Remote Characterization of Gravel Bars in Big Creek, Idaho

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Rationale

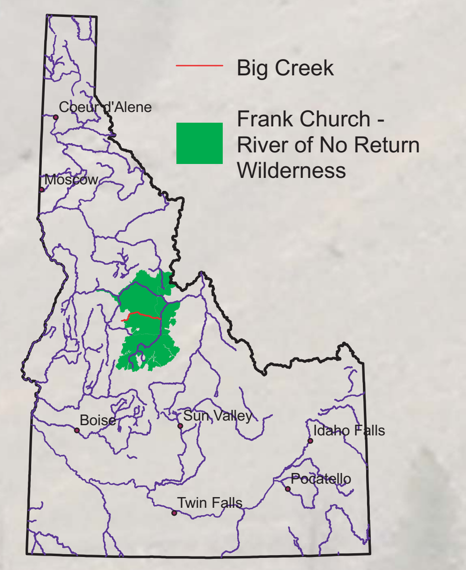
There are several reasons for the quantitative mapping of channel morphology. The most fundamental of these are to better understand channel processes, such as the analysis of discharge rates, sediment load, and flow velocity and resistance, as well as the geologic origins of the channel, including uplift and incision. Mapping of the channel morphology can also assist in the ecological monitoring of the fluvial system for in-stream habitat and the effects of disturbance, such as wildfires and changes in sediment load or discharge. Once these mapping techniques have been developed, they will also be useful in comparing channels and drainages over time and within a global context.

Data

Hyperspectral - The hyperspectral imagery used in this study was collected in the summer of 2004. The imagery consists of 125 spectral bands between 450 nm and 2.5 μm. The flightline is approximately 25 km long and 1 km wide, with a spatial resolution of 3 m.

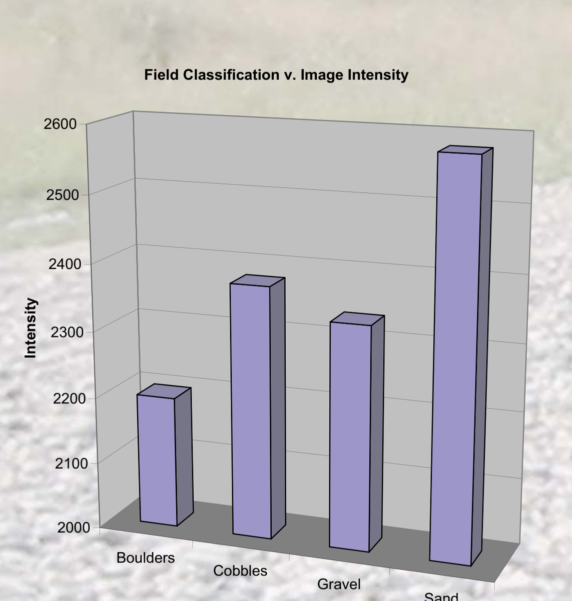
GPS - Differentially corrected GPS data were collected throughout the study area during field campaigns in the summers of 2004 and 2005. This data consisted of polygons classifying gravel bars by relative particle size and sorting.

Photographic - Digital photographs of the sediments were taken during the 2005 field campaign. The photos are downward-looking and were taken from a height of approximately 1 m, producing a field of view of roughly 1 m^2. A total of 362 photos were taken across 27 separate bars. The location of each photo was later digitized.



