Reclamation has a strategic plan to accomplish its mission in accordance with the Government Performance and Results Act. Within the strategic plan, science and research is one of six principles that guide how Reclamation will achieve our strategic, long-term, and annual goals. The goals and strategies below are excerpted from the 2001 Performance Plan and 2001-2005 Strategic Plan. We have quoted them here to tie these to our specific research focus areas.

Reclamation's Goals

Meet water and power contracts

Achieve cost-effective power production

Reclamation's Strategies

"Research related to water and water resource management, watershed modeling, precipitation forecasting, delivery system enhancements, and technology research and development will lead to improvements in water delivery."

"Reclamation conducts research and develops technologies related to effective water resource management. Researchers have been applying water operation models to improve the efficiency of Reclamation's water resource projects."

Chapter 4:
Improving Decision Support

"He that will not apply new remedies must expect new evils, for time is the greatest innovator." — Francis Bacon

Watershed and River System Decision Support Tools

Providing data needed for effective operation decisions

To determine when and how much water Reclamation should release from our facilities, we must answer some tough questions. How much snowpack will we have this year—and what is the danger of flooding? How much water will we need to reserve to meet water contracts and delivery obligations for power and water? How can we meet demands for instream flows for endangered species, recreation, and other competing uses? To manage our water and power resources effectively, we analyze tradeoffs and predict outcomes. For this, we need multifaceted models to paint accurate and timely pictures of our watersheds. The models use new and emerging technologies, coupled with near real-time watershed and river system data. Modern modeling systems help us better serve our customers and meet today's many complex demands.

Reclamation's Science and Technology Program is working to develop urgently needed tools to model watersheds and river systems. Partners in these projects include the U.S. Geological Survey, Tennessee Valley Authority, and the University of Colorado's Center for Advanced Decision Support for Water and Environmental Systems. These tools provide the information we need to quickly and accurately evaluate new policy and operating scenarios.

Under the Science and Technology Program, the Watershed and River Systems Management Program (WaRSMP) coordinates efforts to research, develop, test, and implement decision support systems. See <http://www.usbr.gov/rsmg/rsmgwtrmg.htm>. These systems integrate data from many sources: weather, economic, ecological, hydrological, and more to model and analyze reservoir, river, and power interactions.

WaRSMP concentrates on those river basins in the Western United States that:

- Need improved water resources management tools
- Face critical water resources problems
- Offer substantial potential for interagency and stakeholder participation

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<http://www.usbr.gov/rsmg/warsmp>

The program's integrated products include:

- RiverWare, a comprehensive and reliable modeling framework for managing river basins and reservoirs. Models can be constructed for any river basin and customized with site-specific information. All operational or river system policies are rules in the models that can be adapted and prioritized. <http://cadswes.colorado.edu/riverware/>
- The Hydrologic Data Base (HDB) that allows users to find observed hydrologic data and information generated from models. <http://cadswes.colorado.edu>
- Modular Modeling System (MMS), which forecasts runoff from probability-based weather information. <http://www.brr.cr.usgs.gov/mms>
- An evapo-transpiration (ET) toolbox, which estimates riparian and agricultural water use, including the Agricultural WAter Resources Decision Support (AWARDS) system—an automated information system that provides easy access to rainfall and crop water use estimates on the web. <http://www.usbr.gov/rsmg/nexrad/>
- A Stochastic Analysis Modeling and Simulation Program that allows computer generation of streamflow data to better evaluate operation plans.

