# THE COLORADO SATELLITE-LINKED WATER RESOURCES MONITORING SYSTEM

## ANNUAL STATUS REPORT
## FY 1991-92
## 7TH EDITION



Edited by Jim McDanold

# OFFICE OF THE STATE ENGINEER
# DIVISION OF WATER RESOURCES

STATE OF COLORADO
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Roy Romer
Governor

Harold D. Simpson
State Engineer

# STATE OF COLORADO

**OFFICE OF THE STATE ENGINEER**
Division of Water Resources
Department of Natural Resources

1313 Sherman Street, Room 818
Denver, Colorado 80203
Phone (303) 866-3581
FAX (303) 866-3589

Roy Romer
Governor

Ken Salazar
Executive Director

Hal D. Simpson
State Engineer

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I am pleased to release the FY 1991-92 Annual Status Report of the Colorado Satellite-Linked Water Resources Monitoring System. The report addresses all aspects of the monitoring system including examples of system utilization for all seven major drainage basins in the State of Colorado. The system has proven to be a highly effective tool in management of our precious water resources. Some of the newer uses include supplying data to the Upper South Platte Management Support System and the proposed Colorado River Decision Support System.

There are several key aspects of the system that I would like to point out:

- The system provides cost benefits estimated to be $1.5 million annually. The benefits-to-cost ratio is approximately 6 to 1.

- The system is a public system with access available to all Colorado water users at an inexpensive rate. In addition, much of the data is available free to the public via WATERTALK. WATERTALK provides a voice readout of current readings for selected stations by pressing numbers on a touch tone telephone.

- The system can easily be expanded with additional monitoring stations and additional sensor types. The number of stations has increased in the past three years from 150 to 210. Additional sensors have been added at several stations.

- The system has received National Merit Awards from the Council of State Governments and the National Society of Professional Engineers for innovation and design. The State of Colorado remains on the leading edge of technology.

In FY 1991-92, the State Legislature provided $198,414 from the General Fund for operation of the monitoring system. The remainder of the $254,857 spent on operations was collected from user fees, interest and supplemental appropriations (POTS, for example). The General Fund appropriation has decreased from $200,000 in FY 1990-91 to $195,358 for FY 1992-93. The remainder of the proposed $245,169 budget will be collected from user fees. This is considered workable. To provide funds to replace worn-out equipment, the Department has submitted a Minor Capital Construction Request of $180,000 per year for the next five years and $126,000 thereafter to the Capital Development Committee as part of the Gaging Station Replacement Program.

Hal D. Simpson, P. E.
State Engineer

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## INTRODUCTION

The satellite-linked monitoring system (SMS) provides real-time water resources data on a continuous basis from key gaging stations across the State of Colorado. The computerized system can be accessed by terminal or by phone from any location via telephone communications. These data and appropriate application software provide for more effective water rights administration, computerized hydrologic records development, flood warning, and water resource management.

The system was provided to the State Engineer by the Colorado Water Resources and Power Development Authority pursuant to Section 37-95-107(5), C.R.S. (1983), by enactment of Senate Joint Resolution No. 20. The Authority's Board was convinced through a two-year demonstration project in the Arkansas and Rio Grande River basins that the system could be an important tool in water resource management. Since the enhancement of water resource management is one of its goals, the Authority elected to fund the installation of the system and its first year (FY 84-85) of operation at a total cost of $1.8 million.

The Authority awarded the contract, under competitive procurement, to the Sutron Corporation, Herndon, Virginia, in May 1984. The original contract called for Sutron to provide a turnkey system including remote data collection hardware for 82 stations, a central computer for the collection of data, and operating/applications software. In March 1985, the Authority approved an expansion of the monitoring network to 150 locations. The system acceptance test was successfully run on August 8, 1985. The system was formally dedicated on October 4, 1985. At that time, the Power Authority turned the system over to the State of Colorado under the jurisdiction of the Office of the State Engineer. The Authority funded an additional expansion of forty stations and a new VAX central computer in 1991.

The Colorado satellite-linked water resource monitoring system received national merit awards in 1985 and 1986. The National Society of Professional Engineers selected the system as one of ten outstanding national engineering achievements for 1985. The Council of State Governments selected the system as one of the eight top innovative programs instituted by state government in the nation for 1986. Colorado remains in the forefront in utilization of this technology with other states in the planning process to install and operate similar systems. These states include Utah, Texas, California, Idaho, Washington, Arizona, New Mexico, and Hawaii.

The interest in real-time data collection for monitoring water resources and other natural resources data is growing at a fast rate due to the need for such data and the cost effectiveness. Various federal agencies, water conservancy districts, municipalities, and private entities now operate over 150 satellite-linked data collection stations in Colorado in addition to the state operated network.

# I. PROGRAM DESCRIPTION

The monitoring system represents state-of-the-art technology in real-time data collection. Although the system uses space age technology, it is relatively simple. Conventional data collection hardware and data processing techniques have been incorporated into the system configuration (see Figure 1).

## A. System Configuration

The system is comprised of seven basic components:

1. Gaging stations
2. Remote data collection hardware
3. Transmission receive hardware
4. Central computer
5. Application software
6. Computer terminals for data base access
7. Satellite communications link

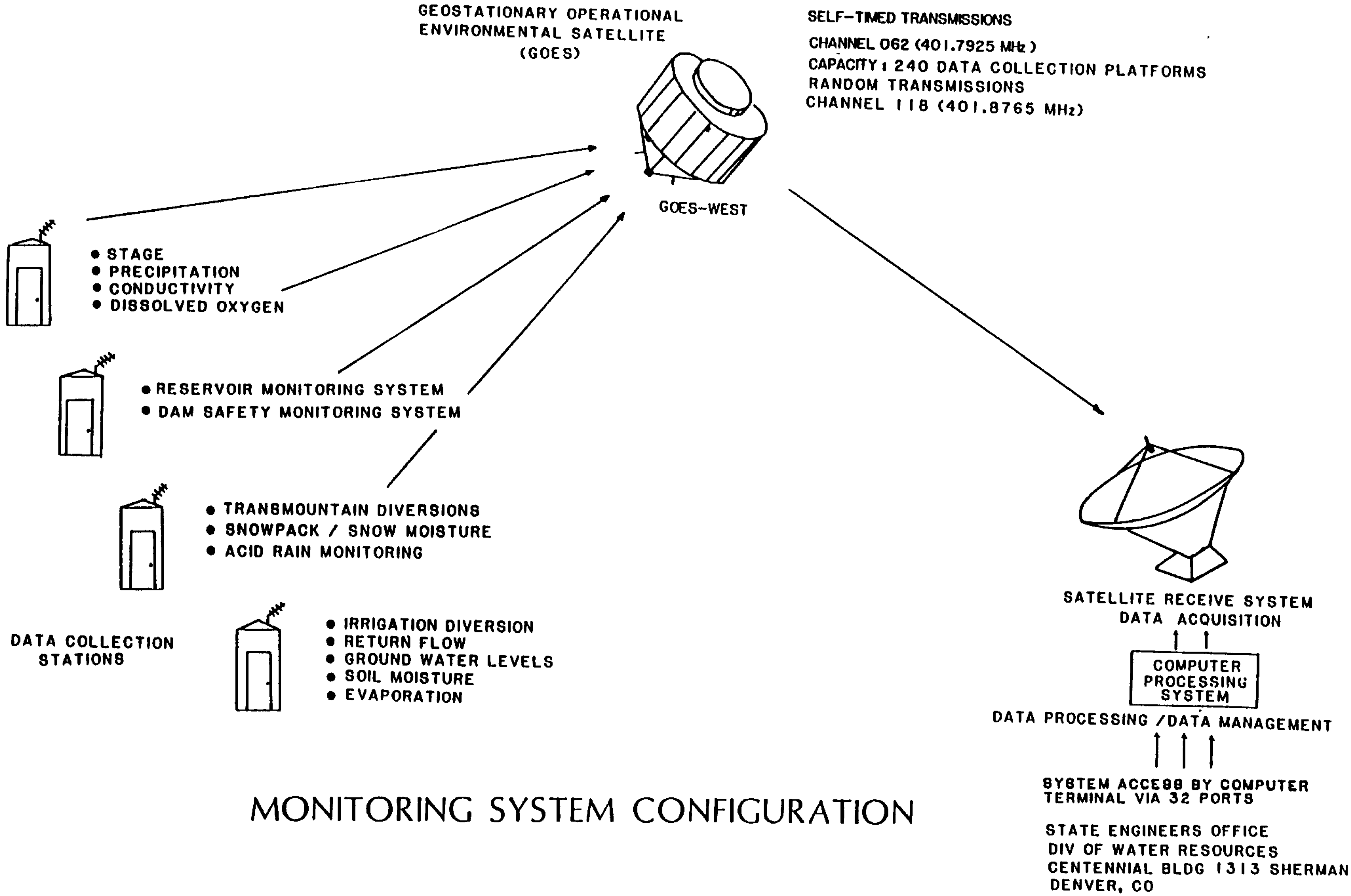
The remote data collection hardware is generally installed at preexisting stream, diversion, and reservoir gaging stations. The hardware interfaces with on-site sensors. The sensor may be either a float operating in a stilling well hydraulically connected to the stream or reservoir, a manometer or other type of pressure transducer, or a direct discharge meter.

The remote site data collection hardware installed in these gaging stations includes a Data Collection Platform (DCP), an incremental analog-to-digital shaft encoder, an environmentally secure NEMA enclosure, a Yagi antenna, a 12-volt battery, a solar panel, and complimentary cables. The DCP is comprised of a sensor interface module, a microprocessor, and a UHF transmitter. The sensor interface module can handle up to 16 sensors. The microprocessor provides for programmable input of data measurement and transmission scheduling, data manipulation, and data storage. The DCP is programmable by using a portable terminal via an RS-232 port. The DCP measures approximately 10"x8"x4". The shaft encoder converts incremental stage values from analog to digital in hundredth of a foot intervals. The shaft encoder communicates directly with the DCP. The shaft encoders were modified with digital displays/data resets. This provides for easy sensor calibration and data display for station operators. The unit measures approximately 8"x6"x6". The NEMA enclosure houses the DCP and the battery. The unit measures approximately 24"x20"x10".

The transmission receive hardware consists of a 5-meter parabolic dish, downconverter, receiver, amplifier, multiplexor, and eight frequency agile programmable demodulators. This Direct Readout Ground Station is located at the Centennial Building, the Office of the State Engineer.

The central computer is a Digital Equipment Corporation (DEC) VAX 4000-300 with 32 Megabytes of physical memory. It has two 650 Megabyte hard disks for program and data storage, one 9-track 1600 bits per inch tape drive for data exchange, one 8-mm high capacity tape drive for backups and archiving, and a 600 line per minute line printer for reports and other large listings. For terminal and modern communications there are two intelligent terminal servers. These

FIGURE 1




MONITORING SYSTEM CONFIGURATION

allow users to access the system remotely over telephone lines connected to four 2400-baud and eight 1200-baud modems. Some terminals in the Centennial Building use these terminal servers also. Most local users connect to the system directly with personal computers by using the DECNET networking protocol. Asynchronous communication ports control the four DEC talk voice synthesizers used for the WATERTALK system, the electronics that receive data from the satellite, and the out-dialing voice synthesizer that generates flood warning telephone calls to the National Weather Service. The central computer hardware is located in the Centennial Building at the Office of the State Engineer.

The operating system software is DEC VMS (virtual memory system) version 5.2. This software controls the operation of the computer, the manner in which the system memory is used and how the users interact with the application software. All applications are written in the FORTRAN programming language. The primary application, HYDROMET, was developed by the Sutron Corporation. Enhancements and additional software were developed by the Office of the State Engineer.

Each of the seven Division offices has at least one Personal Computer (PC) with a printer and a modem to access the main system using the State of Colorado microwave telecommunications system. Several Water Commissioners also have PCs and modems to access the system. Field staff who maintain and operate the DCPs have small hand-held terminals used to program and test the DCPs. With a modem, field personnel can also access the main computer system.

The communications link for data transmissions is the Geostationary Operational Environmental Satellites (GOES). GOES is a series of federal communications satellites operated by the National Oceanic and Atmospheric (NOAA-NESDIS). The GOES satellites are in an equatorial, geostationary orbit at a point 22,500 miles in space. This type of orbit allows for a continuous line-of-site to be maintained with both remote transmitters and the Direct Readout Ground Station. NOAA-NESDIS and the Federal Communications Commission have provided the Colorado State Engineer's Office with 223 transmission slots on satellite channel 62, allowing for 223 DCPs to transmit self-times transmissions at separate 4-hour intervals. They also provide the use of channel 118 for transmitting random emergency alarm messages. We also receive data transmitted by other organizations on nine other channels. Currently, there are no fees for the use of the GOES system.

### B. System Operations

Throughout 1989 and the first six months of 1990, the Division of Water Resources was using the GOES-West (GOES-6) satellite, located at 136 degrees west longitude. This satellite's orbit had continuously deteriorated since its last stabilization maneuver in May 1988. It had no remaining fuel for orbital adjustments. In May it's inclination (up and down movement) exceeded 2.2 degrees, and the receiving antenna no longer had a continuous line-of-sight. To overcome this problem, the Division switched operations to GOES-Central (GOES-7). Its orbit is fixed at 112 degrees W. The inclination of this satellite is less than 0.25 degrees. It has enough fuel for two to three years of orbit maintenance maneuvers.

The launch of the next GOES satellite has again been postponed. The new launch date is December 1993. This will not adversely affect our operations at this time.

After several delays, a data collection system (DCS) proposed by NOAA-NESDIS is in operation. Under this system, all messages from the GOES satellites would be received at NOAA's main data acquisition station and then retransmitted through a domestic communication satellite (DOMSAT). The data from the DOMSAT could be received with a small (1.8 meter) dish antenna. The cost for a DOMSAT receiving system (DRS) is approximately $25,000. Figure 2 shows the changes in the data flow pattern under DCS. These changes are transparent to the SMS end-user.

Figure 3 shows a DOMSAT receive station. The hardware needed to operate under this system will be acquired during this fiscal year from the SMS operating funds. GOES-7 and the current receive system will remain in use throughout the 1992-1993 year. The change over to the DCS-DRS system is planned for the fall of 1993. GOES-7 and the current receive system will remain adequate until this time.

The DCP's collect data measurements at 15-minute, 30-minute, or 60-minute intervals as needed. In most cases 8-hours of these data are stored and transmitted at 4-hour intervals in the standard transmission mode. This provides replicate data in case of a missed transmission. When the DCPs detect that stream flow conditions exceed programmed levels, they transmit random messages, providing real-time alarm warnings. Incoming data transmissions are processed on a real-time basis. The system converts the raw data, generally river stage, into engineering units and calculates discharge or reservoir content values using rating tables or formulas. The results are then time-stamped. The most up-to-date shifts, as determined by actual measurements, are used in these calculations to reflect changes in the stream channel characteristics. Selected DCPs also transmit meteorological and water quality data. The system processes this information in a similar manner.

