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Development of Habitat Enhancement Alternatives for the Teichert Hallwood Facility and Adjacent Areas, Lower Yuba River

Prepared by:

cbec, inc.

November 26, 2014

Project Number 12-1034

DEVELOPMENT OF HABITAT ENHANCEMENT ALTERNATIVES FOR THE TEICHERT HALLWOOD FACILITY AND ADJACENT AREAS, LOWER YUBA RIVER

FINAL REPORT

Prepared using funds from
Pacific Gas and Electric Company's
Yuba River Narrows Project
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GLOSSARY OF ACRONYMS

Acronym	Meaning
DEM	Digital elevation model
DoD	DEM of difference
DPD	Daguerre Point Dam
HEC-EFM	Hydrologic Engineering Center – Ecological Functions Model
LiDAR	Light Detection and Ranging
LYR	Lower Yuba River
MU	Morphological unit
NAIP	National Agriculture Imagery Program
PG&E	Pacific Gas and Electric
RMT	Lower Yuba River Accord River Management Team Planning Group
SYRCL	South Yuba River Citizens League
TRLIA	Three Rivers Levee Improvement Authority
USACOE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WSE	Water surface elevation
YCWA	Yuba County Water Agency
YRDP	Yuba River Development Project

1 INTRODUCTION

cbec, inc., eco engineering (cbec) developed this report which details potential habitat enhancement alternatives for the Teichert Hallwood Facility and nearby areas (Hallwood project area), a site under consideration for habitat enhancement along the Lower Yuba River. Funding for the effort was provided by Pacific Gas and Electric Company's (PG&E) Yuba River Narrows Project (FERC 1403-004) Article 404 fund. First a historical analysis is presented, which is then followed by a synthesis of the existing conditions. Next, several potential project elements are described and then assembled into a variety of potential rehabilitation alternatives for the site. This is intended as Phase I of a two phase effort, with Phase II addressing development of a final proposed design for the site. Once the Phase I report is completed, these enhancement alternatives will be presented to the landowner, Teichert, Inc., and other interested parties, in order to assess the feasibility of the proposed alternatives and move toward the selection of a preferred alternative.

1.1 BACKGROUND

Enhancement of side channels and other types of off-channel habitats to generate additional juvenile salmonid rearing habitat is generally believed to be beneficial for Chinook salmon and steelhead production in the lower Yuba River (LYR). On November 29, 2011 the Yuba River Management Team (RMT) held a meeting to discuss potential enhancement strategies for the Hallwood project area, a site located on river right just downstream of Daguerre Point Dam on the lower Yuba River which includes an existing high-flow channel, floodplain areas and a training wall separating the main channel from the high-flow channel (Figure 1). It is estimated that the high-flow channel connects to the main river channel under higher flow conditions (i.e., 10,000 to 15,000 cfs) at the upstream end, and is connected perennially at the downstream end. The downstream end presently functions as a backwater with established riparian vegetation and deeper aquatic features, and often has flowing water due to substantial intra-gravel flow. Under the conditions observed during a site visit by members of the RMT, flow steadily declined moving upstream and then ceased altogether. Prior field observations as well as numerous resources and studies regarding the past and present geomorphic and hydraulic conditions on the Yuba River provided the launching point for this first phase of concept development.

Several key ideas were identified during initial discussions regarding enhancement alternatives for the Hallwood project area:

- Enhancement designs and project timelines should be developed with consideration given to coordinating, phasing and locating gravel mining activities in conjunction with the landowner (Teichert, Inc.).
- Enhancement designs should emphasize retaining existing riparian vegetation at the downstream end of the high-flow channel as this type of habitat is limited in the LYR.
- Enhancement designs must consider the dynamic nature of the LYR and the uncertain persistence of the proposed features.
- A variety of habitat enhancement alternatives are possible, including: 1) a designed side channel, with a vegetated floodplain; and 2) floodplain broadening (removal of the middle

training wall to provide a wider channel-floodplain corridor) where main channel meandering would likely eventually capture the side channel and yield longer term benefits through a more naturally functioning river.
- Modification of the existing bypass pipe for the Cordua-Hallwood Fish Screen could potentially contribute water (20-30 cfs from April through November) and fish into the side channel, with the consent of the diversion operator.

Thus, additional preliminary planning and review of options for the Hallwood project area were necessary to develop an enhancement project reasonable in scope and budget, that will contribute to the rehabilitation of Yuba River Chinook salmon and steelhead populations, and that will function as a persistent part of the ecosystem and provide an opportunity for adaptive changes in a dynamic river system.

1.2 GOALS AND OBJECTIVES

Based on the initial discussions regarding enhancing habitat within the Hallwood project area, the following goals were defined to improve the reach:

- Enhance habitat for fry and juvenile Chinook and steelhead rearing
- Promote a diverse riparian assemblage
- Retain existing riparian vegetation resources
- As possible, develop a project that discourages creation of habitat preferred by predatory non-native fish species (e.g., striped bass)
- Create an experimental design that can provide a research opportunity to improve understanding of restoration/rehabilitation/enhancement actions in similar settings

The following specific objectives have been defined to reach the goals above:

- Develop habitat enhancement alternatives for discussion with stakeholders
- Collaborate with landowner on alternatives development
- Ultimately, develop a sustainable concept for implementation that is dynamic but persistent

2 HISTORICAL ANALYSIS

2.1 HISTORY OF THE LOWER YUBA RIVER

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. Of this total amount of sediment, 685 million yd^3 (nearly half the total production) was washed from the hillsides of the Yuba River watershed, and 331 million yd^3 (nearly a quarter of the total production) was stored in the valleys of the Yuba 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 Yuba Goldfields region ranged in thickness from 16 to 82 ft (Hunerlach et al., 2004). The slurry of hydraulic mining sediment deposited in the main stem 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 sedimentation and reduce flood risk. Actions such as channelization, levee construction and bank armoring further altered sediment dynamics within the system. Daguerre Point Dam (DPD) was constructed between 1906 and 1910 as a sediment barrier and base-level control for erosion upstream (Hunerlach et al., 2004; James et al., 2009). Contemporary dam technology implemented in the late 1800s generated limited storage capacity and resulted in numerous dam failures, so sediment management policy at the time focused on building levees or training walls (James et al., 2009).

Flood protection and channel modification efforts also targeted floodplain areas for gold production. To provide access to the gold-bearing deposits in the Yuba Goldfields, the California Debris Commission sanctioned the realignment of the river to a location north of its historic position. Training walls were constructed from dredge tailings to confine the channel to a narrow corridor and thus enable widespread mining operations in the roughly 9,000 acre Goldfields area located predominantly to the south of realigned river channel. Between 1898 and 2003, more than 1 billion yd^3 of gold-bearing sediments were dredged in the Goldfields (Hunerlach et al., 2004).

The reach from DPD to a slope break at Eddie Drive (Wyrick and Pasternack, 2012) is unique as it is the only section of the Yuba River with extensive mining operations to both the north and south of the river. Three training walls were constructed along this reach: one to the north, another to the south and a third positioned along the longitudinal midline of the river corridor (hereinafter called the north, south and middle walls, respectively as shown in Figure 1).

Historical accounts describe cultivated "bottom lands" along the LYR with dark fertile soils, presumably indicating floodplains frequently inundated by the river (Gilbert, 1905 as described in James et al., 2009). After the burial of these historic soils under the influx of hydraulic mining sediment, dredging further altered the character and distribution of sediment in the river corridor. Fines and coarse fractions were separated whereby a mixture of clay, silt and sand tens of feet thick was typically covered by 40 to 100 ft of gravels, cobbles and larger materials. Today, the (active) channel alluvium is a mix of sediment derived from hydraulic mining and Quaternary alluvium (James et al., 2009; Hunerlach et al., 2004).

An investigation of subsurface sediment texture conducted by the U.S. Geological Survey (USGS) at a location ~1.2 mi above DPD (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. Between depths of 5 and 10 feet, the substrate consists of 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 DPD are typically well armored with coarse gravel several feet thick (Hunerlach et al., 2004).

2.2 HISTORICAL AERIAL IMAGE DESCRIPTION

To assess historical changes in channel configuration at the Hallwood project area, a qualitative aerial analysis was performed using L.A. James' (2012) compilation of aerial photographs of the LYR. Images from 1947, 1952, 1958, 1964, 1970, 1986, 1999 and 2009 were compared in relation to major flood events on the peak flow record at Marysville Gage (MRY; USGS gage no. 11421000). Figure 2 provides daily average and annual peak flow rates for the LYR between 1945 and 2010, and also indicates the aerial flight dates shown in Table 1.

Table 1. Aerial flight dates and flood events

Image Date	Source[1]	Flow at Aerial Date[2] (cfs)	Preceding Flood Peak[3] (Date) (cfs)
2/22/1947	USGS/State Archives	1,553	Multiple[4]
6/26/1952	State Archives	5,727	78,800 (11/21/1950)
6/17/1958	UC Davis	7,491	136,000 (12/23/1955)
5/31/1964	USDA	2,447	146,000 (2/1/1963)
7/13/1970	USDA	713	180,000 (12/22/1964) and 106,000 (1/22/1970)
11/4/1986	DWR	4,122	111,000 (2/19/1986)
1999	DOQQ	not available	161,000 (1/2/1997)
7/3/2009	NAIP	1,987	114,000 (12/31/2005)

Notes:
1) All photos except the 2009 National Agriculture Imagery Program (NAIP) were extracted from James' (2012) compilation of aerial photos for the RMT.
2) Flow at Smartsville Gage (YRS; USGS 11418000) plus Deer Creek near Smartsville (DCS; USGS 11418500).
3) Instantaneous peak flow data at Marysville (MRY, USGS 11421000).
4) Major flood peaks prior to the first available photo of the DPD Reach: 3/19/1907 (100,000 cfs), 1/15/1909 (111,000 cfs), 3/26/1928 (120,000 cfs), 12/11/1937 (95,000 cfs) and 1/21/1943 (81,100 cfs).

The following summarizes the geomorphic progression visible in the aerial photographs and flow record:

- The earliest available aerial photo for the DPD Reach after the dam's completion in 1910 is dated February 22, 1947 (Figure 3). Numerous flood peaks occurred after the realignment, but prior to this photo (see notes for Table 1).
- The 1947 aerial shows two defined channels with inlets defined by a large island immediately downstream of DPD. It is unknown whether these two channels were constructed to both remain connected at lower flows or whether the two channel configuration formed naturally. In addition, the 1947 aerial shows the presence of a fairly dense riparian stand along the toes of the training walls (Figure 3).
- Following a series of moderate flood events (all less than 80,000 cfs), the 1952 aerial shows that the north channel avulsed just above the middle wall (it is unknown if this was aided by man)

thereby directing the majority of the ~5,700 cfs shown in the June 1952 photo down the south (main) channel (Figure 4).

- Between 1952 and 1958, the upstream end of the northern channel became less connected with the main channel (either through aggradation of the northern inlet, incision of the main channel, or a combination of these), causing this channel to become an "alternate" high-flow channel. Even at ~7,500 cfs as shown in the 1958 aerial, there is only a minor surface flow connection to the northern channel (Figure 5).
- After a large event of 146,000 cfs in February 1963, the May 1964 aerial taken at a flow of ~2,500 cfs shows a complete low/moderate flow disconnection (Figure 6).
- The largest flood peak on record for the LYR occurred in December 1964 (180,000 cfs at Marysville). The 1970 aerial shows that despite this large event, riparian vegetation in the downstream portion of the high-flow channel was not significantly scoured out (Figure 7).
- Between 1964 and 1986 the main channel shifted from a less stable wandering pattern to a single thread channel with a more consistent meandering pattern that remains present today (Figures 6-8). The floods in 1964 and 1970 scoured out many of the alternating bar features that were present in 1964 and formed a meander sequence that began to cut into the south and middle training walls on either side of the main channel.
- Between 1986 and 1999 the main channel's sinuosity increased due to meander extension (Figures 8 and 9), which presumably occurred primarily during the 1997 event. While the outer meander bends eroded into both the south and middle training walls, riparian vegetation persisted in most locations.
- Between 1999 and 2009, main channel meanders exhibited additional lateral extension and minor downstream translation (Figures 9, 10 and 11). The 2009 aerial also shows conditions during the data collection period for the 2D modeling efforts as well as current land uses north of the river.

The flow record and sequence of aerials demonstrate the evolution of this reach of the LYR over the past 62 years as well as its capacity for dynamic behavior. It appears that the northern channel was abandoned due to overbank deposition at its upstream end and perhaps incision of the main channel. The northern channel has remained an alternate high-flow channel in recent decades. The main channel has transitioned to a single thread channel with a more stable meander pattern, and its continued lateral expansion is eroding the middle and south training walls (Figure 11). Riparian vegetation has persisted in the high-flow channel, particularly in the downstream half, through several moderate and large flood events.

2.3 TRAINING WALL RETREAT

Erosion of the south training wall along the DPD reach has become a flood management concern for the Three Rivers Levee Improvement Authority (TRLIA) in recent years. Several efforts have been made to identify high risk areas (MBK Engineers, 2011), quantify historical retreat and predict future retreat rates (cbec, 2013b). cbec (2013b) quantified lateral retreat associated with historical flood events (e.g., 1997 and 2005) as well as provided an estimate of the amount of retreat that would occur during design flood events (e.g., 100-year event). This analysis demonstrated up to 22 feet of average crest retreat along the south wall as a result of a large magnitude event, such as the 1997 flood (cbec, 2013b).

The middle wall has also demonstrated significant retreat at the outside of main channel meander bends. Comparisons of the 1999 U.S. Army Corps of Engineers (USACOE) Comprehensive Study topography to the 2009 RMT digital elevation model (DEM) provide an estimate of middle wall retreat rates along the DPD reach. At two locations along the middle wall, lateral crest retreat ranged from 20 to 32 feet and crest height reduction ranged from 9.5 to 12.5 feet (Figure 12). Carley et al. (2012) confirm this crest height retreat and also show areas with up to 49 feet of vertical erosion along the middle wall (Figure 13). This retreat was likely attributable to the May and December 2005 events. With no revetments and continued retreat dominated by scour during large events, it is likely that the middle wall will naturally breach in the future.

TRLIA is currently undergoing planning to upgrade flood protection for the region to a 200-year event standard. As part of this work, preliminary flood modeling is being performed to assess various scenarios for reducing flood pressures and scour potential. Initial hydraulic modeling results demonstrate a 2.8 foot decrease in peak flood stage at the upstream end of the Hallwood project area for a 200 year event due to the complete removal of the middle wall down to the floodplain elevations present at the existing toe of the wall (Don Trieu [MBK], personal communication). As such, rehabilitation efforts that include middle wall removal could also provide a significant flood management benefit.

3 DESCRIPTION OF EXISTING CONDITIONS

3.1 EXISTING GEOMORPHIC CONDITIONS AND HIGH FLOW CONNECTIVITY

At present, the DPD reach (which encompasses the Hallwood project area) is characterized by a main channel and a high-flow channel separated by the ~2 mile long middle wall. The main channel flows south of the middle wall through a single-thread channel with a relatively stable meandering pattern that continues to expand laterally (at the expense of the middle and south walls) as well as translate downstream. The high-flow channel activates (i.e., becomes inundated) at its upstream end only at high flows (i.e., >10,000 cfs) while its downstream end remains inundated year round due to backwatering by the main channel as well as subsurface flow.

Extensive analyses have been performed to characterize the present geomorphic condition and identify the dominant fluvial processes in the DPD reach. A DEM of the LYR from the Narrows to the confluence with the Feather River near Marysville was created in a two-phase survey effort during a low peak flow period from June 2006 to November 2009 (Carley et al., 2012). In the DPD reach, Light Detection and Ranging (LiDAR) and boat-based surveys were performed primarily in 2008. A highly detailed 2D hydraulic model was developed for the entire LYR (Pasternack, 2009; Barker et al., in prep.), and recent geomorphic and hydrologic analyses have identified three relevant flows for mapping fluvial landforms and understanding existing conditions on the LYR (Wyrick and Pasternack, 2012). These representative flows include *baseflow* (530 cfs below DPD), *bankfull* occurring every ~1.25 years on average (5,000 cfs) and a *floodplain filling* flow occurring every ~2.5 years on average (21,100 cfs). Hydraulic model results demonstrate that the upstream end of the high-flow channel activates between 10,000 and 15,000 cfs, though the exact flow magnitude has not yet been determined.

Based on a well established delineation method, eight geomorphic reaches were defined on the LYR (Wyrick and Pasternack, 2012). The wetted channel width of the DPD reach (from DPD to a slope break at Eddie Drive) nearly doubles between baseflow (530 cfs) to bankfull (5,000 cfs) conditions, and the full floodway width is ~5.2 times wider than the baseflow width. Mean valley width in this reach is wider than all other reaches (Wyrick and Pasternack, 2012). Additionally, the middle wall divides the DPD reach into two defined corridors: the main channel corridor to the south and the slightly narrower high-flow channel corridor to the north. The elevation of the inlet to the high-flow channel is 8 – 10 feet higher than the main channel. Morphological units (MUs) were defined by Wyrick and Pasternack (2012) and are shown in Figure 14.

Table 2. Relevant discharges for LYR DPD reach

Flow Description	Discharge (cfs)	Return Interval (yrs)	Inundation Duration (days)
Baseflow[1]	530	-	-
21-day duration during rearing period[2]	~1,800	1.5	21
21-day duration during rearing period[2]	~3,500	2	21
3-day duration during rearing period[2]	~4,500	2	3
Bankfull (geomorphic and field based)[1]	5,000	1.25	-
Bankfull (statistically based)[3]	6,700	1.5	-
High-Flow Channel Begins to Activate	10,000 to 15,000	-	-
Floodplain Filling[1]	21,100	2.5	-

Notes:

1) Flows identified by Wyrick and Pasternack, 2012.

2) Flows identified by cbec (2013a) using USACOE HEC-EFM (Ecosystems Function Model) software discussed in Section 3.3.

3) Flows identified by cbec et al. (2010) through a standard flood frequency analysis using annual peak flows.

The DPD reach is a net depositional area characterized by significant overbank deposition on floodplain surfaces and bars as well as berm scour at key locations along the south and middle walls (Wyrick and Pasternack, 2012). Supplemental digital elevation model difference (DoD) mapping by Carley et al. (2012) provides precise locations and net elevation changes associated with erosion and deposition between 1999 and 2008 (Figure 13). Along the main channel floodplains and point bars aggraded. As indicated by other studies, significant scour has occurred along the south and middle walls along the outside bank of meander bends, probably due to large events such as the May and December 2005 floods (~53,000 and 114,000 cfs at Marysville, respectively). The high-flow channel was also predominantly depositional although many areas were within the +/- 1 ft range of data exclusion. The high-flow channel also demonstrated localized scour zones at the edges of the middle and north walls.

To summarize, the DPD reach has exhibited fairly dynamic behavior since the start of the aerial photo record and continues to demonstrate a capacity for significant geomorphic change. The ongoing lateral migration and downstream translation of the main channel along the DPD reach, along with the net erosional and net depositional behavior of the LYR above and below DPD, respectively, indicate the river's propensity for future geomorphic adjustments. The design and intended persistence of engineered rehabilitation measures within the Hallwood project area must take into account the river's dynamism and the trends occurring as the river channels continue to adjust.

3.2 EXISTING HYDROLOGIC CONDITIONS AND SUBSURFACE FLOW DURING LOW FLOW

During the summer months, the downstream end of the high-flow channel functions as a slackwater with ponded areas surrounded by dense riparian vegetation on both channel margins. Water surface elevations demonstrate that flow is supplied to the reach via subsurface pathways. On May 2, 2013, a field survey was performed to measure water surface elevations along the main channel, the wetted high-flow channel and the Teichert dredger tailings ponds (Figure 15). Discharge in the LYR on the day of the survey was approximately 1,150 cfs at the Marysville gage.

A simple subsurface flow pattern is depicted with the blue arrows shown in Figure 15. Water surface elevations in the main channel were anywhere from 1 – 6 feet higher than the high-flow channel. Based upon the surveyed gradients, it appears that flow is travelling subsurface through the middle wall from the main channel to the high-flow channel. At many points, the water level in the high-flow channel is lower than the elevation in the main channel at adjacent locations. Several beaver dams are present in the high-flow channel, controlling local water surface elevations. The water levels in the Teichert dredger tailings ponds are also higher than those in the high-flow channel, and these features are likely to be providing flow to the high-flow channel as well (Figure 15).

It should be noted that Figure 15 provides a snapshot of the hydraulic conditions occurring on the day the survey was conducted. It is likely that subsurface flow from the main channel through the middle wall to the high-flow channel increases as river flows increase and therefore the water surface elevations in the main channel increase, however this has not been confirmed. Additional subsurface flow to the high-flow channel could potentially alter the quantity and quality of aquatic habitat present in the high-flow channel.

