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# USING THE WORLD-WIDE-WEB AS A SUPPORT SYSTEM TO ENHANCE WATER MANAGEMENT

by

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## USING THE WORLD-WIDE-WEB AS A SUPPORT SYSTEM TO ENHANCE WATER MANAGEMENT

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### ABSTRACT

StoneFly Technology (StoneFly), the Bureau of Reclamation (Reclamation), Utah State University (USU), and several Utah water user groups are working to create “virtual” river basins on the Internet. Websites with accurate real-time representations of the Sevier, San Rafael, and Duchense river basins are being developed. These river basin Websites, coupled with low-cost automatic remote-control on all major structures, allow for nearly instantaneous decision making. The ability to see what is happening throughout a river basin and to react promptly to changing hydrologic and weather conditions is dramatically improving the way rivers and irrigation canals are operated. Additionally, these Websites are important elements in building trust and encouraging collaboration among the various stakeholders. They also contain important elements for making any technological innovations sustainable.

### INTRODUCTION

In the western United States, Federal and State governments, working with local interests, have spent billions of dollars ($ US) constructing water-related infrastructure (with similar activities occurring worldwide). In many cases, when water infrastructure was constructed, the dynamics of modifying the natural behavior of river systems and the challenge of sustaining water resources, in an environment of increasing demands on water, was not always foreseen or understood. Thus there is a continual need to fine tune project operations. This fine tuning is particularly critical given the current world food situation.

According to Sandra Postel (1999, p. 6) of Worldwatch: “Water scarcity is now the single biggest threat to global food production. Just two decades ago, serious water problems were confined to manageable pockets of the world. Today, however, they exist on every continent and are spreading rapidly. More than a billion people now live in countries or regions where there is insufficient water to meet modest food and material needs per person. In many of these areas, populations are expected to expand greatly over the next few decades, raising the prospect of greatly increased food-import needs. But the poverty levels raise doubts about the ability of these nations to import enough grain to fill their emerging food gaps. Even so, global food models to date largely ignore water constraints, and as a result they present an overly optimistic picture of future food availability.”

Whether or not you agree with these dire predictions, there is universal agreement that there is a need to increase food production with less water. While the solutions that Ms. Postel espouses in Pillar of Sand are decidedly low tech, the authors strongly believe that there is a role for higher tech innovations.

## COMPUTERS/COMMUNICATION SYSTEMS

Increasingly, the places that irrigators and water managers work and the implements that they use are computerized and automated. Workplaces are filled with computers; water control structures and implements are increasingly automated. Additionally, communication networks reach into every corner of our geographic world: Web access continues to soar; cell phones are proliferating; and new wireless technologies are emerging. The convergence of computer and communication networks offers new opportunities for managers to improve the efficiency of water deliveries.

At Stonefly TechnologyBin collaboration with government agencies like the Bureau of Reclamation (Reclamation) and the private sector--we have been prototyping adaptations of Web infrastructure to support the needs of water managers. We have been pushing Web technologies into places and things like environmental monitoring sites and automated water control structures. We are exploring ways for people to use new digital communication devices to interact with these places and things, and use the information they find to enhance water management. Our results have been extremely positive.

Our recent work has focused on extending automation and Web technology, wireless networks, and portable devices to create a bridge between the mobile water manager and their physical entities and electronic services. There is significant evidence that the physical world and virtual world are both richer if they are interconnected.

## AUTOMATION/INTERNET TECHNOLOGIES

Critical components of an integrated Web/automation system include: (1) a comprehensive real-time environmental monitoring system (including real-time images), (2) a low-cost automation system, (3) Web displays that provide accurate real-time visualizations of conditions, (4) enhanced and alternative methods of real-time database access, and (5) decision-support software. We have made significant progress with components (1) and (2), and have a good start on (3), (4), and (5). Results to date show that better and timelier information leads to better decision-making, and with automatic remote-control on key water control structures, required actions can be quickly taken. Thus the bridge between the physical and the Avirtual@ river basin helps meet the growing need for a constant and precise matching of water supply and demand.

### Real-time Environmental Monitoring

In the 1990’s, several Utah water user groups began programs to closely monitor their irrigation canals and rivers. This was accomplished by adding dataloggers and radio telemetry equipment to existing flow monitoring sites, water quality monitoring sites, and weather stations. These diverse smaller projects eventually started to coalesce into something approaching basinwide monitoring systems (see Table 1 and Figure 1.) These monitoring systems proved useful for improving water management, particularly for river commissioners and the larger canal companies.

