DEVELOPING A VIRTUAL WATERSHED: SEVIER RIVER BASIN

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ABSTRACT: The Sevier River Water Users Association (Association), StoneFly Technology (StoneFly), Bureau of Reclamation (Reclamation), and Utah State University (USU) are working to create a virtual watershed, an accurate real-time representation of the Sevier River watershed displayed on the Internet (www.sevierriver.org). This, coupled with low-cost automatic remote-control on all major structures, makes for near instantaneous decision making. The ability to see what is happening throughout the watershed and to react promptly to changing hydrologic and weather conditions has made for consistent improvements in the way the river and irrigation canals are operated. Despite these significant gains, the Association has only scratched the surface of their web site's potential.
KEY TERMS: watershed, Internet, web site, real-time information, low-cost canal automation

INTRODUCTION

Several developments in recent years have made basin-wide real-time monitoring and control cost-effective for rural watersheds. The convergence of the following technologies has made low-cost automation a viable reality: (1) low-cost dataloggers/controllers; (2) growing variety of inexpensive sensors; (3) expanding use of solar-energy systems; (4) innovations in communication equipment; (5) rapid advancements in the PC industry; and (6) the phenomenal growth of the Internet. One example of how these technologies are being applied is in Utah's Sevier River Basin (Basin). This self-contained watershed (no outlet to the ocean) is instrumented with low-cost automation equipment and a SCADA (supervisory control and data acquisition) system which uses the Internet and a web browser as a vehicle for real-time data distribution and display.

Project Area

The Sevier River Basin in rural south-central Utah is one of the state's major drainages. A closed river basin, it encompasses 12.5 percent of the state's total area. From the headwaters, 250 miles south of Salt Lake City, the river flows north and then west 225 miles before reaching the Sevier Lake. In John Wesley Powell's seminal report on the Lands of the Arid Region of the United States (1879), a full chapter is devoted to the Sevier River Basin. Captain C.E. Dutton (Powell, p. 144) marvels that "there is probably no region in the world more admirably suited for easy, cheap, and efficient application of (artificial reservoirs) than this very region drained by the Sevier River." A situation that the water users exploited with the construction of Otter Creek and Sevier Bridge Reservoir and the State of Utah exploited with Piute Reservoir. Since the turn of the century, irrigation has depleted the river and the only flows that reach the terminal lake are occasional floods, like those in 1983 and 1984, and some return flow.

The institutional structure for operating the river is relatively straightforward. Operation of the river is overseen by a River Board (an executive committee of the Association) that meets annually to deal with current issues and to make assessments to offset the costs of operating the river. Water rights are administered by two river commissioners (state employees). Other than the two commissioners, there is only one other full-time employee (the office manager for the canals and reservoirs in the lower Basin). Most of the canal companies operate out of the homes of their managers, and employees (i.e. ditchriders, watermasters) are seasonal.

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Background

In 1985, Donald Worster published his treatise titled: Rivers of Empire: Water, Aridity and the Growth of the American West. Although the authors of this paper disagree with some of the historian's conclusions about hydraulic societies, many of his points are thought-provoking and worthy of discussion; they provide good background for this paper.

In his book, Worster concludes (p. 329): "The ancient water-controlling civilizations of Asia were all stagnant and fearful of change. The elaborate infrastructure they created in their drive for technological dominance over nature became an obstacle to new possibilities, to creativity." He further argues that a similar scenario is unfolding with water-controlling infrastructure in the western United States; large water projects, although technological marvels, have lead to repressive empire building, rigid bureaucracies, and worst of all anti-democratic behavior.

Worster correctly sees the West as at a crossroads and wonders if it will be able to resolve its water-related issues (over-allocation, salinity management, drainage, etc.). He advocates a return to John Wesley Powell's dream of management by river basin and watershed, a concept which has recently been endorsed by a wide range of organizations including the Western Water Policy Review Advisory Commission (1997, p. S-7): "we should organize water planning, programs, agencies, findings, and decision making around natural systems--the watersheds and river basins."

Worster concedes that there is a continuing role for technology, but a technology that is less invasive than large-scale construction. He feels there is a strong need to better operate in-place infrastructure. Powell, during his lifetime, was a strong advocate of technology, but technology applied at the local level. One technology which fits the Worster/Powell requirements is the integration of low-cost automation with the Internet. Combined, they not only allow for more timely decision-making, but they are also empowering. By universally distributing real-time information, they bring knowledge to all over the Internet.

