Stream Restoration Databases and Case Studies: A Guide to Information Resources and Their Utility in Advancing the Science and Practice of Restoration

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Abstract

The successful application of adaptive management to the science and practice of restoration ecology requires specific knowledge about the outcomes of past restoration efforts. Ideally, project results would be readily available to scientists or other project managers with similar goals or in analogous ecosystems. Recently, there has been a proliferation of Internet-accessible databases, lists, and case studies of stream and river restoration projects. These resources include a wide range of information that could be accessed to aid natural resource and conservation professionals in restoration. In the U.S. Pacific Northwest, the National Marine Fisheries Service's Northwest Fisheries Science Center and, on a national scale, the National River Restoration Science Synthesis are combining existing national and regional databases, along with the individual project descriptions, to create comprehensive, web-based databases of stream restoration projects. In this process, more data sources were discovered than fit the scope of either of these projects. Ten international, 19 U.S. national, and 42 U.S. regional web-accessible sources of restoration project databases and case studies are listed in this study. However, to easily use information that is currently scattered in multiple files and Web sites, databases would optimally use a common, standardized format. We provide a recommended list of information to be included in restoration databases. These efforts may provide a blueprint for development of compatible international databases of stream restoration projects.

Key words: adaptive management, database, National River Restoration Science Synthesis, stream restoration.

The Need for Stream Restoration Databases and Case Studies

Major efforts have been initiated throughout the world to maintain and improve the ecological integrity of streams by restoring natural fluvial and landscape processes (NRC 1992; Henry et al. 2002). Bernhardt et al. (2005) found that on average, more than 1 billion dollars are spent each year on stream restoration in the United States. Restorationists have recognized the need for postproject monitoring and reporting to improve future restoration projects and share lessons learned with other practitioners (Kondolf & Micheli 1995; Landers 1997; Lake 2001).

Databases and case studies of restoration projects enable restorationists to save money, time, and effort by avoiding mistakes made by others; to adopt proven strategies to improve their probability of success; and to know about past projects conducted within their watershed to coordinate efforts (Clewell & Rieger 1997). River expert, Luna Leopold, spoke about this opportunity in 1997:

> "We have a problem in river restoration …. The problem is lack of communications and trading of experiences. As a result, successes in field restoration are little known, while mistakes are repeated indefinitely ….
>
> What is needed is a gradually accumulating file of case studies describing with text the illustration of the original condition, an assessment of the basic

cause of the problem, the techniques and construction details of treatment, and an objective analysis of the result." (Leopold 1997)

Regional project information also sheds light on the performance of specific species or techniques, in addition to sources of local materials, contractors, and volunteers. Therefore, even an ecologically unsuccessful project may be termed a partial success if it improves future project design (Palmer et al. 2005).

Knowledge of where different activities have been implemented in a watershed can help inform conservation planning. With specific location information from a restoration database, future restoration projects could be designed to link areas of higher ecological integrity, thereby extending the effectiveness of restoration efforts. This allows new restoration activities located in areas without previous restoration to be successfully monitored without prior projects masking or confounding observed results. Also, knowledge of past or ongoing restoration activities would help prevent the implementation of projects that may cause detrimental effects on projects underway downstream.

Databases could also demonstrate the value of improving the integrity of stream ecosystems to funders and policymakers. Costs could be assessed and evaluated against reported social and environmental successes. Such evaluations could provide greater information for making annual budgetary recommendations for programs that fund restoration projects. Information contained within databases also could aid the prioritization of how and where to allocate limited restoration (e.g., a particular stream reach that could link existing projects or a critical but underfunded program area). Improved accessibility and exchange of information on specific restoration projects will increase the scientific understanding of stream ecosystems along with the collective ability to conduct successful projects (Kershner 1997; Leopold 1997; FISRWG 2001).

The objectives of this study are 3-fold: (1) to provide a listing of publicly available international, U.S. national, and U.S. regional databases on river and riparian restoration; (2) to discuss the challenges of available databases; and (3) to provide recommendations on fields of information to be included in restoration databases, thereby improving their usefulness to restoration practitioners, conservationists, funders, and policymakers.

Methods

This study is a result of projects conducted by the National River Restoration Science Synthesis group (NRRSS) and National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service's Northwest Fisheries Science Center (NWFSC). The NRRSS project consists of a team of university scientists and graduate students from the United States and Australia, who compiled information on river and riparian restoration activities occurring in the past 30 years to characterize the practice

of river restoration and identify common elements of successful river restoration projects. NRRSS identified databases, lists, and case studies of river restoration projects using Internet searches, networking, and phone calls (see Bernhardt et al. 2005, for a more detailed description). The information contained within collected data sources was entered into a database housing more than 14,000 project records.

