PROPOSAL TO MAP THE LOWER YUBA RIVER CORRIDOR IN HIGH RESOLUTION TO SUPPORT RIPARIAN AND CHANNEL RESTORATION

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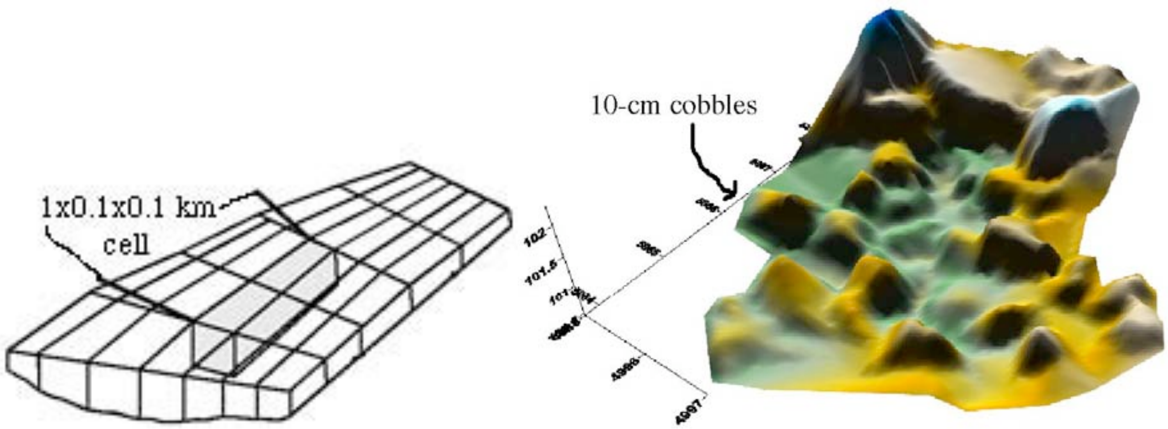
Summary

In-stream and riparian assessments are underway on the lower Yuba River in support of the Yuba Accord and the upcoming dam re-licensing process. Because of periodic floods and loose substrates, the lower Yuba River is changing faster than any river in the Central Valley, including as a result of a major flood over New Years 2006. The last time it was mapped was in 1999, but since then mapping technology has advanced dramatically and prices plummeted. Based on pilot efforts in Timbuctoo Bend and the canyon below Englebright Dam, it is now possible to map the entire lower Yuba River in unprecedented resolution. Such mapping is essential for not only river assessment, but also to support the design of river restoration projects- many of which have been proposed and are under consideration and further refinement. It is proposed to perform high-resolution mapping of the lower Yuba River in 2008. The terrestrial river corridor would be mapped with a horizontal resolution of 0.738 m and a vertical resolution of 0.15 m using airborne LIDAR. The submerged river bottom would be mapped using a specially outfitted boat to yield data with an average horizontal resolution of ~1-2 m and a vertical resolution of 0.15 m. These two datasets would be quality checked against ground-based total station and RTK GPS surveys of overlapping areas as well as against each other in overlapping areas. The final digital elevation model will be made available to the stakeholders at no cost by download from a website. Subsequent proposals for in-channel and riparian restoration would be able to use this independent map as a fair baseline for project planning and design.

Background

Instream Flow Assessment Needs

Most instream flow studies of rivers involve either qualitative habitat assessment or calculation at a few cross-sections (Fig. 1a). However, a fish does not experience a cross-section or "stream-tubes". In fact, fish are acutely tuned to the diversity of features in a river, even down to nooks and crannies that are only 10 cm dips in the bed surface (Fig. 1b). To understand and predict fish behavior, including spawning and rearing life stages, one has to view and analyze the river from the perspective that fish experience it, which is at the 0.1-1 m scale. There are three challenges with doing this. First, one has to know what a fish likes at this scale. A lot of data on fish preferences exists for many species, life stages, and rivers, including the Lower Yuba River- with more data collection planned for the Yuba in the next few years. Second, one has to have a map of a river with the same detail as fish experience it. In recent years the cost of very detailed aerial LiDAR mapping of terrestrial land and boat-based echosounder mapping of channel bathymetry has dropped precipitously with the rapid pace of technological advancement. Third, one has to have significant computing power and an efficient river simulation algorithm to analyze many kilometers of river in this detail. For most of this decade, high-resolution 2D hydrodynamic modeling has been limited to the site scale of ~500-2000'. This forced managers to pick “representative” sites for modeling, but on the lower Yuba River such site selection has been somewhat controversial. Just in the last year a new 2D hydrodynamic model has been developed by the US Bureau of Reclamantion that is capable of accurately and quickly simulating many kilometers of river at a resolution of < 1 m. Modeling the whole river in one simulation eliminates the need for “site selection” and subjective justifications to support site selection. It is now possible to evaluate the river comprehensively.