Every morning the system reads the previous day's data and calculates mean values, minimums, maximums, and other statistics, placing the results in a separate data base. To preserve the integrity of the data, the original real-time data is no longer edited. A subset of the original data is extracted for editing and hydrologic record development. The Division of Water Resources hydrographers also use this system to manually enter and edit stations not included in the GOES-linked system. Only authorized users can edit the data.

Maintaining data base integrity is a primary operations goal. Real-time data are of no value unless the data are accurate. Considerable effort is maintained to ensure that the remote hardware/sensor interface remains in calibration. This effort becomes compounded by the fact that nearly 65% of the stations in the state's monitoring network are operated by other entities that generally are not using the data to make real-time decisions. Stations are

# DOMSAT Receive Station (DRS)

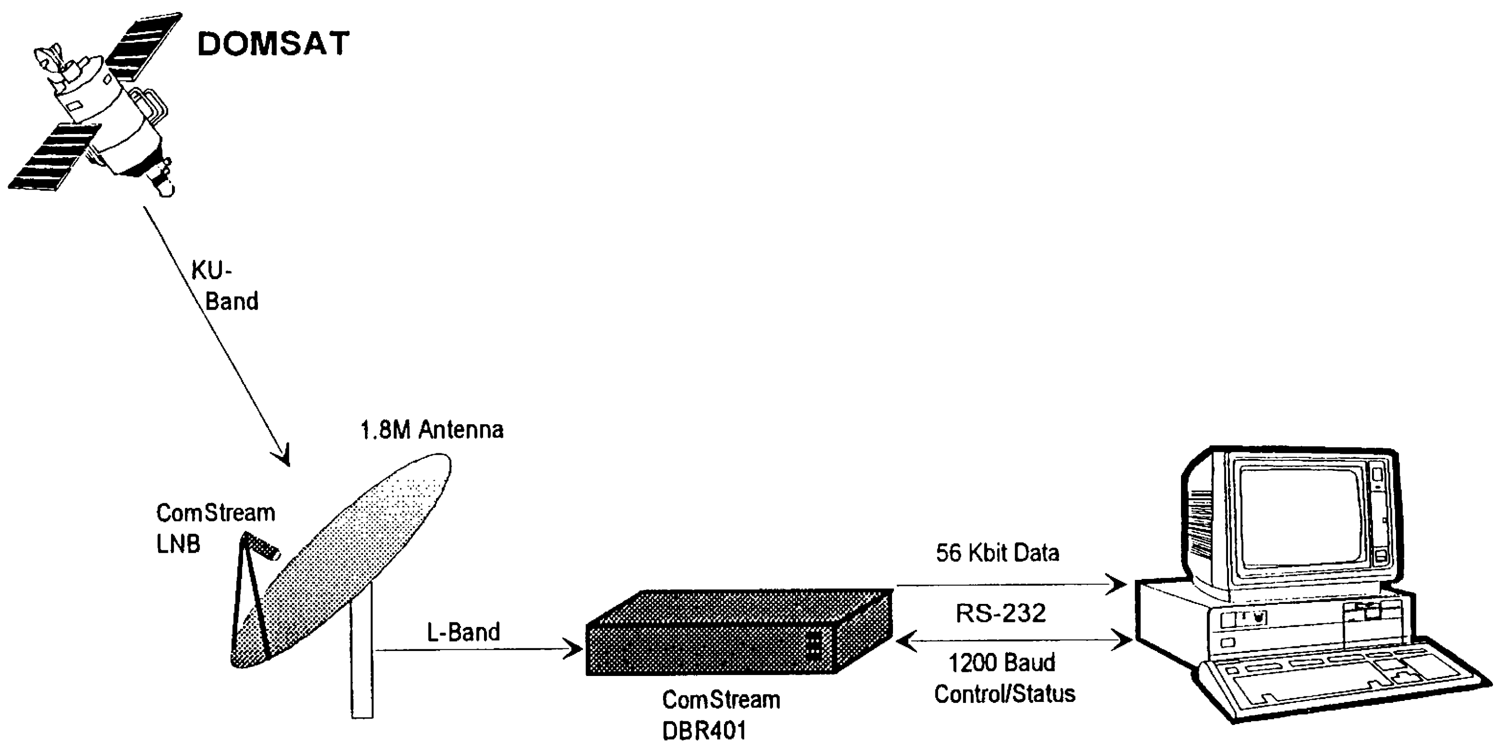



FIGURE 3

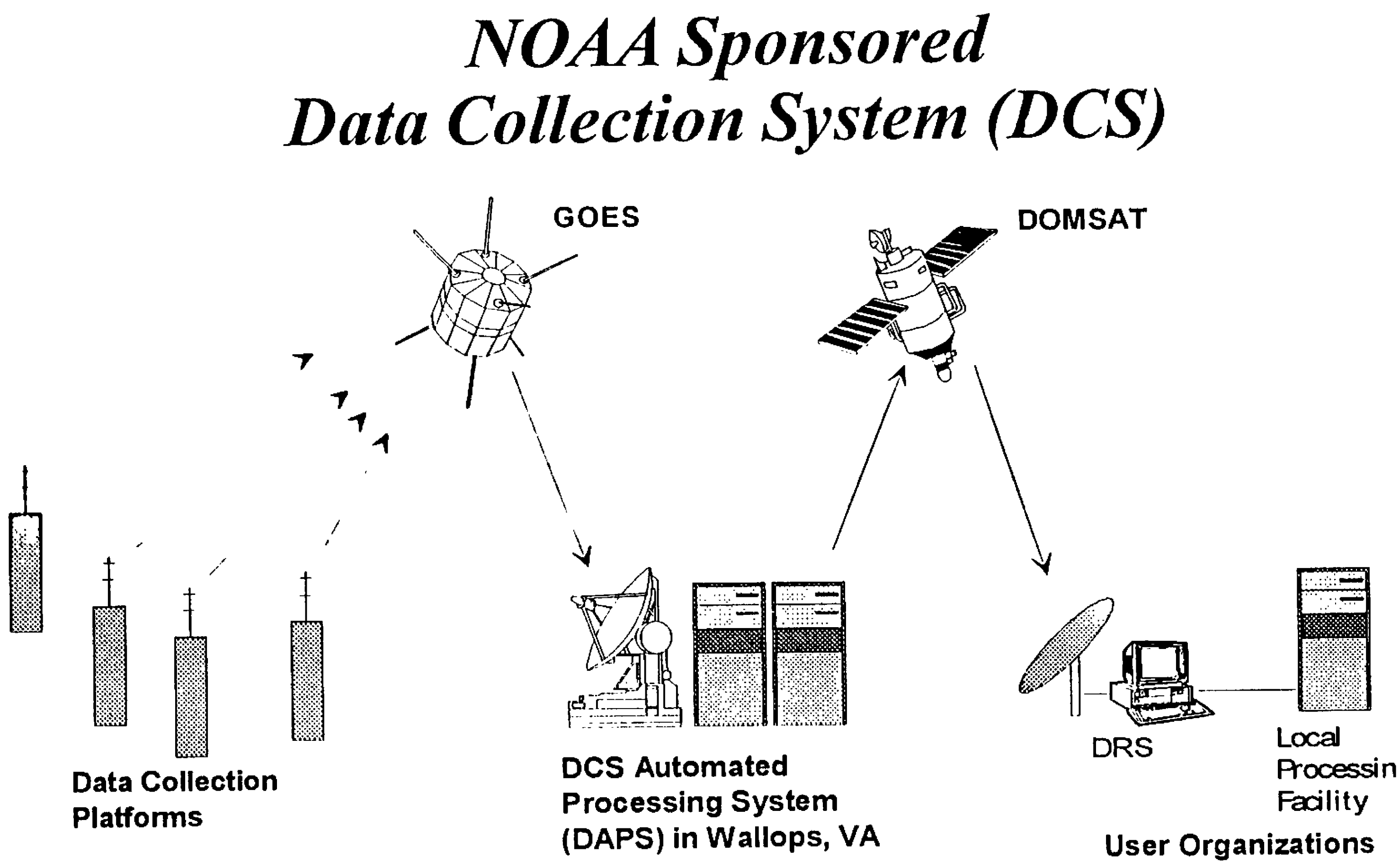

NOAA Sponsored
Data Collection System (DCS)
GOES
DOMSAT
Data Collection Platforms
DCS Automated Processing System (DAPS) in Wallops, VA
DRS
Local Processin Facility
User Organizations

FIGURE 2

typically visited by a hydrographer on two to four week intervals. On-site measurements are made along with any necessary calibrations. Normal data ranges for each station are entered into the central computer. If data values fall outside the expected range, they are flagged accordingly. Flagged values are not used in computing mean daily values. Each day the computer reports the number of "data quality" flags for each station.

Computer generated system diagnostics reports help in monitoring the operating qualities of the remote data collection hardware. The report tabulates the operations characteristics for each station for the previous day. The report lists the number of received, scheduled, and missed transmissions, any message length errors, transmission time errors, errors in transmission quality including power (EIRP) and frequency, any deficiency in remote power supplies, and the number of missing values and parity errors for each station. Frequently, hardware operating problems can be detected before reaching a critical (non-operative) stage.

In October 1990, the Division of Water Resources set up a new facility to support the electronic equipment, primarily Data Collection Platforms and Shaft Encoders belonging to the SMS. The intent was to repair and recalibrate malfunctioning units and also to establish a program of preventative maintenance. The goals included better data collection through increased reliability and reduced downtime, as well as, the cost savings on repairs. From October 1990 until December 1992, the position of Maintenance Manager consisted of a halftime professional engineer based in Montrose. The program has proven to be cost effective. Hardware repair activities were as follows:

| | FY 90-91 | FY 91-92 |
|---|---|---|
| Data Collection Platforms | 331 | 35 |
| Shaft Encoders | 6 | 0 |
| DWR Expenses | $157.56 | $198.93 |

Without the maintenance program, the minimum total cost to the state (based upon manufacturers minimum charge of $250.00 plus parts per unit) would have been at least $18,500. This is considerably more than the $356.25 spent.

In addition to saving through the repair facility, the Division also saved approximately $35,054 during the network expansion that took place in 1991. Capital expenditures were minimized by ordering components directly from the manufacturer, rather than through the hardware vendor and by fabrication of cable assemblies in the maintenance facility. These efforts typically reduced accessory cost per installation by $1,095 per site for the 32 sites involved.

In preparation for the network expansion, all new DCP's were bench-checked at the maintenance facility. Of the 40 units ordered, six were found to contain defective chips. These units were repaired locally with parts furnished under warranty from Sutron Corp. Two additional units were returned to the vendor for more extensive testing and repair under warranty. The maintenance manager submitted proposed installation procedures and programming standards for the new generation of DCP's and Shaft Encoders (Model 8200) to enhance the reliability and simplify troubleshooting.

The Division of Water Resources is responsible for system maintenance. Field personnel from each Division received training from Sutron technicians in the operations and maintenance of the system hardware. Selected staff engineers receive a week of follow-up training at Sutron's facilities in Herndon, Virginia each year. Training is directed at system diagnostics, hardware calibration, and basic repairs. Each division is supplied with a minimum of two sets of replacement hardware. If a component malfunctions and cannot be repaired in the field, it is replaced and sent to our repair facility in Montrose. If we cannot repair it, it is then returned to the manufacturer for repair. We plan to have an additional repair facility in either Denver or Greeley up and running by January 1993.

Communications with NOAA-NESDIS, other GOES DCS users, and the Colorado user community is essential. NOAA-NESDIS coordinates the activities of two national GOES DCS user groups, the Technical Working Group and the Direct Readout Ground Station Working Group. Meetings are held quarterly to discuss GOES DCS operations, future system improvements, system utility, and to facilitate communications between users. These meetings have proven to be beneficial. The Project Manager attends two of the four meetings annually. Within the state of Colorado, a consortium of governmental agencies (federal, state, and municipal) has formed a committee to coordinate activities within the state related to hydrology-meteorology. The Hydromet Committee has been instrumental in promoting real-time data collection in Colorado.

The monitoring system continues to operate with only two full-time employees paid by the appropriations for the program, a Systems Analyst/Program Manager and a Senior Telecommunications/Electronic Specialist. The Systems Analyst/Program Manager's responsibilities include the coordination of daily operations, network development, system enhancement, control and management of system access by the user community, software modification, and ADP training. The Senior Tele./Elect. Specialist's responsibilities will include preventative maintenance and repair of the system hardware for the Eastern Slope. This position was vacant during the fall of 1992. It is expected that it will be filled by December 1, 1992. The repair facility in Montrose will provide preventative maintenance and repair of the system hardware for the rest of the state.

Essential additional support is provided by other staff of the Division of Water Resources. The SMS is managed by the Chief of the Hydrographic Branch. His responsibilities include overall management of the program, integration of the SMS into the hydrographic program of the DWR, maintaining communications with the user community, interagency/intra-agency coordination, user fee development, budget management and program direction. The Chief of the Division's Information Services Branch provides one-half of the time of a computer programmer/operator. The responsibilities of this computer operator include operation of the receive site and central computer, data base management, and data backup. Also, part-time support for western slope preventative maintenance and repair is provided by the Division Engineer's Office for Water Division Four. Overall guidance and direction are provided by the State Engineer and the Assistant State Engineer for Technical Services. Systems operation and maintenance support is provided by the hydrographic staffs of each of the seven Division offices.

### C. System Software

The HYDROMET software package consists of a series of programs that provide for transmission, receive, raw data processing, data conversions, data archiving, data retrieval in various reports and graphics formats, and system diagnostics. The following is a description of the basic applications programs used by the user:

1. DAYFILES maintains and provides access to the real-time data being collected for a given station. This program performs raw data processing, data conversions, shift applications, and archiving of the real-time data.

2. ARCHIVES computes and stores mean daily values for a given data type for a given station.

3. ANNUAL provides a yearly summary of mean daily values for a given data type for a given station. It also summarizes by month the total, mean, minimum, maximum, and any special conversions, i.e. mean daily discharge to acre-feet. The format matches that established by the U.S. Geological Survey-Water Resources Division and accepted by the Colorado Division of Water Resources for publication purposes.

4. PLOT provides for the development of graphical displays of data values plotted against time. In the case of discharge data, this produces a hydrograph.

5. SCHEMATICS provides for a graphical display of the relative locations of monitoring stations along with the most recent data for each station.

6. DIAGNOSTICS provides a detailed daily summary of the operating characteristics for a network of stations. This includes such things as missed transmissions, parity errors, missing data values, remote battery power, transmission power, and data base quality flags.

