inundation event lasting at least 21 days would likely provide the opportunity for macroinvertebrates to colonize off-channel areas.

- Inundation Frequency and Duration Interactions

    - It previously has been suggested that lower Yuba River in-channel floodplain areas could be lowered to elevations which begin to become inundated at 3,000 cfs (cbec 2013) because floodplain areas would be shallowly inundated by a flow that persisted for a 21-day duration in 1 in 2 years during the March-June period. Areas graded to inundate at flow rates lower than 3,000 cfs would be inundated more frequently, and for a longer duration; although prolonged inundation can induce mortality of riparian vegetation seedlings, which could prevent the establishment and persistence of riparian vegetation on these lowered surfaces (cbec 2013). However, because the design strategy for YRERFS planning purposes includes riparian vegetation planting for graded surfaces previously with a 7 to 10 ft depth to water table, inundation at higher frequencies or for longer durations would be appropriate for habitat functionality.

    - A recently conducted HEC-EFM Analysis for Salmonid Rearing Habitat Flows (Reedy 2016) identified a 21-day duration of inundation both above and below DPD of about 2,000 cfs under existing conditions[4] during 2 of 3 years (67% of the time) for the February through June period. That time period encompasses the seed dispersal timeframe, and most of the spring-run YOY juvenile and steelhead fry rearing periods.

Footprint

- Floodplain grading footprint (width, length) will be based on descriptions of the proposed measures presented in the YRERFS Habitat Measures Technical Memorandum (YCWA and Corps 2016) and on previously prepared reports (RMT 2009; DWR and PG&E 2010; cbec 2013; NMFS 2014; cbec 2014).

    - <u>Area</u>: Polygons for project footprints were developed and documented in YRERFS Habitat Measures Technical Memorandum (YCWA and Corps 2016).

    - <u>Depth</u>: Floodplain grading would be conducted with the goal of providing water depths associated with 50 – 100% of juvenile spring-run Chinook salmon optimal water depth suitability (i.e., depths ranging from about 0.5 to 3.3 ft) approximately 80% of the time during the over-summer juvenile rearing period (June through September).

    - <u>Slope</u>: Slope of floodplain grading features will generally follow a linear extrapolation between the waterside and landside limits of the grading area.

[4] YCWA Yuba River Development Project relicensing “Base Case” flow scenario.

3.3 DESIGN FEATURE – VEGETATIVE PLANTING

- Enhancing existing or planting new riparian vegetation.

Design Intent

- Create additional riparian habitat.

Design Strategy

- Conduct riparian vegetation planting corresponding to design elevations based on standardized flow conditions for each habitat/hydrologic zone, or (HZ). Use existing polygons to define areas for riparian vegetation planting. Identify planting locations based on a depth-to-water table of less than 7 feet at each location. Dormant hardwood cuttings will be planted to depth of groundwater during the late fall. The depth-to-groundwater must be known, cuttings must be properly prepared, and the selected implementation methods must be able to reach groundwater at each selected location (SYRCL 2013).

Specific Design Parameters

- Native Species Planting Composition
    - A combination of four native species will be planted, including: Fremont cottonwood (*Populus fremontii*), Gooddings black willow (*Salix gooddingii*), red willow (*S. laevigata*), and arroyo willow (*S. lasiolepis*). The planting design is intended to promote hardwood structure (i.e., forest and large wood production) while also providing species and structural diversity. Although arroyo willow is not a tree-type willow, it is included in the design to create structural diversity known to support neotropical bird habitat (RHJV 2004). Furthermore, arroyo willow is under-represented on the lower Yuba River compared to other shrubby willows (WSI 2012; SYRCL 2013).
    - Donor trees will be selected from existing riparian areas along the lower Yuba River. Multiple cuttings will be taken from red willow and arroyo willow shrubs, but single cuttings will be taken from the other tree species. If red willow donor tree availability becomes limited, Gooding's willow will be substituted.
- Cutting Size
    - Cuttings will be from branches or stems harvested from donor trees, and prepared as cuttings that are about 7 feet in length. Cuttings will be less than 2 inches diameter at the base.
- Equipment
    - Planting will occur with a stinger planting method that uses a specialized planting device mounted on an excavator to quickly plant cuttings one or two at a time. The

stinger device can plant to a maximum depth of nearly 7 feet and a cutting of maximum diameter of approximately two inches.

- Planting Design
  - It is recommended that revegetation should not cover more than 50% of a constructed surface. Revegetating with patchy stands ensures that existing monotypic vegetation will be replaced with a desirable species composition and structural diversity on some surfaces, while leaving other portions of the constructed surface exposed for natural plant recruitment (Hoopa Valley Tribe *et al*., 2011).
  - The planting method will use a pod planting design that organizes planted cuttings into 20 foot diameter planting units (pods) (**Figure 9**). The "pod" design was developed as a way to incorporate structural diversity and spatial variability into larger riparian rehabilitation projects while still being able to contract and implement easily (e.g., Sullivan and Bair 2004; Hoopa Valley Tribe et. al. 2011).
  - Cuttings will be brought to stinger planting locations in the following combination: 6 cottonwoods and 2 of each willow species. Cuttings planted by stinger should be less than 2 inches in diameter and straight.
  - Each planting location will receive two cuttings of the same species, resulting in 12 cuttings per pod. Placing two cuttings per location is a common approach to increase success rate where some proportion of cuttings fail to root and thrive regardless of planting conditions (Hoag 2009). Each willow cutting will be planted approximately 2 inches into the groundwater. The design also specifies the planting of cottonwood cuttings 2 inches above groundwater, as cottonwood are sensitive to rotting from prolonged inundation, but have vigorous rooting to meet proximal groundwater (John Bair, pers. comm. in SYRCL 2013).
- Planting Density
  - Initially, planting density will be 1,500 cuttings per acre. If further analyses of previously conducted pilot programs indicates relatively high (e.g., 75%) survivorship, then planting density could be reduced from 1,500 cuttings an acre to 1,000 cuttings an acre, resulting in a lower cost per acre for implementation (SYRCL 2013).

Footprint

- Riparian vegetation planting footprint will be based on descriptions of the proposed measures presented in the YRERFS Habitat Measures Technical Memorandum (YCWA and Corps 2016) and on previously prepared reports (RMT 2009; DWR and PG&E 2010; cbec 2013; NMFS 2014; cbec 2014).
  - <u>Area</u>: Polygons for project footprints were developed and documented in YRERFS Habitat Measures Technical Memorandum (YCWA and Corps 2016).

- Depth: Depth to groundwater has been estimated by Wyrick and Pasternack (2012) and by cbec *et al*. (2010). Available information will be reviewed and modified, if necessary, to estimate depth to groundwater at the various identified riparian vegetation planting locations. Literature reviews will be conducted to identify inundation frequencies and timing to maximize cutting survival, and to provide benefit to rearing juvenile anadromous salmonids.

Riparian planting will occur in areas adjacent to all side-channel footprint descriptions associated with the proposed measures presented in the YRERFS Habitat Measures Technical Memorandum (YCWA and Corps 2016). At select locations, the depth to groundwater is greater than 10 feet in areas that are within a minimum of 40 feet from the wetted edge of a side channel, which will require terracing to enable riparian vegetation planting. To the extent that larger areas are available adjacent to proposed side channels, and these areas are either less than 7 feet to the water table or would require floodplain grading between 7 and 10 feet of the water table, those areas also will be planted with riparian vegetation.

3.4 Design Feature – Structural Complexity Features

- Placement of new or improvement of existing structural complexity features. Structural complexity features include various types of woody material, ELJs and boulder features. Woody material features may significantly differ depending on design intent.

Design Intent

- Create structural complexity features to enhance microhabitat availability through the addition of physical structure and/or modification of local flows.

Design Strategy

For features placed with the purpose of enhancing physical structure only, utilize descriptions provided in the YRERFS Habitat Measures Technical Memorandum (YCWA and Corps 2016). The design elevation is based on a standardized flow condition for each habitat/hydrologic zone, or (HZ).

- Define a design water depth associated with the standardized flow condition, and apply that resultant streambed elevation to identified locations of structural features.

Specific Design Parameters

- Woody Material
    - Bankline application - Where woody material is described as an addition to a bankline, assume woody features are 25 feet in length and 2 ft in diameter. The material will be anchored in the bankline at a 45 degree angle downstream and

protrude 1/3 of its total length beyond the bankline into the channel. For application in the hydraulic model, these placements will be assumed to be 9 foot long and 1 meter wide polygons. Where applicable, groups of these features will be combined into reasonably proportioned polygons.

  - Floodplain application – Where woody material is placed on a floodplain or seasonally inundated area, the woody material will be placed parallel with the flow, anchored with cables, boulders, and pins. For application in the hydraulic model, these placements will be assumed to be 20 feet in diameter circular polygons.

- Boulders – Boulders are assumed to be 5 ton in weight and average 1 meter in diameter. For application in the hydraulic model, the placements will be assumed to be 1 meter in diameter circular polygons.

4.0 ADDITIONAL TECHNICAL CONSIDERATIONS

This TM has been prepared for the Corps based on assumptions as identified throughout the text and upon information, data and conclusions primarily supplied by others (see the document titled "*Yuba River Ecosystem Restoration Feasibility Study Habitat Measures*", dated October 2016). The Corps and its non-federal sponsor are not in a position to, and do not, verify the accuracy of, or adopt as their own, the underlying analyses conducted by others that were used to develop the measure-specific information presented in the source documentation, which has been used to initially develop the lower Yuba River habitat enhancement measures. As a preliminary step in the planning process, design criteria have been developed by the Corps and the non-federal sponsor. The design criteria developed to date are intended to characterize habitat features associated with specific measures for the purpose of providing the Corps with a sound basis for project costing to determine if a Federal interest in the project exists, to estimate the costs associated with the ecosystem restoration alternatives being considered as part of the Feasibility Study[5], and to provide the local sponsor an indication of potential future cost-sharing apportionments. It is, therefore, recognized that considerable additional technical and engineering-related analyses will be required prior to the preparation of final design plans for measure-specific components that may be implemented in the future. Prior to any such implementation, various aspects of resource- and site-specific risk assessment, impact assessment and permit compliance will be required to fully address considerations such as structural adequacy, hydraulic functionality, channel alignment and geomorphic implications, flood risk management, and public health and safety.

[5] For additional information, refer to the CE/ICA analysis.

LITERATURE CITED

California Department of Water Resources and Pacific Gas and Electric Company (DWR and PG&E). 2010. Habitat Expansion Agreement for Central Valley Spring-Run Chinook Salmon and California Central Valley Steelhead Final Habitat Expansion Plan. November 2010.

cbec, inc. (cbec). 2013. Hydrologic and Geomorphic Analysis to Support Rehabilitation Planning for the Lower Yuba River from Parks Bar to Marysville. Prepared for the South Yuba River Citizens League with Funding Provided by the Anadromous Fish Restoration Program.

cbec. 2014. Development of Habitat Enhancement Alternatives for Daguerre Alley, Lower Yuba River. Prepared for the Lower Yuba River Accord River Management Team Planning Group. June 2014.

cbec, inc., South Yuba River Citizens League and McBain & Trush, Inc. 2010. Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River. November 2010. Prepared for the USFWS with Funding Provided by the Anadromous Fish Restoration Program.

