Predicting Natural Channel Typology for River Restoration in the Columbia River Basin, North America

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Objective

Our primary objective is to predict natural channel patterns (Figure 1) in the 630,000 km^2 Columbia River basin, USA. Channel pattern maps are used to identify reaches needing restoration, and to set restoration targets. We have three analysis steps:

(1) Develop a process-based statistical model for predicting channel patterns,

(2) Map those predictions, and

(3) Assess the accuracy of predictions.

Figure 1. The four basic channel patterns, based on Beechie et al. (2006).

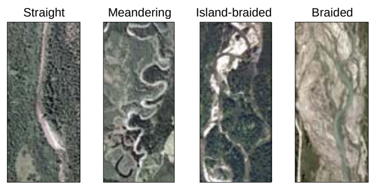
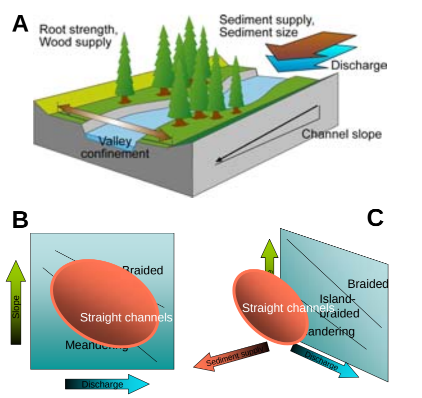


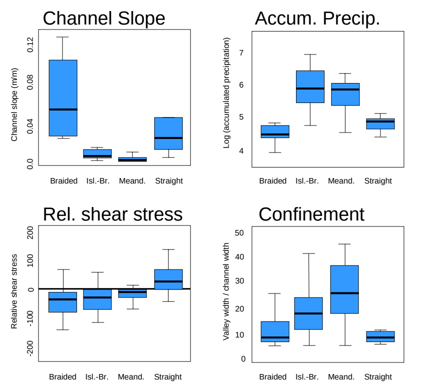
Figure 2. (A) Biophysical controls on channel pattern, (B) illustration of slope-discharge domains (note that straight channels do not have a distinct domain), (C) hypothesized three-dimensional domains.



Approach

Based on literature review we identified six major controls on channel pattern (Figure 2). The most commonly used of these remain slope and discharge (Leopold and Wolman 1957, Church 2002), but straight channels have never been clearly distinguishable from the more complex channel patterns in this two-dimensional, slope-discharge plane. Here we evaluate the utility of additional sediment supply indicators to increase our ability to distinguish the four main channel patterns (conceptually displayed in Figures 2B and 2C). The main variables we use are confinement, slope, accumulated mean annual precipitation upstream of the reach (an index of discharge), and relative shear stress (shear stress in a reach minus shear stress in the reach upstream). We developed alternative models using Linear Discriminant Analysis, with a sample of 104 unmodified analogue reaches randomly selected in the Columbia basin, roughly in proportion to the natural distribution of the four channel types (reach characteristics for four of these variables are shown in Figure 3). We compare alternative predictive models based on overall accuracy of channel pattern predictions.

Figure 3. Box and whiskers plots of four major controlling variables for each of the four channel patterns.



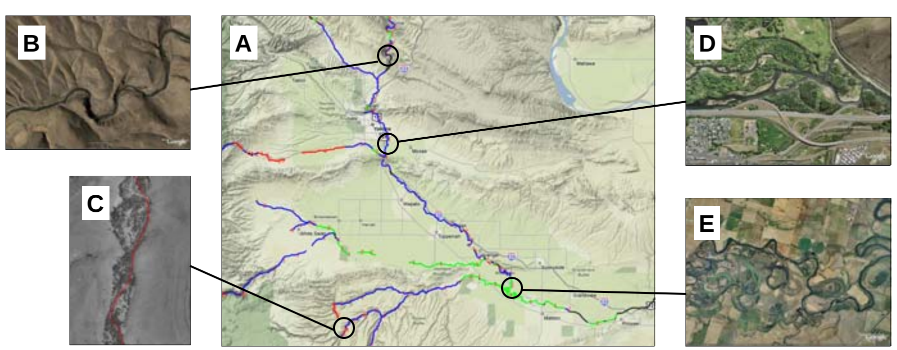
Results

Slope and discharge explain much of the variation in channel pattern within the Columbia River basin (Table 1). Adding an indicator of reach-level sediment supply improves accuracy (orange highlight in Table 1). Accuracy is further improved by adding fourth and fifth variables in combination. Examples of the predictive channel pattern map and present-day channel patterns are shown in Figure 4.

Table 1. Overall accuracies of four potential predictive models of channel pattern based on Linear Discriminant Analysis . Slope and accumulated precipitation (a surrogate for discharge) explain most of the variation in channel pattern, but addition of relative shear stress (an index of local sediment supply) provides the greatest accuracy with relatively few predictor variables (orange highlight).

Model Name	Model Variables	Overall Accuracy
LDA: Model_1p	Slope – Acc. Precip.	52%
LDA: Model_2p	**Slope – Acc. Precip. – R. Shear Stress**	**61%**
LDA: Model_4p	Slope – Acc. Precip. – Sediment	67%
LDA: Model_6p	Slope – Acc. Precip. – R. Shear Stress – Confinement - Sediment	74%

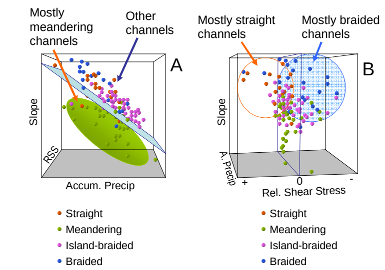
Figure 4. (A) Channel type map in the central Yakima River basin, based on Model_2p which includes slope, accumulated precipitation, and relative shear stress. Current channel patterns at four locations are also shown: (B) confined (non-floodplain), (C) straight, (D) island-braided, and (E) meandering.



Discussion

Our preliminary results show that channel pattern predictions based on only two variables (slope and discharge) are relatively accurate, and that adding an indicator of sediment supply provides a significant increase in accuracy. Statistical accuracy is significantly improved, and visualization of our analysis (Figure 5) indicates that sediment supply is an important avenue of exploration. Two improvements can be made: (1) increase the sample size of straight and braided channels, which are the most sensitive to sediment supply (Figure 5B), and (2) develop a more direct index of sediment supply .

Figure 5. Plots of 'traditional' slope-discharge threshold (A), and separation of straight and braided channels on a sediment axis (B).



Citations:

Beechie, T.J., M. Liermann, M.M. Pollock, S. Baker, and J. Davies. 2006. Channel pattern and river-floodplain dynamics in forested mountain river systems. Geomorphology 78(1-2): 124-141

Church, M. 2002. Geomorphic thresholds in riverine landscapes. Freshwater Biology 47: 541-557.

Leopold, L.B. and M.G. Wolman. 1957. River channel patterns: braided, meandering and straight. Pages 39-85 in Physiographic and hydraulic studies of rivers. USGS Professional Paper 282-B, U.S. Government Printing Office, Washington, DC