Concurrently, the NWFSC developed a separate database, in partnership with the NRRSS project, which includes information on 23,000 projects in the states Oregon, Washington, Idaho, and Montana. Driving this project was the designation under the Endangered Species Act of more than 20 "evolutionarily significant units" of salmon and steelhead as endangered or threatened within the Pacific Northwest. The NWFSC Pacific Northwest Salmon Habitat Project Tracking Database was developed to improve regional tracking and evaluation of the effectiveness of stream restoration. The 23,000 project records of various formats were transformed into a single spatially explicit prototype database designed to be compatible with the NRRSS database. More than 37,000 project records covering all the United States and Southeast Australia makeup the combined NRRSS/NOAA NWFSC dataset (Bernhardt et al. 2005).

International, U.S. National, and U.S. Regional Databases and Case Studies

In the process of compiling the NWFSC and NRRSS databases, we encountered numerous web-accessible databases, many more than fit the scope of our projects. The title of each source, its web address, the number of restoration projects described, and a short description are listed for 10 international databases in Table 1, 19 U.S. national databases in Table 2, and 42 U.S. regional databases in Table 3. Approximately 23 of the 71 sources listed include case studies. International databases are those that cover either the whole or the parts of a single country other than the United States (e.g., The Danish Centre for River Restoration) or those that contain records for multiple countries (e.g., the Community Mapping Network Project Directory). U.S. national databases include databases of projects by federal agencies, nongovernmental organizations, and corporations specializing in restoration. Finally, the majority of U.S. regional sources (33) are either state government agencies or state-based organizations.

Challenges Associated with Using Current Databases

Progressively, more and more electronic databases are being developed explicitly to track river restoration and to allow the transfer of information on restoration projects across basins, ecoregions, and continents. In the United

Table 1. International databases and case studies of stream restoration projects.

Agency, Database Name, Contact/Web Site, and Description	Approximate No. of Records
Community mapping network project directory www.shim.bc.ca/ Map with flags around the globe that link to summarized project reports	20

Danish Centre for River Restoration
Danish River Restoration Projects Database
www2.dmu.dk/1_om_dmu/2_tvaer-funk/3_vlres/database/restaurering.asp
Includes name of stream/basin, UTM coordinates, project type and
   activity, completion year, cost, stream discharge, and catchment area.
   It is only updated to 1998 and is not available in English
	1,068

Denmark Ministry of Environment and Energy, National Environmental Research Institute River Restoration; Danish Experience and Examples www2.dmu.dk/1_viden/2_Publikationer/3_Ovrige/rapporter/River_Restoration_UK_3a.pdf Case studies of river restoration projects	24
Fisheries Project Registry, British Columbia, Canada www.canbcfpr.pac.dfo-mpo.gc.ca/fpr Searchable database that provides map location and project contact information	120

Land and Water Australia Project JCU 15
Travelling Fellowship Report—Trips to Europe and North America
   January 2001 and June 2002 by Ross Kapitzke
www.rivers.gov.au/research/rlrd/streamrehab.htm
Kapitzke visited nine restoration sites around Europe and three sites in North America, and
   numerous river restoration professionals in order to learn and compare Australian
   methods with other approaches
	12

Ontario Streams www.ontariostreams.on.ca/demoprojects.html Status reports on restoration projects	9
River Restoration Centre, United Kingdom RRC Projects Database and Demonstration Project Case Studies www.therrc.co.uk/r_y_p_.htm Contains brief summaries and case studies. Not publicly available over the web www.therrc.co.uk/demonstration_projects.php Five detailed case studies of projects in Great Britain and Denmark	750 5

Rocky Mountain Institute
Daylighting: New Life for Buried Streams
www.rmi.org/sitepages/pid172.php
This report reviews the benefits, challenges, and costs of "daylighting"
   formerly culverted or buried streams and includes case studies of
   several dozen projects from around the United States and internationally
	25

Stewardship Centre for British Columbia, Canada, Case Study Library www.stewardshipcentre.bc.ca/caseStudies/studySearch.asp Location and descriptive information for each project, then results of the study	35
The Nature Conservancy nature.org/initiatives/freshwater/work/ Case studies of freshwater conservation projects in North and South America through a linked map	14
USFWS Division of Bird Habitat Conservation North American Wetlands Conservation Act Grants Program www.fws.gov/birdhabitat/NAWCA/grants.htm Projects, which are mostly in Canada, United States, and Mexico, are listed in biennial reports	1,235

UTM, Universal Transverse Mercator; USFWS, U.S. Fish and Wildlife Service.