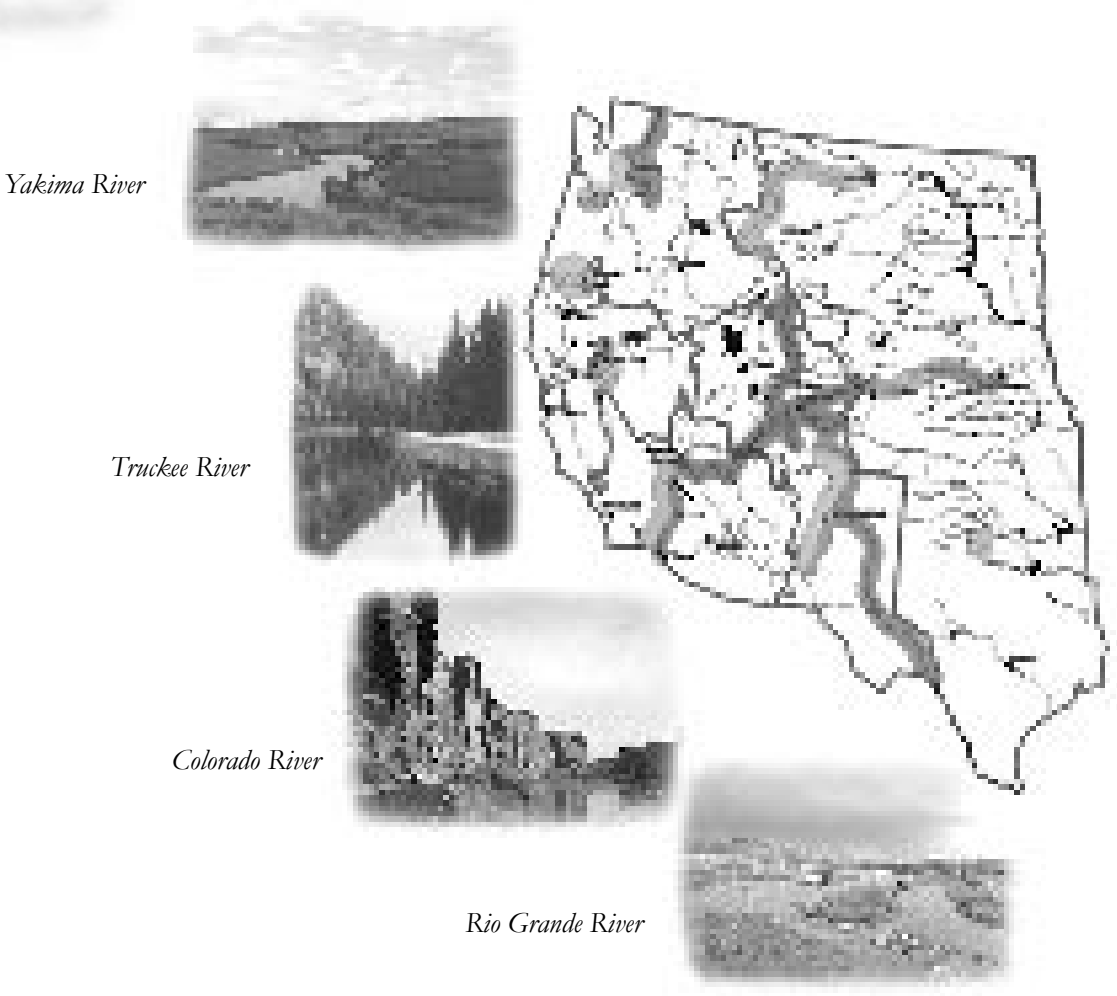
The better our modeling tools, the better we can manage complex river systems. The Science and Technology Program has recently worked on making these tools faster, more available, more sophisticated, and more accurate. Among other accomplishments, we:

- Improved RiverWare's capabilities to analyze rules and operating criteria
- Applied and improved the system in the Colorado River, Gunnison River, Yakima River, Upper Rio Grande, Middle Rio Grande, and other basins
- Inventoried other available hydrologic modeling tools <http://www.usbr.gov/hmi>
- Added functions to RiverWare to better predict shortages
- Planned work to include water quality components in the Truckee River system
- Developed an ET toolbox to calculate and forecast consumptive use demands and improved runoff forecasts for the Upper Rio Grande Water Operations Model
- Developed more accurate algorithms to determine precipitation accumulation in the Pacific Northwest Region
- Put the HDB on the web to allow users to directly use information
- Offered training courses to help Reclamation staff, partners, and stakeholders use and understand the system
- Held workshops and a technical panel to review progress and formulate future priorities