Hoag, J. C. 2009. Cluster Plantings: A way to plant live unroofed cuttings in coarse soils including sands, gravels, and cobbles. USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center. Riparian/Wetland Project Information Series No. 26.

Hoopa Valley Tribe, McBain & Trush, Inc., and Northern Hydrology and Engineering. 2011. Channel Rehabilitation Design Guidelines for the Mainstem Trinity River. Prepared for the Trinity River Restoration Program. Hoopa CA.

Jeffres, C.A., J.J. Opperman, and P.B. Moyle, 2008. Ephemeral Floodplain Habitats Provide Best Growth Conditions for Juvenile Chinook Salmon in a California River. Environmental Biology of Fishes 83:449-458.

Moyle, P. B. 2002. Inland fishes of California. University of California Press.

National Marine Fisheries Service (NMFS). 2014. Recovery Plan for Sacramento River Winter-run Chinook Salmon, Central Valley Spring-run Chinook Salmon, and Central Valley Steelhead.

Reedy, G. 2016. Lower Yuba River Flows, Low Floodplain Inundation for Salmonid Rearing and Cottonwood Recruitment Potential. Presentation to the Yuba Accord River Management Team. April 4, 2016.

Riparian Habitat Joint Venture (RHJV). 2004. Version 2.0. The riparian bird conservation plan: a strategy for reversing the decline of riparian associated birds in California. California Partners in Flight. http: / / www.prbo.org /calpif /pdfs /riparian. v-2.pdf.

Sommer, T.R., M.L. Nobriga, W.C. Harrell, W. Batham, and W.J. Kimmerer, 2001. Floodplain Rearing of Juvenile Chinook Salmon: Evidence of Enhanced Growth and Survival. Canadian Journal of Fisheries and Aquatic Sciences 58:325-333.

Sommer, T., L. Conrad, G. O'Leary, F. Feyrer, and W. Harrell. 2002. Spawning and Rearing of Splittail in a Model Floodplain Wetland. Transactions of the American Fisheries Society 131:966-974.

Sommer, T.R., W.C. Harrell, A.M. Solger, B. Tom, and W. Kimmerer, 2004. Effects of Flow Variation on Channel and Floodplain Biota and Habitats of the Sacramento River, California, USA.

South Yuba River Citizens League (SYRCL). 2013. Hammon Bar Riparian Enhancement Project Report. Nevada City, CA.

Watershed Sciences Inc. and A. Fremier. 2012. Riparian Vegetation Analysis for the Lower Yuba River. Report to the Yuba Accord River Management Team.

Wyrick, J. R. and G. Pasternack. G. B. 2012. Landforms of the Lower Yuba River. Prepared for the Yuba Accord River Management Team as part of the Lower Yuba River Monitoring and Evaluation Program.

Yuba Accord River Management Team (RMT). 2009. Appendix M of the Habitat Expansion Agreement for Central Valley Spring-Run Chinook Salmon and California Central Valley Steelhead Final Habitat Expansion Plan Habitat - Expansion for Spring-Run Chinook Salmon and Steelhead in the Lower Yuba River Prepared for the HEA Steering Committee by Members of the Yuba Accord River Management Team.

Yuba Accord River Management Team (RMT). 2013. Aquatic Resources of the Lower Yuba River – Past, Present & Future, Yuba Accord Monitoring and Evaluation Program, Draft Interim Report. April 2013.

Yuba County Water Agency (YCWA). 2013. Technical Memorandum 7-10 - Instream Flow Downstream of Englebright Dam. Yuba River Development Project FERC Project No. 2246. September 2013.

Yuba County Water Agency (YCWA) and U.S. Army Corps of Engineers (Corps). 2016. Yuba River Ecosystem Restoration Feasibility Study Habitat Measures Technical Memorandum. Prepared by HDR Engineering, Inc. October 2016.

FIGURES

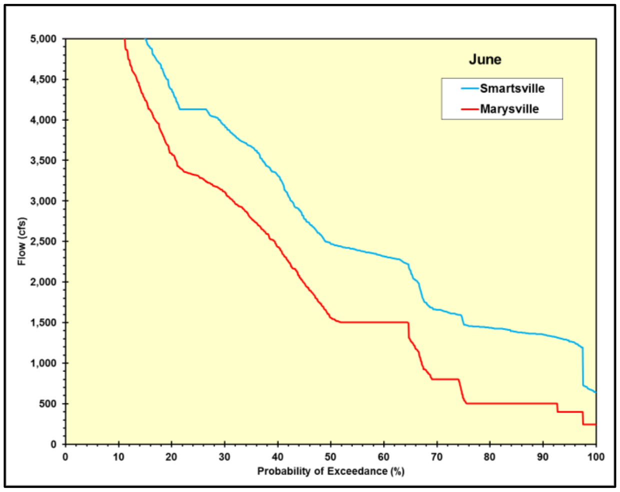


Figure 1. Lower Yuba River monthly flow exceedance during June under the YRDP Relicensing "Base Case" scenario (YCWA 2013).

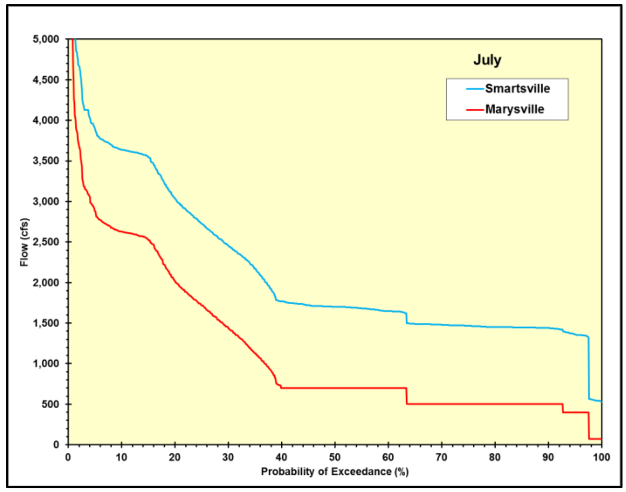


Figure 2. Lower Yuba River monthly flow exceedance during July under the YRDP Relicensing "Base Case" scenario (YCWA 2013).

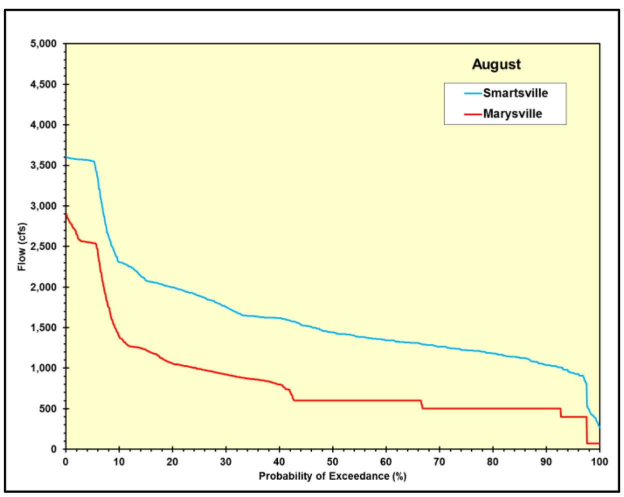


Figure 3. Lower Yuba River monthly flow exceedance during August under the YRDP Relicensing "Base Case" scenario (YCWA 2013).

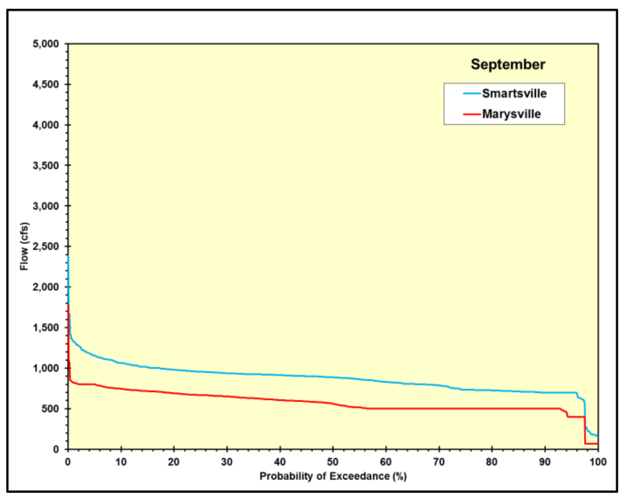


Figure 4. Lower Yuba River monthly flow exceedance during September under the YRDP Relicensing "Base Case" scenario (YCWA 2013).

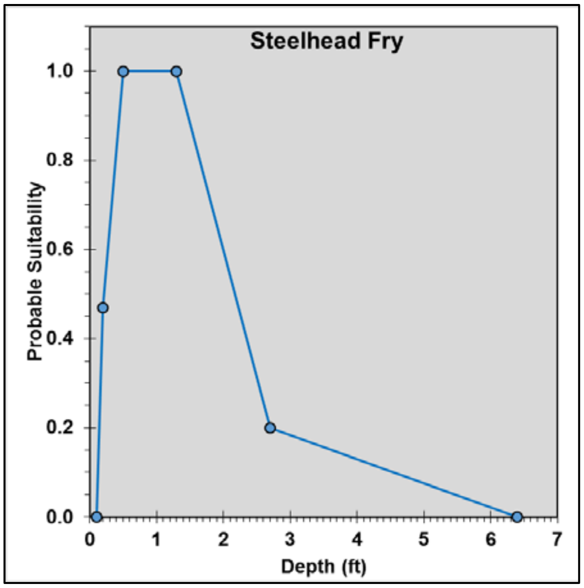


Figure 5. Steelhead fry water depth HSC from YRDP Relicensing (YCWA 2013).

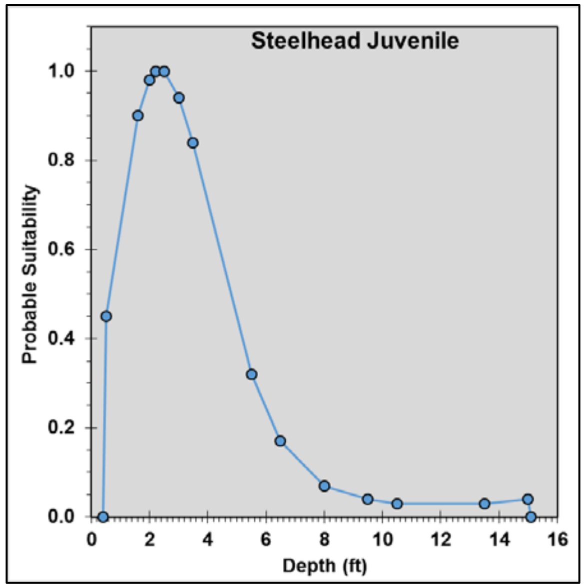


Figure 6. Steelhead juvenile water depth HSC from YRDP Relicensing (YCWA 2013).