A **B**

Figure 1. Comparison of how rivers are normally conceived of in river assessment (a) versus how a fish actually experiences a river (b).

Riparian and Channel Restoration Needs

Gold mining, flow regulation, and a variety of other human activities have dramatically altered river corridors in California. As a result, fish and wildlife habitats have been severely degraded, causing sustained inter-decadal declines in native populations and conditions favorable for non-native species’ invasions. For example, ~100,000 salmon ascended the Yuba River annually before impacts of mining and dams. After the construction of Englebright and New Bullards Bar Dams, the salmon runs averaged 15,000 fish per year. Current salmon runs have reached a critically low level, with the lower Yuba River supporting only 2,600 salmon in 2007. Also, not only has human activities affected aquatic populations, but it has also dramatically damaged riparian species. The lower Yuba River was physically re-located in many sections and the river valley was filled in with tens of meters of hydraulic mining debris. Historical photos show riparian forests along the lower Yuba River in some places, but those are now gone. The river’s floodplain is instead a hot, dry ”moonscape” of largely unvegetated gravel and cobble. Lines of willows occur along present-day and abandoned base-flow channel banks. A few backwater areas have developed since the 1997 flood and are lined with cottonwoods.

River restoration aims to undo enough of the physical degradation to promote a return of native species’ populations to sustainable levels. The Yuba River Fisheries Technical Team (Yuba Accord) identified conditions of Habitat Complexity & Diversity to be one of the most important “stressors” to the Yuba salmon population. For the lower Yuba River, many restoration ideas have been proposed over the years, including in-channel activities (e.g. enhancing salmon spawning riffles, widening riffles, building side channels for steelhead, building backwaters that are nutrient rich habitats for beavers, otters, and rearing fish, adding wood into the channel for habitat diversity, removing "shot rock" from the canyon below Englebright Dam, and performing gravel augmentation) and riparian corridor activities ("feather-edging" gravel/cobble bars to make them flood more frequently, removing roads and off-road tracks, placing soil, and planting trees). One visioning plan even exists to move the entire river corridor south back through the gold fields.

At present the Anadromous Fisheries Restoration program has requests for proposals out for pilot efforts related to both in-channel and riparian restoration projects on the lower Yuba River.

Because river restoration involves re-engineering terrestrial and aquatic landforms, the keystone data underlying environmental analysis and engineering design is a high-resolution topographic map. The map provides the baseline for conceptual design, enabling the altering of topographic contours to obtain the desired ecological functionality. It also serves for detailed modeling and evaluation of design alternatives. No restoration can be performed without a good map. Also, it would be difficult to prioritize among projects without a comprehensive map produced independently of the advocates of individual projects.

1999 Lower Yuba River Map

The last time the Yuba River was mapped was in 1999. Terrestrial land was mapped using aerial photogrammetry. The river bottom was mapped by boat. However, given the technology available at that time, the river bottom was only mapped with cross-sections spaced every 100-300'. Even worse, important areas with high habitat complexity and diversity were not mapped at all, because they could not be easily boated into. The 1999 map is primarily available upon request in the form of 2' contours, but that is insufficient accuracy for restoration design. For the USFWS IFIM study, extensive mapping had to be performed at each study site, because the 1999 map was inadequate. Finally, the 42,930 cfs flood (Yuba+Deer combined hourly peak) of May 2005 and the 109,090 cfs flood (Yuba+Deer combined hourly peak) of New Years' 2006 dramatically changed the river. The 1999 map is no longer representative of large sections of the river.