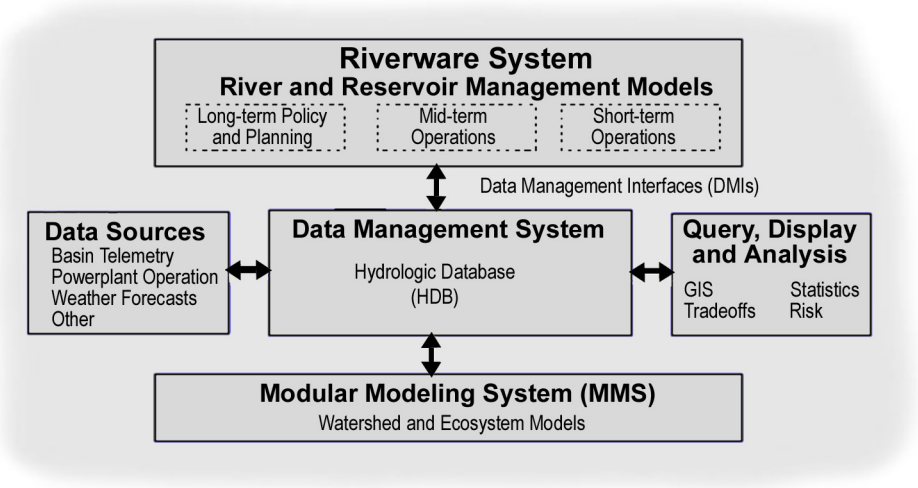
The program continues to develop and refine tools to ensure that Reclamation can make informed and scientifically based operating decisions. Future Science and Technology Program efforts may focus on drought and flood forecasting for monthly and seasonal planning and policy decisions.

Using decision support systems throughout Reclamation

These water resources management tools can be applied to most of Reclamation's river systems. How much time and effort it takes to successfully apply these tools depend on the complexity of the river system. Reclamation managers, decisionmakers, and technical specialists who have used this technology have been well satisfied with its capabilities and results. State water resource agencies, power users, irrigation and municipal water users, and other stakeholders follow these real-time information sources and management decisions.



The Science and Technology Program invests in RiverWare and other watershed and river system decision support tools throughout Reclamation's 17 Western States. The map highlights river systems and watersheds where these tools are either in use or are being developed.



Decison support modeling uses interrelated computer programs and data sources.

The Science and Technology Program has made tremendous strides in contributing to river basin management and addressing tough problems, including:

- In the Colorado River Basin, RiverWare and HDB replaced the older Colorado River Simulation System to rapidly evaluate impacts under a variety of operating scenarios and policies.

- In the Rio Grande Basin, RiverWare and the AWARDS-ET Toolbox are the key water conservation and management tools for Reclamation, managers, and their partners and stakeholders.

- In the Truckee River Basin, RiverWare provides the flexibility and accounting framework that will be used to implement a complex operating agreement among many parties.

- In the Pacific Northwest, RiverWare and HDB effectively manage and analyze the huge amount of data on the Yakima River and the Umatilla River. Implementation on the Columbia River Basin and other systems will begin in 2002. The AWARDS system now provides radar-based precipitation information and produces and estimates agricultural water demands for the Tualatin Project and the Rogue River Project in Oregon. It is being developed for the Yakima and Columbia Projects in Washington.