States, among others, the Army Corps of Engineers, the U.S. Forest Service, the Bureau of Land Management, and the National Park Service are currently working to create databases for their river restoration projects. The European River Restoration Network is also developing a river restoration database.

The wide variety of activities associated with stream restoration makes compilation of project descriptions and

Table 2. U.S. national databases and case studies of river restoration projects.

Agency, Database Name, Contact/Web Site, and Description	Approximate No. of Records
American Rivers Restoration Resource Center www.americanrivers.org/site/PageServer?pagename=AMR_content_7ba0 River restoration success stories	9
Ducks Unlimited www.ducks.org/Regions/index.asp Riparian and upland restoration projects and many more pond and wetland restoration projects. They offer maps of past project locations	3,394
EPA Restoration Project Directory yosemite.epa.gov/water/restorat.nsf/rpd-2a.htm?OpenPage Includes the Mid-Atlantic Integrated Assessment	560
EPA Five-Star Restoration Projects www.epa.gov/owow/wetlands/restore/5star/states.html Projects are listed by state	351
EPA National Showcase Watersheds www.epa.gov/owow/showcase/projects.html Includes detailed project descriptions for 12 projects in 11 states. They also list projects in 40 case study watersheds	52
Federal Highway Administration Transportation Enhancement Program www.enhancements.org/projectlist.asp List projects in the mitigation/wildlife crossings category, wetland restoration, stormwater mitigation, erosion control, and stream restoration categories	307
Inter-Fluve, Inc. www.interfluve.com/ Descriptions of recent projects	9
NOAA, National Marine Fisheries Service NOAA Restoration Center Project Database seahorse.nmfs.noaa.gov/rcdb/class/location_main.html Lists projects by state, listing funding mechanism, total grant amount, and project title and year	575
National Resource Conservation Service Reinvesting in America's watersheds www.nrcs.usda.gov/programs/ws_reinvent/index.html Case studies of watershed restoration projects. Only 19 are highlighted, though they write that by 1998, NRCS had completed more than 2,000 projects	19
National Resource Conservation Service Buffer Success Stories www.nrcs.usda.gov/feature/buffers/bufconts.html Case studies of buffer projects by state	32
The Bioengineering Group, Inc. www.bioengineering.com/tbg_website.htm List of projects with photos and descriptions	13
The River Network Success Stories and Lessons Learned www.rivernetwork.org/library/index.cfm?doc_id=122 Stories submitted by conservationists to this Web site	6
The River Network Watershed Assistance Grants Awardees, 1999–2002 www.rivernetwork.org/howwecanhelp/index.cfm?doc_id=98 List of projects, of which 24 are stream restoration	24
The River Network Watershed Assistance Grants: Building Capacity of Community-Based Watershed Partnerships: An Evaluation by Suzanne Easton, March 2001 www.rivernetwork.org/howwecanhelp/index.cfm?doc_id=94 Describes funded projects and highlights lessons learned	9

Table 2. Continued

Trout Unlimited	467
Dam Removal Success Stories	
www.tu.org/site/pp.asp?c=7dJEKTNuFmG&b=277845	
List of 467 dam removals, with purpose, state, stream, and date. Also, 25 case	
studies of specific dam removal projects	
Trout Unlimited	35
Watershed Restoration	
www.tu.org/site/pp.aspx?c=7dJEKTNuFmG&b=275422	
Case studies of current projects, organized on a clickable map of the United States	
Trout Unlimited	12
City Streams; Trout Unlimited Urban Rivers Success Stories	
www.tu.org/site/pp.asp?c=7dJEKTNuFmG&b=2,77,845	
This document highlights 12 urban restoration projects around the country	
and provides contact information: from Water Quality and Brook	
Trout restoration in Alley Creek in New York City to a stormwater	
utility in River Falls, Wisconsin that charges homes and businesses according	
to the amount of stormwater run-off	
Water Resource Development Acts	400
Available in the American Rivers Web site's "Corps Watch" section	
www.americanrivers.org	
Beginning in the 1970s, money was authorized for restoration projects. The projects are listed	
with name of project, description, and cost	
Wildlife Habitat Council, Waterways for Wildlife	4
www.wildlifehc.org/waterways/index.cfm	
Descriptive case studies	

