Future of Applied Watershed Science at Regional Scales

The Internet-driven evolution of communication and science technologies coincides with a parallel evolution in environmental policy and natural resource management. Resource managers must deal increasingly with land use and conservation plans applied at large spatial scales (watersheds, landscapes, states, regions) involving multiple interacting agencies and stakeholders. Many federal, state, and private organizations have similar objectives, questions, and data and analysis needs. This is motivating the development of community-supported watershed databases and analysis systems of common structure and function across large geographic areas. Numerous state and regional analysis systems are targeting natural resource issues involving management of forests, freshwater fishes, wildlife, and water quality and supply.

This Forum examines how environmental policies and natural resource management in the Pacific Northwest (PNW) region of the United States are motivating the development of Web-based, community-supported watershed databases and analysis systems. Competing land uses involving hydropower, urbanization, logging, and agriculture—juxtaposed with the need to support sustainable ecosystems—have promulgated wide-ranging resource management programs. The Pacific Northwest Electric Power Planning and Conservation Act [*U.S. Congress*, 1980] addresses effects of hydroelectric dams on fish and wildlife within the Columbia River basin, a 500,000-square-kilometer region. Stakeholders involved with conservation of Pacific salmonids across the Columbia basin include the Bonneville Power Administration, the Northwest Power Planning Council, state governments of Idaho, Montana, Oregon, and Washington, Native American tribes in the region, the U.S. National Oceanic and Atmospheric Administration's National Marine Fisheries Service, and the U.S. Fish and Wildlife Service.

Partially overlapping this large geographic area are federal forest lands along the coastal PNW where concern about the effects of logging on salmon and other species (spotted owl) led to the Northwest Forest Plan (NWFP) [*U.S. Department of Agriculture Forest Service*, 1994]. The NWFP coordinates the management of lands administered by the Forest Service and the Bureau of Land Management to achieve both ecosystem protection and development of forest products across an area extending from western Washington to California that encompasses about 100,000 square kilometers. Nongovernmental organizations such as the Wild Salmon Center, Ecotrust, and The Nature Conservancy have developed conservation initiatives across the PNW region (overlapping the aforementioned administrative areas) and extending along the Pacific Rim into Canada, eastern Russia, and northern Japan to address habitat use of far-ranging species such as the Pacific salmon.

The large-scale environmental and natural resource programs in the PNW region have several key features: (1) common land use and conservation objectives, (2) overlapping administrative programs of multiple agencies and organizations involving multiple species, and (3) similar database and analysis tool requirements. These three commonalities among natural resource programs motivate the need for similar watershed databases (e.g., stream networks, vegetation, roads, and so forth) and analysis tools that utilize those databases (e.g., fish habitat quality, erosion potential, fish migration blockages, and so forth).

Coevolution of Watershed Science and Natural Resource Management

Watershed science has evolved in conjunction with natural resource policies. Starting points for the integration of science with land use policies at large scales are federal- and state-sponsored watershed-analysis-style basin assessments [e.g., *Reid and McCammon*, 1993; *Washington Forest Practices Board (WFPB)*, 1997; *Oregon Watershed Enhancement Board*, 1999]. These provide information to guide resource management, conservation, and restoration. This approach, however, cannot be applied practicably at the large spatial scales of today's expanded land use and environmental programs. Watershed analysis (based on the methodologies cited above) can be prohibitively expensive and time consuming, and it can produce information that is geographically spotty and inconsistent from one watershed to another. For example, in Washington only 13% of the state was covered by its watershed analysis program [*WFPB*, 1997] from 1993 through 2000; after 2000, the program became moribund due to cost and time constraints. Geographically extensive databases—including the National Elevation Dataset (NED; http://ned.usgs.gov) and the National Hydrography Dataset (NHD; http://nhd.usgs.gov/applications.html)—lack key attributes relevant to the watershed sciences, such as habitat type and abundance, and they also lack analysis capabilities to characterize processes such as wildfire, erosion, and riparian functions. Moreover, the analysis tools and data to obtain relevant attributes to natural resource management are often not widely available or user friendly.

Nationally, the watershed science community is developing large-scale digital databases and modeling platforms to bolster the integration of science and technology with resource management. Examples of digital data systems include Michigan State University's Digital Watershed tool (http://www.iwr.msu.edu/dw/), the Consortium of Universities for the Advancement of Hydrologic Science, Inc.'s Hydrologic Information System (http://www.cuahsi.org/his.html), and the Community Hydrologic Modeling Platform (CHyMP) [*Famiglietti et al.*, 2008]. These programs can utilize the U.S. Geological Survey's NED and NHD.

