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Supplement of

Bed and width oscillations form coherent patterns in a partially confined, regulated gravel–cobble-bedded river adjusting to anthropogenic disturbances

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Supplemental materials

1 Introduction Supplements

None.

2 Experimental Design Supplements

None.

3 Study Area Supplements

None.

4 Methods Supplements

4.1 Physical data information

Topographic data came from airborne LiDAR scanning (excluding Timbuctoo Bend) at flows ~ 10–16% of bankfull discharge plus thorough in-water mapping using total stations and RTK GPSs as well as boat-based bathymetry mapping with a single-beam echosounder coupled to an RTK GPS and professional hydrographic software (Pasternack, 2009). Essential quantitative information describing topographic and bathymetric data are reported in the box below.

Attribute	Description
Years of data collection	June–December 2006
Bathymetric Resolution	Within the 24.9 cms inundation area, points were collected along longitudinal lines, cross-sections, and on ~3x3 m grids, yielding an average grid point spacing of 28 pts/100m^2.
Topographic Resolution	Outside the 880 cfs inundation area, points were collected on a grid, yielding an average grid point spacing of 11.4 pts/100 m^2.
Bathymetric Accuracy	Comparison of overlapping echosounder and total station survey points yielded observed differences of 0.07-0.09 m.
Topographic	Regular total station control point checks yielded accuracies of 0.009 m -

Accuracy	0.018 m.

4.2 2D hydrodynamic modeling details

The surface-water modeling system (SMS; Aquaveo, LLC, Provo, UT) user interface and sedimentation and river hydraulics–two-dimensional algorithm (Lai, 2008) were used to produce these 2D hydrodynamic models of the Lower Yuba River (LYR) with internodal mesh spacing of 0.91–1.5 m according to the procedures of Pasternack (2011). SRH-2D is a 2D finite-volume model that solves the Saint Venant equations for depth and velocity at each computational node, and supports a hybrid structured-unstructured mesh that can use quadrilateral and triangular elements of any size, thus allowing for mesh detail comparable to finite-element models. A notable aspect of the modeling was the use of spatially distributed and stage-dependent vegetated boundary roughness (Katul et al., 2002; Casas et al., 2010). Model simulations were comprehensively validated for flows ranging over an order of magnitude of discharge (0.1 to 1.0 times bankfull) using three approaches: (i) traditional cross-sectional validation methods, (ii) comparison of LiDAR-derived water surface returns against modeled water surface elevations, and (iii) Lagrangian particle tracking with RTK GPS to assess the velocity vectors (Barker, 2011). Note that the study reach was originally a subset model domain of the LYR, while model performance is reported for the entire river. Model set-up and performance details are reported in the box below:

Attribute	Description
Computational Mesh Resolution	For Q<141.5 cms, 1 m internodal spacing. As flow goes overbank, cell size increases to 1.8 m. For flows >597.5 cms, different mesh has ~3 m internodal spacing.
Discharge Range of Model	8.5 to 3126 cms
Downstream WSE data/model source	Direct observation of WSE at a limited number of flows <~339.8 cms. For higher flows the downstream WSE was taken as the upstream WSE from the HR model

	at that flow.
River roughness specification	Because the scientific literature reports no consistent variation of Manning's n as a function of stage-dependent relative roughness or the whole wetted area of a river (i.e., roughness/depth), a constant value was used for all unvegetated sediment with 0.03 for TBR (based on preliminary testing in 2008-2009). For vegetated terrain, the Casas et al. (2010) algorithm was used to obtain a spatially distributed, flow-dependent surface roughness for each model cell on the basis of the ratio of local canopy height to flow depth.
Eddy viscosity specification	Parabolic turbulence closure with an eddy velocity that scales with depth, shear velocity, and a coefficient (e_0) that can be selected between ~0.05 to 0.8 based on expert knowledge and local data indicators. $Q<283.2$ cms: $e_0 = 0.6$ $Q\geq 283.2$ cms: $e_0 = 0.1$
Hydraulic Validation Range	Point observations of WSE were primarily collected at 880 cfs, with some observations during higher flows, but not systematically analyzed. Velocity observations were collected for flows ranging from 15-141.9 cms. Cross-sectional validation data collected at 22.65 cms.
Model mass conservation (Calculated vs Given Q)	0.001 to 1.98 %
WSE prediction accuracy	At 24.9 cms there are 197 observations. Mean raw deviation is -0.002 m. 27% of deviations within 0.031 m, 49% of deviations within 0.0762 m, 70% within 0.15 m, 94% within 0.31 m'. These results are better than the inherent uncertainty in LiDAR obtained topographic and water surface elevations.
Depth prediction accuracy	From cross-sectional surveys, predicted vs observed depths yielded a correlation (r) of 0.81.
Velocity magnitude prediction accuracy	5780 observations yielding a scatter plot correlation (r) of 0.887. Median error of 16%. Percent error metrics include all velocities (including V <0.91 m/s, which tends to have high error percents) yielding a rigorous standard of reporting.
Velocity direction prediction accuracy	5780 observations yielding a scatter plot correlation (r) of 0.892. Median error of 4%. Mean error of 6%. 61% of deviations within 5 deg and 86% of deviations within 10 deg.

Using the workflow of Pasternack (2011), SRH-2D model outputs were processed to produce rasters of depth and velocity within the wetted area for each discharge. The first task involved creating the wetted area polygon for each discharge. To do this, depth results were first converted to triangular irregular networks (TIN) and then to a series of 0.9144-m hydraulic raster files. Depth cells greater than zero were used to create a wetted area boundary applied to all subsequent hydraulic rasters. Next, the SRH-2D hydraulic outputs for depth and depth-averaged velocity were converted from point to TIN to raster files within ArcGIS 10.1 staying within the wetted area for each discharge. The complete dataset was a series of 0.9144-m resolution hydraulics rasters derived from SRH-2D hydrodynamic flow simulations at the following discharges: 8.5, 9.9, 11.3, 12.7, 15.0, 17.0, 17.6, 19.8, 22.7, 24.9, 26.3, 28.3, 36.8, 42.5, 48.1, 56.6, 70.8, 85.0, 113.3, 141.6, 212.4, 283.2, 424.8, 597.5, 849.5, 1195.0, 2389.9, and 3126.2 m^3/s.

Despite best efforts with modern technology and scientific methods, the 2D models used in this study have uncertainties and errors. Previously it has been reported that 2D models tend to underrepresent the range of hydraulic heterogeneity that likely exists due to insufficient topographic detail and overly efficient lateral transfer of momentum (Pasternack et al., 2004; MacWilliams et al., 2006). For this study those deficiencies result in a conservative outcome, such that there could be more fine details to the sizes and shapes of peak velocity patches than what is revealed herein. Overall, this study involves model-based scientific exploration with every effort made to match reality at near-census resolution over tens of km of river length given current technology, but recognizing that current models do have uncertainties.

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