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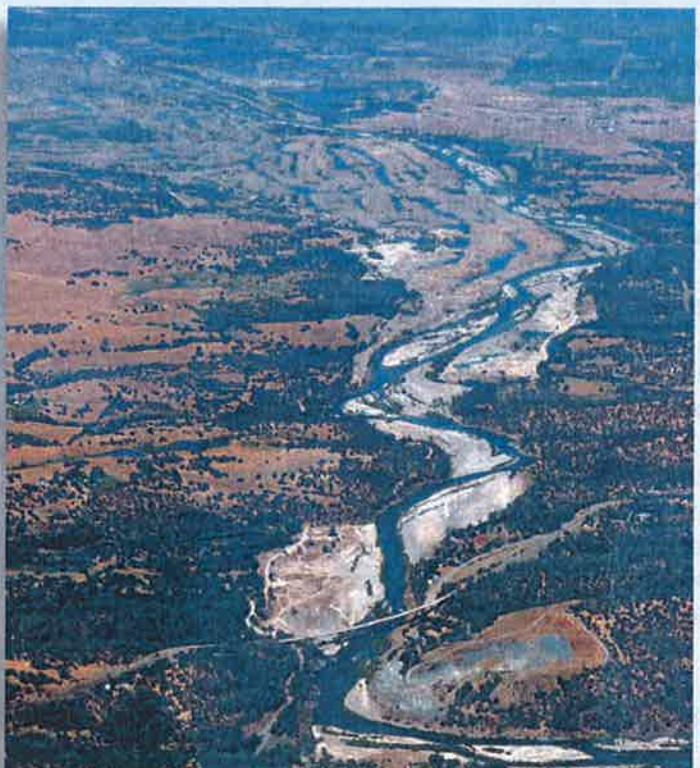

Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River

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EXECUTIVE SUMMARY

Anthropogenic factors, dating back to hydraulic gold mining and inclusive of the current regulated flow regime, contribute to the need for improving rearing habitat quantity and quality via rehabilitation of the channel habitats and riparian vegetation in the lower Yuba River. The status of salmonid populations in the Yuba River warrants investment in rehabilitation actions which can diversify rearing habitats for multiple ages and sizes of juveniles thereby improving the resiliency of populations to poor or uncertain survivorship downstream. The Lower Yuba River Fisheries Technical Working Group (2005) recommended establishing pilot projects for riparian and floodplain enhancement and creation of more off-channel rearing habitat, and the Draft Recovery Plan for Central Valley Salmon and Steelhead (NMFS 2009) points to this type of action as part of a recovery scenario. While there may be other suitable locations for rehabilitation projects in the lower Yuba River, the Parks Bar to Hammon Bar Reach may be prioritized due to favorable land management and supportive landowners.

The goal of improving quality and diversity of rearing habitat can be achieved using a variety of rehabilitation elements, including riparian enhancements, reconnecting floodplain areas, constructing side channels and backwaters, and creating in-channel habitat features such as adding large wood. Albeit altered, the Parks Bar to Hammon Bar reach still has sufficient sediment and large magnitude floods to remain dynamic, and provides both an opportunity and constraint for rehabilitation project design. With an appreciation for this dynamism, project designers should anticipate that constructed project features may evolve or be eliminated when the river alters its alignment during floods. Likewise, projects involving engineered structures may have short life spans depending on the magnitude, frequency and sequencing of floods. The most effective rehabilitation approach will likely utilize a combination of elements. Large wood placement is an element that could be used extensively and warrants a pilot project to further refine cost, benefit and method considerations. Riparian planting would likely be used at every rehabilitation project and would eventually yield a local source of large wood and enhanced aquatic habitat in the following 10-20 years. Training wall setbacks and floodplain terrace excavations are the types of channel modifications which most directly restore hydro-geomorphic function. However, these elements are more expensive than subtle treatments like vegetation plantings and large wood introduction, so costs and expected benefits will need to be further analyzed. Side channels and backwaters may be designed in ways that enhance rearing habitat at moderate costs, but geomorphic and hydraulic analyses are critical for evaluating longevity and refining design.

We recommend the following five "next steps" for rehabilitation of the Parks Bar to Hammon Bar Reach and the lower Yuba River as a whole:

1. Coordinate monitoring and evaluation efforts to refine rehabilitation objectives and evaluate project effectiveness;
2. Promote research on critical questions for prioritizing and designing restoration projects;
3. Implement pilot projects for riparian planting and wood placement that test both design features and success factors;
4. Convene a technical forum for developing rehabilitation concepts and pilot projects;
5. Develop a comprehensive Rehabilitation Plan for the lower Yuba River corridor.

Pilot projects for riparian planting and large wood placement could begin within a year and at relatively low cost. Projects should conduct experimental testing of different implementation methods and conduct monitoring to evaluate success factors. Other steps include developing a technical group for guiding channel designs, applied research in restoration science and a coordinated monitoring program.

A comprehensive rehabilitation plan for the lower Yuba River corridor would provide a synthesis of these efforts, recommendations for types of projects intended to meet articulated rehabilitation objectives and a plan for coordinated actions. Until such a plan is developed, pilot projects such as those listed in this report could be designed and implemented in a manner that advances understanding of specific factors and processes limiting aquatic and riparian habitat.

TABLE OF CONTENTS

1 INTRODUCTION 1
2 BACKGROUND 2
2.1 DEVELOPMENT OF REHABILITATION ACTIONS 3
2.2 GOLD MINING 4
2.3 DAMS AND THE ALTERED MOVEMENT OF WATER, SEDIMENT AND ORGANIC MATTER 5
2.4 STUDY REACH 9
2.5 ECOLOGICAL OUTCOMES OF PHYSICAL AND HYDROLOGICAL ALTERATIONS 10
2.6 BACKGROUND SUMMARY 13
3 REHABILITATION OBJECTIVES 13
4 DESCRIPTION OF REHABILITATION ELEMENTS 14
4.1 RIPARIAN VEGETATION PLANTING 14
4.2 SECONDARY CHANNELS AND BACKWATERS 16
4.2.1 Side Channels 16
4.2.2 High Flow Channels 17
4.2.3 Backwaters/Alcoves 17
4.2.4 Percolation Channels/Backwaters 18
4.2.5 Bank Scallops 18
4.3 FLOODPLAIN ENHANCEMENTS 19
4.3.1 Terrace Excavation 19
4.3.2 Textural Improvement 20
4.3.3 Training Wall Setback or Removal 20
4.4 IN-CHANNEL HABITAT 20
4.4.1 Large Wood 21
4.4.2 Boulder Clusters 21
4.4.3 Bank Bio-Engineering 21
4.5 ADDITIONAL REHABILITATION ELEMENTS 22
4.5.1 Flow Modification 22
4.5.2 OHV Exclusion 22
4.5.3 Coarse Sediment Augmentation 22
4.5.4 Tributary Connection Improvement 23
5 POTENTIAL REHABILITATION PROJECTS 23
5.1 PROJECT 1: DISTRIBUTED RIPARIAN PLANTING 23
5.2 PROJECT 2: DISTRIBUTED LARGE WOOD PLACEMENT 24
5.3 PROJECT 3: BANK SCALLOPING AT UPPER GILT EDGE BAR 25
5.4 PROJECT 4: BACKWATER AT UPPER GILT EDGE BAR 25
5.5 PROJECT 5: PERCOLATION-FED BACKWATER AT LOWER GILT EDGE BAR 26
5.6 PROJECT 6: SIDE CHANNEL AT HIDDEN ISLAND 27
5.7 PROJECT 7: BANK BIO-ENGINEERING 28
5.8 PROJECT 8: SIDE CHANNEL AT SILICA BAR 28
5.9 PROJECT 9: SIDE CHANNEL AT SILICA BAR WITH TRAINING WALL SETBACK 29
5.10 PROJECT 10: HAMMON BAR ENHANCEMENT 30

5.11 ADDITIONAL PROJECTS 30
5.12 PROJECTS SUMMARY 31
5.13 PERMITTING 33
6 RECOMMENDED NEXT STEPS 33
7 REFERENCES 35
8 LIST OF PREPARERS 39
9 ACKNOWLEDGEMENTS 39

LIST OF FIGURES

Figure 2-1. Examples of Complex Habitat Features in the Lower Yuba River 40
Figure 2-2. Hydrologic Features of the Yuba River Watershed 41
Figure 2-3. Lower Yuba River Corridor 42
Figure 2-4. Historic and Present Channel Alignments 43
Figure 2-5. Maximum Annual Yuba River Discharge at Smartsville 44
Figure 2-6. Flood Frequency Analysis: WY 1904-1969 & WY 1970-2009 45
Figure 2-7. Computed Monthly Average Yuba River Hydrographs 46
Figure 2-8. Yuba River at Smartsville Spring Hydrographs by Year Type: 1906-1940 47
Figure 2-9. Yuba River at Smartsville Hydrographs by Year Type: 1970-2005 48
Figure 2-10. Yuba River at Smartsville Spring Hydrographs by Year Type: 2006-2009 49
Figure 2-11. BLM & WA Ownership & Confinement within the Study Reach 50
Figure 2-12. Images of Study Area Showing Type of Confinement 51
Figure 2-13. Existing Riparian Vegetation Patch Types 52
Figure 2-14. Conceptual Cross Section Showing Inundation Extents 53
Figure 2-15. Conceptual Model of Changes to Lower Yuba River 54
Figure 4-1. Estimated Maximum Depth to Groundwater – Upper Reach 55
Figure 4-2. Estimated Maximum Depth to Groundwater – Lower Reach 56
Figure 4-3. Example of Large Wood Used as Bank Protection 57
Figure 5-1. Project 3: Bank Scalloping at Upper Gilt Edge Bar 58
Figure 5-2. Project 4: Backwater at Upper Gilt Edge Bar 59
Figure 5-3. Project 4: Visualization of Backwater at Upper Gilt Edge Bar 60
Figure 5-4. Project 5: Backwater at Lower Gilt Edge Bar 61
Figure 5-5. Project 6: Side Channel at Hidden Island 62
Figure 5-6. Project 7: Bank Bio-Engineering 63
Figure 5-7. Project 8: Side Channel at Silica Bar 64
Figure 5-8. Conceptual Cross Sections for Projects 8 and 9 65
Figure 5-9. Project 9: Side Channel & Training Wall Setback at Silica Bar 66
Figure 5-10. Project 10: Hammon Bar Enhancement 67

LIST OF TABLES

Table 1. Major dams in the Yuba Basin 6
Table 2. Potential project summary 32

GLOSSARY OF ACRONYMS AND ABREVIATIONS

Acronym/Abbreviation	Meaning
°F	degrees Fahrenheit
ac	acre
AFRP	Anadromous Fish Restoration Program
BLM	Bureau of Land Management
cfs	cubic feet per second
FERC	Federal Energy Regulatory Commission
ft	feet
in	inch
LLC	licensed legal contractor
LYRFTWG	Lower Yuba River Fisheries Technical Working Group
mm	millimeter
NAIP	National Agricultural Inspection Program
NID	Nevada Irrigation District
NMFS	National Marine Fisheries Service
OHV	Off highway vehicle
PG&E	Pacific Gas and Electric
Q1.5	1.5 year return interval discharge level
RMT	Yuba Accord's River Management Team
SYRCL	South Yuba River Citizens League
TAF	thousand acre-feet
USACOE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WA	Western Aggregates LLC
WSE	water surface elevation
WY	water year
YCWA	Yuba County Water Agency
yd^3	cubic yard
yr	year
YRDP	Yuba River Development Project

1 INTRODUCTION

This report presents concepts for rehabilitation of channel and riparian conditions along the lower Yuba River, including potential projects within the Parks Bar to Hammon Bar reach. The concepts presented are the result of limited preliminary data analysis, field reconnaissance and a concept formulation meeting conducted by members of the project team, including representatives of cbec, inc. eco engineering, McBain & Trush, Inc., South Yuba River Citizens League and U.S. Fish and Wildlife Service - Anadromous Fish Restoration Program (USFWS-AFRP). Additional investigation and analysis will be required to further refine any of these rehabilitation concepts for prioritization, design, permitting and implementation. The purpose of this report is to provide a foundation for planning effective and broadly supported projects which improve anadromous fish habitat in the lower Yuba River.

Despite considerable interest in restoration and rehabilitation actions within the lower Yuba River corridor, a comprehensive restoration plan has not yet been developed. Such a restoration plan would include a summary of the present state of physical and biological conditions, in addition to a data gaps analysis indicating where further investigation and understanding are needed. Furthermore, a comprehensive restoration plan would provide a consensus on the altered physical and ecological outcomes associated with various anthropogenic actions within the watershed. Examples of restoration plans developed for other Central Valley rivers below major dams include the lower Merced River (Stillwater Sciences 2002) and the lower Tuolumne River (McBain and Trush 2000). A comprehensive restoration plan for the lower Yuba River corridor would provide a framework for coordinated restoration actions along the lower Yuba River, with recommendations for types of projects intended to meet articulated restoration/rehabilitation objectives. The present report is not intended to serve as a substitute for this type of restoration plan. This report provides an initial effort, based upon readily available data and analyses to describe elements and potential projects for rehabilitation of the Parks Bar to Hammon Bar Reach of the lower Yuba River in the near-term, while building support and momentum toward a larger rehabilitation effort with a long-term, broader geographic application.

<u>Restoration or Rehabilitation?</u>
Restoration refers to re-establishment of physical and biological conditions, to those that occurred before some disturbance or impact. By using the term rehabilitation, this report acknowledges that restoration cannot truly be achieved while natural processes and the resulting form and function continue to be impaired. Nonetheless, rehabilitation efforts can partially restore some natural function in a river system and re-create habitat in localized areas resembling pre-disturbance conditions.

The focus of the present report on a four-mile study reach from Parks Bar to Hammon Bar results from the readiness of Western Aggregates LLC (WA) and the Bureau of Land Management (BLM) to support project planning on parcels that they own or manage in this reach. The rehabilitation concepts presented in this report could be utilized to improve the ecological condition of the river and its riparian corridor within other portions of the lower Yuba River between Englebright Dam and its confluence with the Feather River. The Parks Bar to Hammon Bar Reach offers important opportunities for evaluating, planning and implementing appropriate rehabilitation projects; furthermore, the lower Yuba River compels rehabilitation project investment and development due to the following characteristics:

- Flood flows and sediment allow for a dynamic channel unlike other large regulated rivers in California;
- Diversity of anadromous fish including steelhead, spring-run and fall-run Chinook salmon, lamprey and green sturgeon;
- Lack of urban development and agriculture adjacent to the river corridor, along with willing land owners;
- Existing monitoring and evaluation program of the Yuba Accord's River Management Team (RMT, www.yubaaccordrmt.com) and potential for future coordination for evaluating project effectiveness;
- The potential for local match funding from Pacific Gas & Electric's Narrows 1 Enhancement Fund and Yuba County Water Agency's Restoration Fund (Yuba Accord), subject to approval;
- Strong support by the sport-fishing community and stakeholders for restoration planning and implementation[1].

2 BACKGROUND

The need for rehabilitation on the lower Yuba River results from a variety of anthropogenic disturbances to the river channel, its floodplains and upland watershed. The most significant of these disturbances include: 1) gold mining and the structures (e.g., debris dams and training walls) built to address the increased sediment load resulting from the mining, and 2) population encroachment, water supply and hydroelectric dams/reservoirs and levees associated with providing reliable water supply, flood control and power to support the expanding human presence in the watershed and the Central Valley. These disturbances alter the movement of water, sediment, large wood and anadromous fishes through the system. Based upon studies conducted on other similarly altered Central Valley Rivers (e.g., Roberts et al. 2002, Stella et al. 2003), one major, cumulative effect of these historic and ongoing alterations of the natural systems is understood by the authors to be a reduction of the quantity and quality of riparian habitat and the physical form of aquatic habitat in the lower Yuba River. While some recovery has occurred naturally since the cessation of the historical disturbances, and water temperatures have been controlled for the benefit of cold-water fishes, the processes that create habitat diversity and complexity continue to be limited by the effects of upstream dams (i.e., altered supply of wood and sediment), constrained floodplains and managed flows.

Yuba River Steelhead (*Oncorhynchus mykiss*) and Chinook salmon (*O. tshawytscha,* fall-run and spring-run) are species of special interest, because of their commercial and recreational value, and the threatened status of the Central Valley steelhead and Central Valley spring-run Chinook salmon under the Endangered Species Act. Record low abundance of fall-run Chinook has necessitated fishing closures

[1] The Center of Collaborative Policy (Bartlett and Monaghan 2008) performed an assessment of stakeholders which documented a common interest among a variety of interviewees in developing and supporting restoration projects on the lower Yuba River.

in recent years. Central Valley spring-run Chinook and steelhead are considered at risk of extinction owing in large part to loss of historic habitat above dams (NMFS 2009), and on the Yuba River specifically, these fish are limited to a small proportion of their historic habitat range (Yoshiyama et al. 2001). These fish are also of "special concern" due to their dependence upon a complexity of river and riparian habitats to support survival, growth and diversity for multiple life stages. Conservationists increasingly emphasize the importance of population resilience under the threat of extinction. Salmon ecologists know that resilience is afforded by diverse life histories and those in turn are best supported by complex and interconnected rearing habitats (Bisson et al. 2009, Miller et al. 2010).

In-river habitat use by anadromous salmonids falls into three categories: adult migration/holding, spawning and rearing. Neither holding habitat nor spawning habitat is limiting in this reach of the lower Yuba River. Rearing habitat, in general, encompasses a wide variety of microhabitats (e.g., velocity, depth, substrate, cover; Figure 2-1) and the physical alteration of the river has reduced the diversity of those habitats. Rearing habitat supports the growth and survival of juvenile salmonids from the date of emergence from gravel to the date of emigration toward smoltification. For many Chinook salmon juveniles, in-river rearing lasts only a few weeks while the fry migrate downstream during winter or spring flows. However, some Chinook salmon, rear in-river for several months or even a year, and this extended rearing has been shown to result in higher survival rates to adulthood (Miller et al. 2010). Steelhead trout juveniles rear in-river for 1-3 years (Mitchell 2010).

2.1 DEVELOPMENT OF REHABILITATION ACTIONS

Multiple inter-agency management forums and documents have identified the need for rehabilitation to support enhanced rearing for Yuba River salmonid populations. In 1993, the Federal Energy Regulatory Commission (FERC), in response to the comments of resource agencies, required Pacific Gas and Electric Company (PG&E) to produce a Fisheries Enhancement Plan to operate the Narrows 1 project. The brief plan focused on the creation or maintenance of side channels, funding and an advisory group for project development (PG&E 1993). As part of the Central Valley Project Improvement Act Anadromous Fish Restoration Program, USFWS (1995) identified the need for increasing the amount of instream woody material to improve juvenile salmonid rearing habitat in the lower Yuba River. USFWS (2001) identified as a high priority the need to evaluate the benefits restoring stream channel and riparian habitat, including the creation of side channels for rearing. In 2005, the Lower Yuba River Fisheries Technical Working Group (LYRFTWG) published the Draft Implementation Plan for Lower Yuba River Anadromous Fish Habitat Restoration, which attempted to provide a framework for planning restoration or enhancement actions (LYRFTWG 2005). The Plan's recommended actions for rehabilitation (see text box below) provide a rationale for this report. The Public Draft Recovery Plan for Central Valley Steelhead Trout and Spring-run Chinook salmon (NMFS 2009) identifies seven "key near-term and long-term habitat restoration actions" to secure a viable independent population of spring-run Chinook salmon and steelhead in the lower Yuba River. Those actions include improving riparian habitats for juvenile salmonid rearing, enhancing off-channel rearing habitat and increasing floodplain habitat availability (NMFS 2009). Building on these planning documents, this report provides concepts for development of scientifically sound and collaboratively supported project proposals.

Habitat Restoration/Enhancement Actions Proposed by the Lower Yuba River Fisheries Technical Working Group (LYRFTWG 2005)

- Develop and implement a plan to establish riparian vegetation along the lower Yuba River;
- Develop a plan or policy for management of large woody debris, consistent with recreation safety needs;
- Conduct a pilot project to identify suitable locations and evaluate the efficacy of placing large in-stream objects (e.g., boulders or logs) to modify flow dynamics to increase cover and diversity of instream habitat for priority fish species;
- Conduct a pilot project to identify suitable locations and evaluate the efficacy of creating shallow inundated floodplain habitat for multi-species benefits;
- Conduct a pilot project to identify suitable locations and evaluate the efficacy of establishing shaded riverine aquatic habitat along the lower Yuba River to benefit priority fish species;
- Conduct a pilot project to evaluate the efficacy of placing large woody debris in near-shore habitats along the lower Yuba River to benefit juvenile salmonids;
- Conduct a pilot project to evaluate locations in the lower Yuba River where existing revetments could be modified to incorporate bank protection habitat features to aid in preservation and re-establishment of both high-quality near-shore aquatic and riparian habitats, without having an impact on the integrity of the bank protection; implement such measures on a small scale where suitable opportunities are available and evaluate the efficacy of implementing such measures on a large scale; and
- Conduct a pilot project to identify opportunities to, and potential benefits and detriments of, enhancing or constructing mainstem and side channel habitats that provide fall-run Chinook salmon and steelhead spawning and rearing habitat, and implement on a small scale where suitable opportunities are available and evaluate the efficacy of implementing such measures on a large scale.

2.2 GOLD MINING

Between 1853 and 1884, hydraulic gold mining produced 1.4 billion cubic yards (yd^3) of sediment from the foothills of the northern Sierra Nevada. From this total amount of sediment, 685 million yd^3 (nearly half the total production) was washed from the hillsides of the Yuba watershed (Figure 2-2), and 331 million yd^3 (nearly a quarter of the total production) was stored in the valleys of the Yuba River watershed (Gilbert 1917 quoted in James et al. 2009). This large volume of sediment overwhelmed the transport capacity of the stream and river channels, resulting in aggradation that blanketed the existing aquatic and riparian habitats (James et al. 2009). Aggradation reached its peak in roughly 1906, with an estimated 45 feet (ft) of aggradation at Parks Bar, and 32 ft of aggradation at the Dry Creek confluence (James et al. 2009). A separate study reports hydraulic mining debris in the Gold Fields region ranged in thickness from 16 to 82 ft (Hunerlach et al. 2004). The slurry of hydraulic mining sediment deposited in the mainstem of the Yuba contained as much as 57% silt and sand (Gilbert 1917 cited in Hunerlach et al. 2004)

During the early 1900's, the Yuba River had a braided planform with many alternate channels. The aggradation of hydraulic mining sediments led to channel avulsions and flooding, which prompted river management efforts to control flooding and sedimentation (e.g., channelization, leveeing and bank protection), further altering sediment dynamics within the system. Even before the construction of the large dams that curtailed bedload supply to the lower Yuba River and reduced stream power, the river began to incise through the hydraulic mining sediments. This incision focused on one main channel, leaving floodplains as high terraces, abandoning secondary channels (James et al. 2009) and presumably lowering the shallow groundwater table which supports riparian vegetation.

A second round of gold mining-related disturbance occurred as the sediments, stored in the lower Yuba River corridor were dredged and processed. The Yuba Gold Fields (Figure 2-3) consist of 9,000 acres of land thoroughly dredged beginning in 1906. Dredge activity has waxed and waned, with a maximum of 12 dredges operating simultaneously, followed by periods of no operation as well (Sutherling 2010). At present, one dredge, Number 17, is still operating in the Gold Fields (Lanferman 2000). In order to safely access potential gold-bearing sediment deposits, mining operations, in cooperation with the California Debris Commission, altered the alignment of the river corridor through the construction of training walls, in order to expose new areas for mining (Figure 2-4). Training walls hindered the wandering and meandering nature of the Yuba River and ultimately confined the limits of the river to a narrow corridor situated at the northern extent of its historic floodplain.

Dredging activities altered the character and distribution of the sediment in the river corridor. Prior to the influx of hydraulic mining sediment, historical accounts describe cultivated "bottom lands" along the Yuba with dark fertile soils, presumably representing floodplains in frequent connectivity with the river (Gilbert 1905 as described in James et al. 2009). As a result of dredging the modern channel alluvium, is a mix of hydraulic-mining sediment and Quaternary alluvium (James et al. 2009, Hunerlach et al. 2004). In the process of dredging, the mined sediment was separated into fine and coarse fractions, with a mixture of clay, silt and sand typically tens of feet thick, with the coarse fraction (gravel and larger) stacked above 40-100 ft in thickness.

An investigation of subsurface sediment texture conducted by the U.S. Geological Survey (USGS), at a location ~1.2 mi above Daguerre Point Dam (sample DPD-3, the furthest upstream sample) describes the stratigraphy (Hunerlach et al. 2004). The uppermost 5 ft are described as large cobble and gravel with quartz-rich sand. From 5-10 ft the sediment is described as gravel and quartz-rich sand, with some sandy silt. Despite considerable fractions in the sand and smaller classes (<4.75 mm), the exposed gravel bars and channel upstream of Daguerre Point Dam are typically well armored with coarse gravel several feet deep (Hunerlach et al. 2004). An investigation is currently underway by the RMT to map surficial substrate composition along the lower Yuba River.