Additional programs have been developed internally to supplement the Hydromet software. SMSEQPT provides for a computerized inventory and tracking system for the remote data collection hardware, primarily 210 DCP's and 210 shaft encoders with a replacement cost of $1,260,000. RECORD was developed to facilitate the development of the hydrologic records. It modifies the Hydromet records development programs to better meet the needs and requirements of the Division of Water Resources. Data editing can be performed on either the 15-minute resolution data or the mean daily values. Editing is done on a separate working file duplicated from the original data base. In this fashion, the integrity of the real-time data is maintained. This is necessary since administrative decisions are based on the evaluation of real-time data. LOG was developed to monitor transmission activity on a specified demodulator. This includes scheduled and unscheduled transmissions making it possible to identify unauthorized transmissions that could cause interference problems. Sutron has released a new version of the Hydromet software that the DWR is altering to fit our system and plans to install by the summer of 1993.

### D. System Capabilities

The ability to collect data remotely on a real-time basis is the most fundamental capability of the system. The latest data values are never more than four hours old. Random (emergency) transmissions update the data base at intervals down to two minutes if user defined thresholds at the remote site are surpassed. The remote data collection hardware is easily installed and can be operated in remote locations using portable power packs and solar panels. The hardware can be operated in a wide environmental range from -40 degrees C to +55 degrees C. The DCPs are user programmable in the field. The units can interface with up to 16 sensors simultaneously in either analog or digital mode. Very few locations in Colorado do not have a line-of-sight with either GOES-CENTRAL or GOES-WEST. The Direct Readout Ground Station can operate in an urban environment with negligible radio frequency interference. The receive site is equipped with eight demodulators allowing the monitoring of eight GOES channels simultaneously. A Sutron developed program was installed in FY 87-88 that allows for programmable operation of the demodulators. Operator input directs the demodulators to switch channels by time. All transmissions through GOES are in the public domain. The state's receive site can thus monitor all transmissions of interest through either GOES-CENTRAL or GOES-WEST. The system can handle a minimum of 350 DCPs. Data storage capacity is 912 MBytes. Up to 12 users can access the system simultaneously. The system evaluates incoming transmissions and prepares a detailed summary of pertinent operating characteristics.

The Office of the State Engineer operates a computer accessory unit, WATERTALK, that allows data to be output to the user by phone using computer-generated voice-synthesis. The user can dial the WATERTALK unit, located in Denver, and receive up-to-date flow conditions at key gaging stations across the state by input of commands using the keypad of a touch-tone phone. Flow information is automatically updated by the central computer in communicating with WATERTALK. Four phone lines are dedicated for WATERTALK user access such that four users can access the unit simultaneously.

Data transmissions are processed automatically on a real-time basis. Data conversion including analog-to-digital, stage-to-discharge, and mean daily values computations are performed based on user input. Data are automatically screened and appropriately flagged if they fall outside a user defined normal range, thus providing a basis for data quality assurance. Data editing routines, with access controlled by user name/password, allow for data base modification in both the real-time data and the archival data base. Data for stations not in the monitoring network may be entered manually, from computer-to-computer transfer, or by computer tape.

The data can be retrieved and output in various reports and graphics formats. The most fundamental output forma for the evaluation of flow data is the hydrograph. Data from up to four stations or from four periods of record for a single station can be plotted on a single hydrograph.

The system is capable of providing flood warnings. If river conditions surpass user identified high water levels, the system automatically sends out warning messages to designated personnel by either computer-to-computer communications or by delivering a voice-synthesized message over the phone.

### E. Future System Developments

The satellite-linked monitoring system can be both expanded and enhanced to increase its capabilities and effectiveness. The expansion of the state's monitoring network and the enhancement of the system by the addition of other sensor types will be limited by the availability of funds. The cost to purchase and install GOES-linked data collection hardware at an existing shelter is approximately $6,000 per station. Refer to Appendix A. Current funding levels do not provide for capital expenditure beyond hardware replacement costs. There are a large variety of sensor types available over a wide cost range. Sensors are available that can interface with the Sutron DCP and provide valuable data on a real-time basis. These include precipitation, air temperature, water temperature, soil moisture, snow depth, solar radiation, pH, dissolved oxygen, conductivity, wind direction and speed, humidity, and soil temperature. Costs for specific sensors range from $300 to $4,500. Refer to Appendix B. The need for additional data must be coupled with funds from the state of Colorado and from various user groups to cover the costs. System enhancement cannot become a reality without additional operations and maintenance field support staff.

This office is also interested in real-time data that can assist in runoff forecasting and in dam safety monitoring. Other state agencies including the Division of Wildlife and the Department of Health identified the need for an additional 20 to 25 stations. The Division of Wildlife is interested in monitoring minimum stream flows and water quality relative to fisheries management. The Department of Health is interested in monitoring basic water quality parameters. The Office of the State Engineer has made the receive site and central computer facilities available to any state agency desiring to get involved in GOES-linked data collection. Technical expertise will also be provided on a cooperative basis.

Numerous non-state water resources management entities are planning on installing and operating additional satellite-linked stations statewide. These include the National Weather Service, Bureau of Reclamation, Northern Colorado Water Conservancy District, City of Colorado Springs, and the City of Aurora. The National Weather Service (NWS) has installed sensors measuring air temperature and precipitation along with stage at 38 stations in the Colorado River basin in Colorado. Through a cooperative agreement, the NWS installed precipitation and air temperature sensors at two state operated stations, Colorado River near Dotsero and the Blue River below Green Mountain Reservoir. The Northern Colorado Water Conservancy District is planning on installing additional GOES-linked meteorological stations for use in runoff forecasting and irrigation planning. The Bureau of Reclamation and the City of Colorado Springs are planning on the installation and operation of real-time monitoring stations for reservoir management and dam safety. The City of Aurora will be increasing its network of stations in South Park for water resources accounting. The stations that are of interest to the user community will be monitored by the state's system.

The input of historic flow data into the system's data base for key gaging stations in Colorado is expected to be completed by early 1994. This will allow for comparisons of recent data with data covering in some cases 100 years of record. Current flow conditions can be compared with normal, wet, and dry periods. Examples of historic flow records available are:

| STATION | INITIAL DATE OF RECORD |
|---|---|
| Arkansas River at La Junta | 1889 |
| Arkansas River At Pueblo | 1885 |
| Big Thompson River at Mouth of Canyon | 1881 |
| Cache La Poudre at Mouth of Canyon near Ft. Collins | 1881 |
| South Platte River at Denver | 1889 |
| Dolores River at Dolores | 1895 |
| Gunnison River near Grand Junction | 1894 |
| Rio Grande near Del Norte | 1889 |

It has become evident that there are situations where short-term real-time data collection is necessary. This could include stations for flood warning, dam safety, or for specific water rights administration such as water exchanges. An example of one of these uses took place in May 1987, when the Cucharas Reservoir (Division 2, Arkansas River Basin) showed signs of possible dam failure. The reservoir was at near capacity with 51,000 acre-feet of water. A monitoring station was installed the next day at the reservoir using a pressure transducer to monitor stage elevation. Another station was installed upstream on the Cucharas River to monitor inflow. Both stations remained operational until August 1, 1987. Four sets of remote data collection hardware, portable shelters, and sensors have been prepackaged to assist in meeting future needs.

The ability to extract information from the enormous amounts of real-time data being collected can be enhanced through the development of more sophisticated software. Currently, several division offices are developing water resource accounting programs. Programs in the area of short-term runoff forecasting and automated river call determination are of special interest. Over the next couple years the SMS will become an integral part of the Upper South Platte Management Support System and the Colorado River Decision Support System. These two programs use SMS data, GIS, water rights tabulations, etc. to assist the Division Engineer in making administration decision using computer technology on a real-time basis.

### F. Monitoring System Network

The real-time hydrologic data collection network operated by the state of Colorado is comprised of approximately 210 stations. These stations were selected by the State Engineer, Division Engineers, and Water Commissioners with an emphasis on the need for real-time data for water rights administration. A detailed list of these stations is included in Table 1. In the network development, the primary considerations are administrative importance, utility in project management, and the interrelationship of each station to other stations in a subnetwork. The goal is to incorporate those stations that satisfied as many of these requirements as possible to obtain maximum benefits from real-time data collection. The most important element in network development is in establishing station interrelationships. Rather than selecting stations, it is more important to incorporate integrated subnetworks. Data collected from one station are not as useful as information extracted from a subnetwork of stations. This is critical for compact administration, project management, developing water resources accounting systems, and in developing water resources management programs. Changes in the network can be made any time at the discretion of the State Engineer or one of the Division Engineers. The remote data collection hardware is easily removed and installed at a substitute gaging system.

Considerable cooperation was necessary in developing this network. One hundred-one (101) of the locations installed with remote data collection hardware by the State of Colorado are owned and operated by non-state entities. Access and installation agreements were negotiated with the following:

| ENTITY | NUMBER OF STATIONS |
|---|---|
| U.S. Geological Survey - Water Resources Division | 32 |
| U.S. Bureau of Reclamation | 18 |
| Denver Water Department | 9 |
| Northern Colorado Water Conservancy District | 4 |
| Farmers Reservoir and Irrigation Company | 1 |
| North Sterling Irrigation District | 1 |
| U.S. Army Corps of Engineers | 2 |
| City of Colorado Springs | 2 |
| City of Pueblo | 5 |
| Highline Canal Company | 1 |
| Twin Lakes Canal Company | 1 |
| Catlin Canal Company | 2 |
| Fort Lyon Canal Company | 3 |
| Oxford Farmers Canal Company | 1 |
| Rocky Ford Highline Canal Company | 1 |
| Colorado Canal Company | 1 |
| Holbrook Canal Company | 1 |
| Upper Yampa Water Conservancy District | 1 |
| Water Supply and Storage Company | 2 |
| Lower Latham Ditch Company | 1 |
| Lamar Canal Company | 1 |
| Union Ditch Company | 1 |
| Mutual Irrigation Company | 1 |
| Terrace Irrigation Company | 1 |
| South Canal Company | 1 |
| Grand Valley Water Conservancy District | 1 |
| Grand Valley Water Users Association | 1 |
| Silt Water Conservancy District | 2 |
| MVI Diversion Company | 1 |
| La Plata and Cherry Creek Ditch Company | 1 |
| Metropolitan Denver Sewage Disposal District #1 | 1 |

The cooperation that has been extended to the Office of the State Engineer by these entities is invaluable and demonstrates the interest by the water user community in the satellite monitoring system.

Various entities involved with water resources management and development within the state of Colorado have installed and are operating hydrological real-time data collection hardware in Colorado utilizing the GOES satellite as a communications link. As this is a federal satellite, all resource data transmitted through the satellite data collection system are in the public domain. The State Engineer's Office can schedule its Direct Readout Ground Station to receive and process these raw transmissions. The State Engineer's Office is cooperating with these entities in planning network expansion to maximize utility of real-time data collection without redundancy.

Approximately twenty-five satellite-linked monitoring stations operated by the state of Colorado are done so on a seasonal basis only. These stations are primarily gages at transmountain diversions and irrigation diversions where actual diversions are not made during the winter months, and at high elevation sites where ice-effects negate a valid record.

## TABLE 1

## SATELLITE-LINKED DATA COLLECTION NETWORK
## MONITORED BY THE STATE OF COLORADO
## DIRECT READOUT GROUND STATION

**Stations Operated by the State of Colorado**
**Office of the State Engineer**

**DIVISION 1 (South Platte River Basin)**

| | | Data Type |
|---|---|---|
| 1. | South Platte River at Waterton | S |
| 2. | South Platte River near Kersey | S |
| 3. | South Platte River at Balzac | S |
| 4. | Boulder Creek near Eldorado Springs | S |
| 5. | South Platte River at Julesburg, Channel #4 | S |
| 6. | South Platte River at Julesburg, Channel #2 | S |
| 7. | South Platte River near Weldona | S |
| 8. | Big Thompson River in the Canyon | S |
| 9. | St. Vrain Creek at Lyons | S |
| 10. | St. Vrain Creek at Mouth near Platteville | S |
| 11. | Cache La Poudre at Mouth of Canyon near Fort Collins | S |
| 12. | Cache La Poudre near Greeley | S |
| 13. | Harold D. Roberts Tunnel | S |
| 14. | Moffat Water Tunnel | S |
| 15. | Alva B. Adams Tunnel | S |
| 16. | Burlington-Wellington Canal at the Headgate | S |
| 17. | North Sterling Canal at the Headgate | S |
| 18. | Riverside Canal at Reservoir Inlet Gage | S |
| 19. | Boulder Creek near Orodell | S |
| 20. | Laramie Poudre Tunnel | S |
| 21. | Grand River Ditch | S |
| 22. | Big Thompson River above Lake Estes | S |
| 23. | Olympus Tunnel | S |
| 24. | Hoosier Pass Tunnel | S |
| 25. | South Platte River at Fort Lupton | S |
| 26. | Lower Latham Ditch | S |
| 27. | Union Ditch | S |
| 28. | South Platte River below Strontia Springs | S |
| 29. | South Platte River below Chatfield Reservoir | S |
| 30. | Metro Sewage Effluent Outlet Gage | S |
| 31. | Hansen Feeder Canal | S |
| 32. | Cheesman Reservoir | SE |
| 33. | South Boulder Creek below Gross Reservoir | S |
| 34. | Big Thompson River below Lake Estes | S |

**DIVISION 2 (Arkansas River Basin)**

| | | Data Type |
|---|---|---|
| 1. | Arkansas River at Canon City | S |
| 2. | Arkansas River at Portland | S |
| 3. | Arkansas River above Pueblo | S |
| 4. | Arkansas River near Nepesta | S, AT |
| 5. | Arkansas River near Avondale | S, C, WT DO, pH |
| 6. | Arkansas River near Wellesville | S |
| 7. | Arkansas River at La Junta | S |
| 8. | Arkansas River at Las Animas | S, C, WT |
| 9. | Fountain Creek near Pinon | S, C, WT |
| 10. | Purgatoire River near Las Animas | S, C, WT |
| 11. | Purgatoire River near Thatcher | S, C, WT, SS |
| 12. | Lake Fork Creek above Turquoise Lake | S |
| 13. | John Martin Reservoir | SE |
| 14. | Arkansas River below Catlin Dam near Fowler | S, C, WT |
| 15. | Purgatoire River at Ninemile Dam near Higbee | S |
| 16. | Charles H. Boustead Tunnel | S |
| 17. | Homestake Tunnel | S |
| 18. | Busk-Ivanhoe Tunnel | S |
| 19. | Twin Lakes Tunnel | S |
| 20. | Ewing Ditch | S |
| 21. | Purgatoire River below Trinidad Reservoir | S |
| 22. | Purgatoire River at Madrid | S |
| 23. | Fort Lyon Storage Canal | S |
| 24. | Pueblo Water Works Diversion | DM |
| 25. | Lake Creek below Twin Lakes | S |
| 26. | Lake Fork Creek below Sugar Loaf | S |
| 27. | Timpas Creek near Rocky Ford | S, P |
| 28. | Amity Canal | S |
| 29. | Lamar Canal | S |
| 30. | Crooked Arroyo near Swink | S |
| 31. | Arkansas River at Granada | S |
| 32. | Wurtz Ditch | S |
| 33. | Columbine Ditch | S |
| 34. | Pueblo Reservoir | SE |
| 35. | Arkansas River below John Martin Reservoir | S, C, WT |
| 36. | Fort Lyon Canal at the Headgate | S |
| 37. | Catlin Canal at Gage Downstream from Catlin Dam | S |
| 38. | Oxford Farmers Ditch at Headgate | S |
| 39. | Rocky Ford Highline Canal at Headgate | S |
| 40. | Colorado Canal at Boone | S |
| 41. | Holbrook Canal near Rocky Ford | S |
| 42. | Horse Creek at Highway 194 | S, WT, C |
| 43. | Cucharas Reservoir | SE, pz(2) |
| 44. | Arkansas River near Rocky Ford | S |
| 45. | Arkansas River at Salida | S |
| 46. | Cottonwood Creek near Buena Vista | S |
| 47. | Cucharas at Boyd Ranch near La Veta | S |
| 48. | Grape Creek near Westcliffe | S |

