This document gives more extensive explanations and descriptions of the system and how it works. In addition, it offers a brief history of the basin and the web site as well as future developments on the Sevier River Basin Hydrologic Web Site. Its purpose is to give the viewer a better understanding and a more detailed overview of the entire basin and the automation behind it.

Introduction

The Sevier River Basin Hydrologic Web Site is the center piece of a system of communications links, computer servers, remote measurement devices, and water gate actuators which enable water managers in the Sevier River Basin to more effectively measure and control their water resources.

Sevier River Basin Description

The Sevier River Basin in south-central Utah is one of the State’s major drainages. A closed river basin, it contains approximately 12.5 percent of the State’s area—10,575 square miles (6.8 million acres). The terrain varies from high plateaus to narrow valleys and across broad deserts. Twenty-three percent of the region’s land is privately owned; federally controlled lands account for 69%, with state lands making up the other 8%. Indian tribal lands cover 1,735 acres of the basin. The basin is bounded on the east and south by the Colorado River Basin, on the west by the Beaver River drainage, and on the north by the Great Salt Lake drainage.

For the administration of water rights, the Sevier River Basin is divided into two major divisions, the Upper and Lower. The dividing point is Vermillion Diversion Dam, located east of Richfield.
The Vermillion Diversion Dam, located east of Richfield, is the administrative dividing point between the Upper and Lower Sevier River.

Mountain ranges in the Basin trend southwest to northeast. Most are high plateaus, but there are some basin-and-range types in the northwest. Elevations range from 4,500 to 12,200 feet above sea level. Except where the river flows into the Sevier Desert, valleys are long and narrow.

Average annual precipitation ranges from 6.4 to 13.0 inches in the valleys to more than 40 inches in the high mountains. Cold winters and mild summers result in growing seasons ranging from 60 to 178 days. Freezing temperatures have been recorded and can occur in every month of the year.

With such a wide variety of elevation, precipitation, and temperatures over the basin, there are several vegeta-
tive types that thrive in the area. In the higher mountains, a Conifer-Aspen forest supports white fir, Douglas fir, Ponderosa pine, spruce, and quaking aspen trees. The second type of vegetation the basin supports is Mountain Brush. This category includes gambel oak, seviceberry, and curlleaf mountain mahogany. Pinyon-Juniper vegetation is found in the foothills, between elevations of approximately 5,500 ft and 7,500 ft. Examples of this vegetation type are; pinyon pine, Utah juniper, shrubs, grasses, and forbs. The valleys contain mostly Northern Desert Shrub vegetation, plants such as Indian ricegrass, needle and thread grass, winterfat, black greasewood, and shadscale. These tend to thrive in areas where the soil is affected by salts. The final vegetation category the Sevier River basin supports is Sagebrush, which can be found at nearly every elevation (Watershed Description).

The population of the Basin was more than 56,700 people in 1997, with most of the populace residing in small farming communities. The population of the basin is expected to reach over 86,000 people by 2020 (based on the current annual growth rate of 1.82%). Richfield (6,500 residents at the beginning of 2002) is the largest town. The economy of the Basin is based primarily on agriculture. Other important economic activities include tourism and a few mining and manufacturing enterprises; including the 1,600-MW Intermountain Power Project near Delta.

**Principal Water Sources**

**Physiography and Geology**

The Sevier River once terminated in ancient Lake Bonneville just south of present day Gunnison; with all of the Sevier Desert and Pahvant Valley under water. As Lake Bonneville receded to the north, the Sevier River drained into the Great Salt Lake by way of an old channel located north of Delta. More recently the Sevier River was joined by the Beaver River and flows into Sevier Lake, a dry playa which receives water only on the wettest years (Watershed Description).

As mentioned above, the Sevier River once entered prehistoric Lake Bonneville near Gunnison. Today, any remaining water not consumptively used is discharged into Sevier Lake. Since the turn of the century, irrigation has depleted the river and only occasional floods, like those in 1983 and 1984, and some irrigation return flows reach Sevier Lake.

**Major Streams**

Major streams in the basin include the main stem of the Sevier River and its tributaries: the San Pitch River, the East Fork Sevier River, and Otter Creek. Agricultural return flows are an important component of the Sevier River. Fifty percent or more of the total tributary and river diversions reappear as return flow downstream.