2.3 DAMS AND THE ALTERED MOVEMENT OF WATER, SEDIMENT AND ORGANIC MATTER

Dam construction in the Yuba watershed has a long and complex history. Initial efforts began with the onset of gold mining in the mid to late 1800s, as water was diverted from streams to feed the hydraulic nozzles used in hydraulic mining and shortly thereafter, the use of hydroelectric facilities to supply mines with power began. Rapidly following these initial efforts the construction of large dams imposed disturbances to the river system by interrupting the downstream transport of sediment, the upstream migration of anadromous fishes and altering the natural flow regime. Several large dams operated by various agencies (Table 1, Figure 2-2) were built for a variety of purposes, including water supply, flood control, hydroelectric power generation and sediment retention (James 2005). The contemporary system is elaborate and complex, consisting of several dams (including 6 over 150 ft in height, and over 50 additional smaller dams) with facilities in place to store and/or transfer water between the sub-watersheds of the Yuba Basin (i.e., North Yuba, Middle Yuba, South Yuba and Deer Creek), as well as out of basin transfers to major watersheds to the north and south (i.e., Feather River, Bear River and American River).

Table 1. Major dams in the Yuba Basin

Major Dams	Operating Agency	Date of Completion[1]	Storage (TAF)[2]	Drainage Sub Basin	Drainage Area (mi^2)
Spaulding	PG&E	~1913	75	South Yuba	118
Bowman	NID	1926	68	Canyon Creek[3]	28
Fordyce	PG&E	~1926	50	Fordyce Creek[3]	31
Englebright	USACOE	1941	70	Mainstem Yuba	1110
Jackson Meadows	NID	1965	67	Middle Yuba	37
New Bullards Bar	YCWA	1969	966	North Yuba	489

Notes:

1) Dates indicate most recent completion. At most locations facilities were in place earlier, starting as early as 1849.
2) Approximate impounded storage at time of completion, may be less at present. For example bathymetric surveys of Englebright Reservoir have documented a 25% reduction of the initial volume (Childs et al. 2003).
3) Canyon Creek and Fordyce Creek are tributaries to the South Yuba River.
4) Drainage areas are approximate and provided solely for the purpose of comparison

The size and position within the Yuba Basin of these dams provide the ability to store large volumes of water, and therefore regulate the flow regime. The North Yuba has New Bullards Bar Reservoir, located relatively low in the watershed, functioning as the dominant flood control and water supply reservoir in the basin (LYRFTWG 2005). Storage capability in the Middle Yuba and South Yuba basins is comparably small, totaling ~307 thousand acre-feet (TAF), with Lake Spaulding, Bowman Lake, Jackson Meadows Reservoir, Fordyce Lake and several smaller impoundments located in the upper extents of the Yuba Basin (YCWA, 2009). The size and position of these impoundments allow the South Yuba and Middle Yuba to respond to larger precipitation and snow-melt events by sending large flood pulses downstream to Englebright Reservoir, and beyond to the lower Yuba River when the capacity of Englebright Reservoir is exceeded. Since 1969 when New Bullards Bar (the last of large dams built in the system) was completed, over 100 uncontrolled flow events have overtopped Englebright Dam.

Two dams on the mainstem, Englebright and Daguerre Point also play an important role in the altered movement of water, sediment and organic matter. Englebright Dam is the only large dam on the mainstem. It was erected primarily for sediment retention and its volume has been reduced by 25% or more due to sedimentation of the reservoir (Childs et al. 2003). In addition to blocking the passage of sediment downstream, Englebright Dam prevents the upstream passage of migrating anadromous salmonids. Downstream of Englebright, USACOE's Daguerre Point Dam is small in comparison to the major dams listed; however, it is significant in several ways. First, it provides base level control for incision for the reach immediately upstream (including much of the study reach). Second, while fish ladders are in place, Daguerre Point Dam may still impede passage of anadromous salmonids (NMFS 2007).

Despite the presence of several significant dams in the watershed, the lower Yuba River still experiences floods capable of inducing geomorphic changes to the mainstem (Pasternack 2009). A study of the geomorphic thresholds in the Timbuctoo Bend Reach (Figure 2-3) identified several values including: 1) a preferential riffle scouring discharge of <11,000 cfs, 2) a preferential run scouring discharge range of ~9,000-25,000 cfs, 3) a preferential pool-scouring discharge of >45,000 cfs, and 4) a floodplain filling discharge of ~20,000 cfs (Pasternack 2009).

Discharge data collected from USGS gages #11419000 (Yuba River at Smartsville) and #11418000 (Yuba River below Englebright Dam near Smartsville), located on the mainstem (Figure 2-2) provide insight into the past and present flood regime of the lower Yuba River (Figure 2-5). We conducted a flood flow frequency analysis for the 106 year period of record of the two USGS Yuba River at/near Smartsville gages (Figure 2-6). The data were divided into two meaningful hydrologic periods: a *transitional* period, WYs 1904-1969, and the contemporary, *regulated* period, WYs 1970-2009, the period following the completion of all major storage projects within the basin. The *transitional* period includes the completion of all major storage projects within the basin, and it is important to note that this period does not fully reflect unregulated conditions. Storage facilities were in place prior to the beginning of transitional period and additional facilities were built during its range (Table 1), all potentially affecting peak flood values in some way. The *regulated* period, follows the completion of all major storage projects within the basin and is reflective of the current flood regime. This analysis shows that the flood that occurs or is exceeded every 1.5 years was reduced 67% from 20,100 cfs to 6,700 cfs at the Smartsville gage location. Floods with a 5 year return period were reduced 40% from 61,400 cfs to 36,900 cfs. However larger, less frequent flood flows (i.e., 20 and 50 year return periods) do not show clear change between to two periods.

In addition to reducing peak flow values, the large storage reservoirs and in and out of basin transfers alter the annual runoff volume and pattern in the mainstem. Figure 2-7 provides an annual time series comparison of average monthly discharge values for three development conditions: 1) *unregulated* conditions (i.e., no dams or out of basin transfers, essentially natural conditions), 2) *partially regulated* or Non-Yuba River Development Project (YRDP) conditions (i.e., all dam and transfer facilities except those operated by YCWA as part of the YRDP, which includes New Bullards Bar) and 3) *current (regulated)* conditions (i.e., all dam and transfer facilities, including YRDP facilities). When comparing the unregulated and partially regulated values, this figure shows that out of basin exports amount to a long-term average of ~534 TAF of the ~2,370 TAF per year total runoff at Smartsville (YCWA 2009). Although the runoff volume is reduced due to out of basin exports, the same general pattern is present.

In addition, it shows that average monthly flows in the winter and spring are reduced by up to 2,000 cfs due to the Non-YRDP facilities. However, average monthly discharge values for the baseflow period of July-October are reduced relatively little. With the inclusion of the YRDP further hydrologic alteration is apparent. While the YRDP does not reduce the amount of annual runoff passing Smartsville, it does alter the pattern, by further reducing the monthly discharge values in the winter and spring (e.g., ~1,400 cfs additional reduction in May), as well as increasing discharges substantially in the baseflow period of July through October (e.g., ~1,500 cfs increase in August).

Figure 2-7 is instructive towards understanding changes in average volume and pattern of flow; however, important details regarding the magnitude, frequency, duration and rates of change for flood events are obscured by the monthly time step. Figures 2-8, 2-9 and 2-10 are provided to illustrate these important flood components using daily average discharge data from Smartsville, for the April-September portions of three meaningful hydrologic time periods. Figure 2-8 displays WYs 1906-1940, the period prior the completion of Englebright, Jackson Meadows and New Bullards Bar Dams. Figure 2-9 displays WYs 1970-2005, the period after completion of all major dams, but prior to the implementation of Yuba Accord flows. Figure 2-10 displays WYs 2006-2009, the period after completion of all major dams, as well as the implementation of Yuba Accord flows.

In addition to altering or blocking the movement of water, sediment and migratory fishes, dams in the Yuba Basin have also altered the downstream movement of large wood. During flood events, some wood is passed over Englebright Dam. However, wood that enters New Bullards Bar Dam, is gathered annually, boomed together and stored in designated areas until disposed of by burning. Every 1-3 years, the accumulated wood is burned. Research quantifying the large wood loading in the Yuba Basin is presently underway by Anne Senter, a student advised by Dr. Pasternack. Preliminary estimates have quantified the volume of wood stored in New Bullards Bar Reservoir at two times, 1998 and 2006. Using aerial photographs from 1998 and an estimated thickness of 3.3 ft for the boomed wood, a wood volume of 34,400 yd^3 was determined (A. Senter unpublished data). The 2006 estimate was made using reservoir management measurements and an estimated thickness of 3.3 ft for boomed wood; resulting in a stored wood volume of 110,000 yd^3 (A. Senter unpublished data). Again it is noted that the accumulated wood is burned every 1-3 years so the 110,000 yd^3 value only represents the large wood inflow since the last disposal burn.

To summarize, the hydrology of the Yuba Basin is complex, consisting of several dams with facilities in place to store and/or transfer water within and out of the basin altering both the volume and pattern of runoff as well as sediment and large wood. The above discussion has attempted to simplify the altered flow regime of the basin as a basis of understanding the need for rehabilitation within the study area. This report neither attempts to provide a comprehensive explanation of all hydrologic changes to the system, nor represents rationales for altered flows from the standpoint of balancing beneficial uses of water. Most Yuba Basin water resource projects regulated by the Federal Energy Regulatory Commission (FERC) are up for relicensing in the near future. These include NID's Yuba-Bear Project (license expires 2013, FERC Docket # 2266), PG&E's Drum-Spaulding Project (license expires 2013, FERC Docket # 2310) and YCWA's YRDP (license expires 2016, FERC Docket # 2246). As such, the responsible agencies have established individual re-licensing websites providing a wealth of information about each of the projects.

2.4 STUDY REACH

The focus of the current study is the 4 mile reach extending from Parks Bar to Hammon Bar, or the Highway 20 Bridge to the Dry Creek confluence (Figures 2-3 and 2-11). Within this reach, the lower Yuba River is a wandering gravel-bed river flowing over a thick deposit of hydraulic mining derived sediment. At the upstream portion of the study reach, the river is laterally confined by bedrock canyon walls; however, in the downstream portion of the reach, the river is laterally confined to approximately the same width by training walls, a remnant of historic gold dredger mining in the river corridor (Figures 2-11 and 2-12). The functional valley width in the reach ranges from ~310 ft (min) to ~1420 ft (max) with a mean of 980 ft and an overall slope of 0.19% (G. Pasternack unpublished data). Alternating alluvial bars, high flow secondary channels and high terraces are common, and the terraces are former floodplains or dredge tailings abandoned as the main channel incised. Most portions of the alluvial bars are too high in elevation to be inundated by frequent floods (i.e., floods which occur every 1.5 to 5 years on average) under the modern flow regime.

Although Englebright Dam blocks the downstream replenishment of sediment, sediment stored in the channel upstream provides a source of sediment to the study reach. An investigation of the change in topography in the Timbuctoo Bend Reach (Figure 2-3), documented a net export of 605,000 yd^3 of sediment between 1999 and 2006 (Pasternack 2009). It is unclear what the textural characteristics of this sediment are, as compared to what might be expected under natural conditions (i.e., no dams or upstream mining legacy), however presumably fine sediment comprises a portion of this transported material. Downstream of the study reach, Daguerre Point Dam acts as a local base level control, limiting the amount of ongoing incision in the study area (Figures 2-2 and 2-3). An analysis is currently underway lead by Dr. Pasternack and University of California, Davis investigating the modern day rate of incision in the study reach (G. Pasternack pers. comm.).

An analysis of aerial photography for the period between 1952-2009, indicates that the upper portion of the study reach (~1.4 mile reach from the Highway 20 Bridge to the downstream end of Lower Gilt Edge Bar) has followed a relatively consistent path, controlled by bedrock outcrops in the valley walls (Figures 2-4, 2-11 and 2-12). The lower portion (~2.6 mile reach from the downstream end of Lower Gilt Edge Bar to the downstream end of Hammon Bar) has a more dynamic pattern due to both anthropogenic and fluvial processes. As recently as 1952, the channel followed a different path through the Yuba Gold Fields; by 1958 (not shown in Figure 2-4) dredging activities relocated the river to its present corridor, and laterally confined it by constructing training walls. Evidence of channel movement is observed between the 1996 and 1997 channel alignments, which span the massive New Year's Day rain on snow flood (instantaneous peak discharge of 154,000 cfs at Smartsville USGS gaging station). Between these two time periods, the main channel in the Hammon Bar area shifted ~1,800 ft downstream, roughly doubling the size of Hammon Bar. In addition, the side channel that creates First Island was scoured enough to become a perennial aquatic feature.

2.5 ECOLOGICAL OUTCOMES OF PHYSICAL AND HYDROLOGICAL ALTERATIONS

Quantitative data documenting the ecological condition of the lower Yuba River prior to these disturbances is not available. Even though aerial photographs pre-date most hydrologic alteration, assessing effects of this disturbance to channel form and riparian cover is not simple due to the confounding effects of hydraulic mining sediment, dredger activity and channel incision active across this period. However, a large body of literature documents both the biotic and abiotic effects of dams and levees on river function (for reviews see Ward and Stanford 1979, Williams and Wolman 1984, Ligon et al. 1995, Collier et al. 1997, Poff and Hart 2002, Carlise et al. 2010). Levees (or training walls) constrain alluvial process resulting in simplified channel form including reduced amounts of floodplain, side channel and backwater habitat (Brookes 1988). Poff and Hart (2002) summarized the effects of dams: they 1) alter the flow of water and sediment, modifying biogeochemical cycles in addition to the structure and dynamics of riparian and aquatic habitats; 2) change water temperatures, which influence organismal bioenergetics and vital rates; and 3) they create barriers to upstream-downstream movement of organisms and nutrients which hinders biotic exchange. These effects include two possible benefits in the form of cooler water temperatures and control of excessive amounts of fine sediment from remaining hydraulic mining debris. Notwithstanding, it is highly likely, if not apparent, that the anthropogenic actions have reduced the quantity and quality of aquatic and riparian habitat in the lower Yuba River.

The riparian corridor is defined as the location where shallow groundwater is higher in elevation than adjacent areas where the groundwater is supplied by precipitation alone (Warner and Hendrix 1984). Streamflows are the agent for creating the elevated groundwater condition, connecting the floodplain to the low water channel and maintaining riparian corridor width. Topographic modification of the historic floodplain (i.e., deposition of upstream mining sediment, incision through these sediments, subsequent dredging and lateral constraint by training walls and levees) prevent much of the area adjacent to the channel within the riparian corridor from being inundated during more frequent, lower magnitude flood events (i.e., 1.5-5 year return interval flows). The reduction in magnitude of frequent lower magnitude flood events, has further contributed to the reduction of frequently inundated area. Another probable consequence of historic incision would be the deepening of riparian groundwater beneath floodplain surfaces.

The project team conducted a field reconnaissance of the study reach by walking and floating the reach in order to assess present conditions and to develop possible rehabilitation elements and projects. Quantitative measurements were not taken; rather qualitative observations and assessments were made based upon the experience of the team in other similar riparian systems of the region. Initial field observations indicated that riparian plant cover on surfaces away from the summer baseflow water edge is low, connectivity between older riparian patches and younger patches is low and that species and structural diversity are low throughout most of the study reach as compared to riparian zones of similar Central Valley Rivers. The dominant plant species within riparian vegetation stands along the mainstem are predominantly shrub forming and grow to heights less than 20 ft (Figure 2-13). Specifically, narrowleaf willow (*Salix exigua*), dusky willow (*S. melanopsis*) and white alder (*Alnus rhombifolia*) were observed to be growing in dense semi-continuous bands along the summer baseflow channel margin where shallow riparian groundwater can be sustained by near constant streamflows. These bands comprise the prevalent riparian vegetation pattern reflective of the contemporary hydrologic regime.

Woody plant species that grow higher than 30 ft are uncommon along the mainstem[2]. Infrequently within the narrowleaf-dusky willow patches an occasional individual Fremont cottonwood (*Populus fremontii*), red willow (*S. laevigata*), shiny willow (*S. lucida* ssp. *lasiandra*), ash (*Fraxinus latifolia*), or box elder (*Acer negundo*) may be found. Small, isolated stands of structurally diverse, mature vegetation dominated by older Fremont cottonwood were observed growing as patches around the mainstem where tributary confluences or remnant dredger swales maintain access to shallow riparian groundwater. These older riparian vegetation stands have greater structural, species and age diversity, than younger more recently recruited woody riparian vegetation (Figure 2-13). Cottonwood trees, which could grow in excess of 120 ft, are largely absent near the channel where they could be recruited as large wood[3] during channel migration or bank undercutting. Few younger classes of Fremont cottonwood were observed. No valley oaks (*Quercus lobata*) were observed within the project reach riparian corridor.

We hypothesize that the limited woody riparian plant diversity is due to a combination of past and ongoing anthropogenic alterations, including: 1) lack of fines and organic matter in the surficial sediments of the riparian corridor due to mining and lack of upstream replenishment, 2) alterations of the natural flow regime (i.e., magnitude, frequency, duration, timing and rate of change of flow) following construction of large dams in the watershed (Figures 2-8, 2-9 and 2-10), and 3) possible channel incision. Further investigation of each of these alterations is currently underway yet elucidation of the relative and synergistic effects of hydrology and substrate will require pilot projects with intensive testing, such as that conducted on the Merced River (Stillwater Sciences 2007).

In unregulated river systems with snowmelt runoff, flows typically receded in the late spring and summer (Figure 2-8), exposing freshly deposited fine sediment (i.e., nursery sites) that are available to seeds being dispersed. Different woody plant species came to occupy different spatial niches due to the timing of seed dispersal and the corresponding availability of suitable habitat as determined by river flow levels and recession rates. The modern day, impaired hydrology has favored woody plant species that disperse seeds during the June-August period (e.g., narrowleaf and dusky willow) when shallow groundwater is consistently available. Woody plants that seed earlier (e.g., cottonwood) have less favorable flows (Figures 2-9 and 2-10) for broad dispersal of seeds and lack suitable nursery sites.

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[2] Vegetation height plays a role in the potential for structural complexity of vegetation as it pertains to wildlife habitat. In addition, the size that woody plants are able to grow to influences the potential for influencing hydro-geomorphic processes once the wood is recruited.

[3] Minimum size thresholds for the determination of "large" wood found in the literature vary considerably with research objectives (for a review see Seo et al. 2010). For the purpose of discussion in this report we define large wood as pieces of wood, conifer or hardwood, ≥16 inch diameter and ≥15 ft in length.

We further hypothesize that in some years the early flood peaks may recede too quickly for growing roots to keep up, and/or reduced flood peaks are not able to inundate areas, providing moisture to surfaces where seedlings may have germinated earlier in the year. Current hydrology has supported the establishment and persistence of dense, narrow, semi-continuous bands of narrowleaf willow, dusky willow and white alder along the active channel. Areas above these bands of riparian vegetation are inundated for very short periods of time during the seed dispersal period and flows may recede quickly such that a shallow groundwater table cannot be maintained for a sufficient period of time (Figures 2-8, 2-9 and 2-10). Streamflow recession rates during the growing season, including the late summer and fall can affect the successful establishment of riparian trees (Mahoney and Rood 1998, Amlin and Rood 2002, Stella et al. 2010). For a review of both biotic and abiotic processes affected by altered rates of the change during the spring recessional period, please see Yarnell et al. (2010).

We hypothesize that limited recruitment (i.e., germination, establishment and survival to reproduction) by many riparian species is due to a combination of potentially inadequate nursery sites (e.g., substrate is too coarse) and reduced area for germination and early survival. Figure 2-14 shows a conceptual cross section of the lower Yuba River, illustrating the reduction of inundation area of reduced flood flow levels, and increased summer baseflow levels due to dam regulation. It also provides a time series comparison of regulated flow as compared to a computed estimate of unregulated flow. Areas above the regulated flood flow levels do not have sufficient moisture available for the establishment of riparian species. Areas below the current band of riparian vegetation are typically inundated during seed release and therefore unavailable to terrestrial species. Before flow regulation, the lower elevations of the potential recruitment area were subject to scour by 2 year and greater floods and therefore were unlikely to provide for long-term establishment of riparian species. However, plants which did establish in this zone were seasonally inundated by lower flow levels providing fine woody structure and potential rearing habitat in the period before the next scouring flood.

Based upon our observations, large wood availability along the lower Yuba River is likely inadequate to provide meaningful effects on channel morphology and fish habitat. The supply of large wood is further confounded by the dams upstream that block the delivery of large wood from the upper watershed to the lower Yuba River. Large wood provides important structure to aquatic species and promotes localized geomorphic processes of scour and deposition, which act to enhance the mosaic of habitat types (Bisson et al. 1987, Montgomery et al. 2003). In addition, large wood may improve adult salmonid spawning habitat by making less desirable habitats more suitable and allow greater concentrations of redds on suitable sites (Merz 2001). Snorkel observations of fish habitat on the lower Yuba River indicate juvenile salmonids are using the willow and alder bands which line the summer baseflow channel more heavily than large wood, where it may be found (G. Reedy and B. Mitchell pers. communication, Figure 2-1).

In an attempt to summarize the major changes to the lower Yuba River, the processes these changes influence and the result upon aquatic and riparian habitat, a simplified conceptual model has been developed (Figure 2-15). This conceptual model does not include all human actions, the associated processes they influence and the resulting effects to habitat. For example alterations to water quality (e.g., mercury from upstream mining or water temperature due to dams) are not included. In an attempt to maintain simplicity, many processes have been grouped. For example, a suite of geomorphic processes including scour, deposition, avulsion, channel migration and incision are grouped, as are the components of the flow regime, which individually influence various other processes. This model illustrates how we believe the system works and indicates the current interactive hypotheses. It is provided as a first step toward building a greater holistic understanding of the anthropogenic disturbances to the system, and how the complex interactions of the various alterations affect biotic and abiotic processes, which in turn create and maintain aquatic and riparian habitats.

2.6 BACKGROUND SUMMARY

The lower Yuba River is an altered system, which has been confined to a narrower corridor than its historical width. Anthropogenic alterations to the system have reduced the aquatic and floodplain area of the lower Yuba River and altered processes that create and sustain aquatic and riparian habitats. Upstream mining activities resulted in the deposition of sediment that blanketed the existing aquatic and riparian habitats and dredger mining activities simplified channel configuration, coarsened bed and floodplain surfaces and laterally constrained the channel and floodplain. The development of water resource infrastructure (i.e., dams) has altered the natural flow regime of the system, which is widely regarded as the "master variable" in limiting the distribution and abundance of riverine species (Poff et al. 1997, Power et al. 1995, Resh et al. 1988).

While quantitative data are not available to ascribe cause and effect to particular changes, it is likely that each type of anthropogenic disturbances has reduced the amount of aquatic and riparian habitat in the study reach, such that there is a need, and multiple opportunities for, river channel and riparian corridor rehabilitation. Dams have limited sediment and large wood replenishment from upstream, reduced the magnitude of more frequently occurring flood flows (i.e., 1.5 to 10 year return period floods) and altered the seasonal pattern of flow. However, larger magnitude, less frequent floods are still present, which allows the river to perform geomorphic work and remain dynamic within its constrained corridor. Despite the lack of sediment replenishment from upstream, the river still recruits hydraulic mining derived sediment currently stored in the banks/bars and mining tailings, which facilitate the river's dynamic ability. This ability represents functional geomorphic process that provides both opportunity and constraints for planning rehabilitation actions.

3 REHABILITATION OBJECTIVES

The primary objective of rehabilitation is to increase the capacity and diversity of juvenile salmonid rearing, by increasing the availability or complexity of limited rearing habitats. Secondary objectives, which promote this primary objective, include the following:

- Restore channel-floodplain connectivity
- Increase woody riparian vegetation area and diversity (age, species and structural) with an emphasis on species that produce recruitable large wood

- Promote natural woody riparian vegetation seedling initiation and establishment on floodplains by re-establishing favorable physical conditions
- Preserve existing riparian vegetation where feasible
- Increase large wood supply
- Work with the dynamic nature of the river

Many other secondary objectives exist yet warrant additional analysis. Furthermore, the value of accomplishing these objectives extends beyond the target of rearing habitat for anadromous salmonids and involves a variety of ecosystem services. Large wood, increased cover of riparian vegetation and increased cover of secondary channels have certain benefits for spawning habitat, particularly for steelhead. However, a variety of wildlife, including birds and herpetofauna, likewise benefit from areas of restored structurally diverse riparian habitat and off-channel aquatic habitat.