**DIVISION 3 (Rio Grande Basin)**

| | | Data Type |
|---|---|---|
| 1. | Rio Grande near Del Norte | S,AT |
| 2. | Rio Grande near Lobatos | S |
| 3. | Rio Grande at Thirty-Mile Bridge near Creede | S |
| 4. | Conejos River near Mogote | S,AT |
| 5. | Conejos River near La Sauses, North Channel | S,AT |
| 6. | Conejos River near La Sauses, South Channel | S |
| 7. | Los Pinos River near Ortiz | S |
| 8. | San Antonio River at Ortiz | S |
| 9. | Alamosa Creek above Terrace Reservoir | S,AT |
| 10. | Conejos River below Platoro Reservoir | S,AT |
| 11. | Closed Basin Project Outlet | S |
| 12. | Terrace Reservoir | SE |
| 13. | Rio Grande above the Mouth of Trinchera Creek | S |
| 14. | Saguache Creek near Saguache | S,AT |
| 15. | La Jara Creek near Capulin | S |
| 16. | South Fork Rio Grande at South Fork | S,AT |
| 17. | Rio Grande at Alamosa | S,AT |
| 18. | Rio Grande River near Monte Vista | S |
| 19. | North Clear Creek below Continental Reservoir | S |
| 20. | Pinos Creek near Del Norte | S |
| 21. | San Antonio River near Manassa | S |
| 22. | Alamosa Creek below Terrace Reservoir | S |
| 23. | Ute Creek near Fort Garland | S |

**DIVISION 4 (Gunnison River Basin)**

| | | |
|---|---|---|
| 1. | Surface Creek near Cedaredge | S |
| 2. | Gunnison River below East Portal Gunnison Tunnel | S |
| 3. | Surface Creek at Cedaredge | S |
| 4. | Muddy Creek above Paonia Reservoir | S |
| 5. | Muddy Creek below Paonia Reservoir | S |
| 6. | Cimarron River near Cimarron | S |
| 7. | South Canal | S |
| 8. | Uncompahgre River near Ridgway | S |
| 9. | Dallas Creek near Ridgway | S |
| 10. | Redlands Canal near Grand Junction | S |
| 11. | Uncompahgre River near Olathe | S |
| 12. | Kannah Creek at Juanita Enla Diversion | S |

**DIVISION 5 (Colorado River Basin)**

| | | |
|---|---|---|
| 1. | Blue River below Dillon | S |
| 2. | Dillon Reservoir | SE |
| 3. | Blue River below Green Mountain Reservoir | S |
| 4. | Green Mountain Reservoir | SE |
| 5. | Williams Fork below Williams Fork Reservoir | S |
| 6. | Colorado River at Hot Sulphur Springs | S |
| 7. | Eagle River below Gypsum | S |
| 8. | Fryingpan River near Ruedi | S |
| 9. | Colorado River near Dotsero | S |

**DIVISION 5 (Colorado River Basin) cont.**

| | | Data Type |
|---|---|---|
| 10. | Williams Fork Reservoir | SE |
| 11. | Colorado River below Lake Granby | S |
| 12. | Lake Granby | SE |
| 13. | Willow Creek Reservoir | SE |
| 14. | Shadow Mountain Reservoir | SE |
| 15. | Willow Creek Pump Canal | S |
| 16. | Government Highline Canal | S |
| 17. | Grand Valley Canal | S |
| 18. | Plateau Creek near Cameo | S |
| 19. | Rifle Creek below Rifle Gap Reservoir | S |
| 20. | Grass Valley Canal | S |
| 21. | Fryingpan River near Thomasville | S |
| 22. | Willow Creek below Willow Creek Reservoir | S |

**DIVISION 6 (White/Yampa River Basin)**

| | | |
|---|---|---|
| 1. | Yamcolo Reservoir | SE |
| 2. | Illinois River near Rand | S |
| 3. | Yampa River above Stagecoach Reservoir | S |
| 4. | Michigan River near Gould below the Confluence of the North and South Forks | S |
| 5. | Little Snake River near Slater | S |
| 6. | Yampa River below Craig | S |
| 7. | Elk River near Milner at the Mouth | S |

**DIVISION 7 (Dolores and San Juan River Basins)**

| | | |
|---|---|---|
| 1. | Lost Canyon Creek near Dolores | S |
| 2. | Navajo River below Oso Diversion Dam | S |
| 3. | Rio Blanco below Blanco Diversion Dam | S |
| 4. | La Plata River at Hesperus | S,AT |
| 5. | La Plata River at Colorado-New Mexico State line | S,AT |
| 6. | Dolores River at Dolores | S |
| 7. | Lone Pine Canal below Great Cut Dike | S |
| 8. | Dolores Tunnel | S |
| 9. | Azotea Tunnel Outlet near Chama,NM | S |
| 10. | Mancos River near Mancos | S |
| 11. | Dolores River below McPhee Reservoir | S |
| 12. | Florida River below Lemon Reservoir | S |
| 13. | Florida River above Lemon Reservoir | S,AT |
| 14. | La Plata and Cherry Creek Ditch | S |
| 15. | Pine River below Vallecito Reservoir | S |
| 16. | "U" Lateral Canal below Great Cut Dike | S |
| 17. | Navajo River at Banded Peak Ranch | S,AT |
| 18. | Pioneer Ditch at Colorado/New Mexico line | S |
| 19. | Enterprise Ditch near Colorado/New Mexico line | S |
| 20. | Hay Gulch above Red Mesa Ward Reservoir | S |

## Stations Operated by the U.S. Army Corps of Engineers (Omaha District)

**DIVISION 1 (South Platte River Basin)**

| | | Data Type |
|---|---|---|
| 1. | Bear Creek at Kittredge | P |
| 2. | Bear Creek at Morrison | S,P |
| 3. | Bear Creek Reservoir | SE,P |
| 4. | Bear Creek at Sheridan | S,P |
| 5. | Chatfield Reservoir | SE,P |
| 6. | Cherry creek at Parker | P,AT |
| 7. | Clear Creek at Blackhawk | P |
| 8. | Clear Creek at Derby | S,P |
| 9. | Clear Creek at Georgetown | P,AT |
| 10. | Clear Creek near Golden | S,P |
| 11. | Conifer | P |
| 12. | South Platte River below Cheesman Reservoir | S,P |
| 13. | South Platte River at Denver | S |
| 14. | North Fork South Platte River at Grant | S,P,AT |
| 15. | South Platte River above Elevenmile Reservoir | S,P,AT |
| 16. | South Platte River at Henderson | S,P |
| 17. | South Platte River at South Platte | S,P |
| 18. | Plum Creek at Larkspur | P |
| 19. | Cherry Creek Reservoir | SE,P |

**DIVISION 2 (Arkansas River Basin)**

| | | |
|---|---|---|
| 1. | Purgatoire River at Trinidad | S |

## Stations Operated by the National Weather Service, Colorado River Forecast Center (Salt Lake City)

**DIVISION 3 (Rio Grande Basin)**

| | | |
|---|---|---|
| 1. | Rio Grande Reservoir | P,AT |

**DIVISION 4 (Gunnison River Basin)**

| | | |
|---|---|---|
| 1. | Blue Mesa Reservoir | P,AT,SE |
| 2. | Crested Butte | P,AT |
| 3. | Gunnison River at Delta | S,P,AT |
| 4. | East River at Almont | S,P,AT |
| 5. | Gunnison River near Grand Junction | AT |
| 6. | Ouray | P,AT |
| 7. | Paonia | P,AT |
| 8. | San Miguel River near Placerville | S,P,AT |
| 9. | Sargents | P,AT |
| 10. | North Fork Gunnison River near Somerset | S,AT |
| 11. | Taylor River at Almont | S,AT |
| 12. | Gunnison River near Gunnison | S,P,AT |

**DIVISION 4 (Gunnison River Basin) cont.**

| | Station | Data Type |
|---|---|---|
| 13. | Dolores River near Bedrock | S, P, AT |
| 14. | Taylor Park Reservoir | P, SE |
| 15. | Uncompaghre River near Colona | S, P |

**DIVISION 5 (Colorado River Basin)**

| | | |
|---|---|---|
| 1. | Breckenridge | P,AT |
| 2. | Colorado River near Cameo | S |
| 3. | Colorado River below Glenwood Springs | S,P,AT |
| 4. | Colorado River near Kremmling | S |
| 5. | Colorado River near Colorado-Utah State line | S,AT |
| 6. | Dillon | P,AT |
| 7. | Grand Lake | P,AT |
| 8. | Meredith | P,AT |
| 9. | Roaring Fork River near Aspen | S,P,AT |
| 10. | Roaring Fork River at Glenwood Springs | S |
| 11. | Ruedi Reservoir | SE,P,AT |
| 12. | Winter Park | P,AT |
| 13. | Eagle River at Redcliff | AT,P,S |
| 14. | Piney River near State Bridge | AT,P,S |
| 15. | Crystal River near Avalanche Creek | AT,P,S |
| 16. | Eagle River near Redcliff | AT,P,S |

**DIVISION 6 (White/Yampa River Basin)**

| | | |
|---|---|---|
| 1. | White River near Meeker | S,P,AT |
| 2. | Yampa River near Maybell | S,AT |
| 3. | Little Snake River near Lily | S,P |
| 4. | Little Snake River near Dixon, WY | S,P,AT |

**DIVISION 7 (Dolores and San Juan River Basin)**

| | | |
|---|---|---|
| 1. | Animas River at Durango | S,P,AT |
| 2. | San Juan River at Pagosa Springs | S,P,AT |
| 3. | Vallecito Reservoir | SE,P,AT |

## Stations Operated by the National Weather Service, Central Forecast Office (Denver)

**DIVISION 1 (South Platte River Basin)**

| | | |
|---|---|---|
| 1. | Clear Creek at Lawson | S,P |
| 2. | Big Thompson River North Fork near Drake | S,AT |

**DIVISION 6 (White/Yampa River Basin)**

| | | |
|---|---|---|
| 1. | North Platte River near Northgate | S |

## Stations Operated by the U.S. Geological Survey, Water Resources Division

**DIVISION 1 (South Platte River Basin)**

| | | Data Type |
|---|---|---|
| 1. | Boulder Creek at Boulder | S |
| 2. | Cache La Poudre at Fort Collins | S |
| 3. | Clear Creek at Golden | C, WT |

**DIVISION 2 (Arkansas River Basin)**

| | | |
|---|---|---|
| 1. | Arkansas River at Buena Vista | S |
| 2. | Apishapa River near Fowler | S |
| 3. | Teller Reservoir near Stone | SE |
| 4. | Four Mile Creek near Canon City | S |
| 5. | Arkansas River near Boone | S |
| 6. | Purgatorie River at Rock Crossing | S |
| 7. | Arkansas River near Coolidge, KS | S |
| 8. | Frontier Ditch near Coolidge, KS | S |
| 9. | Trinidad Reservoir | SE |
| 10. | Arkansas River near Nathrop | S |
| 11. | Arkansas River near Parkdale | S |
| 12. | Monument River at Pikeview | S, P |
| 13. | St. Charles River at Vineland | S |
| 14. | Beaver Creek above Upper Beaver Creek Cemetery | S |
| 15. | Beaver Creek near Penrose | S |

**DIVISION 6 (White/Yampa River Basin)**

| | | |
|---|---|---|
| 1. | Yampa River below Stagecoach Reservoir | S, WT, C |
| 2. | Yampa River near Deer Lodge Park | S, WT, C |
| 3. | White River below Boise Creek near Rangley | S |
| 4. | Yampa River at Steamboat | S |

**DIVISION 7 (Dolores and San Juan River Basins)**

| | | |
|---|---|---|
| 1. | Animas River near Cedar Hill, NM | S |
| 2. | San Juan River at Farmington, NM | S |
| 3. | Lemon Reservoir | SE |

## Stations Operated by the U.S. Bureau of Reclamation

**DIVISION 3 (Rio Grande River Basin)**

| | | |
|---|---|---|
| 1. | Platoro Reservoir | SE, P |

**DIVISION 4 (Gunnison River Basin)**

| | | |
|---|---|---|
| 1. | Silverjack Reservoir | SE |
| 2. | Paonia Reservoir | SE |
| 3. | Ridgway Reservoir | SE |

**DIVISION 5 (Colorado River Basin)**

| | Station | Data Type |
|---|---|---|
| 1. | Lincoln Creek below Grizzly Reservoir | S, P, RT, AT |
| 2. | Roaring Fork River above Lost Man Creek | S, P, SR, AT |
| 3. | Mormon Control House | DM, P, SR, AT |
| 4. | Chapman Control House | DM, P, SR, AT |

**Stations Operated by the**
**Trinchera Conservancy District in Conjunction**
**with Trinchera Irrigation Company**

**DIVISION 3 (Rio Grande River Basin)**

| | | |
|---|---|---|
| 1. | Mountain Home Reservoir | SE, S, AT |
| 2. | Trinchera Creek above Turner Ranch | S |