Headwaters of the Sevier River are in the Markagunt and Paunsaugunt Plateaus of south-central Utah. The river generally flows northward to just below the Sevier Bridge (Yuba) Reservoir, where it turns to the northwest and then southwest through Leamington Canyon. From the main stem near the town of Hatch, the river flows 225 miles before it reaches Sevier Lake. The river is regulated by reservoirs and irrigation systems.

The Sevier River and its tributaries constitute the major sources of water for agriculture in western Garfield, Piute, Sevier, Sanpete, Millard, and southeastern Juab Counties.

**Groundwater**

The basin above the Sevier Bridge (Yuba) Reservoir is characterized by a series of groundwater reservoirs, each separated from the one upstream by a relatively impermeable, underground geologic restriction. These groundwater sources have a storage capacity that is estimated to be about 5.5 million acre-feet (source: U.S. Geological Survey). Groundwater tributary yield is estimated at 20-25% of the surface water yield. Average withdrawals from groundwater are 155,450 acre-feet annually.

**Cloud Seeding**

In recent years, the U.S. Bureau of Reclamation has installed cloud seeding machines in the mountains separating the Sevier River Basin and the Emery Water Conservancy District, in an attempt to increase the amount of water being stored in the reservoirs. While these cloud seeding machines are primarily intended to help reservoirs and rivers in the Emery district, there is probably some residual benefit to the Sevier River. The machines are located in the San Pitch region (part of the Sevier River basin) and rely on the wind to carry the seeding material and results over the ridge and into the water supply for Emery county.
Sevier River Basin System Description

Reservoirs
The three largest storage reservoirs in the Sevier River Basin (Otter Creek, Piute, and Sevier Bridge [Yuba]), account for about 75 percent of the total storage capacity. The combined capacity of the remaining reservoirs is approximately 120,000 acre-feet. These smaller reservoirs are used exclusively to store irrigation water, and some contain water only in years of excess precipitation. Several are extremely inefficient and lose considerable water through evaporation and seepage.

Table 1. Major Reservoirs in the Sevier River Basin

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Water Source</th>
<th>Capacity (acre-feet)</th>
<th>Surface (acres)</th>
<th>Use*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Otter Creek</td>
<td>East Fork Sevier</td>
<td>52,660</td>
<td>2,520</td>
<td>IR, R</td>
</tr>
<tr>
<td>Piute</td>
<td>Sevier River</td>
<td>71,830</td>
<td>2,508</td>
<td>IR</td>
</tr>
<tr>
<td>Sevier Bridge</td>
<td>Sevier River</td>
<td>236,150</td>
<td>10,905</td>
<td>IR, I, R</td>
</tr>
</tbody>
</table>

*Primary use of stored water: IR = Irrigation, I = Industrial, R = Recreation

Water Usage
Agriculture accounts for the single largest use of water in the basin (61 percent). In 1997 total diversions for irrigation were 903,460 acre-feet. Secondary irrigation used 8,590 acre-feet. In that same year the use of secondary water ratio was 153 gallons per capita per day, which is significantly higher (and better) than the state average of 50 gallons per capita per day.

Due to the lack of large population centers, domestic use before the turn of the century accounted for less than one percent of the total. Domestic use has been increasing in recent years, with culinary use diverting 23,360 acre-feet in 1997. Drinking water is projected to become an issue in the near future. Currently the basin-wide use of culinary water is 267 gallons per capita per day. Millard County and Juab County had especially high rates, 357 gallons per capita per day and 415 gallons per capita per day, respectively.

Industrial use also accounts for 26,290 acre-feet of diversions. The Intermountain Power Project is currently diverting approximately 20,000 acre-feet of water from agriculture in the Delta area. There are a total of 12 hydroelectric power plants operating within the basin boundaries.

Table 2. Annual Water Usage

<table>
<thead>
<tr>
<th>Use Type</th>
<th>Water Use (acre-feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>2,959</td>
</tr>
<tr>
<td>Reservoir Evaporation</td>
<td>66,815</td>
</tr>
<tr>
<td>Wetlands &amp; Open Water</td>
<td>173,547</td>
</tr>
<tr>
<td>Agriculture</td>
<td>633,385</td>
</tr>
<tr>
<td>Total Basin Yield</td>
<td>1,015,419</td>
</tr>
</tbody>
</table>

