Forest Service
Remote Sensing Tips
WATERSHED MAPPING

Assessing Watershed Conditions Using Remote Sensing and Geographic Information Systems

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Figure 1—The Forest Service is exploring methods to assess riparian resources and protect watersheds more efficiently.

Overview

This project demonstrates one way geospatial technologies can be used to map features of the stream channel and adjacent vegetation that influences the stream (i.e., riparian zone) and support watershed restoration. Effective applications include an automated program for calculating stream order, sinuosity, and gradient from 10-meter digital elevations models (DEMs); determining relative water depth to detect deep and shallow portions of the stream (i.e., pools and riffles); and providing a means for manual vegetation interpretation. Automated vegetation classification was also tested but proved unsuccessful.

Watershed Management

Restoring watersheds, improving water quality, and protecting aquatic habitats are clear goals of the Forest Service (figure 1). Many partnerships exist among Federal, State, and local governments, as well as private landowners, to inventory riparian resources and restore critical riparian habitat. Water management across jurisdictional boundaries, however, requires a great deal of cooperation and understanding among vastly different groups and individuals. Geospatial technologies such as remote sensing and geographic information systems (GIS) have proven to be invaluable tools for collecting resource baseline data and establishing common ground to discuss watershed management constructively.

The digital, color-infrared (DCIR) camera is a practical tool for acquiring imagery along river corridors and generating detailed hydrologic and vegetation information. Resource specialists can use this technology to characterize riparian systems over large areas and aid compliance with the Clean Water Act (CWA), Endangered Species Act (ESA), and Pacific Northwest Forest Plan (PNFP). To support watershed restoration, the Rogue River National Forest, the Medford District Bureau of Land Management, and the Remote Sensing Applications Center (RSAC) jointly developed a practical and operational set of procedures to assess riparian and aquatic resources.

Multiscale Watershed Analysis

The cooperators undertook a multiscale assessment to characterize aquatic and terrestrial features along the Applegate River watershed in southwestern Oregon. The study area encompassed approximately 500,000 acres of publicly and privately managed land (figure 2). Project work was completed at two scales, defined by the hierarchical framework of aquatic ecological units: valley segment

at 1:24,000, and stream reach at 1:12,000 (Maxwell and others 1995). To capture and describe specific ecosystem elements, the project used a variety of geospatial technologies:

- Landsat TM satellite imagery (30-meter pixel);
- Digital elevation model (DEM) (10-meter-pixel);
- Digital orthophoto quad (DOQ) (1-meter pixel); and
- Digital, color-infrared camera imagery (1-foot pixel).

Processing Digital Camera Imagery

In August 2000, the project specialists acquired continuous, high-resolution, DCIR camera imagery along 120 miles of the Applegate River and many major tributaries. In 3 days, they collected thousands of digital images with a Kodak DCS 420-camera system mounted on a light, fixed-wing aircraft. Individual frames were stitched into small, manageable strips, or mosaics, using Canon PhotoStitch 3.1 automated image mosaic software. Each mosaic typically consisted of 10 camera frames and was georegistered to a corresponding DOQ (figure 3). Research specialists improved file management and data retrieval, by reducing each georegistered image mosaic by nearly 80 percent using Enhanced Compressed Wavelet (ECW) image compression software available as a free download from ER Mapper (www.ermapper.com/). Manual and computer-assisted analysis techniques helped resource specialists interpret hydrologic and riparian vegetation features and map them into a GIS.

Valley-Segment Scale

Hydrology

Hydrologic information collected at the valley-segment scale included sinuosity, gradient, and stream-order measurements. These attributes were automatically derived from a continuous mosaic of 10-meter DEMs. A resource specialist developed an Arc/Info 7.2 AML program to simplify the spatial analysis and enable other resource specialists to standardize valley-segment scale protocols. This program generated a network of streams that were labeled with Strahler stream order, sinuosity, and gradient—key indicators in the Rosgen stream classification system (figures 4 and 5).

Vegetation

General descriptions of upland and riparian vegetation are appropriate at the valley-segment assessment scale. Most land managers have access to digital map products describing vegetation. The Rogue River National Forest manages a similar vegetation database that includes the Applegate watershed. This database stores specific information about plant communities such as seral stage, canopy closure, and size (table 1). In a GIS, resource specialists can generate vegetation summaries and examine the relationships between variables that characterize landscape form and structure (i.e., morphometric variables) and riparian vegetation patterns.