3.3 EXISTING OFF-CHANNEL HABITAT INUNDATION REGIME

Wyrick and Pasternack (2012) described the LYR floodplain as well connected given the 1.25 to 2.5 year recurrence interval of bankfull and floodplain filling flows (5,000 and 21,100 cfs), respectively. To date, flow frequency analyses have focused largely on instantaneous annual maximum flood peak data. However, there has been little study of the functional importance of duration, timing and seasonality of flow levels with respect to targeted management species on the LYR, particularly anadromous salmonids.

In order to identify flow magnitudes sustained for specified durations and occurring at specified frequencies during ecologically important periods, a HEC-EFM (Ecosystem Functions Model) analysis was performed by cbec (2013a). This methodology has been applied on the lower Feather River as part of the Central Valley Flood Protection Plan Restoration Opportunity Analysis (CVFPP, 2012), as well as various other locations in the Central Valley. For the LYR, ecosystem function relationships were developed using available LYR-specific life history characteristics and fisheries use datasets (cbec, 2013a). A modeled time series of river flow[1] was analyzed to determine flow magnitudes that persist long enough and occur frequently enough to provide functional off-channel habitat to juvenile to yearling+ fall-run Chinook and steelhead during the March to June rearing and emigration period[2].

The following summarizes the relevant values based upon modeled Yuba Accord flows for the March to June analysis period (see cbec, 2013a for more detailed methodology and discussion):

- In 1 of 2 years (i.e., 50% exceedance), flows exceed ~4,500 cfs for at least 3 consecutive days
- In 1 of 2 years (i.e., 50% exceedance), flows exceed ~3,500 cfs for at least 21 consecutive days
- In 2 of 3 years (i.e., 67% exceedance), flows exceed ~1,800 cfs for at least 21 consecutive days

These results coincide with other preliminary findings regarding the connectivity of off-channel features such as swales. Morphological unit (MU) mapping by Wyrick and Pasternack (2012) shows several swales along the main channel in the DPD Reach. Overlaying the MU maps with 2D model results from the RMT demonstrates that these swales tend to activate and function (via surface water connection) at flows ranging from 3,000 to 5,000 cfs. Additionally, at river discharges between 3,000 and 5,000 cfs, many swales along the entire LYR demonstrate depths between 1 and 1.5 ft and flow velocities between 0.75 and 1 ft/s (Greg Pasternack, personal communication). Groundwater fed swale channels have also been shown to support high densities and growth rates of salmonids even through the summer (DWR & PG&E, 2010).

These preliminary flow timing, duration and frequency findings can be used to more effectively target rehabilitation actions along the DPD reach. Increasing the amount of area inundated by flows less than 4,500-5,000 cfs should have a positive impact on salmonid rearing as these flows occur frequently enough and for long enough durations to provide beneficial habitat. In particular, creating additional off-channel features such as swales, side channels and topographically diverse floodplains should be strongly considered in designs. See Section 4.1 for more discussion on this topic and its relevance to concept development.

[1] Yuba River Development Project (YRDP) Accord flow as reported in (YCWA, 2012a)
[2] March through June represents the fall-run Chinook salmon rearing and outmigration season (RMT, 2010)

3.4 EXISTING RIPARIAN RESOURCES

Historical aerial photographs show persistent stands of woody riparian vegetation in the high-flow channel corridor since at least 1947. In 2012, Watershed Sciences, Inc. performed a riparian vegetation analysis of the LYR, which included the Hallwood project area. Mapping procedures used field-validated LiDAR to provide details about species diversity and stand height classes. Of the overall ~240 acres in the high-flow channel corridor (including channel, floodplain and terrace areas), approximately 93 acres are inhabited by riparian and upland woody vegetation. Watershed Sciences, Inc. categorized existing vegetation into four height classes: shrubs (< 10 ft), low trees (10 - 35 ft), medium trees (35 - 50 ft) and tall trees (> 50 ft) (Figure 16). Approximately 40 of the 93 vegetated acres in the high-flow channel corridor consist of medium or tall trees, the majority of which lie outside the 21,100 cfs (i.e., floodplain filling flow) footprint. In the upstream portion of the high-flow channel corridor, anecdotal field evidence from a cbec site visit confirmed the presence of upland species (e.g., *Pinus sabiniana*). Additionally, the field visit confirmed the presence of multiple dead snags along the high floodplain margins. The South Yuba River Citizens League (SYRCL) conducted a survey of the relative abundance of willow species which included four transects through the heavily vegetated portions of the downstream section of the high-flow channel corridor (SYRCL 2013). A total of six willow species were found, and these are listed as follows in order of decreasing relative abundance: *Salix melanopsis, S. exigua,, S. lasiolepsis, S. goodingii, S. lasiandra,* and *S. laevigata*.

3.5 FISH OBSERVATIONS IN THE EXISTING SIDE CHANNEL HABITAT

Recent observations have been made of Chinook salmon, steelhead, California roach and Sacramento sucker in existing side channel habitat features of the high-flow channel corridor. In April 2013, U.S. Fish and Wildlife Service (USFWS) and SYRCL personnel snorkeled three side channel sites in a portion of the downstream section of the high-flow channel (see Appendix A for Campbell (2013) report). They observed numerous juvenile Chinook salmon at all three sites along with steelhead, yearling Chinook salmon and other fish species in various combinations by site. The fish sightings as well as descriptions of habitat, bed substrate, terrestrial wildlife and water temperature are described in detail in the full site visit report located in Appendix A.

3.6 EXISTING CONSTRAINTS

Concept development of rehabilitation designs for the Hallwood project area must consider both existing and future constraints. Potential constraints that have been identified to date include those listed below.

Condition of the North Wall

The first constraint identified for the Hallwood project area concerns the condition of the north wall along the Teichert facility. While more robust sections of the wall have base widths of over 200 feet, other sections are as narrow as 50 feet (Figure 17). Additionally, crest height of the north wall differs dramatically along the high-flow channel (e.g., a 50 ft difference is seen between the cross sections provided in Figure 17). The dimensions (i.e., height and width) and erodibility of the north wall raises significant concerns regarding its potential for failure and the flooding that could result. Perhaps even more problematic is the potential capture by the main channel of the large dredged ponds immediately north of this training wall. These potential problems could have devastating consequences for aggregate extraction activities, adjacent landowners and the river itself (e.g., geomorphic and ecological). Enhancement designs must address this risk.

Power Transmission Line Tower

The power transmission lines spanning the project area pose a second constraint for the project. There are two transmission line easements that cross the LYR and Hallwood project area (Figure 1) along with one transmission tower situated on the middle wall (Figure 17). It is important to note that there is a high degree of topographic diversity in the middle wall at this location which includes a deep swale and a pond in the middle of the wall (Figure 18). Rehabilitation designs that incorporate removal of the middle wall must retain a significant "island" of existing material in addition to revetment of some form (e.g., engineered log structures or deflector weirs) to ensure the structural integrity and longevity of the foundation of this tower, or otherwise it must be relocated outside of the active river corridor. The next stage of project planning should include the following:

1. For an alternative retaining an island for the transmission tower, further analysis of the island's size and alignment, design considerations, potential erosion rates, future maintenance access to the tower, and associated costs
2. For an alternative involving relocation of the PG&E transmission tower, an assessment of potential alternative tower locations and the associated land, environmental, engineering and access constraints and costs

Existing Ecological Resources

The high-flow channel corridor in its current condition provides a mosaic of aquatic, riparian and upland habitat types. Rehabilitation designs will alter this mosaic by enhancing some types and converting other types. The current value and utilization of these habitats must be fully understood to provide a means to assessing the net benefit of any project for the species using this area of the LYR.

River Dynamism

The dynamic nature of the LYR creates an additional project constraint; however, it also provides a significant opportunity. Given the river's somewhat unregulated flood regime, abundant local sediment supply and corridor width, there is considerable uncertainty regarding the geomorphic persistence of engineered rehabilitation features in the DPD reach. It cannot be guaranteed that all project features will persist through major flood events. The river is highly dynamic, exhibiting a variety of erosional and depositional mechanisms. As such, some components of designs should be expected to evolve through time. This is an appropriate expectation, as rivers are dynamic in nature. This should be acknowledged and therefore project phasing should be structured to facilitate adaptive implementation and management of rehabilitation designs if desired.

3.7 LAND OWNERSHIP

There are several ongoing aggregate extraction operations within the Goldfields. The two most relevant operations to this project are those of Teichert and Western Aggregates. Teichert's Hallwood Plant covers an approximately 1,100 acre area on the north side of the LYR. The boundary of the Hallwood property, includes the nearly all of Hallwood project area high-flow channel and it extends approximately to the centerline of the middle wall (Figure 1). Western Aggregates own or have surface mining rights to a vast area of the Goldfields. Their property includes the very upper most part of the high-flow channel, as well as the area to the south of Teichert's Hallwood property.

3.8 ENHANCEMENT OPPORTUNITIES

The Hallwood project area presents a significant opportunity for a multi-objective project benefiting a diverse group of interests. Potential benefits include:

- Creation of an additional 2 or more miles of side channel and over 200 acres of floodplain rearing habitat for Chinook salmon and Central Valley steelhead
- Reductions in 200-year flood stages of nearly 3 feet following removal of the middle wall
- Collaboration opportunity with landowners to offset construction costs
- Tax revenue for Yuba County generated by sale of aggregate removed from the site

Despite the effects of more than a century of extensive gold mining and active manipulation and management by humans, the LYR supports important populations of wild (i.e., non-hatchery supported) Chinook salmon and Central Valley steelhead. However, studies suggest that sparse juvenile rearing habitat may be limiting these populations within the LYR (LYRFTWG, 2005). Redd surveys from 2009 to 2011 have shown that approximately 75% of Chinook salmon spawners prefer sites upstream of DPD in the Timbuctoo and Parks Bar reaches (YCWA, 2013). Additionally, snorkel surveys have found high densities of juveniles near lateral bar features, slackwater areas, slow glides and riffle transitions (YCWA, 2013).

Given the presence of a vibrant spawner population yet a heavily altered river corridor, it appears that generating additional off channel rearing habitat between upstream spawning locations and the Feather River confluence would significantly benefit rearing and outmigrating juvenile salmonids. Appropriate rehabilitation designs can convert extensive areas within the Hallwood project area from upland and/or infrequently inundated floodplain to highly functional, off-channel rearing habitat for Chinook salmon and steelhead. Floodplain grading and planting efforts can also increase the abundance and enhance the diversity of woody riparian vegetation, providing ecological benefits for a large array of organisms.

In addition to habitat benefits, preliminary hydraulic modeling demonstrates that floodplain grading and removal of the middle wall could reduce 200-year flood stages by more than 2.8 feet (Don Trieu [MBK], personal communication). This area is currently a focus of flood risk reduction by TRILIA with six of the ten sites that have been identified as providing flood risk located adjacent to the Hallwood project area

(MBK, 2011). Stage reduction in this reach would lower flood risk for the areas to the south and west including the cities of Linda and Olivehurst.

Coordinating with Teichert for material removal from the site will expedite project execution and reduce costs. Given the scale of their operations, Teichert has indicated a potential capacity to remove the material within a window of 2 to 6 construction seasons. This range depends significantly on market demand for aggregate and whether Teichert can feasibly store additional material on the Hallwood property but outside of the active river corridor. Depending on the overall volume of aggregate material removed from the project site, material sales could generate several hundred thousand dollars of tax revenue for Yuba County. Teichert may also be able to provide a source of fine-grained material (i.e., surface soils from a nearby mining operation) that could be used to improve the texture of constructed floodplain areas. The costs of removing the aggregate material and final grading of the site could be partially offset by the revenue generated from the sale of the material, thus greatly reducing overall project expenses.

The Hallwood project area offers an incredible opportunity to create and enhance salmonid rearing habitat while simultaneously reducing peak flood stages and reducing flood risk. Furthermore, the proximity of the Teichert Halwood processing facility could lead to substantial cost savings with regards to the excavation and relocation of some of the alluvial material present in the Hallwood project area. Not only would the sale of these aggregate resources offset construction costs, but it would also provide considerable tax revenue to Yuba County. Effective collaboration between all interested stakeholders can facilitate a successful, multi-benefit project.

4 ENHANCEMENT ALTERNATIVE CONCEPT DEVELOPMENT

4.1 POSSIBLE PROJECT ELEMENTS

A number of potential project elements could be used in a rehabilitation effort in the Hallwood project area. These elements are summarized below and discussed in more detail in the proposed concept alternatives (see Sections 4.4 through 4.8). Additional concept elements for LYR projects and associated discussion can be found in a report titled "Rehabilitation Concepts for the Parks Bar to Hammon Bar Reach of the Lower Yuba River" (cbec et al., 2010).

Floodplain Grading

Creating a more frequently inundated and topographically diverse floodplain serves as the foundation for all proposed enhancement alternatives in the Hallwood project area. While portions of the floodplain currently inundate with a relatively high frequency (e.g., flows of at least 5,000 cfs occur every 1.25 years on average), the duration and timing of inundation may not provide meaningful juvenile rearing habitat. When designing off-channel features (e.g., floodplains and side channels) it may be useful to consider flows lower than bankfull, which persist for periods long enough to improve rearing habitat availability. As discussed by cbec (2013a) and summarized in Section 3.3, there is a 50% likelihood in any year that flows of ~3,500 cfs would persist for at least 3 consecutive weeks during

March-June. Thus some areas graded to begin inundating at 3,000 cfs would have some amount of inundation when flows reached and stayed at or above 3,500 cfs. Proposed floodplain grading would remove material from higher elevation areas such that most areas inundate between 3,000 and 7,000 cfs. The resulting gradient of elevations, inundation frequencies, groundwater depths and flood energy would generate a diverse mosaic of habitat types for juvenile salmonid rearing and riparian vegetation.

Side Channel or Split Channel

The existing high-flow channel within the Hallwood project area could also be graded to a lower-elevation side channel that provides habitat the is inundated more often. Concept alternatives range from a split channel of similar size to the main channel to a much smaller side channel. Different side channel types could be considered (e.g., stream-type or pond-type) as well as the seasonality of their flow (e.g., fully perennial or seasonally inundated). Rosenfeld et al. (2008) investigated the influence of side channel type and size on fish utilization and growth. In addition to exhibiting higher average density of coho salmon parr, stream-type side channels supported parr biomass values that were three times greater than those found in pond-type side channels. The authors also found that small side channels are more likely to be productive than larger ones, as the incremental benefit decreases with increasing channel area. Finally, they indicated that side channels providing a diversity of stream and pond-type habitats are likely to be the most productive as they can provide species with life stage refugia (Rosenfeld et al., 2008). Given these findings, three of the five proposed concept alternatives feature smaller stream-type side channels.

Different channel inlet configurations under consideration include a perennial surface connection and a perennial subsurface connection (e.g., similar to the groundwater fed swale channels described by DWR & PG&E (2010)) coupled with a seasonal surface connection (e.g., activating when main channel discharge reaches 3,000 cfs as seen with other swales along the LYR).

Middle Wall Grading

As part of the overall floodplain grading effort, some portion of the middle wall could be removed for the combined benefit of increasing habitat and reducing flood levels along the DPD reach. Sections of the wall that could be left in place include an island for the power line transmission tower (near the middle wall's downstream end) and strategically located islands to buffer geomorphic adjustments of the main channel (further upstream). Removal of the middle wall would require the excavation of a large volume of aggregate (i.e., ~4-6 M yd^3 depending on extents).

Alternatively, a project design could be developed that leaves the middle wall intact. However, this plan would forgo the opportunity of creating additional habitat, reducing peak flood stages, allowing for a more dynamic river corridor, gaining support of the major landowner, and generating significant tax revenue for Yuba County.

Topographic Modification of Existing Downstream Aquatic Features

Two general options are presented for the existing aquatic features at the downstream end of the high-flow channel corridor. A new, lower-elevation side channel could tie-into the existing network of beaver ponds, channels and backwater areas at their upstream end, leaving them relatively undisturbed from construction. Alternatively, the existing pond and backwater features could be modified by adding sediment to create floodplains and a narrower faster-flowing side channel that should reduce refuge for predators and provide greater rearing benefits for juvenile salmonids.

North Wall Enhancement

The existing north wall should be enhanced to protect it from being eroded and a connection made to the dredged ponds to the north. This is important for all alternatives that increase the amount of flow in the high-flow channel, but it is particularly important if a perennial split channel is constructed. Scour protection measures include rock and log revetments along the wall, as well as augmentation of the wall with aggregate derived from the middle wall, or finer grained material from a nearby source.

Engineered Large Wood Structures

Engineered log jams may be placed at key locations (e.g., upstream connection with main channel) to both resist scour of important elements (e.g., northern wall or power line transmission tower island) as well as to promote scour and maintain side channel inlets. Large woody material placements or engineered log jams can also be designed to create localized areas of scour, geomorphic complexity and habitat diversity (e.g., cover).

Engineered Diversions to Side Channel

A diversion from the Cordua-Hallwood Diversion Structure Fish Screen to the upstream end of a rearing side channel could provide a source of both juvenile salmonids and flow to the side channel. The diversion structure could be augmented with an open channel or large pipe that would be controlled by a simple gate operated at the diversion structure. This could allow for fish salvaged at the screen to be directed to the main channel (current practice) or alternatively to the side channel depending on flow and habitat conditions.

Swales

Additional features to enhance or create are swales and other associated morphological units identified by Wyrick and Pasternack (2012). Swales and slackwater areas have been shown to be utilized by juvenile salmonids (DWR & PG&E, 2010; YCWA, 2013). Swales are defined in Wyrick and Pasternack (2012a) as “a weakly-defined geometric channel or adjacent bench on the floodplain that only conveys flow at stages above low-flow”. Slackwater areas are defined as “shallow, low-velocity regions of the stream that are typically located in adjacent embayments, side channels, or along channel margins” (Wyrick and Pasternack, 2012a). Groundwater fed swale channels have been shown to support high densities and growth rates of salmonids even through the summer (DWR & PG&E, 2010). In addition, the Habitat Expansion Plan (HEP) for the LYR confirms the feasibility and benefit of enhancing groundwater fed channels (DWR & PG&E, 2010; Wyrick and Pasternack, 2012a).

4.2 DISCUSSION OF POTENTIAL EVOLUTION

Within the given river corridor and existing constrains, there is a considerable spread of potential rehabilitation approaches with respect to the level of engineered design. The minimal intervention approach may consist of removing material from the floodplain and middle wall, and then allowing the river itself to carve new channels and sculpt the floodplain through fluvial processes. At the more heavily engineered end of the spectrum, a floodplain and side channel system can be extensively designed with numerous features that may or may not persist for a long period as the reach continues to evolve given the existing hydrologic and sediment regime.

Consideration should be made regarding the expected persistence of any designed features implemented as part of this project. The rehabilitation approach can include some amount of control features (e.g., remnant middle wall islands) to provide a strong chance for establishment of off-channel habitat and riparian vegetation, with the main goal being to put the river on a recovery trajectory regardless of the persistence of certain features. Alternatively, numerous engineering controls (e.g., anchored log jams coupled with boulder placements or rock groins) can be implemented to limit the likelihood of main channel capture of designed features, or abandonment of the features via channel meandering or deposition. Such an approach will likely require greater levels of monitoring, adaptive management and maintenance, and may hamper the river's capacity to create and sustain habitat on its own.

Stakeholders must also recognize that at any point a large flood event may also considerably modify engineered rehabilitation features. Approaching the overall project with an understanding that significant geomorphic adjustments following large events are indicative of a dynamic gravel-bedded river is advisable, and that changes to designed features does not constitute failure of the project.

4.3 TEICHERT RECLAMATION PLAN

Teichert owns and operates the Hallwood facility with the property extents shown in Figure 1. cbec has communicated with personnel from Teichert to discuss potential collaboration on this project and to understand Teichert's vision for the reclamation of the Hallwood property and surrounding land. As part of these conversations, Teichert operations managers shared their "2003 Conceptual Reclamation Plan" which provides a visual representation of their initial concepts (Figure 19). Teichert's goals include improving habitat, public amenities and aesthetic values of the Hallwood Property. Although the plan provides for pond depths of 60 feet (East Lagoon on Figure 19, closer to river) and 200 feet (West Lake on Figure 19, further from river) at the cessation of operations, recent conversations indicate that Teichert is unlikely to mine below a clay layer present at roughly 60 feet below the present-day land surface. Additional elements of the Teichert reclamation plan include a commitment to planting various native trees across the grassland, riparian upland and riparian wetland habitat types with wandering footpaths for public use (Figure 19).

At the time it was developed, Teichert's reclamation plan did not include material removal along the high-flow channel or middle wall. However, since being introduced to the proposed project, Teichert has expressed a strong interest in expanding the extent of their reclamation activities to include the Hallwood project area site. Teichert's willingness to collaborate and play a key role in this project is paramount. Not only is the proposed project on their property, but their adjacent facilities will facilitate the ease and speed of material removal resulting in a reduction in overall project costs. Teichert also recognizes the necessity of keeping the river corridor separate from the rest of their property, particularly the two ponds.