4 DESCRIPTION OF REHABILITATION ELEMENTS

Multiple elements or strategies are necessary for achieving the rehabilitation objectives. The rehabilitation elements vary in the spatial extent of their influence and the difficulty/cost of implementation, ranging from elements that modify the physical processes within the river/floodplain system to elements that achieve an immediate but finite increase in a specific type of habitat. The rehabilitation elements are described below and are organized into four main categories: riparian vegetation planting, secondary channels and backwaters, floodplain enhancements and in-channel/structural enhancements. A section listing additional rehabilitation elements is included for elements that do not fit into the above listed categories, or are of lower priority in the study reach. While the elements are presented separately for organizational purposes, it is likely that many elements would be used in combination for any specific project.

4.1 RIPARIAN VEGETATION PLANTING

Riparian vegetation is an important component of river ecosystems. We hypothesize that species composition and structural attributes have been altered within the lower Yuba River riparian corridor as described in section 2.5. Beyond the benefits to terrestrial organisms, riparian vegetation can enhance fish habitat by providing shade and cover, food supply to benthic macro invertebrates through allochthonous inputs, a source of large wood, as well as providing structural complexity and velocity refugia when inundated at higher flow levels.

Field observations of the project team indicate that at present, the extent and diversity of riparian vegetation in the lower Yuba River corridor are limited as compared to our experience with other Central Valley riparian systems, typically consisting of narrowleaf willow and dusky willow (typically much less than 20 ft tall), with young Fremont cottonwoods infrequently found. At few select locations, small patches of greater diversity, in both species and structure, are found (Figure 2-13). These patches of more mature and diverse woody riparian vegetation provide a vision of the desired end goal of riparian vegetation rehabilitation along the lower Yuba River. It is hoped that riparian planting, in some cases combined with topographic and textural modification of the floodplain and secondary channels as discussed in the conceptual projects below, will enhance fishery habitat and contribute to the eventual development of a more diverse and extensive riparian community. However, if other natural processes are not rehabilitated (e.g., hydrologic regime and channel-floodplain connectivity), on-going planting will be necessary to achieve the mosaic of vegetation size/age classes found in more natural riparian forests of the Central Valley.

The goal of planting would be to expand the area where riparian vegetation occurs and allow for a more diverse composition. Expansion would focus on planting areas where suitable groundwater is available, but streamflows and substrate composition appear unable to initiate revegetation through the natural processes of seed dispersal and germination. Planting locations would be prioritized by their hydraulic and geomorphic environment, ability to enhance fish habitat objectives, proximity to high quality existing riparian vegetation and the maximum annual depth to groundwater. Although plants can be planted anywhere, revegetation is most successful where groundwater depth does not exceed 5 ft during the driest time of the year. Figures 4-1 and 4-2 provide an estimate of the spatial distribution of the maximum annual depth to groundwater as well as the inundation extents of 1.25-1.5 year return period flood using the best available information at the time of analysis.

We estimated maximum annual depth to groundwater by developing an estimated minimum groundwater elevation surface and subtracting this surface from the existing topography. The minimum groundwater elevation surface was developed by extrapolating in channel water surface elevations for a low flow value (a flow of 880 cfs simulated with a two dimensional hydraulic model), laterally to the margins of the riparian corridor to create a three dimensional surface of minimum annual groundwater elevation. The low flow value of 880 cfs was chosen due to the availability of simulated water surface elevations for this flow and deemed representative of annual minimum flow levels (typically >700 cfs), occurring in the Fall. The estimated groundwater surface was then subtracted from the existing topography to yield the estimated depth to groundwater distribution shown in Figures 4-1 and 4-2. This analysis assumes that groundwater elevation is equal to the low flow water surface elevation and does not slope toward or away from the channel. Flood inundation extents are provided to allow for the selection of areas which do not lie within the typical frequently occurring flood zone, in order to increase the chance of long-term survival of the plantings. Furthermore in this zone, natural regeneration of hardwoods appears to be occurring. The depth classes provided indicate zones that may be appropriate for planting by different methods as discussed further below. Flood inundation extents (5,000 cfs) and low flow water surface elevations (880 cfs) were simulated with a two dimensional hydraulic model developed for the study area and represent the best available information at the time of analysis (Pasternack, unpublished data).

Willows and Fremont cottonwood can be planted into the groundwater using unrooted dormant cuttings (i.e., poles). Hardwood poles of multiple species (e.g., cottonwood, red, shiny, black and arroyo willow) would be prepared from male and female plants growing locally. Pole cuttings can be planted several ways. One method rapidly plants hardwood poles using a special tool called a "stinger." The stinger can be mounted to an excavator for navigating almost any location. The stinger can plant hardwoods where the late summer groundwater is within 6 ft of the ground surface. In locations where the groundwater is in excess of 6 ft but less than 10 ft plantings can be achieved in holes dug by a backhoe. In locations where the groundwater is greater than 10 ft deep, pole planting and plant establishment is unlikely to be successful. In this method, poles are planted into the groundwater, and therefore may not need external irrigation.

Pole plantings would enhance the riparian vegetation diversity and ultimately structural complexity along the lower Yuba River. The establishment of vigorously growing pole cuttings would enhance fish habitat through shading, long term wood supply, food supply, cover from predation, structural complexity, etc. Additional species of interest, other woody species (e.g., sycamore, box elder, Oregon ash, valley oak, etc.) and herbaceous species (e.g., *Carex* and *Juncus* sp.) could be planted from rooted container stock and would typically require irrigation for the first 3 years. Planting could be undertaken on surfaces that currently are at appropriate relative elevations above the water table (Figures 4-1 and 4-2), or implemented on modified (lowered) surfaces as described in section 4.3.1. For additional details riparian vegetation planting, see section 5.1.

4.2 SECONDARY CHANNELS AND BACKWATERS

A variety of options are possible with regards to creating aquatic habitat for rearing juvenile salmonids through the creation of new aquatic habitat features lateral to the mainstem channel, including the construction of new side channels or lowering abandoned side channels currently acting as high flow channels. Constructed secondary channels could be designed to flow year round under the current flow regime, including the fall baseflows (~700-900 cfs), or designed as high flow channels, which would convey flow only under higher flow conditions (e.g., >2,500 cfs, typical of winter, spring and summer of a normal year), with the downstream extents forming inundated backwaters or alcoves at fall baseflow levels. Decisions regarding the side channel design and the period they are inundated and provide aquatic habitat should be based upon a determination of what time of year rearing habitat is most needed, and the flow levels which typically occur during that time of year. Our observations at Hammon Bar suggest that the backwater there affords valuable rearing habitat during all seasons and river flows, and that the channel functions like a side channel at all but the lowest river levels due to substantial hyporheic flow through the upper part of the bar (see section 4.2.4 regarding percolation fed backwaters, below).

4.2.1 Side Channels

This concept seeks to create or rejuvenate year round side channels in order to add year round habitat heterogeneity and additional edge habitat to the river corridor, beyond what is found presently in the mainstem. This type of feature would be designed so that it remained longitudinally connected as river discharge reached its typical annual minimum under the current flow regime (~800 cfs), which typically occurs in the fall. A channel would be excavated at a selected location through an existing point bar with initial dimensions determined through a combination of hydraulic modeling and an analysis of existing reference features. At locations where abandoned side channels or high flow channels are present, side channel elevations would be lowered to allow connectivity of surface flow at typical fall baseflow levels.

A potential concern with this rehabilitation element is that the river may still be incising, despite the base level control exerted by Daguerre Point Dam. Due to this incision, or possible channel migration, constructed side channels may be abandoned if the river incises, changes its alignment, or entrances are plugged with sediment. Side channel entrances may require wood/rock structures to enhance geomorphic maintenance (i.e., scour) in order to increase the temporal longevity of the feature. Alternatively, due to the dynamic nature of the lower Yuba River, constructed side channels may capture the main flow with unintended consequences.

4.2.2 High Flow Channels

High flow secondary channels are channels that are inundated during flood flow conditions or may remain longitudinally connected at winter/spring baseflows, providing longer periods of habitat availability. They do not remain inundated all the time, and therefore, the aquatic habitat they provide is temporally limited. High flow channels would be designed so that they are inundated with sufficient frequency and duration during the times that juvenile rearing habitat is needed. When determining the elevation of these channels, a trade-off between cost and duration of rearing habitat availability is present. Higher elevation channels are cheaper to construct, because less material is moved, however they provided aquatic habitat less frequently and for a shorter duration. While the upstream portion of high flow channels becomes disconnected at lower discharge levels (i.e., fall baseflows), in many cases a remnant backwater or alcove could be retained at lower discharge levels, providing year round aquatic habitat.

4.2.3 Backwaters/Alcoves

Backwaters or alcoves can provide excellent rearing conditions for juvenile fishes due to extremely low velocities, increased food availability, dense cover of riparian and aquatic vegetation and in some cases the absence of larger predatory fishes. In the Parks Bar reach, backwaters can be warmer than the mainstem Yuba River and still be below thresholds of thermal stress to salmonids, thus potentially providing increased growth opportunities through higher metabolic rates. Data collected in 2009 showed a maximum 7-day average temperature of 59.9 °F in the lower portion of the Hammon Bar Backwater, compared to 57.9 °F in the main channel (data published at www.yubashed.org). The optimal growth range for juvenile Chinook salmon in 50.0-60.1 °F, and yet higher temperatures within this range support higher growth and feeding rates for the same food availability (McCullough 1999). Use of backwaters by juvenile salmonids can vary greatly due to life stage and environmental conditions. During high flow events, backwaters can harbor high densities of juvenile salmonids, thereby supporting extended rearing (Beechie et al. 2005). To increase the amount of this type of habitat, new backwaters could be created, or existing backwaters could be enhanced through the excavation of sediment. Several existing backwaters are present along the river, typically forming in the downstream portion of a high flow channel (or abandoned historic side channel). As water levels drop in the summer and fall, some of these existing backwaters become disconnected from the main channel and may result in stranding mortalities. In other cases, the backwaters remain connected at fall baseflows and appear to provide functional habitat throughout the year. In addition, backwaters are subject to eventual infill of sediment, limiting their longevity as aquatic habitat, however providing an opportunity for recruitment and establishment of riparian vegetation. To address this potential infill of sediment, connection to a high flow secondary channel, and the potential for scour to maintain the backwater, may increase the longevity of a backwater. Stranding mortality, seasonal habitat quality and potential longevity of backwaters require site-specific assessments.

4.2.4 Percolation Channels/Backwaters

A variant on a standard backwater is a percolation channel/backwater. For this element, hyporheic flow to the backwater could be increased through the inclusion of a percolation gallery upstream of the backwater channel. The creation of a percolation gallery involves the excavation of a deep side channel along the upland/distal edge of a gravel bar. The upper section of the side channel would then be back filled with clean coarse sediment (e.g., 3-24 in). The voids surrounding the large sediments would provide a hyporheic (shallow subsurface) flow path for water to follow from the main channel into the backwater channel downstream. Final grade of the percolation gallery could be level with the adjacent floodplain/terrace surface, or slightly below, creating a high flow channel. This project element would only be placed where historical aerial photo analysis indicates reasonable medium-long term geomorphic stability of the feature, and data and/or modeling indicates an appropriate hydraulic gradient could be achieved. A percolation channel/backwater may have a longer life span, and perform better than a traditional side channel and backwater. Due to the fill of large material, as well as being located on the inside of the bar, the excavated channel is much less likely to capture the main flow and become the main channel. Infiltration through the substrate would promote adequate delivery of cold water compared to a side channel which may become disconnected from the main channel due to sediment deposition at the mouth.

4.2.5 Bank Scallops

Many of the banks along the main channel are tall (8-12 ft above the low water surface elevation) and steep, lacking much aquatic habitat complexity. Previous observers of the channel at Parks Bar have noted channel incision and prescribed “feather-edging” to restore a less efficient channel cross-section and thereby enhance low velocity marginal habitats and the retention of spawning gravels (ENTRIX 2004). This rehabilitation element would involve excavating small scallops 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. The steep slopes surrounding the alcoves would be feathered to at least a 10:1 slope to provide additional shallow inundated areas with desirable depth-velocity combinations over a range of flows. Initially, these scallops/alcoves would provide year-round juvenile salmonid rearing habitat. Over time, we expect fine sediment to 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 the shallow access to the water table, and the fine texture of the deposited sediments.

Large wood could also be placed within and protruding from the scallops, mimicking the natural process of large wood recruitment as the river laterally migrates into a steep bank with mature riparian forest at the top of bank. The combination of natural large wood recruitment and large wood placement could create habitat hotspots along a fairly monotonous channel margin where little suitable habitat currently exists. This action would also increase the possibility that other woody riparian plants could establish naturally and create greater species richness and increase stand structure.

4.3 FLOODPLAIN ENHANCEMENTS

The lower Yuba River has a dramatically reduced floodplain area compared to historic conditions (James et al. 2009). Although the training walls are the principal factor in creating this condition, the functionality of remaining floodplain within the constrained Yuba River corridor is also limited by disconnection of the channel and floodplain (due to high topographic relief and incision), reduced flood flows and a lack of fine substrate for riparian establishment.

Creation of floodplain surfaces functional under the future flow regime could substantially enhance juvenile habitat growth and survival, even if those floodplain surfaces were only inundated for a small portion of the spring season. Research on other rivers in the Central Valley has shown higher growth rates for juvenile Chinook salmon rearing on floodplains compared to main channel river habitats, with no apparent difference in survival when considering stranding and predation (Jeffres et al. 2008 and Sommer et al. 2005). Those authors suggest that restored floodplain connectivity support alternative life histories for salmon which may increase overall production of smolts under varying environmental conditions. Furthermore, size and fitness of smolts increases likelihood and success of return of adults.

4.3.1 Terrace Excavation

Many areas within the river's historic corridor are now hydraulically disconnected from the main channel because they sit above the zone typically inundated by frequently occurring floods (i.e., 1.5-5 year return period floods). This disconnection of the main channel and its former floodplain is likely due to historic incision, which requires a higher discharge amount for flows to inundate floodplains and terraces, and the present day hydrologic regime, which has reduced the magnitude of more frequently occurring flood events (i.e., 1.5-10 year recurrence interval events, see Figure 2-6), reducing the area adjacent to the channel inundated by these more frequent events. High floodplain surfaces are not accessible to water-transported seeds or propagules, and are typically too far above minimum groundwater levels to support most riparian vegetation. To enhance channel-floodplain connectivity, increase the frequency of inundation and decrease the depth to groundwater, high geomorphic surfaces (terraces) can be lowered via excavation. These surfaces would be lowered to an elevation that is inundated by the anticipated 1.5-2 year flood. Once proper relative elevations are established, these areas can be planted with woody riparian species, and may support natural recruitment and establishment of riparian plant species. The relative elevation of these lowered surfaces will be determined through a combination of hydraulic modeling at each site, anticipated future Yuba River flood frequency, the location of existing woody riparian patches within the Yuba River riparian corridor relative to existing streamflows, the seed dispersal periods of common woody plants found along the

Yuba River, the proximity to groundwater, and similar physical-plant life history relationships used in other Central Valley river rehabilitation projects. The relative elevation of the surfaces is highly dependent upon the anticipated future flow regime.

4.3.2 Textural Improvement

Depending upon the substrate quality, additional fine materials and organic matter could be introduced into the upper zone of the soil column in low energy floodplain areas. Riparian hardwoods need exposed fine textured substrates to germinate. There are few quantified characteristics of particle size distributions that support germination in the literature. Substrates with a cumulative surface pebble count distribution of over 20% less than 2 millimeter (mm) have been shown to support hardwood germination on the Trinity River; however, the highest numbers of seedlings were associated with substrates where over 60% of the sample was less than 2 mm (Bair 2001). Substrates with a higher percent composition of finer textured particles were better for seed germination due to a higher capillary fringe (and therefore less opportunity for desiccation) and fewer interstitial air pockets (which are fatal to roots). Ideally, constructed floodplain surfaces and high water channel substrates should be composed of no less than 20% of the overall composition smaller than 2 mm to meet the woody plant seed germination requirement; the higher the percent composition of fines in the substrate, the better.

4.3.3 Training Wall Setback or Removal

This element involves setting back or removing a portion of the training walls that laterally confine the river channel within the Gold Fields reach. This element would widen the river's floodway, allowing for lateral migration of the main channel, as well as adding functional floodplain area, with the potential for sustainable riparian forest development. In addition, training wall setback or removal may reduce water surface elevations within the river corridor during floods; as such benefits have been simulated in previous studies of levee setbacks along the Feather River (Philip Williams & Associates 2007). This element is only possible in the downstream portion of the study reach where training walls are present; however, additional opportunity is present downstream of the study reach. One concern with this element is that portions of the existing training walls provide some flood protection to areas downstream. Therefore, instead of just removing the training walls, alternate protection (levees) may be need to be constructed depending upon the location and extent of proposed training wall removal.

4.4 IN-CHANNEL HABITAT

This group of rehabilitation elements focuses on creating immediate instream aquatic habitat by placing physical structures within the active channel(s). Elements in this group include large wood, boulder clusters and bank bio-engineering. These elements could be employed solely to provide aquatic habitat, or to promote geomorphic processes (e.g., side channel maintenance) or discourage geomorphic processes (e.g., bank stabilization to protect a road). In general, placement of in-channel structures has had mixed results in providing sustained habitat improvement and one factor influencing the persistence or risk of such projects is the dynamics or flood potential of the stream.

4.4.1 Large Wood

Few pieces of large wood are found within the study reach, presumably due to large upstream dams disrupting downstream transport from the upper watershed and the overall lack of supply and available inventory along the riparian corridor of the river downstream of Englebright Dam. Large wood is present at historic flood elevations (e.g., the 1997 flood elevation) however; this wood does not interact with the wetted channel at typical flow levels and contribute to aquatic habitat. Placement of large wood (e.g., ≥16 inch diameter and ≥15 ft in length, conifers or hardwoods) and root wads within low energy areas of the main channel, side channels and backwaters would immediately enhance habitat for aquatic organisms by providing structural diversity. Large wood in interaction with channel margins has been shown to create a variety of microhabitats and affect geomorphic processes in a way that supports natural riparian recruitment and diversity (Gerhard and Reich 2000). Juvenile salmonids are known to show preference for habitats with cover and velocity refugia associated with large wood (Roni and Quinn 2001). Large wood has been found to locally improve spawning conditions (Merz 2001, Senter and Pasternack 2010).

Placed wood could either be fixed with cables or keyed into the bank to inhibit movement, or alternatively placed and allowed to potentially move under high discharge conditions. In some locations, large wood would promote the geomorphic processes of scour and deposition, further enhancing a heterogeneous mosaic of aquatic and riparian habitat types. Figure 4-3 provides an example of large wood on the Clear Creek, in this instance placed to provide bank protection. A review of the use of wood for river rehabilitation throughout the world (Nagayama and Nakamura 2010) emphasizes that wood placement should be used in conjunction with actions designed to restore the processes that produce wood supply and create desirable habitat structures, such as promoting the growth of riparian species which grow large enough to provide large wood. In the lower Yuba River, this may involve a wood supply and management plan, but would also involve the enhancement of riparian hardwood forests.

4.4.2 Boulder Clusters

Clusters of large rocks placed in the channel, or on the floodplain, can provide habitat heterogeneity in regions of otherwise homogeneous habitat. Such clusters create velocity refuges, which fish can utilize for holding and feeding. Similar to large wood, in some locations, boulder clusters would promote the geomorphic processes of scour and deposition, further enhancing a heterogeneous mosaic of aquatic habitat types. Boulder clusters could be helpful in creating a desirable geomorphic effect (e.g., grade control to inhibit incision).

4.4.3 Bank Bio-Engineering

This element would involve the placement of a combination of willow wall revetments, brush mattresses, willow and rock baffles, root wads and/or logs along channel banks (Flosi et al. 1998). Logs and root wads would be placed at the bank toe and keyed into the bank to inhibit movement of the structure and the bank. Bank bio-engineering would add structural complexity to the river edge, improving and/or increasing rearing habitat. In addition, bank bio-engineering could be used to resist lateral migration of the river channel (Figure 4-3), in order to protect existing infrastructure (e.g., an existing road).

4.5 ADDITIONAL REHABILITATION ELEMENTS

4.5.1 Flow Modification

Altering reservoir release patterns has the potential to improve natural and sustainable regeneration of desired woody riparian plant species along the entire lower Yuba River. As described in section 2.4, initial field observations indicated that riparian plant cover and diversity are low throughout most of the study reach. We hypothesize that limited woody riparian plant diversity is due partially to alterations of the natural flow regime (i.e., magnitude, frequency, duration, timing and rate of change) following construction of large dams in the watershed, combined with unsuitable substrate (i.e., lack of fines and organic matter in the surface due to dredge mining and Englebright Dam) and historic and possible modern day channel incision.

The Trinity River Flow Evaluation (USFWS & HVT 1999) provides an example of hydrograph modification to support ecological integrity of a regulated river in California, even if particulars of that environmental setting differ from the Yuba River. It targeted physical and riparian processes as a foundation for fishery and ecological rehabilitation. Another example of hydrograph modification to support fishery and ecological rehabilitation is presently underway on the San Joaquin River. The potential for hydrograph manipulation in the Yuba River is limited by a balancing of beneficial uses as most recently resolved in the Yuba Accord. In addition, the flow regime of the lower Yuba River is subject to FERC license requirements. The effect of the current flow regime on fish and other resources will be evaluated during the relicensing of the Yuba River Development Project (#2246), a process scheduled for completion in 2016. Although hydrograph manipulation is not addressed further in this report, this element has the potential to broadly affect rehabilitation of the lower Yuba River, including the success of any individual projects. Physical rehabilitation is expected to overcome some, but not all of the adverse effects of altered flows.

4.5.2 OHV Exclusion

Exclusion of off highway vehicles (OHVs, including motorcycles) by fencing, signage and/or enforcement may be warranted to protect sensitive areas (e.g., areas where natural vegetation recruitment is occurring). A variety of potential rehabilitation projects would include some riparian planting and thereby require protection from vandalism or damage from OHVs. The extent and means of exclusion should be determined with consideration of the sensitivity of the area, wildlife, landowner rights and concerns, and impacts to legal public use of the river corridor.

4.5.3 Coarse Sediment Augmentation

Coarse sediment augmentation is the additional of coarse sediment (e.g., 0.75-4 in) to increase the available spawning habitat, improve geomorphic processes and increase channel complexity. It is a rehabilitation element not highlighted in this report, as spawning habitat does not appear to be limited by an inadequate supply of coarse sediment within the project reach due to ample storage of mining sediments in the banks, bars, training walls, etc. Provision of additional spawning habitat in association with other elements such as side channels or large wood could significantly enhance the quality, if not the quantity, of available spawning habitat. This benefit would be stronger for steelhead than Chinook salmon, since steelhead are known to preferentially select smaller channels for spawning.

4.5.4 Tributary Connection Improvement

Tributaries can provide good non-natal rearing habitat, if accessible, and are also locations where there is naturally greater riparian vegetation diversity, extant and cover. The focus of this element is to improve flow conditions and fish passage at the confluence of tributaries to the main channel or side channels. Specific actions are heavily dependent upon the tributary of concern, but could involve altering the present alignment of the furthest downstream reach of the tributary to improve juvenile access. Another option for smaller tributaries involves creating a channel across or along gravel bars to provide surface connection to ephemeral tributaries which otherwise infiltrate into floodplain/terrace sediments.

5 POTENTIAL REHABILITATION PROJECTS

Applying these rehabilitation elements to specific areas within the Parks Bar to Hammon Bar reach, ten potential projects are identified below. Table 2 provides a preliminary comparison of the potential projects. More detailed descriptions and prioritization will be possible following an analysis of feasibility, risk, cost/benefit and other criteria. For some projects, further analysis may include investigation of project interactions with fluvial processes using a hydrodynamic model, and additional data collection at the proposed site. Figures are provided for some of the projects (Figures 5-1 to 5-10), and location landmarks refer to the names listed on Figure 2-11. The alignment and extent of various elements (e.g., setbacks, side channels, surface lowering) are conceptual and will be refined as projects are prioritized further. A simple ranking of estimated costs has been employed in the following descriptions. More precise opinions of probable cost are not possible at this stage of project development, due to the general nature of the project descriptions. The rankings are provided to allow the reader to differentiate between projects of varying cost and effort. For the purpose of these potential projects, low refers to <$100,000, medium refers to >$100,000 but <$500,000 and high refers to projects which would likely cost >$500,000.

5.1 PROJECT 1: DISTRIBUTED RIPARIAN PLANTING

Location and current conditions – This project would cover the entire study reach, focusing on areas with willing land owners/managers and where the difference between the elevation of the ground surface and the elevation of the water table at its annual minimum is small enough to support planted woody riparian vegetation without altering the floodplain elevation. Figures 4-1 and 4-2 show the estimated depth to groundwater in order to identify potential planting areas as described in section 4.1. Within the BLM boundary on Hammon Bar and the planned conservation easement on Western Aggregates land (Figure 2-11), we estimate >50 ac of currently unvegetated area with less than 10' depth to groundwater.