Stream-Reach Scale

Assessing hydrology at the stream-reach scale requires finer resolution and more detailed information than at the valley-segment scale. The DCIR camera imagery provides such closeups. A single valley segment along the main stem of the Applegate River was selected for analysis at the stream-reach level. This section's variety

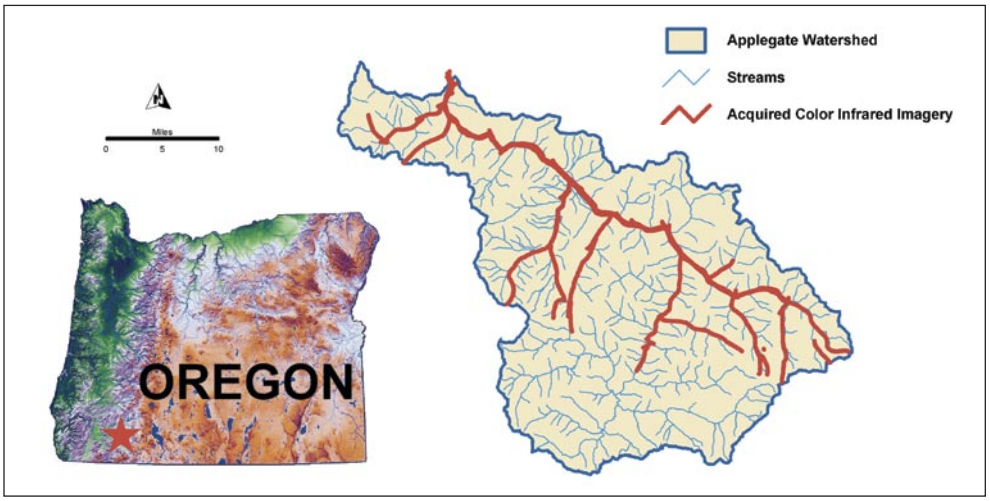

Figure 2—Location Map of the Applegate River watershed and acquired digital camera imagery *(red)*.

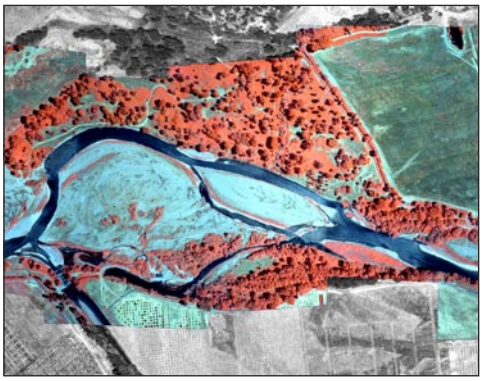

Figure 3—Mosaicked and georegistered digital color-infrared camera imagery overlaid on a DOQ and prepared for analysis.

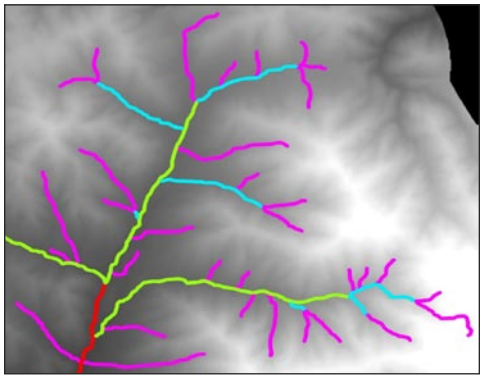

Figure 4—DEM derived stream network.

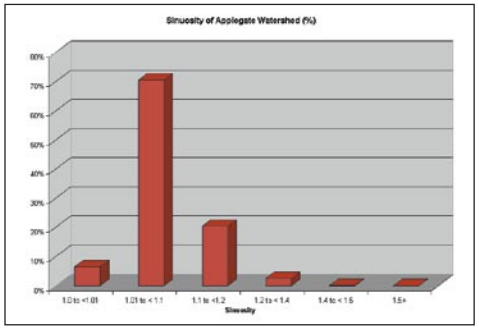

Figure 5—Graphic display of the Applegate River watershed sinuosity data derived from an Arc/Info AML.

of hydrologic features and lack of obstructing vegetation, made it an excellent candidate for developing hydrologic and vegetation mapping applications.