Water Quality
The best or highest water quality is found in the "upper" region of the Sevier River. At the lower end of the river, salinity is a major problem. The www.sevierriver.org web site currently displays information from three different salinity sensors located in the lower region of the basin. Some salinity issues are due to erosion, caused by overgrazing in the upper regions. Efforts have been made and are continuing to be made, to help improve the water quality throughout the river. In recent years, $375,000 was expended on the Otter Creek Reservoir watershed to implement best management practice in an attempt to improve water quality (Utah State Water Plan).
Water Development

Development of the Sevier River system is a tribute to the stamina, ingenuity and independence of early water users. Using comparatively crude implements, they excavated hundreds of miles of irrigation canals and constructed Gunnison Bend, Otter Creek and Sevier Bridge (Yuba) Reservoirs. The State and Federal governments had some involvement in the Piute and Delta projects, but it was chiefly the water users who developed the Sevier River water system. In so doing, they transformed much of the desert wilderness of south-central Utah into productive farmland.

Early Development

From about 1850 to 1890, water users relied on direct diversions from the river and its tributaries for irrigation. Until the early 1890’s, natural flow, along with the stabilizing effects of irrigation return flows, yielded enough water for most of the irrigated acreage. Heavy snowpack provided abundant water in the winter and spring, but not in late summer when crop needs were greatest.

Because it was prohibitively expensive to construct storage dams, settlers often depended solely on low diversion weirs to dam a creek or river. The geological features at a few locations such as Gunnison Bend in the lower Sevier River Basin were suited to construction of an impoundment reservoir, but most storage dams were not constructed until the 20th century.

Otter Creek

Construction of Otter Creek Dam and Reservoir was prompted by dry conditions during the 1890’s. Prior to building the dam, the reservoir company obtained options on ranches along Otter Creek that would be inundated. Robert Dixon Young, a prominent Richfield resident, volunteered to oversee construction of the reservoir, and ground was broken in 1897. Skeptical State officials doubted that the financially strapped company could complete the project. Construction was also hampered by a lack of equipment, difficult working conditions, and a lack of local support.

Interest in the project increased when crops in Sevier Valley were saved with water impounded by the partially completed structure. Most of the dam was completed by 1901, though work continued for several years on the outlet works, spillway, and feeder canal.

Sevier Bridge Reservoir

In 1902, a surveyor hired by the Deseret Irrigation Company recommended a site at Sevier Bridge (Yuba) in Juab County for a reservoir to impound unappropriated water from the Sevier River. Shortly thereafter, the State Engineer approved plans and specifications for a dam 60 feet high. Construction was funded by a $5 assessment against each share of stock in the irrigation company, and a stockholder could work off the assessment at the rate of $2.50 a day for one man and a team of horses. Nearing completion, the earthen dam was compacted with wagon wheels. But, in 1907, runoff on the Sevier River nearly washed out the incomplete structure. The dam was completed two years later, but because the structure’s cutoff trench was inadequate, water from the reservoir percolated under the dam, causing seepage problems.

Four irrigation companies in the Lower Sevier Basin enlarged the Sevier Bridge (Yuba) Reservoir and corrected seepage problems. The enlarged dam--90 feet high--was the largest dam constructed in Utah, using hydraulic methods. Most of the work was done by stockholders of the Deseret Irrigation, Melville Irrigation, Delta Land and Water, and Sevier River Land and Water companies, under the direction of consulting engineers. The enlarged structure was completed June 17, 1916.

Area northwest of Delta, circa 1915, with its newly constructed irrigation system.
The State of Utah funded water and land projects with money from the sales of Federal lands, and after constructing the water facilities sold irrigable land downstream from the reservoirs. The Piute Dam and Reservoir were constructed to service the Sevier and Gunnison valleys. A canal 65 miles long was then constructed along the western valley bench to deliver water to 20,000 acres. Land sales in the area were promoted in the eastern and midwestern United States. Among those attracted to the area was the short-lived Jewish Agricultural and Colonization Association. Local water users struggled with financial problems for many years, until the State finally turned the project over to them.

Tombstone of Aaron Binder, agricultural colonist. The Gravesite, located west of Centerfield, is mute evidence of the Jewish Agricultural and Colonization Association.

Water Rights

Water rights in the Sevier River Basin consist of two types: primary or streamflow rights and storage rights. Storage rights are entitlements to water that is not usable for irrigation by direct diversion, e.g., winter runoff, floodflow, and water returned by those holding the primary right. Most of the conflict over water in the Sevier River Basin involves distinctions between these two types of water rights.