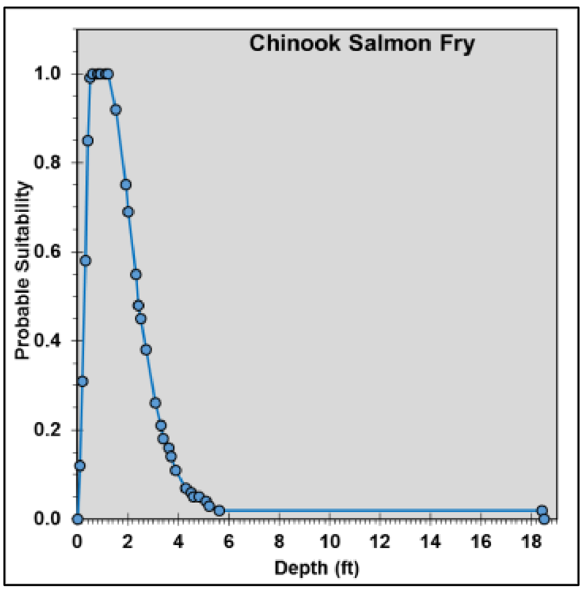


Figure 7.

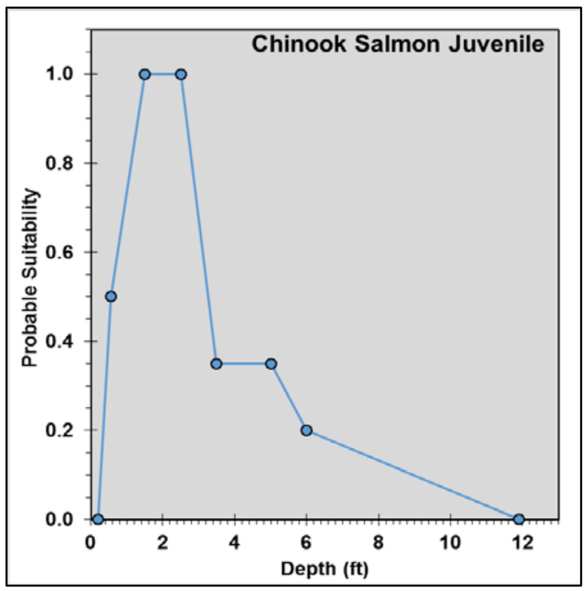


Figure 8. Chinook salmon juvenile water depth HSC from YRDP Relicensing (YCWA 2013).

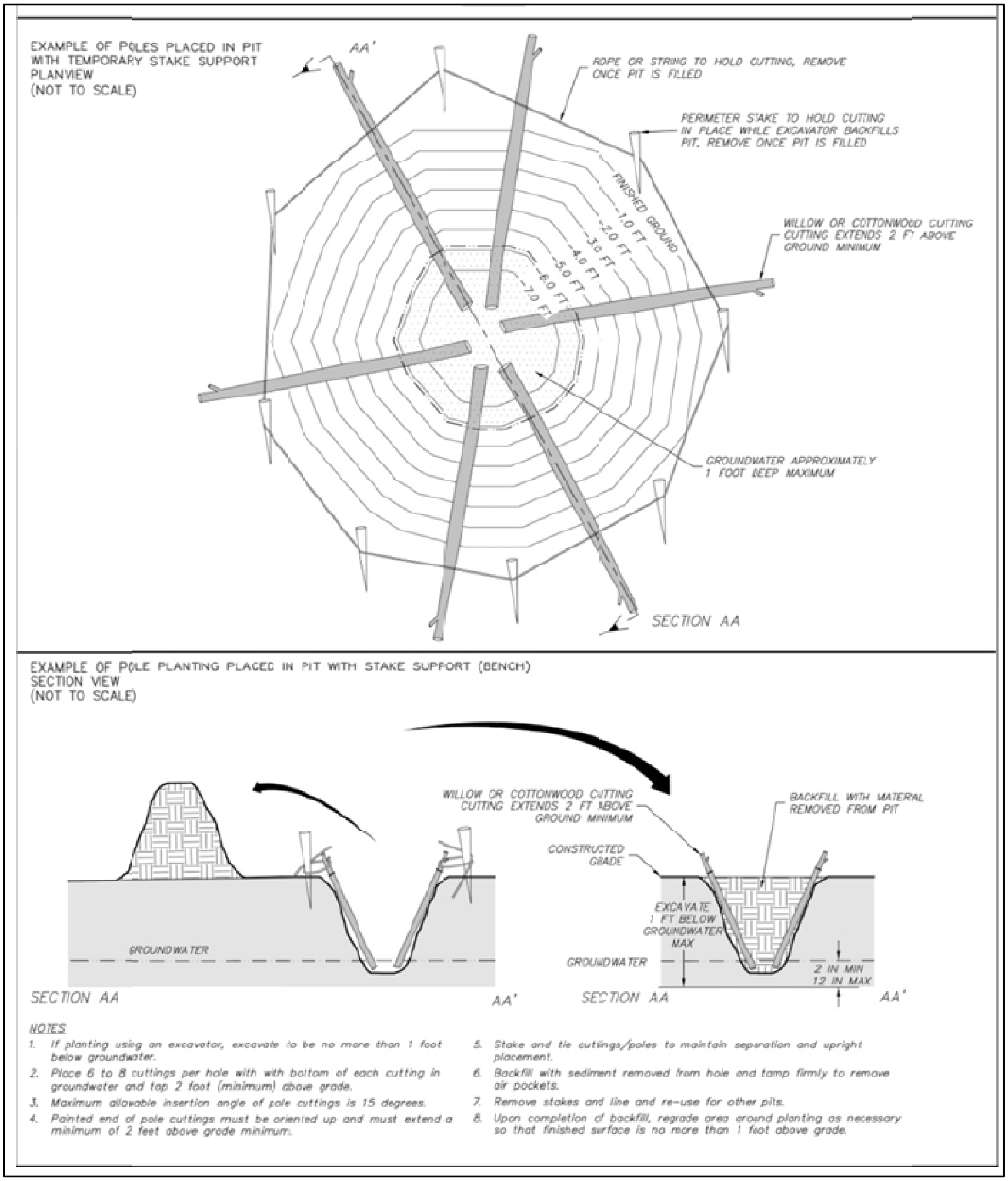


Figure 9. Example of pole planting method (Hoopa Valley Tribe *et al*. 2011).

ATTACHMENT CV-B: GIS GENERATED QUANTITIES

Using data from HDR:

1) The original (**All**) Measures Shapefile
2) The Raster LYR LiDAR Bathy Merge UC Davis
3) Depth to Water Table Raster
4) Terrain Modification Raster with HDR Side Channels Surfaces and USACE Lowering/Backwater Surfaces
5) HDR Surfaces and TIN parts for Side Channels

Surfaces/Tin created and mosaicked into existing terrain:

Side Channel Measures: 17, 24, 34, 47, 48, 46, 55

Backwater Area Measures: 18, 21, 51, 52

Floodplain Lowering Measures: 19, 22, 24, 30, 32, 37, 46, 49, 50

Using ArcGIS 10.3.1:

Backwater Measures:

1) Designate Backwater outlines from Base Flow Contour (determine by comparing overlapping edge of Water table Raster and 2015 Aerial Imagery) of River (Inlet) and edge of Measures Polygon. (1ft Contours created from UCdavisLiDARbathyMergeFINAL.tif AKA LYR Raster) Apply Cartographic smoothing of Measures edges to retain more natural alignment with topography.
2) Interpolate Polyline extents to 3d line at LYR Raster base height. This creates a wireframe to be included in a TIN surface.
3) Add to wireframe: Design base contour from inlet to within extents to represent floor of Backwater area at elevation of base inlet Contour and inward to a moderate slope.
4) Edit and match all intersecting 3d vertices and verify in 3D viewer. These are the TIN lines.
5) Convert Polyline to Polygon for inclusion in TIN creation. This is the TIN extent (soft clip).
6) Convert TIN to Raster with 1ft cell size.
7) Backwater raster is mosaicked into the existing LYR raster to 'implement' the measure.
8) This process is repeated for all Backwater measures along the reach.

Floodplain Lowering:

Using Depth_to_Water_Table.tif and UCdavisLiDARbathyMergeFINAL.tif

1) Created Minus Raster (UCdavisLiDARbathyMergeFINAL.tif - Depth_to_Water_Table.tif) to produce @ Water Table Raster.
2) Created Raster Math Int to add 7ft to Water Table Raster (Raster @ 7ft to Table as per Design Criteria). Cut/Fill of UCdavisLiDARbathyMergeFINAL.tif and +7ft Water Table Raster.
3) Reclassify Cut/Fill to delineate Areas already/below 7ft from Water Table to Polygon. This identified 33% of (Amount of) polygons that are 5% of total area already 7ft to the Water Table.
4) Extract Cut value from Cut Fill to new Raster and Polygon Existing7ftToWaterTableCutPoly.
5) Extract by Mask Cut value Raster from 7ft to the Water Table. This creates the bottom surface of the Floodplain Lowering areas that are 7ft to Water Table with almost exactly 5% less area than original Habitat Measures Polygon.
6) Interpolate Poly to UCdavisLiDARbathyMergeFINAL.tif
7) Raster to Point
8) Interpolate Point to +7ft Water Table Raster
9) Remove point a 3 feet from inside edges (For Slope)
10) Remove more inner points where depth to +7ft Water Table Raster is greater
11) Create Tin
12) Convert TIN to Raster with 1ft cell size.
13) Floodplain Lowering raster is mosaicked into the existing LYR raster to 'implement' the measure.
14) This process is repeated for all Floodplain Lowering measures along the reach.

Side Channels:

Completed by HDR

1) Designate channel outlines as the wetted edge of the new surface Feature
2) Criteria define the slope of features to not exceed 1:3 (rise over run)
3) Extend wetted edge boundary into active existing water channel to ensure surface continuity from main channel into side channel
4) Buffer wetted edge 1.5' inside and 15' outside (allows for 0.5' water depth at start and finish of channel)
5) Assign line geometry elevations as follows: interior buffer is assigned an elevation equal to 0.5' lower than the wetted edge of the active channel (at the upstream and downstream ends of the side channel) at 530cfs/700cfs (below and above Daguerre Point Dam respectively) to ensure water depth of 0.5' at those flows. The outer buffer was assigned a value of 5' higher than the active channel water elevation. This establishes a gradient of 1:3 for the

channel.

6) Line data examined in 3D viewer to verify the proper wireframe geometry of the channel.
7) Wireframe channel converted to TIN with a linear slope from upstream end to downstream end (extent limited to outer buffer of channel).
8) This channel surface is intersected with the digital surface model (DSM) TIN to establish a boundary describing channel extent that is below the existing surface of the LYR.
9) The channel TIN is converted into a raster (with same cell size, snapped to LYR surface raster) and simultaneously clipped to the intersect boundary established in Step 8.
10) Channel raster is mosaicked into the existing LYR raster to 'implement' the measure.
11) This process is repeated for all side channel measures along the reach.

Volume calculation:

1) Each Measure TIN converted to Raster (DEM)
2) Cut/Fill created for each Measure Raster with UCdavisLiDARbathyMergeFINAL.tif as original Surface
3) Each Cut/Fill exported to Table
4) Volumes calculated in Table
5) Volumes recorded in Civil Design Cost spreadsheet tool.