PROJECT DEVELOPMENT

In the 1990's, the Association began a systematic program to instrument and automate their watershed. Automation equipment was installed on all major water control structures, including 3 major reservoirs and 15 diversion structures. Additionally, over 15 real-time river and canal monitoring sites and four weather stations were equipped with telemetry. All these various monitoring and automation systems were generating a lot of data, but it was unavailable to all but a few water managers. This was a constant source of frustration to secondary water managers, irrigators, forecasters, researchers, river runners, and others who could benefit from access to the real-time data.

Meanwhile, the rapid rise in the development and use of the Internet meant that many of the water managers were either getting "on-line" or considering it. It became apparent that getting the real-time data onto the Internet would be a good way to distribute it to a wide audience without requiring the purchase of specialized equipment.

In 1997, the Association teamed with StoneFly, a private consulting firm, and Reclamation to establish a web site (www.sevierriver.org) for the distribution of real-time data on Sevier streamflows, canal diversions, reservoir levels and releases, snowpack, and weather. Since then, the web site has been continually evolving. On-going activities related to www.sevierriver.org (Hansen et.al., 1999) including: (1) the National Weather Service and Utah State Climatologist are using the Association's communication system and web site to fill gaps in their weather monitoring network, allowing for a more comprehensive historic record and better forecasts; (2) StoneFly is expanding the scope of the web site to include dam safety, recreation, and tourism information; (3) one USU team is working on a water rights model which updates daily; (4) another USU team is incorporating GIS formats (including snow-pack coverage) into the Internet displays; (5) Reclamation and StoneFly are writing software so water orders can be placed over the Internet; (6) Reclamation is currently adding diagnostic sensors to the automation system to allow for anticipatory maintenance and distance troubleshooting (using Internet displays); (7) a real-time water balance is being developed to monitor the status of gaging stations and to estimate ungauged inflows and outflows; (8) Reclamation and USU staff are developing a salinity monitoring system for the lower Sevier River Basin; (9) StoneFly is working to extend the Internet displays to include canal monitoring; and (10) Reclamation has plans to develop a real-time decision-support system. These enhancements are, in part, being funded by a grant from the Department of Commerce's Technology Opportunity Program (TOP).

The Sevier River web site has become a cooperative effort of a diverse consortium of groups including: local water users, private enterprise, federal agencies, and university researchers.

TOUR OF www.sevierriver.org

The web site consists of four major data collection categories: reservoirs, rivers/canals, weather, and snow-pack. By clicking on a selection from the navigation bar, the user is taken to a page where specific measurement locations in the given category can be selected. For example, the web page presents the user with a schematic diagram of the reservoirs in the Sevier River Basin (see Figure 1). The relative size of the teacup indicates the storage capacity of the reservoir. The current storage in the reservoir is indicated by the level in the teacup. By clicking on individual teacups, one can get more detailed data about the reservoir. In addition to the teacup diagram, a table showing the reservoir elevations is included on the page. Since data transmission between the reservoir and the web site is not always perfect, each measurement is color coded to indicate how old it is. Red indicates a measurement over 24 hours old.