By 1890, all the land along the Sevier River that could be served by direct flow was under cultivation. One spring, after no water reached the town of Deseret, residents were so angry they hired a posse in an unsuccessful attempt to remove upstream dams. The Deseret and Leamington Irrigation companies subsequently filed a successful lawsuit to establish their water rights.

Higgins and Morse Decrees

In 1901, Judge Higgins resolved the conflicting claims by issuing what has since become known as the Higgins Decree. His decree (1) used the pro rata method of determining equitable water allocation, and (2) determined that legal action along the Sevier River should not be limited by county boundaries. The decree also established a
common priority for users in the Lower Basin. In 1906, Judge Morse also used the pro rata method to determine the supply of water from the headwaters to Vermillion Dam. However, because funds were not available to hire a river commissioner, the Higgins and Morse Decrees never had any significant effect.

**Cox Decree**

In the absence of effective river management, disputes continued throughout the Basin, the most difficult being the division of water between the Piute and Sevier Bridge (Yuba) reservoirs. In 1916, the Richlands Irrigation Company brought action against various Lower Basin interests to adjudicate its claimed rights. The cost of litigation associated with the dispute exceeded $350,000. Because the costs of resolving the more than 750 remaining claims was likely to exceed the value of land and water, regional committees were formed to resolve these issues. Most of these committees adopted, by stipulation, the existing Higgins and Morse Decrees, and eventually succeeded in reaching a decision in the Richlands action, which is now known as the Cox Decree.

The Cox Decree did not eliminate or even diminish water conflicts in the Basin. Even though it helped define individual rights in local areas, it was much less specific about the allocation of water rights over the length of the river. In addition, the Cox Decree is a legal document and not an operation plan. As a result, the river commissioners who began administering the river in 1934, under the direction of the State Engineer, had to interpret various provisions of the decree.

The Cox Decree finalized in 1936 was the final determination of all the water rights. Although there have been modifications to this decree, it is still in use today.
The 1938 Agreement

The 1938 Agreement was one of the most important documents to influence water use along the Sevier River because it (1) allowed companies to hold over any unused water and (2) allowed Piute to exchange their primary rights in the lower zone.

Before the Agreement, all of the unused water in the Sevier Bridge (Yuba) Reservoir remaining at the end of the irrigation season was forfeited and redivided at the start of the next irrigation season, which encouraged wasteful practices. The 1938 Agreement allows each irrigation company to retain ownership of its unused, year-end supply. The irrigation companies in turn, allow each stockholder to hold over his/her unused annual allotment. The holdover practice stabilizes the water supply from year to year by allowing the Sevier Bridge (Yuba) Reservoir to operate as a long-term carryover reservoir. Under these conditions, a user cannot afford to divert water except for sound economic reasons.

Implications

Enhanced management in the Sevier River is facilitated by (1) the concept of pro rata division introduced by the Higgins Decree of 1901, which ensures that all irrigation systems are in place to utilize water when water is plentiful; (2) the ability to treat water rights as personal property, i.e., water can be bought, sold, and used as collateral, just like land, homes and automobiles; and (3) the 1938 Agreement, which helped stabilize the water supply from year to year. As a result, the water supply is stable, and water can flow to the most beneficial use. During drought, only the most productive land is irrigated. The system also provides for long-term changes in water use, e.g., the acquisition of 45,000 acre-feet of water by a power company.
GOES Real-time Monitoring System

In the late 1980s, GOES (Geosynchronous Operational Environmental Satellite) technology was used on river and canal monitoring stations along the Sevier River. These stations, which provided data on an hourly basis, demonstrated the usefulness of real-time information for improving management of the river. The problems with the initial system were two-fold: (1) the communication system was one way and thus not suitable for most control applications, and (2) the system for distributing the data was primitive, each river commissioner had his own satellite downlink station, hence, the data was not widely distributed.

It should be noted that the current website, www.sevierriver.org, still has links to the GOES satellite image of the western portion of the United States. This image shows cloud patterns both currently covering the western states and the weather systems forming over the Pacific Ocean and moving east.