4.4 ALTERNATIVE 1 – TOPOGRAPHICALLY DIVERSE FLOODPLAIN

Creating a more frequently inundated and topographically diverse floodplain serves as the baseline for all proposed enhancement alternatives in the Hallwood project area. Most higher elevation areas between the existing main channel alignment and the north wall (~163 acres of floodplain, bar and off-channel habitat) would be graded such that they inundate between approximately 3,000 and 7,000 cfs (see Sections 3.1 and 3.3 for justification of flows; see Figure 20 for concept map). In addition, some areas located adjacent to perennial channels (e.g., the main channel) could be graded to lower elevations allowing for inundation at flows less than 3,000 cfs. Areas graded to the lower end of this range would serve as more frequently available floodplain habitat for juvenile salmonids. On the other hand, areas graded to the higher end of this flow range would create riparian vegetation habitat that becomes inundated less frequently and are somewhat more sheltered from more powerful flood flows. These higher elevation areas would ideally generate mature stands of large riparian trees (e.g., cottonwood, black willow, sycamore, etc.), that could eventually provide a source of large wood for the river. The topographically diverse floodplain would be graded to drain back into perennial channels (e.g., the main channel), to reduce the risk of fish stranding.

Exceptions to the specified grading range could include stands of existing riparian and upland vegetation (if desired), existing aquatic and riparian habitat along the downstream half of the high-flow channel, and sections of the middle wall that protect infrastructure or serve an intended geomorphic purpose in the design (Figure 20). The existing downstream pond-type features could be laterally constricted with sediment to create a faster-flowing side channel and to reduce refugia for predatory fish. Riparian vegetation would be retained to the greatest extent possible to provide allochthonous inputs, shade, cover, and a source of large wood in the event of recruitment during large events.

In addition to grading the floodplain to allow for more frequent inundation, additional features would be created to provide greater habitat diversity. These would include swales and other small, channel-like features that would be seasonally inundated. The location, elevation and dimensions of these features would be determined as part of a more detailed design process that would occur after the proposed alternatives are discussed by various stakeholders. Floodplain grading would be performed to minimize disconnected isolated depressions that could provide a risk for stranding as flows recede.

Floodplain grading and middle wall removal would generate significant volumes of material. Initial material yield calculations have been performed for grading the site to the elevation of 5,000 cfs in the main channel. Removal of the entire middle wall (a roughly 80 acre footprint at the 5,000 cfs elevation) would generate approximately 3.8 million yd^3 of material. Of that number, roughly 334,000 yd^3 would be left in place as part of the 10-acre area to protect the power line infrastructure. Grading the upstream end of the high-flow channel to this 5,000 cfs elevation would net roughly 183,000 yd^3 of substrate. Lowering the main channel bar surfaces on the river side of the toe of the middle wall to this same elevation profile would yield an additional 236,000 yd^3 of material.

Primary constraints and uncertainties of concern for the topographically diverse floodplain include:

- Integrity of the north wall and its ability to maintain the separation between the river corridor and the ponds to the north.
- Main channel migration and capture of the high-flow channel; high geomorphic uncertainty, but could also be an acceptable result.
- Amount of fine material required to provide a floodplain surface that would support the establishment and persistence of riparian vegetation.
- Size and stability of the middle wall island retained for the transmission tower.

4.5 ALTERNATIVE 2 – PERENNIAL SPLIT CHANNEL

The perennial split channel design draws on the channel alignment present in 1947 when flow in the project area was roughly split between two similar channels located on either side of the middle training wall (Figure 21). This alternative incorporates the grading footprint proposed above in Alternative 1 and a perennial side channel that would carry roughly half of the river flow. The perennial channel's geometry would be guided by the main channel's existing geometry. This design could generate a bankfull channel footprint of approximately 30 acres although this is a rough estimate as the grading geometry would determine the resulting inundation area. In addition, if the perennial split channel were designed to convey approximately half of the flow, the surface area of the main channel would be reduced. Approximately 15,000 feet of new additional shallow edgewater habitat would be created along the new channel margins.

The ability to maintain two channels and the hydraulic conditions for split flow would need to be carefully considered in a later design evaluation phase. This area is currently aggrading (Figure 14) and historically reverted from a split channel to a single primary channel (Figure 3 through Figure 10). Perhaps the channel inlet could be maintained by leaving a portion of the middle wall, the use of engineered log structures (or rock structures), or a combination of these. For the purpose of discussion, we have hypothesized that retaining a portion of the middle wall and augmenting it with an engineered log structure(s) could maintain the split channel inlet. In addition, another portion of the middle wall has been retained to slow the lateral migration of the main (southern) channel into the new northern perennial channel. These areas could be adjusted based on further modeling and analysis of localized hydraulics to determine shear stresses necessary to erode these "islands" of material.

With the exception of the middle wall islands described above and the 30 acre bankfull footprint of the split channel, floodplain grading would be very similar to that proposed in Alternative 1. Most areas would be lowered to inundate at flows between 3,000 and 7,000 cfs while the existing downstream pond-type channels would be improved through the addition of sediment. Existing large woody riparian vegetation would be retained as practical.

Due to the introduction of significantly greater flows to the northern channel, the north wall would be enhanced along its full length. Rock or log scour protection measures and/or wall augmentation would be implemented after additional analysis and modeling of erosion under proposed conditions.

The perennial side channel alternative provides a comparison to an alternative that would create smaller, stream-type side channels (see Table 3, and Sections 4.6 through 4.8). Construction of a split channel alignment would produce a second channel with similar geometry, water depths and flow velocities as the main channel. For the purposes of juvenile salmonid rearing, this would create habitat that is fairly similar to that already present in the main channel, which is not as critical for Chinook salmon and steelhead as other habitat types proposed in the following alternatives.

Primary constraints and uncertainties of concern with a perennial split channel include:

- Integrity of the north wall and its ability to maintain the separation between the main channel and the Teichert dredger ponds to the north.
- Persistence of the new channel inlet in what is currently a depositional environment.
- Main channel migration and abandonment of one split channel alignment; high geomorphic uncertainty.
- Utility of the new channel as juvenile salmonid rearing habitat.
- Size and stability of the middle wall island retained for transmission tower.

4.6 ALTERNATIVE 3 – REARING SIDE CHANNEL

The rearing side channel design would create stream-type side channel habitat in the Hallwood project area to benefit juvenile salmonids. As noted by Rosenfeld et al. (2008), smaller stream-type channels may be more productive than larger pond-type side channels. Habitat utilization within the existing habitat features in high-flow channel is currently being investigated in concurrent efforts by the USFWS, SYRCL and Cramer Fish Sciences. As these datasets become more available, usage patterns specific to the high-flow channel may help guide side channel dimensions.

Several reference sites along the LYR may also help guide design. A side channel at First Island in the Parks Bar Reach (upstream of the DPD reach) demonstrates bankfull widths from 75 - 125 feet according to the RMT 2D model results (Pasternack, 2009). Existing stream-type features within the high-flow channel corridor may also provide a good baseline for stream-type side channel geometry. When supplied by subsurface flows, their widths range between 20 and 40 feet but would grow with a greater amount of flow. An example of a stream-type side channel in the project area is shown in Figure 22.

While additional analysis would be necessary to determine optimal side channel geometry for rearing habitat, this preliminary concept design proposes a side channel with a 75-foot bankfull width and a seasonal surface water connection at the upstream end (Figure 23). The designed channel would extend from the upstream end of the middle wall through the improved downstream reach of the high-flow channel. The configuration would generate approximately 15,000 feet of shallow edgewater habitat along the new channel margins and create a footprint of roughly 12 acres. At flows above 3,000 cfs, the

Table 3. Hallwood project area enhancement alternatives comparison

Alternative	Components	Middle Wall Retained (ac)	FP Area Created (ac)	Wetted Edge Created (ft)	Side Channel Created (ac)	Benefits	Constraints
1 Topographically Diverse Floodplain	• Create a topographically diverse floodplain graded to elevation inundating between 3,000-7,000 cfs • Retain middle wall island at transmission tower • Channel improvements at downstream aquatic features • Enhance existing swales	~ 10	~ 163	None	None	• Increased inundation frequency and duration • Diverse mosaic of habitat types for juvenile salmonid rearing and riparian vegetation • One created floodplain leading edge and wetted edges around retained existing upland vegetation islands	• North wall • High geomorphic uncertainty
2 Perennial Split Channel	• Create alternate channel with invert below baseflow elevation • FP grading same as Alt. 1 except for channel footprint • Retain middle wall islands at tower and 2 other locations • Channel improvements at downstream aquatic features • Enhance north wall along full length of Daguerre Alley	~ 17	~ 108	~ 15,000 depending on stage and grading	Larger split channel, more similar to main channel (~ 40 ac)	• Increased inundation frequency and duration • Two created channel edges and wetted edges • Perennial alternate channel connection could potentially benefit rearing juveniles and spawners	• North wall • High geomorphic uncertainty
3 Rearing Side Channel	• Create small side channel with a surface connection activating at ~3,000 cfs and a perennial percolation gallery • FP grading same as Alt. 1 except for channel footprint • Retain middle wall islands at tower and 2 other locations • Channel improvements at downstream aquatic features • Enhance north wall along full length of Daguerre Alley	~ 17	~ 136	~ 15,000 depending on stage and grading	Smaller stream-type side channel (~ 12 ac)	• Increased inundation frequency and duration • Two created channel edges and wetted edges • Creation of small stream-type channel habitat supporting increased juvenile salmonid biomass • Percolation gallery provides habitat diversity and buffer against geomorphic change/deposition	• North wall • Moderate geomorphic uncertainty • Predation • Spawner attraction to percolation fed backwater • Stranding
4 Diverse Rearing Side Channels	• Create small side channel with a surface connection activating at ~3,000 cfs and a perennial percolation gallery at meander bend • Create a pilot channel with invert near bankfull at existing upstream connection • FP grading same as Alt. 1 except for channel footprint • Retain middle wall islands at tower and 2 other locations • Channel improvements at downstream aquatic features • Enhance north wall along full length of Daguerre Alley	~ 14	~ 138	~ 7,000 + additional 8,000 activated at higher flows, depending on stage and grading	Smaller stream-type side channel (~ 5 ac) with self forming channel upstream (~5+ ac)	• Increased inundation frequency and duration • Two created channel edges and wetted edges • Creation of diverse stream-type channel habitat supporting increased juvenile salmonid biomass • Habitat diversity and design resilience with two connection points at variable inverts • Percolation gallery provides habitat diversity and buffer against geomorphic change/deposition	• North wall • Moderate geomorphic uncertainty • Predation • Spawner attraction to percolation fed backwater • Stranding
5 Diversion to Rearing Side Channel	• Divert water and fish from Cordua-Hallwood Fish Screen • Operable gate allows potential for alternate diversion to main channel • All other elements same as Alt. 3	~ 17	~ 136	~ 15,000 depending on stage and grading	Smaller stream-type side channel (~ 12 ac)	• Same benefits as Alt. 3 with addition of supply of juveniles and minor flows to side channel	• Same as Alt. 3 with addition of water rights/permitting constraints

channel's upstream end would exhibit a direct surface water connection with the main channel. The channel head would also be constructed with a percolation gallery to continue supplying flow after river discharge drops below 3,000 cfs. Constructing this feature would require the excavation of material at the head of the side channel and installation of locally obtained large cobble and boulder substrate to increase porosity and permeability. The design aims to protect juvenile salmonids from predation by isolating the side channel from the main channel as river discharge declines later in the rearing season. At the same time, the substantial, year-round subsurface connection would help maintain stream-type habitat and temperature conditions. Conversations with RMT members upon a preliminary presentation of these scenarios showed strong interest in utilizing subsurface flow by percolation galleries as proposed in this alternative.

Floodplain and middle wall grading would be similar to that proposed in Alternative 1 with the exception of the side channel's footprint and two additional middle wall islands. The north training wall would be enhanced in select locations where the wall's width and crest height and proximity are of significant concern.

The main constraints and uncertainties of concern with a small side channel are:

- Integrity of the north wall and its ability to maintain the separation between the main channel and the ponds to the north. While the risk may be less than that generated by a split channel design, careful analysis of changes to flow and erosion conditions is advised.
- Side channel beds may aggrade or scour depending on local hydraulics. The presence of a percolation gallery with large cobble/boulder inset into local substrate *may* help fix the minimum bed elevation and maintain a perennial flow connection.
- Predation of juveniles may become more of a concern in the summer as the side channel disconnects. However, this configuration exists currently after the recession of events exceeding 10,000 -15,000 cfs that may be carrying juveniles.
- The potential for spawner attraction during the summer and fall months due to subsurface flow at the percolation fed backwater is an unknown
- Stranding in side channel pools especially if the morphological configuration of the channel adjusts over time.
- Extent of thermally suitable rearing habitat during summer and fall.
- Size and stability of the middle wall island retained for transmission tower.

4.7 ALTERNATIVE 4 – DIVERSE REARING SIDE CHANNELS

This enhancement alternative builds on design elements from Alternatives 1 and 3 to create a side channel configuration with greater spatial and temporal habitat diversity. As shown in Figure 24, the primary side channel would originate at the main channel's first meander bend downstream of the high-flow channel's existing entrance. The side channel would be designed with similar dimensions (a ~75-foot bankfull width) and would generate a roughly 5-acre footprint between its upstream end and downstream tie-in to the improved channel. It would also provide approximately 7,000 feet of additional perennial shallow edgewater habitat as well as an additional 8,000 feet of edgewater habitat activated at higher flows. Similar to the side channel in Alternative 3, this channel would exhibit a surface connection above 3,000 cfs and would maintain a year-round subsurface connection via a constructed percolation gallery at the channel head.

This side channel configuration would be complemented with a pilot channel constructed from the upstream end of the high-flow channel to a tie-in point with an existing flood runner/high-flow channel. This configuration would provide a greater diversity of inundation frequencies and depths as compared to the more uniform side channel proposed in Alternative 3. The flood runner feature would activate at roughly 4,500 cfs, providing additional flows and potential downstream-emigrating juveniles earlier in the rearing season. During March-June, this upstream segment may inundate for approximately 3 days, while areas downstream may inundate for approximately 21 days on average, every other year. If desired, the upstream flood runner bed elevation could be reduced to encourage more frequent inundation with longer duration and greater depths. The primary side channel would be responsible for prolonging the surface connection with the main channel at discharges below 5,000 cfs.

Floodplain and middle wall grading would be similar to that proposed in Alternative 1 with the exception of the side channel's footprint and the retained portions of the middle wall. The north wall would be enhanced in select locations where the wall's width and crest height and proximity are of significant concern.

Main constraints and uncertainties of concern for a small side channel and moderate flow pilot channel include the following:

- Integrity of the north wall and its ability to maintain the separation between the main channel and the Teichert dredger ponds to the north. While the risk may be less than that generated by a split channel design, careful analysis of changes to flow and erosion conditions is advised.
- Moderate geomorphic uncertainty, as both side channel and pilot channel beds may aggrade or scour depending on local hydraulics.
- Predation of juveniles may become more of a concern in the summer as the side channel disconnects. However, this situation may already exist during the receding limb of events exceeding 10,000 -15,000 cfs that may be carrying juveniles.
- The potential for spawner attraction during the summer and fall months due to subsurface flow at the percolation fed backwater is an unknown.
- Stranding in side channel or pilot channel pools especially if the morphological configuration of these channels adjust over time.
- Size and stability of the middle wall island retained for transmission tower.

4.8 ALTERNATIVE 5 – DIVERSION TO SIDE CHANNEL

This alternative proposes diverting water and entrained juveniles from the Cordua-Hallwood Diversion Structure Fish Screen into a constructed side channel with a configuration similar to Alternative 3. The upstream inlet of the side channel would activate at 3,000 cfs while maintaining a perennial subsurface connection through a percolation gallery. Minor flows could be sourced from the fish screen when the diversion is active. The diversion structure would be augmented with an open channel or large pipe that would carry both water and juvenile fish to the side channel (Figure 25). A simple gate could be added to the head of the diversion channel or pipe to provide operator control over when this connection is active. It may also be beneficial to develop an alternate connection from the fish screen to allow entrained juveniles to be transported to the main channel in case conditions in the side channel are not conducive for rearing.

Other than the grading associated with a channel or pipe from the diversion structure, floodplain and middle wall grading would be exactly the same as that proposed in Alternative 3. The north wall would be enhanced in select locations where the wall's width and crest height and proximity are of significant concern.

In addition to the topics covered in Alternative 3, the main constraints and uncertainties of concern with a diversion to the side channel include:

- Existing diversion water rights and permitting constraints for potential take under the Endangered Species Act or other permitting considerations.

4.9 POTENTIAL ISSUES OF CONCERN

Several potential challenges have been identified that would significantly jeopardize project success or severely impact the landowner. Careful analysis, design and construction should be performed to avoid their occurrence. Issues of concern include the potential of:

Breaching of the north wall

As discussed in section 3.6, the north wall currently serves as a physical barrier between the active river corridor and private property located on the river floodplain, and in several locations is fairly narrow (i.e., 50 ft base width). Floodplain grading and removal of the middle wall would likely result in more frequent communication of the north wall with overbank flows. Removal of the middle wall would also significantly increase the possibility of or rate of main channel migration to the north, and the potential for increased erosive forces acting on the north wall during major flood events. At the same time, the associated removal of a large volume of material from the river corridor will reduce river stages during flood events. Reduced flood stages could act to reduce the energy of overbank flows interacting with the north wall. Failure of the north wall could result in devastating impacts to landowners and to the river itself (e.g., geomorphic and ecological). Enhancement designs, particularly those involving removal of the middle wall, must address this risk.

Stranding of adult salmonids in a side channel

Adult salmon and steelhead migrating upstream may be stranded in a side channel when a surface water connection with the main channel is not present at the upstream end of the side channel. This concern is particularly relevant for designs featuring a percolation gallery where attraction flows may exist despite the absence of an upstream surface water connection with the main channel.

Excessive predation of juvenile salmonids

Depending on the depth of the aquatic features, presence of cover (e.g., large wood, overhanging riparian vegetation, etc.) and other factors, predation of juvenile Chinook salmon and steelhead could significantly affect survivorship. Enhancement designs should consider predation pressures and provide features that reduce this risk.

Side channel inlet aggradation and loss of connectivity with main channel

Flood events may deposit significant volumes of sediment near the inlet(s) of an engineered side channel, which may decrease the extent and frequency of the surface water connection between the main channel and side channel. The side channel inlet(s) can be designed with this concern in mind to reduce the likelihood of inlet aggradation (e.g., use of engineered log jams or other structures to promote sediment transport). However, designs must balance this concern with the goal of creating a dynamic, healthy river corridor. Features such as a percolation gallery can also be employed to maintain higher flows in a side channel despite potential inlet aggradation while reducing the use of engineered structures or controls.

Realignment of the main channel via lateral migration or avulsion following project implementation

Floodplain grading and removal of middle wall material will diminish existing barriers to the river's capacity for dynamic behavior. Success criteria for the project must consider the potential for channel realignment through lateral migration, avulsions or other processes and the persistence of various features within the overall project reach.

Damage to existing power transmission lines and transmission tower

If the existing transmission tower on the middle wall is left in place as part of the project, there exists potential for damage to the transmission tower and associated power transmission lines due to flood hydraulics and scour. Erosion of a middle wall island retained for the transmission tower could undermine the integrity of the tower's foundation and result in significant damage to the tower and the transmission lines. Such an occurrence would affect PG&E's operations and could pose a significant safety concern. As discussed in section 3.6, project analysis and design must consider the integrity of a middle wall island if the existing transmission tower is left in the river corridor.

Increased risk to existing stands of riparian vegetation

Topographic modification of the river floodplain and middle wall could increase the likelihood of the loss of mature vegetation patches, particularly at the downstream end of the high-flow channel. Such a loss of mature vegetation within the floodplain is a natural aspect of dynamic river processes and supports the development of diverse in-channel habitat conditions and the recruitment of large wood. Project goals and success criteria should consider this component of dynamic river behavior.

Construction sequencing and material removal coordination with Teichert

Successful implementation of a project depends significantly on the sequencing and timeline of construction activities and coordination with Teichert for material removal. The partnership with Teichert will be critical for limiting construction costs and ensuring an expeditious removal of material present on the floodplain and middle wall. Phasing of construction activities must consider construction permits, establishment of high-priority riparian vegetation and aquatic features, and Teichert's capacity for material removal and equipment access. A loss of Teichert's interest or capacity for material removal or an incompatibility between construction timelines and permitting can dramatically affect project scope and implementation.

5 POTENTIAL CONSTRUCTION SEQUENCE

Construction sequencing and an associated timeline will depend largely on the details of the selected rehabilitation design and coordination with Teichert. As a potential starting point for future planning, this report identifies a phased approach of earthwork, grading, feature installation and planting activities that includes the removal of the majority of the middle wall (with exceptions of an island for power transmission line structures and strategic "islands") and the creation of a ~2 mile side channel as described by Alternative 3.