EPA, Environmental Protection Agency; NOAA, National Oceanic and Atmospheric Administration.

results challenging. Stream restoration objectives vary among regions as well as between countries (Jungwirth et al. 2002; Shields et al. 2003). For example, within the United States, stream restoration in the Pacific Northwest focuses on restoring endangered salmon habitat, whereas Chesapeake Bay restoration centers on improving water quality (Bash & Ryan 2002; Mayer et al. 2004; Palmer et al. 2004). Depending on the area, the same activities can be either restorative or detrimental. In Southeast Australia, exotic willow removal and bank stabilization with native plantings dominate restoration activities (Ladson et al. 1997; Bobbi 1999), whereas restorationists in other areas plant native willow species to restore riparian vegetation.

The majority of available international, national, and regional restoration databases and case studies (Tables 1–3) include basic descriptive information such as contact information, dates, location, cost, and project goals or activities. Because these databases are designed with different goals and scopes, they contain varying amounts of information and detail, which enables different levels of recall and evaluation. The level of detail in these databases tends to vary inversely with the scale of the region described. Generally, regional databases contain the most detailed information, followed by national and multinational databases. To our knowledge, Oregon and Washington currently lead the world in number, size, detail, and Internet availability of stream restoration databases (Table 3).

Sharing restoration knowledge through data sources available over the Internet can expand the learning potential of restoration ecology. However, given the variety of formats and data fields in existing databases, answering the question of "Where have pool habitat restoration projects occurred in the John Day River, Oregon?" could require days of searching through various Web sites to find an adequate population of projects from which to learn. For example, different Pacific Northwest databases describe location information in different ways: state, county, latitude, longitude, Township Range Section, Stream, Sub-basin, Latitude–Longitude ID, Hydrologic Unit Code, and begin and end stream mile. In addition, project reporting can be complicated by the fact that multiple objectives, sites, and phases of a single project are common, and project locations on private lands may be sensitive. A single project may be reported by more than one entity or with more than one funding source with dissimilar information, causing multiple and differing listings of a given project.

As new databases are developed, the acceptance and usage of similar formats will allow information to be readily synthesized and queried to avoid overlap across databases. As part of the NRRSS project, a database structure was developed by Bruce Powell at U.S. Geological Service National Biological Information Infrastructure. The database schema is free and publicly available at http://nrrss.nbii.gov/schema.html. This may serve as a blueprint

Table 3. U.S. regional databases and case studies of river restoration projects.

Agency, Database Name, Contact/Web Site, and Description	Approximate No. of Records
Alaska Department of Fish & Game The Evaluation of Wetland and Riparian Restoration Projects www.sf.adfg.state.ak.us/SARR/Publications/techpub.cfm Detailed case studies with evaluation results	3
Appalachia, Trout Unlimited Restoring the Wealth of the Mountains: Cleaning Appalachia's Abandoned Mines www.tu.org/site/pp.asp?c=7dJEKTNuFmG&b=277845 Report includes case studies of five projects	5
Arizona Arizona Water Protection Fund www.awpf.state.az.us/funded.htm Project descriptions, a clickable map, and searchable database	157
Asotin Subbasin Plan, Asotin Conservation District www.nwcouncil.org/fw/subbasinplanning/asotin/plan/ An impressive list of projects completed by this conservation district	700
California, CalFish Habitat Restoration Project Database www.calfish.org Project database located under *Data*, then *Habitat Restoration* on the CalFish Web site	2,000

California, Natural Resource Project Inventory
endeavor.des.ucdavis.edu/nrpi or www.ice.ucdavis.edu/nrpi
Includes California Ecological Restoration Projects Inventory, Watersheds Project
    Inventory, and California Watershed Project Inventory. Information includes the
    type of ecosystem restored, plant species used, soil and nutrient amendments, erosion
    control measures, and project goals, performance standards, and monitoring data
	2,000