2006 Timbuctoo Bend Map

To evaluate the scope of change 1999-2006 and its significance on fish spawning, UC Davis used funding from the USFWS to make a high-resolution map of Timbuctoo Bend and compare it to the 1999 map. A boat-based method similar to that proposed for 2008 below was used for the river bottom survey and the terestial land was mapped manually using a robotic total station and 4 months of student labor. The resulting map shows unprecedented details in the river (Fig. 2), and large-format plots were provided to all members of the LYRTWG.

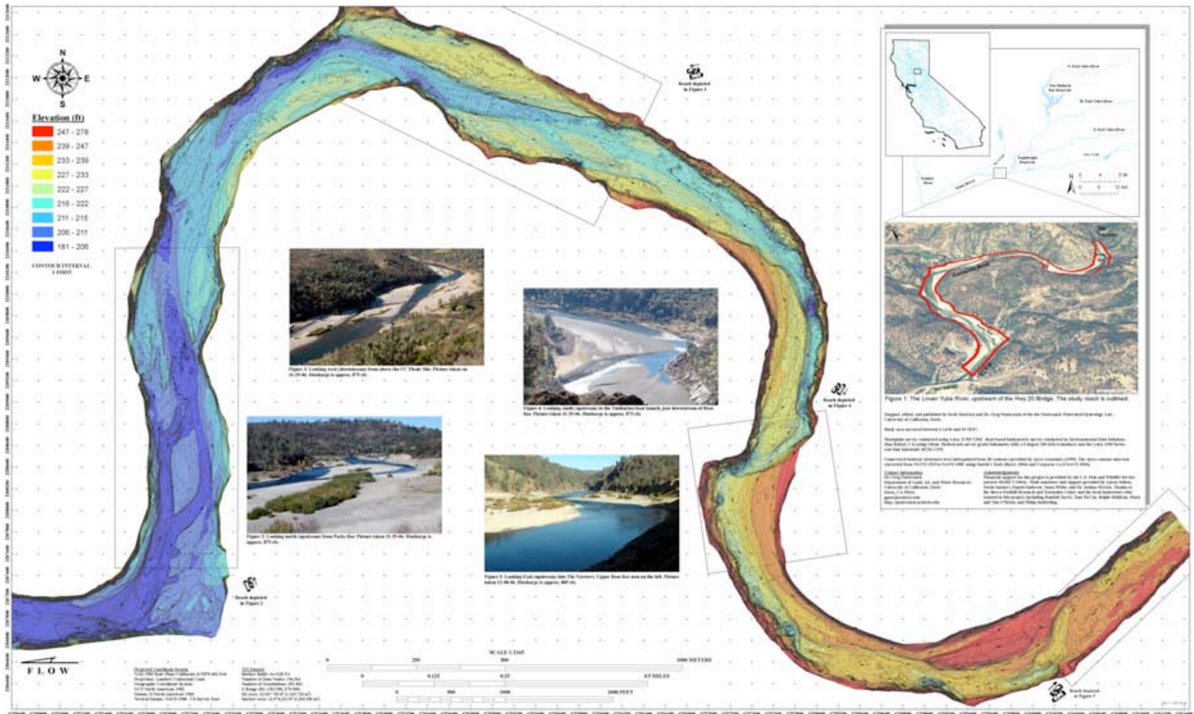


Figure 2. 2006 high-resolution topographic map of Timbuctoo Bend on the lower Yuba River.