While a project timeline is unclear at the time of this report, potential construction sequencing should be developed that allows Teichert access to the material present in the middle wall, potentially for multiple construction seasons. Conversations with Teichert have indicated that the company has a capacity to remove the necessary material from the site in 2 to 6 years. The timeframe for material removal depends on market demand for aggregate and Teichert's capacity to stockpile additional material elsewhere on the Hallwood facility, but outside of the river corridor.

A selected construction sequence should include the following as possible:

- Continued access for Teichert machinery between their processing facilities and the middle wall during the removal of the wall
- Early floodplain grading and textural improvement in areas not covered by the middle wall to allow vegetation planting to occur during the first fall/winter dormant period
- Enhancement of the north wall before significant alteration of river corridor flood hydraulics

Proposed Construction Sequence

1. Enhancement of the north wall.
2. Floodplain grading followed by textural improvement in the non-training wall sections (Zone 1). A zone of high ground at the upstream entrance to the high-flow channel will be left in place to reduce the amount of surface water that would enter the project area between construction years. Until construction is nearly complete, the upstream portion of high ground would be left in place to reduce risk of high-flow channel capture by the main channel during construction. Grading would be conducted in a direction that is logical for Teichert, or for the optimal establishment of riparian vegetation. Additionally, two semi-permanent crossings will be established between the Teichert facilities and the middle wall. These crossings would be maintained until the respective sections of the middle training wall are removed.
3. Perform vegetation planting in select sections of Zone 1 (some areas would be left open to natural recruitment of riparian vegetation) with the exception of the two semi-permanent crossings and areas where side channels and swales will be installed.

4. Removal of a majority of the middle wall aside from retained islands. Removal would start at the downstream extent and move upstream.
5. Provide revetment (engineered log structures or other) to retained portions of the middle wall (i.e., the "islands")
6. Complete material excavation, middle wall grading and textural improvements creating a topographically diverse floodplain.
7. Perform vegetation planting in all remaining created floodplain areas
8. Construct percolation gallery at head of side channel (if applicable).
9. Construct side channel(s).
10. Install large wood habitat features (as applicable).
11. Remove remaining material at the head of the north channel to encourage surface water connection.

The approach outlined above would need to be modified based on a selected project design and construction timeline. Additionally, it is likely that the implementation of many of the components above will have overlapping timelines and that some will occur over multiple construction seasons. If the schedule is protracted, an emphasis should be placed on grading and planting some areas in the earlier portions of the project to give these stands the ability to mature while the rest of the project is constructed. In addition, a longer timeline could allow for an adaptive design approach that integrates findings from monitoring of early phases into designs and/or construction of later phases of the project.

6 CONCLUSIONS AND NEXT STEPS

The Hallwood project area presents an unusual opportunity for a multi-objective project benefitting a diverse group of ecological, flood management, commercial, agency and local government interests. The existing high-flow channel offers a promising site to generate two or more miles of side channel rearing habitat for Chinook salmon and Central Valley steelhead in a river system in need of such features. The creation of a topographically diverse floodplain through grading activities could provide additional, frequently inundated off-channel habitat as well as support a diverse assemblage of riparian vegetation. Removal of the floodplain and middle wall material would reduce flood stages significantly and would help relieve pressure on this part of a stressed flood protection system, or reduce the costs of a flood management project that is currently being planned. Finally, the project benefits from the presence of a willing landowner who can assist greatly in material removal and grading, thereby reducing project costs and coincidently providing a significant source of tax revenue for Yuba County.

This report summarized relevant hydrologic, geomorphic and ecological information regarding the project site and the LYR, and then presented five enhancement alternatives. These alternatives feature a number of important project elements, including a variety of side channel configurations and options. While all alternatives included a removal of a portion of the middle wall, it is also possible that a project could be conceived that retained all or a vast majority of the middle wall. This would result in dramatically reduced flood reduction benefits and inhibit the ability of the river to be dynamic.

Given the site opportunities and the conditions along the overall LYR, a perennial side channel bordered by frequently inundated floodplains represent strong enhancement elements that are featured in several of the concept alternatives presented. Future collaboration with stakeholders will help refine preferred concepts to carry forward for further investigation and design assessment.

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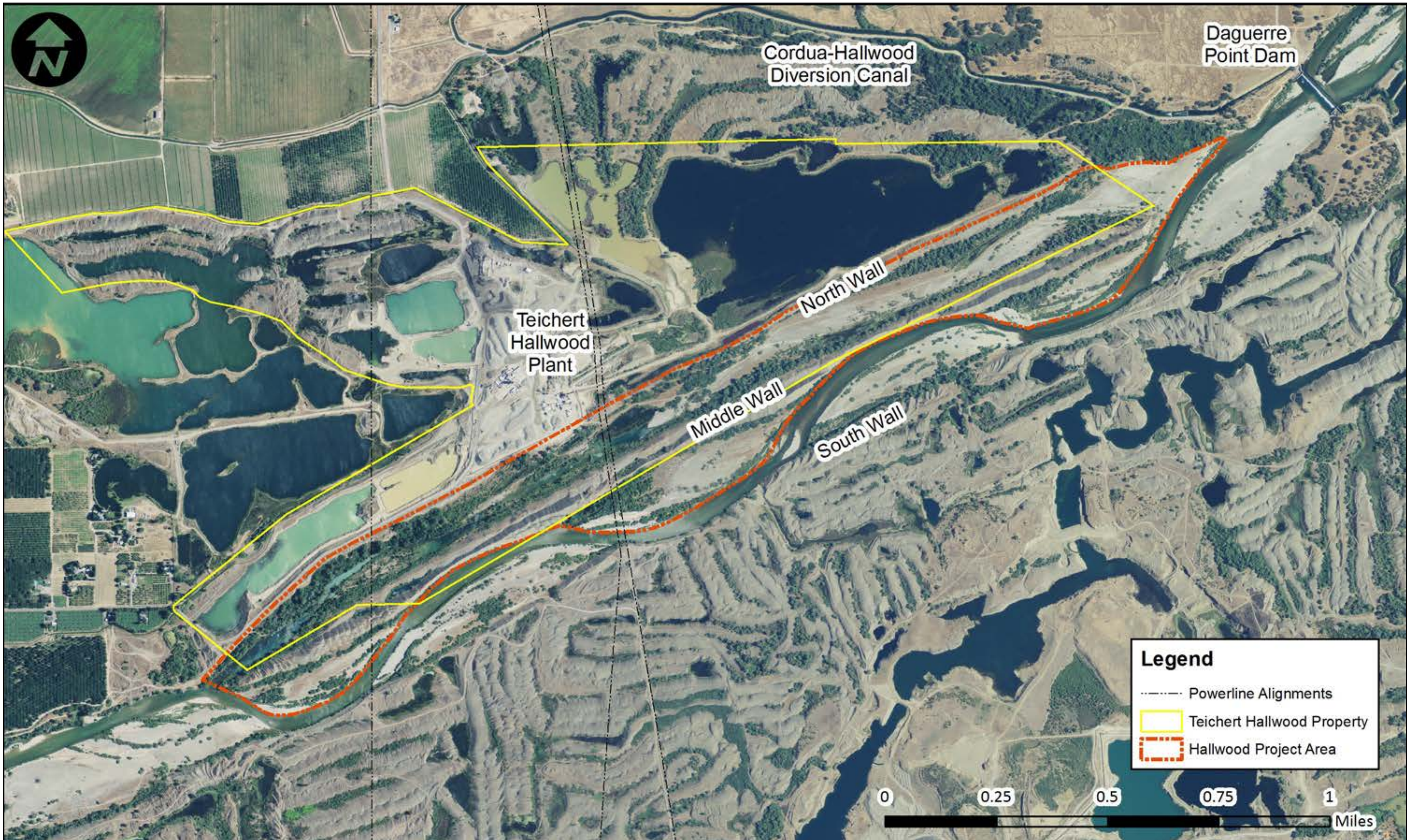

Notes: Aerial image courtesy of NAIP (2012). It is our understanding that the land between the Teichert property line and the active river channel is owned by Western Aggregates. The absolute downstream-most end of the high-flow channel appears to be owned by Baldwin Contracting Co.

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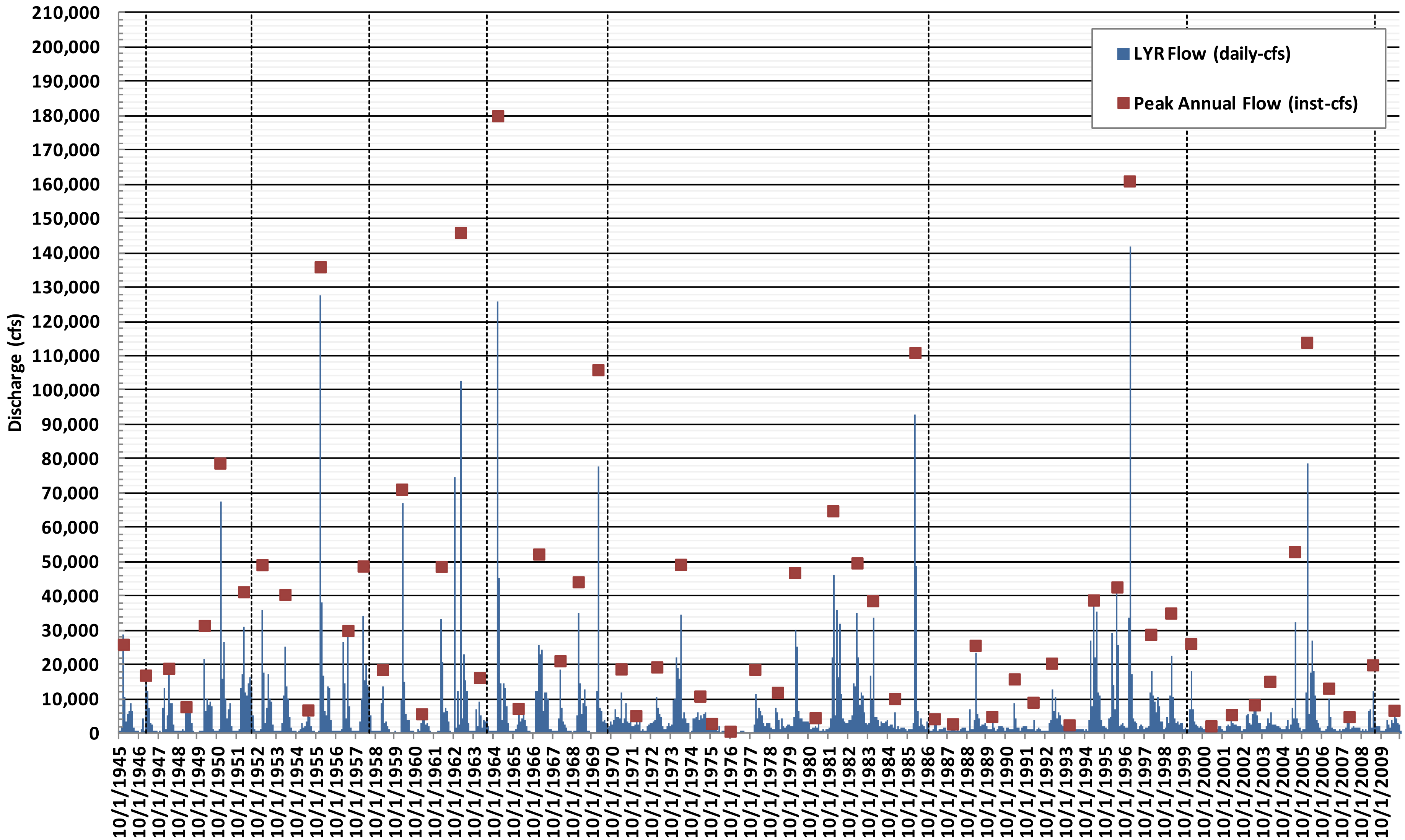
Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River

Hallwood project context

Project No. 12-1034	Created By: JDS	**Figure 1**



Notes: Dashed black lines represent aerial photographs on the subsequent figures. LYR Flow is daily flow at the Smartsville plus Deer Creek gages, Peak Annual Flow is at Marysville gage.

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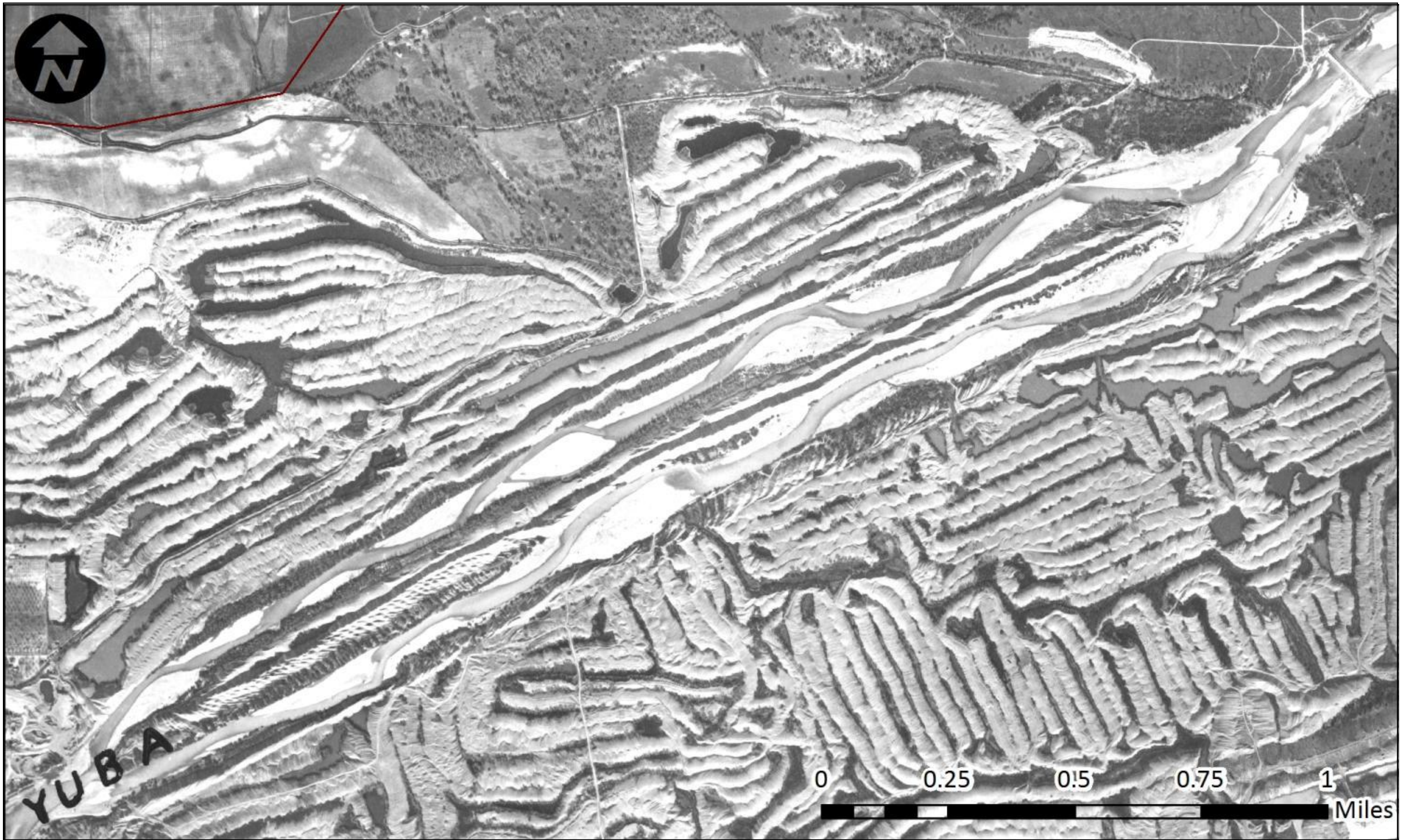
Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River

LYR daily and peak annual flow

Project No. 12-1034	Created By: AMS	**Figure 2**

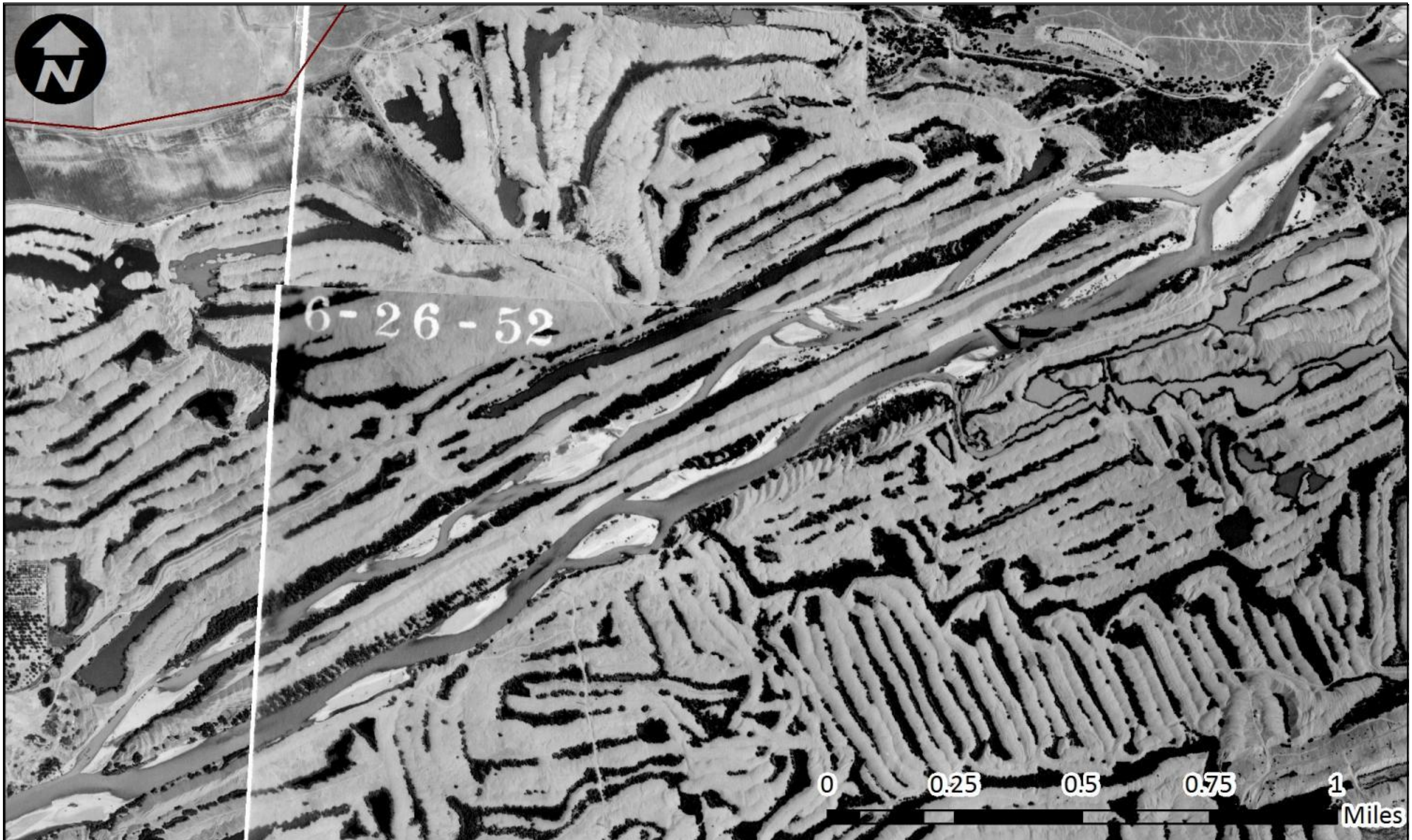


Notes: Aerial image from James (2012). See Figure 2 for hydrologic time series. Flight date of 2/22/1947 at flow of approximately 1,553 cfs.