For other measures (20, 26, 28, 29, 33, 53, and 54) riparian planting area was calculated to determine the benefit. Quantities generated are listed in Table CV-B-1.

TABLE CV-B-1: Increment Quantities

Measure Number	TSP Increment	Measure Tybe	Surf. Area (ac)	Excavation Volume (cy)	Average Excavation Depth (ft)	Staging Site	Staging Site Bulked Excavation Volume (cy, @ 1.1)
19	2	Floodplain Lowering	8.1	18,416	1.4	S-1	22,996
19	2	Riparian Planting	2.5				
20	2	Bank Scalloping	0.3				
20	2	Riparian Planting	0.4				
21	2	Backwater Area	0.3	2,489	4.7		
21	2	Riparian Planting	0.6				
22	2	Floodplain Lowering	5.9	12,257	1.3	S-2	13,483
22	2	Riparian Planting	5.2				
24	2	Floodplain Lowering	6.2	11,568	1.2	S-3	26,729
24	2	Riparian Planting	5.0				
24	2	Side Channel	0.8	12,731	10.3		
26	3a	Riparian Planting	2.3			S-4	0
28	3a	Riparian Planting	6.3			S-5	3,050
29	3a	Gravel	1.6				
30	3a	Floodplain Lowering	1.6	2,773	1.1		
30	3a	Riparian Planting	3.5				
32	3a	Floodplain Lowering	5.2	13,531	1.6	S-6	206,238
32	3a	Riparian Planting	11.6				
33	3a	Gravel	1.9				
34	3a	Side Channel	10.5	173,958	10.3		
46	5a	Floodplain Lowering	13.0	33,545	1.6	S-7	250,630
46	5a	Riparian Planting	16.6				
46	5a	Side Channel	10.3	118,075	7.1		
47	5a	Riparian Planting	4.7				
47	5a	Side Channel	4.8	76,225	9.9		
48	5b	Side Channel	9.2	127,625	8.6	S-8	165,767
49	5b	Floodplain Lowering	6.9	8,599	0.8		
49	5b	Riparian Planting	21.1				
50	5b	Floodplain Lowering	0.8	1,127	0.9		
50	5b	Riparian Planting	3.7				
51	5b	Backwater Area	1.9	8568	2.7		
52	5b	Backwater Area	1.0	4778	2.9		
53	5b	Riparian Planting	2.4			S-9	0
54	5b	Riparian Planting	2.5				

Attachment CE-A. Total Project Cost Summary Sheet

WALLA WALLA COST ENGINEERING MANDATORY CENTER OF EXPERTISE

COST AGENCY TECHNICAL REVIEW

CERTIFICATION STATEMENT

For Project No. 325840

SPK – Yuba River Ecosystem Restoration
Feasibility Study

The Yuba River Ecosystem Restoration Feasibility Study, as presented by Sacramento District, has undergone a successful Cost Agency Technical Review (Cost ATR), performed by the Walla Walla District Cost Engineering Mandatory Center of Expertise (Cost MCX) team. The Cost ATR included study of the project scope, report, cost estimates, schedules, escalation, and risk-based contingencies. This certification signifies the products meet the quality standards as prescribed in ER 1110-2-1150 Engineering and Design for Civil Works Projects and ER 1110-2-1302 Civil Works Cost Engineering.

As of January 4, 2019, the Cost MCX certifies the estimated total project cost:

FY19 Project First Cost: $ 97,219,000
Fully Funded Amount: $111,444,000

It remains the responsibility of the District to correctly reflect these cost values within the Final Report and to implement effective project management controls and implementation procedures including risk management through the period of Federal Participation.

FOR: Michael P. Jacobs, PE, CCE
Chief, Cost Engineering MCX
Walla Walla District

****** TOTAL PROJECT COST SUMMARY ******

PROJECT: Yuba River Restoration -Feasibility
PROJECT N P2 # 325840
LOCATION: Marysville, CA

DISTRICT: SPK Sacramento PREPARED: 12/19/2018
POC: CHIEF, COST ENGINEERING, Theresa A. Gneiting-James

This Estimate reflects the scope and schedule in report; -

Program Year (Budget EC): 2019
Effective Price Level Date: 1 OCT 18

Civil Works Work Breakdown Structure			ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)						TOTAL PROJECT COST (FULLY FUNDED)			
WBS NUMBER *A*	Civil Works Feature & Sub-Feature Description *B*		COST ($K) *C*	CNTG ($K) *D*	CNTG (%) *E*	TOTAL ($K) *F*	ESC (%) *G*	COST ($K) *H*	CNTG ($K) *I*	**TOTAL ($K)** *J*	Spent Thru: **9/30/2018** ($K)	**TOTAL FIRST COST** ($K)	INFLATED (%)	COST ($K) *M*	CNTG ($K) *N*	FULL ($K) *O*
06	FISH & WILDLIFE FACILITIES	- Construction	$46,792	$11,698	25%	$58,491	0.0%	$46,792	$11,698	$58,491	$0	$58,491	10.3%	$51,611	$12,903	$64,514
06	FISH & WILDLIFE FACILITIES	- Monitoring	$1,907	$477	25%	$2,384	0.0%	$1,907	$477	$2,384	$0	$2,384	35.8%	$2,589	$647	$3,236
06	FISH & WILDLIFE FACILITIES	- Adaptive Management	$7,520	$1,880	25%	$9,400	0.0%	$7,520	$1,880	$9,400	$0	$9,400	38.8%	$10,438	$2,609	$13,047
16	BANK STABILIZATION		$0	$0	-	$0	-	$0	$0	$0	$0	$0	-	$0	$0	$0
20	PERMANENT OPERATING EQUIPMENT		$0	$0	-	$0	-	$0	$0	$0	$0	$0	-	$0	$0	$0
	CONSTRUCTION ESTIMATE TOTALS:		$56,219	$14,055		$70,274	0.0%	$56,219	$14,055	$70,274	$0	$70,274	15.0%	$64,638	$16,160	$80,798
01	LANDS AND DAMAGES		$7,078	$1,982	28%	$9,060	0.0%	$7,078	$1,982	$9,060	$0	$9,060	10.4%	$7,814	$2,188	$10,002
30	PLANNING, ENGINEERING & DESIGN		$11,491	$2,873	25%	$14,364	0.0%	$11,491	$2,873	$14,364	$0	$14,364	15.5%	$13,267	$3,317	$16,584
31	CONSTRUCTION MANAGEMENT		$2,717	$679	25%	$3,396	0.0%	$2,717	$679	$3,396	$0	$3,396	15.6%	$3,141	$785	$3,926
18	CULTURAL RESOURCE PRESERVATION		$100	$25	25%	$125	0.0%	$100	$25	$125	$0	$125	7.2%	$107	$27	$134
	PROJECT COST TOTALS:		$77,605	$19,614	25%	$97,219		$77,605	$19,614	**$97,219**	$0	**$97,219**	14.6%	$88,967	$22,476	$111,444

__________________ CHIEF, COST ENGINEERING, Theresa A. Gneiting-James

__________________ PROJECT MANAGER, Chelsea Stewart

__________________ CHIEF, REAL ESTATE, Adam Olson

ESTIMATED TOTAL PROJECT COST: $111,444

__________________ CHIEF, PLANNING, Alicia Kirchner

__________________ CHIEF, ENGINEERING, Rick Poeppelman

__________________ CHIEF, OPERATIONS, Randy Olsen

__________________ CHIEF, CONSTRUCTION, Norbert Suter

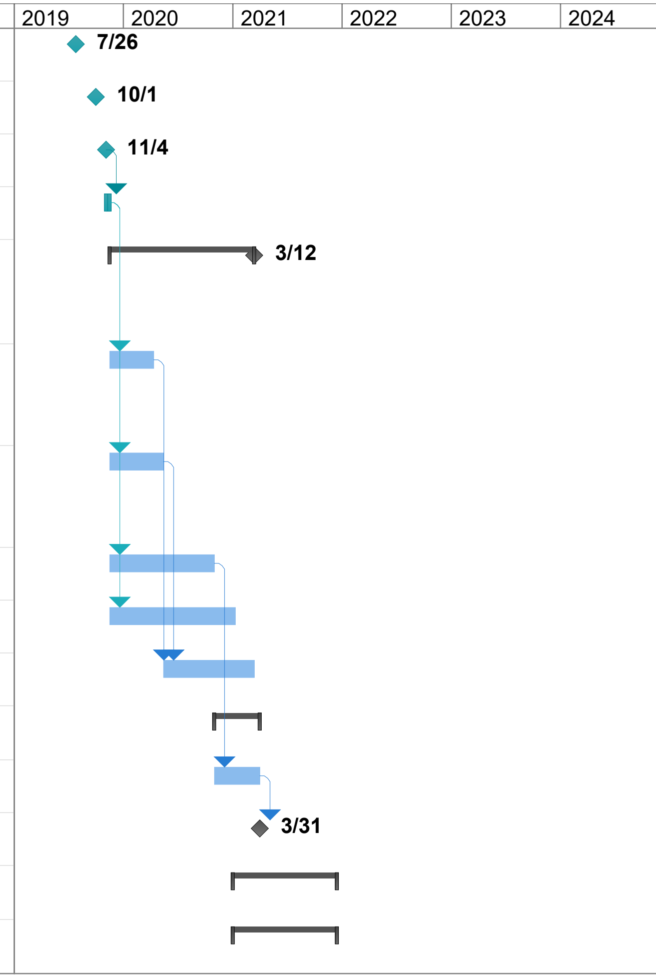
__________________ CHIEF, CONTRACTING, Kim Ford