Delta Area Canal Automation

In 1991, the Delta Canal and Melville Irrigation Companies in the Lower Basin asked USU and Reclamation to develop and install a system to control the flow of water through Canal A, which supplies water to the two companies. The system was developed and installed by engineers through USU’s Biological and Irrigation Engineering Department (Walker, 1993). The canal automation system included: (1) a radio-telemetry network that transmits data and commands; (2) a datalogger/controller that collects data about gate positions and water levels, as well as raises and lowers gates; and (3) a microcomputer that controls the system.

The aim of the Canal A automation project was to reduce losses while maintaining a high degree of on-demand flexibility in the canal’s operation. The system was designed to improve regulation through easier and more timely changes in gate openings, better flow measurement as a result of more stable outflows, and automatic regulation during periods when the canal was unattended. The project proved successful, producing a water savings of 3,000 acre-feet in 1993, its first full year of operation.

Richfield Area Canal and Reservoir Automation

After viewing the success of the Delta project, irrigators in the Richfield area opted to try components of a selective automation system. During 1993, in a joint effort with Reclamation, the Richfield Irrigation Company installed a radio-telemetry monitoring station on the Parshall flume at the head of their canal. The station allowed the water manager to observe conditions and improve canal operations. After a year of monitoring canal flows, the company decided to upgrade to real-time control.

During the early Spring of 1994, the telemetry equipment and controller were moved 200 feet from the flume to the diversion structure. Subsequently, the gates on the diversion structure were motorized with solar-powered DC motors, and the datalogger/controller was reprogrammed for manual remote control. This enabled the water manager to make gate changes from his residence. Richfield’s new system proved to be a useful water conservation tool (Pugh and Hansen, 1995).

During 1995, the Richfield diversion structure was equipped with automatic remote control. This was accomplished by installing enhanced software at the field site. Now instead of moving the gates by remote control, the water manager could set a canal flow target remotely and the gates automatically move to maintain the require flow. The canal manager estimates that the system has helped the company conserve approximately 12 percent of its water supply.

After the success of the Richfield Canal automation project, Reclamation assisted seven other canal companies in the Richfield area to automate their structures. Both major reservoirs serving the area (Piute and Otter Creek) were also automated. In addition, there were 15 real-time river and canal flow monitoring sites. Since 1999 there have been several sites added to automate the entire basin. All data communications in the area are via a combination of VHF radio and telephone equipment (Hansen and Pugh, 1997).

This site--the Richfield Canal Diversion Dam on the central Sevier River--is fully automated. The 3 main gates automatically move up and down to maintain a target flow, as measured through the flume located just down the canal from the dam. The flow targets are transmitted to the site and the flow data is sent to the canal manager by radio telemetry.
To automate the diversion structure, the 3 gates were retrofitted with fractional-horsepower 12-Volt DC motors, gate position sensors, and limit switches (see photograph that follows). Other equipment at the site includes a remote terminal unit, telemetry radios, and a float-and-pulley potentiometer system to measure water depth in the well adjacent to the flume. The system is low cost and powered by solar energy.

**Photograph (not live) - Low-cost gate actuator:** The box left of the gate stem contains the gate position sensor and limit switches. On the right of the stem is the 12-Volt DC motor. Both units are attached to the gate stem with a sprocket and chain.

In 1998, a digital camera system was added at the site. This system sends an updated digital image--via spread-spectrum radios--to the Internet every 10 minutes.

**Automation of the Entire Sevier River Basin**

Since 1999, automation equipment has been installed and is currently collecting data at stations throughout the entire basin. The site has expanded to include sensors on reservoirs, canals, diversions, and the river itself. Currently there are six weather stations in addition to flow sensors. The site also links to several cameras, some of which can be user controlled -- zoomed in and out as well as pan the area. All of these items will be covered more extensively in the WebSite: www.SevierRiver.org section.

Evapotranspiration is another area that has been expanded in recent years. After gathering and processing data from the weather stations located in the basin, programming code calls a program that calculates and then displays evapotranspiration data for a number of different crops on a daily basis. This aides farmers and homeowners in knowing the amount of water their crops and lawns need. This is part of the weather section that will be covered later on.

**Web Site History**

The various monitoring and automation systems in the Sevier River Basin were generating substantial amounts of data, but it was unavailable to all but a few water managers. This was a constant source of frustration to a number of water managers who needed the data to improve their operations.
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 might become a good way to distribute the data to a wide audience without requiring the water users to purchase specialized equipment.