**Low-Cost Automatic Remote-Control**

The low-cost dataloggers used in these monitoring systems had the ability to control as well as datalog. This created the possibility of automatic remote control on all major water control structures. Unfortunately, at the onset of these projects, there was little to control as most gates were operated manually. One major obstacle to adding motors was the lack of affordable commercial power.

Table 1. Utah River Basin Websites
General Information

| River Basin | Website (www.-) | Since | Sponsor | Water Monitor/ Control | Weather/ Webcam | Total |
|---|---|---|---|---|---|---|
| Sevier (including San Pitch) | sevierriver.org | 1998 | Sevier River WUA* | 19/21 | 4/5 | 49 |
| San Rafael | ewcd.org | 1999 | Emery WCD** | 75/4 | 5/2 | 86 |
| Duchesne/ Strawberry | duchesneriver.org | 2002 | Duchesne/ Strawberry WUA* | 10/5 | 1/0 | 16 |

* Water Users Association
** Water Conservancy District

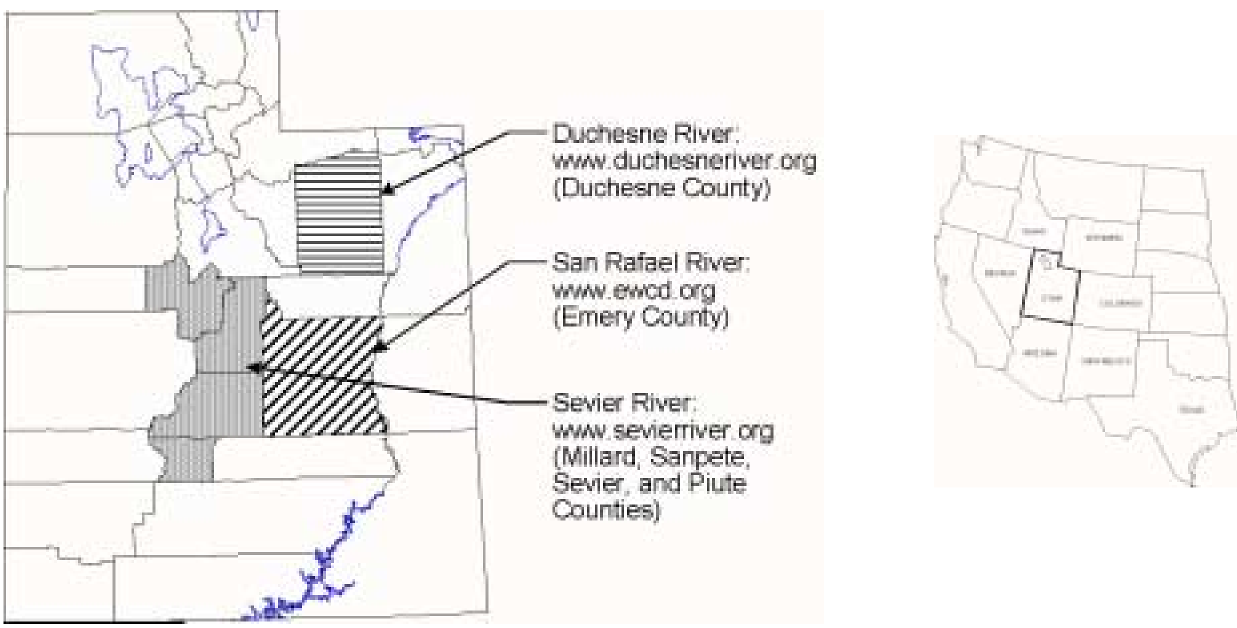


Figure 1. Counties served by Utah's real-time Websites.

Another obstacle was the scarcity of commercially available gate actuators that could be easily solar-powered. Reclamation developed several designs for low-cost, 12-VDC gate actuators that can be easily retrofitted onto existing slide and radial gates (Hansen et. al., 2001). In the meantime, several gate actuator manufacturers developed their own 12 and 24-VDC models that can be powered by small solar panels and deep-cycle batteries. These developments have made the jump to automatic remote control very doable and cost-effective. Today, every major water control structure in many of Utah's river basins are fully automated, most sites using solar-powered gate actuators.