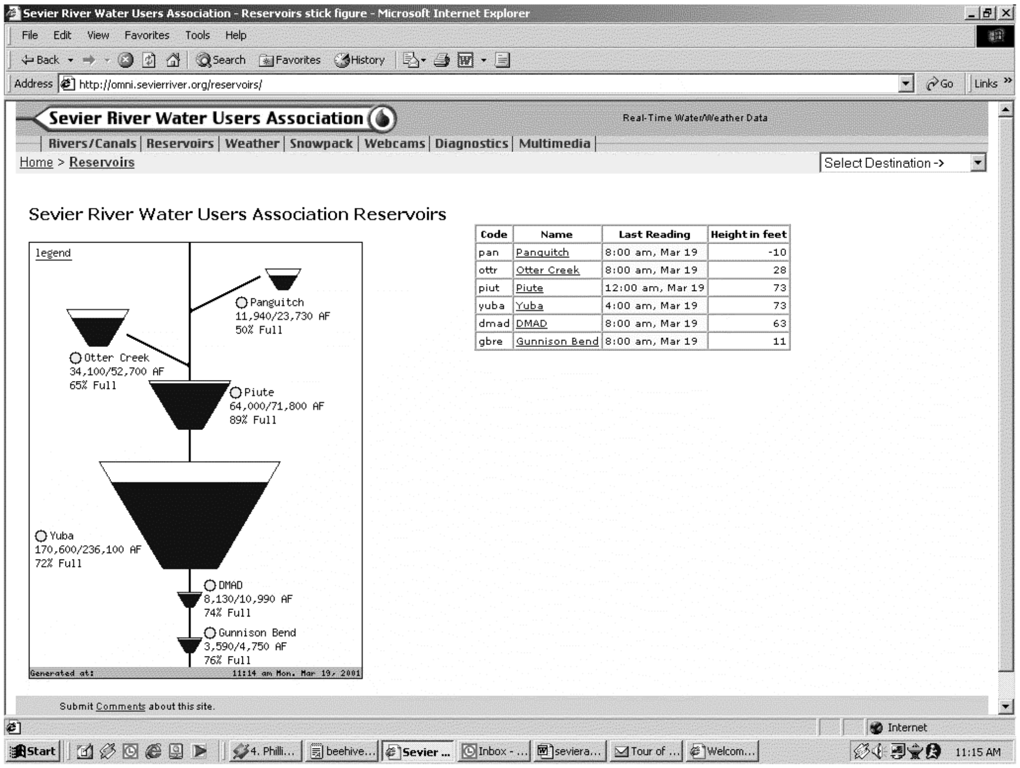


Figure 1: Real-time status of all major water storage reservoirs in the Sevier River Basin.

The rivers/canals pages allow the user to select the individual canal and river monitoring points. The monitoring points are represented on a schematic map which graphically shows the geographical relationship of the stations on the river (see Fig. 2).

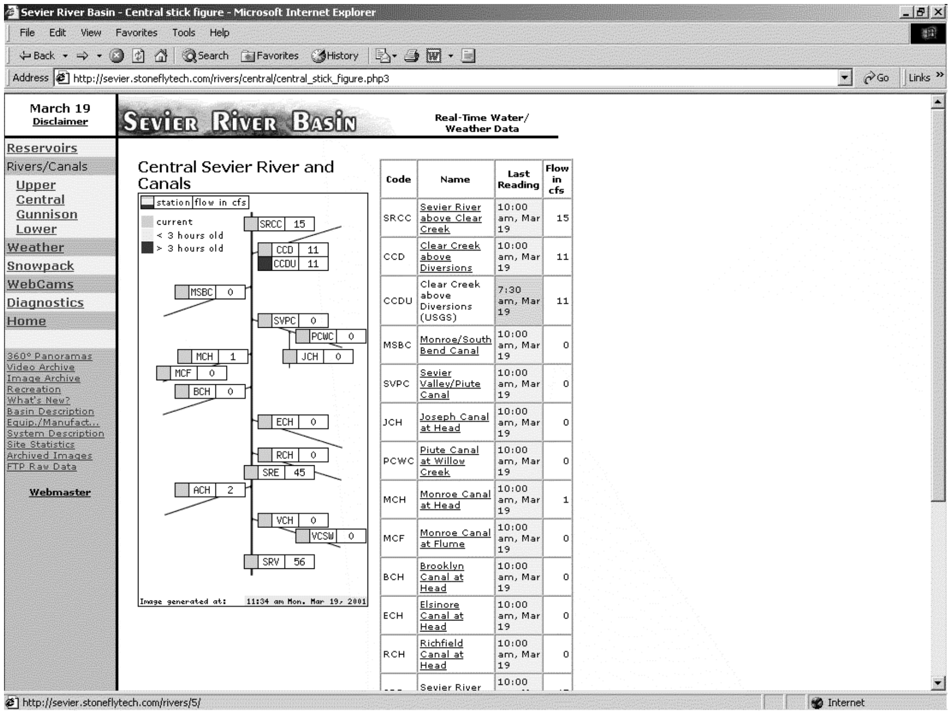


Figure 2: Spatial diagram displaying real-time information for a stretch of the Sevier River.

By clicking on the station, the user can "drill down" to get more detailed data. Fig. 3 shows a 7-day time-series graph of stream flow. The user can change the time period of the graph by clicking on the menu below the displayed graph. Weather and snow-pack data pages follow the same basic format as the reservoir and rivers/canals pages.