Water Characterization

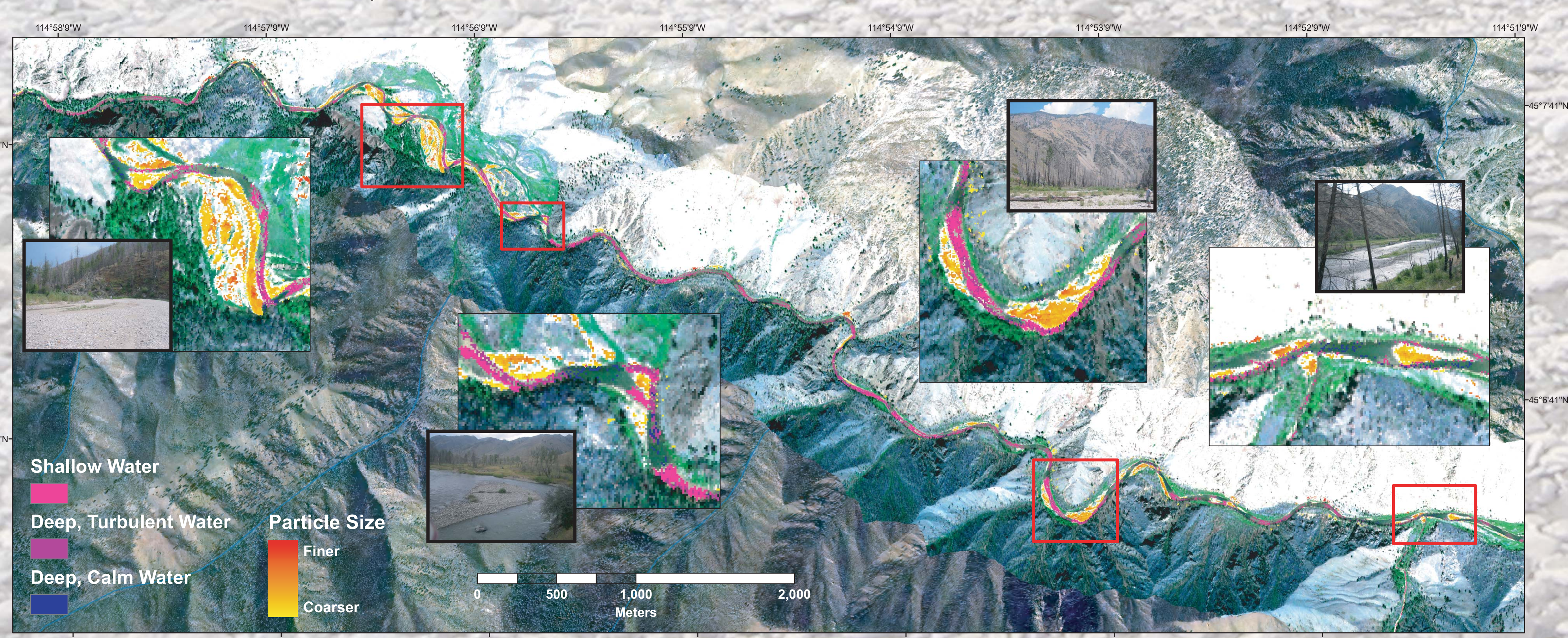
Using stream characteristics mapped in the field, remote sensing methods were used to describe the hydrology of the active channel of Big Creek. The imagery was processed in a standard fashion, first performing a minimum noise fraction (MNF) transform on the full spectral range of the data and subsequently applying spectral angle mapping (SAM) classification to the output. Training endmembers included three characteristic environments: 1) deep and calm, such as pools or deep glides, 2) deep and turbulent, such as fast moving channels, and 3) shallow. This classification generated a dataset identifying the stream regions falling into one of these three environments.

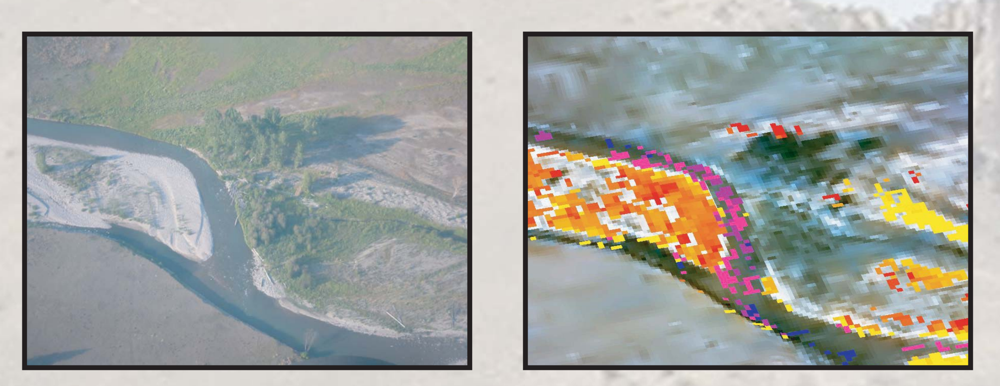


Calculation of Relative Particle Size

Field crews digitally recorded the particle size class of 36 separate bars directly onto georegistered hyperspectral maps, thereby generating a coregistered dataset. Using a geographic information system (GIS), these distributions were intersected (on a pixel by pixel basis) with the reflectance intensity of the 2.10 μm band, and plots contrasting reflectance intensity with field-estimated particle class were generated. A weak but significant inverse relationship was determined between particle size and reflectance intensity, as is shown in the figure to the left. Based on this relationship, it is hypothesized that remotely sensed imagery may be capable of discriminating particle size distributions on exposed in-stream sediment bars.

The map below shows the results of these classifications, with several of the larger gravel bars magnified for examination, as well as inset photographs displaying the local bars. Sediment size gradations are apparent on many of the gravel bars, which are shown in orange and red. Similarly, the fast-moving, main channel of the river is visible in several locations (shown in purple), distinct from the shallow water near the shore (shown in pink). A number of deep pools can also be identified (shown in blue).