__________________ CHIEF, PM-PB, Mary Evans

__________________ CHIEF, DPM, Tambour Eller

Attachment CE-B. Project Schedule for Construction

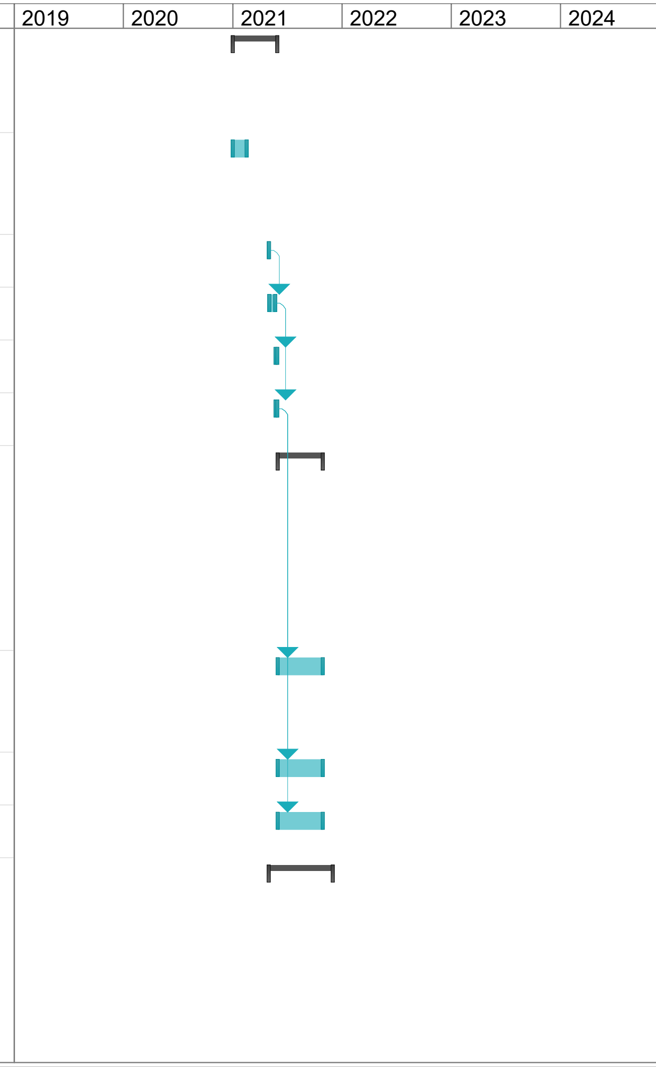
ID		Task	Task Name	Duration	Start	Finish	Predecessors
1			Chief's Report	0 days	Fri 7/26/19	Fri 7/26/19	
2			Potential Authorization	0 days	Tue 10/1/19	Tue 10/1/19	
3			Potential Receipt of Funds	0 days	Mon 11/4/19	Mon 11/4/19	
4			Sign Design Agreement	11 days	Mon 11/4/19	Fri 11/15/19	3
5			**Preconstruction Engineering and Design**	**414 days**	**Sat 11/16/19**	**Fri 3/12/21**	
6			Site Characterization (including ROE Acquisition)	126 days	Sat 11/16/19	Fri 4/10/20	4
7			Detailed Surveying (including ROE Acquisition)	154 days	Sat 11/16/19	Wed 5/13/20	4
8			Modeling and Design	300 days	Sat 11/16/19	Fri 10/30/20	4
9			RE Acquisition	360 days	Sat 11/16/19	Fri 1/8/21	4
10			Permitting	260 days	Thu 5/14/20	Fri 3/12/21	6,7
11			**Acquisition**	**130 days**	**Sat 10/31/20**	**Wed 3/31/21**	
12			Acquisition	130 days	Sat 10/31/20	Wed 3/31/21	8
13			First Construction Contract Award	0 days	Wed 3/31/21	Wed 3/31/21	12
14			**Construction Year 1**	**298 days**	**Fri 1/1/21**	**Tue 12/14/21**	
15			**Site 7,8,4,5,9**	**298 days**	**Fri 1/1/21**	**Tue 12/14/21**	



Project: YRR - Sched - 24Oct20
Date: Mon 10/29/18

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

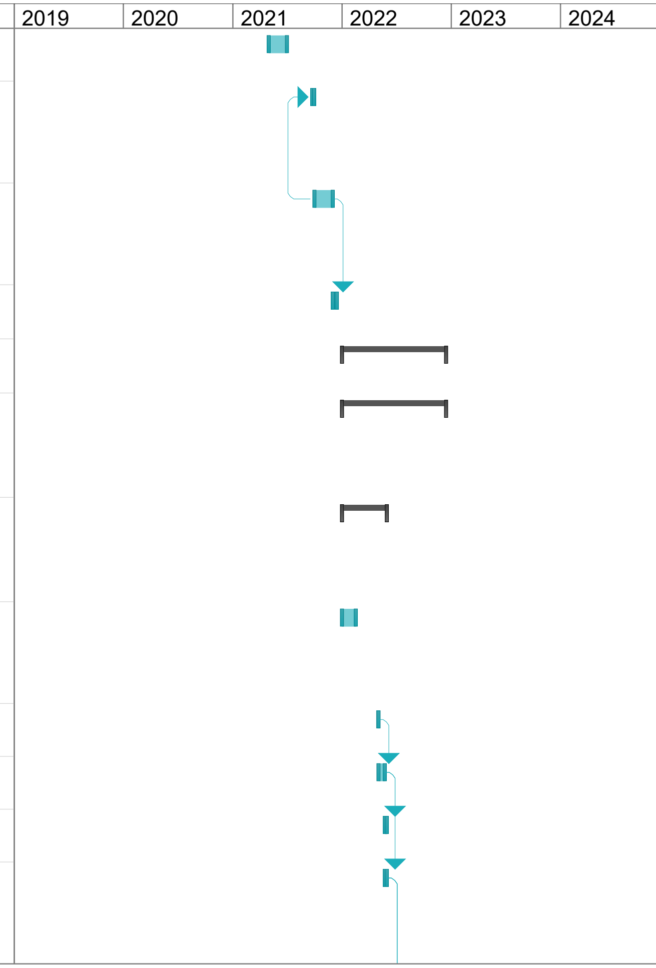
ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
16		**First Site Mobilization for Excavation**	**128 days**	**Fri 1/1/21**	**Sat 5/29/21**	
17		Initial Trimming and Clearing of Vegitation	39 days	Fri 1/1/21	Mon 2/15/21	
18		Mobilization	1 day	Sat 5/1/21	Sat 5/1/21	
19		Access Road	18 days	Mon 5/3/21	Sat 5/22/21	18
20		Clear and Grub	6 days	Mon 5/24/21	Sat 5/29/21	19
21		Establish BMPs, Site Controls	6 days	Mon 5/24/21	Sat 5/29/21	19
22		**Excavation, Hauling, Placement Site Work (S-8 Full 1 crew; S-7 Partial 1 crew)**	**130 days**	**Mon 5/31/21**	**Thu 10/28/21**	
23		Excavation (Side Channel, Lowering)	130 days	Mon 5/31/21	Thu 10/28/21	21
24		Dumptruck Haul	130 days	Mon 5/31/21	Thu 10/28/21	21
25		Placement Site Work	130 days	Mon 5/31/21	Thu 10/28/21	21
26		**Plantings (S-4 full, S-5 Partial w/ 1 crew; S-9 Complete w/ 2 crews; S-7 Partial w/ 2 crews)**	**183 days**	**Sat 5/1/21**	**Tue 11/30/21**	



Project: YRR - Sched - 24Oct20
Date: Mon 10/29/18

Task		Inactive Summary		External Tasks	
Split		Manual Task		External Milestone	
Milestone		Duration-only		Deadline	
Summary		Manual Summary Rollup		Progress	
Project Summary		Manual Summary		Manual Progress	
Inactive Task		Start-only			
Inactive Milestone		Finish-only			

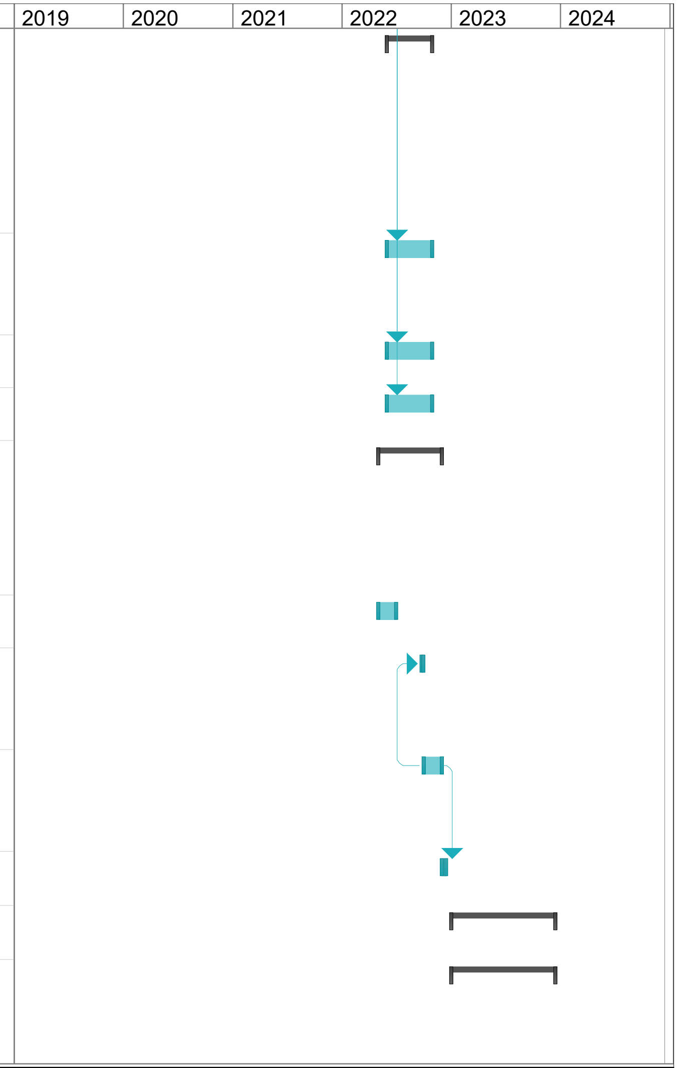
ID	Info	Task Mode	Task Name	Duration	Start	Finish	Predecessors
27			Scout and Mark Trees	52 days	Sat 5/1/21	Wed 6/30/21	
28			Begin Harvest and Soak, Trees	5 days	Fri 9/24/21	Wed 9/29/21	29SS-6 days
29			Med. Excavator with Stinger Planting Only	52 days	Fri 10/1/21	Tue 11/30/21	
30			**Site Demob, Secure**	12 days	Wed 12/1/21	Tue 12/14/21	29
31			**Construction Year 2**	**298 days**	**Sat 1/1/22**	**Wed 12/14/2**	
32			**Site 7,8,6**	**298 days**	**Sat 1/1/22**	**Wed 12/14/22**	
33			**Site Mobilization for Excavation**	**128 days**	**Sat 1/1/22**	**Mon 5/30/22**	
34			Initial Trimming and Clearing of Vegitation	39 days	Sat 1/1/22	Tue 2/15/22	
35			Mobilization	1 day	Mon 5/2/22	Mon 5/2/22	
36			Access Road	18 days	Tue 5/3/22	Mon 5/23/22	35
37			Clear and Grub	6 days	Tue 5/24/22	Mon 5/30/22	36
38			Establish BMPs, Site Controls	6 days	Tue 5/24/22	Mon 5/30/22	36