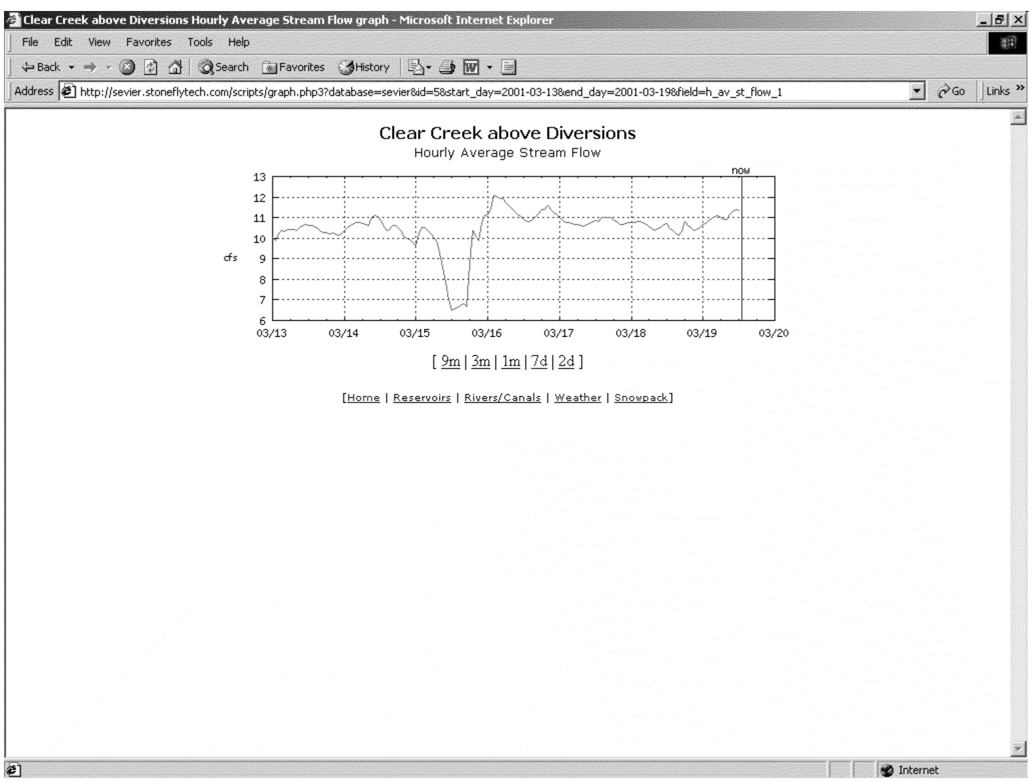
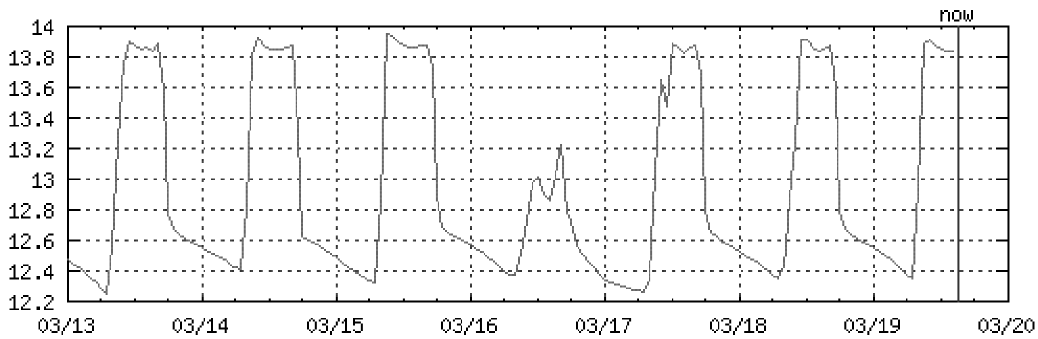


Figure 3: Time-series plot displaying hourly flows at a river gaging site for the previous 7 days.

A popular part of the www.sevierriver.org web site is the web cam section. This displays live still images taken from two



cameras located at the head of the Richfield Canal. The web cam pages were recently expanded to include easy methods of viewing past images. Movies in MPEG-1 format are created by the web server on an hourly basis. These movies allow the viewer to see "time-lapse" views of both the past 24 hours and past 2 hours of images taken by each camera. In these movies, it is possible to the view the accumulation of trash in the diversion structure, canal gates moving up and down, and human activity at the scene. Another way to view the image data is by viewing the gallery pages. These pages contain thumbnail views of the past 24 hours of images. By clicking on the thumbnail, a full size view of the image is obtained.

In order to gage the use and popularity of the web site, software was installed on the server which generates reports showing how users interacted with the web site. Graphs and tables are created, which can themselves be viewed on the web site, which show how many users visited the web site, who these visitors were, what pages were popular, which pages were the first page to be visited, and many other views of how the web site was accessed. The study of this data allows the web site creators to concentrate on improving the most popular uses of the web site and get insight into how the web site is used.

The canal and reservoir automation system spreads over six counties and hundreds of square miles. Early on the importance of troubleshooting tools was recognized. The website has several data products which allow the operators of the river system to spot potential trouble with the automation equipment. Almost all of the automated gates are powered by solar-panel/lead-acid battery systems. Seeing a time-series graph of the battery voltage can tell the user a lot about the state of the power system. In Figure 4 a 7-day view of voltage level in a canal head gate system is displayed.