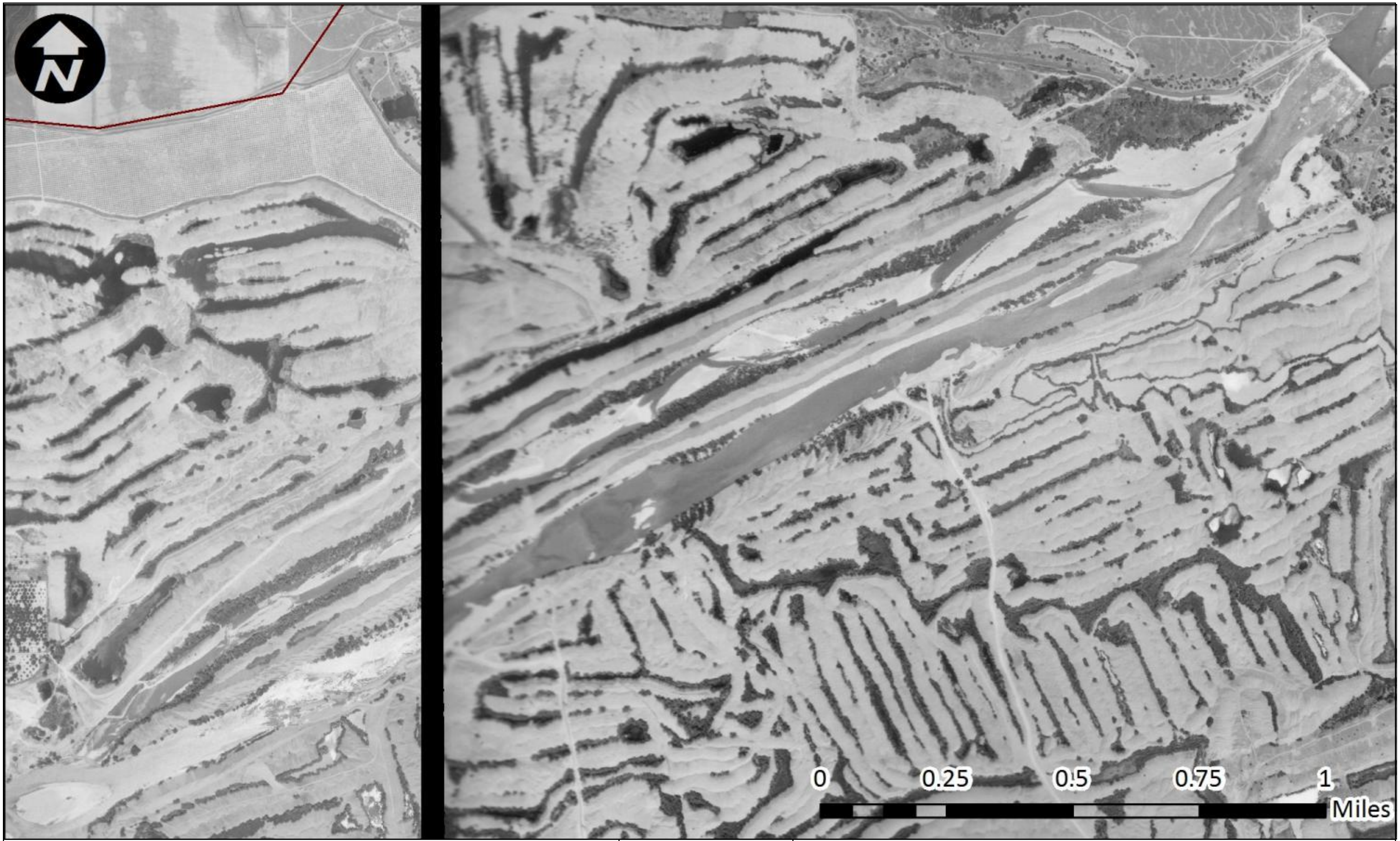
Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River

1947 aerial image

Project No. 12-1034	Created By: AMS	**Figure 3**



Notes: Aerial image from James (2012). See Figure 2 for hydrologic time series. Flight date of 06/26/1952 at flow of approximately 5,727 cfs.	cbec eco engineering	*Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River* **1952 aerial image**		
		Project No. 12-1034	Created By: AMS	**Figure 4**



Notes: Aerial image from James (2012). See Figure 2 for hydrologic time series. Flight date of 06/17/1958 at flow of approximately 7,491 cfs.

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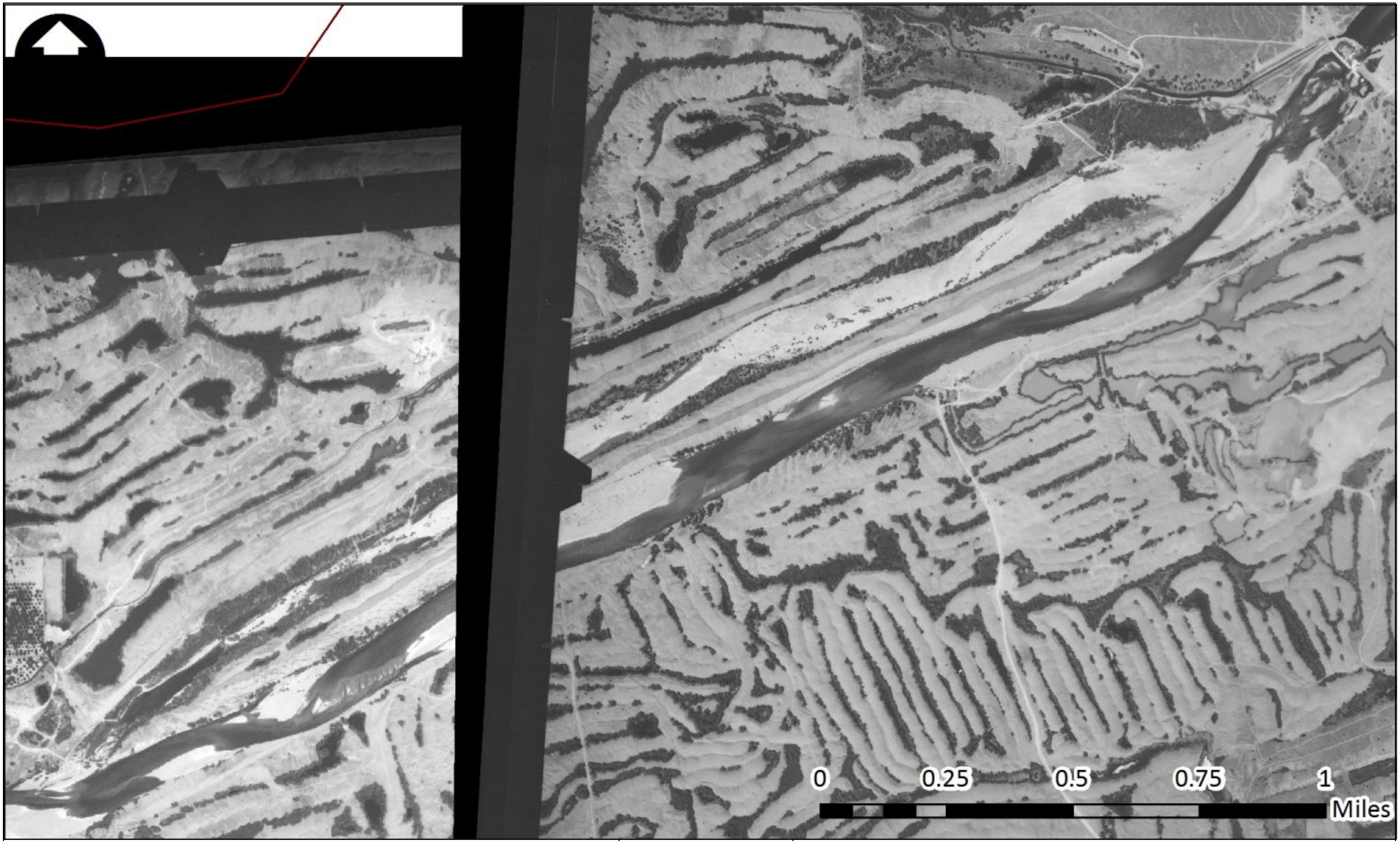
Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River

1958 aerial image

Project No. 12-1034	Created By: AMS	**Figure 5**

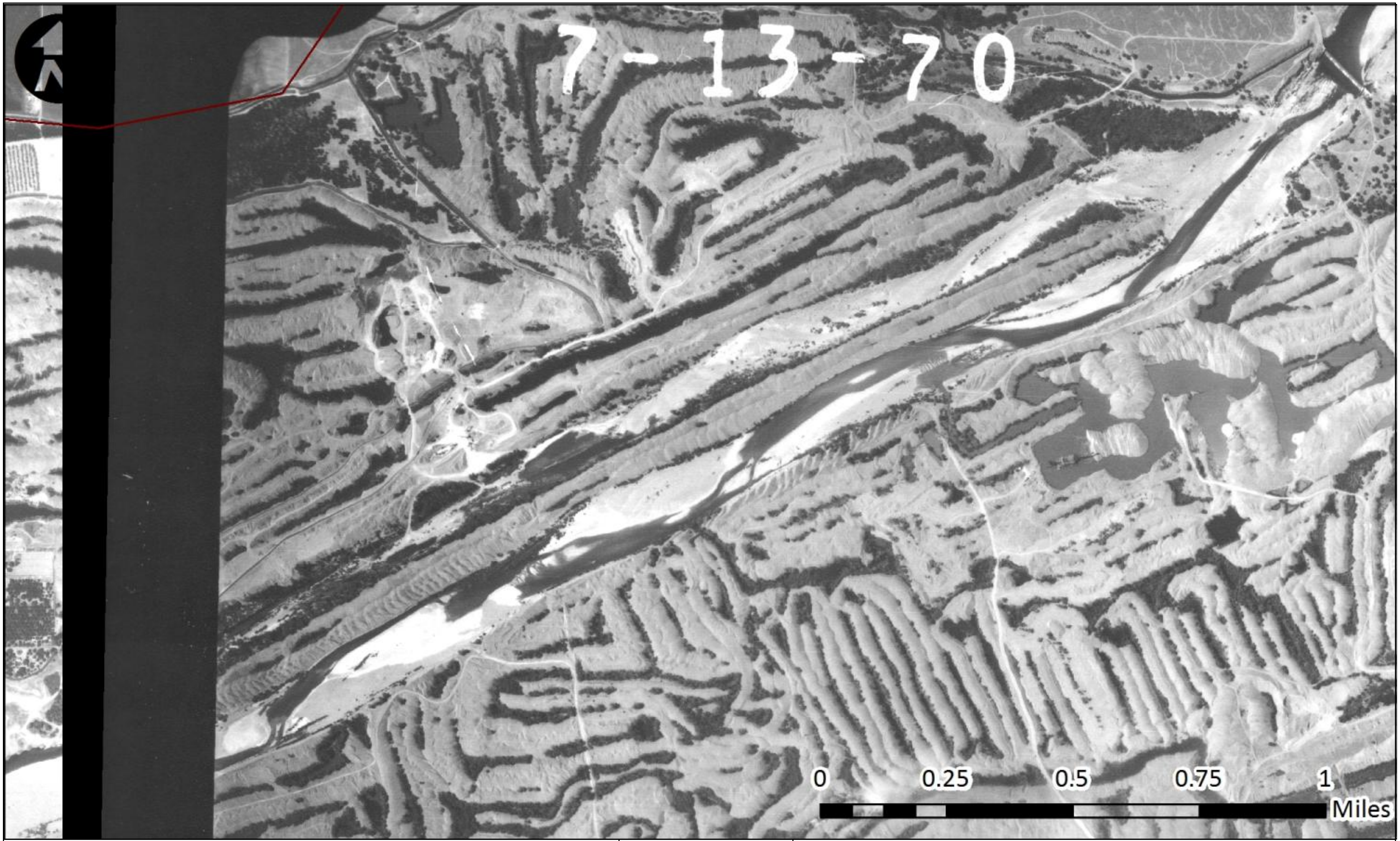


Notes: Aerial image from James (2012). See Figure 2 for hydrologic time series. Flight date of 05/31/1964 at flow of approximately 2,447 cfs.

Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River

1964 aerial image

Project No. 12-1034 | Created By: AMS | **Figure 6**



Notes: Aerial image from James (2012). See Figure 2 for hydrologic time series. Flight date of 07/13/1970 at flow of approximately 713 cfs.

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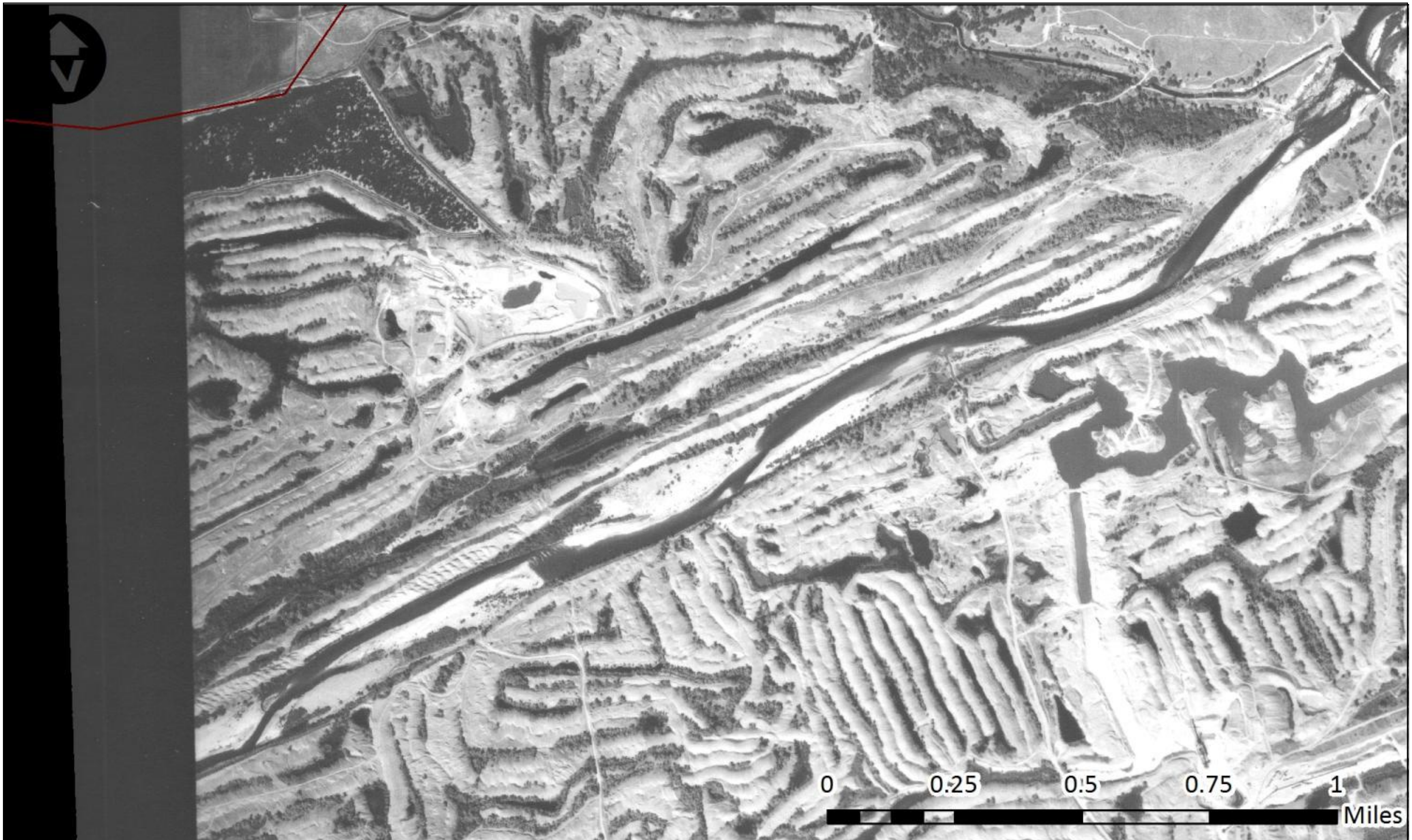
Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River

1970 aerial image

Project No. 12-1034	Created By: AMS	**Figure 7**



Notes: Aerial image from James (2012). See Figure 2 for hydrologic time series. Flight date of 11/4/1986 at flow of approximately 830 cfs.

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Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River

1986 aerial image

Project No. 12-1034 | Created By: AMS | **Figure 8**

Notes: Aerial image from James (2012). See Figure 2 for hydrologic time series. Flight date in 1999 unknown.

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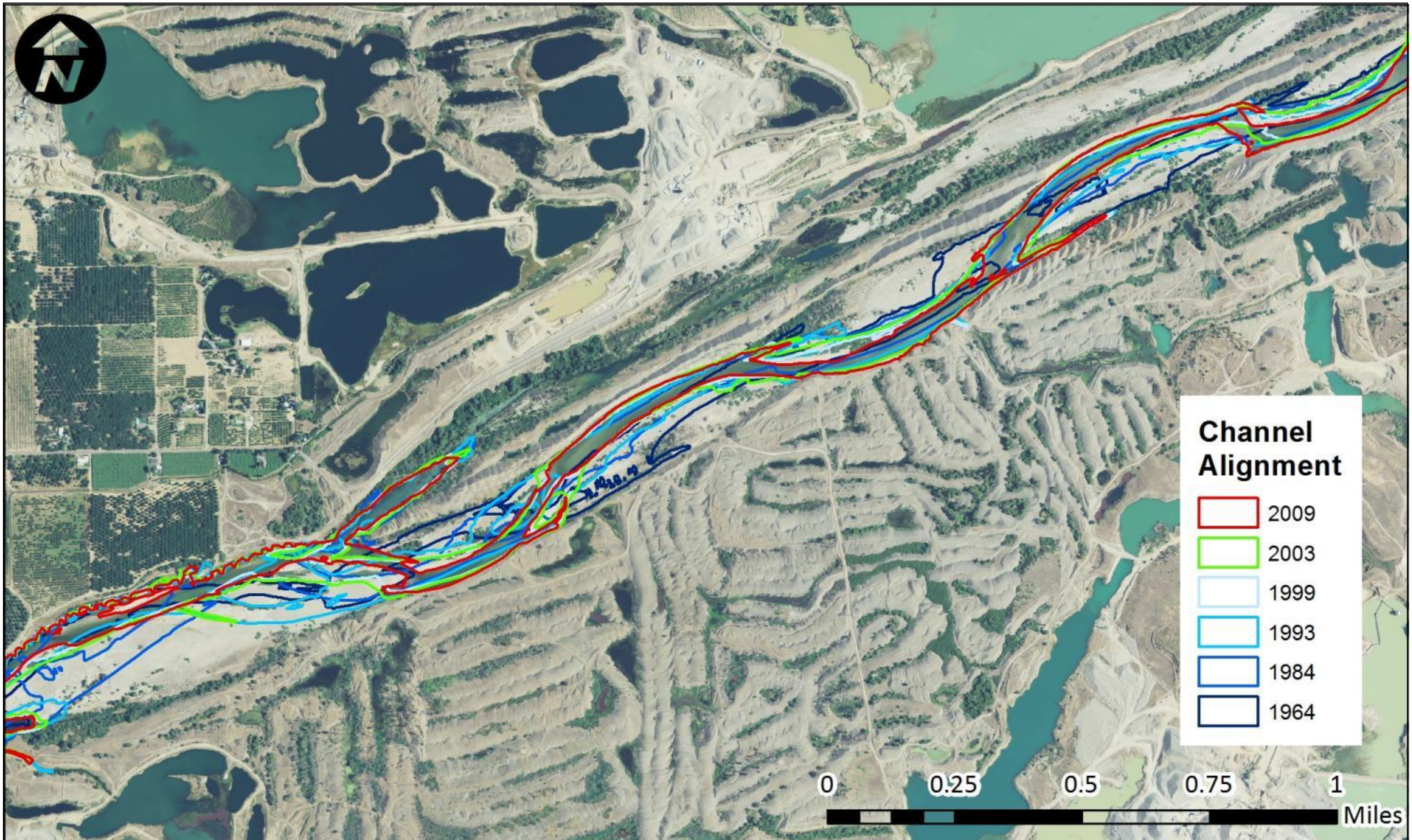
Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River

1999 aerial image

Project No. 12-1034	Created By: AMS	**Figure 9**

Notes: Aerial image from James (2012). See Figure 2 for hydrologic time series. Flight date of 7/3/2009 at flow of approximately 1,987 cfs.	cbec eco engineering	*Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River* **2009 aerial image**	
		Project No. 12-1034	Created By: AMS	**Figure 10**



Notes: Channel wetted edge alignments at time of aerial flight digitized.