**River Basin Web Site Development**

In the past, monitoring and automation systems generated substantial amounts of data, but it was unavailable to all but a few water managers. This was a constant source of frustration to the excluded water managers and others who needed the information to improve their operations. Meanwhile, the rapid rise in the development and use of the Internet meant that many water managers were either getting on-line or considering it. It became apparent that getting the real-time data onto a Website would be a good way to distribute the information to a wide audience without requiring the purchase of specialized equipment.

In 1997, StoneFly developed a plan to connect the real-time databases to the Web. Reclamation agreed to assist with the project. The initial effort began in 1998 for the Sevier River Basin, Utah. (The development of the Sevier River Website is being partially funded through a grant from the Technology Opportunity Program of the U.S. Department of Commerce.) A second Website was installed for the San Rafael River system in 1999. By the start of the 2002 irrigation season, a similar site had been installed for the Duchesne Rivers system. Any water manager or interested individual is now able to sit down at a computer and survey hydrologic and weather conditions throughout these three river basins.

The Websites created by StoneFly are designed to serve a variety of users with a variety of displays. The log-in page gives the user several options. One popular display gives hourly flow data for the previous 7 days (see Figure 2). Current river and canal flow information is displayed in spatial diagrams (see Figures 3 and 4). Another popular display shows the real-time status of all major reservoirs throughout a Basin (see Figure 5). Web cams are being integrated into all three Websites.

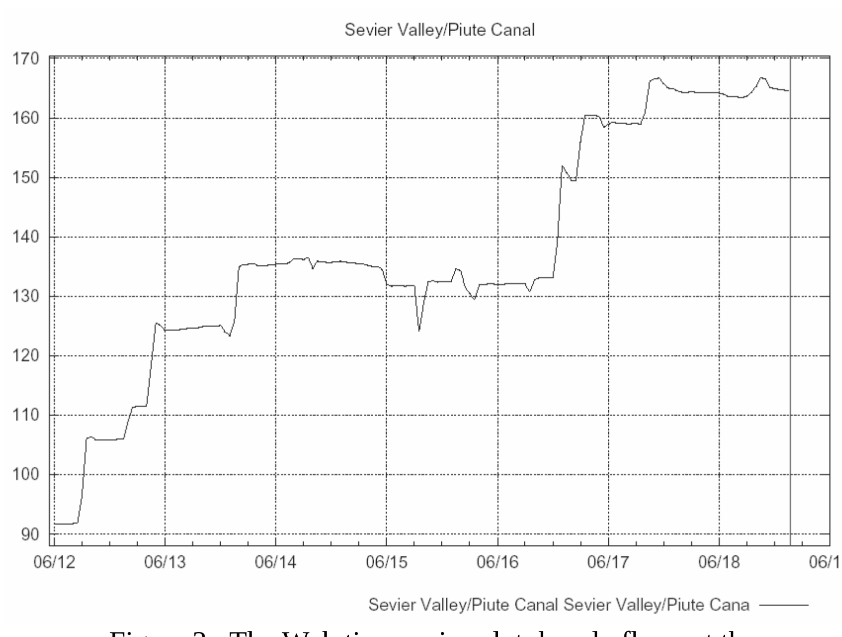


Figure 2. The Web time-series plot: hourly flows at the head of Sevier Valley/Piute Canal for the previous 7 days .