By subtracting the digital elevation model of the 2006 map from that of the 1999 map, it was possible to determine that 605,000 cubic yards of gravel and cobble have been exported out of Timbuctoo Bend. Lacking a map of the downstream river, we do not know where that vast amount of material went. Furthermore, by combining the 1999-2006 change map with a geomorphic map of landforms in the river corridor, it was possible to evaluate how each landform changed over that time (Table 1). Every single landform in the river corridor eroded, except for medial bars, which grew slightly. Pools eroded more and deeper than riffles, which demonstrated a sustainable riffle-pool self-maintenance. The river's floodplain contributed the third most volume of sediment exported out of Timbuctoo Bend. This continual scour of the floodplain explains why a natural riparian corridor cannot establish itself in Timbuctoo Bend. Also, the topographic and geomorphic maps were combined with a redds survey to identify which aquatic landforms salmon were selecting for building redds (Table 2).

2007 Englebright Dam Reach Map and Model

In 2007, the Yuba River RMT funded a survey of the river bottom in the bedrock canyon between Englebright and the junction with Deer Creek. That canyon was **not** mapped in 1999, presumably because it was deemed un-navigable. To the contrary, in 2005 and 2006, UC Davis and Environmental Data Solutions successfully mapped two sections of that canyon and proved the feasibility of the overall mapping. Then in 2007 the rest of the canyon was fully mapped (Fig. 3). Subsequently, the map was used to make a 2D hydrodynamic model of the canyon for 855 cfs and 1600 cfs (i.e. the flows for which model-inputs are available at present) with a horizontal resolution of 3'. This map and 2D model will help guide gravel augmentation and evaluate proposed shot rock removal and riffle enhancement activities. Similar models of Timbuctoo Bend are underway at present and are planned for the entire lower Yuba River.

Table 1. Elevational and volumetric changes in Timbuctoo Bend organized by landform type.

Morphological Unit	Mean Cut/Fill (m)	StDev (m)	Cut/Fill Volume (m^3)
Backwater	-1.22	0.87	-3642
Chute	-1.21	1.44	-7412
Forced Pool	-1.22	1.05	-25268
Glide	-0.78	0.84	-87641
Pool	-1.45	1.28	-90623
Recirculation	-1.03	0.65	-732
Riffle	-0.54	0.86	-39532
Riffle Entrance	-0.73	0.69	-21938
Run	-1.03	0.74	-25392
Secondary Channel	-1.53	0.73	-19667
Lateral Bar	-0.55	0.92	-32100
Medial Bar	0.40	1.00	8485
Point Bar	-0.08	0.79	-2190
Cutbank	-0.95	1.57	-5892
Floodplain	-0.15	0.76	-58288
Hillside	-0.07	0.55	-12820
Tailings	-0.64	1.03	-22737
Terrace	-0.29	0.42	-8226
Tertiary Channel	-0.73	0.46	-4448
Tributary Delta	-0.15	0.47	-1960
TOTAL			**-462022**

Table 2. Distribution of observed redds among landform types in Timbuctoo Bend.

Morphological Unit	Redds	%Redds	Electivity
Backwater	0	0.00	0.00
Chute	0	0.00	0.00
Forced Pool	0	0.00	0.00
Glide	22	4.69	0.48
Pool	0	0.00	0.00
Recirculation	0	0.00	0.00
Riffle	322	68.66	9.38
Riffle Entrance	53	11.30	4.31
Run	39	8.32	3.87
Secondary Channel	19	4.05	3.50
Lateral Bar	7	1.49	0.27
Medial Bar	4	0.85	0.45
Point Bar	3	0.64	0.29
Cutbank	0	0.00	0.00
Floodplain	0	0.00	0.00
Hillside	0	0.00	0.00
Tailings	0	0.00	0.00
Terrace	0	0.00	0.00
Tertiary Channel	0	0.00	0.00
Tributary Delta	0	0.00	0.00
TOTAL	469	100.00	