**Stations Operated by the**
**Northern Colorado Water Conservancy District**

**DIVISION 5 (Colorado River Basin)**

| | | |
|---|---|---|
| 1. | Upper Fraser River above Winter Park | S |
| 2. | Lower Fraser River near Winter Park | S |
| 3. | St. Louis Creek above Fraser | S |
| 4. | Ranch Creek above Tabernash | S |
| 5. | Crooked Creek at Tabernash | S |
| 6. | Ten Mile Creek near Granby | S |
| 7. | Strawberry Creek near Granby | S |
| 8. | Vasquez Creek at Winter Park | S |
| 9. | Berthoud Pass Meteorological Station | SW, ST, SMU SML, P, AT, SR |
| 10. | Arrow Meteorological Station | SW, ST, SMU SML, P, AT |
| 11. | Fraser Meteorological Station | SW, ST, SMU SML, P, AT |
| 12. | Meadow Creek Meteorological Station | SW, ST, SMU SML, P, AT |
| 13. | Cottonwood Pass Meteorological Station | SW, ST, SMU SML, P, AT |
| 14. | Granby Meteorological Station | SW, ST, SMU SML, P, AT |
| 15. | Fraser River near Windy Gap | S |
| 16. | Upper Blue River | S |

**Stations Operated by the City of Aurora**

**DIVISION 1 (South Platte River Basin) (April to October)**

| | | |
|---|---|---|
| 1. | Michigan River near Jefferson | S |
| 2. | South Platte River above Spinney Mtn. Res. | S |
| 3. | Fourmile Creek near Hartsel | S |
| 4. | Middle Fork at Santa Maria | S |
| 5. | Fourmile Creek at Highcreek | S |
| 6. | Middle Fork at Prince | S |
| 7. | South Fork above Antero | S |
| 8. | Jefferson Creek above Jefferson | S |
| 9. | Ohler Gulch above Jefferson | S |
| 10. | Tarryall Creek near Como | S |

**DIVISION 2 (Arkansas River Basin)**

| | | Data Type |
|---|---|---|
| 1. | Rocky Ford Ditch near Rocky Ford | S |

**Stations Operated by the City of Colorado Springs**

**DIVISION 2 (Arkansas River Basin)**

| | | |
|---|---|---|
| 1. | Fountain Creek at Fountain | S,C,WT |
| 2. | Fountain Creek at Pueblo | S,C,WT |
| 3. | Fountain Creek at Security | S |
| 4. | Lake Creek above Twin Lakes | S,AT |
| 5. | Bob Creek at Colorado Canal | S,AT,P,BPE H,WS,WD |
| 6. | Fountain Creek at Colorado Springs | S,WT,C |
| 7. | Fountain Creek at Mouth | S |
| 8. | Lake Henry Reservoir and Outflow Gage | SE,S |
| 9. | Meredith Reservoir | SE |
| 10. | Meredith Reservoir Inflow | S |
| 11. | Meredith Reservoir Outflow | S |
| 12. | Sugar City Flume | S |

**Stations Operated by Pueblo Water Works**

**DIVISION 2 (Arkansas River Basin)**

| | | |
|---|---|---|
| 1. | Clear Creek Reservoir and Outflow | S,SE,WS,AT,P |
| 2. | Arkansas River at Granite | S |
| 3. | Wurtz Extension Ditch near Tennessee Pass | S,AT |

**Station Operated by Santa Maria Reservoir Company**

**DIVISION 3 (Rio Grande River Basin)**

| | | |
|---|---|---|
| 1. | Continental Reservoir | SE |

**Station Operated by the Rio Grande Reservoir Company**

**DIVISION 3 (Rio Grande River Basin)**

| | | |
|---|---|---|
| 1. | Rio Grande Reservoir | SE |

**Station Operated by the Rio Grande Water Users Association**

**DIVISION 3 (Rio Grande River Basin)**

| | | |
|---|---|---|
| 1. | Rio Grande Canal | S |

## Stations Operated by the Division of Wildlife

DIVISION 3 (Rio Grande River Basin)

| | | Data Type |
|---|---|---|
| 1. | Tabor Transmountain Diversion | S |
| 2. | Beaver Creek Reservoir | SE |

## Stations Operated by the Tri-State Generation and Transmission Assn., Inc.

DIVISION 4 (Gunnison River Basin)

| | | |
|---|---|---|
| 1. | Trout Lake | SE |
| 2. | Trout Lake Outflow | S |

DIVISION 7 (Dolores and San Juan River Basins)

| | | |
|---|---|---|
| 1. | Electra Lake Outflow | S |
| 2. | Electra Lake Diversion | S |
| 3. | Electra Lake | SE |

## Station Operated by the Aspen Consolidated Sanitation District

DIVISION 5 (Colorado River Basin)

| | | |
|---|---|---|
| 1. | Roaring Fork River below Maroon Creek near Aspen | S |

## Station Operated by the Great Sand Dunes National Monument

DIVISION 3 (Rio Grande River Basin)

| | | |
|---|---|---|
| 1. | Sand Creek at Great Sand Dunes National Monument | S |

## Stations Operated by the Southwestern Water Conservation District

DIVISION 7 (Dolores and San Juan River Basins)

| | | |
|---|---|---|
| 1. | Cherry Creek near Red Mesa | S |
| 2. | Long Hollow Creek at the Mouth near Red Mesa | S |

## Data Type Abbreviations

| | |
|---|---|
| S | Stage |
| SE | Stage Elevation (Reservoir) |
| DM | Discharge Meter |
| P | Precipitation |
| AT | Air Temperature |
| SR | Solar Radiation |
| SW | Snow Water |
| ST | Snow Temperature |
| SMU | Soil Moisture Upper |
| SML | Soil Moisture Lower |
| V | Voltage Metering |
| C | Conductivity |
| WT | Water Temperature |
| E | Evaporation |
| PZ | Piezometer |
| DO | Dissolved Oxygen |
| pH | pH |
| WS | Wind Speed |
| BP | Barometric Pressure |
| WD | Wind Direction |
| H | Humidity |

## II. SYSTEM APPLICATIONS

### A. Water Rights Administration

The primary utility of the Colorado satellite-linked monitoring system is for water rights administration. The availability of real-time data from a network of key gaging stations in each major river basin in Colorado provides an overview of the hydrologic conditions of the basin that was previously not available. By evaluating real-time data for upstream stations, downstream flow conditions can typically be predicted 24 to 48 hours in advance. This becomes an essential planning tool in the hands of the Division Engineers and Water Commissioners. The "river call" can be adjusted more precisely to satisfy as many water rights as possible. Access to real-time data makes it possible to adjust the "river call" to match dynamic hydrologic conditions. If additional water supplies are available, more junior rights can be satisfied. On the other hand, if water supplies decrease, then water use can be curtailed to protect senior rights.

The administration of water rights in Colorado is becoming increasingly more complex due to increased demands, implementation of augmentation plans, water exchanges, transmountain diversions, and minimum stream flow requirements. For example, the number of water rights increased by 23% from 1982 to 1988, from 102,028 to 124,994. This increase in the number of water rights has continued through 1992. Plans for water rights transfers approved by the water courts are becoming increasingly complex. This is especially evident where agricultural water rights are transferred to municipal use. One point that must not be overlooked is that Colorado is coming out of a wet cycle. Historical and statistical evidence strongly indicate that Colorado can expect to experience a downturn in this cycle. As the availability of water decreases, the necessity of the system for water rights administration increases.

There is considerable interest in monitoring transmountain diversions, both by western slope water users and the eastern slope entities diverting the water. Transmountain diversion water is administered under different laws than water originating in the basin. In general, this water may be claimed for reuse by the diverter until it is totally consumed. Fourteen transmountain diversions are monitored by the system.

Water exchanges between water users are becoming increasingly frequent. These exchanges can provide for more effective utilization of available water resources in high demand river basins, but can be difficult to administer. The satellite-linked monitoring system has proven to be an integral component in monitoring and accounting of these exchanges.

Many municipalities and major irrigation companies have reservoir storage rights. Generally, these entities can call for release of stored water on demand. The Division Engineer must be able to delineate the natural flow from the storage release while in the stream. He then must track the release and ensure that the proper delivery is made. The system has demonstrated to be effective in this area.

The utility of the system in the administration of interstate compacts is an especially important application. The State Engineer has the responsibility to deliver defined amounts of water under the terms of the various interstate compacts, but not to over-deliver and deprive Colorado of its entitlement. Fifteen stations incorporated in the statewide monitoring network are utilized for the effective administration of these interstate compacts.

The majority of the large, senior water rights in Colorado belong to irrigation companies. These rights are often the calling right in the administration of a water district. The direct diversion rights exercised can affect significantly the hydrology of the river. Twenty-one major irrigation diversions are monitored by the system.

Water rights have been acquired by federal and state agencies to guarantee minimum stream flow for both the recreational and fisheries benefits. The availability of real-time data is essential in ensuring that these minimum stream flows are maintained.

### B. Hydrologic Records Development

Specialized software programs provide for the processing of raw hydrologic data on a real-time basis. Conversions such as stage-discharge relationships and shift applications are performed on a real-time basis as the data transmissions are received. Mean daily values are computed automatically each day for the previous day. Data values that fall outside of user defined normal or expected ranges are flagged appropriately. Flagged data values are not utilized in computing mean daily values. Missing values can be added and invalid data values corrected by the respective hydrographer for that station using data editing functions. The records development software was significantly modified to allow for progressive records development. Computations are carried out by the computer alleviating the chance for human error.

Data can be retrieved and displayed in various formats including the standardized U. S. Geological Survey-Water Resources Division annual report format adopted by the Colorado Division of Water Resources for publication purposes. An advantage of real-time hydrologic data collection is in being able to monitor the station for on-going valid data collection. If a sensor or recorder fails, the hydrographer is immediately aware of the problem and can take corrective action before losing a significant amount of data.

It is essential to understand that real-time records can be different from the final record for a given station. This can be the result of editing raw data values because of sensor calibration errors, sensor malfunctions, analog-to-digital conversion errors, or parity errors. Discharge conversions can be modified by the entering of more current rating tables and shifts. Corrections to the data are sometimes necessary to compensate for hydrologic effects such as icing. Human error can also result in invalid data. The final record for those gaging stations operated by non-state entities, such as the U. S. Geological Survey-Water Resources Division, is the responsibility of that entity. Modifications to the real-time records for these stations are accepted by the state of Colorado.

### C. Water Resources Accounting

There is a growing need for the ability to perform automated water resources accounting. Currently, the satellite-linked monitoring system is being utilized for such accounting for the Colorado-Big Thompson Project, the Dolores Project, and the Fryingpan-Arkansas Project Winter Water Storage. The ability to input real-time data into these accounting programs allows for current and on-going tabulations. Since the computations are performed on a computer, the accuracy is increased significantly.

### D. Dam Safety

Dam safety monitoring has developed in recent years into a major issue. Numerous on-site parameters are of interest to the State Engineer in assessing stability of a dam. At this time, the system monitors seven reservoirs in Colorado. Currently, the parameters monitored are limited to inflow, outflow, and stage elevation. These data do, however, provide a basis for evaluating current operating conditions as compared to specific operating instructions. The installation and operation of additional sensor types could provide essential data on internal hydraulic pressure, vertical and horizontal movement, and seepage rates.

### E. Automated Flood Warning System

The Office of the State Engineer, Division of Water Resources, in cooperation with the National Weather Service-Central Forecast Office (NWS-CFO) in Denver, operates a statewide flood warning system utilizing 78 stream gaging stations that are part of the Colorado satellite-linked water resources monitoring network operated by the State Engineer. The NWS-CFO, which operates on a 24-hour basis, is alerted to changing flow conditions. If conditions warrant, either a flood WATCH or a flood WARNING is issued.

Table 2 lists the incorporated stream gaging stations with the designated alert levels used to flag high water conditions. A synopsis of how the system operates follows:

#### 1. Remote Data Collection/Data Transmission

Stream stage levels are measured and recorded every fifteen minutes for transmission at standard 4-hour intervals. If stage alert levels are surpassed, emergency transmissions are made at random intervals of from 2-10 minutes. All transmissions are sent via the Geostationary Operational Environmental Satellite (GOES). Transmissions are received and processed at the receive site located in Denver operated by the State Engineer.

#### 2. Flagging High Water Levels

Data are screened in an automated fashion by the system's central computer to flag high water levels. The central computer automatically contacts the NWS-CFO by phone giving a voice-synthesized message that relays pertinent information. The transmission is not completed until the message is received and verified. A file is generated in the computer that lists all stations reporting high water levels during the last hour.

3. **Hydrologic Conditions Assessment**

The NWS-CFO OFFICIAL-IN-CHARGE (OIC) immediately accesses by computer terminal the satellite monitoring system data base to further evaluate overall upstream and downstream flow conditions for the effected watershed. Sophisticated software including color graphics capability allows the user to effectively evaluate the data. The OIC follows up by consulting with the NWS regional offices of Pueblo, Grand Junction, Colorado Springs, and Alamosa. Radar coverage is utilized to identify and determine the intensity of precipitation events. The appropriate county sheriff offices and official spotters are contacted for verification of hydrologic conditions.

4. **Watch/Warning dissemination**

If flooding is considered a possibility, a WATCH is issued. If flooding is considered to be imminent, a WARNING is issued. The National Warning System (NAWAS), utilizing the Colorado State Highway Patrol and the Colorado Division of Disaster Emergency Services (DODES) communications networks, is utilized to contact the various law enforcement agencies and county emergency preparedness offices. These agencies in turn provide a "fanout" to secondary points of contact including hospitals, schools, etc. Public announcements are made over the National Weather Service designated VHF-FM radio frequencies, known as the National Weather Radio (NWR), and through the news media via the Automation of Field Operations and Services (AFOS) national weather wire. In the Denver metropolitan area, the Metropolitan Emergency Telephone System (METS) is utilized.

It is important to comprehend inherent limitations of the satellite monitoring system relative to its utilization as a warning system. There are no absolute safeguards against false alarms. Sensor malfunctions are an obvious cause for such false alarms. However, the computer can b programmed to ignore data values that are not plausible. For example, stage values greater than 10 to 15 feet are not physically possible at most stream gaging stations. In the event of a flash flood in a narrow, confined canyon, the remote data collection hardware would be washed away. This is especially the case for a station operating downstream of a failed dam. Ice jams on a river can cause the upstream stage to increase and consequently provide invalid discharge conversions. There is always a time lapse from the time a hydrologic event occurs to when the system identifies that it has occurred and when a random (emergency) transmission is sent. If an event occurs at 1410 hours, the system is not aware of the condition until 1415 hours since the DCP is programmed to activate at even 15-minute intervals to record a data measurement. The DCP then computes a transmit interval utilizing a random number generator. This interval is between 2 and 10 minutes. If a 6-minute interval is utilized, the random transmission will be made at 1421 hours. The elapsed time from event occurrence to transmission of data is 11 minutes. Scenarios could be given which would give a minimum elapse time of two minutes or a maximum elapse time of 24 minutes. In addition, a random transmission occurring on channel 118 has approximately a 20% chance (with current channel load levels) of not being received due to interference with another random transmission being sent at the same time.