Project: YRR - Sched - 24Oct20
Date: Mon 10/29/18

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

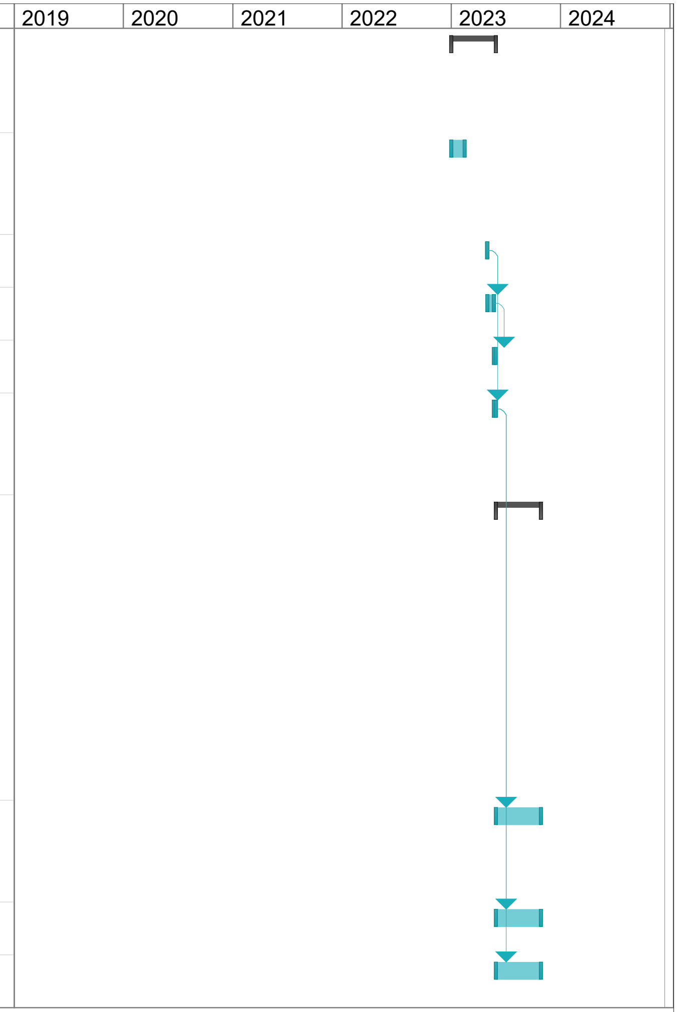
ID	Task	Task Name	Duration	Start	Finish	Predecessors
39		**Excavation, Hauling, Placement Site Work (Complete S-7 w/ 1 crew; S-6 Partial w/ 1 crew)**	**130 days**	**Tue 5/31/22**	**Fri 10/28/22**	
40		Excavation (Side Channel, Lowering)	130 days	Tue 5/31/22	Fri 10/28/22	38
41		Dumptruck Haul	130 days	Tue 5/31/22	Fri 10/28/22	38
42		Placement Site Work	130 days	Tue 5/31/22	Fri 10/28/22	38
43		**Plantings (S-8 Complete w/ 3 crews, S-7 complete w/ 2 crews)**	**183 days**	**Mon 5/2/22**	**Wed 11/30/22**	
44		Scout and Mark Trees	52 days	Mon 5/2/22	Thu 6/30/22	
45		Begin Harvest and Soak, Trees	5 days	Sat 9/24/22	Thu 9/29/22	46SS-6 days
46		Med. Excavator with Stinger Planting Only	52 days	Sat 10/1/22	Wed 11/30/22	
47		**Site Demob, Secure**	12 days	Thu 12/1/22	Wed 12/14/2	46
48		**Construction Year 3**	**298 days**	**Sun 1/1/23**	**Thu 12/14/23**	
49		**Site 6, 5, 3, 2, 1**	**298 days**	**Sun 1/1/23**	**Thu 12/14/23**	



Project: YRR - Sched - 24Oct20
Date: Mon 10/29/18

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

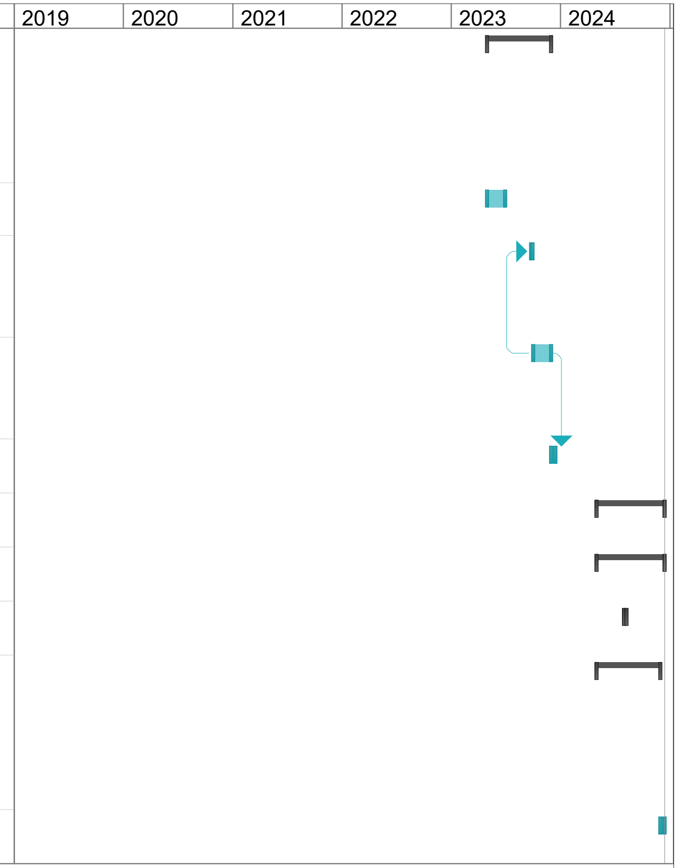
ID	ℹ	Task	Task Name	Duration	Start	Finish	Predecessors
50			**Site Mobilization for Excavation**	**127 days**	**Sun 1/1/23**	**Mon 5/29/23**	
51			Initial Trimming and Clearing of Vegitation	39 days	Sun 1/1/23	Tue 2/14/23	
52			Mobilization	1 day	Mon 5/1/23	Mon 5/1/23	
53			Access Road	18 days	Tue 5/2/23	Mon 5/22/23	52
54			Clear and Grub	6 days	Tue 5/23/23	Mon 5/29/23	53
55			Establish BMPs, Site Controls	6 days	Tue 5/23/23	Mon 5/29/23	52
56			**Excavation, Hauling, Placement Site Work (Complete S-6 w/ 1 crew; Complete Sites 1,2,3, remainder of 5 w/ 1 crew))**	**130 days**	**Tue 5/30/23**	**Fri 10/27/23**	
57			Excavation (Side Channel, Lowering)	130 days	Tue 5/30/23	Fri 10/27/23	55
58			Dumptruck Haul	130 days	Tue 5/30/23	Fri 10/27/23	55
59			Placement Site Work	130 days	Tue 5/30/23	Fri 10/27/23	55



Project: YRR - Sched - 24Oct20
Date: Mon 10/29/18

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

ID		Task Mode	Task Name	Duration	Start	Finish	Predecessors
60			**Plantings (S-6 Partial w/ 1 crew; S-5 and S-3 complete w/ 2 crews)**	**184 days**	**Mon 5/1/23**	**Thu 11/30/23**	
61			Scout and Mark Trees	52 days	Mon 5/1/23	Thu 6/29/23	
62			Begin Harvest and Soak, Trees	5 days	Mon 9/25/23	Fri 9/29/23	63SS-6 days
63			Med. Excavator with Stinger Planting Only	52 days	Mon 10/2/23	Thu 11/30/23	
64			**Site Demob, Secure**	12 days	Fri 12/1/23	Thu 12/14/23	63
65			**Construction Year 4**	**195 days**	**Wed 5/1/24**	**Fri 12/13/24**	
66			**Site 6, 2, 1**	**195 days**	**Wed 5/1/24**	**Fri 12/13/24**	
67			**Site Mobilization for Planting**	**7 days**	**Thu 8/1/24**	**Thu 8/8/24**	
70			**Plantings (Complete S-6 w/ 1 crew; Complete S-2, S-1 w/ 2 crews)**	**183 days**	**Wed 5/1/24**	**Fri 11/29/24**	
74			**Site Demob, Secure**	12 days	Sat 11/30/24	Fri 12/13/24	73



Project: YRR - Sched - 24Oct20
Date: Mon 10/29/18

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

Attachment ENV-A. Environmental Site Assessment Phase 1

ENVIRONMENTAL SITE ASSESSMENT

YUBA RIVER ECOSYSTEM RESTORATION
YUBA RIVER, CALIFORNIA

Prepared By:

Bruce Van Etten, Senior Engineering Technician
Environmental Design Section
U.S. Army Corps of Engineers, Sacramento District

US Army Corps of Engineers ®

Approved By: Date:

15 December 2017

Chris Goddard, PE
Section Chief, Environmental Design Section
U.S. Army Corps of Engineers, Sacramento District

TABLE OF CONTENTS

ACRONYMS

AST	Aboveground Storage Tank
ASTM	American Society for Testing and Materials
CESPK	US Army Corps of Engineers, Sacramento District
DTSC	Department of Toxic Substance Control
EDR	Environmental Data Resources Inc.
ESA	Environmental Site Assessment
HTRW	Hazardous, Toxic, and Radioactive Waste
RCRA	Resource Conservation and Recovery Act
USEPA	US Environmental Protection Agency
UST	Underground Storage Tank

1.0 EXECUTIVE SUMMARY

The methodology of ASTM 1527-13 is used to conduct an Environmental Site Assessment (ESA) to identify Recognized Environmental Conditions in order to establish the presence or likely presence of hazardous substances or petroleum products under conditions that indicate a likely release, a past release, or a material threat of a release of those substances. This practice permits the user to qualify for the innocent landowner, contiguous property owner, or bona fide prospective purchaser limitations on Comprehensive Environmental Response, Compensation, and Liability Act liability. The ESA also provides background information for National Environmental Policy Act (NEPA) documents and can be included in the appendix of NEPA documents or included by reference.

In October 2017, USACE performed an ESA for the Yuba River Ecosystem Restoration project, in accordance with ASTM 1527-05. The ESA consisted of reviewing regulatory databases of Hazardous and Toxic Waste (HTW) sites, historical literature, and conducting interviews with people who are knowledgeable about the project site and the surrounding area. A site reconnaissance was also conducted as part of the ESA process.

The study area for this ESA of the Yuba River Ecosystem Restoration included approximately 20 miles upstream of Marysville. The project has an upstream boundary approximately 2 miles downstream of Englebright Dam and a downstream boundary at the confluence of the Yuba River and the Feather Rivers. The study area for this project included ¼ mile both north and south of the river although the project will only be +/- 200 feet from the river’s edge.

Work will consist of channel alignment to be restored to inundate at 3,000 cfs and function as swale habitat. The side channel and adjacent floodplain would be lowered and graded. Additionally, riparian vegetation would be planted on each side of the restored swale/side channel. Engineered log jams would be placed in a patchwork configuration at the inflow of the swale. In addition, large woody material would be placed in the backwater area to increase structural and habitat complexity in the area.

The ESA contained herein was conducted in accordance with ASTM E1527-13 and ER1165-2-132. Although below EPA levels Mercury is a Recognized Environmental Condition identified at the project site during completion of this report. Appropriate caution should be taken during any excavating.

2.0 INTRODUCTION

2.1 *PURPOSE*

The Environmental Design Section (ED-ED) of the Environmental Engineering Branch of the USACE in Sacramento, California, has prepared this report for the Yuba River Ecosystem Restoration project.

The National Environmental Policy Act (NEPA), the California Environmental Quality Act (CEQA) and USACE regulations require that an Environmental Site Assessment (ESA) be performed for this project site and its surrounding area. The purpose of the ESA is to identify and document Recognized Environmental Conditions that may have adverse impacts on the proposed project. ASTM 1527-13 defines Recognized Environmental Conditions as "...the presence or likely presence of any hazardous substances or petroleum products in, on, or at a property: (1) due to any release to the environment; (2) under conditions indicative of a release to the environment; or (3) under conditions that pose a material threat of future release to the environment."