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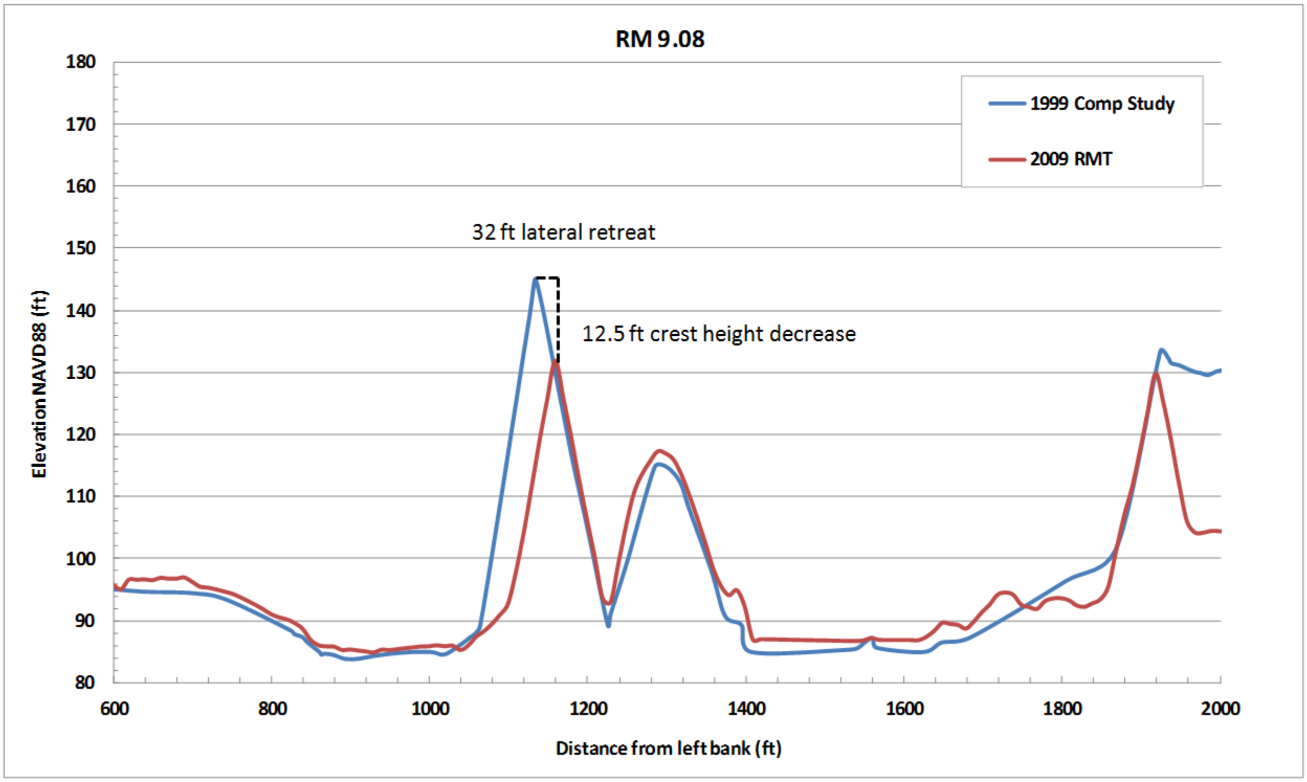
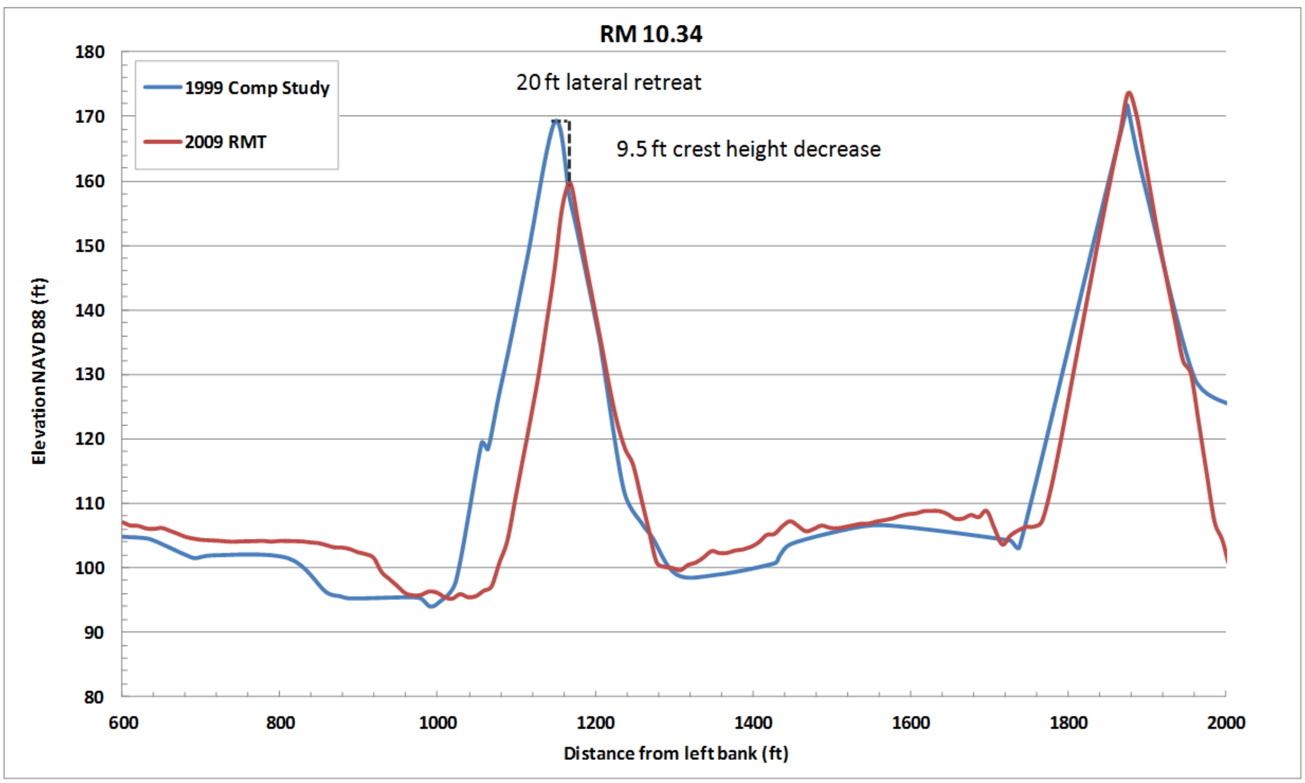
Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River

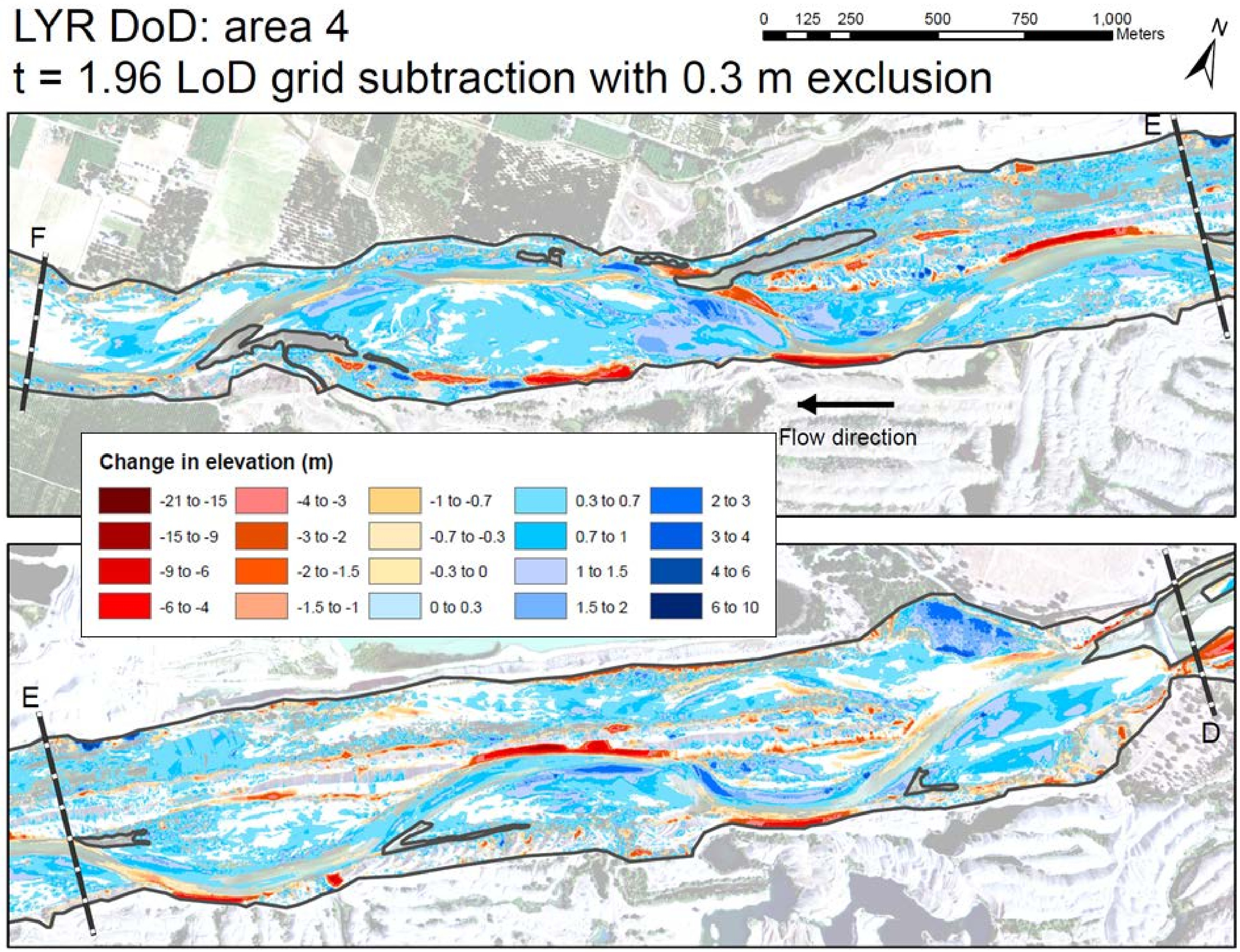
Channel adjustment over 45 years

Project No. 12-1034	Created By: AMS	**Figure 11**

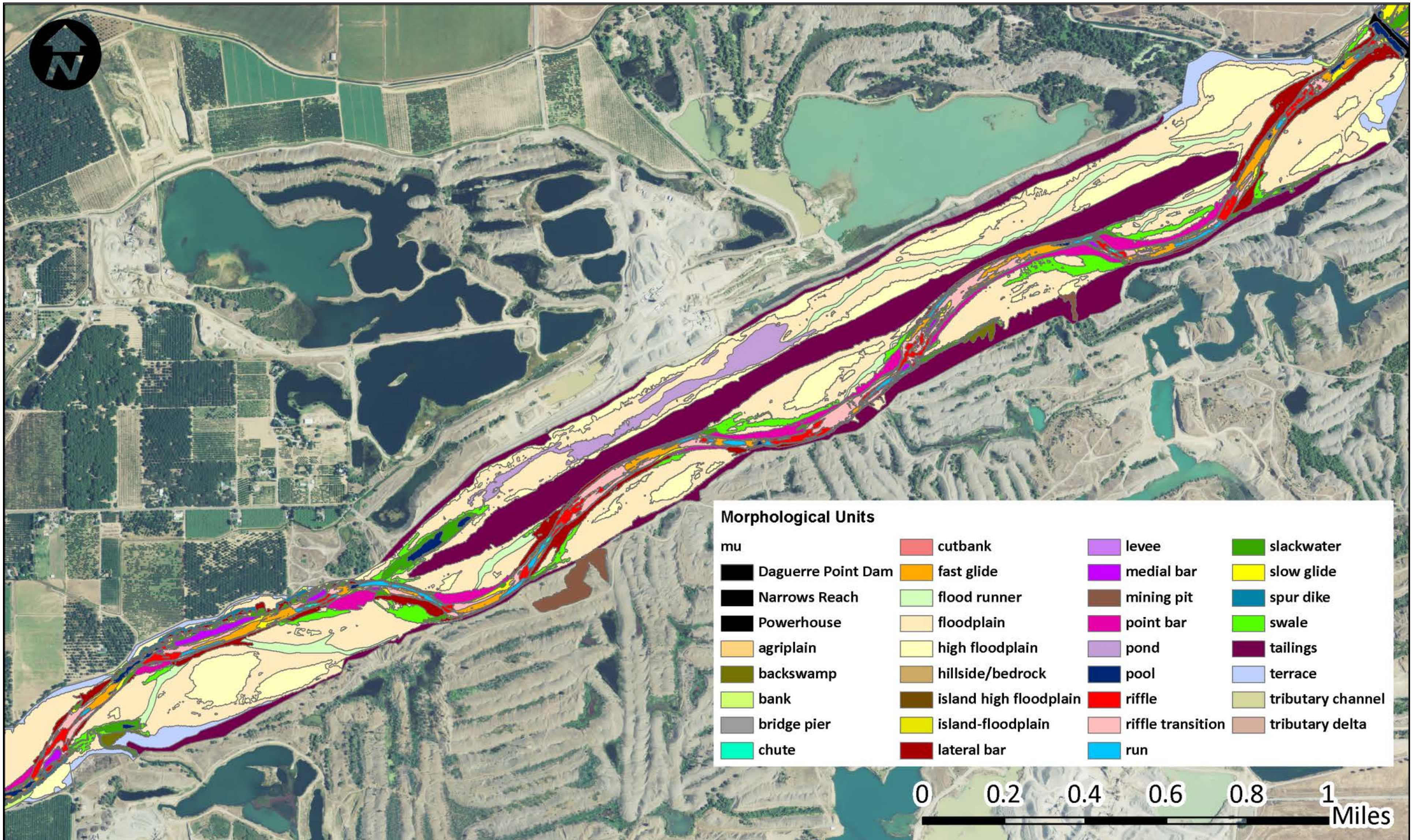




Notes: Cross sections at approximate apex of main channel river right meander bends in DPD reach	cbec eco engineering	*Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River* **Middle wall retreat**		
		Project No. 12-1034	Created By: JDS	**Figure 12**



Notes: Upper panel is downstream of lower panel. Daguerre Point Dam is located at section D. LYR is net erosional above DPD and depositional below. Also note berm retreat at meander bends and channel migration at the downstream connection point.	cbec eco engineering	*Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River* **Supplemental maps from Carley et al. (2012)** Project No. 12-1034 / Created By: JDS / **Figure 13**

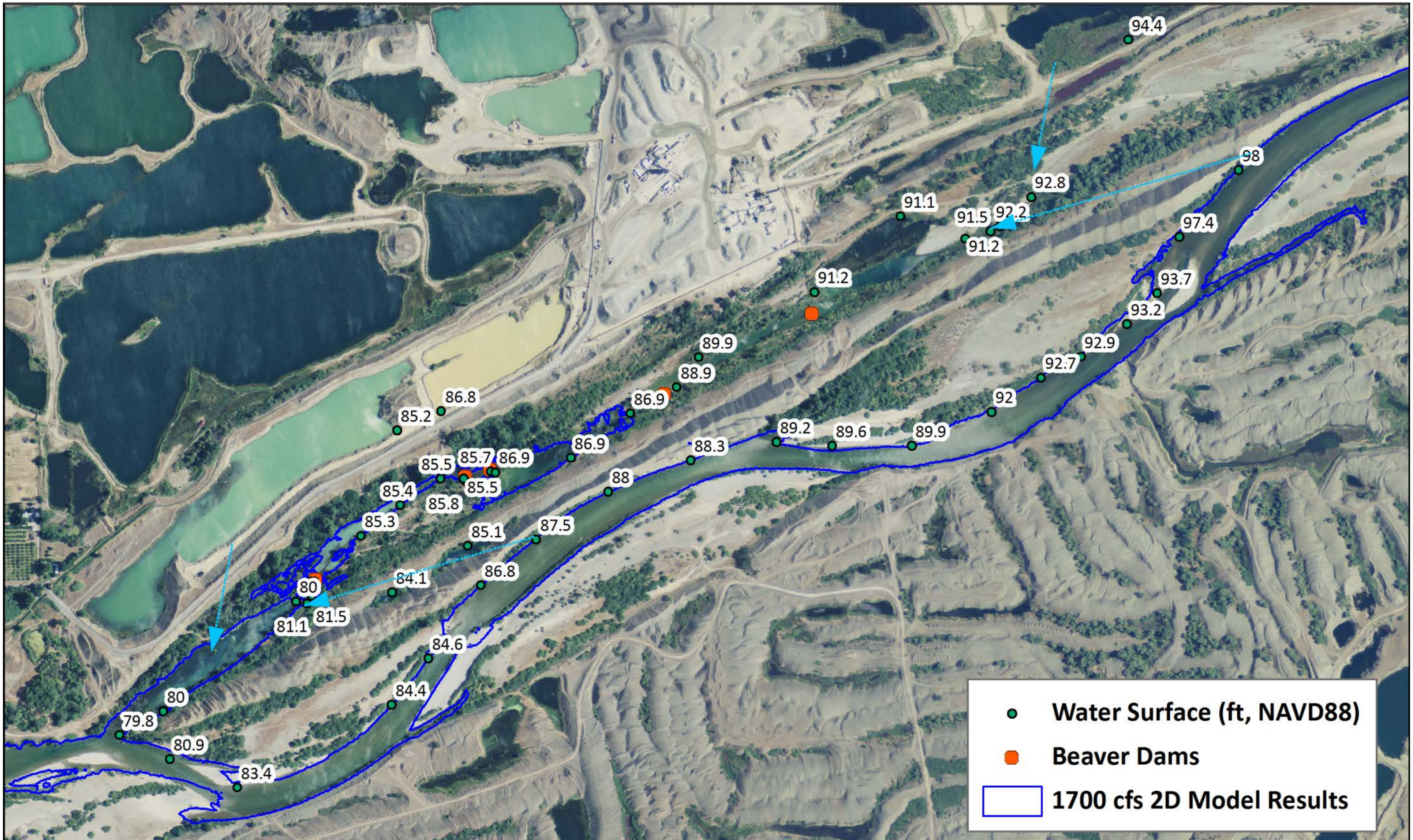


Notes: Aerial image courtesy of NAIP (2012). Morphological units courtesy of Wyrick and Pasternack (2012).

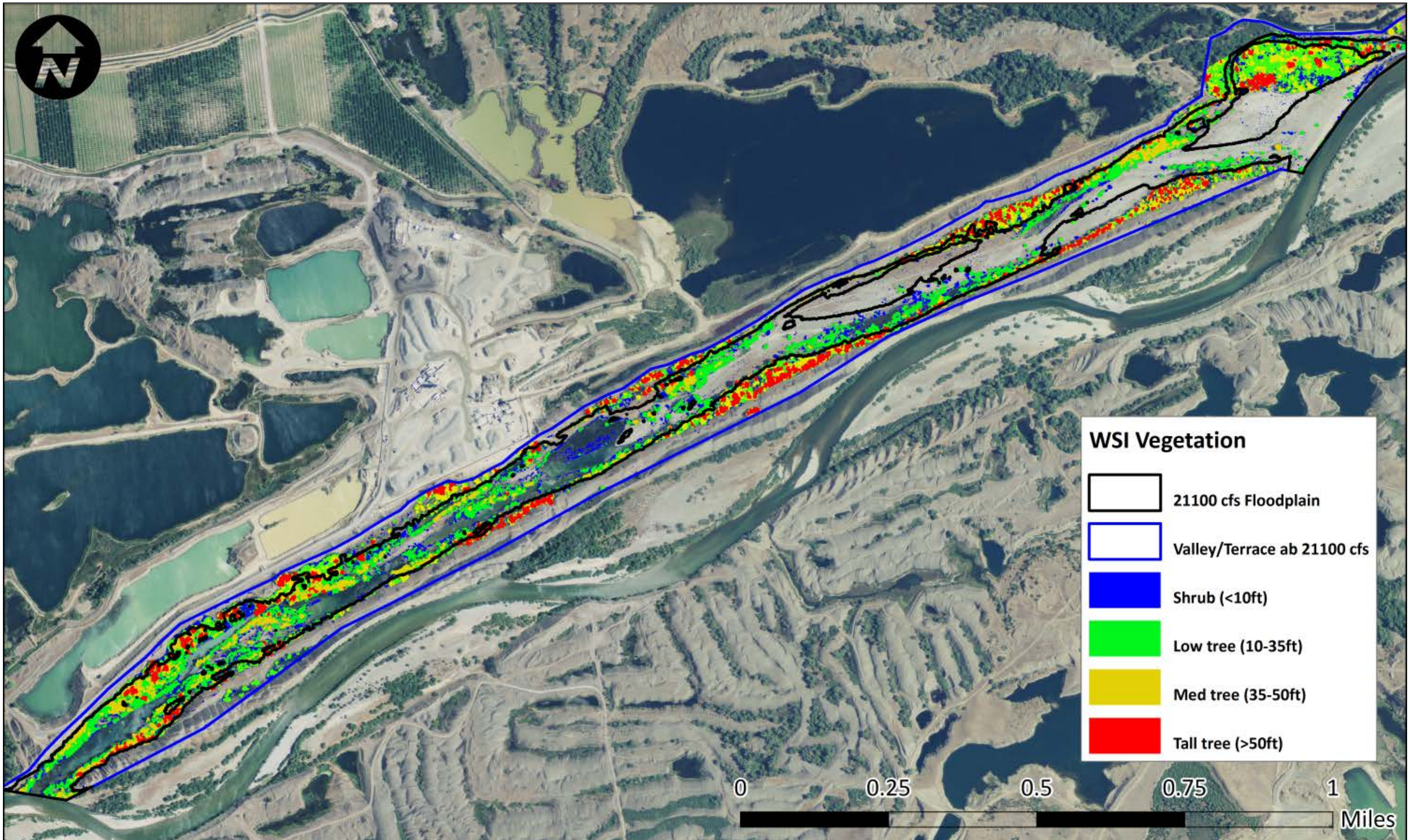
Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River