### F. Future Applications

Any data that can be collected remotely can be monitored by the satellite-linked monitoring system. Future applications, based primarily on current sensor capabilities, are likely to be in the areas of runoff forecasting, water quality monitoring, and in irrigation planning. Runoff forecasting will require the addition of sensor configurations capable of monitoring liquid and frozen precipitation, air temperature, solar radiation, and soil moisture. Water quality monitoring covers an extremely wide spectrum but would likely consist of a sensor configuration capable of monitoring conductivity (total dissolved solids), water temperature, dissolved oxygen, and turbidity. Irrigation planning would require a sensor configuration capable of monitoring humidity, precipitation, soil moisture, air temperature, wind velocity and azimuth, evaporation rates, and solar radiation.

## TABLE 2

## SATELLITE MONITORING SYSTEM
## FLOOD WARNING NETWORK

| | | ALERT LEVEL (FEET) | DISCHARGE (CFS) |
|---|---|---|---|
| **DIVISION 1 (South Platte River Basin)** | | | |
| 1. | Bear Creek at Morrison | 5.50 | 345 |
| 2. | Clear Creek at Golden | 4.00 | 345 |
| 3. | Boulder Creek near Orodell | 3.50 | 590 |
| 4. | St. Vrain Creek at Lyons | 5.60 | 1,610 |
| 5. | North Fork Big Thompson near Drake | 4.60 | 172 |
| 6. | Cache La Poudre at Canyon Mouth near Fort Collins | 4.50 | 2,000 |
| 7. | South Platte Rive at Denver | 6.00 | 3,930 |
| 8. | South Platte River at Henderson | 9.00 | 4,450 |
| 9. | South Platte River near Kersey | 7.00 | 6,560 |
| 10. | South Platte River near Weldona | 7.00 | 4,200 |
| 11. | South Platte River nr. Balzac So. Channel | 7.00 | 2,230 |
| 12. | So. Platte River nr. Julesburg R. Channel | 7.00 | 4,280 |
| 13. | Cache La Poudre at Greeley | 7.00 | 2,500 |
| 14. | Big Thompson River at Mouth of Canyon | 5.00 | 2,400 |
| **DIVISION 2 (Arkansas River Basin)** | | | |
| 1. | Arkansas River near Wellesville | 7.90 | 5,000 |
| 2. | Fountain Creek near Pinon | 6.53 | 5,020 |
| 3. | Arkansas River near Avondale | 5.00 | 5,000 |
| 4. | Arkansas River below Catlin Dam | 7.70 | 10,000 |
| 5. | Purgatoire River near Thatcher | 11.30 | 10,040 |
| 6. | Purgatoire River at Las Animas | 8.00 | 2,910 |
| **DIVISION 3 (Rio Grande River Basin)** | | | |
| 1. | Alamosa Creek above Terrace Reservoir | 3.50 | 1,480 |
| 2. | Conejos River Below Platoro Reservoir | 3.75 | 1,085 |
| 3. | Conejos River near Mogote | 5.25 | 2,970 |
| 4. | La Jara Creek near Capulin | 4.05 | 211 |
| 5. | Los Pinos River near Ortiz | 6.25 | 1,840 |
| 6. | Rio Grande near Del Norte | 5.10 | 7,060 |
| 7. | Rio Grande at Thirty-Mile Bridge | 4.70 | 2,700 |
| 8. | South Fork Rio Grande at South Fork | 6.60 | 3,280 |
| 9. | Saguache Creek near Saguache | 4.50 | 540 |
| 10. | San Antonio River at Ortiz | 5.00 | 1,000 |
| 11. | Conejos River nr. La Sauses North Channel | 6.00 | 1,550 |
| 12. | Rio Grande near Monte Vista | 7.50 | 5,000 |

FLOOD WARNING NETWORK (cont.)

| | | ALERT LEVEL (FEET) | DISCHARGE (CFS) |
|---|---|---|---|
| **DIVISION 4 (Gunnison River Basin)** | | | |
| 1. | Cimmaron River near Cimmaron | 5.40 | 1,050 |
| 2. | East River at Almont | 7.00 | 3,000 |
| 3. | Gunnison River at Delta | 11.30 | 18,500 |
| 4. | Gunnison River near Grand Junction | 12.85 | 20,540 |
| 5. | Gunnison River near Gunnison | 5.00 | 5,760 |
| 6. | Muddy Creek above Paonia Reservoir | 7.90 | 2,680 |
| 7. | Muddy Creek below Paonia Reservoir | 7.20 | 2,580 |
| 8. | North Fork Gunnison River near Somerset | 7.25 | 7,000 |
| 9. | Surface Creek at Cedaredge | 3.20 | 590 |
| 10. | San Miguel River near Placerville | 6.00 | |
| 11. | Surface Creek near Cedaredge | 3.40 | 630 |
| 12. | Taylor River at Almont | 4.25 | 2,015 |
| 13. | Uncompahgre River at Colona | 5.00 | 2,970 |
| 14. | Uncompahgre River near Ridgway | 4.95 | 1,550 |
| 15. | Dallas Creek near Ridgway | 5.20 | 540 |
| **DIVISION 5 (Colorado River Basin)** | | | |
| 1. | Willow Creek below Willow Creek Reservoir | 5.30 | 1,260 |
| 2. | Colorado River at Hot Sulphur Springs | 4.65 | 4,200 |
| 3. | Williams Fork below Williams Fork Res. | 5.90 | 1,950 |
| 4. | Blue River below Dillon | 3.80 | 1,840 |
| 5. | Blue River below Green Mountain Reservoir | 9.10 | 2,820 |
| 6. | Eagle River below Gypsum | 8.80 | 5,850 |
| 7. | Colorado River near Dotsero | 11.70 | 16,120 |
| 8. | Fryingpan River near Ruedi | 3.70 | 1,240 |
| 9. | Fryingpan River near Thomasville | 4.20 | 1,290 |
| 10. | Rifle Gap below Rifle Gap Reservoir | 2.60 | 90 |
| 11. | Colorado River near Kremmling | 10.00 | 3,800 |
| **DIVISION 6 (Green River Basin)** | | | |
| 1. | Yampa River at Steamboat Springs | 6.00 | 4,500 |
| 2. | Yampa River near Maybell | 7.00 | 7,000 |
| 3. | White River near Meeker | 3.90 | 4,150 |
| **DIVISION 7 (Dolores and San Juan River Basins)** | | | |
| 1. | Rio Blanco below Blanco Diversion Dam | 4.37 | 1,000 |
| 2. | Navajo River below Oso Diversion Dam | 4.80 | 1,200 |
| 3. | Dolores River at Dolores | 6.40 | 4,050 |
| 4. | Lost Canyon Creek near Dolores | 6.10 | 500 |
| 5. | La Plata River at Hesperus | 3.88 | 800 |
| 6. | La Plata River at CO/NM State line | 3.60 | 800 |
| 7. | Mancos River near Mancos | 4.00 | 900 |
| 8. | Florida River above Lemon Reservoir | 3.90 | 1,000 |
| 9. | Florida River below Lemon Reservoir | 5.00 | 970 |
| 10. | San Juan River at Pagosa Springs | 8.00 | 7,620 |
| 11. | Animas River at Durango | 6.50 | 6,120 |

## III. OPERATING BUDGET

### SATELLITE MONITORING SYSTEM
### FY 91-92

| ITEM | BUDGET | ACTUAL |
|---|---|---|
| FIXED EXPENSES | | |
| I. PERSONNEL COSTS | $ 127,052 | $ 126,735 |
| II. OPERATING COSTS | $ 65,046 | $ 67,415 |
| A. Hardware Maint. Contracts | (3,541) | (3,775) |
| B. Telecommunications | (40,075) | (37,376) |
| C. Computer Operations | (2,200) | (1,990) |
| D. Scheduled Maintenance | (19,230) | (24,274) |
| III. INDIRECT COST ASSESSMENT | $ 2,922 | $ 7,882 |
| | $ 195,020 | $ 202,032 |
| VARIABLE EXPENSES | | |
| I. OPERATING COSTS | $ 27,332 | $ 25,128 |
| A. Travel and Per Diem | (8,900) | (8,616) |
| B. Training | (9,932) | (8,868) |
| C. Hardware Service | (2,000) | (3,494) |
| D. Other Operating Costs | (6,500) | (4,150) |
| II. CAPITAL OUTLAY | $ 27,930 | $ 27,697 |
| A. Hardware Replacement | (14,540) | $15,395) |
| B. System Enhancement | (13,390) | (12,302) |
| | $ 55,262 | $ 52,825 |
| TOTALS | $ 250,282 | $ 254,857 |

Notes:

1. The cost of the maintenance contract on the new VAX 4000-300 computer (installed in July, 1991) is incorporated into the purchase price, providing coverage for five years with a total savings of $75,480 over that period.

2. This amount exceeds the spending authority of $240,628 by $14,229. This was offset by supplementals of $12,368, including POTS and the health insurance supplemental which are not added to the spending authority limit. In addition, the Indirect Cost Assessment ($7,882) is also not included in the spending authority limit.

## SATELLITE MONITORING SYSTEM
## FY 92-93 (proposed)

| | | Projected |
|---|---|---|
| I. | Personnel Costs | $ 84,775 |
| II. | Operating Costs | |
| | A. Hardware & Software Maint. Contracts | $ 3,317 |
| | B. Telecommunications | $ 41,114 |
| | C. Computer Operations | $ 2,500 |
| | D. Hardware Service | $ 3.500 |
| | E. Required Maintenance | $ 26,700 |
| | F. Travel and Per Diem | $ 9,500 |
| | G. Training | $ 9,750 |
| | H. Other Operating Costs | $ 2,053 |
| III. | INDIRECT COST ASSESSMENT | $ 6,500 |
| IV. | CAPITAL OUTLAY | |
| | A. Hardware Replacement | $ 16,930 |
| | B. System Enhancement | $ 13,530 |
| | C. DRS Hardware | $ 25,000 |
| | TOTAL | $ 245,169 |

Indirect costs:

It is necessary to point out that certain indirect costs in operating the system are also realized. These indirect costs are absorbed by the Division of Water Resources. These costs for FY 92-93 are estimated as follows:

| | | |
|---|---|---|
| 1. | Manpower to maintain the monitoring network 7 Divisions/30 hrs. per mo. @ $14 per hr. | $35,280 |
| 2. | Travel costs to maintain remote data collection hardware | $14,000 |
| 3. | Office space and secretarial support @ $1,000 per month | $12,000 |
| 4. | Computer room and utilities for VAX 4000-300 @ $1,000 per month | $12,000 |
| 5. | Support from Information Services Branch 0.5 FTE (computer operator) | $17,800 |
| 6. | Administrative costs 0.35 FTE (Chief of Hydrographic Branch) | $23,370 |
| | TOTAL | $114,450 |

# IV. FUNDING SOURCES

## A. FY 91-92 FUNDING

One hundred ninety-eight thousand four hundred fourteen dollars ($198,414) was appropriated from the General Fund for the operation of the satellite-linked monitoring system for FY 91-92. A total of $240,628 was approved for total program expenditures. The remaining $42,214 was to be collected from user fees, pursuant to Section 37-80-111.5 (c), C.R.S. (1985 Supplement).

In FY 91-92, user fees amounting to $43,489 were collected as compared to $45,050 collected in FY 90-91 and $40,884 collected in FY 89-90. Interest on cash funds amounted to $4,012. The following is a summary of the fees collected in FY 91-92:

| | |
|---|---|
| Arkansas River Compact Commission | $8,000 |
| Dolores Water Conservancy District | $6,500 |
| City of Aurora | $5,800 |
| Colorado-Ute Electric Association | $4,800 |
| Aspen Consolidated Sanitation District | $3,200 |
| Pueblo Board of Water Works | $2,400 |
| Denver Water Department | $2,400 |
| Southwestern Water Conservancy District | $2,400 |
| Santa Maria Reservoir Company | $1,200 |
| U.S. Bureau of Reclamation | $1,200 |
| City of Thornton | $1,200 |
| Farmers Reservoir and Irrigation Company | $1,200 |
| Urban Drainage and Flood Control District | $1,200 |
| Denver Metro Sewage Disposal District #1 | $1,200 |
| Rio Grande Canal Water Users Association | $ 700 |
| Other revenues | $ 89 |
| TOTAL | $43,489 |

Total funds available for FY 91-92 amounted to $258,283. A summary of the funding is as follows:

| | |
|---|---|
| Fund Balance remaining from FY 90-91 | $ 21,377 |
| General Fund Appropriation | $198,414 |
| User Fees | $ 43,489 |
| Interest on Cash Funds | $ 4,012 |
| Other Appropriations (including POTS) | $ 12,368 |
| TOTAL | $279,660 |

Actual expenditures for FY 91-92 amounted to $254,857 leaving a fund balance of $24,803. The fund balance is an accumulation of unspent year-end funds going back to FY 85-86. The amount of fees collected in any given year varies. Fees are also received throughout the fiscal year rather than at the beginning of the fiscal year. Efforts are made so as to not overspend against available funds. In addition, a fund of $25,000 to $30,000 is considered desirable to handle possible emergency expenditures.

## V. COST-BENEFIT CRITERIA

It is estimated that the Colorado satellite-linked water resource monitoring system provides benefits to the State of Colorado amounting to between $1,337,000 and $1,505,000 per year. These benefits are increasing as the system becomes further assimilated into the statewide administration and management of water resources. Benefits will also increase dramatically during periods of water shortages. Since the cost to operate the system is $369,300 ($254,850 in direct costs and $114,450 in indirect costs), the net benefit to the State of Colorado is estimated between $968,000 and $1,136,000. If the original capital cost of the system and the 1991 expansion of approximately $1,900,000 are amortized over the last seven years, net benefits realized are between $696,500 and $865,000 per year.

Direct and indirect benefits are calculated as follows:

1. Approximately $5,300,000 per year is budgeted by the Office of the State Engineer for statewide water rights administration. If the operation of the satellite-linked monitoring system conservatively increases effectiveness by 10%, that equates to a benefit of $530,000 per year. Direct benefits are attained by water commissioners having more time for water administration and reduction in overtime to accomplish ever-increasing workloads. Indirect benefits relate to the ability to be more effective in water rights administration. This leads to greater co-operation among water users and fewer legal problems.
   Despite that fact that the number of water rights increased from 102,028 in 1982 to 124,994 in 1988 (increase of 23%), the number of water commissioners decreased from 94 to 93. These statistics indicate that based strictly upon the number of water rights, the number of water commissioners should have been increased by twenty-three. We must also consider the increased workload due to the growing complexity being incorporated into water rights administration. The monitoring system cannot be expected to replace the need for twenty-three additional water commissioners, but can compliment a moderate increase in water commissioners. If the system can potentially eliminate the need for ten additional water commissioners, savings may be an estimated $350,000 to $400,000 annually. The responsibility of water rights administration is a statutory responsibility given to the State Engineer. The necessary personnel and tools to carry out this responsibility must also be provided.