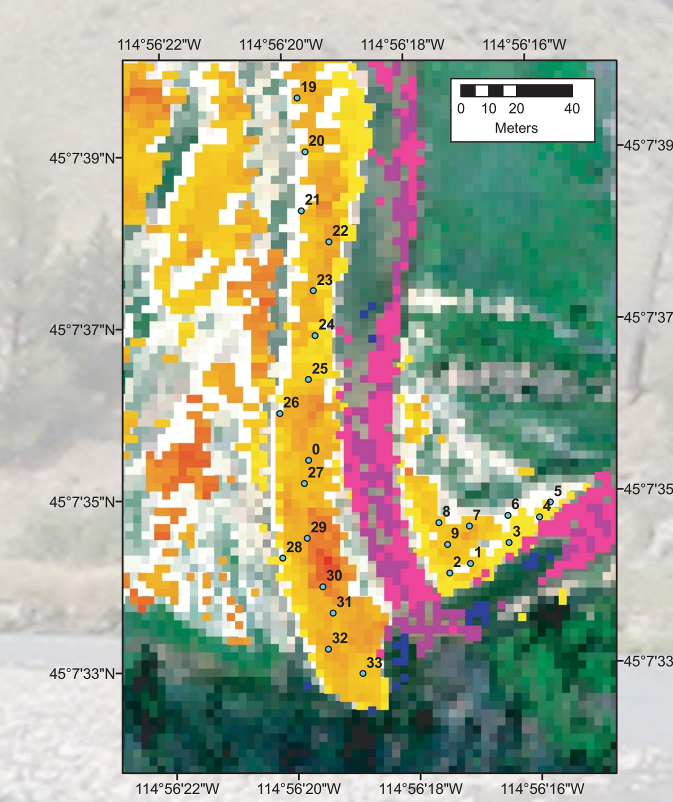


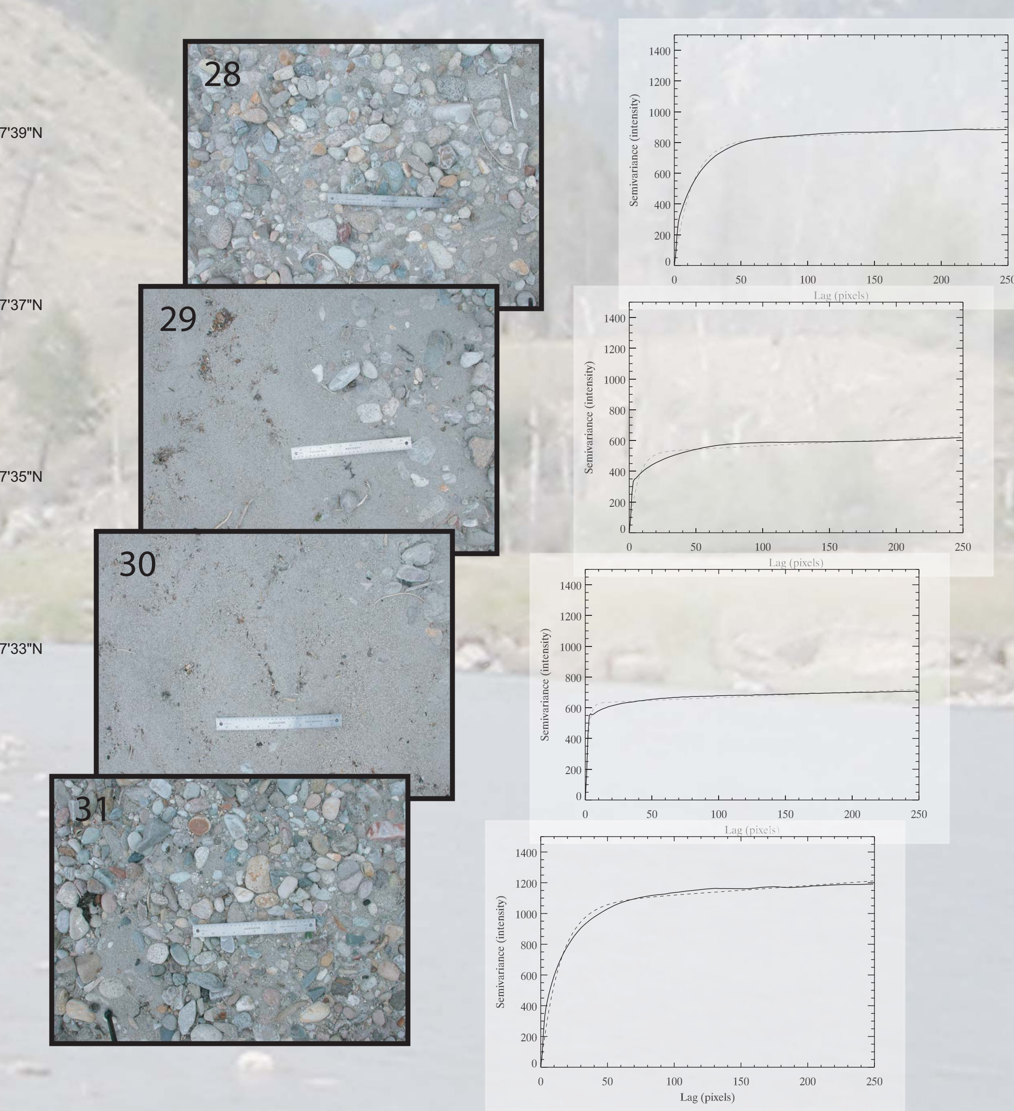
The images at left compare the sediment and water classifications, overlain on 1 m aerial imagery, with an oblique photograph taken from a low-flying airplane. Note that the classification does a reasonably good job of distinguishing the coarse sediments near the edge of the gravel bar from the finer sediments found in the interior. The large sediments in the remnant channel on the right side of the image are also identified.