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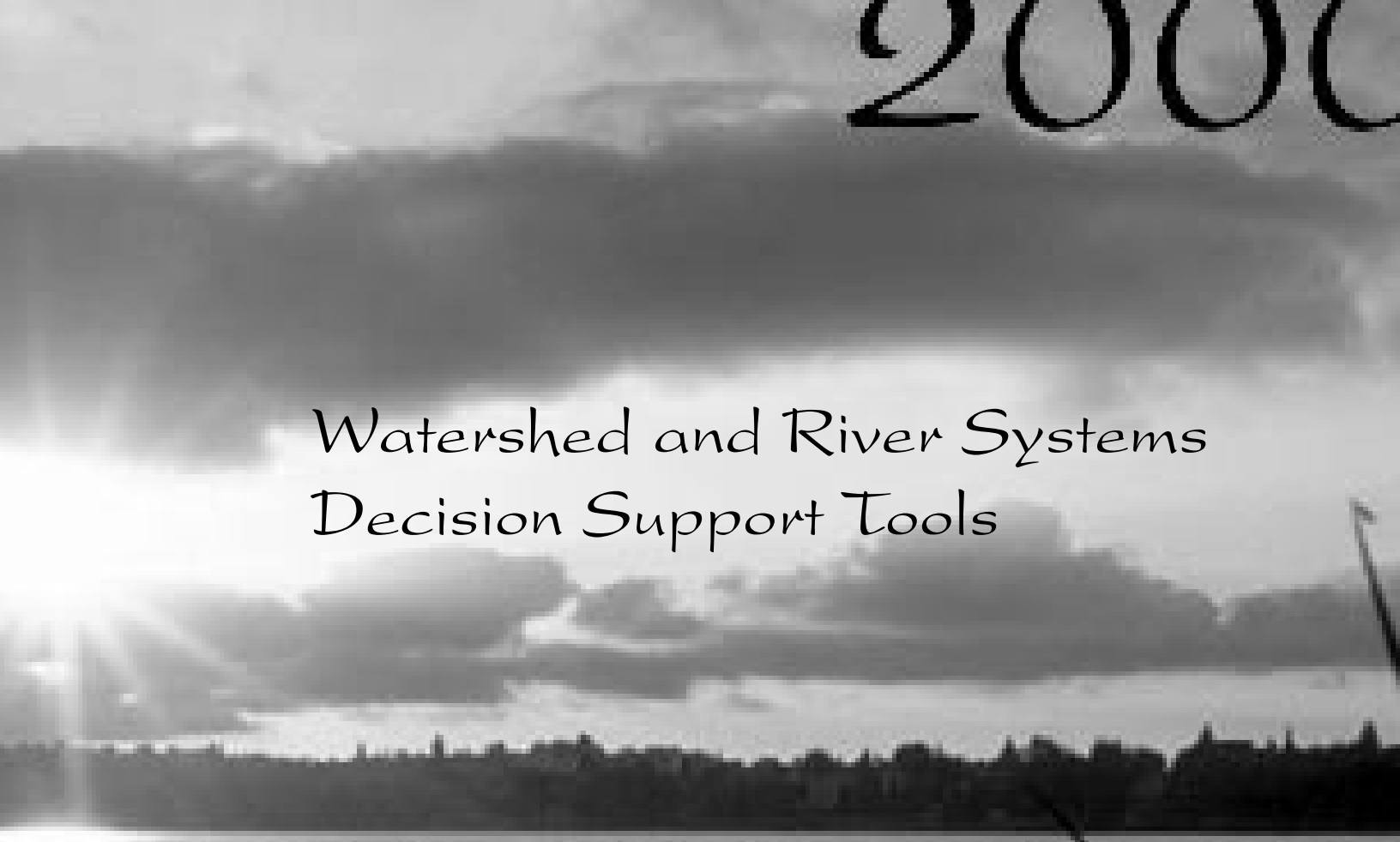
a retrospective

Over the last decade, the River Systems and Meteorology Group in the Technical Service Center has provided research services to the Science and Technology Program to develop the best models, programs, and decision support tools. Water managers use models and decision support tools for determining effective operations for flood control, power production, instream flows, fisheries, recreation, and other water uses. The more accurate models and decision support tools, the more effective and efficient water operations are.

- Improve water supply forecasts.—Developed the Lane's Applied Stochastic Techniques (LAST) modeling package and its successor—the Stochastic Analysis Modeling and Simulation (SAMS) program. These programs are used internationally and Reclamation uses SAMS on the Colorado River Basin. (FY85-present)

- Improve reservoir operations.—Combined existing orographic (mountain-induced) precipitation and runoff models, now used in the American River basin. (FY92-95)

- Help water managers distribute water to meet competing demands.—Developed and successfully demonstrated the RiverWare modeling framework and the associated HDB on a number of key river basins throughout Reclamation, including Colorado River Basin, San Juan, and Gunnison River in Colorado; the Green River in Utah; the Yakima River in Washington; Umatilla River in Oregon; Upper Rio Grande in New Mexico; and the Truckee River Basin in Nevada. Uses include daily operations decisions, environmental impact statement analyses, and long-range planning studies. (FY95-present)



Watershed and River Systems Decision Support Tools

- **Improve water conservation.—Developed the AWARDS system using NEXt generation weather RADar (NEXRAD). This decision support system provides near real-time NEXRAD rainfall accumulation and crop evapo-transpiration information. The evapo-transpiration toolbox builds on the AWARDS system, adding GIS land use to specify crop, riparian, and open water acreage within each river reach. Enhanced AWARDS with higher resolution data and added 24-hour quantitative precipitation forecasts. Implemented AWARDS systems for the Rogue River Basin in southwest Oregon and the Middle Rio Grande Basin in New Mexico. (FY96-98)**

- **Improve precipitation, water supply, and flash flood estimates.—Helped develop and test a Snow Accumulation Algorithm for NEXRAD radar and modified to use lower resolution but available data. Developed a web site to access near real time Snow Accumulation Algorithm products <http://yampa.earthsci.do.usbr.gov:8080/awards/Mn/index.html>. Adapted Snow Accumulation Algorithm to high elevations and tested in Rogue River Basin and Tualatin, Oregon. (FY95-present)**