Hydrology

Resource specialists developed successful hydrology application using combined manual and computer-assisted image processing. The process differentiates deep, moderate, shallow, and very shallow water depths, as well as sediment bars and large woody debris (figure 6). The specialists stratified aquatic and terrestrial land cover using computer, onscreen digitizing techniques. Next, they performed an unsupervised classification on the aquatic portions of the digital camera imagery and labeled each resulting class. If class distinctions were unclear, they performed additional unsupervised classifications. Finally, they smoothed classification by using a low-pass filter to minimize the occurrence of isolated pixels. This combined approach proved both efficient and effective for stratifying water depth, especially for resource specialists who have minimal experience with image processing. Additionally, fishery biologists have suggested that identifying relative stream depth and the distribution of pools and riffles can help identify salmonoid spawning habitat.

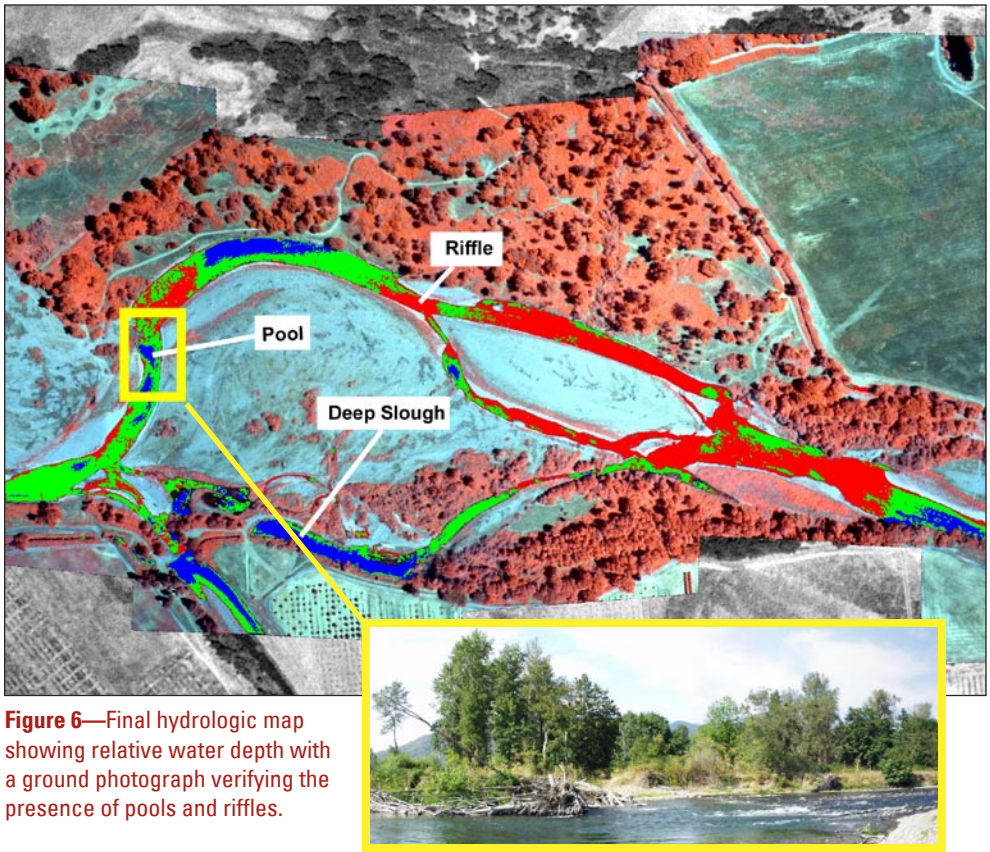

Figure 6—Final hydrologic map showing relative water depth with a ground photograph verifying the presence of pools and riffles.

Table 1—Results of Valley Scale Vegetation Analysis Using Landsat TM Imagery

Successional Stage	*Applegate Acres*	*Little Applegate Acres*
Grass/Forb	1,294	275
Shrub	280	100
Early Seral	1,695	553
Low Density Forest	244	122
11 to 17 inch DBH	722	228
17 inch + DBH	92	128

Note: diameter at breast height (DBH).

Vegetation

The closeup view of the riparian system provided by digital camera imagery was the primary basis for a vegetation map. The resource specialists developed a classification scheme depicting 13 land cover categories. It consisted of conifer, deciduous, and mixed forest; riparian, upland, and blackberry shrub; wet, riparian moist, riparian dry, upland moist, and upland dry grass; gravel bars, bare ground, and urban/residential.

Manual Interpretation

Forest cooperators used Arc/TOOLS to view and delineate vegetation polygons manually onscreen as GIS data layers. They assessed landscape patterns at a variety of scales to formulate map unit concepts and eventually digitized individual vegetation patches at a scale no finer than 1:2,000. This limited scale improved map unit consistency and eliminated the possibility of creating insignificantly small polygons. Each polygon was classified according to the scheme and labeled with up to three vegetation types, with percentages specified. This manual approach proved both accurate and economical (figure 7).