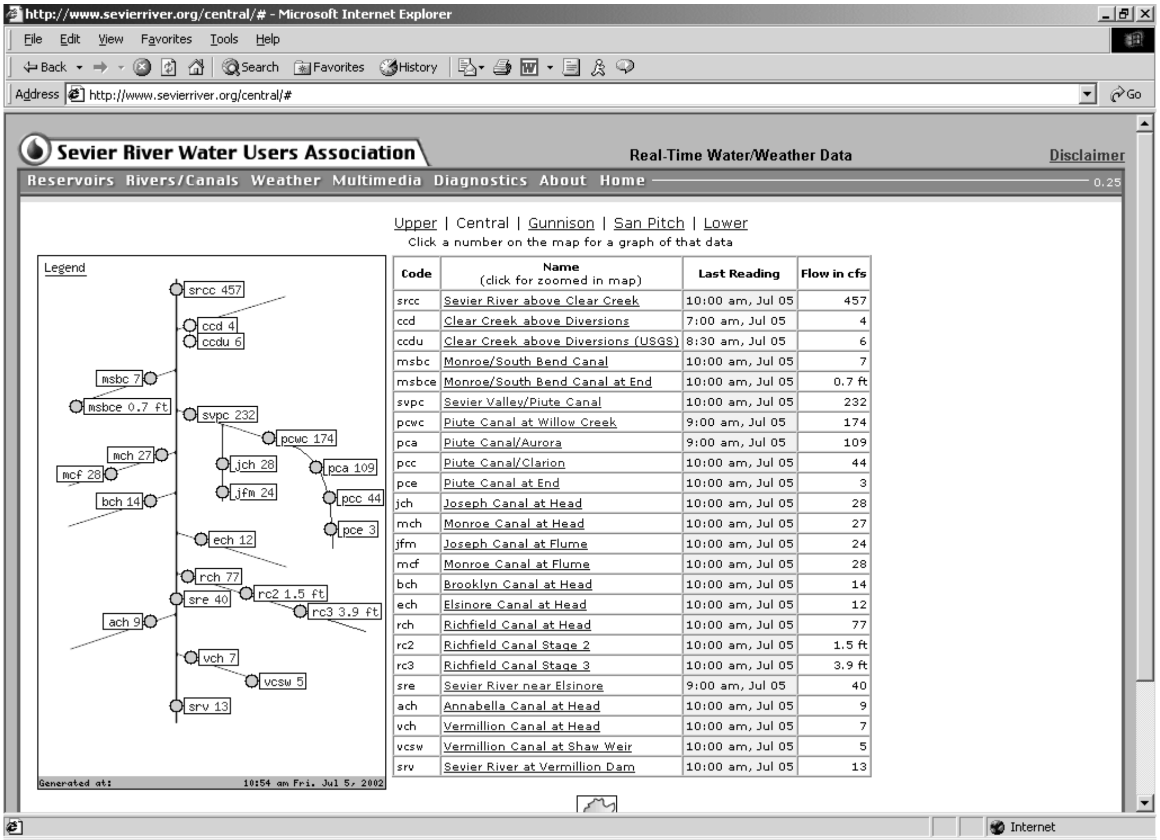


Figure 3. A spatial diagram displaying real-time canal diversion information along the central Sevier River (vertical line).

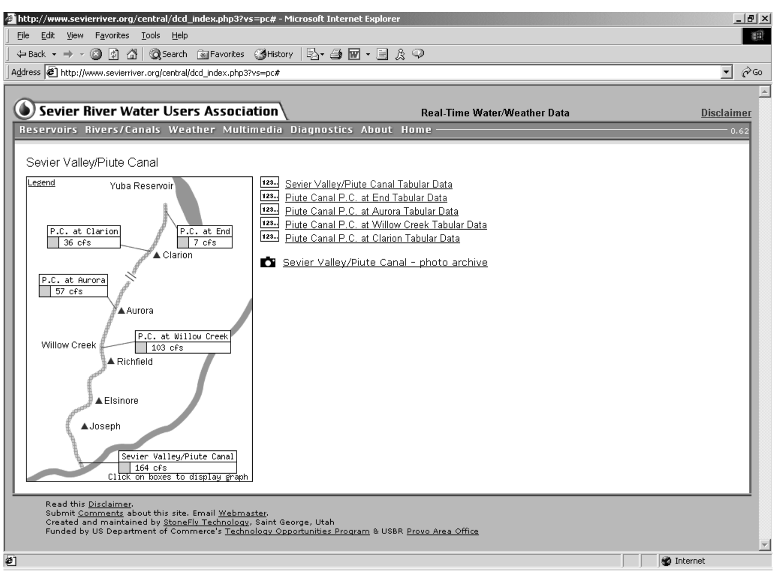


Figure 4. A spatial diagram displaying real-time information at 5 sites along the Sevier Valley/Piute Canal.

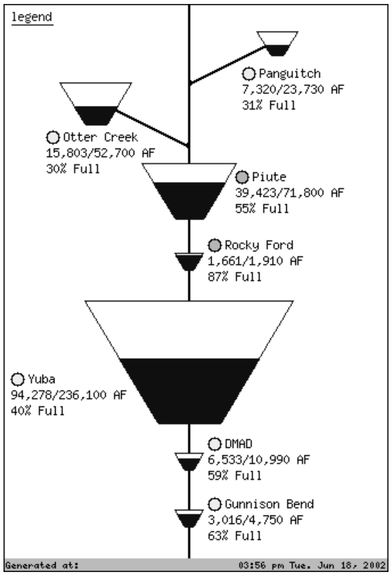


Figure 5. Real-time status of all major water storage reservoirs in the Sevier River Basin.