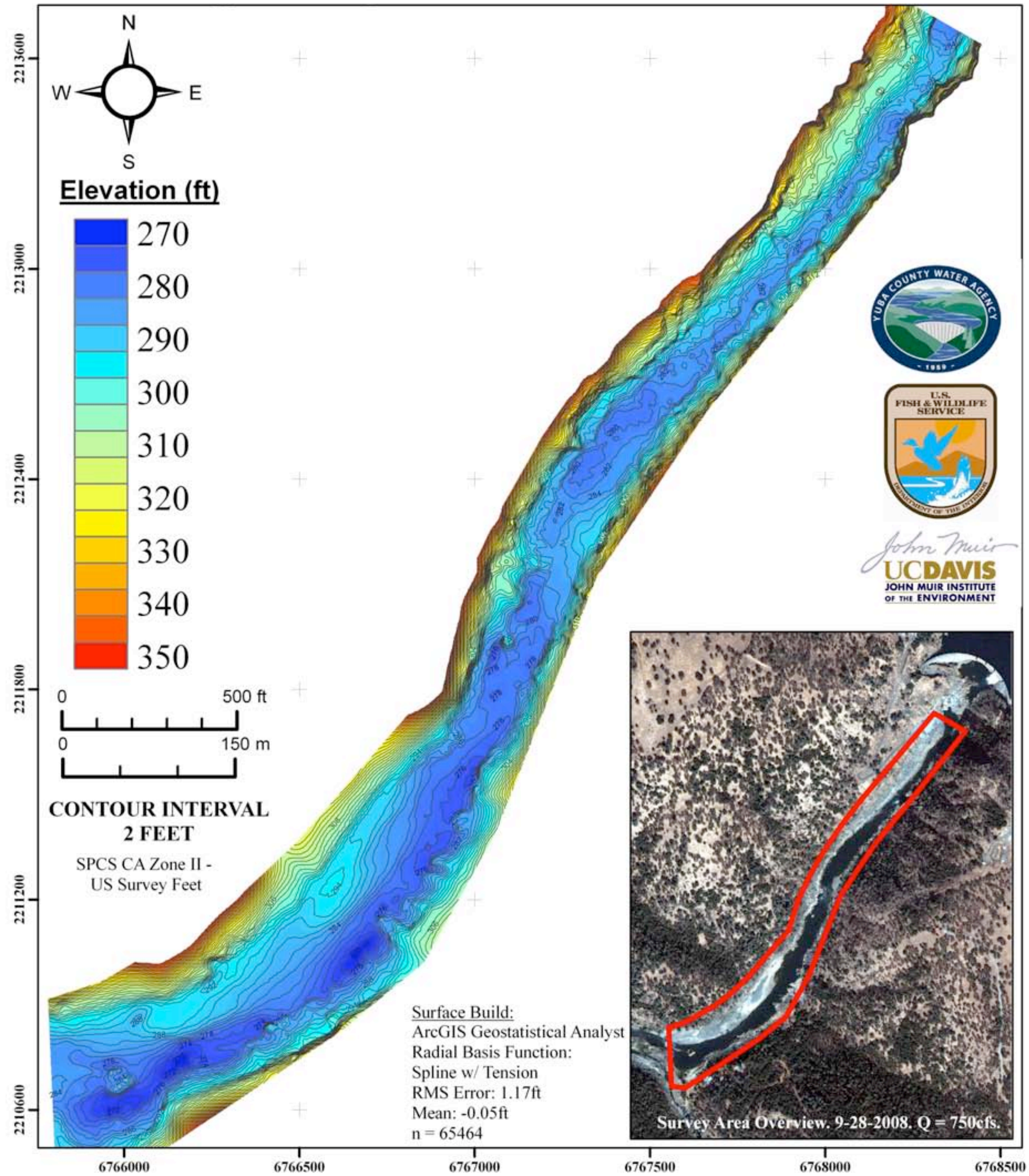


Figure 3. 2007 map of the Englebright Dam Reach of the lower Yuba River.