- **Improve streamflow forecasts.—Partnered with the National Weather Service and U.S. Army Corps of Engineers to demonstrate advanced hydrologic prediction and extended streamflow prediction programs for the Upper Missouri in Montana during the snowmelt and spring precipitation runoff season. Developed a web page to provide water operations managers with radar-based precipitation accumulation estimates <http://yampa.earthsci.do.usbr.gov:8080/awards/Mt/WestMontana.html>. (FY99-present)**

Improving spatial information for more informed decisionmaking

Geography is the science of space, place, and relationships. Geographers ask where things are (from soils to landforms to diseases to concentrations of human settlement), why they are located where they are, how places differ from one another, and how people interact with the environment.

Today, geographers make use of space age technologies to conduct their work, including global positioning systems (GPS) that allow accuracy at or below a centimeter, image processing of satellite data, and geographic information systems (GIS). GIS helps archive, display, and analyze digital geospatial data. Understanding what is happening on the ground and in the water provides powerful tools for analyzing a wide variety of operations, impacts, and changes. Using these technologies, scientists might employ satellite imagery to detect and map climate change by observing changes in global vegetation. Or, they might use annual aerial photography to produce maps to monitor changes in critical wildlife habitat from year to year.

In FY00 and FY01, the Science and Technology Program created a variety of successful remote sensing and GIS applications, such as:

- Examining the feasibility of using Light Detection and Ranging (LIDAR) technology to model terrain features. Accurate terrain representation is vital for modeling the routing and extent of potential flood waters. Reclamation uses modeled flood boundaries to assess risks to life and property. LIDAR may prove to be an attractive, lower-cost alternative to field survey and photogrammetry.

- Evaluating LIDAR as an alternative to photogrammetry in the Colorado River. We applied this research to dam safety and fisheries applications and extended LIDAR to the Yakima River.

- Using hyperspectral imagery, a new remote sensing technology with fine spectral resolution, that more accurately identifies surface materials than traditional multispectral imagery. All Reclamation regions can use this technology to map soils, minerals, water quality, and vegetation types including invasive species. The Science and Technology Program partners with National Aeronautics and Space Administration (NASA); the Pacific Northwest Regional Office; U.S. Geological Survey; National Park Service; University of Idaho; Earth Search Sciences, Inc.; and California Department of Agriculture.

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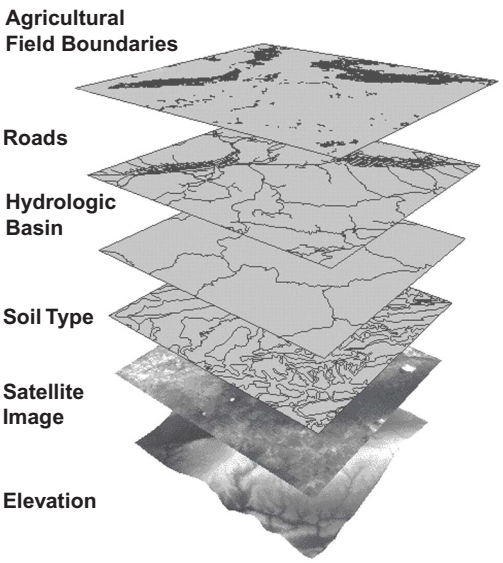
- Testing synthetic aperture radar (SAR) data to characterize riparian vegetation. The program is working with partners, including Reclamation's Lower Colorado Region, NASA, and the Technology Services Corporation, to use this radar to determine the consumptive uses of water and to protect endangered species habitat. Research in the Cibola National Wildlife Refuge on the Lower Colorado River indicates that this radar may be effective for mapping aquatic vegetation, inundated areas under floating vegetation mats, and wetland vegetation not discernible through traditional aerial photo interpretation. Groups throughout Reclamation that assess and monitor riparian resources could benefit from this technology.

The Science and Technology Program's remote sensing and geographic information research is dedicated to finding more cost-effective ways to accurately map and analyze Reclamation's lands and facilities. We can map floods, predict precipitation, examine water quality, track changes in vegetation, and find out what is on the ground and what would happen where. With these advanced techniques, we can provide information vital for understanding Reclamation lands, projects, and operations.