Figure 4. Time-series plot displaying hourly voltage level at a solar-power canal automation site.

The daily charge/discharge cycle is clearly evident. Also easy to spot is a cloudy day, where the sun was obscured enough to depress the charging voltage. A common failure mode of the batteries is the loss of one of the six cells in the 12-volt battery. This failure tends to occur after the batteries have been in service for 3 or more years. This type of failure is easy to spot in a graph showing the battery voltage over time; the average voltage simply drops by about 2 volts. Another failure mode is the loss of a solar panel. Solar panels can be stolen (infrequently), damaged by gunfire, or blown off their mountings by extreme wind. The loss of a solar panel is also easy to spot on the time-series graphs. It shows up as a constantly discharging voltage with no evident charging during the day.

VISION

Jorges Luis Borges, the Argentine short-story writer, gives the best vision albeit fictional of where the consortium wants to head. He describes an enigmatic spot in the house of one Carlos Argentino Dameri. Borges refers to the spot as the Aleph, "as one of the points in space containing all points" and "the place where . . . all the places in the world are found, seen from every angle."

The Aleph was physically located in Dameri's dining-room cellar. To view the Aleph, Dameri descended a flight of stairs and lay down on the tile floor, a pillow under his head. The cellar door was shut, leaving him in darkness, in almost total sensory deprivation. He then fixed his eyes on the 19^{th} step. Toward the right was a small iridescent sphere, of almost intolerable brilliance. The Aleph's diameter was 2 or 3 centimeters, but the world was within it.

In the above description, substitute "watershed" for "world" and "www.sevierriver.org" for "Aleph", and you have a good description of where the consortium is going. They want to create a complete visual representation of all places (or more specifically conditions) in the Sevier River watershed. But unlike Borge's Aleph, which could only enlighten, the Sevier River Aleph will have the ability to react: to make changes as weather and hydrological conditions dictate. The Sevier River Aleph is also freed from Dameri's basement.

SYSTEM EVOLUTION

The nature of the automation/Internet technological intervention needs discussion. Reclamation's projects in the past have typically had beginnings and ends. For example, the agency constructed a dam and then turned it over to the water users to repay and operate. In the case of automation/Internet technologies, there is a continually evolving product. The technologies get more sophisticated and less costly with each passing day. And as the technologies get more complex, so do the needs of the water users. With real-time technologies, we are describing a process more than a specific product.

At the start of the Sevier River automation/Internet project, StoneFly and Reclamation staff were hesitant to speculate on where the project might be evolving, for fear of scaring off the water users. Today the water users are frequently ahead of the technologists. Association members are continually inventing new uses and innovations for their automation/Internet system. This was recently demonstrated when one of the principal users of www.sevierriver.org was interviewed as part of an evaluation process required by the TOP grant (Jacques, 2001).

During the interview, one of the water managers indicated that he was interested in having the real-time information displayed on his cell phone. He went on to envision "being able to pull up the information on my watch, and then (being) able to see and negotiate it by using a stylus on my watch." He further dreamt: "Eventually I want to have something that goes behind my ear, so I can just think in my mind what I need done, and the system (will act) on my thoughts." While its easy to dismiss these comments as being a put-on, they demonstrate that expectations are rapidly expanding. The interviewee went on the mention several new uses for the automation/Internet system.

Having an automation/Internet system that is continually evolving has not always been easy on the water users. It is not uncommon for them to express frustrations with new "improvements." Comments like: "But I just got used to last one" are not uncommon. Ways to mitigate the impact of a continually changing product need to be carefully addressed, particularly as the rate of technological change continues to increase. The ultimate goal of Sevier technology consortium is the one outline by Rosenberg and Birdzell (1990, p. 48): "one clear requirement for economic growth is the ability to shape productive technology to local needs. Whatever the origins of a technology, the people and institutions using it must be able to understand it, experiment with it, and evaluate the economics repercussions of its use."

CONCLUSIONS

By any measure, the Sevier River automation/Internet project has been a success. According to the water user quoted above: "When something goes down and I have to go back to the old way of doing things, it is like being blind after being able to see." But admittedly the process of using low-cost automation/Internet technologies to improve water management is in its infancy.

The Association with their web site has done several things right: (1) their technological innovations are being applied basin-wide; (2) they are striving to improve the operation of their in-place infrastructure; (3) information is being distributed universally helping to develop trust and empowering a wider range of users; and (4) they are applying technology at the local level where it can do the most good.

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