Columbia Basin Fish and Wildlife Authority, Bonneville Power Administration Bonneville Power Administration Projects www.cbfwa.org/cfsite/maps/cfm Maps of projects with restoration type. Project proposals listed at www.subbasin.org	151
Columbia River Inter-Tribal Fish Commission Pacific Northwest, Tribal Successes under the Pacific Coastal Salmon Recovery Fund; FY 2000–2002 www.critfc.org/text/pcsrf/crit_proj.html A list with project name, year, cost, and location	68
Georgia Stream Restoration Sites www.arches.uga.edu/%7eesudduth/sites.html Table of restoration projects	31
Idaho Department of Fish and Game Middle Snake Subbasin Report www.nwcouncil.org/fw/subbasinplanning/lowermidsnake/plan/Inventory_AppA_Projects.pdf Lists by subbasin and includes project type, limiting factors, and monitoring comments	242
Minnesota River Basin Data Center Minnesota River Basin Water Quality Improvement Grant Projects 1998–1999 mrbdc.mnsu.edu/projects/cshareARE9899/costshareARE.html Map and a list of projects with sponsors, location, anticipated results, total project cost, grant amount, and project status	15
Montana Future Fisheries Future Fisheries Improvement Project Funding and Status www.fwp.state.mt.us/habitat/futurefisheries/content.asp Table of projects listed with name, year, applicant, and cost	312
Montana Water Center Montana Watersheds Project Directory water.montana.edu/watersheds/projects/default.asp Complex access database with abundant information and great contact information	311

Table 3. Continued

Montana Water Center Case Studies wildfish.montana.edu/Cases/casehistories.asp Covers nine western states. Stories of the projects including background and contacts	18
Montana, University of Montana ecorestoration.montana.edu/ Montana Ecosystem Restoration page describing rangeland and mine restoration with case histories and photo tours	23
New Mexico, Middle Rio Grande Bosque Initiative mrgbi.fws.gov Name, description, location, and timing details for river restoration projects	58
North Carolina North Carolina Clean Water Management Trust Fund Database www.cwmtf.net/ Lists approved projects and costs, organized by county	300
North Carolina Department of Natural Resources Wetlands Restoration Program H2o.enr.state.nc.us/wrp/project/projects.htm Case studies linked to a clickable map	11
North Carolina State University Stream Restoration Institute www.bae.ncsu.edu/programs/extension/wqg/sri/ Database of their projects and some case studies	10
Ohio Department of Natural Resources Ohio Stream Management Guide No. 10 www.dnr.state.oh.us/water/pubs/fs_st/stfs10.htm Descriptions and a map of biotechnical projects	49
Ohio State University, Stream and Ditch Design Projects streams.osu.edu/projects.php Case studies of channel reconfiguration projects in Ohio plus links to other states around the United States	70
Oregon Department of Fish & Wildlife, Restoration and Enhancement Program www.dfw.state.or.us/ODFWhtml/InfoCntrFish/rneprogram/R&EHistory.html Database linked to case studies about the projects	600
Oregon Plan Stories The Oregon Plan for Salmon and Watersheds egov.oregon.gov/OPSW/stories/stories.shtml A map linked to brief project descriptions with photos and captions	46
Oregon Trout Oregon Trout Success Stories www.ortrout.org/8success/success.html Stories of the projects, with photos and contacts	11
Oregon Water Trust www.owt.org/projects.html Descriptions of water conservation projects	5
Oregon, Grand Ronde Model Watershed Program www.fs.fed.us/pnw/modelwatershed/ Database, maps, and descriptions for projects in this watershed in northeast Oregon	531
Palouse-Clearwater Environmental Institute www.pcei.org/water/restoration.htm Includes photos, descriptions, and statistics on projects that this nonprofit has completed in northern Idaho and eastern Washington	35
Pennsylvania Department of Environmental Protection Green Project Bank www.dep.state.pa.us/greenprojectbank/ Searchable "Green Project Bank" so you can find a water restoration project	29