Objectives – Increase cover and diversity of woody riparian vegetation and increase the production of large wood (in 40 or more years once trees have matured).

Prescription and design elements – Planting woody riparian plant species in locations where there is sufficient contact with a shallow streamflow supported groundwater table to increase species richness, structural diversity and the extent of existing riparian vegetation. Planting would be undertaken with a combination of methods, including a stinger in areas where the maximum depth to the water table is less than 6 ft, and backhoe dug holes for areas where the maximum depth to the water table is less than 10 ft (Figures 4-1 and 4-2). It is anticipated that initial efforts will rely primarily upon pole plantings which do not require irrigation. Future efforts may include planting container stock to increase species diversity; however this type of planting requires irrigation for 3 years. Within each planting area, poles will be planted across the suitable elevation range. In addition, the effect of additional treatments (e.g., weed cloth, tree protectors, mychorhizal inoculants) will be evaluated to inform future efforts. Plantings will be monitored to evaluate the success of the various locations, methods and treatments.

Uncertainties and additional analysis – Additional hydraulic modeling and field investigation of existing mature vegetation will be necessary to refine the estimate of areas suitable for this approach. The distance to fall groundwater is only an estimate at this time. During pilot project implementation, test pits will be dug to evaluate depth to groundwater, piezometers placed and groundwater subsequently monitored to establish the elevation and the influence of mainstem streamflows on the shallow groundwater table to inform future planting efforts. Field surveys will be necessary to inventory existing riparian stands to provide appropriate source material, and appropriate staging and pole preparation areas.

Cost – Low-medium; however, the cost for this project is dependent upon the area planted, the density of plantings and the planting method (stinger vs. backhoe holes). Based on similar projects from the Trinity River, we estimate that 20 ac could be densely planted for ~$100,000.

Anticipated Benefits – Increased cover and diversity of woody riparian vegetation, increased production of large wood and increased terrestrial inputs to aquatic zones.

5.2 PROJECT 2: DISTRIBUTED LARGE WOOD PLACEMENT

Location and current conditions – This project would cover the entire study reach, placing large wood along the margins of the active main channel, side channels and backwaters.

Objectives – Increase juvenile rearing habitat by increasing instream structural diversity and providing velocity refugia and cover.

Prescription and design elements – Large wood placement along channel margins. A variety of approaches are possible depending on the location, including simple placement with potential movement under higher discharges, as well as placement with a portion of the large wood keyed into the channel bank to resist movement. Figure 4-3, illustrating large wood placement on Clear Creek is provided as an example of one possible type of installation.

Uncertainties and additional analysis – Hydraulic modeling will be needed to determine low energy areas, where large wood placement would likely persist.
Cost – Low
Anticipated Benefits – Immediate increase in juvenile rearing and adult salmonid habitat.

5.3 PROJECT 3: BANK SCALLOPING AT UPPER GILT EDGE BAR

Location and current conditions – This project is located along the channel edge of Upper Gilt Edge Bar, where the bank is 8-15 ft high, with a narrow band of narrowleaf and dusky willow at the bank top (Figure 5-1). The channel edge in this region is relatively monotonous with little habitat complexity.
Objectives – Increase juvenile rearing habitat, increase the extent of woody riparian vegetation, promote natural riparian vegetation recruitment by re-establishing favorable physical conditions and increase the inventory and potential recruitment of large wood (in 40 or more years once trees have grown large enough to become large wood).
Prescription and design elements – The project would excavate small scallops 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 groundwater, and the fine texture of deposited sediments. In addition, large wood would be placed within, and protruding from the scallops, mimicking the natural process of large wood recruitment as the river laterally migrates into a steep bank with mature riparian forest at the top of bank.
Uncertainties and additional analysis – The longevity of the aquatic features is uncertain, however it is probably low. Hydraulics associated with large wood placement may provide the scouring forces necessary for maintenance of aquatic/inundated features; however, some degree of sedimentation is expected.
Cost – Low-medium
Anticipated Benefits – Increased juvenile rearing habitat in the scallop alcoves, increased cover and diversity of woody riparian vegetation in the area surrounding the scallops, increased production and storage of large wood and increased terrestrial inputs to aquatic zones.

5.4 PROJECT 4: BACKWATER AT UPPER GILT EDGE BAR

Location and current conditions – This project is located at the downstream end of Upper Gilt Edge Bar, where an ephemeral tributary creates a mainstem backwater alcove. The tributary confluence area is surrounded by a diverse riparian stand (Figures 5-2 and 5-3). Elsewhere along the mainstem a dense monotypic band of willows grows along the mainstem channel.
Objectives – Increase juvenile rearing habitat, increase the extent of woody riparian vegetation, promote natural riparian vegetation recruitment by re-establishing favorable physical conditions next to

the existing riparian vegetation, and increase the inventory and potential recruitment of large wood (in 40 or more years once trees have grown large enough to become large wood).

Prescription and design elements – The project would enhance the backwater and increase the extent and species richness of the existing riparian stand. It would involve excavation of sediment to allow for backwater inundation at fall baseflows, and potential excavation/lowering of the surrounding area to allow for inundation in a typical 1-2 year recurrence interval flood (see Table 2), in order to promote the natural regeneration of Fremont cottonwood. Riparian woody species may be planted to promote species richness and structural diversity. If necessary and economically possible, additional fine material could be introduced to the upper 3 ft of the soil column in excavated areas to increase soil capillarity and the amount of soil moisture available to herbaceous riparian vegetation. Large wood would be placed within the backwater to provide aquatic structure.

Uncertainties and additional analysis – The physical mechanism that creates/maintains the existing backwater is unclear. It could be due to scouring flood flows from a tributary that joins the mainstem at this location, mainstem flood flows that rejoin the main channel due to bedrock on river left, or a very old abandoned channel. In addition, at this point it is unclear if this enhanced backwater would sustain itself or infill with fine sediment. It was present in 1952 (Figure 2-4) however at present it is not inundated when mainstem flow is ~800 cfs. The distance to fall groundwater is only an estimate at this time and will need further investigation to ensure revegetation success. Test pits will need to be dug, piezometers placed and groundwater monitored to establish the elevation and the influence of mainstem streamflows on the shallow groundwater table.

Cost – Medium

Anticipated Benefits – Increased juvenile rearing habitat in the enhanced backwater, increased cover and diversity of woody riparian vegetation in the area surrounding the backwater, increased production and storage of large wood and increased terrestrial inputs to aquatic zones.

5.5 PROJECT 5: PERCOLATION-FED BACKWATER AT LOWER GILT EDGE BAR

Location and current conditions – This project is located along the southern edge of Lower Gilt Edge Bar, a stable point bar that starts near the low water elevation at the top of the bar and extends well above the low water elevation at the downstream end of the bar (Figure 5-4). Inspection of aerial photography (Figure 2-4) indicates that this bar location has been stable in recent history and is therefore a good candidate for a percolation gallery fed backwater.

Objectives – Increase juvenile rearing habitat, increase cover and diversity of woody riparian vegetation, promote natural riparian vegetation recruitment by re-establishing favorable physical conditions and increase the production of large wood (in 40 or more years once trees have matured).

Prescription and design elements – The project would create a percolation gallery fed backwater with floodplain lowering and riparian planting adjacent to the backwater. A side channel would be excavated in the point bar. The upper most portion of this side channel would be backfilled to the existing grade with clean large alluvium (e.g., 3-24 in) creating a percolation gallery. This percolation gallery would encourage hyporheic flow from the main channel into the backwater channel due to the high hydraulic conductivity of the gallery sediment. The thalweg of the backwater channel would need to be lower than the upstream water surface elevation in the main channel to create a hydraulic gradient. Along the sides of the side channel, a riparian bench would be created by excavating the bar sediments to an elevation that would allow for inundation in a typical 1-2 year recurrence interval flood (see Table 2). If necessary, fine sediment would be added to the upper 3 ft of the riparian bench. This riparian bench could be planted with native riparian hardwoods, or allowed to revegetate naturally. Large wood would be place along the margins of the backwater channel to provide structure.

Uncertainties and additional analysis – Details of the infiltration gallery would need to be designed. What size sediment should be backfilled, and for what length? What amount of hyporheic flow is desirable, and can this be achieved? A combination of field data collection and hydraulic/hydrologic modeling will be required to design this project. Specifications from similar projects completed in the Pacific Northwest should be reviewed.

Cost – High

Anticipated Benefits – Increased juvenile rearing habitat, increased cover and diversity of woody riparian vegetation, increased production of large wood and increased terrestrial inputs to aquatic zones.

5.6 PROJECT 6: SIDE CHANNEL AT HIDDEN ISLAND

Location and current conditions – This project is located through the alluvial bar located on the northern side of the river downstream of Lower Gilt Edge Bar, where a high flow side channel is present (Figure 5-5). Inspection of historic aerial photography (Figure 2-4) indicates that the side channel used to remain inundated and longitudinally connected at lower river discharges and has presumably become disconnected at lower discharges. Field observation indicates that at present the high flow side channel becomes longitudinally connected at mainstem flows >3,300 cfs.

Objectives – Increase juvenile rearing habitat, increase cover and diversity of woody riparian vegetation, promote natural riparian vegetation recruitment by re-establishing favorable physical conditions and increase the production of large wood (in 40 or more years once trees have matured).

Prescription and design elements – The project would rejuvenate this side channel by lowering its elevation to allow connectivity at fall baseflow levels. Along the northern margin of the rejuvenated side channel, a riparian bench would be created through surface lowering as necessary to allow for inundation in a typical 1-2 year recurrence interval flood (see Table 2). The upper 3 ft of the soil column within the riparian bench would be texturally improved by incorporating fine sediment if necessary. The riparian bench would be planted with native hardwoods, and large wood would be placed along the banks and within the side channel.

Uncertainties and additional analysis – We hypothesize that the historic side channel has converted into a high flow channel due to incision of the mainstem and/or deposition on the bar. A comparison of past and present bathymetry, which is currently underway (Pasternack unpublished data), will provide additional information to evaluate this hypothesis. It is uncertain how long a constructed side channel can be maintained at this location, if the main channel is indeed incising in this area or a future flood deposits on the bar. In addition, access and cooperation the north bank land owner has not been pursued. The distance from constructed surfaces to fall groundwater table elevation is unknown and will need quantification to ensure revegetation success. Test pits will need to be dug, piezometers placed and groundwater monitored to understand the influence of mainstem streamflows on the shallow groundwater table.

Cost – Medium

Anticipated Benefits – Increased juvenile rearing habitat, increased cover and diversity of woody riparian vegetation, increased production of large wood and increased terrestrial inputs to aquatic zones.

5.7 PROJECT 7: BANK BIO-ENGINEERING

Location and current conditions – This project is located along the southern bank of the main channel just downstream of Lower Gilt Edge Bar, where lateral migration of the channel is eroding the 15-20 ft tall steep bank, threatening Hammonton Road (Figure 5-6).
Objectives – Protect road from erosion, and increase juvenile rearing habitat by adding structure to a steep bank with high velocities.
Prescription and design elements – This project would involve the design and installation of a large revetment structure composed of large wood (bole sections with root wads attached, Figure 4-3), cables and probably rip rap as well. To prevent flanking by the river, the structure would be constructed along the alignment of the road prism, with ~ 50% of the structure reburied with native gravels and cobbles, and ~50% of the structure expose along the left bank of the main channel. If possible, narrowleaf willows would be planted, but steep banks slopes may make planting difficult.
Uncertainties and additional analysis – It is unclear what the lifespan of such a structure would be if improperly designed, or if a large magnitude flood (e.g., 1997 flood) occurred. In addition, by attempting to fix the position of the left bank, channel complexity on the opposite bank might be reduced.
Cost – Medium-high
Anticipated Benefits – Protection of road, potential for increased juvenile rearing habitat on outside of bend.

5.8 PROJECT 8: SIDE CHANNEL AT SILICA BAR

Location and current conditions – This project is located along Silica Bar, where due to training walls, the river corridor is constrained to its narrowest width within the study reach (Figure 2-11, 2-12, 5-7 and 5-8). The upper portion of Silica Bar borders a side channel, while the lower portion borders the main channel. The maximum elevation of Silica Bar is ~12 ft above the fall baseflow water surface elevation. Along the southern distal edge of the bar, directly adjacent to the training wall, a diverse (in species composition, age and structure) riparian stand occupies a topographic depression in the bar.
Objectives – Increase juvenile rearing habitat, increase cover and diversity of woody riparian vegetation, promote natural riparian vegetation recruitment by re-establishing favorable physical conditions, increase the production of large wood (in 40 or more years once planted trees have matured) and improve main channel-floodplain connectivity.
Prescription and design elements – The project would create a side channel through the bar adjacent to existing stands of mature riparian vegetation (Figures 5-7 and 5-8). The side channel could remain inundated year round, or be composed of a high flow side channel in the upper portion, followed with a year round backwater in the downstream portion. Large wood would be placed along the margins of the side channel. In addition, areas adjacent to the constructed side channel would be lowered to allow for inundation in a typical 1-2 year recurrence interval flood. If needed, fine sediment would be

incorporated into the upper 3 ft of the soil column, and the floodplain surface would be planted with native riparian woody vegetation.

Uncertainties and additional analysis – The effect of the new side channel on the existing side channel that forms First Island is unclear. Hydraulic modeling and field investigations will provide necessary information toward assessing this effect. The distance to fall groundwater is unknown and will need quantification to ensure revegetation success. Test pits will need to be dug, piezometers placed and groundwater monitored to understand the influence of mainstem streamflows on the shallow groundwater table.

Cost – Medium-high

Anticipated Benefits – Increased juvenile rearing habitat, increased cover and diversity of woody riparian vegetation, increased production of large wood, increased terrestrial inputs to aquatic zones and increased channel-floodplain connectivity.

5.9 PROJECT 9: SIDE CHANNEL AT SILICA BAR WITH TRAINING WALL SETBACK

Location and current conditions – This project is a variant of Project 8 and is also located along Silica Bar, where due to training walls, the river corridor is constrained to its narrowest width within the study reach (Figure 2-11, 2-12, 5-8 and 5-9). The upper portion of Silica Bar borders a side channel, while the lower portion borders the main channel. The maximum elevation of Silica Bar is ~12 ft above the fall baseflow water surface elevation. Along the southern distal edge of the bar, directly adjacent to the training wall, a diverse (in species composition, age and structure) riparian stand occupies a topographic depression in the bar.

Objectives – Increase juvenile rearing habitat, increase cover and diversity of woody riparian vegetation, promote natural riparian vegetation recruitment by re-establishing favorable physical conditions, increase the production of large wood (in 40 or more years once trees have matured), improve main channel-floodplain connectivity, provide additional functional floodplain and expand river corridor width.

Prescription and design elements – In addition to creating a side channel through the bar adjacent to existing stands of mature riparian vegetation, it would setback a ~5,000 ft segment of the southern training wall in this area to expand the river's corridor from ~700 ft to ~1,150 ft (Figures 5-8 and 5-9). The side channel could remain inundated year round, or be composed of a high flow side channel with a year round backwater in the downstream portion. Large wood would be placed along the margins of the side channel. In addition, areas adjacent to the constructed side channel would be lowered to allow for inundation in a typical 1-2 year recurrence interval flood. If needed, fine sediment would be incorporated into the upper 3 ft of the soil column, and the floodplain surface would be planted with native riparian woody vegetation.

Uncertainties and additional analysis – The effect of the new side channel on the existing side channel that forms First Island is unclear. Hydraulic modeling and field investigations will provide necessary information toward assessing this effect. In addition, it is unclear if a new training wall (levee) would need to be built, or if one of the existing dredger tailings piles could perform the same function. The distance to fall groundwater is unknown and will need quantification to ensure revegetation success. Test pits will need to be dug, piezometers placed and groundwater monitored to establish the elevation and the influence of mainstem streamflows on the shallow groundwater table.

Cost – High
Anticipated Benefits – Increased juvenile rearing habitat, increased cover and diversity of woody riparian vegetation, increased production of large wood, increased terrestrial inputs to aquatic zones, increased channel-floodplain connectivity, increased functional floodplain area and increased opportunity for lateral migration of main and/or side channel. Additional benefits, not related to habitat rehabilitation, involves the additional flood control that would be achieved with the construction of an engineered levee in place of the training wall, reduced water surface elevations, as well as the creation of storage area for floodwaters.

5.10 PROJECT 10: HAMMON BAR ENHANCEMENT

Location and current conditions – This project is located within and along the existing backwater on the southern edge of Hammon Bar (Figure 5-10). Along the upper portion and some edges of the existing backwater, woody riparian vegetation is well established. Along the middle portion of the backwater, as well as within the interior of Hammon Bar, the ground surface is mostly lacking riparian vegetation. Portions of the bar are low enough in elevation to support woody vegetation without requiring surface lowering.
Objectives – Increase and enhance juvenile rearing habitat, increase cover and diversity of woody riparian vegetation and increase the production of large wood (in 40 or more years once trees have matured)
Prescription and design elements – The project would plant riparian vegetation in the barren areas adjacent to the middle portion of the backwater and place large wood throughout its length.
Uncertainties and additional analysis – The distance to fall groundwater is unknown and will need quantification to ensure revegetation success. Test pits will need to be dug, piezometers placed and groundwater monitored to establish the elevation and the influence of mainstem streamflows on the shallow groundwater table. Placed wood may not persist past floods even with conventional anchoring techniques.
Cost – Low-medium (assuming $5,000/ac) with modest area of planting (~20 ac) and simpler methods of wood placement.
Anticipated Benefits – Increased juvenile rearing habitat, increased cover and diversity of woody riparian vegetation, increased production of large wood and increased terrestrial inputs to aquatic zones.

5.11 ADDITIONAL PROJECTS

In addition to the ten projects described above, several other possible rehabilitation projects within the Parks Bar to Hammon Bar reach may warrant consideration, but were not given attention in this report for several reasons:

- *Side channel creation* of on the bar on the north side of the river between Silica Bar and Hammon Bar would require willingness of a landowner not yet contacted.
- *Removal or realignment of Hammonton Road* between Lower Gilt Edge Bar and First Island would require support of Yuba County and easement holders to the roadway. This alternative to bio-engineering a hardened bank to protect the road would reconnect the main river corridor

to the mature riparian forest patch adjacent to the tributary that joins the river at this location and provide fish access to the habitat it provides.

- *Improvement of the confluence and lower reaches of Dry Creek* has potential to improve and increase aquatic habitat, but concepts for this type of project should be developed in a separate process involving the new landowner (Yuba County) and the large background of information on Dry Creek.

These projects and other additional projects may be advanced beyond concept even though not formally listed in this report.

5.12 PROJECTS SUMMARY

The ten potential rehabilitation projects outlined in this report represent an initial assortment of project types, grounded in conceptual elements, and useful for considering pilot efforts and longer-term options for a collaborative rehabilitation program. Table 2 compares the projects by contributing elements, relative cost, benefit and uncertainty. While these potential projects require more development to be described with accurate cost estimates or robust risk assessments, the relative degree of these characteristics is informative at this point for the purpose of preliminary planning.

Distributed riparian planting and large wood placement have cost/benefit ratios lower than any other types of projects. Although these two types of projects each provide enhanced rearing habitat through the provision of cover and velocity refuge, the expected outcomes contrast sharply in short-term versus long-term considerations of form and function. Large wood can be placed in configurations that provide immediate enhancement to rearing habitat, albeit with considerable risk to flood displacement or additional cost for fixing techniques. Riparian planting can be a relatively inexpensive way to produce a variety of enhanced rearing habitat features (e.g., large and small structural elements, food source) that self generate, but substantial benefits may not accrue in less than a decade, and the majority of shorter-term benefits would be limited to moderate flow levels occurring for only days or weeks of normal years. Hammon Bar is a unique location for testing methods of both riparian planting and large wood because of the following characteristics:

- Abundant area of suitable depths to groundwater for planting
- Diversity of bar surface substrate characteristics
- Backwater habitat including areas devoid of large wood and canopy cover
- Support by the BLM including existing signage and ranger patrols.

Among the remaining projects, side channel re-creation at Hidden Island likely has the lowest cost-benefit ratio because the side channel could provide a variety of aquatic and riparian habitat at frequently occurring discharge levels, and a modest amount of sediment would need to be excavated. Following necessary confirmation of access from the north side of the river, this side channel project warrants focused analysis to further evaluate costs and risks. High benefit projects of side channel creation and training wall removal or setback currently have high degrees of uncertainty, although training wall removal or setback alone has low uncertainty of long-term benefit. Hydrodynamic modeling is expected to reduce uncertainty for side channels of certain configuration in some locations.

Table 2. Potential project summary

#	Project Type	Contributing Elements	Cost[1]	Benefit[2]	Risk[3]
1	Distributed riparian planting	Optionally, planting could be done in conjunction with placement of wood.	low	medium	?
2	Distributed large wood placement	Optionally, placement could be done in conjunction with planting of riparian vegetation.	low	medium	??
3	Bank scalloping	Excavation of alcoves would involve lowering of floodplain elevation. Riparian planting would likely occur on the feathered slopes surrounding the alcoves.	low-medium	medium	??
4	Backwater expansion	Excavation of expanded backwater would involve lowering of floodplain elevation. Riparian planting would likely occur throughout modified area.	medium	medium	??
5	Percolation-fed backwater	Long backwater would involve area of floodplain lowering and riparian planting. Texturing, large wood or boulder placement would be optional.	high	high	???
6	Side channel re-creation	A minimal approach to excavation may involve negligible area of floodplain lowering, yet side channel could also be enhanced with riparian planting, large wood and boulders.	medium	medium	??
7	Bank bio-engineering	Bio-engineering structure would include riparian vegetation, boulders and large wood.	medium -high	medium	???
8	Side channel construction	Long excavated channel would involve area of floodplain lowering and riparian planting. Texturing, large wood or boulder placement would be optional.	medium -high	high	???
9	Training wall setback & side channel construction	In addition to elements for described for side channel, large area of new floodplain surface would be set to functional elevation and planted with riparian.	high	high	??
10	Riparian & wood enhancement at Hammon Bar	This project is expected to minimize cost by only planting riparian and placing wood, but addition of boulders would be optional.	low-medium	medium	?

1) Cost categories (inclusive of design and permitting) are low (<$100,000), medium ($100,000 - $500,000) and high (>$500,000).
2) Benefit defined as relative increase in capacity of juvenile salmonid rearing habitat over a 20-yr period.
3) Risk defined as relative uncertainty in meeting habitat enhancement objectives due to lack of persistence in design features or chance of failure resulting from natural disturbance. The Project Screening Risk Matrix at www.restorationreview.com was used as a tool to assign projects to one of three categories of risk.

5.13 PERMITTING

Permitting is an important consideration from the standpoints of feasibility, cost and scheduling. Any of the projects described would require permits from multiple state and federal agencies. An expert in permitting of environmental projects participated in our team's discussion of potential projects and has offered the opinion that all these actions could be permitted, but the exact permits to be obtained can only be determined following design details and consultation with permitting authorities. The California Department of Fish and Game, USFWS and USACOE should be consulted immediately upon planning a specific project. A requirement by the Corps for a Clean Water Act 404 permit would be a trigger for permits from as many as six other agencies and regulations.

6 RECOMMENDED NEXT STEPS

The lower Yuba River has been subject to intensive inter-agency and collaborative processes focused on evaluating flow regulation, water temperature and salmonid populations. While none of these processes focused on developing habitat rehabilitation projects, several addressed the need for such projects, and the Narrows Relicensing and Yuba Accord processes established funds for project implementation. Current funding by the AFRP for rehabilitation planning and pilot project implementation represents the beginning of a new process, which will begin rehabilitating the lower Yuba River following impacts dating back more than a century. The success of these rehabilitation efforts depends on thorough scientific and procedural steps of development, as well as the support of Yuba County citizens and stakeholders. We recommend the following five actions or directions as next steps:

1) **Coordinate monitoring and evaluation efforts to refine rehabilitation objectives and evaluate project effectiveness.** The RMT has already developed draft protocols for substrate, cover and riparian mapping, as well as a protocol to locate juvenile fish observed during snorkel surveys. Many important hypotheses regarding rearing habitat limitations, and opportunities for enhancement, can be tested when fish habitat utilization data are integrated with high-resolution topography and mesohabitat mapping being developed by Dr. Pasternack. However, the RMT is only charged with evaluating habitat within the operational limits of Yuba Accord flows (<5,000 cfs), and additional funds are necessary to expand these monitoring and evaluation efforts into other areas for potential habitat improvement, including lower elevation floodplains that are inundated by flows greater than 5,000 cfs. Furthermore, the RMT's Monitoring and Evaluation Plan (Yuba Accord River Management Team 2010) provides an excellent foundation for attaching specific monitoring objectives related to rehabilitation projects, yet the plan is not mandated to extend beyond 2016. Expanded scope, timeline, and funding will be necessary to adapt the Monitoring and Evaluation Plan to evaluate project effectiveness of rehabilitation objectives requiring a longer monitoring period that extends beyond 2016.