2. It is calculated that in an average year, between 42,000 and 56,000 acre-feet of water can be saved for use in Colorado through utilization of the system. At a conservative price of $12.00 per acre-foot of water, this amounts to between $504,000 and $672,000 per year. In years of water scarcity, the amount that is actually saved for may vary but the value of the water would naturally be higher.

3. Cost savings in the area of hydrologic records developed are calculated to be $106,080 per year.

a. Automated data processing and data entry
   210 stations/2 hours per month @ $14 per hour   $70,560

b. Data archiving and retrieval
   $1,000 per month   $12,000

c. Cost of lost data
   210 stations/8 hours per year @ 14 per hour   $23,520

4. Water resource accounting programs utilizing the system have been set up for the Dolores Project, the Colorado-Big Thompson Project, and the Fryingpan-Arkansas River Project. Savings are estimated to be 40 hours per month @ 14 per hour or $6,720 per year.

5. The benefits attributed to the system from flood warning are calculated to be $175,000 per year. if a real-time flood monitoring network of 50 stations is considered essential, and the operating cost for each station is $4,500 per year, this amounts to $225,000 per year.

6 An estimated $78,120 per year is saved in reduced manpower and travel costs in manually reading stream gages.

a. Manpower savings
   210 stations/8 hours per month @ 14 per hour   $23,520

b. Travel Savings
   210 stations/1 trip per week
   25 miles per trip @ $0.20 per mile   $54,600

## VI. SYSTEM USERS

The following is a list of users of the satellite-linked water resources monitoring system:

A. Office of the Colorado State Engineer

1. Division of Water Resources
   a. Division 1, Greeley
   b. Division 2, Pueblo
   c. Division 3, Alamosa
   d. Division 4, Montrose
   e. Division 5, Glenwood Springs
   f. Division 6, Steamboat Springs
   g. Division 7, Durango
   h. Central Office, Denver
   i. Water Commissioners

B. Water Conservancy Districts/Irrigation Districts

1. Southeastern Colorado Water Conservancy District
2. Lower South Platte Water Conservancy District
3. Colorado River Water Conservation District
4. Southwestern Water Conservation District
5. Dolores Water Conservancy District
6. Animas-La Plata Water Conservancy District
7. Florida Water Conservancy District
8. Northern Colorado Water Conservancy District
9. Rio Grande Water Conservation District
10. North Sterling Irrigation District
11. Central Colorado Water Conservancy District
12. Henrylyn Irrigation District
13. Mancos Water Conservancy District
14. Pine River Irrigation District
15. Aspen Consolidated Sanitation District

C. Municipalities

1. Denver Board of Water Commissioners
2. Pueblo
3. Colorado Springs
4. Durango
5. Alamosa
6. Westminister
7. Aurora
8. Thornton
9. Metropolitan Denver Sewage Disposal District #1

D. State Agencies

1. Division of Disaster Emergency Services
2. Colorado Water Conservation Board
3. Colorado Water Resources and Power Dev. Authority
4. Division of Wildlife

5. Department of Health
6. Division of Parks
7. Department of Highways

E. Federal Agencies
   1. Bureau of Reclamation
      a. Loveland
      b. Denver
      c. Grand Junction
      d. Albuquerque
      e. Montrose
   2. USGS - Water Resources Division
      a. Denver
      b. Pueblo
      c. Grand Junction
      d. Meeker
      e. Durango
   3. National Weather Service
      a. Denver
      b. Salt Lake City
      c. Washington, D.C.
   4. Corps of Engineers
      a. Omaha
      b. Albuquerque
   5. Soil Conservation Service
   6. Colorado-Kansas Arkansas River Compact Commission

F. Associations
   1. Rio Grande Water Users Association
   2. Urban Drainage District
   3. Arkansas River Rafters Association
   4. Trout Unlimited

G. Private Entities
   1. Fort Lyon Canal Company
   2. Santa Maria Reservoir Company
   3. Mutual Reservoir and Irrigation Company
   4. Farmers Reservoir and Irrigation Company
   5. Tri-State Generation & Transmission Ass., Inc
   6. Rio Grande Reservoir Company

H. WATERTALK

   Users estimated at 500-600

## VII. UTILITY OF THE SATELLITE-LINKED MONITORING SYSTEM WITHIN THE COLORADO DIVISION OF WATER RESOURCES

### A. Division 1, Greeley, Colorado, South Platte River Basin Alan Berryman, Division Engineer

The satellite-linked monitoring system has become an integral tool in daily water rights administration in Division 1. With increasing complexity in the administration of the South Platte River Basin, the system provides the key to effective decision making.

In past years, stream flow data needed for river administration was slow, if not impossible, to acquire because of the remote location of key gaging stations. Administration was difficult and time consuming to the water commissioner and to downstream water users. With the satellite monitoring system, comprehensive river data is available to the water commissioner allowing him to administer water rights on a timely and accurate basis without going to the gaging stations. This ability allows the water users to adjust more quickly to the changing conditions of the river system and expand the number of water rights able to divert and use water. The system allows the water commissioner to determine the river conditions largely on his own, not having to rely as much on data supplied by water users. This results in closer administration of water rights, potentially benefiting all water users of the area by assuring that the available supply of water is being diverted by the correct water right. Another advantage of the satellite monitoring system is that the water commissioner can release water downstream knowing that the amounts released reflect actual river conditions and won't have to be adjusted at a later date. The efficiency afforded to the water commissioner allows him to attend to more of his other duties which are ever increasing with the growth of the water rights system such as ground water administration.

With the satellite monitoring system data, the water commissioner can immediately evaluate river conditions both upstream and immediately above the senior rights. Subsequently, he can adjust diversions in his own district to satisfy the more senior rights or send a demand (call) to the upstream districts for more water to satisfy those rights early in the day. This is especially critical in administering water exchanges where it is important to know if and when water reaches points of replacement and what the intervening flow is.

The river can be run more efficiently simply as a result of the increased knowledge of the river conditions provided by the satellite monitoring system. The readily available knowledge of river conditions also provides the water commissioner with "evidence" that can be beneficial when interacting with water users that question administrative practices. The system makes it easier for the water commissioner to interact with other district water commissioners in receiving or passing water through his district. The ability to monitor diversions by some of the major irrigation diversions including the Burlington-Wellington Canal, the Union Ditch, the North Sterling Canal, the Lower Latham Ditch, and the Riverside Canal, is essential since the large amounts diverted by these ditches can have a significant effect on the flow of the South Platte river below Denver.

## B. Division 2, Pueblo, Colorado, Arkansas River Basin
**Steve Witte, Division Engineer**

The Satellite monitoring system has become essential for water rights administration throughout Division 2. This includes the administration of direct diversion rights, storage rights, transmountain diversion water, the Arkansas River Winter Water Storage Program, and the Arkansas River Interstate Compact. Division 2 covers a large and diverse geographical area with a number of major senior rights. It is an arid, water thirsty area that typically dries up the Arkansas River at several locations during the late irrigation season.

Division 2 staff use the satellite monitoring system to keep an accounting of transmountain diversions that are delivered to storage, storage by exchange, and routed to ditches in the Lower Arkansas River Valley. The system has been valuable in determining daily diversions in a timely manner for accurate accounting and delivery. An example involves the exchange of Colorado Springs' transmountain diversion water discharged into Fountain Creek for storage in Twin Lakes Reservoir.

The capability to monitor inflows and outflows of reservoirs with accuracy in a timely manner has helped in the administration and accounting of reservoirs in the division. The routing of natural stream flow and reservoir releases to storage or through a reservoir is difficult and takes constant attention to maintain proper discharge and storage. The system also helps in keeping close watch on reservoir releases so that we can determine the section of the river the release is in and prevent any diversion of these releases except by the ditch or ditches calling for the water. The Division Engineer routinely utilizes the system to track reservoir releases from Clear Creek Reservoir, Pueblo Reservoir, and John Martin Reservoir.

Another success of the satellite monitoring system is the real-time monitoring of exchanges of water. These exchanges allow irrigators, through the use of reservoir water, to irrigate when not in "priority" and are also vital for large municipalities such as Colorado Springs and Aurora to move water upstream in the Arkansas River Basin to a point where the water can be diverted to these cities. This use of the satellite monitoring system permits the maximum beneficial use of exchange water, which in both of the above cases, translates into real dollars for the water users.

Division 2 personnel have found the system to be an essential tool in setting the "river call." Flow conditions can vary dramatically in the period of hours rather than days due to diurnal effects of spring runoff, major tributary inflow, flash flooding from summer precipitation events, the effects of major irrigation diversions, and a high volume of imported water (transmountain diversions). The basin wide overview provided by the system on a real-time basis is a valuable tool for both short-term and long-term planning. This allows for maximum efficiency in putting Colorado water to beneficial use in Colorado. The system has been especially effective in setting the "river call" in the lower Arkansas River basin from Pueblo Reservoir to the state line.

The WATERTALK features of the satellite monitoring system is a valuable and time saving tool. In addition to its main purpose of allowing public phone access to water flow and storage levels, in Division 2, WATERTALK is also used to communicate the current "river call." This aspect of WATERTALK allows water users phone access to the current river call which saves Division 2 personnel time and provides much improved communication to water users which in turn prevents water disputes.

During periods of high stream flow and high storage in the reservoirs, the satellite monitoring system is used to control releases to avoid exceeding channel capacity. Reservoir inflow stations are in the system's monitoring network, as are major canal diversions. This capability provides valuable lead time so that administrative decisions can be made concerning stream flow routing through reservoirs relative to standard operating procedures. These decisions affect water administration in the entire basin.

Within the past several years, temperature sensing instruments and precipitation instruments were installed at some locations, and are monitored by the satellite system. More are to be installed in the future. Data from these and other instruments are used to warn of floods, monitor snowpack, assist in computing flow records, and calculate snow melt. Water quality parameters data, sediment samples, wind speed data, and other information is being collected at some sites. Within the past year to 18 months, satellite monitoring equipment has been installed by the Colorado Division of Water Resources at these stations:

Arkansas River at Salida
Cucharas River near La Veta
Arkansas River near Rocky Ford
Grape Creek near Westcliffe

In cooperation with the Pueblo Board of Water Works, satellite monitoring equipment has been installed at these stations:

Arkansas River at Granite
Wurtz Extension Ditch
Clear Creek Reservoir
Clear Creek below Clear Creek Reservoir

Cooperation between Division 2 and other agencies, municipalities, and the public has steadily increased the past 5-6 years. At numerous stream flow stations, Division 2 shares instruments, shelters, and the hydrologic data collection effort with the U.S. Geological Survey (USGS). Daily stream flow reports are given to the USGS and U.S. Bureau of Reclamation. At several locations, Division 2 and the City of Colorado Springs, City of Aurora, Pueblo Water Works, cooperate in instrument operation and in hydrologic data and collection. The Southeast Colorado Water Conservancy District and some of the Federal agencies continue to observe and use the information provided by the system. Daily satellite monitoring system information is given to some of the southeast Colorado newspapers and radio stations.

The satellite monitoring system is used to collect basic data for use in developing hydrologic records. The data is analyzed to provide stream flow quantities for annual publications and for daily, monthly, and other time periods. Annual maximum and minimum flows. base flows, travel time, and means are but a few of the other hydrographic statistics which can be determined through the system's use. The system is also used to indicate problems at stream flow stations so that records are improved through more timely maintenance and repair.

**C. Division 3, Alamosa, Colorado, Rio Grande Basin
Steve Vandiver, Division Engineer**

Due to the complexity of the administration of the Rio Grande Compact, the San Luis Valley was the first drainage basin in Colorado to receive satellite-linked monitoring sites during the summer of 1984. During the time the system has been in place, the annual runoffs in the Rio Grande Basin have gone from one extreme to the other; therefore, the utilization of satellite-linked monitoring system has also varied considerably. Water years 1985-87 were high runoff years and the satellite system was used extensively to monitor flooding conditions on the Rio Grande and Conejos rivers. Water years 1988-91 have been low runoff years and have created drought conditions in the basin. Due to the spill of Elephant Butte Reservoir in New Mexico during water years 1985-88, Colorado was exempt from some of the tough constraints imposed by the Rio Grande Compact. Drought conditions forced Division 3 personnel to return to strict Compact administration during the 1989-91 irrigation seasons. The Rio Grande Compact obligation was met early during the 1991-92 irrigation season due to an above average snow pack on the valley floor. The satellite monitoring system was extensively utilized to administer senior water rights on the lower end of the system while minimizing over delivery to the state line. The satellite monitoring system has become an integral part of daily water rights administration, and is a valuable tool to ensure compliance of the interstate compact.

Division 3 currently maintains 32 satellite sites. These included 23 stream gaging stations, 6 reservoirs, 2 canals, and one transmountain diversion. Of the 32 satellite stations, 23 are owned by the Colorado Division of Water Resources, 5 by private irrigation companies and water users, 2 by the Colorado Division of Wildlife, 1 by the United States Bureau of Reclamation, and 1 by the Great Sand Dunes National Monument.

The main use of the satellite monitoring system in fiscal year 1991-92 was to aid Division personnel in the daily administration of the Rio Grande Compact and decreed water rights in the San Luis Valley.

The Rio Grande Compact requires Colorado to deliver a specific percentage of the annual flows recorded at the upper index gages on the Rio Grande and Conejos rivers to the New Mexico/Colorado state line. Even though the Conejos is tributary to the Rio Grande, the Compact requires a separate delivery schedule for each river, which adds to the complexity of the administration. The satellite monitoring system enables our staff to monitor the flows and major diversions on a daily basis which helps minimize the amount of over delivery at the state line for each river system. The Rio Grande and Conejos systems are also each credited with a portion of the water introduced to the river by the Bureau of Reclamation's Closed Basin Project. The Closed Basin Project deliveries are measured using a twelve-foot Parshall flume which is also tied into the satellite-linked monitoring system. By accurately crediting each river system with flows delivered to the lower index gaging stations, the water users are able to help meet their Compact obligations with Closed Basin Project water which enables them to use more native stream flow for irrigation on the upper reaches of their systems. The station on Platoro Reservoir (Bureau of Reclamation) and the gaging station below Platoro Reservoir (Division of Water Resources) on the Conejos River are used on a daily basis to account for water purchased by the Conejos water users from the Conejos Water Conservancy District.

The Satellite monitoring stations have become an integral part of the daily administration of water rights in Division III. Of the eight water districts in Division III, five have installations utilizing the satellite monitoring system. Each morning the water commissioners access data from the computer in Denver to determine how much water is available for delivery to decreed water rights. The availability of this data via personal computers or from WATERTALK has had a profound effect on how our commissioners make daily administrative decisions. The ability to monitor reservoir releases and changing river conditions on a real-time basis results in better management and utilization of the resource.