In 1997, StoneFly Technology approached the water users in the Upper Basin with a proposal to connect their real-time database to the Internet. This proposal was accepted and Reclamation agreed to assist with the project. That fall, a preliminary web site was tested and well received. The site was expanded for the 1999 irrigation season and the graphic displays were enhanced.

During 1998, the web site came to the attention of the National Weather Service (NWS). Their meteorologists expressed an interest in using the water users’ communications system and web site to fill gaps in the Utah Mesonet; a real-time weather monitoring web site operated by the University of Utah. Reclamation and the water users association, in a joint effort with the Utah State Climatologist, agreed to add two weather stations immediately and other stations in the future, when feasible. Currently the National Weather Service is able to draw data from six different weather stations in the basin.

At their annual meeting in January 1999, the Sevier River Board enthusiastically endorsed a proposal to expand the web site to include the entire Sevier River Basin. At the end of 1999, the web site began presenting an accurate real-time representation of conditions throughout the Basin. Any water manager or interested individual is able to sit down at a computer and survey hydrologic and weather conditions throughout the region.

Web Site: www.SevierRiver.org

What the website has to offer

Introduction

The web site created by StoneFly Technology is designed to serve a variety of users with different needs by presenting information in a variety of displays. Current river and canal flow information is displayed in spatial diagrams.

A variety of time-series information is available. One popular display is of hourly flow data for the previous seven days. Since most of the field sites are solar powered, a display showing battery voltage is critical for troubleshooting the automation system.

In addition to real-time displays, descriptive information is also posted on the web site. This information includes: (1) a description of the Sevier River Basin and (2) a history of water development in the Basin. (The latter is important because the water users feel strongly that their history has been misrepresented in past studies, like Arrington’s 1951 treatise.)

Another important component of the descriptive information is detailed descriptions of the real-time (automation) equipment and a comprehensive list of manufacturers and vendors. This information is important for making repairs.

For newcomers, a Frequently Asked Questions (FAQ) is posted. This system description tries to give a general and yet detailed description of the basin and the technology used to automate the region.

Web site usage is also monitored. A comprehensive log is maintained, which allows web site designers to assess the utility of the various tables and displays.

Reservoir and River Monitoring

There are several real-time data monitoring sensors in place across the entire basin. The site makes all of this data easily accessible and interpretable. A user is able to click on the map indicating which of the five regions he or she would like to view information for. A map is then displayed showing all of the stations in that region. Clicking on the specific station brings up seven day graph of the data for that station. The display shows what the sensor is monitoring (i.e. Gate Height), the current reading on the sensor, and a color. The color index is a unique way of showing how recently the data being displayed was recorded. This color index is used throughout the site to indicate the timeliness of the data.

In addition to the graphical representation of data, all the data can be viewed in tabular form. Graphs are dynamically generated to show the values for the past day, seven days, one month, three months, or nine months.
This can be a great tool in recognizing patterns or seeing disturbances in the water flow. Tabular data for each station is also available in a printer-friendly version (PDF).

**Neural Networks and Modeling Tools**

Prior to 2002, many water managers were using an old mass balance model of their canals and waterways to calculate and predict flows to meet water orders. During 2002, the Bureau of Reclamation contracted with Utah State University to develop a model/prediction neural net for Piute Canal. Since that time, the model has been expanded to include not only the Piute Canal but also the Piute Reservoir. Developers are hoping to soon have a model of the entire basin. Also enhancements to the model are expected from collecting this year’s actual diversion and predicted diversion. This will also be used to evaluate the effectiveness of the model and make adjustments.

A neural network takes yesterday’s collected flow and tomorrow’s orders and calculates a predicted flow or release for today based on patterns of the past (previous years). The current model was trained using water data from 2001, then tested on data from the 2002 water year, and is currently running and collecting as well as predicting 2003 data. In addition to the Annular Neural Network, a Support Vector Machine model is also available (started and tested during 2002 as well). This gives the canal or water manager three choices for determining the required release; the former mass balance model, the Annular Neural Network model, and the Support Vector Machine model.

The new models (ANN and SVM) are written in C++ code and the webpage uses a PHP script to transfer information between the webpage and the model. The model is not available to the general public. There are a few disadvantages to using real-time data for the model. A broken station anywhere along the canal or waterway usually results in a broken model. This is sometimes overcome because the models are based on a daily average flow. Station downtime plays a big part in how well the model works.