In addition to the real-time data collected by the water users, the Website displays real-time information gathered by a variety of other groups including: Natural Resources Conservation Service, National Weather Service, U.S. Geologic Survey, Stream Forecast Center, and individual project SCADA (Supervisory Control and Data Acquisition) systems.

**Enhanced and Alternative Methods of Database Access**

The value of the data on river basin Websites is enhanced by improving Internet access. When information is available over high-speed, full-time connections, water managers make much greater use of the Websites. Because these three Utah projects are in rural areas, access to broadband Internet service is limited. It was determined that connecting a few of the key water managers' homes to the Internet full time would be an important step in the project's success. This was achieved by using low-cost, license-free spread spectrum radio links. The water managers with "full-time" connections access their Website frequently throughout the day, sometimes more than 20 times.

One planned enhancement to the real-time data access system is the addition of telephone touch-tone data retrieval, since water managers often find themselves in need of access to the information while in the field. StoneFly is in the process of adding equipment which will enable anyone to call in on a telephone and retrieve specific real-time data by entering the proper number on a telephone keypad. This will allow cell phone access to the system.

A second alternative method of remote real-time data access is the Web-enabled cell phone and/or wireless personal digital assistant (PDA). These phones and PDAs allow the users to view small renditions of Web pages. At the moment, the availability of Web service on rural cellular systems is limited. In the future, however, this service will be more wide spread so there are plans to create alternative versions of data display pages which would be optimized for cellular phone and PDA Web browsers.

**Decision-Support**

Within the next few years, we anticipate being able to build a system that is capable of operating a river basin with little or no direct human intervention required, by tying decision-support models to the automation systems. This will allow a system to operate at maximum efficiency around the clock. To this end, we are working on several decision-support models. Two of these are discussed below.

***Decision Support for Water Rights:*** All western water rights are established by legal decree or statute. In Utah, regulation of water rights is an administrative procedure executed by river commissioners acting under the direction of the State Engineer. In the Sevier River Basin, the river is managed by two commissioners using procedures so complex that few people fully understand them. The most difficult aspect of the allocation procedure involves the determination of the primary flow and the segregation of this water from storage water. Another confusing aspect is the division of the flow into zones.

In view of the importance of water rights in the management of water resources, Dr. Wynn Walker, Head, Department of Biological and Irrigation Engineering at Utah State University (USU), and Roger Walker, retired Sevier River commissioner, developed a computerized water rights allocation model—SEVIER—for use by the river commissioners and others (Walker, 1991). SEVIER duplicates the computations and record analyses performed by the two river commissioners.

To provide water rights updates in a timely manner, Dr. Walker is currently working with StoneFly to connect his model to the Sevier River monitoring system (river flows, canal diversions, and reservoir storage). This will provide the river commissioners, water users, and others with water rights information that is updated daily. By posting this information on the Web, each irrigator will have continually updated information on the status of his/her water rights and will be notified when additional water is available. This Web software is being tested during water year 2002.

***Canal Routing with Artificial Normal Networks:*** A common requirement for real-time irrigation management is the anticipation of canal inflows that will be required to both satisfy irrigators' demands and minimize wastage. An accurate forecast of the quantity of water to be diverted is an important tool for canal managers. Forecasting the requisite diversions is a difficult task because the flow in a canal depends on physical and hydrological processes that are nonlinear and the exhibit a high degree of variability.

To assist canal managers with inflow forecasts, Abedalrazq F. Khalil and Dr. Mac McKee at USU are developing a canal inflow prediction model using an artificial neural network (ANN). A nice feature of ANN is the capability to extract the relationship between the inputs and outputs without a complete understanding of the physical processes involved. This property makes it well suited to the problem of forecasting flows through fairly primitive delivery systems.

The USU ANN model is currently being applied to the Sevier Valley/Piute Canal in the Sevier River Basin. The canal is approximately 65 miles long and supplies water to about 12,000 acres of irrigated land. The travel time for water flowing to the end of the canal is up to 3 days. Diverting an appropriate amount of water from the river into a canal of this length is a challenging problem for the canal operators.

Model inputs include the real-time flows at monitoring stations along the canal (see Figures 3 and 6) and the associated water orders for each stretch of the canal. Early results from the USU modeling efforts have been encouraging, and the Piute Canal manager is currently field testing the model.