Once again, the stream flow record development system was utilized extensively for 1991-92 water year records. All of the annual flow records for the 23 stream gages, Tabor Ditch (transmountain diversion), and the Closed Basin Project Canal were computed by our hydrographic section using the record development system. Fourteen of these records are published by United States Geological Survey. In addition to the annual stream flow records, the record development system is used on a 10-day and monthly basis to monitor compliance with the Rio Grande Compact.

Additional uses for the system have become apparent, For example, we regularly use the system to answer questions about flows at particular gages or reservoir contents. These inquiries are from private citizens, federal agencies, and state agencies. Also, historic data stored in Denver can be retrieved and plotted in the Division office to give visual representations of flows. These plots are extremely useful for public meetings, studies, and presentations. Likewise, air temperature probes installed on selected sites have been a very useful tool for estimating winter flows at stream gaging stations.

Not a day goes by that the data collected by the satellite monitoring system isn't used. Whether it's monitoring river flows, reservoir contents, Compact administration, or the development of hydrographic records the satellite monitoring system has increased productivity and has made data more readily available to the public and to our staff.

D. Division 4, Montrose, Colorado, Gunnison River Basin
Keith Kepler, Division Engineer

The satellite monitoring system has become an extremely useful tool in the daily administration of water rights in Division 4. The system provides the real-time data necessary for meaningful water resources accounting, flood monitoring, dam safety and hydrologic records development. In 1991-92 Division 4 has made several additions to its satellite monitoring system in order to better manage the available water resources. These additions to the system were funded out of Water and Power Authority funds pursuant to the legislature's resolution approving this use of funds. The additions include three new measurement sites. The first location is the Uncompahgre River at Olathe, Colorado (UNCOLACO). This location is below the East Canal which is operated by the Uncompahgre Valley Water Users Association (UVWUA). This is the lowest point to which water is delivered from the various sources available to the demands of the UVWUA. These sources include trans-basin water from the Gunnison River (both direct flow and storage), water from Ridgeway Reservoir, and administration of upstream junior rights. Knowing the flow at this point helps to make best use of available supplies.

The second site which was added was the Big Ditch near Cedaredge. The Big Ditch carries water to Surface Creek from several other creeks. Much of the water so delivered is storage water which is very valuable to the apple growers. Having the Big Ditch on the satellite helps to manage the water in this highly over-appropriated area.

Another new site in the past two years is the Kannah Creek gage. Kannah Creek is the source of supply for the City of Grand Junction as well as many irrigators. It is highly over-appropriated. Diurnal fluctuations in supply in the early season and reservoir deliveries later in the year require considerable attention to timing of changes in headgate and reservoir releases. Real time data at the top of the creek is a great aid in administering this water.

The availability of real-time data provides for administering direct flows to maximize beneficial use. This is critical in Division 4 where the senior water rights are generally downstream of junior water rights. A timely knowledge of the amount of water available allows delivery to junior water rights while assuring senior users of their entitlement. During the runoff season with large diurnal variations in flow, real-time knowledge of the water supply allows serving a maximum number of users.

Real-time data is useful in separating natural flow from reservoir releases at a point in the stream system. Examples of this application exist at the reservoirs on Muddy Creek and the Uncompahgre River. Satellite-linked gaging stations above and below each reservoir monitor inflows, and storage and outflows. This information allows the Division Engineer and his staff to regulate the operation of the reservoirs and differentiate reservoir water from direct flow for proper deliveries.

A benefit of the satellite monitoring system is in operations cost reduction. Like water, operating funds are in short supply. The real-time data provided by the satellite system has served to hold down man hours and travel costs associated with the administration of a growing and complex set of water rights.

Currently, Division 4 is participating in developing daily accounting spreadsheets for the Gunnison River in cooperation with the Colorado River Water Conservation District, Colorado Water Conservation Board, U.S. Bureau of Reclamation, Upper Gunnison Water Conservancy District, Uncompahgre Valley Water Users Association, and Tri County Water Conservancy District. One of the anticipated outcomes of this effort will be to better identify real-time data requirements for flows on the Gunnison River in light of need for increased water management and administration resulting from new demands for instream flows, endangered fish flows, reserved water rights, hydro-electric power, sophisticated augmentation and exchange plans, etc.

**E. Division 5, Glenwood Springs, Colorado, Colorado River Basin Orlyn Bell, Division Engineer**

The utility of the satellite monitoring system in the Colorado River basin is still developing. As the only major river basin in Colorado that has significant amounts of unappropriated water, the system is becoming a powerful planning tool in the area of water resources development. The Colorado Front Range has numerous transmountain diversions from the Colorado River Basin currently operating, with several others on the drawing board. The resurgence of the oil shale industry could put added demand on the available supplies.

The Colorado River accounting system is a necessary tool for the administration of a mainstem call. It can determine which structures are in and/or out of priority, which owe the river, and what reservoir releases should be made for transmountain diversions, west slope depletions, and augmentation replacement. Key components of the real-time monitoring network include stations that monitor the operations of Green Mountain Reservoir and the gages at the key calling points on the Colorado River.

The initial step in this process is the assimilation of data for direct diversions, stream flow, reservoir contents, evaporation, and precipitation. Once the data are entered into a spread sheet, needed diversion or storage adjustments can be made. The remainder are obtained from the satellite monitoring system. Although a small percentage of a water commissioner's structures are monitored by the system, those monitored are the majority of the ones most critical to a mainstem call, the largest, and the most likely to change from day to day. The real-time data allow us to track the river and anticipate an upward or downward trend in the river. We can reduce the lag time between a shortage or rise in flow and the corresponding adjustment to the river call. This increases the effectiveness and the efficiency of administration and saves water during critical periods.

Administration of the Blue River involves tracking a paper fill in Green Mountain Reservoir, accounting for transmountain diversions and power interference, out-of-priority replacement from a separate basin, and upstream exchanges. The system is valuable not only for its real-time data, but also for the daily, monthly, and annual data stored in the archives.

**F. Division 6, Steamboat Springs, Colorado, White/Yampa River Basin**
**Ed Blank, Division Engineer**

The administration of water rights in Division 6 is complicated, not as much by demand, as by limited manpower resources and geographic diversity. The increasing number of complex changes to old water rights and many new water rights approved by the Water Court, have forced the Division into finding more efficient means to use our limited manpower resources. The use of the satellite monitoring system has provided a valuable increase in the efficiency of administrative efforts of this office. Division 6 personnel use the system to obtain real-time stream flow data for critical water right administration purposes, monitor compliance with the Colorado River and Upper Colorado River Compacts, track storage releases from Stagecoach Reservoir. and monitor compliance with the Supreme Court Decree in Nebraska v. Wyoming and Colorado.

Monitoring releases from Steamboat Lake for the Endangered Fish Recovery Program required installation of system equipment in the Yampa River Station below Craig (moved from Bear Creek near Toponas). In cooperation with the Colorado Division of Parks and Outdoor Recreation, and the U.S. Fish and Wildlife Service, a new station to further improve our monitoring capability is in the planning stages on Willow Creek below Steamboat Lake. Additional changes in the historic use of water within the Division may require installation of equipment at additional stations.

WATERTALK is an economical way for water commissioners to obtain information from the system. It is estimated that obtaining real-time data via telephone rather than actually traveling to the station, saves Division 6 approximately $4,000 per year. Providing WATERTALK system access to water users enables Division personnel to spend more time on administrative responsibilities. Although system utilization and benefits may not match that of the front range Divisions, the day-to-day operation of Division 6 would be hampered if the system were to be lost. Much of the data in the Division comes from U.S.G.S. equipped monitoring stations and recent modifications to the system seems to have resolved the problem of lost data.

**G. Division 7, Durango, Colorado, San Juan and Dolores River Basins**
**Ken Beegles, Acting Division Engineer**

The satellite monitoring system is being effectively utilized in Division 7 for water rights administration, reservoir management, water resources accounting, and flood monitoring. The benefits of the system have reached the majority of water users in this Division. Our monitoring network is unique in that the stations are located in a stream drainage which consists of separate and individual but large streams which exit the state without becoming a single administrative unit as in the other Divisions.

The McPhee Reservoir and Dolores Project administration is not as yet totally functional since the project is not complete, although there are 6 monitoring stations in operation. The La Plata River Compact is probably our most extensive present use and it is being used on a daily basis at several sites. The San Juan-Chama Project subnetwork has been effective in monitoring the Bureau of Reclamation operations, and the Lemon Reservoir subnetwork was quite helpful this past season to adjust reservoir releases.

The satellite monitoring system is being utilized for daily water rights administration relative to the Dolores Project. This includes administering allocations to the Montezuma Valley Irrigation District, Mountain Ute Indian Tribe, City of Cortez, and the Dove Creek Canal. The Division Engineer and the manager of the Dolores Water Conservancy District utilize the system in the operation of McPhee Reservoir. A water resources accounting system for the Dolores Project incorporates real-time data from 6 satellite monitoring stations.

The La Plata River Compact is administered on a daily basis by the Division Engineer and the District 33 water commissioner utilizing the satellite monitoring system. The water commissioner is able to access the system's data base at any time utilizing a portable computer terminal. An upstream station provides stream flow data necessary for advance planning. These conditions are typically dynamic. Early morning flows can be used to predict anticipated daily flows. Diversions are adjusted to allow for maximum daily usage yet meeting compact requirements. Dry conditions experienced in late summer and early fall required precise and prompt delivery of irrigation water to Colorado users. A station at the Colorado-New Mexico state line gives data on actual deliveries. Additional stations were added to the Pioneer Ditch at the Colorado-New Mexico state line and to the Enterprize Ditch near the Colorado-New Mexico state line to aid in the administration of the La Plata River compact. The flow at both stations is added to the flow at the La Plata River at the Colorado-New Mexico state line to determine the total flow delivered to New Mexico as required by the compact. Another station was installed on Hay Gulch above Red Mesa Ward Reservoir. The water commissioner utilizes this real time data to determine both direct flow and storage releases from the reservoir in an effort to maximize Colorados' use of its compact entitlement.

Through the use of the satellite monitoring system, the water commissioner can operate the La Plata River on a real-time basis. He can observe the changes occurring at Hesperus and the state line, and in turn, direct the diversions or curtailment of ditches in Colorado to meet the compact needs. We have found that the real-time data have greatly enhanced our ability to administer the La Plata River and are of the opinion that there has been an increase in the amount of water available to Colorado users through the prompt administration of the stream. This office has realized significant savings in travel and manpower relative to this task.

Four monitoring stations are being operated for the benefit of administering the San Juan-Chama Project and the associated interstate compact. The compact provides for the diversion of up to 1000 cfs into New Mexico. The network includes a monitoring station on the Azotea Tunnel outlet near Chama, New Mexico. The Division Engineer and the San Juan-Chama Project Manager coordinate the operation of the project utilizing real-time data. Both have access to the system's data base. Currently an upstream gage is being operated at Banded Peaks Ranch on the Navajo River.

The satellite monitoring system is being utilized in the daily administration of Lemon Reservoir on the Florida River. Two monitoring stations, one above the reservoir and one below the reservoir, provide real-time data used to account for storage, delineating natural flow from storage releases, and for flood control. Diurnal inflow conditions are flattened through controlled releases.

We were able to utilize the historic data records to make tabular and graphical presentations to public groups showing effects of various water right's demands on the La Plata and Florida Rivers. These data were assembled using the Hydromet applications software.

System improvements have been made at several locations with the installation of air temperature gages. La Plata River at Hesperus and the La Plata River at the Colorado-New Mexico state line and Navajo River at Banded Peak Ranch had air temperature sensors added this year to assist in Winter flow estimates and to give an indication of snow melt flows in the spring runoff season.

# VIII. DEFINITION OF TERMS

## NOMENCLATURE FOR STATION NAMES

Station names have been abbreviated to eight characters. The first three characters identify the river basin, the second three characters identify the station location, the last two characters identify the state. Example: The monitoring station, Colorado River near Dotsero, Colorado, is abbreviated COLDOTCO.

## DIVISIONS

The Office of the Colorado State Engineer, Division of Water Resources, is divided statutorily into seven divisions for purposes of water rights administration. The seven divisions coincide with the seven major drainage basins in Colorado. Each division has a central office administered by a Division Engineer.

Division 1, Greeley, Colorado, South Platte River Basin
Alan Berryman, Division Engineer

Division 2, Pueblo, Colorado, Arkansas River Basin
Steve Witte, Division Engineer

Division 3, Alamosa, Colorado, Rio Grande Basin
Steven Vandiver, Division Engineer

Division 4, Montrose, Colorado, Gunnison River Basin
Keith Kepler, Division Engineer

Division 5, Glenwood Springs, Colorado, Colorado River Basin
Orlyn Bell, Division Engineer

Division 6, Steamboat Springs, Colorado, White/Yampa River Basin
Ed Blank, Division Engineer

Division 7, Durango, Colorado, Dolores and San Juan River Basins
Ken Beegles, Acting Division Engineer

## DISTRICTS

The Office of the State Engineer, Division of Water Resources, divided the state of Colorado into eighty districts for purposes of water rights administration on a smaller geographic area than a division. District administration is carried out directly by the designated water commissioner.

## RIVER CALL

The "river call" refers to a date in the water rights appropriation records where water rights senior to that date may continue to divert their water rights. Water rights junior to that date may not be exercised. The "river call" reflects the availability of water to satisfy those senior water rights for a district or districts. A call is placed by a water right owner when his or her right is not receiving the water to which they are entitled.

## FREE RIVER

A "free river" designation exists when the availability of water exceeds the demand of active water rights.

## INDEX STATION

A key gaging station that determines the availability of water for establishing the "river call" or determines the water to be delivered under a compact agreement.

## FLOW AND VOLUME CONVERSIONS

Real-time discharge values, as listed in DAYFILES, are instantaneous values in cubic feet per second (cfs).

Daily discharge values, as listed in ARCHIVES, are mean values computed from 96 real-time measurements, and are in cubic feet per second (cfs).

Daily content values, as listed in ARCHIVES, are mean values computed from 96 real-time measurements, and are in acre-feet.

## COMMON WATER CONVERSION FACTORS

one cubic foot per second equals one cubic foot of water passing a point in one second of time.

one acre foot equals the quantity of water required to cover one acre of land one foot deep.

## VOLUME

1 acre-foot = 325,851 gallons
1 acre-foot = 43,560 cubic feet
1 cubic-foot = 7.4805 gallons
1 cubic foot/second = 448.8 gallons/minute
1 cubic foot/second = 646,317 gallons/day
1 cubic foot/second = 86,400 cubic feet/day
1 cubic foot/second = 1.9835 acre-feet/day

**VOLUME cont.**

1 cubic foot/second = 723.96 acre-feet/year
1 million gallons/day = 1.547 cubic feet/second
1 million gallons/day = 3.07 acre-feet/day

**TIMES**

Times given are local time based on a 24-hour clock.