Similarly, the shallow water near the point of the gravel bar is correctly classified, as is the deeper water near the bottom of the image.

Photographic Analysis

The sediment photographs are used to perform a photo-sieve analysis, which will be used to validate the hyperspectral classification. This analysis is performed by calculating the semivariance of each image and plotting it on a semivariogram. (Semivariance measures the spatial variance of the data as a function of distance, or *lag*.) These semivariograms are then fit to a spherical model, and the fit parameters are used to categorize the photos. These parameter include the *sill*, the value at which the data variance plateaus at large lag values, and the *range*, the lag at which the variance reaches the sill.





The photos and semivariograms shown at right are an example of this. These photos are a sample of the those taken on the gravel bar shown in the map above.

In general, the dominant sediment size in the photo correlates well with the semivariogram range. When compared to the classification map above, the two sand-dominated photographs (#29 and #30) are from locations classified as finer sediment size, while the gravel dominated photos (#28 and #31) are from locations with coarser sediments. As the semivariograms show, the sand-dominated photos have lower values for both the sill and the range than do the gravel-dominated photos. In this way all of the 362 photos can be classified and used to validate the hyperspectral classifications.

Conclusions

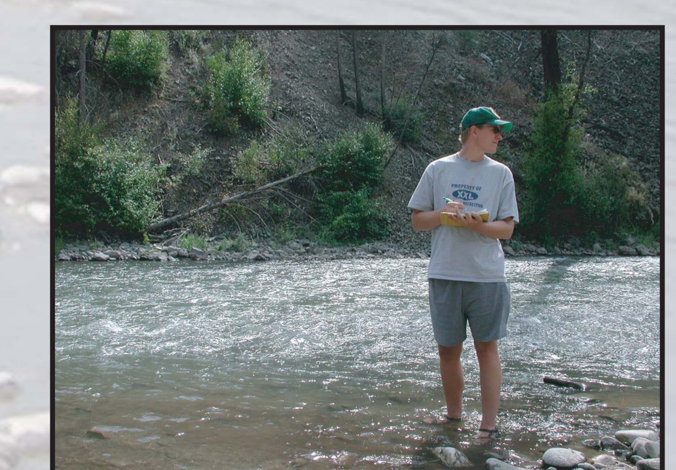
The initial results of this study have shown that hyperspectral imagery can be used to map channel morphology, for both the sediment size of exposed gravel bars and the hydrologic character of the water channel. Semivariogram analysis of sediment photographs can also be used to classify the particle size distributions within the photographs, which can then be used to validate the hyperspectral classifications.

Future work

There remain several tasks for the completion of this study. The first is to fine-tune the hyperspectral analysis. As can be seen from the maps, many areas of sediment and water were not classified using the current methodology. The photo-sieve analysis also requires more attention in order to produce better semivariogram fitting, as well as to determine absolute, instead of relative, particle size distributions.

Once these issues are resolved, this methodology can be applied to a second channel system for which hyperspectral data was also acquired, that of Bear Valley, Idaho.

Future studies may also include the use of LiDAR data to better map the channel morphology. LiDAR textural analysis may improve upon the sediment size calculation, and bathymetric LiDAR would be particularly useful in determining water depths.



Acknowledgements

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