Morphological units in the DPD Reach

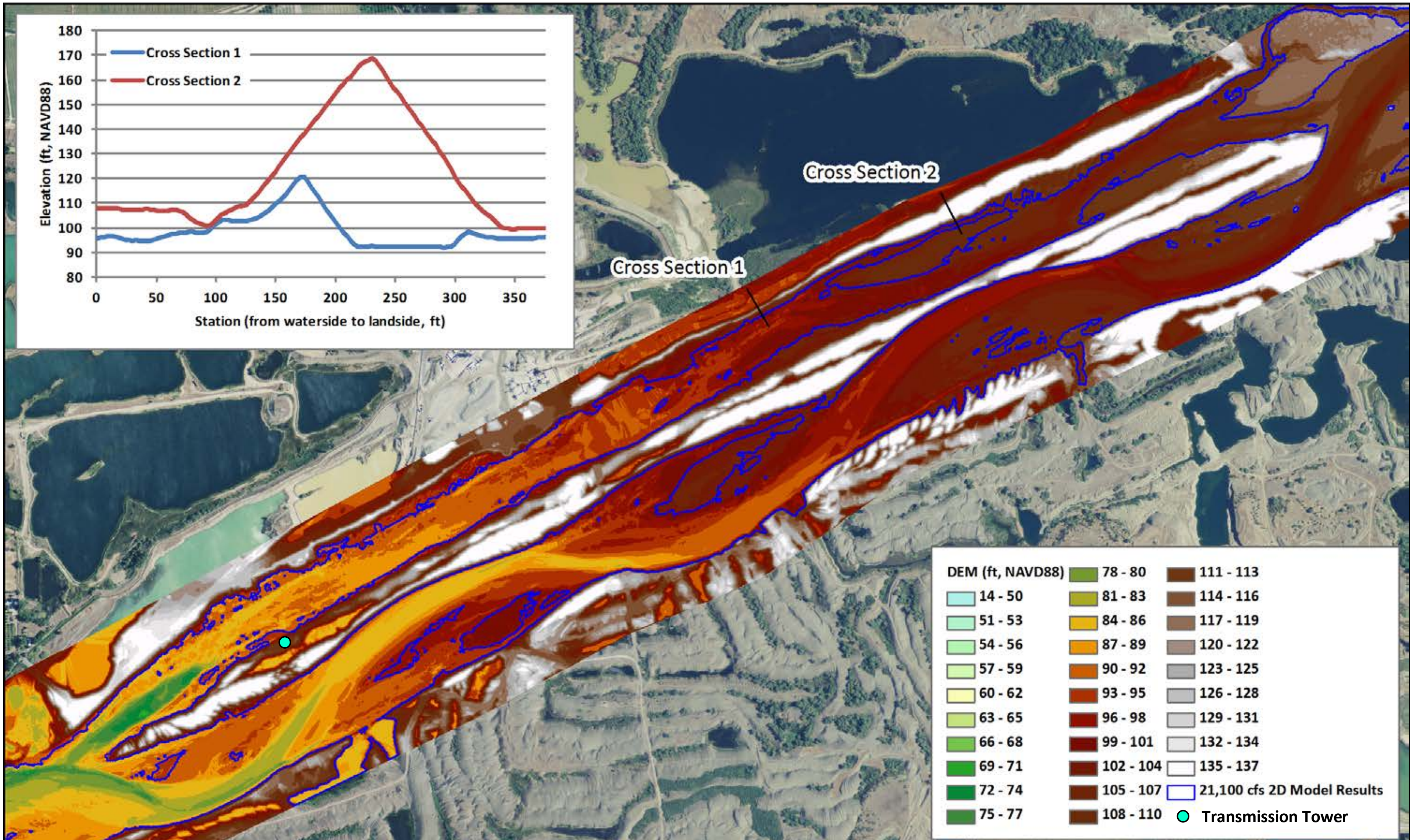
Project No. 12-1034 | Created By: AMS | **Figure 14**



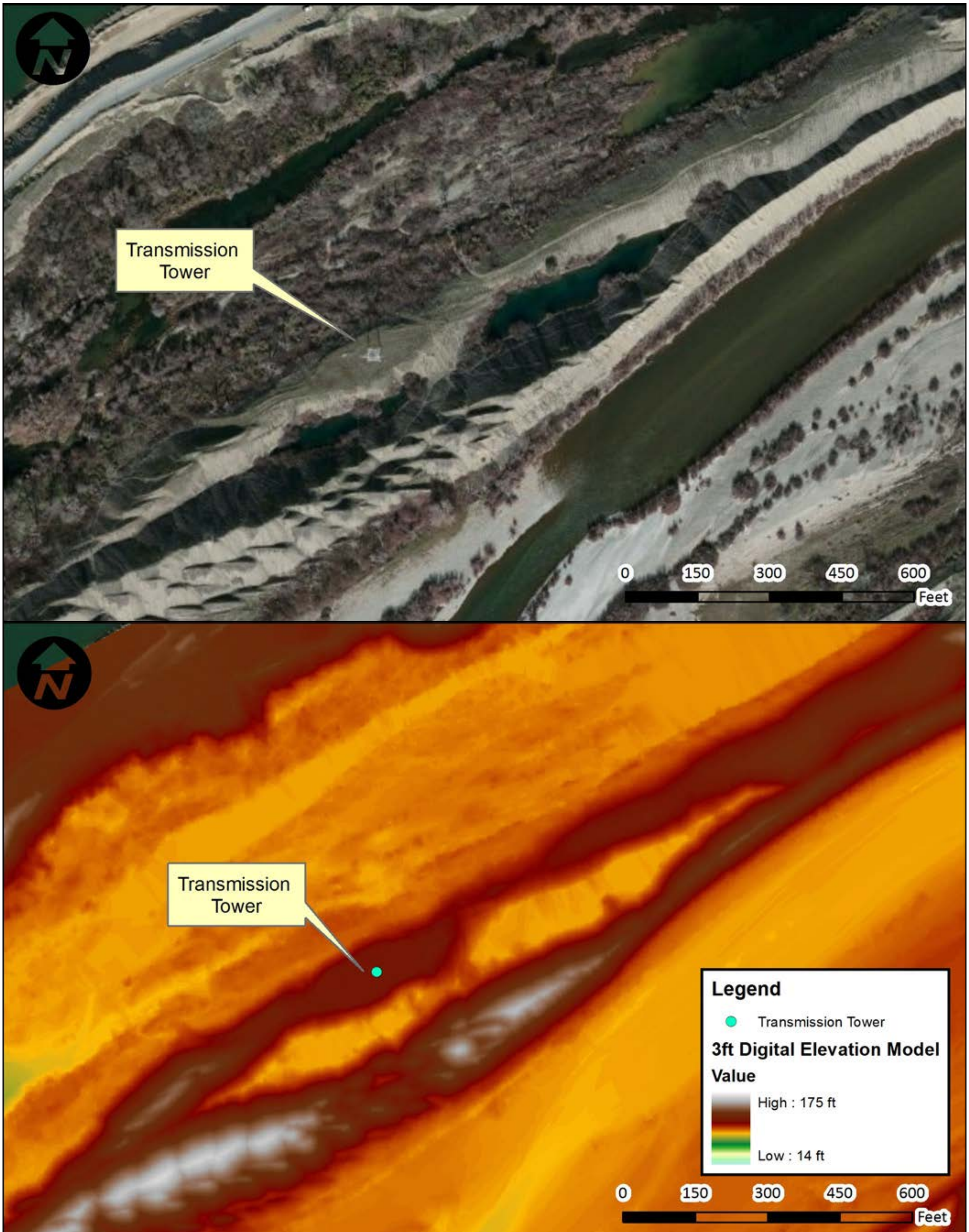
Notes: Aerial image courtesy of NAIP (2012). 2D model results courtesy of Pasternack (2009).	cbec eco engineering	*Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River* **Observed WSE on May 2, 2013**	
		Project No. 12-1034	Created By: AMS	**Figure 15**



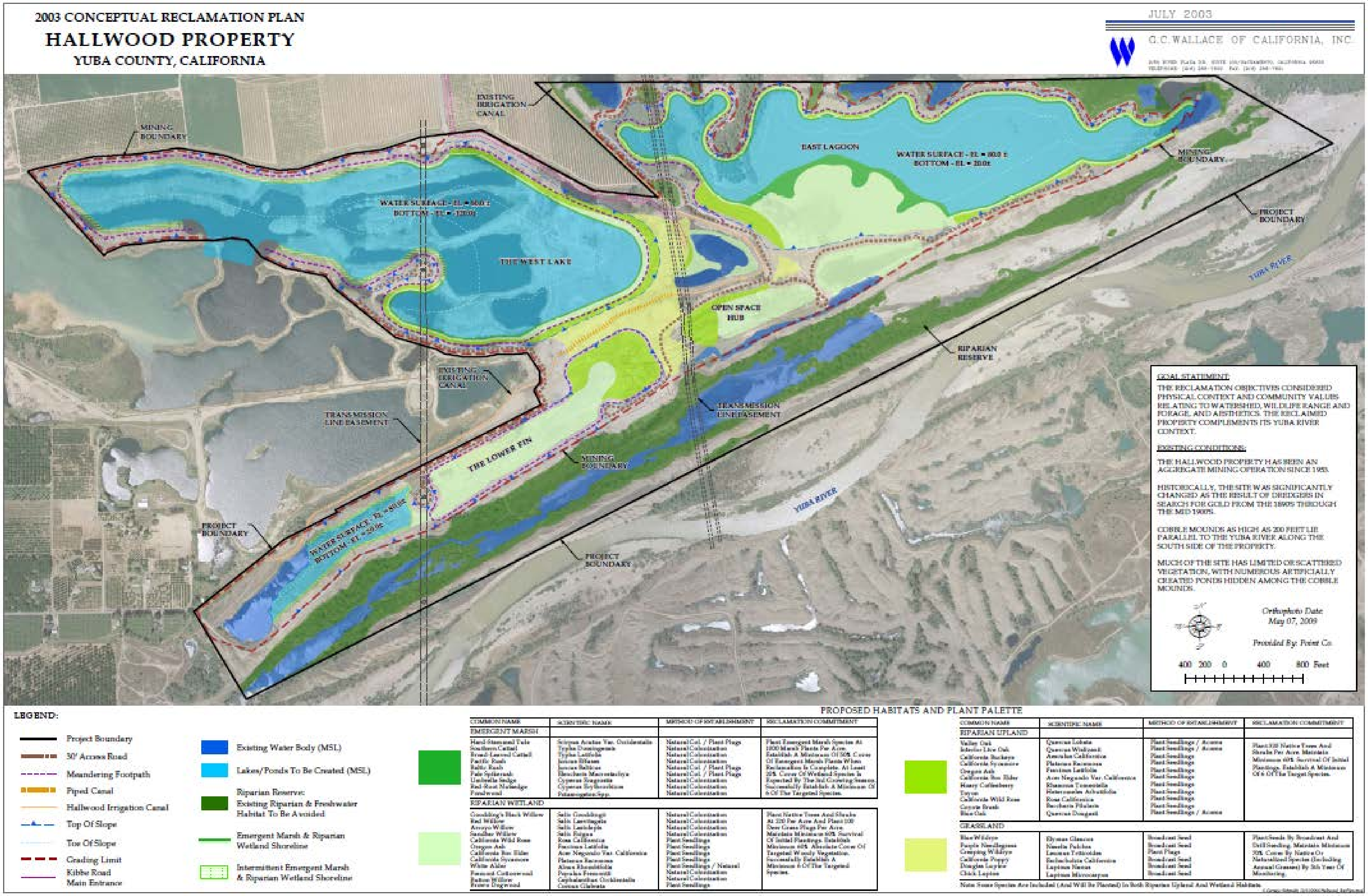
Notes: Aerial image courtesy of NAIP (2012). 2D model results courtesy of Pasternack (2009). Vegetation mapping courtesy of WSI (2012).	cbec eco engineering	*Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River* **WSI vegetation mapping**		
		Project No. 12-1034	Created By: AMS	**Figure 16**



Notes: Aerial image courtesy of NAIP (2012). DEM and 2D model results courtesy of Pasternack (2009).	cbec eco engineering	*Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River* **North wall comparison**
		Project No. 12-1034 / Created By: AMS / **Figure 17**



	cbec eco engineering	*Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River*		
		Middle wall transmission tower		
		Project No. 12-1034	Created By: JDS	**Figure 18**

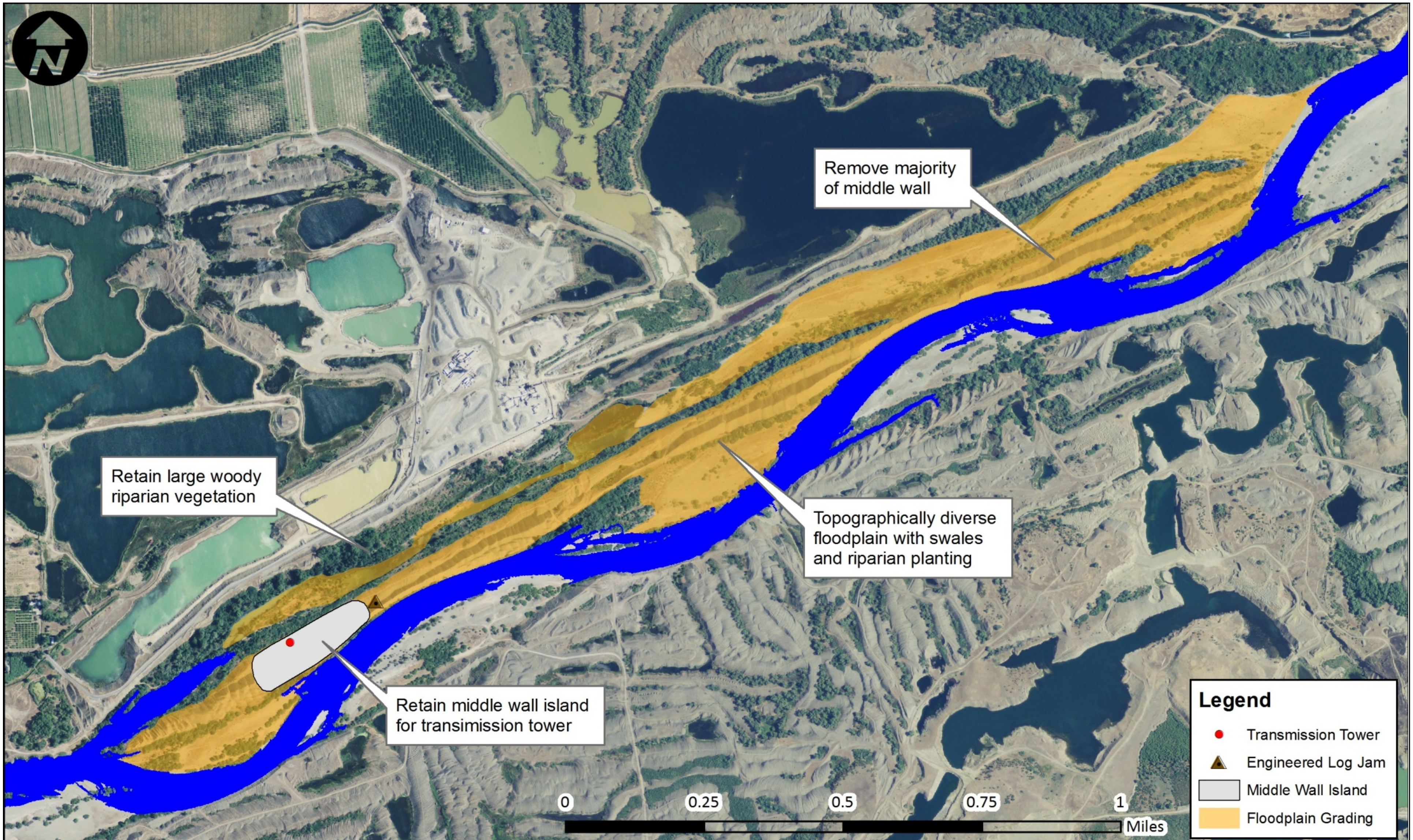


Notes: Plan graphic provided by Alberto Ramirez during a site visit in February, 2013.

Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River

Hallwood Property Reclamation Plan - Teichert

Project No. 12-1034	From: A. Ramirez	**Figure 19**

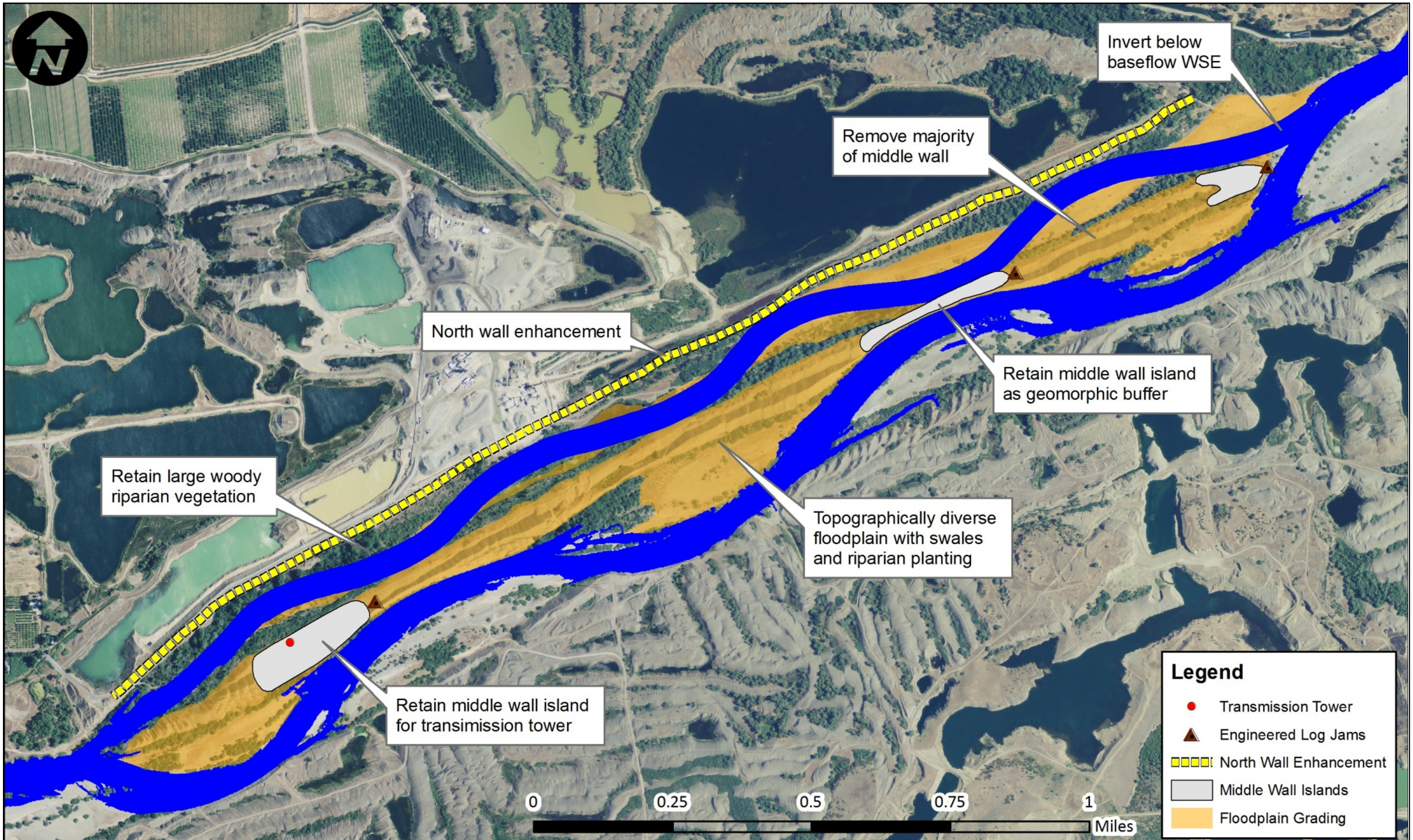


Notes: Aerial image courtesy of NAIP (2012). Blue overlay from bankfull (5,000 cfs) 2D model results (Pasternack, 2009).

Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River

Alternative 1 – Topographically Diverse Floodplain

Project No. 12-1034	Created By: JDS	**Figure 20**



Notes: Aerial image courtesy of NAIP (2012). Main channel blue overlay from bankfull (5,000 cfs) 2D model results (Pasternack, 2009).