2) **Promote research on critical questions for prioritizing and designing restoration projects.** This report has not generated a list of critical questions, but for the purpose of describing rehabilitation elements and potential projects has noted these examples:
   - What are channel incision rates at different longitudinal locations and in association with training walls? What are expected future incision rates, and how will these rates affect side channel, alcove, floodplain and riparian revegetation designs?
   - What change in riparian stand dynamics over time can be attributed to hydrologic change, channel incision, dredger mining, training walls, substrate size changes, or other activities?

   Recent research of geomorphic processes has provided an improved understanding of factors limiting or contributing to the existence of various habitat features, and there is more to be accomplished. Research into riparian stand dynamics and factors influencing recruitment on other rivers in the Central Valley (e.g., Stella and Battles 2010, Harper et al. 2010) has similarly advanced the science and policy of riparian restoration; however, unique factors of the lower Yuba River require field experimentation for developing useful models for riparian hardwood recruitment success. These types of research and those addressing other questions germane to restoration science can be funded through non-local sources such as the National Science Foundation.

3) **Implement pilot projects for riparian planting and wood placement that test both design features and success factors.** A pilot project for riparian planting could take advantage of the attributes of Hammon Bar and smaller locations upstream to test the survival of pole plantings according to the following factors: species, cutting diameter, substrate, elevation and depth to groundwater. In addition, soil amendments, browse protection and partial irrigation could be administered in an experimental design. We recommend a minimum two-year project. In the first year, install peizometers with first-year plantings to accurately monitor groundwater data and plant survival. In the second year, plantings could benefit from refined planting locations and various planting machinery (e.g., ripper bars, Stinger, backhoe, excavator) to achieve greater cost-efficiency. Large wood placement could be included into the pilot project at Hammon Bar in a similar experimental fashion, or merely as a pilot for developing logistics (i.e., identify partners, large wood sources and transportation processes). These pilot projects should be done without delay because monitoring and assessment of these project will provide data for research (item 2 above) and technical discussions (item 4 below), as well as recommendations in the Rehabilitation Plan (item 5 below).

4) **Convene a technical forum for refining rehabilitation concepts and developing additional pilot projects**. The high cost of most channel modifications warrant additional analyses prior to choosing final project designs and locations. For example, the best location for a side channel may not be in the Hammon Bar reach, but in another reach of the lower Yuba River. The technical forum should consider the entire riverscape and all relevant ecological information to articulate specific objectives prior to developing projects with high cost. In the event that projects 3, 4, or 6 prove to have feasible cost and anticipated high ecological benefit, this technical forum would advise final design of those projects. This forum could be held by the River Management Team or a subgroup of the Lower Yuba Fisheries Technical Working Group.

5) **Develop a comprehensive Rehabilitation Plan for the lower Yuba River corridor.** The plan should summarize our understanding of how the lower Yuba River used to function, how it's been changed (for better or worse) and how the associated ecological values have changed to provide a framework for identifying, prioritizing, designing, implementing and monitoring prioritized rehabilitation actions along the lower Yuba River. The Rehabilitation Plan should provide an overall strategy, with goals and objectives to achieve that strategy, followed by rehabilitation actions that achieve those goals, objectives and strategy. In contrast to the Draft Implementation Plan for Lower Yuba Anadromous Fish Habitat Restoration (LYFTWG 2005), a Rehabilitation Plan would include specific recommendations for projects that meet articulated goals and objectives, and provide tools for evaluating the sequencing and placement of projects in the riverscape. The plan should also coordinate the permitting, funding and monitoring of such projects. This plan must address needs for long-term coordinated monitoring (item 1 above), and include the entire spatial extent of the lower Yuba River from Englebright Dam downstream to its confluence with the Feather River.

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A) This section of the Hammon backwater exhibits interaction of complex aquatic and riparian habitat and has historically contained high densities of juvenile salmonids[1].

B) This complex riparian-aquatic interaction is resulting in scour to create depths greater than 6 ft. Juvenile Chinook, Steelhead and two other species of native fish are shown.

C) Salmon carcass retained by small wood in turn retained by a piece of large wood.

D) Juvenile Chinook using velocity refuge and cover provided by willow stems and roots.

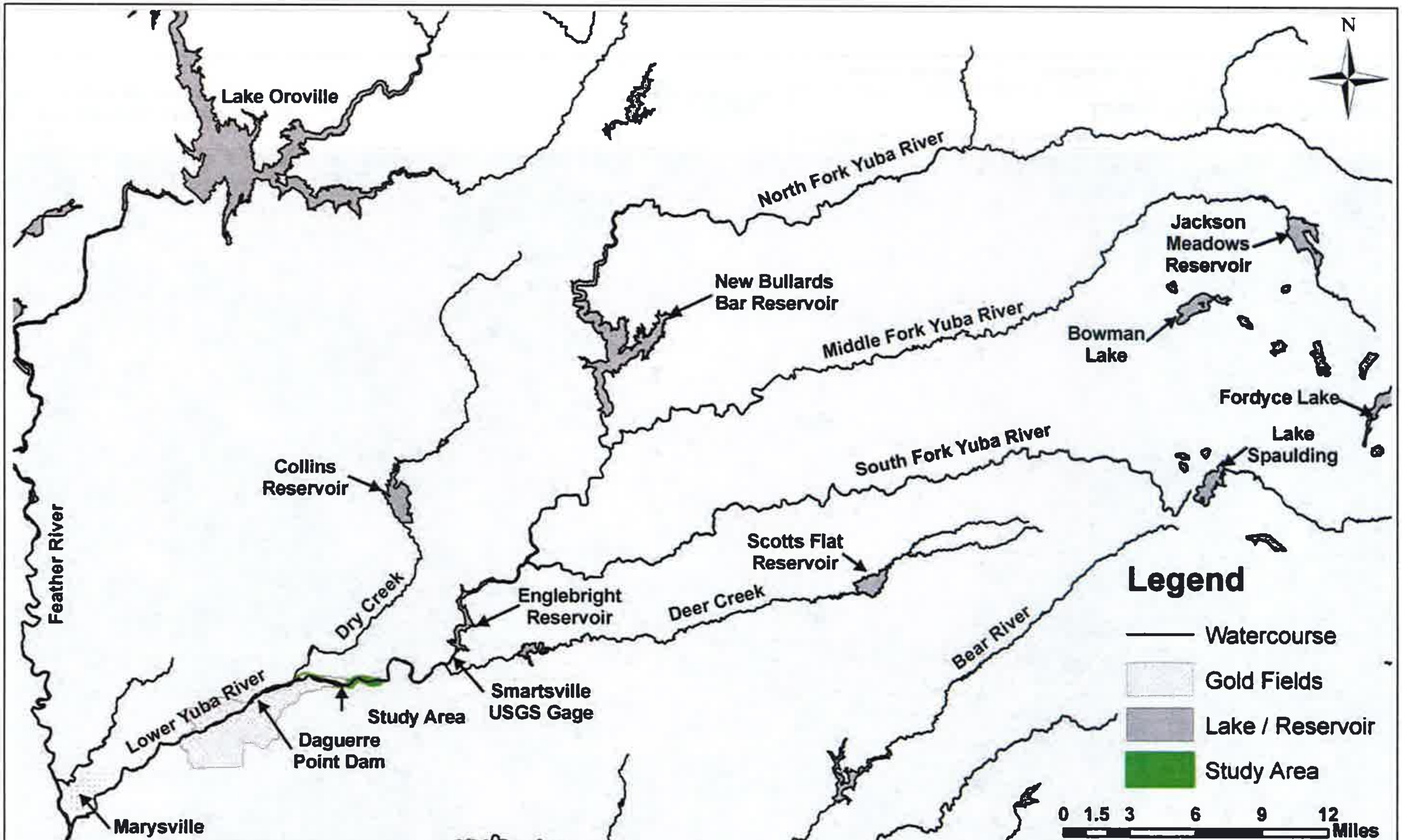
Notes: 1) Visual estimates by G. Reedy in 2006 & 2008, contained higher densities in the backwater than in the proximal main channel. 2) All photographs taken within main channel and off channel aquatic habitats found in the lower Yuba River. 3) Photos credits: A-C, G. Reedy; D, R. Cutter.

cbec

Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River

Examples of Complex Habitat Features - Lower Yuba River

Project No. 08-1021	Created By: GR/CTH	**Figure 2-1**

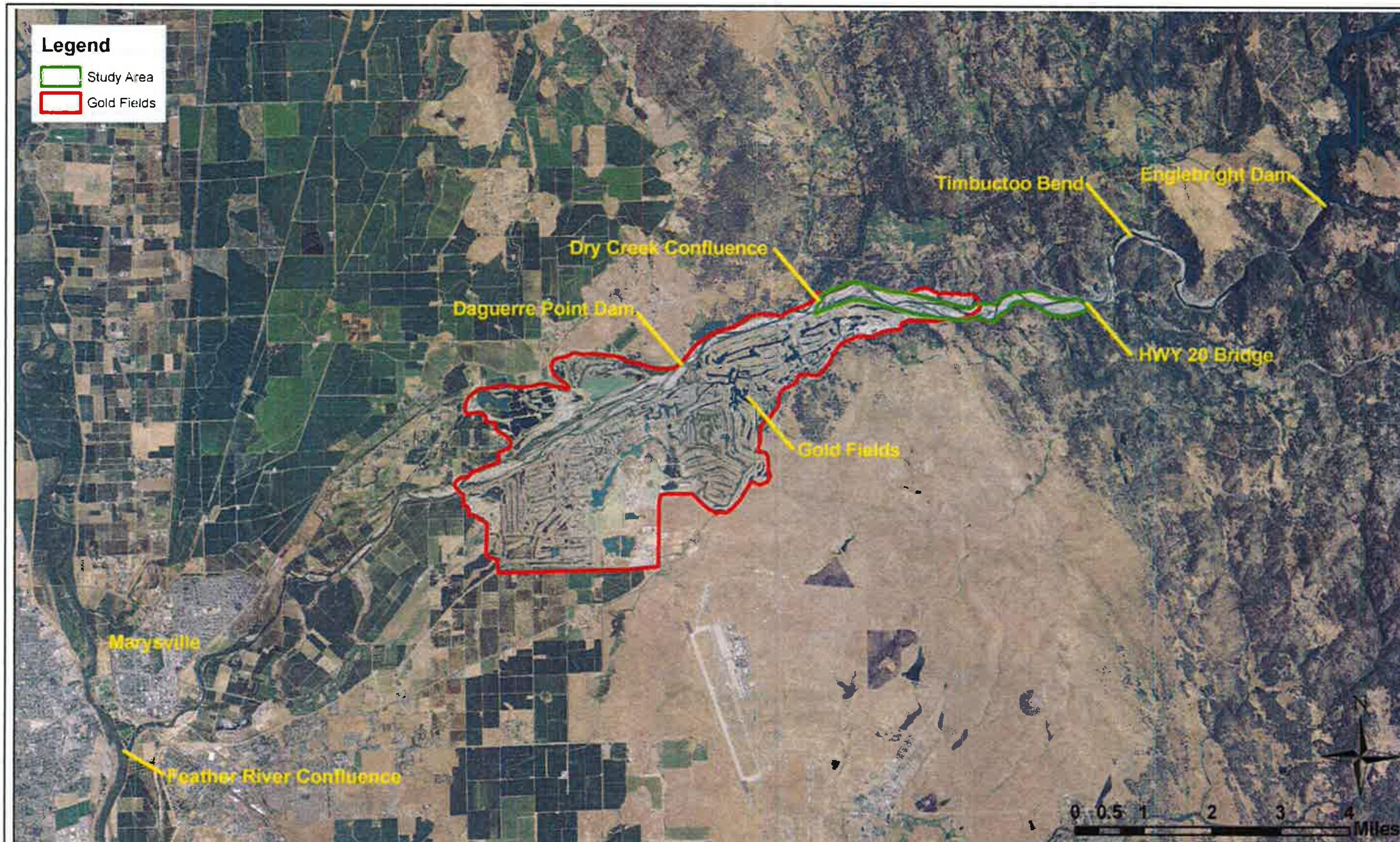


Notes:
Gold Field boundaries are approximate.

Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River

Hydrologic Features of the Yuba River Watershed

Project No. 08-1021	Created By: CTH	**Figure 2-2**



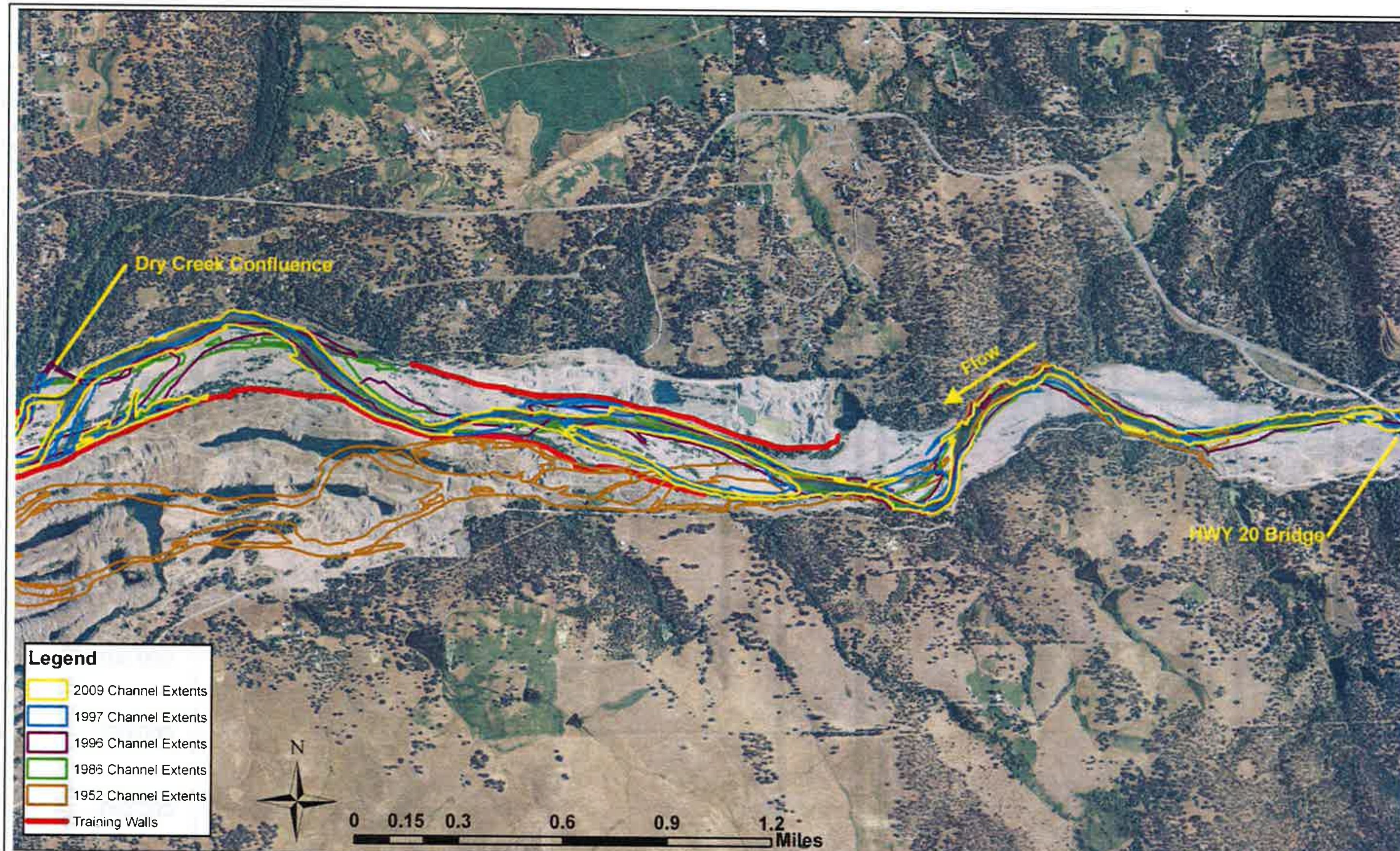
Notes:
Aerial image source, 2009 NAIP.
Boundaries are approximate.

cbec

Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River

Lower Yuba River Corridor

Project No. 08-1021 | Created By: CTH | **Figure 2-3**



Notes:
Aerial image source, 2009 NAIP. Figure includes a subset of channel alignments derived from geo-referenced aerial photographs. Additional years analyzed, but not shown here include: 1958, alternate 1986, 1987, 1991, 2002, 2005 and 2008.

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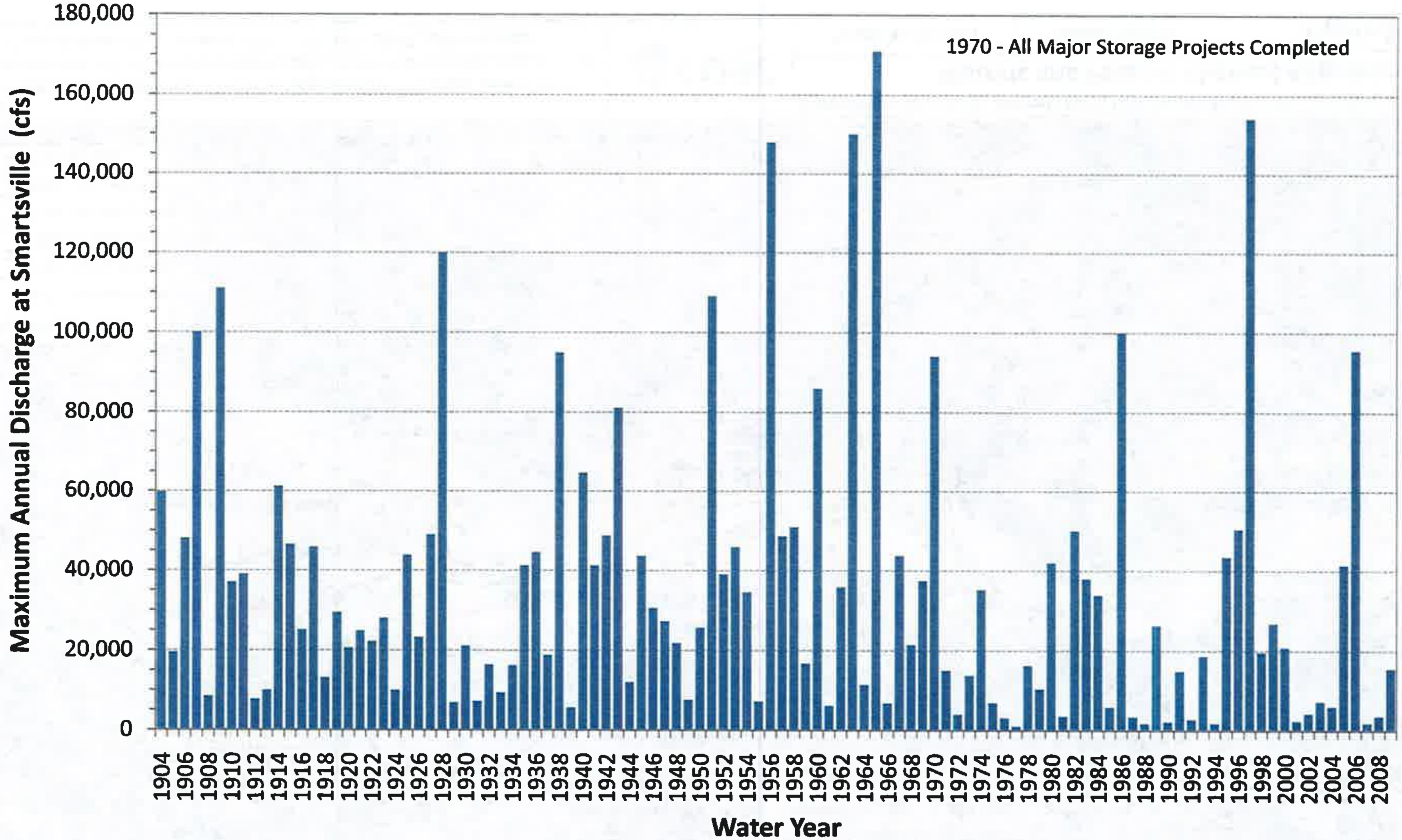
Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River

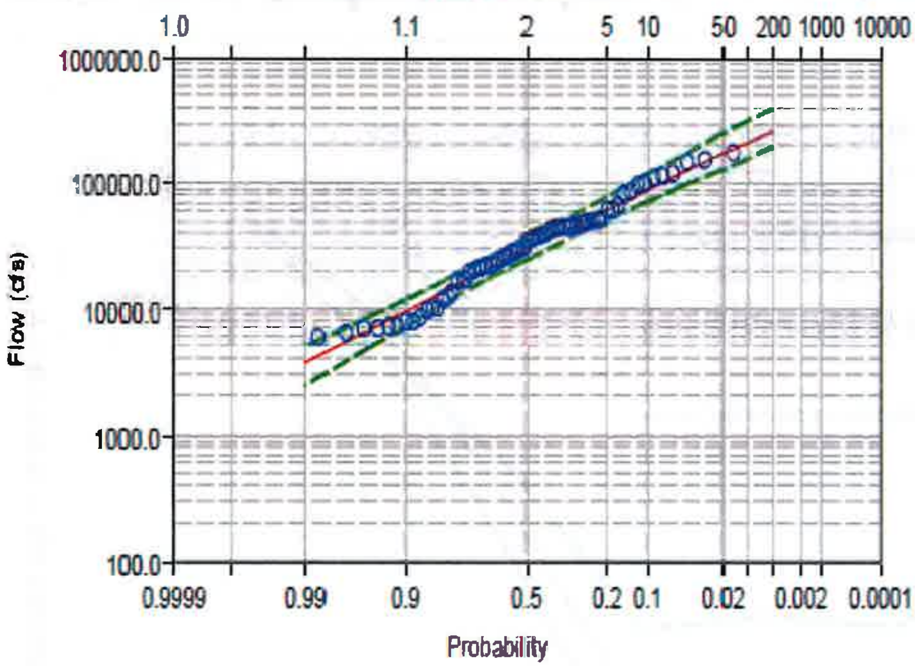
Historic and Present Channel Alignments

Project No. 08-1021	Created By: CTH	**Figure 2-4**



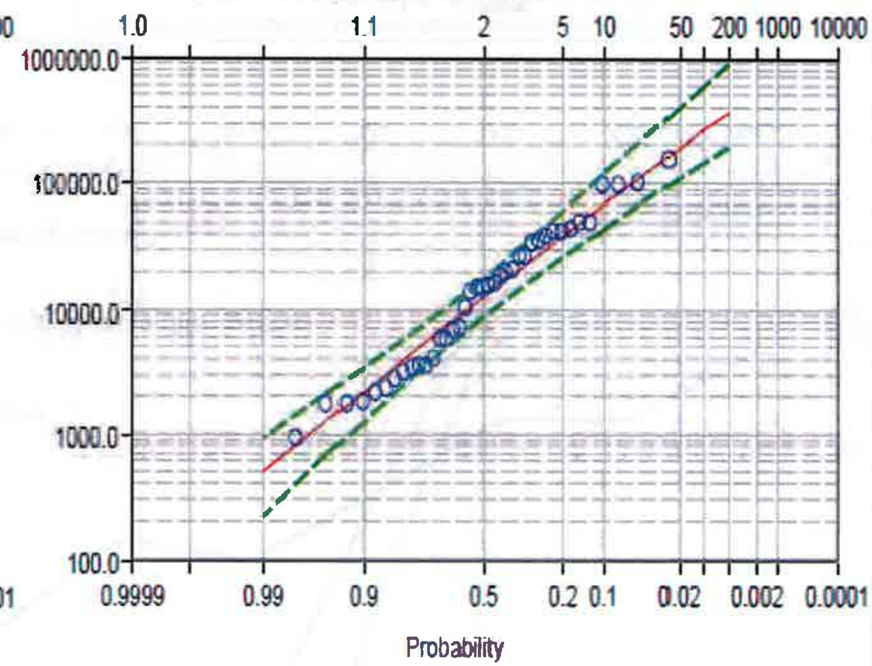
Notes: Maximum annual instantaneous discharge data for USGS Smartsville Gages: # 11419000 (1904-1941), #11418000 (1942-2009).	cbec	*Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River* **Maximum Annual Yuba River Discharge at Smartsville** Project No. 08-1021 | Created By: CTH | **Figure 2-5**

Transitional Period WY 1904-1969



Return Period	Discharge (cfs)
1.5	20,100
2	29,500
5	61,400
10	89,500
20	121,700

Regulated Period WY 1970-2009



Return Period	Discharge (cfs)
1.5	6,700
2	11,900
5	36,900
10	66,500
20	108,200

Notes: Flood flow frequency analysis performed with HEC-SSP 1.1 (USACOE 2009) following Bulletin 17B procedures (USGS 1982), using max. annual inst. discharge data for USGS Smartsville Gages: # 1141900 (1904-1941), #1141800 (1942-2009). Dashed green lines represent 5 % and 95% confidence intervals.