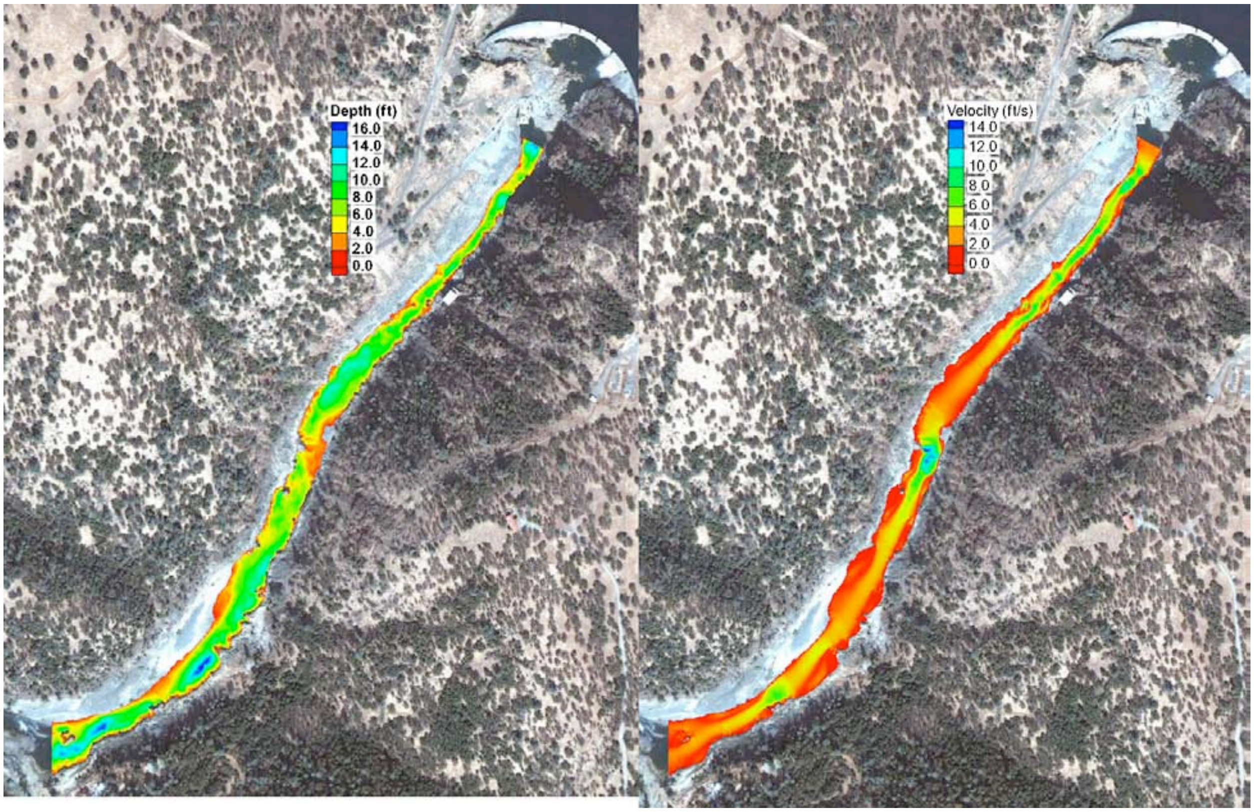


Figure 4. 2D hydrodynamic model simulation of the Englebright Dam Reach at 1600 cfs showing depth (left) and velocity (right) predictions at 3' resolution.

Proposed 2008 Lower Yuba River Map

Half-Foot Accuracy Terrestrial Survey

Airplane-based Light Detection And Ranging (LIDAR) technology offers one of the most accurate, expedient and cost-effective ways to capture wide-area elevation information for terrestrial land. By merging laser ranging, GPS positioning, and inertial attitude technologies, airborne laser mapping directly measures the shape of the earth's surface beneath the aircraft's flight path. Elevation data is generated at the rate of thousands of points per second. After hitting the tree-canopy (where present), the laser beam finds a hole between the foliage and reaches the ground. The returns are registered and a digital dataset is created instantly. After the flight, data is directly processed and reduced to obtain a detailed "bare earth" only dataset with a vertical accuracy of ~0.15 meters and a spatial resolution of 1 point every 0.738 m . In addition to the topographic data, the LIDAR survey will also yield a shapefile of the water's edge, since the laser returns off the water's surface are highly different form those off the dry ground. The water's edge delineation will be accurate in the horizontal plane to within 0.738 m. With increased data collection rates and accuracy, Optech's new ALTM 3100EA system (EA stands for Enhanced Accuracy) is regarded as the best model available today. Quality assurance and quality control information beyond the scope of this summary is kept on file with the contractor. Independent surveys of stable sections of the river bed are performed using a robotic total station to evaluate the accuracy of the bathymetric data. Data points from the LIDAR survey are then imported into ArcGIS 9 to create a digital elevation model of the terrestrial land around the river using a standard TIN-based approach with breaklines and additional quality assurance measures.