In October 2017, USACE performed an ESA for the Yuba River Ecosystem Restoration project, in accordance with ASTM 1527-05. The ESA consisted of reviewing regulatory lists of Hazardous and Toxic Waste (HTW) sites, historical literature, and conducting interviews with people who are knowledgeable about the project site and the surrounding area. A site reconnaissance was also conducted as part of the ESA process.

2.2 *DETAILED SCOPE-OF-SERVICES*

The Yuba River Watershed encompasses 1,340 square miles on the western slopes of the Sierra Nevada Mountain Range, and is located in portions of Sierra, Placer, Yuba, and Nevada counties. The Yuba River is a tributary of the Feather River which, in turn, flows into the Sacramento River near the town of Verona, California.

The Yuba River flows through forest, foothill chaparral, and agricultural lands. Levees are absent for most of its course except for near the river's confluence with the Feather River. At that point, the Yuba River is bounded by setback levees for approximately six miles.

The study area for this part of the Yuba River Ecosystem Restoration included approximately 20 miles upstream of Marysville. The project has an upstream boundary approximately 2 miles downstream of Englebright Dam and a downstream boundary at the confluence of the Yuba River and the Feather Rivers. The study area for this project included ¼ mile both north and south of the river although the work for this project will only be the river and +/- 200 feet on either side of the river's edge.

Work will consist of channel alignment to be restored to inundate at 3,000 cfs and function as swale habitat. The side channel and adjacent floodplain would be lowered and graded. Additionally, riparian vegetation would be planted on each side of the restored swale/side channel. Engineered log jams would be placed in a patchwork configuration at the inflow of the swale. In addition, large woody material would be placed in the backwater area to increase structural and habitat complexity in the area.

The ESA is concerned with identifying and documenting Recognized Environmental Conditions as defined by ASTM 1527-13 on this site and the adjacent properties using commonly known and reasonably ascertainable information, such as historical records and regulatory databases.

2.3 *SIGNIFICANT ASSUMPTIONS*

There are no assumed conditions as defined by ASTM 1527-13 that would be considered a Recognized Environmental Condition.

2.4 *LIMITATIONS AND EXCEPTIONS*

The ESA does not include any sampling or testing of soil, air, water or building materials. The interiors of buildings and structures were not inspected.

2.5 *SPECIAL TERMS AND CONDITIONS*

The project site does not involve purchase of the property for commercial purposes, subsurface investigation or any construction, and as such, the conditions for the ASTM specifications are not completely applicable. Where applicable, the format and guidance recommended by ASTM is followed as stated in standard ASTM 1527-13.

3.0 SITE DESCRIPTION

3.1 *LOCATION AND LEGAL DESCRIPTION*

The ESA site has an upstream boundary approximately 2 miles downstream of Englebright Dam and a downstream boundary at the confluence of the Yuba River and the Feather Rivers.

The Lower Yuba River flows from the dam at Englebright Lake to its confluence with the Feather River, just south of Marysville. It begins the journey in a rocky basin paralleled by steep canyon walls, a deep gorge otherwise known as the Narrows. The Yuba River continues, winding its way west, down through canyons and over gravel beds until the landscape begins to flatten out just above the Parks Bar Bridge (Highway 20). From here, the river parallels the highway for the next 20 miles or so as it makes its way to the Feather. About seven miles below the bridge stands the Daguerre Point Dam. Built in the early 1900’s to prevent hydraulic mining debris from washing into the Feather River, it now acts as an obstacle to boats and fish alike.

Hammonton Road on the south side of the river, previously a private road maintained by an aggregate company, has been opened recently to public access as a result of a lawsuit. However, lack of maintenance makes the road difficult to use.

3.2 *SITE AND VICINITY GENERAL CHARACTERISTICS*

The study area has been heavily impacted by past hydraulic mining. Extensive hydraulic mining occurred in the Yuba River watershed from 1852 until the enactment of the Caminetti Act 1893 that severely limited its use. In hydraulic mining, water cannons shot high-pressure flows out to wash away hillsides. The material that was dislodged was then sluiced to expose the gold. It is estimated that during the years1849-1909, 684 million cubic yards of gravel and debris due to hydraulic mining were washed into the Yuba River system. The quantity of material washed in the river due to mining has been variously estimated, but it seems safe to say that there are now upwards of 333,000,000 cubic yards in the bed of the lower Yuba River. This debris field is still mined for residual gold deposits and gravel. Hydraulic mining in the Yuba River accounted for 40 percent of all the mining debris that washed into the Central Valley

Hydraulic mining resulted in torrents of sediment being transported downslope to the valley and caused flooding along Central Valley Rivers, including the lower Yuba River. Two major debris dams (i.e., Daguerre Point Dam in 1906 and Englebright Dam in 1941) were constructed on the Yuba River to prevent the continued movement of sediment into the Feather and Sacramento rivers, and ultimately the San Francisco Bay-Delta.

The Yuba Goldfields, located from approximately 8 to 16 miles upstream of Marysville, are dominated by approximately 20,000 acres of dredge tailings that were reworked from hydraulic mine waste. Dredging of gold from the hydraulic waste in the Goldfields began in 1902, and by 1910, 15 dredges were operating in the lower Yuba River. The area has been dredged and re-dredged intermittently throughout the years, and dredging continues today for spatial and temporal changes in the area.

Along with harmful effects downstream due to hydraulic mining, mercury was used to process gold deposits. According to the US Geological Survey, hundreds of pounds of liquid mercury were added to the typical sluice box for gold extraction.

Based on Yuba River Ecosystem Restoration Feasibility Study (dated 10/17/2017), much of this left over mercury is contained in sediment held behind the debris dams. The most concerning contaminant is mercury because large amounts were introduced into the watershed from the hydraulic mining process. However, cost risks of dealing with potential mercury are low for restoration measures. This is because the real danger of mercury contamination is the potential for methylation, which is the process that makes mercury bio-available in the environment. Materials that would be excavated for Lower Yuba River Habitat Restoration are coarser, thus trapping less mercury, and permeable and therefore likely already stripped of mercury contaminants.

Although most of the mercury is not biologically available, enough has methylated in Englebright Lake that it is bioaccumulating in the larger predatory fish. Mercury levels in the larger predatory fish are high enough that the California Office of Environmental Health Hazard Assessment issued a safe-eating advisory for Englebright Lake.

3.3 *CURRENT USE OF THE PROPERTY*

Currently, public river access is limited to just a few points: the Highway 20 Bridge at Parks Bar, Hammon Grove Park, Hallwood Boulevard, and the Highway 70 Bridge in Marysville. Motorized boats, except for research purposes, are not allowed above Daguerre Point Dam. The entire river is open to non-motorized boats. Private fishing membership clubs also have river access through the private lands along the river that they own or lease.

The Yuba River Ecosystem Restoration project site is used primarily for recreation. This river is a tail water fishery that provides year round cold water and supports a healthy population of wild steelhead and king salmon at times but the resident wild rainbows are the most sought after species throughout the year.

3.4 *DESCRIPTIONS OF STRUCTURES, ROADS, OTHER IMPROVEMENTS ON THE SITE*

The site contains scrub oak trees and natural grasses. The only evidence of any construction or man-made fixtures are:

Daguerre Point Dam. Daguerre Point Dam is located on the Lower Yuba River approximately 11.5 miles upstream of Marysville. The dam is 25 feet high and has two fish ladders. The CDC recommended the dam to prevent hydraulic mining debris from washing into navigable waters of the Sacramento and Feather Rivers. Congress authorized the dam's construction in the 1902 Rivers and Harbors Act (P.L. 57-154). The dam was built by the CDC in May of 1906 and the river was diverted over the dam in 1910. Daguerre Point Dam was rebuilt in 1965 after it was damaged and breached by floods in 1963 and 1964. The area behind the dam is filled with approximately 4 million cubic yards of sediment that has accumulated since it was rebuilt. The dam also provides hydraulic head for three non-federal water diversions. The Water Resources Development Act of 1986 eliminated the CDC and transferred Daguerre Point Dam to USACE.

Hammonton, CA. Hammonton was a company owned mining town located 10 miles east of Marysville, California. It's founding was a direct result of the gold rush of 1849 and the subsequent hydraulic mining that followed. It is a major dredge field that extends along the river about eight miles. It also is known as the Yuba River district. Bucket-line dredging began in the district in 1903 under the direction of W. P. Hammon. In 1905 his interests were taken over by Yuba Consolidated Gold Fields, which had just been organized. This concern perfected large-scale bucket-line dredging here into one of the most efficient methods for mining placer gold. Yuba Dredge No. 20 was one of the largest gold dredges in existence. The district was dredged almost continuously from 1903 to 1968 and was the principal source of gold in California for some time. The estimated total output from dredging was estimated in 1964 at 4.8 million ounces.

Operations have been gradually curtailed by 1967 only two dredges were operating. On October 1, 1968 the last dredge was shut down, thus ending a major industry that had existed for nearly 70 years. More than a billion cubic yards of gold-bearing gravels were dredged. The extensive piles of gravel have become increasingly important as sources of aggregate.

The town of Hammonton, which once housed over 1,800 at one time, is now deserted. A few structures, foundations and a water tower are all that remain.

3.5 *CURRENT USES OF THE ADJOINING PROPERTIES*

Public river access is currently limited to just a few points: the Highway 20 Bridge at Parks Bar, Hammon Grove Park, Hallwood Boulevard, and the Highway 70 Bridge in Marysville. Motorized boats, except for research purposes, are not allowed above Daguerre Point Dam. The entire river is open to non-motorized boats. Private fishing membership clubs also have river access through the private lands along the river that they own or lease.

The Goldfields are the subject of an ongoing dispute as to land title and access. Much of the land is owned by Western Aggregate, a mining company extracting gravel from the Goldfields. The remainder of the land is split between small private owners, the Bureau of Land Management, and the United States Army Corps of Engineers. The BLM land is free for the public to use for recreational purposes, but much of it is actually unreachable. Some of it can be accessed via boats on the river, but other access roads have been closed off by Western Aggregate. The parcel of land owned by the Army Corps of Engineers is technically public land, but it is also inaccessible and it is closed for recreation. Western Aggregate owns mining rights over much (but not all) of that property as a result of a purchase from a gold mining company in 1987 by its parent company Centex Construction, based in Texas. The Goldfields is the largest aggregate mine in the State of California, as well as one of only two dredge gold-mining operations in North America (as of 1989).

Besides a few scattered private residences there are three major quarries along the project site:

1. Parks Bar Quarry on the north side of the river at the Yuba River Bridge.

2. Western Aggregates on the north side of the river is a manufacturer and distributor of concrete and aggregates.

3. Teichert Materials' Hallwood Plant is located near the town of Marysville in northern California. It mines aggregate in the Yuba Goldfields along the banks of the Yuba River, producing crushed stone, sand, and gravel.

4.0 USER PROVIDED INFORMATION

4.1 *TITLE RECORDS*

Title records were not obtained as they were not required to develop a history of the previous uses of the site, per ASTM 1527-13.