Table 3. Continued

Regional Ecosystem Office, Interagency Restoration Database	10,000
www.reo.gov/restoration/index.htm	
Contains federal agency projects for Washington, Oregon, and California including	
Bureau of Land Management, USDA Forest Service, and Fish and Wildlife Service	
Rhode Island Habitat Restoration	80
Restoring Coastal Habitats for Rhode Island's Future	
www.edc.uri.edu/restoration/asp/projects.asp	
Searchable database, map, and project descriptions for mostly coastal restoration projects	
StreamNet	2,808
www.streamnet.org	
Searchable database of projects in the Northwest United States	
Washington Department of Ecology Water Quality and Aquatic Weed Removal Grants Programs	433
www.ecy.wa.gov/programs/wq/plants/grants/projects.html	
List of aquatic weed removal and water quality projects	
Washington Department of Transportation	51
Washington State Highway System Fish Passage Program	
www.wsdot.wa.gov/environment/fishpass/state_highways.htm#Grant%20Programs	
Reports on funded and completed projects	
Washington Interagency Committee for Outdoor Recreation	857
Salmon Recovery Funding Board Project Information System	
www.iac.wa.gov/maps/default.asp	
Map linked to project description, photos, location, and contact information	
Washington State, City of Seattle	30
Salmon Habitat Projects	
www.cityofseattle.net/salmon/salmonmaps/project.htm	
A map linked to stories about salmon habitat restoration projects	
Washington State, Uniform Environmental Project Reporting System	342
www.ueprs.wa.gov	
Database of stream restoration projects among other environmental projects	
Washington Water Trust	20
www.thewatertrust.org	
List of projects by year	
Wisconsin DNR	65
dnr.wi.gov/org/water/wm/dsfm/dams/removal.html	
Case studies and a descriptive list of dam removals in Wisconsin	
Wisconsin Trout Stamp Fiscal Reports	200
Expenditures of Inland Waters Trout Stamp Revenues FY 1998–2001	
dnr.wi.gov/org/water/fhp/fisISh/pubs/pubindex.htm	
Online PDF which contains descriptions of habitat restoration projects accomplished	
through Trout Stamp funds	
Wisconsin, River Alliance of Wisconsin	12
www.wisconsinrivers.org/	
List and descriptions of dam removals in Wisconsin	
Wyoming Game & Fish Department	71
A Compendium of Trout Stream Habitat Improvement Projects Done by the Wyoming	
Game and Fish Department, 1953–1998, by Dr. N. Allen Binns	
gf.state.wy.us/habitat/aquatic/compendium/index.asp	
Each case history contains basic project data, color photos and graphs, and a summary	
of fish and its habitat response to the project. The introductory section includes a	
statewide analysis of these projects, including fish response, project costs, and structure types	

USDA, U.S. Department of Agriculture; DNR, Department of Natural Resources.

for similar efforts and as the structure upon which global datasets are developed and combined.

Working toward an Ideal Stream Restoration Database

NRRSS reviewed approximately 500 data sources for river restoration projects over three years and had developed a summary database with fields chosen to represent quantitative information on restoration projects (Bernhardt et al. 2005). This information was found to be available from many existing data sources and, although useful, lacked the depth and detail to really understand the outcomes of the project. A more effective data reporting scheme would include information on why the project was done, how it was planned, specific activities, types of professionals involved, and also how the project was monitored and evaluated, what successes and failures were identified, and project constraints. Based on the experience of compiling and analyzing synthesis database, we suggest that the types of information to be included in the ideal stream restoration database are:

- Contact information for participants
- Project dates (year started, year constructed, and year completed)
- Location information with latitude and longitude coordinates
- Project costs (broken down into specific components, including matching costs)
- Sources of funds, materials, and in-kind donations
- Explicit success criteria (i.e., measurable objectives) for relevant ecological, social, and economic objectives
- Species addressed and purpose (e.g., endangered species, non-native species)
- Project design and specific restoration practices
- Parameters monitored, frequency and duration of monitoring, protocols used, and whether reference sites were included as part of monitoring design
- Project constraints (e.g., time, money, staff availability, climate)
- Lessons learned (successes and failures) as the next step in adaptive management
- Links to case studies and/or other information.

In general, databases and lists provide basic facts but often lack the specificity and depth of case studies. The story behind the project often provides more insight than project cost or size information found in databases. Case studies also address human dimensions (e.g., social or economic) that are more difficult to quantify (e.g., community sentiment for stewardship, increased capacity to construct more beneficial projects, economic growth related to a restored site, and personal and spiritual rewards of restoration). For this reason, databases should not replace case studies, but through web links, the latter can continue to enhance the depth of the former.

In the future, researchers will be able to compare the effects of specific restoration techniques, particularly if a restoration database contains links to documents con-

taining information on monitoring efforts, such as (1) monitoring criteria and protocols; (2) baseline and/or reference reach data; (3) as-built surveys; (4) postproject monitoring data; and (5) analytical summaries of major findings. However, in order for this to happen, increased availability of funds for monitoring and/or mandated monitoring funding will be necessary.

Conclusions

Without coordinated data tracking of restoration projects, we will be limited in our ability to draw conclusions about restoration effectiveness at scales larger than the individual project. In order to maximize the cost-effectiveness of restoration efforts as components of watershed and basin management strategies, we must begin to examine the cumulative impacts of restoration projects at these larger scales. At a minimum, various management agencies need some mechanism for sharing information about restoration projects in the same watershed between and across institutional boundaries. In the ideal scenario, seamless integration of project information at all scales will encourage and enable evaluation and research on populations of projects and facilitate information sharing between restoration practitioners, managers, and scientists.

Acknowledgments

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