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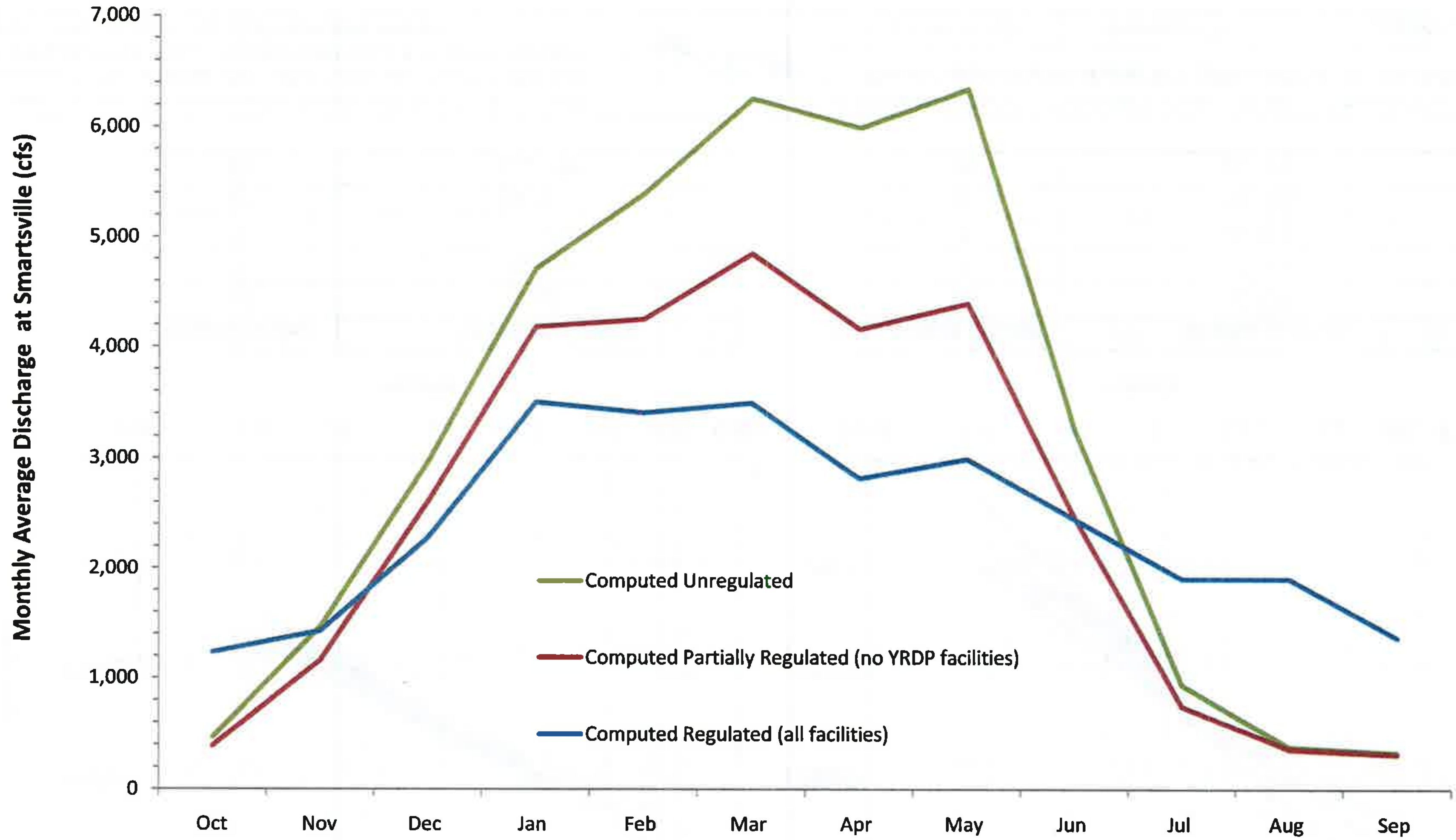
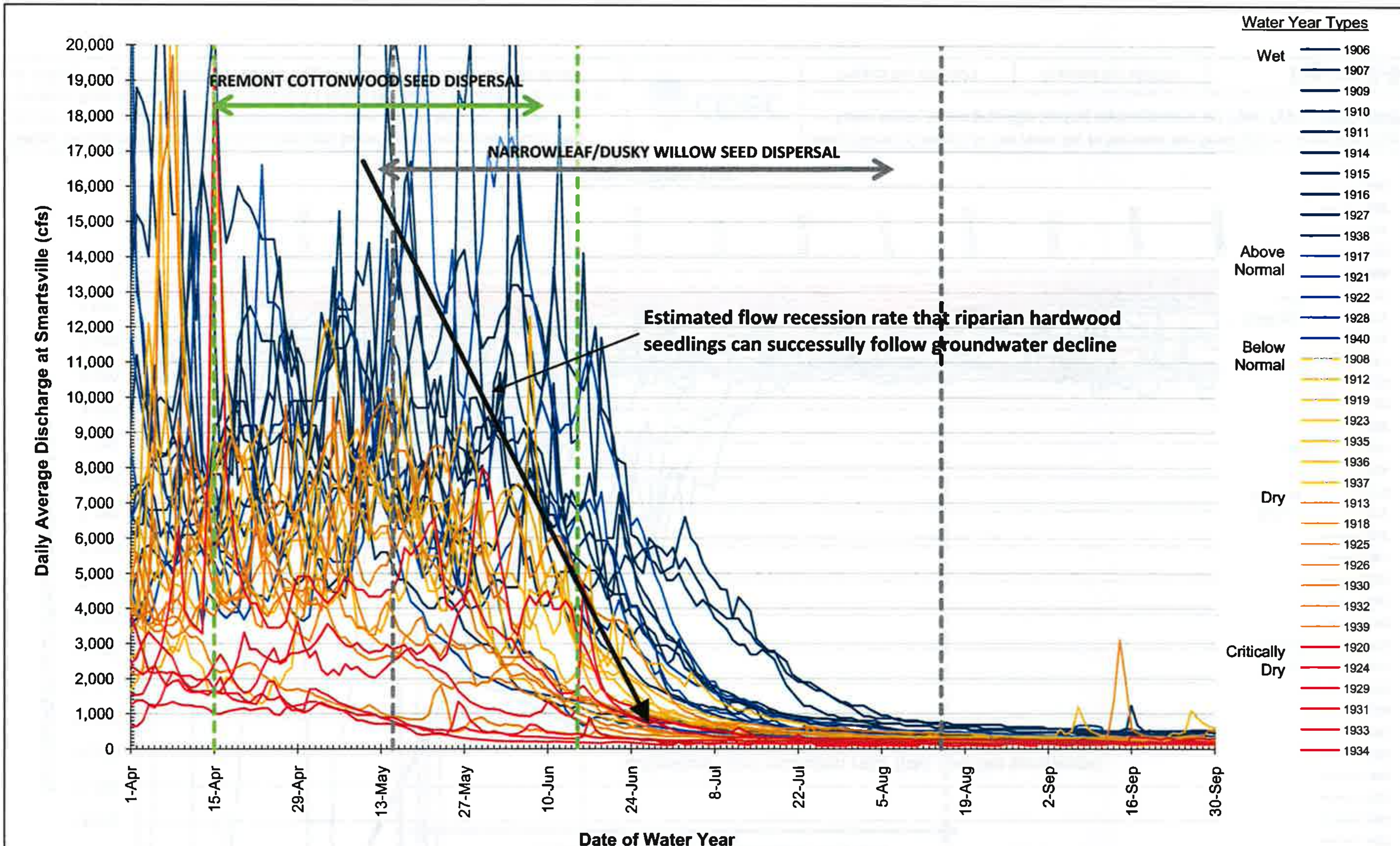
Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River

Flood Frequency Analysis: WY 1904-1969 & WY 1970-2009

Project No. 08-1021 | Created By: CTH | **Figure 2-6**



Notes: Data obtained from YCWA, 2009. Computed unregulated period of record is WY 1976-2004, while the computed partially regulated and fully regulated period of record is WY 1970-2008. For explanation of different conditions, see section 2.3.	cbec	*Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River* **Computed Monthly Average Yuba River Hydrographs**		
		Project No. 08-1021	Created By: CTH	**Figure 2-7**



Notes: Woody riparian seed dispersal periods based upon preliminary 2010 field studies (SYRCL unpub data) and data available from other California riparian systems. Rate of change corresponds to 0.1 ft/day (Mahoney & Rood 1998, Stella et al. 2010), using an h/Q table for above Daguerre Dam (Pasternack unpub. data).

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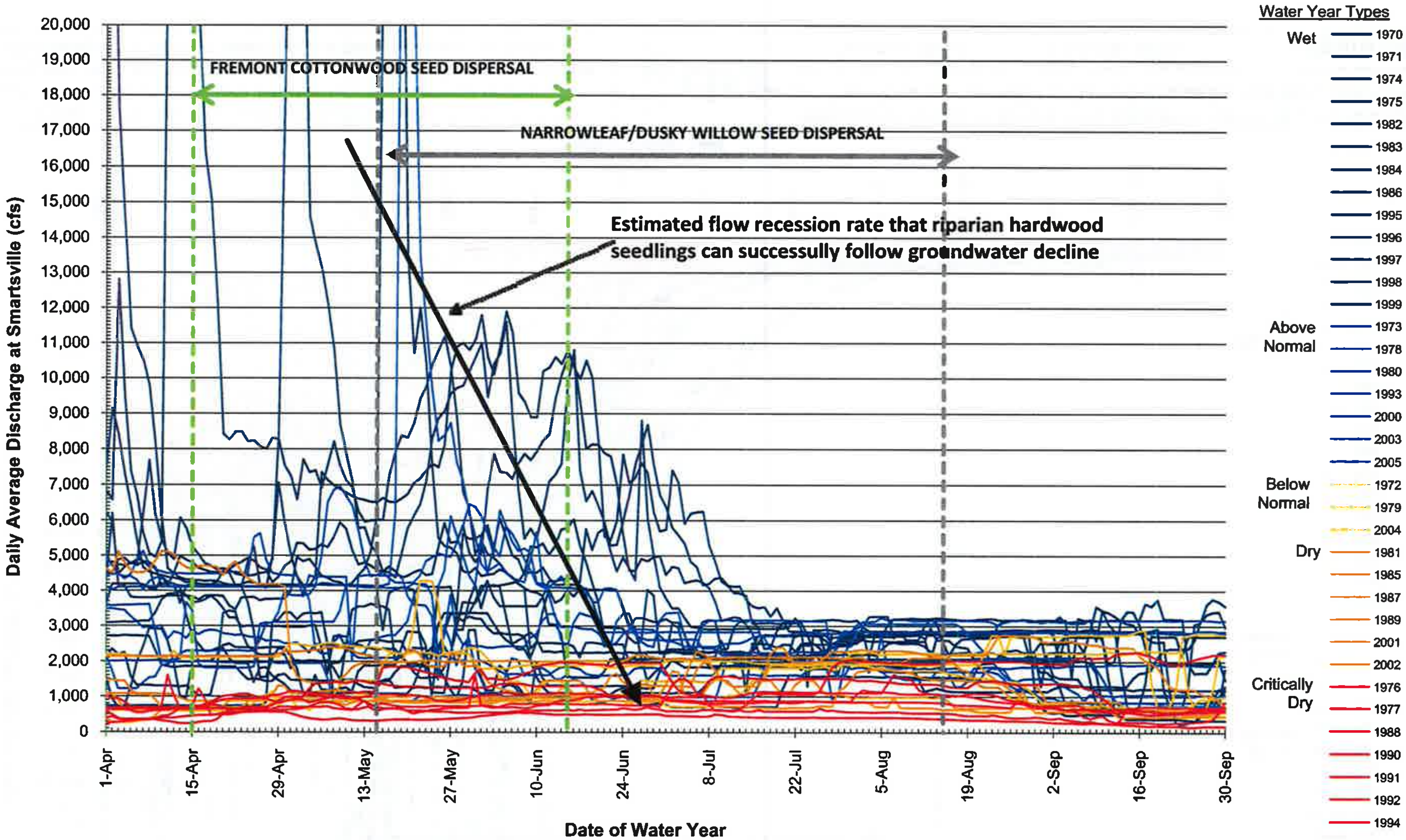
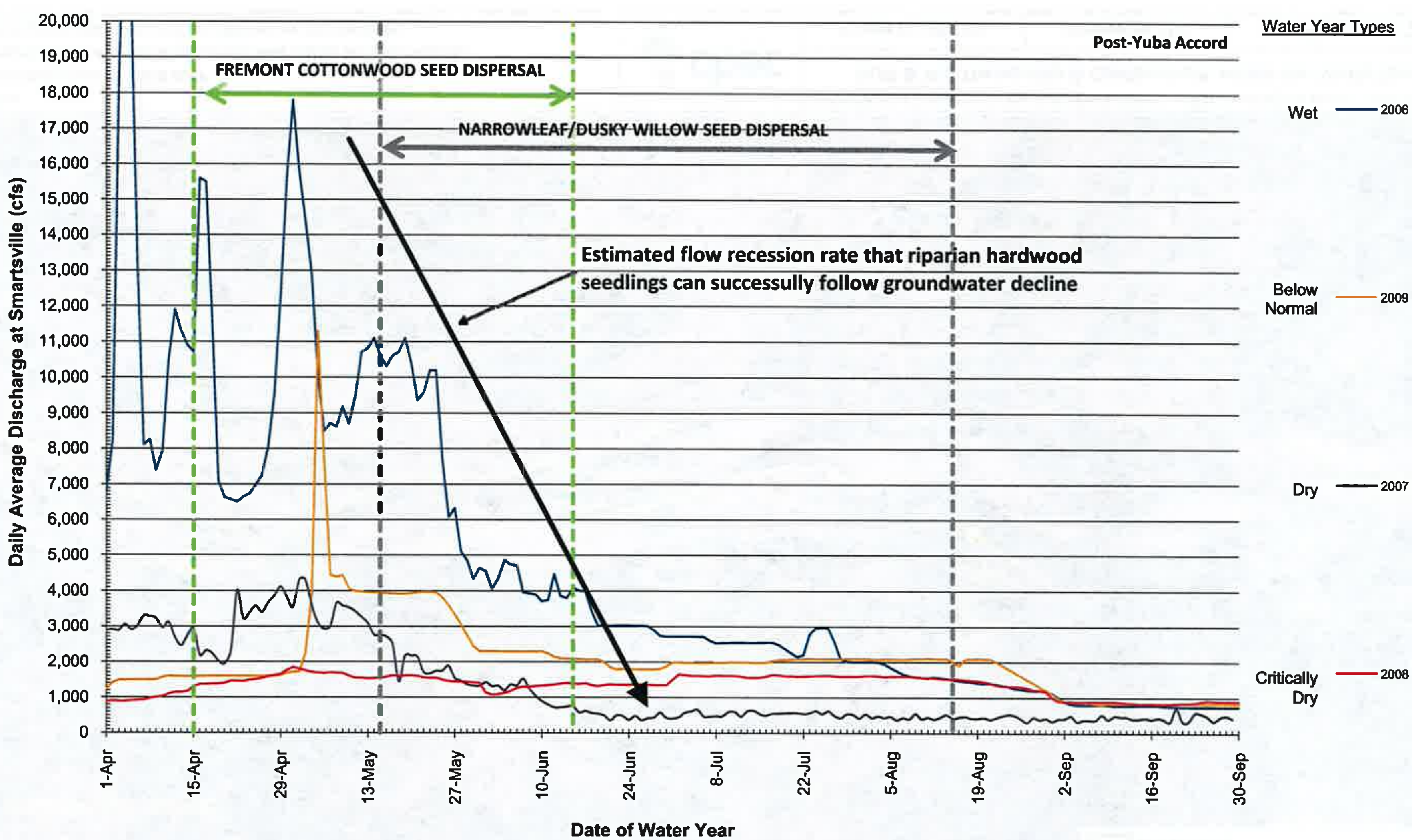
Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River

Yuba River at Smartsville Spring Hydrographs by Year Type: 1906-1940

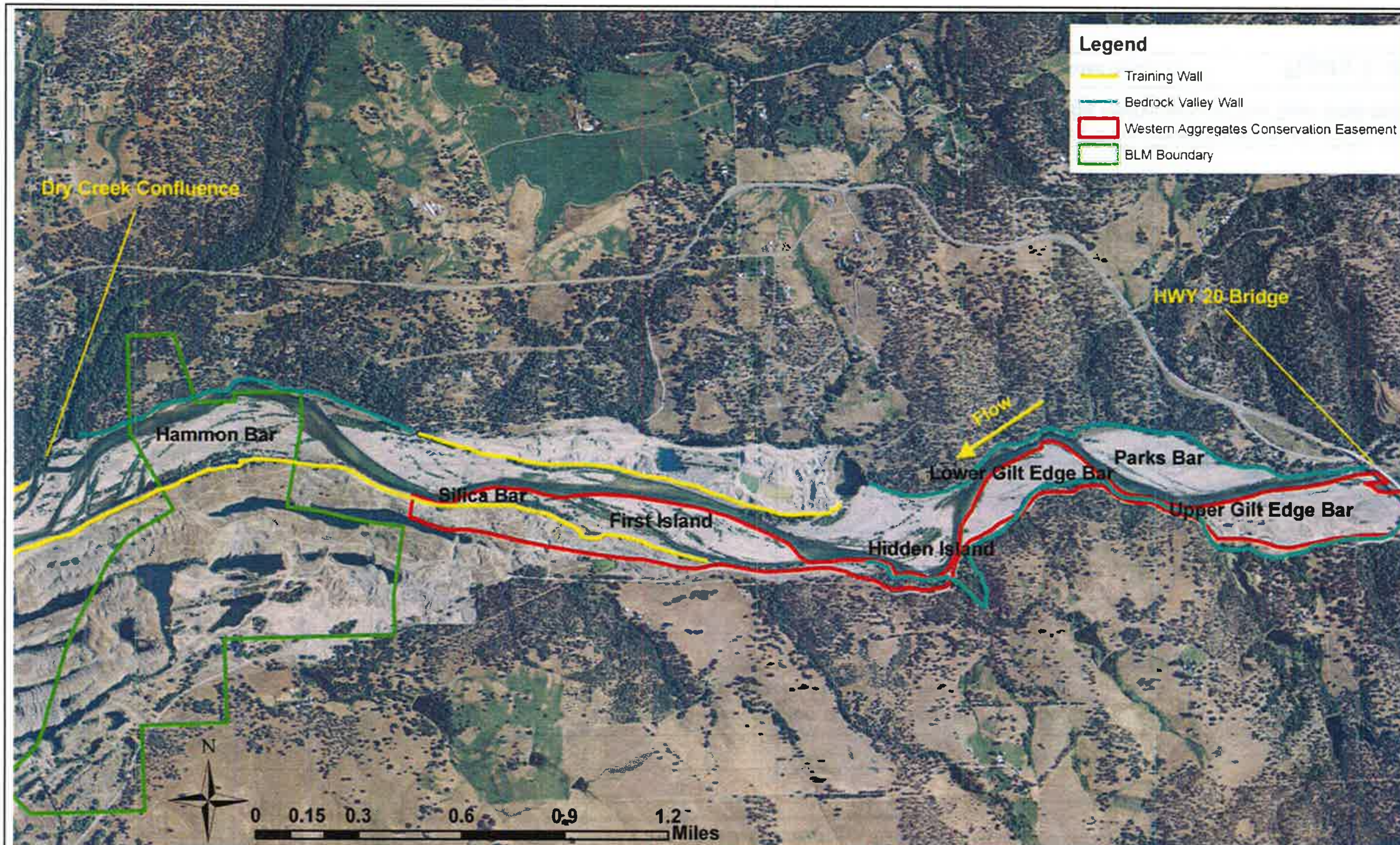
Project No. 08-1021	Created By: JB/CTH	**Figure 2-8**



Notes: Woody riparian seed dispersal periods based upon preliminary 2010 field studies (SYRCL unpub data) and data available from other California riparian systems. Rate of change corresponds to 0.1 ft/day (Mahoney & Rood 1998, Stella et al. 2010), using an h/Q table for above Daguerre Dam (Pasternack unpub. data).	cbec	*Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River* **Yuba River at Smartsville Spring Hydrographs by Year Type: 1970-2005**		
		Project No. 08-1021	Created By: JB/CTH	**Figure 2-9**



Notes: Woody riparian seed dispersal periods based upon preliminary 2010 field studies (SYRCL unpub data) and data available from other California riparian systems. Rate of change corresponds to 0.1 ft/day (Mahoney & Rood 1998, Stella et al. 2010), using an h/Q table for above Daguerre Dam (Pasternack unpub. data).	cbec	*Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River* **Yuba River at Smartsville Spring Hydrographs by Year Type: 2006-2009**
		Project No. 08-1021 | Created By: JB/CTH | **Figure 2-10**



Notes:
Aerial image source, 2009 NAIP.
Property and conservation easement boundaries are approximate.
Training wall and valley wall boundaries are approximate.