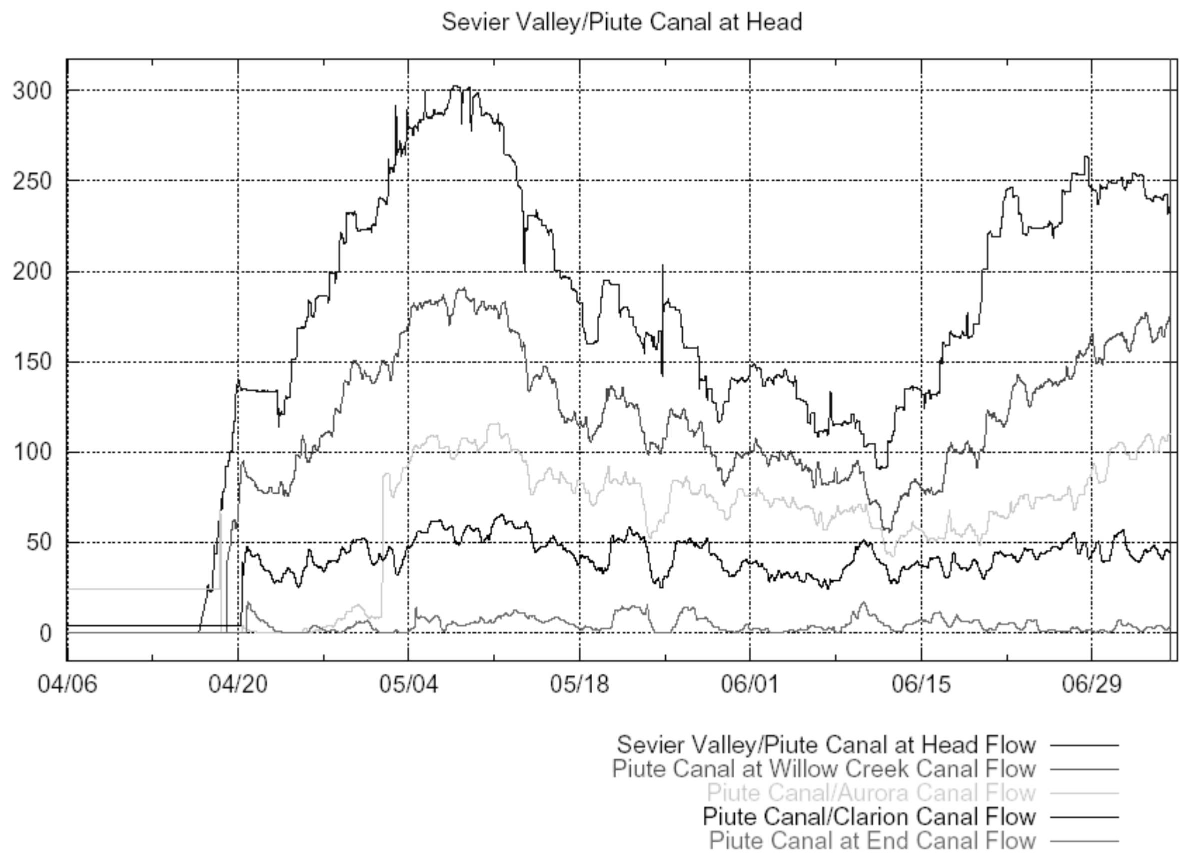


Figure 6. Web time-series plot: hourly flows at five monitoring sites along the Sevier Valley/Piute Canal for the previous 3 months.

## ADDITIONAL BENEFITS

In addition to optimizing management of a water distribution system, these new automation/Internet/decision-support systems can: (1) build trust through complete disclosure; (2) encourage collaboration in water resource management; and (3) allow for adaptive management practices.

### Complete Disclosure

Observers of our evolving global economy claim that the concept of transparency, or complete disclosure, is essential to economies which hope to prosper in the future. They argue that information about financial data and transactions should be available to all in a timely and consistent fashion. This ensures that sound decisions can be made by investors and that financial problems don't fester until they explode with unfavorable consequences. We believe that the same principal applies in the case of water resources. When all the stakeholder groups, irrigators, municipalities, sports enthusiasts, boaters, and environmentalists are privy to the same information, no one can hide their actions. While this may be painful to some in the short run, in the long term we believe it to be good for all. When the www.sevierriver.org went live, there were concerns voiced about making the information available to everyone. After more than 3 years of operation, however, we have not yet heard of anyone wishing for the days when information was scarce and out of date.