4.2 *ENVIRONMENTAL LIENS OR ACTIVITY AND USE LIMITATIONS*

There are no environmental liens or activity and no use limitations for this project property. The records used to ascertain this information include: the National Priority List, Federal Superfund Liens, Federal Institutional Controls/Engineering Controls Registries, State and Tribal Equivalent NPL - State Response Sites, State and Tribal Registered Storage Tank Lists – Active UST Facilities, Aboveground Petroleum Storage Tank Facilities and USTs on Indian Land, US Clandestine Drug Labs, CERCLA Lien Information, Land Use Control Information System, Environmental Liens Listing, Military Cleanup Sites Listing, Department of Defense Sites, and Formerly Used Defense Sites.

4.3 *REASON FOR PERFORMING PHASE I*

The use of ASTM 1527-13 is to identify Recognized Environmental Conditions in order to establish the presence or likely presence of hazardous substances or petroleum products under conditions that indicate a likely release, a past release or a material threat of a release of those substances. This practice permits the user to qualify for the innocent landowner, contiguous property owner, or bona fide prospective purchaser limitations on CERCLA liability.

4.4 *OTHER*

This ESA will follow the environmental industry practice of using the guidelines set forth in the USEPA rule concerning “All Appropriate Inquiries,” the ASTM E 1527-13 standard, and USACE Engineering Regulation (ER) 1162-2-132. ASTM E 1527-13 was designed to protect persons purchasing property from liability arising from adverse environmental conditions, but also may be used for other situations per section 4.2.1 of the standard.

5.0 RECORDS REVIEW

5.1 *STANDARD ENVIRONMENTAL RECORD SOURCES*

A records review was ordered October 2017; this EDR report is included in Section 12.4. The sites found in the standard records review are investigated using publicly available information. The EDR report includes additional environmental records (see map and detailed information in section 12.4). A review of these records includes the following findings, none of which presented Recognized Environmental Conditions within the project site, therefore the data is given for information only:

1. Nine sites listed on the MINES site, which list mine site locations
2. One RCRA small quantity generator
3. One RCRA large quantity generator
4. Seven historical UST's
5. Ten sites listed under the county's CUPA site which consolidates the administration, permits, inspections, and enforcement activities.
6. Eight listed AST's

5.2 *HISTORICAL USE INFORMATION ON THE PROPERTY AND ADJOINING PROPERTIES*

ASTM E 1527-13 requires that an ESA consist of diligently conducting a reasonable search of all available information, performing a site reconnaissance, and interviewing people who are knowledgeable about the current and past uses of the project site and surrounding area, its waste disposal practices, and its environmental compliance history.

Specifically, the current search consisted of information from the following sources:

a. A reconnaissance of the entire project was performed to fulfill the requirements of ASTM E 1527-13 on April 6, 2017. Photographs of significant or typical observations were made to document the reconnaissance and to provide additional visual information. These photographs are included in Section 12.3. This site reconnaissance revealed no Recognized Environmental Conditions.

b. A search of the available records as provided by the EDR Corridor Study with GeoCheck®" dated October 2017, is included as Section 12.4.

c. Interviews of appropriate personnel that might have knowledge of recognized environmental conditions were conducted.

6.0 SITE RECONNAISSANCE

6.1 *METHODOLOGY AND LIMITING CONDITIONS*

The extent of the October 2017 site reconnaissance by Bruce Van Etten of Environmental Design Section was conducted based on previously available information. The site reconnaissance involved walking or driving the entire project boundaries of the Yuba River on both the north and south sides. Photographs taken during the site visit are located in Section 12.3.

6.2 *GENERAL SITE SETTING*

The study area for this part of the Yuba River Ecosystem Restoration included approximately 20 miles upstream of Marysville. The project has an upstream boundary approximately 2 miles downstream of Englebright Dam and a downstream boundary at the confluence of the Yuba River and the Feather Rivers. The study area for this project included ¼ mile both north and south of the river although the work for this project will only be in the river and +/- 200 feet on either side of the river's edge.

7.0 INTERVIEWS

The purpose of conducting interviews is to obtain up-to-date information and confirm known information about Recognized Environmental Conditions in connection with the site. During the ESA, only two persons who are knowledgeable about the past and present history of the project site and its surrounding area were interviewed. The interview did not reveal any REC site.

Name: Tom Ehrke, Corps of Engineers Operations Area Manager at Englebright Dam (530) 432-6427

Mr. Ehrke stated that he had no knowledge of any HTW incidents since he has been stationed at Englebright Dam.

Name: Leslie Drexel, Loma Rica/Browns Valley Fire Department Chief (530) 741-0755

Captain Drexel stated that besides the close proximity of the recent fires he is not aware of any HTW incidents that would impact this project.

8.0 FINDINGS

The ESA yielded the following results:

No Recognized Environmental Conditions were observed on the project site. All of the adjacent properties appeared well maintained and clean during the site visit.

The most concerning contaminant is mercury because large amounts were introduced into the watershed from the hydraulic mining process. However, the risks of dealing with potential mercury are low for restoration measures. It is likely that only a very small fraction of the total mercury associated with these gold mining sediments is actually 'reactive' and available to bacteria for methylation (Singer et al 2016). However, because mercury in aquatic environments preferentially partitions to soil, sediment, and suspended matter (i.e., dissolved mercury concentration is far lower than the concentration in soil, sediment, and suspended matter), most of the mercury in the water column is removed not by reduction to the elemental species, but by sedimentation of the particles to which divalent mercury and methylmercury are bound (CEPA, 2002). Additionally, restoration excavation quantities are a fraction of the quantities stored behind either dam (Yuba River Ecosystem Restoration Feasibility Study dated 10/17/2017).

9.0 OPINION

The material threat of hazardous substances release is very small. The Project site is relatively low in organic sediments and is a generally higher energy reach with flowing, well-oxygenated water resulting in reducing the likelihood of methylation. Methylation in the Goldfields, due to mining activities, has been previously found to be of 'less than significant' concern (SMGB, 2014). Although below EPA levels Mercury is a Recognized Environmental Condition identified at the project site during completion of this report.

10.0 CONCLUSIONS

A Phase I Environmental Site Assessment was performed in conformance with the scope and limitations of ASTM Practice E 1527-13 for the Yuba River Ecosystem Restoration project. Any exceptions to, or deletions from this practice are described in Section 2.4 of this report. Although below EPA levels Mercury is a Recognized Environmental Condition identified at the project site during completion of this report. Appropriate caution should be taken during any excavating.

11.0 REFERENCES

(1) ASTM, E 1527-13 Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process (Phase I ESA)

(2) The EDR Radius Map Report™ with GeoCheck®, Marysville Ring Levee, Phase 2A, Environmental Data Resources Inc., February 2014.

(3) USACE, ER 1165-2-132 Hazardous, Toxic and Radioactive Waste (HTRW) Guidance for Civil Works Projects, 26 June 1992.

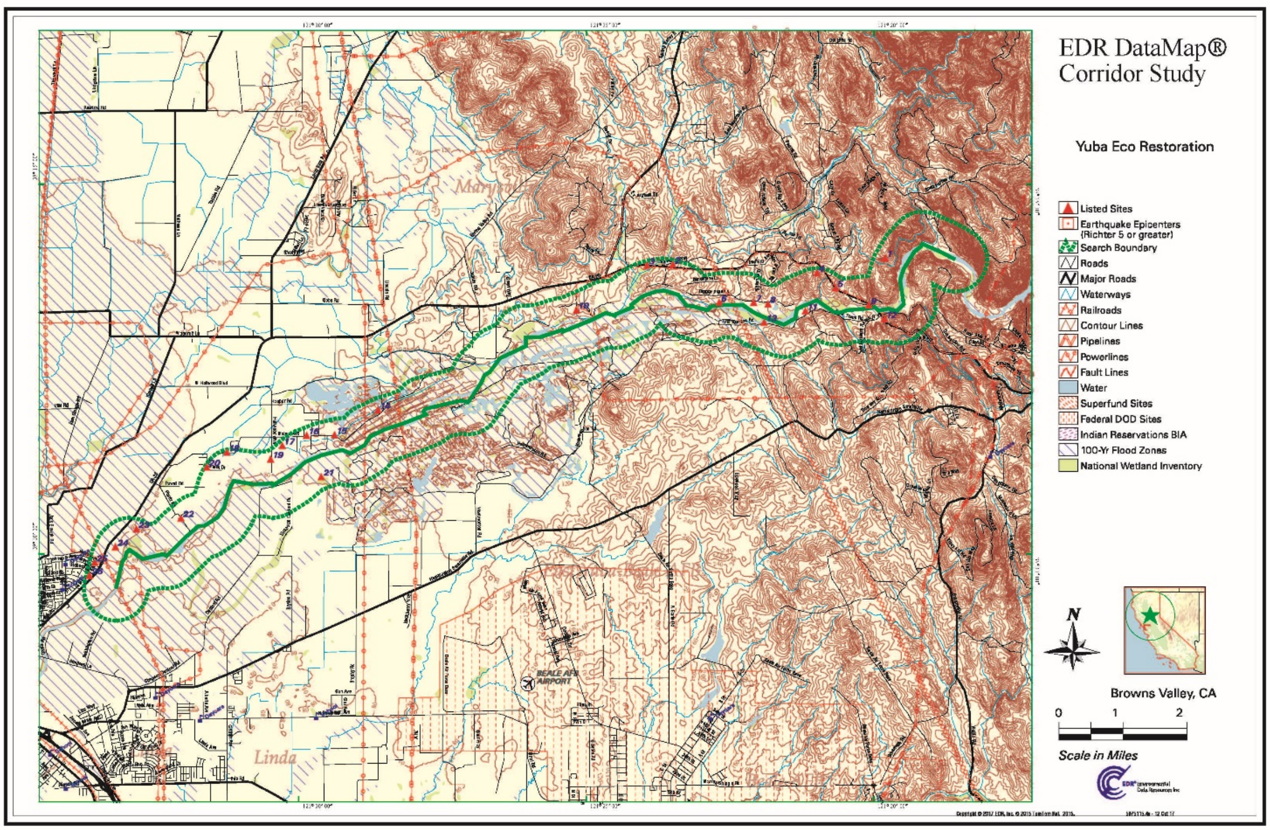
(4) Yuba River Ecosystem Restoration Feasibility Study (dated 10/17/2017)

(5) Mercury Concerns Technical Memorandum, cbec Eco Engineering, 3 October 2017

(6) State Mining and Geology Board (SMGB), October 2014. Western Aggregates LLC Yuba County Operations Amended Reclamation Plan – Draft Environmental Impact Report.

12.0 ATTACHMENTS

12.1 *YUBA RIVER ECOSYSTEM RESTORATION VINICITY MAP*



12.2 *YUBA RIVER ECOSYSTEM RESTORATION GOLDFIELDS*

12.3 *SITE PHOTOGRAPHS*

Photo 01: South side of Goldfields gravel piles looking north

Photo 02: Yuba River Ecosystem Restoration Goldfield gravel piles looking north

Photo 03: One of the buildings in the town of Hammonton

Photo 04: Water tower in the town of Hammonton, CA

Photo 05: Unknown concrete bunker in the middle of the Goldfield gravel piles