Reclamation's Remote Sensing and Geographic Information Group has been doing this work for more than two decades. They use GIS to inventory and analyze natural resources associated with water projects. The group supports planning, habitat assessment, wildlife management, and other critical environmental efforts. They serve a variety of users including environmental wildlife biologists, fisheries biologists, resource planners, and engineers.



GIS maps show relationships between many factors.

In FY01, Center for Studies and Experimentation of Obras Publicas researchers from Spain visited with Reclamation researchers for continued cooperation on advancing satellite mapping for water quality.

1990

a retrospective

In the past decade, the Science and Technology Program contributions have helped Reclamation do more with less—we can process much greater volumes of spatial data with more accuracy and less expense per unit of land than ever before.

- Evaluating three thermal imaging systems in the mid-1990s for monitoring temperature patterns within the Colorado River in the Grand Canyon, the Little Colorado River Canyon, and the lower Yakima River.—Temperature maps derived from these images helped identify critical habitat for endangered fish species.

- Mapping snow-covered areas with satellites.—About 1990, we delivered an algorithm to the National Weather Service's National Operational Hydrologic Remote Sensing Center for using images from polar-orbiting weather satellites to map surface areas covered by snow, excluding cloud-covered areas. The same technique works with the new geostationary weather satellite images.

- Mapping snow accumulation with NEXRAD radar data.—We supplied an algorithm in the late 1990s to map the accumulation of dry snow. The algorithm will be adopted for nationwide use after the NEXRAD computer systems are upgraded. Meanwhile, we are improving the algorithm to measure (or exclude) rain, melting snow, and precipitation that never reaches the ground.

- Examining the feasibility of using GIS and other geospatial technologies to assess flood impacts resulting from modeled dam failures and operational releases.—This effort resulted in person at risk and economic damage studies for more than 40 Reclamation high and significant hazard dams under the program name "Inundation Mapping Products" (IMAPS).

Remote Sensing and Geographic Information

- **Conducting further research using geospatial technologies to assess flood impacts.—This research improved the positional and classification accuracy of facility and land use data from secondary sources, such as vendors and government agencies. Improvements included using better addressing geocoding technology, U.S. Geological Survey digital orthorectified quarter quadrangles, aerial photography, and image processing. This research reduced positional errors for addressed data by 40 percent. It greatly enhanced the positional accuracy for non-addressed facilities, such as bridges and dams, and revolutionized the procedures for gathering flooded areas for farms and forests.**

- **Mapping surface water quality in reservoirs using multispectral satellite imagery.—These images record reflected sunlight in many wavelengths from the reservoir. These technologies have successfully detected and mapped chlorophyll-a concentrations, turbidity, and water surface temperature variations. Future work is concentrating on detecting heavy metals, bacteria, various species of algae, and other pollutants. Now, we can provide more complete and accurate water quality mapping at half the cost and in half the time than more conventional manual methods. We are helping to protect the health and safety of hundreds of thousands of people.**

The Science and Technology Program's remote sensing research is dedicated to finding more cost-effective ways to produce accurate maps of surface materials. We can only make balanced decisions if we know about the earth's surface and water movement. These new techniques will help Reclamation identify and meet new challenges, effectively manage our facilities, and make informed water management decisions.

Economics

Comparing economic values for habitat, recreation, and operations

A whooping crane walks into a bank for a mortgage. The loan officer asks, "How much is your home worth?"

"Well," the crane muses, "It's worth everything to me. It's an invaluable winter home, as there are so few suitable places around these days."

The loan officer shakes his head. "No, I mean, what is the assessed economic value of the land?"

"In whose eyes?" the crane asks. "Lots of people think that knowing my winter habitat and I are still around is valuable, even though they've never seen me. That has to be worth something."

The Science and Technology Program may not help the whooping crane get a mortgage on its winter home. But by estimating and comparing economic values, Reclamation can more effectively balance investments to improve habitat with other competing needs and ensuring effective operations.

Many resources are not sold in private markets, yet benefit society and have economic values. Management decisions rely on understanding the economic values of all resources. Reclamation managers and decisionmakers need to be able to compare economic values of recreation, fish and wildlife habitat, power production, agriculture, industry, domestic water supply, and more.

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The Science and Technology Program research is determining ways to consider these values in economic analyses by answering many questions like:

What is the Central Flyway habitat worth?