**Weather Information**

There are currently six weather stations in the Sevier River Basin. All of the stations are equipped with cameras and several sensors. Information collected includes: current temperature, humidity, precipitation, wind gusts, wind speed, wind direction, panel temperature, soil temperature, battery voltage, and solar radiation. In addition, the initial weather page displays the total precipitation for the month, the day before, and the current day. It also keeps track of the temperature high for that day. In addition, there are links to Php Weather pages that show the current conditions at the Delta Airport and the Bryce Canyon Airport.

One of the more recent additions to the weather page is the evapotranspiration information. This information is calculated based on the data that is collected. The calculations of the previous day and earlier can be viewed to compare current conditions to days past. This new information is intended to help inform users about how much water to use when watering their crops and plants. More of this type of information will be likely in the future.

There are several other types of information available under the weather section. There is a link to the national weather service, which provides updates on current storm warnings, forecast for Utah - for the area that day, as well as a summary of expected conditions for the day in various cities in Utah. The Western Regional Climate Center provides information on Snow Pack in the Sevier River Basin and all of Utah year round. More detailed information regarding the snow pack can be found in the SNOTEL report.

**Diagnostics**

Providing real-time or current data is the highest priority of the website. Due to the vast area the Basin covers and the remote location of some of the sensors, the diagnostics page is one of the most important for site administrators. It helps to diagnose what is causing data to remain un-updated. Some of the features include; battery voltage and the latest data time insertion. In addition to helping with troubleshooting at the stations, the diagnostic page also has links to the web site usage statistics. As stated earlier, this helps developers at StoneFly Technology know what is most viewed and thus concentrate their efforts on updating those areas first.

Two other important links under the diagnostics section are the dam safety and salinity links. Currently there is only one major dam safety monitoring station, at Otter Creek Reservoir. The page displays the measurement of several piezometers in feet. The type of piezometers being used are essentially wells. The data shown is the
height of the water in the well. This indirectly indicates the water pressure for that area. Click here for a more detailed explanation.

As previously mentioned, salinity in the lower regions of the basin, near Gunnison especially, is a concern. There are three salinity monitoring stations that collect real-time data regarding salinity in the river. In the future, there will likely be more of these type of data collection stations added.

Discussion Forums

Currently, there are four different discussion forums hosted on the Sevier River site. The lower and upper region both have a forum to discuss issues in those areas. In addition, there is a forum for maintenance and repair issues. The most popular forum is the Web Site Comments forum. This allows users to make direct comments about what they like and what they don’t. It helps the developers to know overall how they are doing and how the site is being utilized, as well as, what to keep, and what users would like to see change.

Other Features

The site has many things to offer besides just the display of data collection from sensors, although that is its main purpose. The site hosts a photo gallery, containing pictures of almost all of the stations and the equipment used. For a brief introduction to what the site has to offer, check out the slide show presentations available. All presentations were given to groups investigating real-time monitoring systems and how it works. The Developing a Virtual Watershed Show does a great job of “walking” through the website and giving a general overview of all the information available. Another link on the site with useful information is the “Recreation” link in the “About” section. The page provides updates on fishing throughout the state, ATV trails, whitewater rafting information, and national as well as state park information. An earthquake link routes to a page that gives all the recent earthquakes and their magnitude throughout the state.

How the Site Works

The data is collected and stored at the station. Usually once every hour the data is transmitted via VHF radio and telephone equipment and inserted into a database. The database is housed on a hard drive in the datahut. The webservice is Apache-powered and installed on a Linux Red-Hat system. Code on the website is written using a combination of HTML and PHP. Some scripts are written using Perl. The code is programmed to dynamically query the database (using MySQL) to find the most recently inserted data for the station. Case statements within the code then determine which color should be displayed with the data to show the timeliness.

Internet Camera System

During the summer of 1998, StoneFly Technology in conjunction with the Provo Area Office of the U.S. Bureau of Reclamation, under contract with the Sevier River Water Users Association designed and installed a prototype Internet camera system at the head of the Richfield Canal in the Upper Basin. This camera takes high-quality color images of the headgates every 10 minutes and makes them immediately available worldwide via the Internet at www.sevierriver.org.

The real-time images have several benefits. The canal company manager is now able to visually verify the gate settings on the automation system. (The camera serves as a redundant gate position sensor.) The image is also used to check for the trash build-up on the river side of the gates, and for deterring vandalism.