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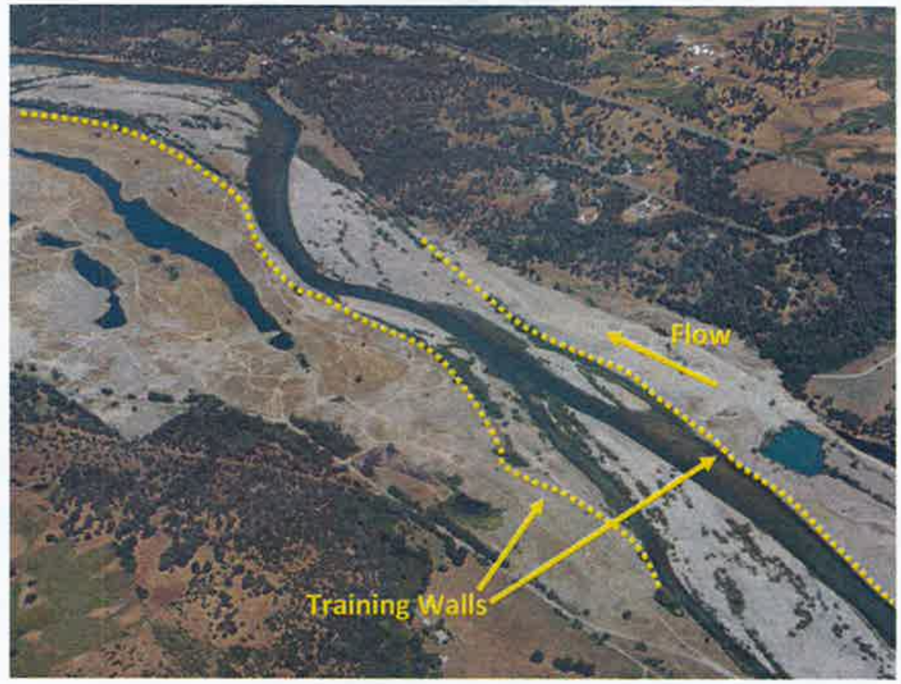
Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River

BLM & WA Ownership & Confinement within the Study Reach

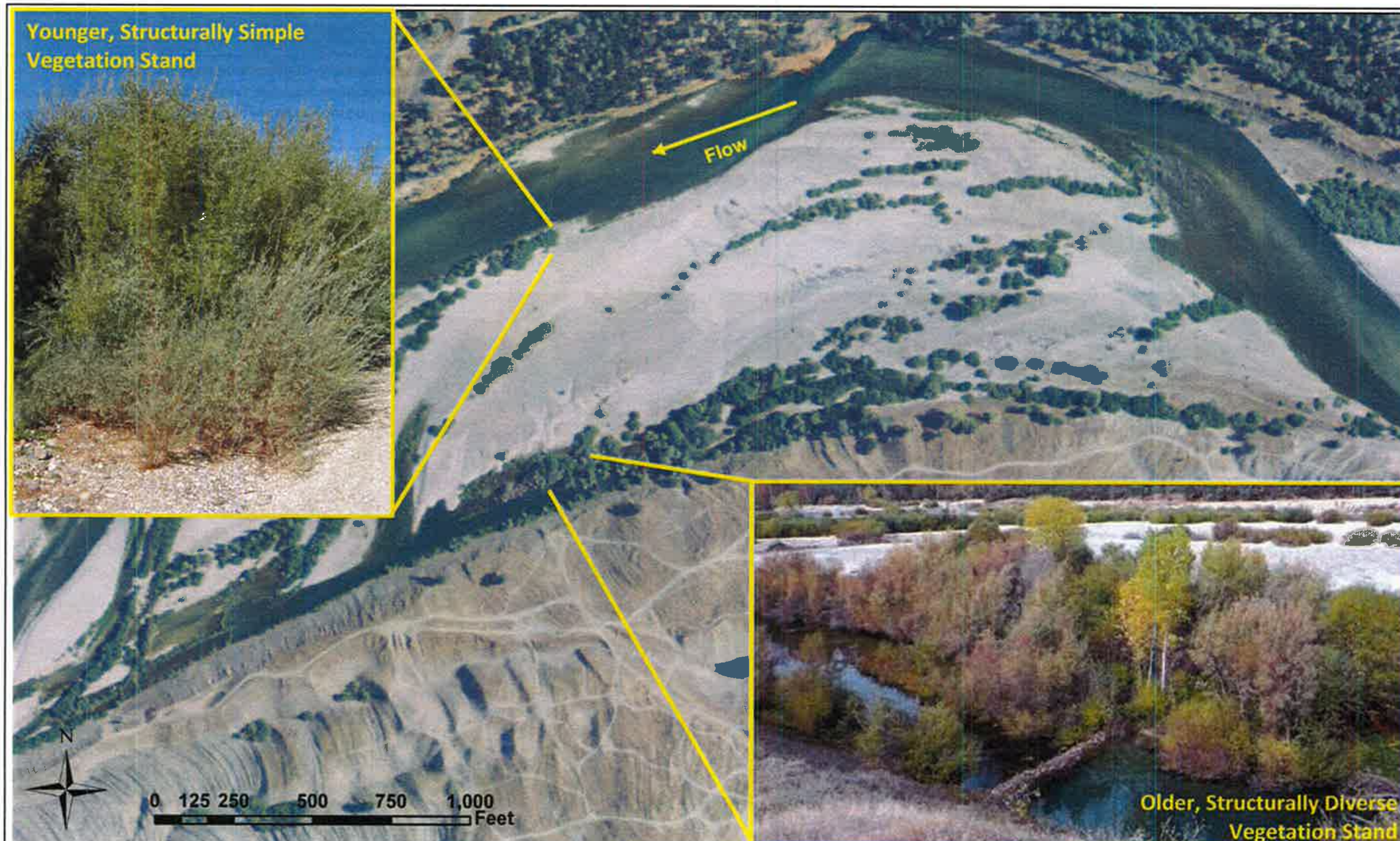
Project No. 08-1021	Created By: CTH	**Figure 2-11**

Upper Portion of Study Reach
Laterally Confined by Bedrock Canyon Walls

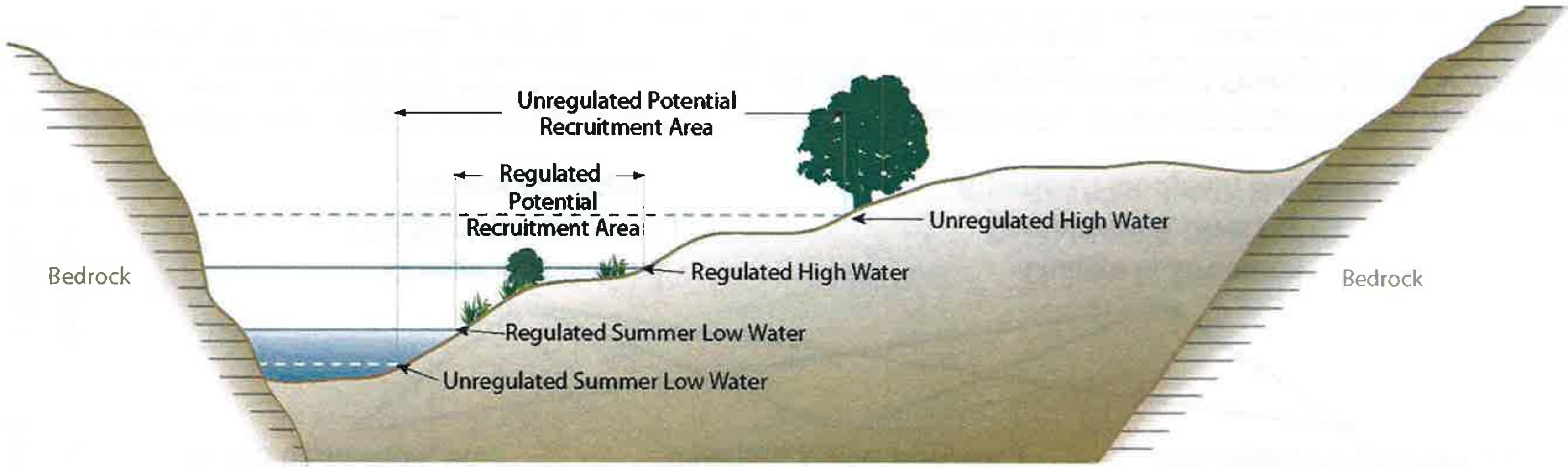
Lower Portion of Study Reach
Laterally Confined by Training Walls

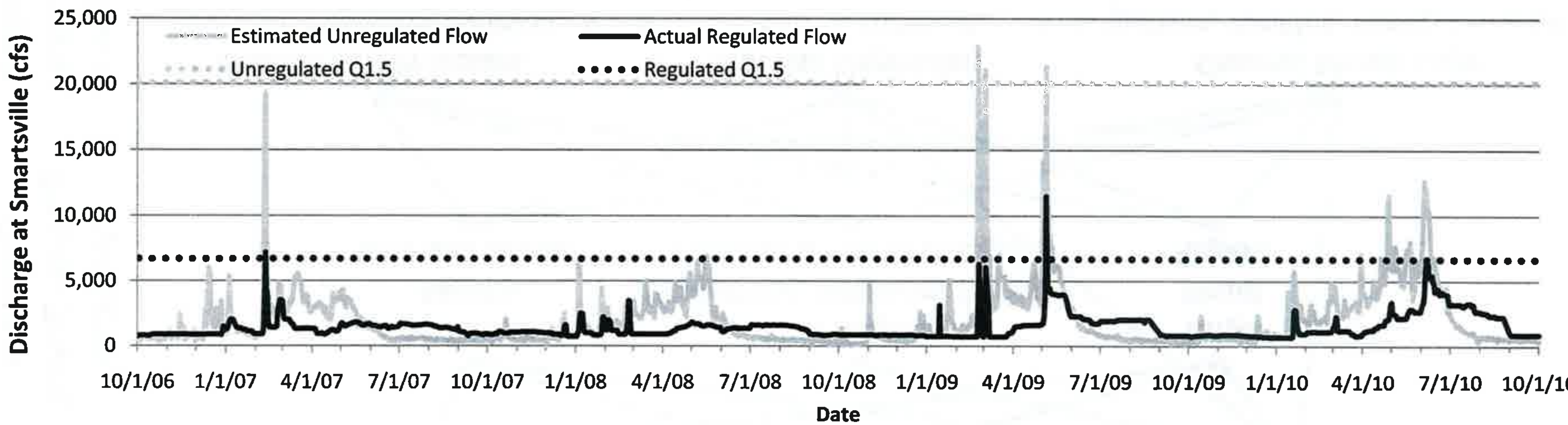


Notes: Photographs taken by G. Reedy. Aerial support provided by LightHawk. In the upper portion photograph, the flow direction is from left to right. In the lower portion photograph, the flow direction is from right to left.	cbec	*Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River* **Images of Study Area Showing Type of Confinement**		
		Project No. 08-1021	Created By: CTH	**Figure 2-12**

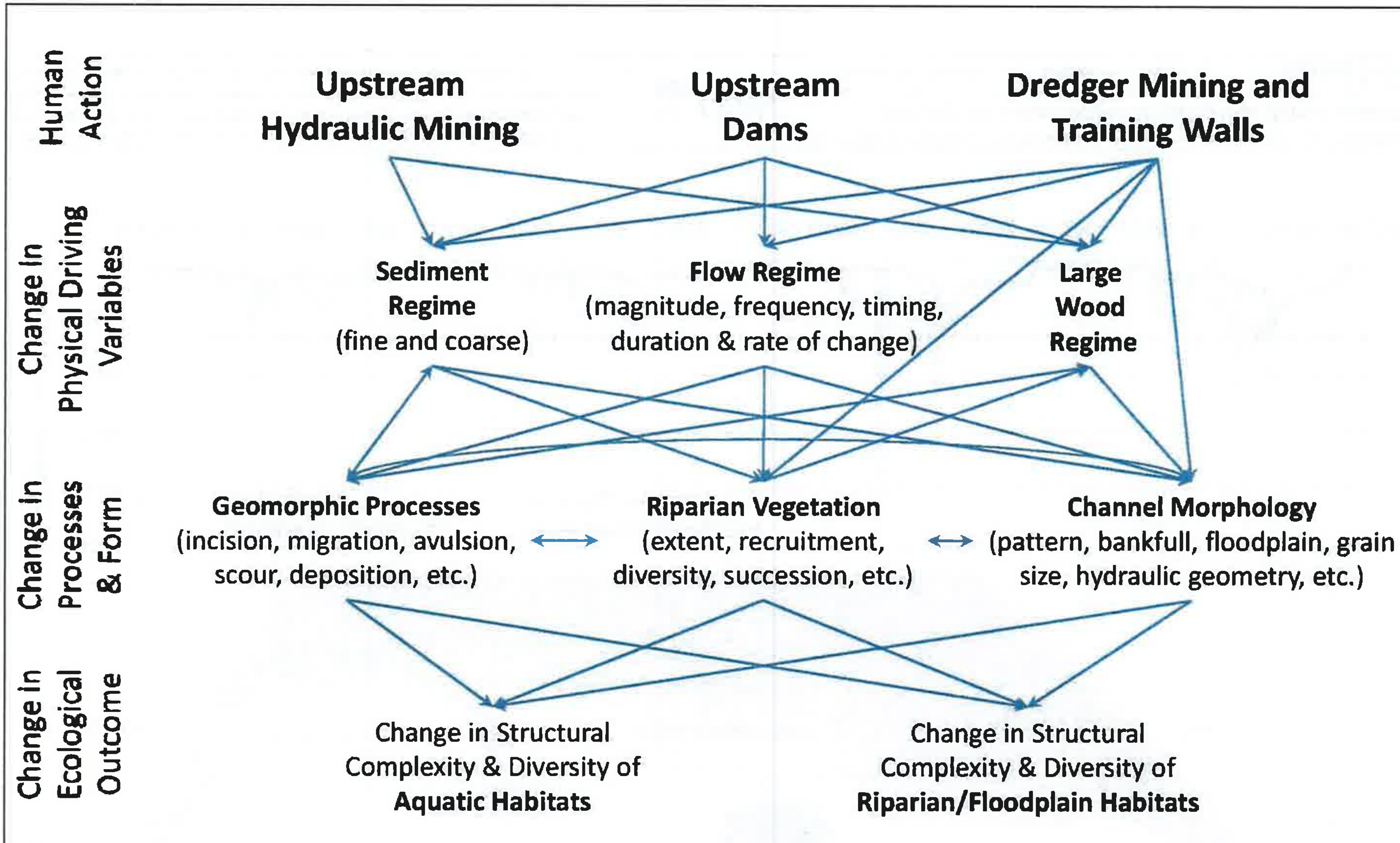


Notes: Aerial image source, 2009 NAIP. Younger vegetation photo taken by C. Hammersmark. Older vegetation photo taken by G. Reedy.	cbec	*Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River* **Existing Riparian Vegetation Patch Types**	
		Project No. 08-1021	Created By: CTH
			Figure 2-13





Notes: Upper figure is conceptual, and not to scale. High water levels reflect estimates of Q1.5-Q2. Hydrographs are presented for conceptual purposes only. Regulated and Unregulated flow data obtained from CDEC. Estimated unregulated flows are estimates and may differ from actual natural runoff conditions.	cbec	*Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River* **Conceptual Cross Section Showing Inundation Extents**		
		Project No. 08-1021	Created By: CTH/ML	**Figure 2-14**



Notes: Arrows represent linkages between 3 human actions (top) and aquatic and riparian habitat condition (bottom). The diagram does not include all actions, physical processes of habitat conditions (e.g., water temp.), but was created to aid conceptualization of categorical factors affecting habitat in the study reach.

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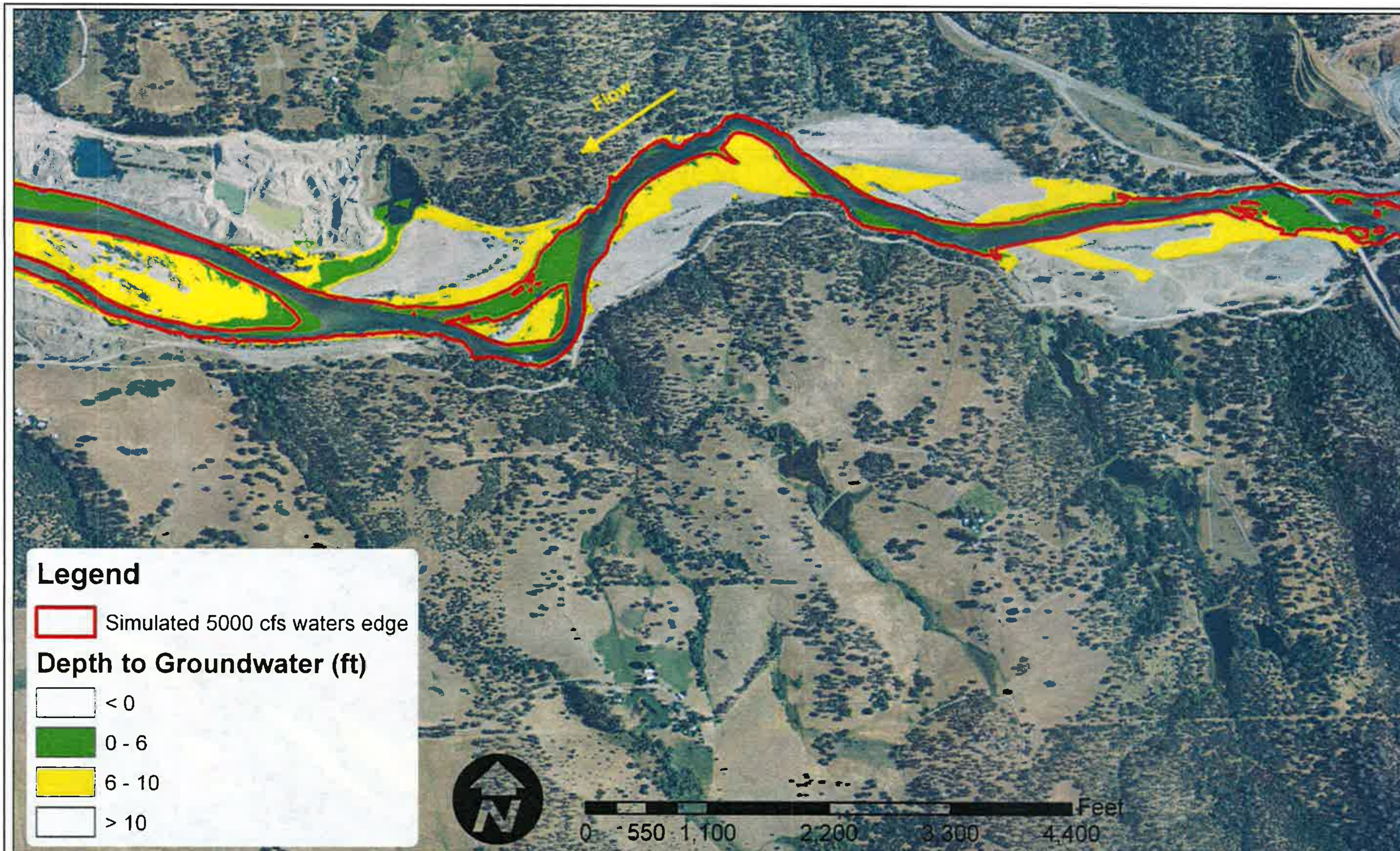
Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River

Conceptual Model of Changes to Lower Yuba River

Project No. 08-1021 | Created By: CTH | **Figure 2-15**



Notes:
Aerial image source, 2009 NAIP. Depth to groundwater computed as ground surface elev. minus simulated low flow (880 cfs) WSE. 5000 cfs and 880 cfs WSEs simulated with a 2D hydraulic model (Pasternack unpub. data), see section 4.1.

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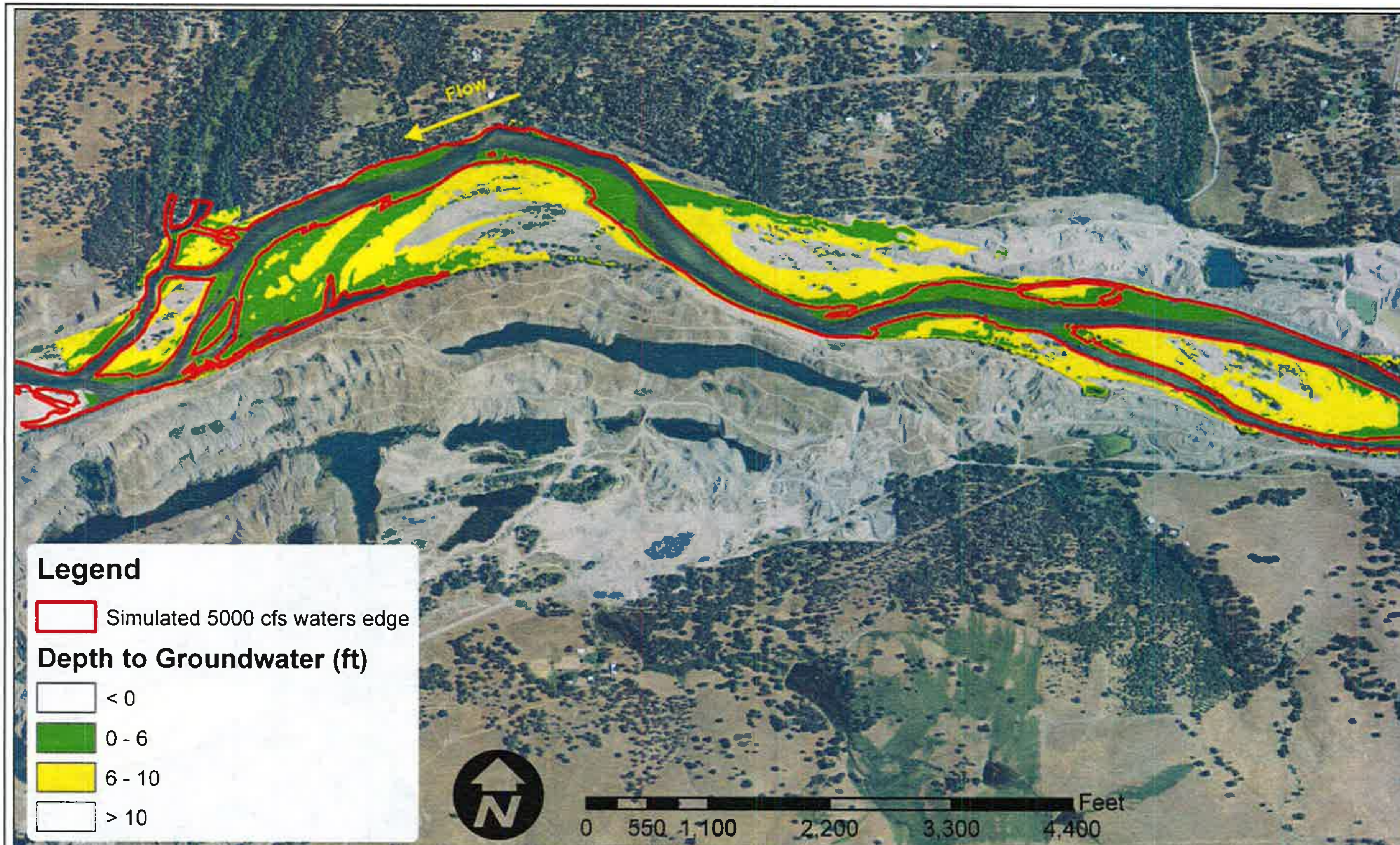
Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River

Estimated Maximum Depth to Groundwater – Upper Reach

Project No. 08-1021	Created By: CTH	**Figure 4-1**



Notes:
Aerial image source, 2009 NAIP. Depth to groundwater computed as ground surface elev. minus simulated low flow (880 cfs) WSE. 5000 cfs and 880 cfs WSEs simulated with a 2D hydraulic model (Pasternack unpub. data), see section 4.1.

Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River

Estimated Maximum Depth to Groundwater – Lower Reach

Project No. 08-1021 | Created By: CTH | **Figure 4-2**

Notes:
Photograph of Lower Clear Creek, taken by M. Tompkins.

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Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River

Example of Large Wood Used as Bank Protection

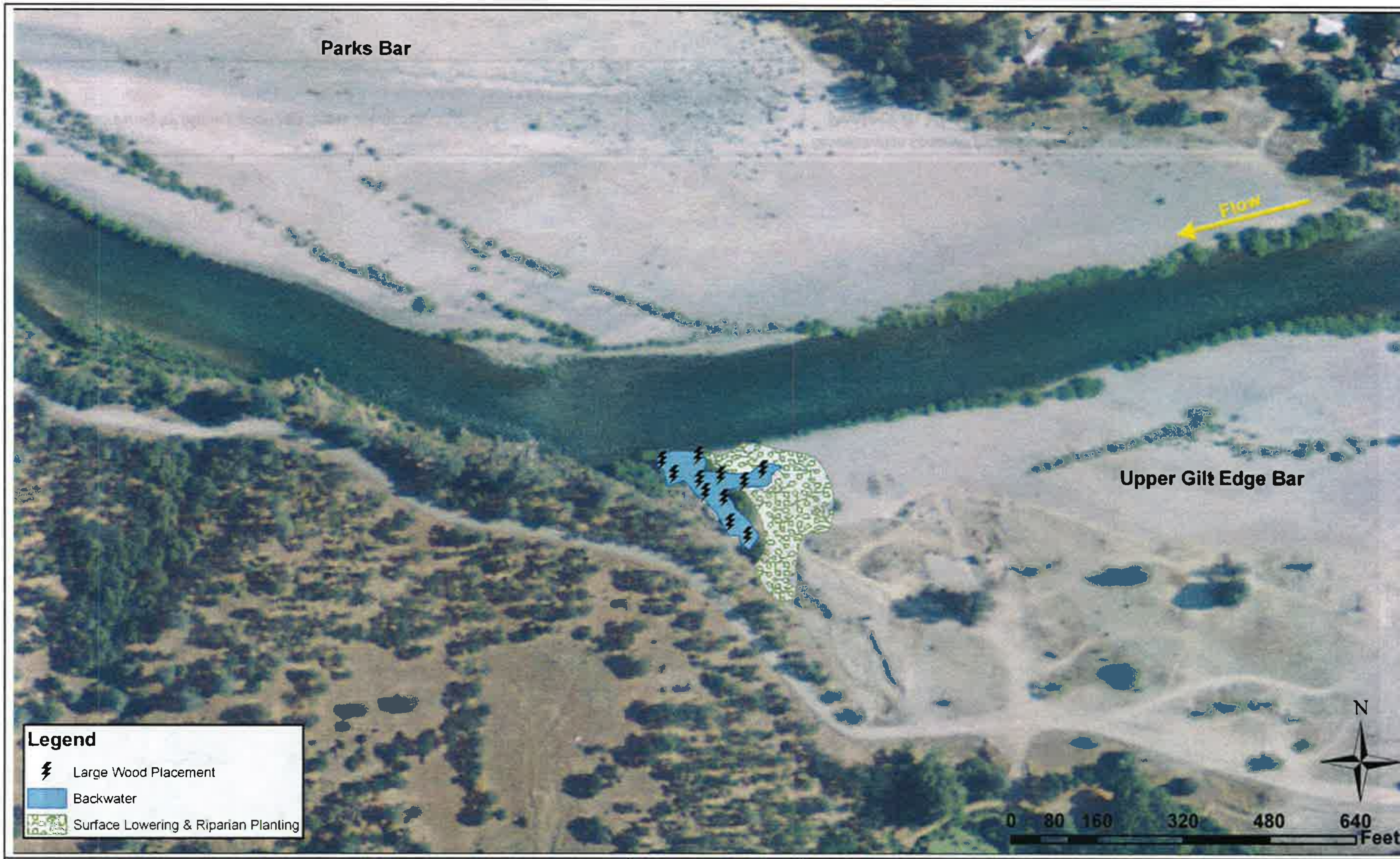
Project No. 08-1021 | Created By: CTH | **Figure 4-3**

Notes:
Aerial image source, 2009 NAIP.

Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River

Project 3: Bank Scalloping at Upper Gilt Edge Bar

Project No. 08-1021 | Created By: CTH | **Figure 5-1**



Notes:
Aerial image source, 2009 NAIP.

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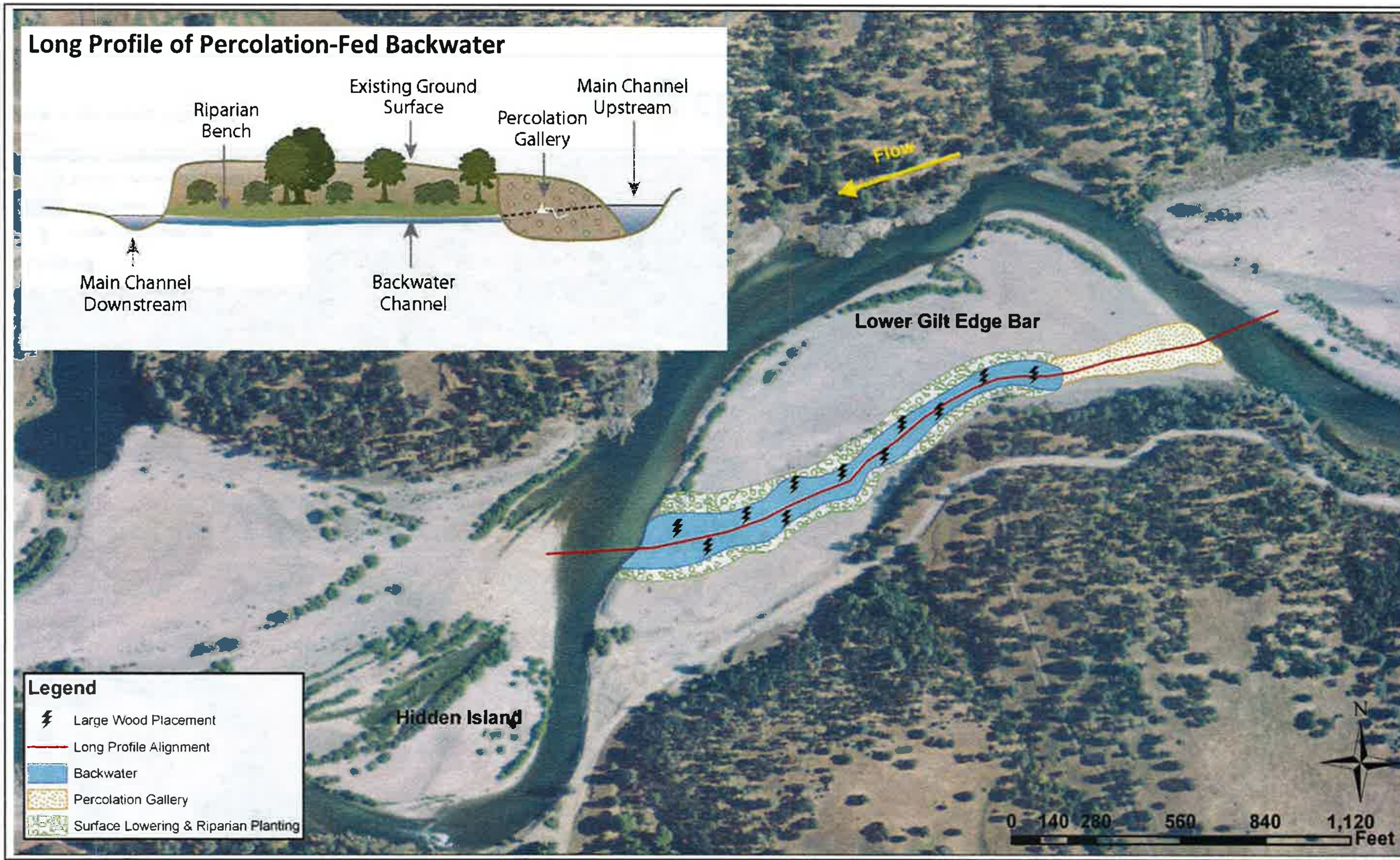
Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River

Project 4: Backwater at Upper Gilt Edge Bar

Project No. 08-1021 | Created By: CTH | **Figure 5-2**

Notes: Conceptual drawing by Mona Carlon and Derek Hitchcock.	cbec	*Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River* **Project 4: Visualization of Backwater at Upper Gilt Edge Bar**		
		Project No. 08-1021	Created By: CTH	**Figure 5-3**



Notes:
Aerial image source, 2009 NAIP.

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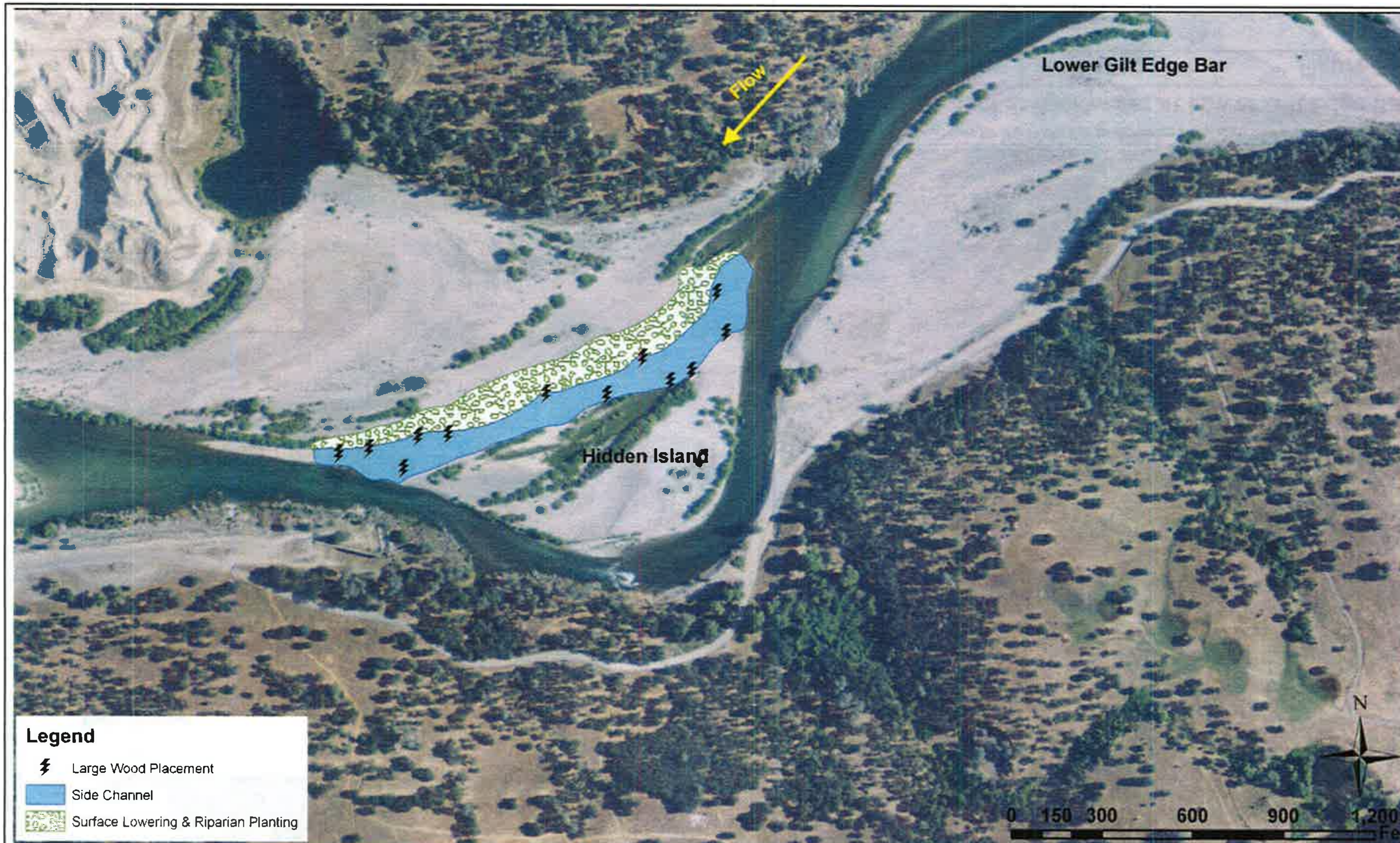
Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River

Project 5: Backwater at Lower Gilt Edge Bar

Project No. 08-1021 | Created By: CTH/ML | **Figure 5-4**



Notes:
Aerial image source, 2009 NAIP.

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Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River

Project 6: Side Channel at Hidden Island

Project No. 08-1021	Created By: CTH	**Figure 5-5**

Notes:
Aerial image source, 2009 NAIP.

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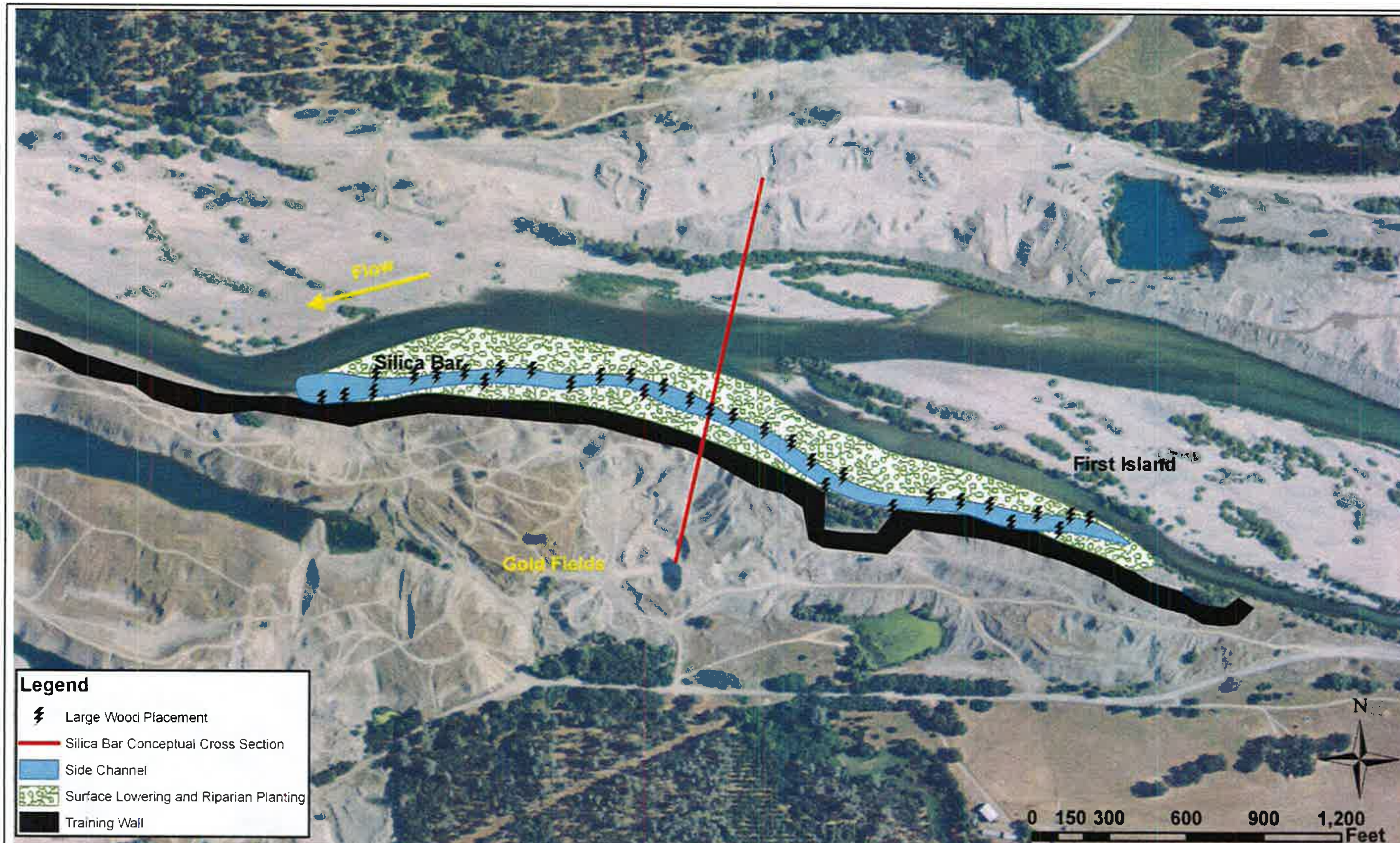
Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River

Project 7: Bank Bio-Engineering

Project No. 08-1021	Created By: CTH	**Figure 5-6**

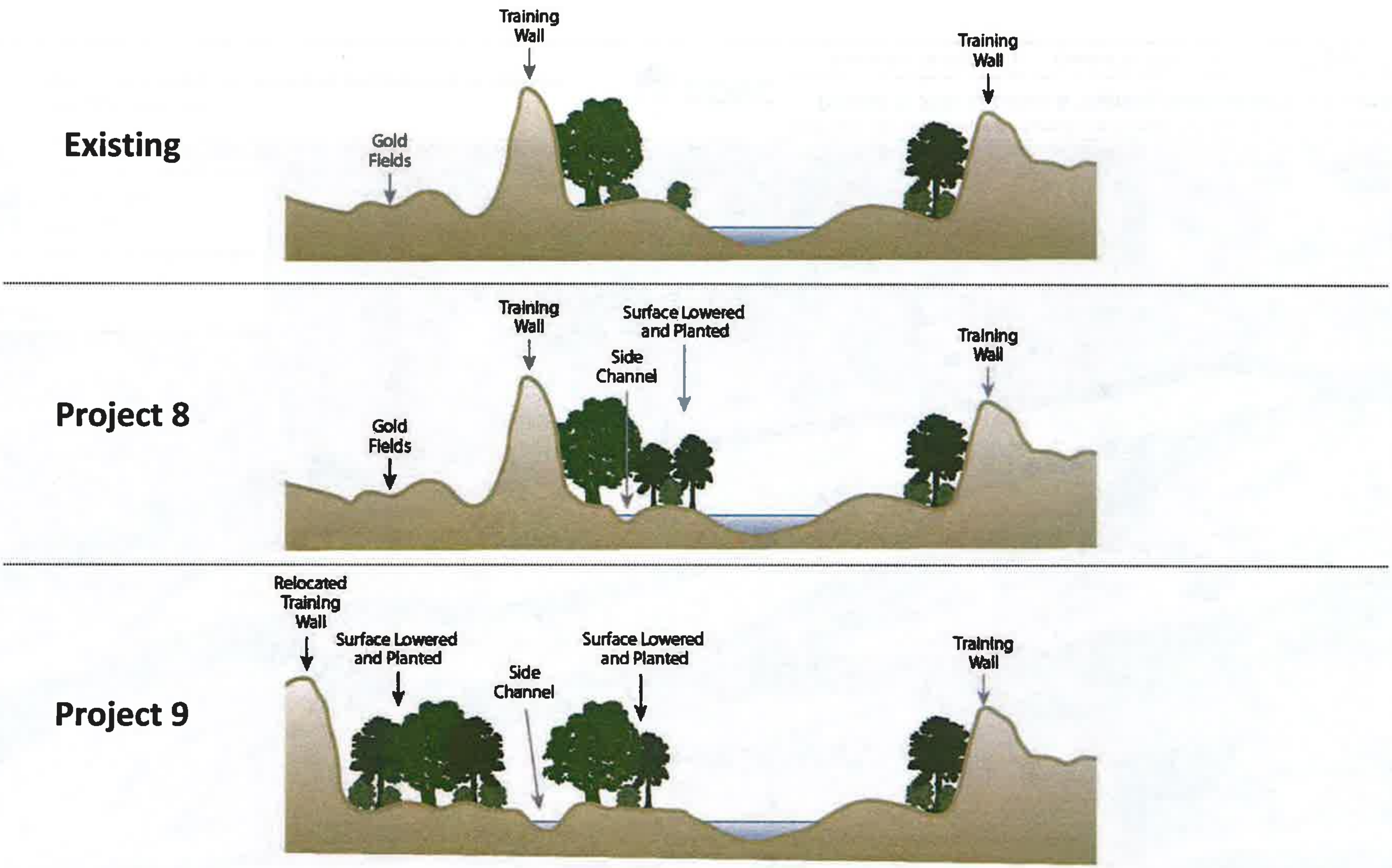


Notes:
Aerial image source, 2009 NAIP.
Refer to Figure 5-8 for a conceptual cross section along the indicated alignment.

Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River

Project 8: Side Channel at Silica Bar

Project No. 08-1021	Created By: CTH	**Figure 5-7**



Notes:
Refer to Figures 5-7 and 5-9 for conceptual planform drawings of Projects 8 and 9, and the alignment of this conceptual cross section.

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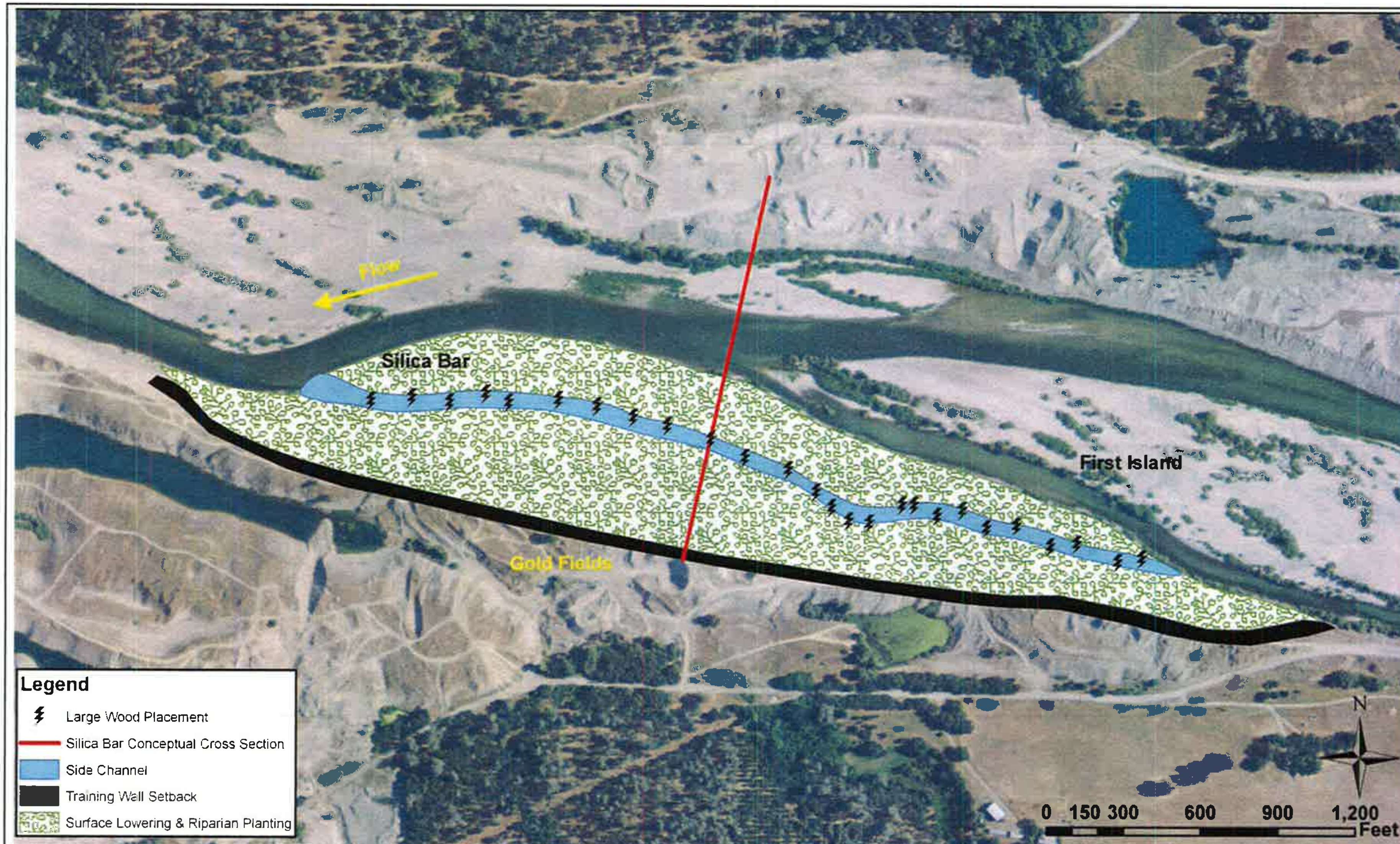
Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River

Conceptual Cross Sections for Projects 8 and 9

Project No. 08-1021	Created By: CTH	**Figure 5-8**



Notes:
Aerial image source, 2009 NAIP.
Refer to Figure 5-8 for a conceptual cross section along the indicated alignment.

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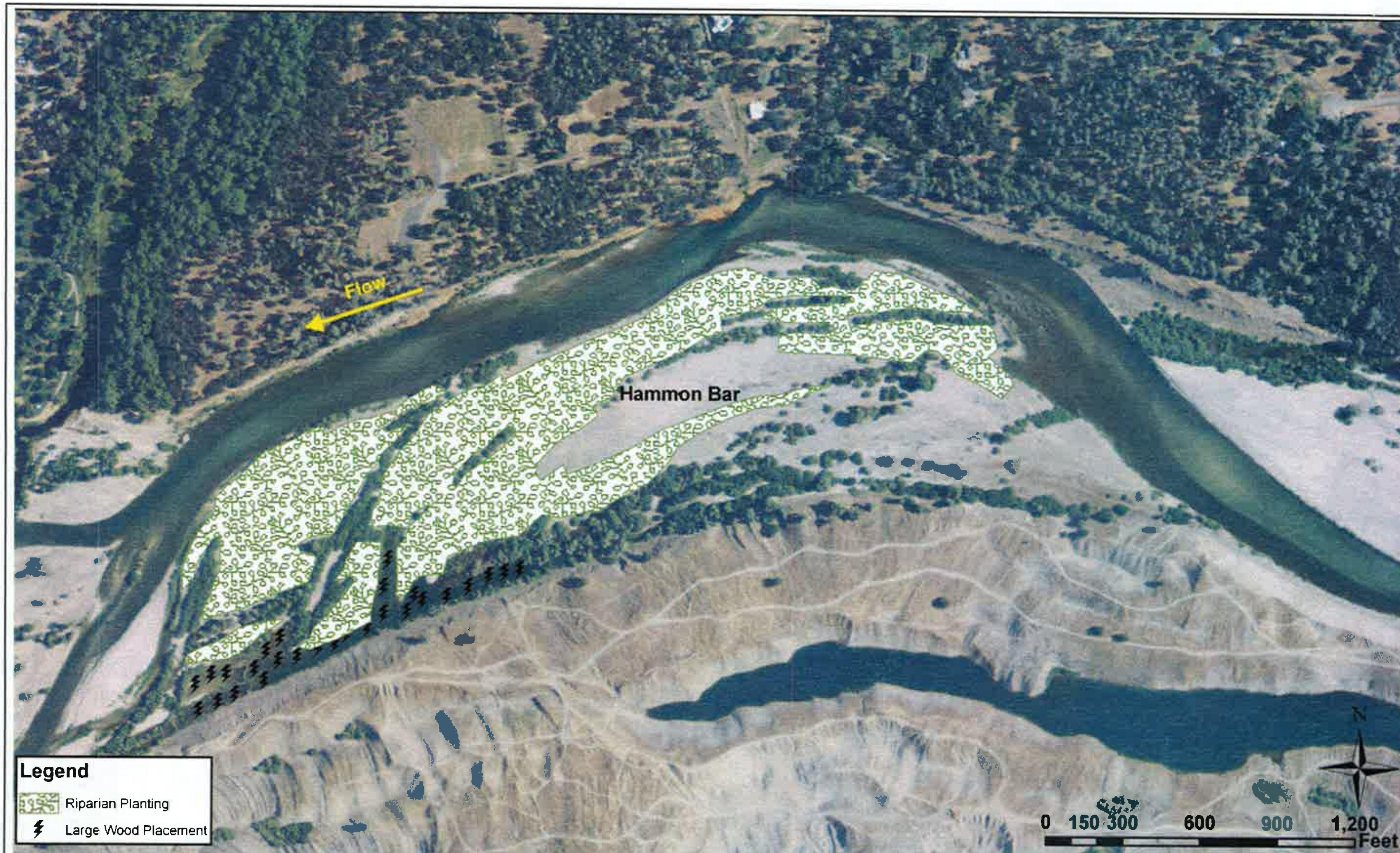
Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River

Project 9: Side Channel & Training Wall Setback at Silica Bar

Project No. 08-1021	Created By: CTH	**Figure 5-9**



Notes:
Aerial image source, 2009 NAIP.
Riparian planting locations determined through analysis presented in section 4.1 and Figure 4-2.

Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River

Project 10: Hammon Bar Enhancement

Project No. 08-1021 | Created By: CTH | **Figure 5-10**

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