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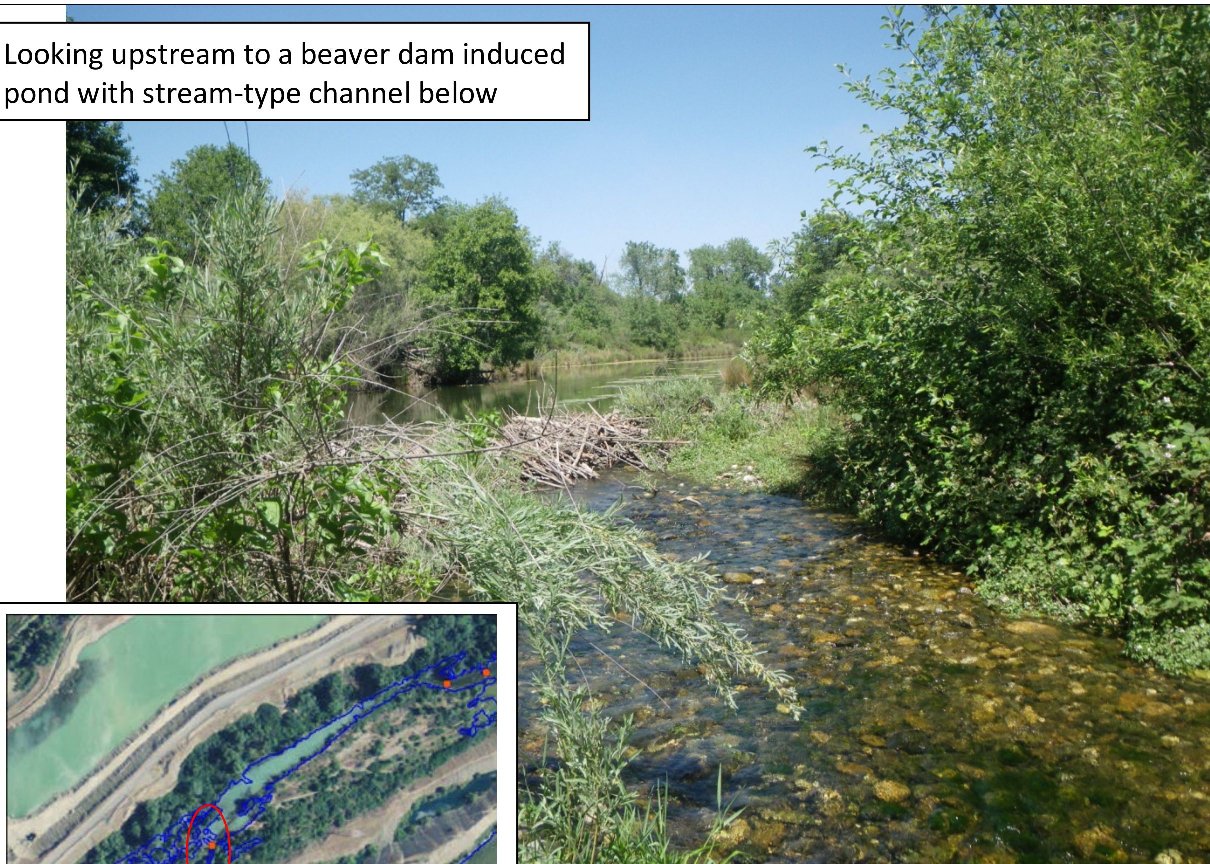
Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River

Alternative 2 – Perennial Split Channel

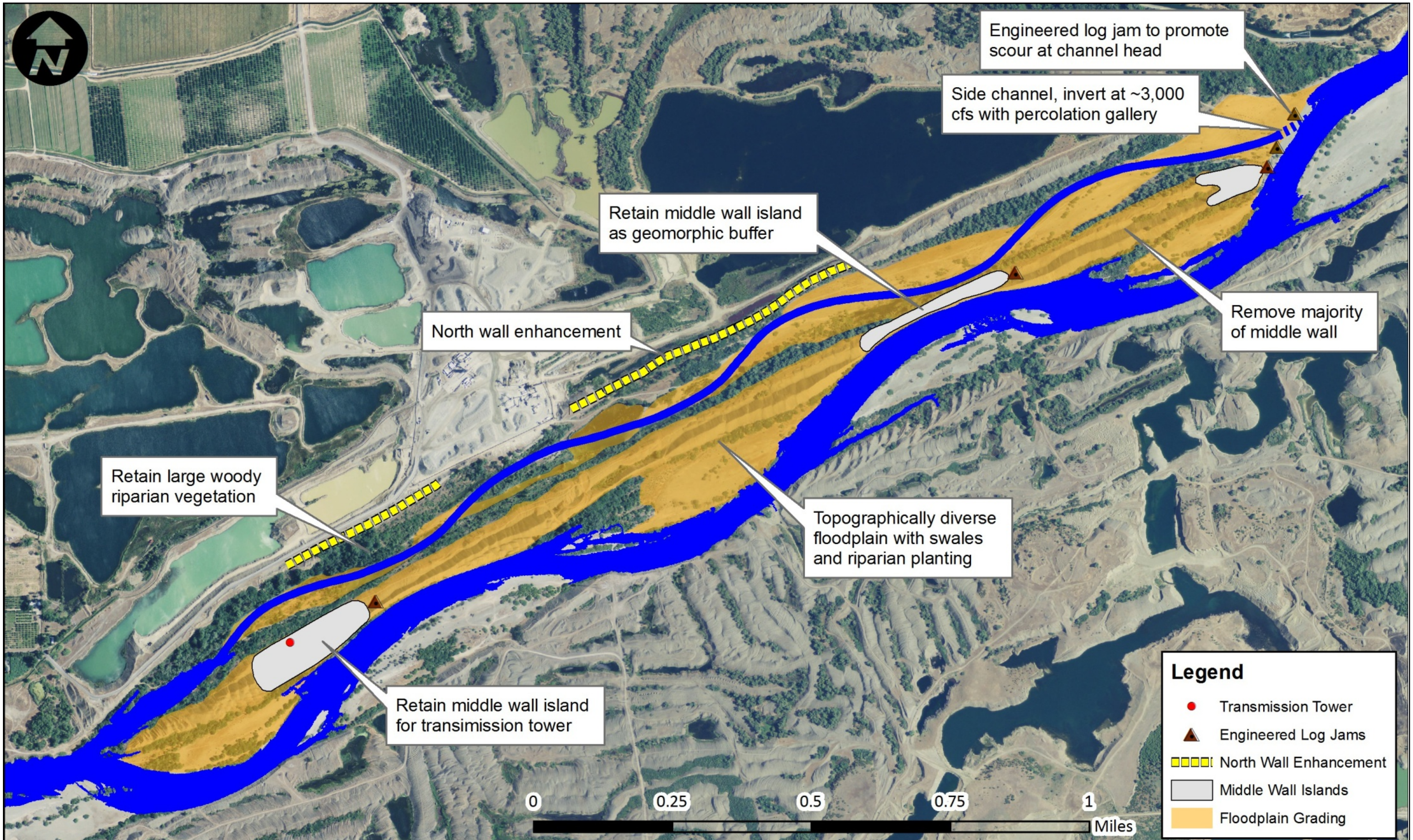
Project No. 12-1034 | Created By: JDS | **Figure 21**

Looking upstream to a beaver dam induced pond with stream-type channel below



Looking upstream in stream-type channel

Notes: Photos taken by A. Sawyer 05/02/13.	cbec eco engineering	*Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River* **Daguerre Alley stream-type habitat**	
		Project No. 12-1034	Created By: AMS	**Figure 22**



Notes: Aerial image courtesy of NAIP (2012). Main channel blue overlay from bankfull (5,000 cfs) 2D model results (Pasternack, 2009).

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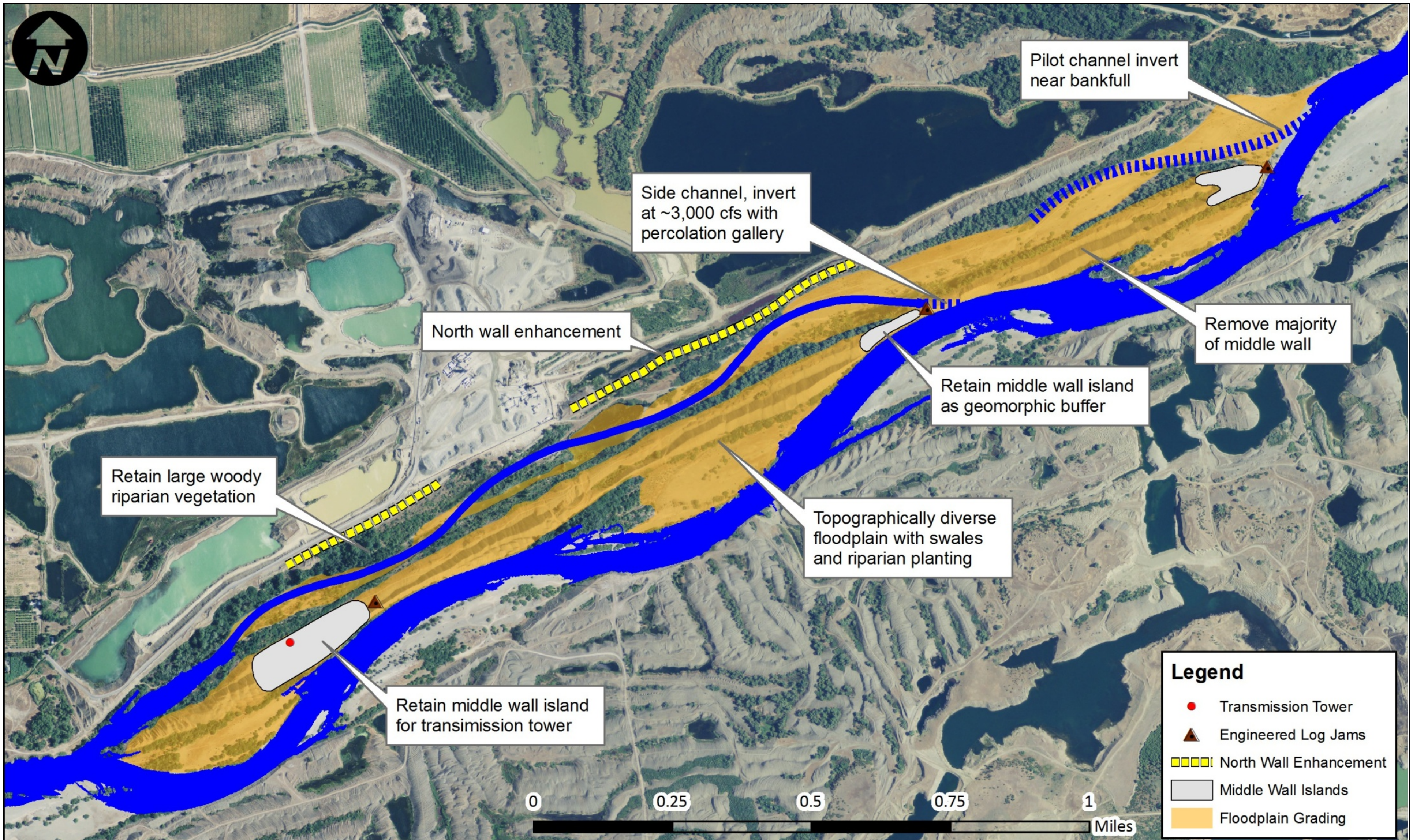
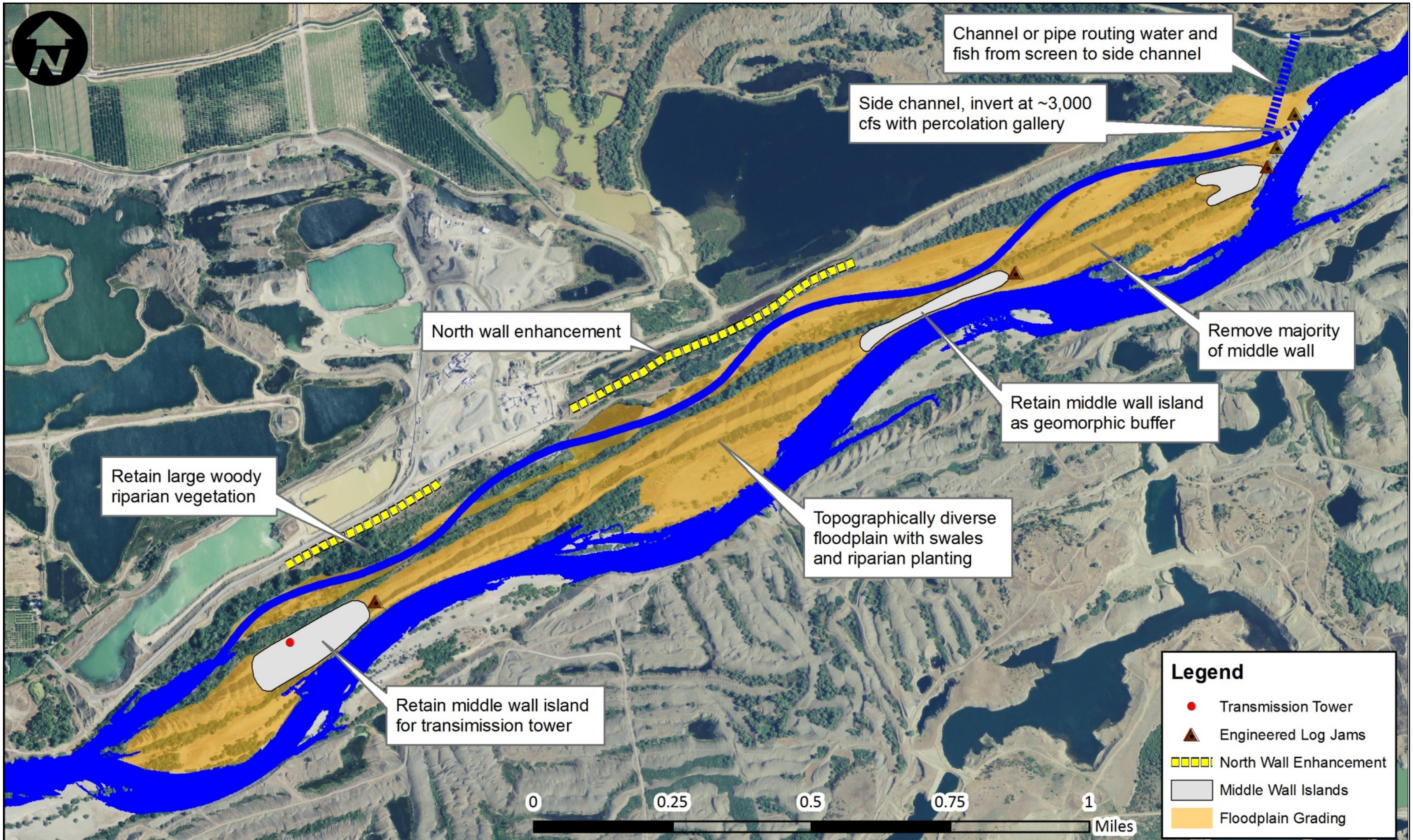
Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River

Alternative 3 – Rearing Side Channel

Project No. 12-1034 | Created By: JDS | **Figure 23**



Notes: Aerial image courtesy of NAIP (2012). Main channel blue overlay from bankfull (5,000 cfs) 2D model results (Pasternack, 2009).	cbec eco engineering	*Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River* **Alternative 4 – Diverse Rearing Side Channels**		
		Project No. 12-1034	Created By: JDS	**Figure 24**



Notes: Aerial image courtesy of NAIP (2012). Main channel blue overlay from bankfull (5,000 cfs) 2D model results (Pasternack, 2009).

Hallwood Off-Channel Habitat Enhancement Alternatives, Lwr. Yuba River

Alternative 5 – Diversion to Rearing Side Channel

Project No. 12-1034 | Created By: JDS | **Figure 25**

APPENDIX A

USFWS Site Visit Report

Site Visit Report: "Daguerre Alley" – Teichert Hallwood Property

Elizabeth A. Campbell, U.S. Fish and Wildlife Service

On April 15, 2013, staff from U.S. Fish and Wildlife Service (USFWS) and South Yuba River Citizen's League (SYRCL) snorkeled a portion of the lower reach of "Daguerre Alley," a large area containing a side channel between the middle and north training walls located on Teichert's Hallwood Property on the north side of the lower Yuba River, California. The purpose of the work was to identify existing fish species and use of side channel habitat in the area. Yuba River mean daily flow reported at Marysville was 968 cfs. Water temperature in the pond portion of the side channel just west of the power lines adjacent to Teichert's conveyor facility was 58.1 ^{o}F at 0930 hours (Figure 1). No fish were observed when snorkeling the main pond itself; maximum depth in the pond was about 3 feet, and it contained abundant, presumably non-native invasive *Elodea* interspersed with *Myriophyllum*. Substrate was hard (likely embedded gravel/cobble) covered with a 4-inch layer of fine silt. Lateral visibility was about 15 feet in undisturbed locations.

Three primary locations were selected for snorkeling while looking for fish, especially rearing salmonids. Snorkel site 1 and site 2 were at the base of successive beaver dams downstream of the main pond (Figure 2). Site 3 was in a pool in a secondary side channel located adjacent to the south training wall and across from the main pond. The secondary side channel was separated from the main pond by a porous island that was made more impervious to flow by beaver dams constructed along the side of the pond against the island. All three locations were much more stream-like than the pond due to the mild turbulence and accelerated velocity created by the beaver dams and constriction of the side channel. The secondary side channel also had a pool-riffle-pool configuration with abundant instream woody material due to being adjacent to the training wall which supports larger trees.

Two snorkelers saw a total of approximately 20 juvenile and 10 yearling Chinook salmon, 5 steelhead/rainbow trout, 100 California roach, and a few Sacramento sucker at Site 1; 20 juvenile Chinook salmon and 50 California roach at Site 2; and 20 juvenile Chinook salmon at Site 3. Chinook salmon ranged in size from about 40 mm to 125 mm, and steelhead/rainbow trout from 40 mm to 150 mm.

Also on April 15, 2013, staff from USFWS, Clear Creek Natives, and SYRCL drove and walked a portion of Daguerre Alley for the purpose of examining general flow and vegetation patterns, to note the presence of protected species and non-native invasive species, and to conduct a brief on-the-ground assessment of the site as a location for anadromous fish habitat restoration. Water temperature in the main side channel along the middle training wall at the most upstream location contacted was 60.2 ^{o}F at 1320 hours; water temperature in a sunnier backwater at the same location and time was 68.8 ^{o}F (Figure 1).

Ospreys and turkey vultures were observed, and bullfrogs and tree frogs were detected by ear. Teichert employees indicated that rattlesnakes often are seen at this time of year on the property. Non-native invasive Asian clams (*Corbicula fluminea*) were noted in-water, but not New Zealand mudsnail (*Potamopyrgus antipodarum*). Large cottonwood trees were common on the middle training wall itself, many infested with mistletoe. Shrub-type willows predominated in the flood plain, and colonization patterns coincide with the tracks of high flows which occurred most recently in December 2012. Elderberry bushes were present on the north training wall. High flow patterns were obvious in the floodplain; flow appeared to have traversed between the training walls.

Major observations of the day included that any fish habitat restoration action on this property should maintain the habitat near to and downstream (i.e., west) of the power lines in good condition because of its current use by juvenile salmonids. Additionally, the effects of the existing beavers on juvenile salmonid habitat quality may be complex. The beaver dams apparently improve juvenile salmonid habitat quality by creating a head flow with riffles just downstream of the dams and in the secondary side channel. In contrast, the main pond area (i.e., also created by beaver dams) contains an abundance of non-native invasive, submergent vegetation and likely supports only a few juvenile salmonids (none were observed). Somewhat surprisingly, no predator fish were observed even in the likely habitat of the main pond; populations of predators such as largemouth bass may be low because water temperatures remain consistently cool from intragravel flow from the main river channel.

On May 8, 2013, USFWS staff visited Daguerre Alley along with staff from the National Marine Fisheries Service (NMFS) and California Department of Fish and Wildlife (CDFW). The purpose was again to conduct a brief on-the-ground assessment of the site as a location for anadromous fish habitat restoration by personnel from multiple resource agencies. The water level was lower in Daguerre Alley than previously observed, although Yuba River mean daily flow reported at Marysville was 1085 cfs. In an isolated pool just east of the power lines, *Gambusia* and one dying juvenile cyprinid were observed, and bullfrogs were detected by ear.

The Teichert Hallwood Plant manager took this group on a more extensive tour of the Hallwood property from the Hallwood Plant access near the power lines upstream (the likely location of potential habitat restoration activities) to the location of high flow entrance into Daguerre Alley near Daguerre Point Dam. The manager indicated that Hallwood Plant-based conveyors could potentially be used to assist with substrate removal for habitat restoration. Specifically, conveyors could be moved to a restoration site and installed within approximately two weeks. About 1-2 M tons of substrate per year could be removed and processed either from the floodplain or middle training wall. Feasibility of assistance with habitat restoration from mining activities would depend in part on demand for the product. The manager identified typical floodplain inundation flow patterns, and locations where he had observed fish stranding and gravel erosion and deposition related to inundation events (Figure 1). He indicated that coyote, deer, garter snake, and great blue heron often were observed on the Hallwood Plant property.

The Hallwood Plant manager indicated that Teichert has a reclamation plan in place through the State Mines and Geology Board which includes e.g., water quality monitoring and perhaps could be integrated into fish habitat restoration actions. Reclamation time frame is 10 years. The large reclamation pond located north of the north training wall has approximately a 50 foot maximum depth. Reclamation activities for this pond resulted in the creation of marshy shoreline habitat using silt obtained from settling ponds, and islands planted with native species.

Figure 1. Sites and features of the Teichert Hallwood Plant property, lower Yuba River, visited and discussed in view of potential fish habitat restoration on April 15 and May 8, 2013. The area of interest is the floodplain, which is bounded by the north training wall indicated by the line of three green spheres, and middle training wall indicated by the line of three red spheres.

Figure 2. Three snorkel sites surveyed for fish on April 15, 2013 on the Teichert Hallwood Plant property, lower Yuba River, California.

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