Computer-Assisted Interpretation

The resource specialists also attempted computer-assisted classification of vegetation for the same stream reach. Although the resulting land cover patterns generally matched features in the imagery, the vegetation types were mislabeled and this approach proved unreliable. As expected, traditional spectral classification produced significant pixel misidentification, which could be caused by a variety of factors related to the DCIR camera, including:

- Frame-to-frame illumination differences
- High-resolution imagery —too many pixels per feature
- Failure to distinguish shrub and tree chlorophyll by near-infrared photography.

Based on this evaluation, manual methods are preferable for classifying vegetation from digital-camera imagery.

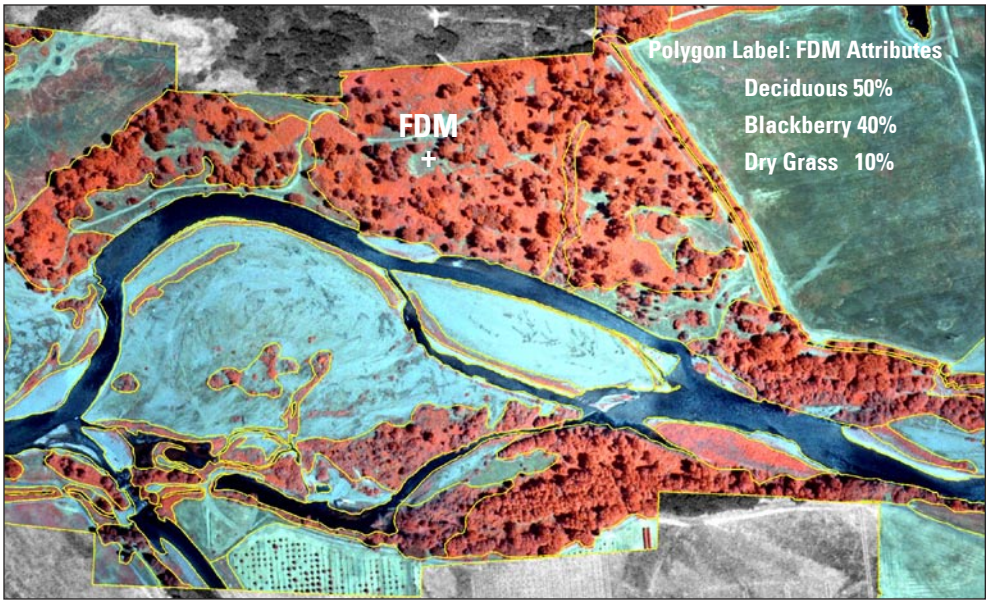

Figure 7—Final vegetation map demonstrating polygon line precision, polygon label accuracy, and attributing detail.

Cost

Acquiring DCIR camera imagery includes the cost of aircraft rental, a pilot, and labor for initial data preparation (table 2). Digital-image processing and interpretation costs are based on the estimated time to complete the project tasks described. Traditional watershed assessments typically cost $500 to $600 per mile, and it might take three field seasons to assess 100 miles of river. Using this project's techniques, 120 miles of river were assessed for $275 per mile, and the work was completed in a single off-field season. This estimate does not include the purchase price of the Kodak camera system nor the hardware and software to process the digital data.

Forest Management Implications

Land managers are combining high-resolution, map-referenced imagery; hydrologic and vegetation data layers; and traditional field information to assess and restore watersheds, protect riparian systems, and improve water quality. High-resolution, DCIR-camera imagery proved to be a valuable tool for mapping and analyzing ecosystem elements at the stream-reach scale. Hydrologic information was obtained by combining manual and computer-assisted data interpretation. Manual methods produced reliable vegetation information, whereas, automated spectral classification techniques generated unacceptable results. Future technologies that utilize sophisticated algorithms to recognize landscape features may improve the accuracy of maps generated automatically.

Table 2—Project Cost

Project Components	*Cost per mile in dollars*
Remote Sensing Data acquisition	100
Digital Image Processing	75
Image Interpretation	100
Total	**275**

Suggested Readings

Knapp, A.; Hoppus, M. 1996. Evaluation of a color infrared digital camera system for forest health protection applications. In Proceedings of the sixth biennial Forest Service remote sensing applications conference, April 29—May 3, 1966, Denver, CO. Bethesda, MD: American Society for Photogrammetry and Remote Sensing. 213–219.

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