The plan for the proposed 2008 airborne LIDAR survey is to map the river at a low flow with maximal exposed river bed. Alternately, it may be desirable to do the mapping at a typical spawning habitat discharge to obtain a water's edge shapefile for use in mapping the spatial pattern of water depth at that spawning discharge without having to simulate it with a hydrodynamic model.

The spatial domain of the proposed 2008 terrestrial survey spans the entire riparian corridor between the hillside and/or high "training berms" on either side of the river corridor. The extent has been reviewed and approved by UC Davis and SYRCL. It is available for further review by any parties upon request.

Half-Foot Accuracy Bathymetric Survey

In 2005-2007 a private hydrography firm (Environmental Data Solutions, San Rafael, CA) was contracted to partner with UC Davis to produce map of sections of the lower Yuba River between Englebright Dam and highway 20 bridge. A customized aluminum jet-boat is outfitted with one to five Odom Hydrotrack survey-grade fathometers (each with a 3°, 200-kHz transducer) and a TSS 335B motion sensor that adjusted for roll/pitch of the vessel. Position data for the fathometers are collected using real-time kinematic (RTK) GPS receiving corrections by radio from an on-site base station located on one of the pre-established benchmarks. Both streams of data are recorded onto a laptop running Hypack Max 4.3 (Hypack, Inc., Middletown, CT). Where depth permits, the boat makes cross sections on a ~3-m interval and performs six longitudinal transects approximately evenly spaced across the channel. To account for the water surface slope and its changes through time, Mini Troll 400 vented pressure transducers (In-situ, Inc., Fort Collins, CO) are placed in the river along the survey area and their elevations are surveyed using RTK GPS. An algorithm within Hypack (tide adjustments) is used to interpolate water surface slopes based on the distance between the pressure transducers. In post-processing, a radial filter is applied to the boat-based data to ensure a 0.25-m spacing between points to reduce unnecessary redundancy. The goal is to obtain bathymetric data at a resolution of 1 point per square meter. Quality assurance and quality control information beyond the scope of this summary is kept on file with the contractor. Independent surveys of stable sections of the river bed are performed using a robotic total station to evaluate the accuracy of the bathymetric data. The obtained results meet U.S. Army Corps of Engineers' rigorous Class 1 standard (±0.15m vertical accuracy). Data points are then imported into ArcGIS 9 to create a digital elevation model of the river using a standard TIN-based approach with breaklines and additional quality assurance measures.

The plan for the proposed 2008 survey is to map pools, runs, and glides (i.e. areas with water depths >3') at any discharge on a given day as soon as possible and then map the shallowest areas (e.g. riffle crests and backwaters) by boat at a higher flow conditions permitting. Supplemental RTK GPS surveying of shallow areas is optional if necessary. Ideally, the boat survey is done at a higher discharge and the airborne LiDAR survey at a lower discharge, so the two dataset overlap and can be intercompared.

Map Production and Dissemination

Once the terrestrial and bathymetric datasets are collected and checked for quality, they will be combined to produce a single comprehensive DEM of the river corridor. Then the water's edge shapefile from the LIDAR survey will be superimposed on the DEM to obtain a map of local water depth at the discharge of the aerial survey. This depth map may be of use for redd mapping, stranding surveys, evaluating aquatic habitat, and validating computer models.

A variety of output options are available for how different maps could be produced from the underlying datasets. To facilitate that, a few standard outputs will be produced, such as a contour map and a raster file. These products along with the entire dataset will be made available on a website for download by stakeholders and managers.

In conclusion, maps are the foundation of environmental science and management. A unique opportunity exists to obtain a high-resolution map of the lower Yuba River. The methods have already been proven and the price is low. The proposed independent mapping effort would provide a common baseline for all restoration projects and management plans for the lower Yuba River.