**Collaboration**

It has been widely reported in the national news media that attitudes are changing in the western United States. For example, a recent edition of *Time Magazine* (MacCarthy, 2001, p. 21) quoted Patricia Limerick, a history professor at the Center of the American West in Boulder, CO: "There has been a tremendous surge in collaborative conservation groups and watershed alliances in the past 10 years." This evolution toward broader input into decision-making is, in part, the result of over-allocated or over-stressed resources and changing values.

The trend toward collaborative and localized decision-making is well served by real-time monitoring/Internet technologies because the latter provides information to everyone with access to the Internet (which is rapidly becoming everyone). There is no more information elite. Better and timelier data, universally available, is leading to better decision-making and improved water management. Websites like www.sevierriver.org reports real-time conditions throughout the Sevier River Basin (including river and canal flows, reservoir storage, snow and weather conditions, water quality, etc) for everyone to see. Decisions are made with a better understanding of present (and recent past and historic) conditions.

With Websites like www.sevierriver.org, the networking possibilities for connecting real-time field sites to the Internet are being exploited (near universal data sharing). However, there are also potential gain to interconnecting all the human players together. This allows the water users to interact with each other (ie. placing water orders over the Internet), water users to interact with engineers and scientists (ie. seek advice on scientific questions), and for low-cost troubleshooting of the network itself. The intent here is to make technological innovations more sustainable.

**Adaptive Management**

Environmental monitoring Websites can provide timely feedback on important management issues like the effectiveness of salinity control programs or erosion control projects. The benefits of "adaptive management" have long been touted. But adaptive management depends upon carefully monitoring the effects of management actions on the environment, and then using that information to refine our understanding of the system and to adjust our decision-making and management plan (Western Water Policy Review Advisory Commission, 1998, pp 30-31). What better way to assess the effectiveness of management strategies than with real-time monitoring systems, coupled with comprehensive decision-support software?

## SYSTEM EVOLUTION

The nature of these technological interventions needs discussion. In the past, Reclamation=s projects have had beginnings and ends. For example, the agency constructed a dam and then turned it over to the water users to pay for and operate. In the case of automation and 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 irrigators and other water users. With real-time technologies we are promoting a process more than a product.

How this process might work is described in Eric S. Raymond's (1997) seminal monograph: "The Cathedral and the Bazaar". Raymond likens a traditional approach to product development to constructing a cathedral, an edifice carefully crafted by artisans working in inspirational isolation, with no beta release before its time. The process he envisions (the bazaar), however, is more promiscuous. No quiet, reverent cathedral building here, rather a noisy bazaar of differing agendas and approaches out of which a coherent and stately system emerges. The mantra becomes Arelease early, release often.@ It is this Abazaar@ (or bizarre) that the authors have tried to emulate on its automation/Internet projects.

Traditionally, Reclamation had a fairly rigid product development process (cathedral). This approach was taken in the development and installation of large SCADA systems. The problems with the "cathedral process" for small-scale automation systems are numerous: (1) it is too costly; (2) it takes too long; (3) the equipment is seriously out of date by the time it is installed and fully functional; (4) hardware and software are frequently proprietary; (5) the customer does not always get what he needs; and (6) it is difficult for the product to evolve.

With the everybody-get-involved, bazaar-style development, the product evolves over time in concert with technological change and maturing water user needs. As prototypes (both hardware and software) are rushed to the field, feedback is critical. It becomes necessary for everybody involved in the project to interact, something the Internet facilitates.

## CONCLUSION

The irrigators report that the system has been useful on a variety of fronts. Water deliveries at the head of canal and on-farm are more reliable. It has become easier to get a consistent supply to end users on irrigation systems. Reservoir releases are fine-tuned, thereby conserving water. In the lower Sevier River Basin, where salinity is a problem, steps are being taken to manage water quality to increase crop production in a cost-effective manner.

At the start of the river basin automation/Internet project, we were hesitant to speculate on where the projects might be headed, for fear of scaring off the water users. Today the water users are frequently ahead of the technologists. The water users are continually inventing new uses and innovations for their river basin Websites.

Admittedly, the process of using low-cost automation/Internet technologies to improve water management is still in its infancy. But, by any measure, the river basin Websites have been successes. According to one water user: "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."

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