In March 1999, a second camera was added to the system. This camera takes an image of the northern sky every 10 minutes. These horizon images are fed to the National Weather Service and Utah Mesonet and used to verify weather conditions.

Since 1999, more cameras have been added to the basin. Currently there are five different cameras: Richfield Canal Head, Richfield Airport southwest, northwest, and west views, and the datahut interior view. The camera type depends on the site. For a more detailed explanation of a specific camera system please refer to that webcam page.
Other Hardware

The Web Server
The web server is located at the ISP site in Richfield. A new server was installed in the Spring of 2003. All of the stations upload information to the web server.

Sluice Gate Control
During the spring of 1999 the system was enhanced to allow authorized users to set the sluice gate height. Motorized controls have been added to the sluice gate and connected to the CR10x data logger. Software allows authorized users to raise and lower the gates by using a web browser.

Full-Time Internet Connections
Two of the key players in the management of the Upper Sevier River have a need for frequent access to the real-time hydrologic data now available on the Internet. Both had Internet accounts with a local dial-up provider but were often unable to connect during periods of peak Internet use, commonly in the late afternoon and early evening. To solve this problem, equipment was installed to give each user a wireless full-time Internet connection.

The radio links which connect the water users to the Internet use license free 900 MHz spread-spectrum radio modems. These radio systems have a range of up to 50 miles. One end of the radio link terminates at the Richfield ISP, the other at the water managers home. A custom-built router was installed at each home. The router allows the manager to connect his home computer, using an inexpensive network card and cable, to the Internet. The routers accommodate multiple computers. The speed of the Internet data link is between 57 kbps (thousand bits per second) and 115 kbps.

Since the installation of the full time radio modem links, both water managers are frequent users of the www.sevierriver.org web site. Web site log files and personal conversations with them show them connecting to the site as often as 10 or more times per day. Since their Internet connection is always "on", there is no set up time involved with looking at the web site. Both managers leave their computers on full time and their web browsers loaded. This means the latest water data is only a mouse click away.

Future of the System
The automation/Internet system of the Sevier River Water Users Association continues as a work in progress. Ongoing or planned projects include the following:

More Sensors
Plans to install more sensors throughout the basin are in place. StoneFly and Reclamation are working to install more air temperature probes at various sites throughout the basin. These will also assist in advancing the evapotranspiration models and other calculations for the basin. More salinity probes along the river are also forthcoming. At the weather stations, soil moisture probes are being considered.

Limited Control via the Internet
At the Richfield Canal diversion structure, a halogen floodlight for night-time illumination and a gate actuator on the sluice gate have been connected to the Internet host. When the software is completed, an authorized individual will be able to use his web browser to either turn on and off the floodlight or raise and lower the sluice gate.
Water Orders over the Internet

For the Richfield area, software is being developed to allow canal company managers to place water orders over the Internet. This, coupled with better streamflow forecasts, will allow the River Commissioner to fine-tune his reservoir releases and provide more operational flexibility to his canal company customers. Part of this has been accomplished with the newly developed neural networks.

Daily Water Rights Updates

To keep water users apprised of the status of their water rights, the appropriate real-time data will be linked to an existing water rights allocation model developed by Dr. Wynn Walker at USU, and daily updates will be distributed over the Internet.

Real-time River Model

To date, each automated canal head gate is being operated individually. A real-time river model is being developed to further coordinate reservoir, river, and canal operations.

Battery Neural Network

A battery neural network is currently being worked on and should reduce the amount of station downtime by helping maintenance crews predict dying batteries, shot out solar panels, bad connections, etc.

System Evolution

The nature of this technological intervention needs discussion. Reclamation’s projects in the past have had beginnings and ends. For example, in the past, 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 water users. With real-time technologies we are promoting a process more than a specific product.

How this process might work is described in Eric S. Raymond’s 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 released 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 "Release Early, Release Often." It is this "bazaar" process that we have tried to emulate on the Sevier River automation/Internet project.

Traditionally, Reclamation had a fairly rigid product development process (cathedral). This approach was taken in the development and installation of large SCADA (Supervisory Control and Data Acquisition) 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) hardware and software are frequently proprietary; (4) the customer does not always get what he needs; and (5) it is difficult for the product to evolve.

With the everybody-get-involved, bazaar-style development, the product evolves rapidly over time in concert with technological change and maturing water user needs. 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.

Sources

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