New Initiatives: Geographically Focused, Application-Oriented Systems

The commonalities of large-scale environmental programs in conjunction with recent advances in science and technology pertinent to the watershed sciences (e.g., watershed process models, fast computers, and advanced geographic information system (GIS) technology) can motivate and underpin future efforts in applied watershed science. One aspect of that future is community-supported, geographically focused, and application-oriented analysis systems. Community-supported programs require multiple stakeholder support and the use of collective databases and analysis tools. A community-supported system would (1) promote computer analyses of universal watershed attributes (hillslope morphology, stream morphology, road networks, vegetation, climate, and so forth) to create geographically extensive and uniform landscape databases of common structure that can cross-reference other digital databases (for example, the NHD), incorporate data from user-supplied analyses and field efforts, and provide data to user-supplied models and field studies; (2) support user-friendly analysis tools that use landscape databases to inform resource management, including applications in forestry, fisheries, wildfire planning, grazing, restoration, monitoring, research, and education; and (3) rely on stakeholder design, implementation, and maintenance of shared databases and analysis tools.

Watershed database and analysis systems that are based on the three components above could be applied in an application-oriented and geographically focused way that targets specific stakeholders and particular purposes. For instance, a community analysis and database system developed for natural resource management and environmental applications in the PNW region would serve practitioners in forestry, prewildfire and postwildfire planning, restoration, water supply planning, and environmental regulation. Analysis tools and databases would emphasize watershed attributes pertaining to aquatic habitats, erosion, flooding, water quality, stream temperature, and organic flux into streams over a range of spatial scales. The focus of application-oriented systems would be on development of applied tools and watershed databases with a specific structure and set of attri-

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butes necessary for addressing a finite set of critical issues.

Existing examples illustrate aspects of geographically focused systems. The Information Center for the Environment at the University of California, Davis (ICE; http://ice.ucdavis.edu/) provides resources for water-related projects throughout California. The Klamath (River) Resource Information System (KRIS; http://www.krisweb.com/) provides information and databases relevant to fisheries and water quality for watersheds along the northwest coast of California. The Northwest Forest Plan data repository (http://www.blm.gov/or/gis/data.php) and the Oregon Coastal Landscape Analysis and Modeling Study (http://www.fsl.orst.edu/clams/) provide resources specifically for the management of coastal PNW forests.

Moving further along in the integration of the three components outlined above, two authors of this report (Benda and Miller) are coordinating development of NetMap (http://www.netmaptools.org), a coupled watershed database and analysis system designed to support resource management, restoration, and conservation in the Pacific Northwest [*Benda et al.*, 2007]. Application-oriented systems require the ability to communicate with larger national efforts (e.g., CUAHSI, CHyMP, NHD). This could be accomplished by using universal languages, such as CUAHSI's WaterML, or by incorporating the ability to transfer data across diverse GIS systems and data layers.

Advantages of Application-Oriented Systems

Access to a geographically focused and application-oriented database would allow users in different locations and with different concerns to quickly access similar types of information in a consistent format. The use of uniform tools that analyze dissimilar watersheds in similar ways can promote common methodologies, vocabularies, and problem-solving techniques, serving to increase communication and collaboration within and among agencies and stakeholders. A regional database and analysis system could support existing analysis and regulatory programs, including watershed analysis–style basin studies, the U.S. Environmental Protection Agency's Total Maximum Daily Load program, and statewide habitat restoration activities.

By contributing to the development of a geographically extensive community database, agencies and groups could pool their resources, thereby sharing costs, increasing availability of the highest-resolution data and most advanced tools, and providing smaller groups—such as local watershed councils—with data and tools they could not otherwise afford. Shared resources can contribute to economic efficiency by creating geographically extensive and coordinated prioritization strategies for habitat restoration, road maintenance and abandonment, and prewildfire and postwildfire management planning. User input to a community-supported system will promote evolution in tool design based on specific needs and current shortcomings.

The tools and data to assemble geographically focused and application-oriented watershed data and analysis platforms exist today, and efforts to integrate databases with analytical tools for land use and conservation decision support are under way. Local projects can contribute to a community database and analysis system if data acquisition and metadata requirements are managed in a central (Web-based) location, consistent methods are used to synthesize the data into forms usable by widely available analysis tools, and protocols for data storage and distribution are established. Initially, such systems could be desktop and client based, particularly if linked with commonly used desktop GIS software, but over time could be hosted by Web servers.

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