Many people have never seen the Grand Canyon or a whooping crane, but feel that the world would be a poorer place without these natural wonders. Non-use values measure what monetary value people would assign to resources that they do not use but value anyway. Court decisions, government panels, and interagency committees have determined that estimates of non-use values are important considerations in government decisions. The Science and Technology Program is studying ways to estimate the value of the Central Flyway, a major migratory bird habitat that stretches north to south across the United States. Reclamation's reservoir and flow operations often create habitat for birds in this flyway or provide water to these habitats. Decisions about our operations need to consider the economic value of this habitat. Other Reclamation projects can benefit from the insights gained in this non-use study.

What is a rafting trip worth?

The economic benefits of recreation go beyond what tourists spend. The question is, how do we determine these non-market values? The Science and Technology Program is working with the U.S. Forest Service to determine the value of recreation such as rafting and motor boating in Hells Canyon, Idaho, as well as with researchers at the New Mexico State University to estimate recreation values at reservoir sites in New Mexico. Reclamation projects and flow operations either directly or indirectly create or affect these sites. Yet we have little or no data about the economic values of recreation in these sites.

How can we optimize the economic benefits from our water operations?

Using models that link hydrology, biology, and economic impacts effectively evaluates the trade-offs between different water uses and the resulting changes in benefits from water resource use over time. The Science and Technology Program is working on a model that links economics and physical factors. This model will help estimate the effects of water management changes in Reclamation's projects and facilities on water-related uses and the associated project benefits. The program is applying this model to reservoirs along the upper Rio Grande. We are developing general recommendations to improve water resource management based on the model results.

Sociology

Finding ways to help irrigation districts identify and cope with changes

The year is 1900; the scene, a quiet farming community 10 miles from a small town. The railway is in place; people have homesteaded and settled down on their 160-acre plots. But droughts and floods make it difficult to assure a steady water supply. Farmers band together to form an irrigation district and pool their water rights. In 1920, the district asks Reclamation to investigate the feasibility of a water project to help ensure a steady supply of water. Reclamation builds a project, and farmers weather through good years and bad. The town grows.

The year is 2000; the scene, a busy intersection of highways and subdivisions. Children are moving to the city, and the farmers are retiring. Now the district consists of 10-acre ranchettes where people raise kids and build houses and swimming pools. Farmers still band together, and irrigation districts have canals and infrastructure to deliver water. But now, they face many different issues. Increasing pressures from urban and population growth, environmental and water quality issues, and the need to maintain quality food production in the future all pose severe challenges for Reclamation projects.

The Science and Technology Program is finishing a sociological study to address irrigation issues such as:

- What does the encroaching urbanization, growing population, changes in water quality, environmental issues, and more mean for irrigation districts?
- What challenges and opportunities for water resource management do these sociological changes present?
- How can government, irrigation districts, and other water users get together to find low-cost, innovative, and non-structural solutions to sustain and share water resources, protect infrastructure, address rising operation and maintenance costs, and meet emerging challenges?

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This research examines programmatic issues important to long-term water management. Issues such as urbanization of agricultural areas, environmental concerns, water quality, land use, and municipal and industrial water demands affect the sustainability and effective use of Reclamation facilities and resources. Understanding these issues and what they mean to irrigation districts strengthens many of Reclamation's programs and partnerships.

Through this research, Reclamation is establishing solid working relationships with many irrigation districts, Reclamation area offices, and local governments through workshops, conferences, and interviews. The research ties in with Reclamation's Water Conservation Field Services Program to support continuing partnerships with irrigation districts. These programs work together to provide study tours, training, and workshops for irrigators in setting up their own ditch companies or irrigation districts.

Solutions identified so far include water exchanges, water transfers, water banking and marketing efforts, secondary or "dual water" systems, improving the quality of return flows, and many other non-structural innovations. The project continues to monitor the success of these innovations and identify emerging innovations that address water quality of return flows, wetlands mitigation, water marketing and more. These solutions are shared in the agricultural community.

The year is 2100; irrigation districts, cities, local governments, environmental organizations, and Reclamation are working together to meet the emerging challenges with innovative solutions, thanks, in part, to Reclamation's Science and Technology Program's evaluation of water management practices.

The Four States Irrigation Council presented the 1999 Colorado Headgate Award to John Wilkins-Wells, an assistant professor of sociology at Colorado State University, for his work on this science and technology project.

"The research is bringing about a better understanding of the many issues facing irrigation districts and canal companies in the Rocky Mountain region. This significant research is addressing problems and concerns affecting the irrigation entities as they manage this vital resource and will be a valuable benefit to the water community."—Grand Valley Water Users' Association

Considering our past for our future

Who lived at the sites of Reclamation projects a hundred years ago? Or thousands of years ago? What were they like, and how did they live? These are important questions for managing Reclamation's projects—we need to understand and preserve buried hints about the past as a treasured national inheritance. The federal government recognizes how valuable and irreplaceable these prehistoric and historic cultural resources are. Reclamation is committed to protect them from damage and to follow numerous laws passed to protect these resources, including the National Historic Preservation Act and the Native American Grave Protection and Repatriation Act.

Finding ways to identify historic and prehistoric sites without digging and disturbing them is crucial to managing our cultural resources. This way, we can leave our heritage intact for future researchers, and we can avoid disturbing burial and other sites. The Science and Technology Program is investigating different ways to determine where sites are and how many sites are in an area.

Locating buried sites

The Elephant Butte Reservoir levels have dropped in recent years, uncovering the site of a Civil War era adobe fort, Fort McRae. All of the walls at the fort have deteriorated, leaving only vague outlines of foundations. Reclamation needed to locate buried structures, features, and a cemetery before the fort was inundated again and before vandals could come in and damage the site. The Science and Technology Program used several kinds of remote sensing techniques to confirm historic maps and to locate buildings and the cemetey. Reclamation worked with a local group interested in hometown heroes and determined that the cemetery had most likely been moved—laying to rest the legend that a local hero, a congressional medal of honor winner, was buried under the reservoir.

This study also tested remote sensing techniques at a modern campground at Reclamation's Leasburg Diversion Dam. While installing a septic system, construction workers uncovered a prehistoric pithouse, where people lived sometime between AD 900-1300. Finding other buried prehistoric features is critical to management and planning at this campground, so that the features can be avoided during future development.

These technologies can prevent costs from inadvertent damage to structures, features, and human remains during construction—costs that can easily exceed $100,000 per incident. This also saves the costs of excavation. It also saves the government the cost of prospecting with a backhoe and archeological crew for all future projects (upwards of $5,000/day). The archeological site is prepared intact—backhoe prospecting would partially destroy the site. For more information, contact Signa Larralde (slarralde@uc.usbr.gov).

Predicting how many sites are in an area

If we know how many sites may occur in an area, we can much more easily plan and manage cultural resources. Reclamation can select sites for construction, rehabilitation, and other activities that minimize impacts to archeological sites, thus saving considerable mitigation costs and helping to protect our nation's precious prehistoric sites. The Science and Technology Program is using GIS to evaluate geophysical factors such as soils, elevation, vegetation, and landforms to determine the relationships among these factors and prehistoric site locations. This research is providing information for planning studies in the Central Valley Project by determining these relationships in the greater American-Cosumnes River watershed and downstream Sacramento-San Joaquin Delta areas.

While this technology won't pinpoint archeological sites, it will help predict how many sites are likely to be in a particular area. This research uses a method called Weights of Evidence to extend existing models and spatial analysis programs. Researchers evaluate the data in a statistical framework and test against known data or by going into the field. In one area with many potential reservoir sites, researchers used the program to analyze potential effects to cultural resources, primarily prehistoric sites. The program allowed Reclamation technical staff to quickly estimate the number of sites in the area and to test these estimates against known data. This avoided a much longer and intensive evaluation and helped Reclamation avoid damaging or disturbing sites.

Not only is this prediction useful for planning, it helps us understand what past landscapes were like and what types of flooding occurred along river drainages. This history gives Reclamation more information for determining future operations and the possibility for future flooding. For more information, contact Jim West (jwest@mp.usbr.gov).

Dating rock art without harm

Images carved into rock (called petroglyphs) are important clues to aboriginal cultures. Until now, we have had no way to date these images without destroying them in the process. Reclamation needs to understand and protect petroglyphs that may be on our lands and could be affected by our operations, particularly Colorado River operations.

Science and Technology Program worked with the University of Texas, El Paso, to research ways to use x-ray techniques and chemical indicators of age. These non-destructive techniques provide rapid, portable, onsite techniques to date petroglyphs. This new research helps preserve important archeological information and identify valuable cultural sites. For more information, contact Pat Hicks (phicks@lc.usbr.gov).