UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

COMPARISON OF AUTOMATED SATELLITE SYSTEMS WITH CONVENTIONAL SYSTEMS FOR HYDROLOGIC DATA COLLECTION IN WEST-CENTRAL FLORIDA

By W. M. Woodham

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ABBREVIATION AND CONVERSION FACTOR

Factor for converting inch-pound unit to International System (SI) unit and abbreviation of unit

Multiply inch-pound unit	By	To obtain SI (metric) unit
mile (mi)	1.609	kilometer (km)

GLOSSARY

ADR.--Analog-to-Digital Recorder; a recorder that punches data values as binary coded digits on paper tape at preselected time intervals for digital computer processing.

Analog.--Graphical or electrical representation of variations in quantities such as voltages, resistance, water levels, etc.

CDCP.--Convertible Data Collection Platform; a battery-powered telemeter that transmits data from a remote field site to a geostationary or polar orbiting satellite for relay to a ground-receive site.

DARDC.--Device for Automatic Remote Data Collection; a battery-powered telemeter that transmits observed field data from a remote site when interrogated either by telephone or radio link.

DCP.--Data Collection Platform; a battery-powered telemeter that transmits observed field data from a remote station to a polar orbiting satellite for relay to a centrally located ground-receive site.

GOES.--A Geostationary Observational Environmental Satellite operated by the National Oceanic and Atmospheric Administration (NOAA). The satellite used in this study is in orbit above the Earth's equator at an altitude of about 22,000 miles and remains continuously over the same point on the Earth.

Ground-receiving station.--A communications facility that receives, records, and relays information from a satellite.

HYDRECS.--Hydrologic Data Real-time Computer Processing System. Data received via satellite relay are entered into WATSTORE for near real-time processing. HYDRECS also provides reference and performance information about field sites that are transmitting data for satellite relay.

Land line.--Standard or dedicated telephone line that provides direct two-way communication between two points.

National Center computer system.--The U.S. Geological Survey computer system at Reston, Va. The National Center water-data files are accessible to various Survey District offices by terminal connection.

Real-time data.--Real-time data values are immediately available to users.

Redundant data.--Data transmitted from a field site telemeter that were included in a previous transmission.

ROMP.--Regional Observation and Monitor-Well Program; a program administered by the Southwest Florida Water Management District to provide an integrated, District-wide network of hydrologic data collection for ground-water wells.

Sensor.--A gage or other detection device that measures change in hydrologic variables or parameters.

Telemeter.--A device that transmits digital or digital encoded data from one point to another. The CDCP is a telemeter that is battery powered and transmits data from ground-based sensors to the GOES satellite on specially assigned frequencies.

WATSTORE.--The Geological Survey's National Water Data Storage and Retrieval System located at the National Center in Reston, Va.

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ABSTRACT

This report provides results of reliability and cost-effective studies of the GOES satellite data-collection system used to operate a small hydrologic data network in west-central Florida. The GOES system, in its present state of development, was found to be about as reliable as conventional methods of data collection. Benefits of using the GOES system include some cost and manpower reduction; near real-time data availability; and direct computer storage and analysis of data. The GOES system could allow annual manpower reductions of 19 to 23 percent with reduction in cost for some and increase in cost for other single-parameter sites, such as streamflow, rainfall, and ground-water monitoring stations. Manpower reductions of 46 percent or more are possible for multiple-parameter sites. Implementation of expected improvements in instrumentation and data handling procedures should further reduce costs.

INTRODUCTION

West-central Florida is an attractive area for development because of its moderate climate and waterfront property. Urban developments are under construction, many in low-lying, flood-prone areas. These developments are producing increased stresses on the hydrologic system. As a result, water managers are developing programs to protect and conserve water resources and protect residents from flood hazards. Hydrologic data are needed to support these new programs. To meet these needs, data-collection networks are being expanded, and data-collection and processing methods are being improved so that current data can be available on a near real-time basis.

In 1972, the U.S. Geological Survey began experimenting with satellite telemetry in search of cost effective means of meeting increasing data-collection needs. An automated data-collection system, using satellite relay of field data directly to a centralized computer, would provide the following benefits:

(1) cost reductions;

(2) manpower reductions;

(3) minimized data losses;

(4) near real-time data availability;

(5) increased systems reliability;

(6) direct computer storage of data and automatic computer processing, analysis, and reporting;

(7) possible automatic warning of potential hazards or problems.

In 1976, the Geological Survey in Tampa entered into a cooperative program with the Southwest Florida Water Management District to evaluate the feasibility of using land-line and satellite telemetry in data-collection activities. During the first-phase study (September 1976 to May 1978), one land-line (DARDC) site, one GOES (CDCP) site, and two Landsat (DCP) sites were operated for testing and evaluation. The results were reported by Turner and Woodham (1979).

The program was continued into a second phase (June 1978 to September 1979) for evaluating cost effectiveness of using the GOES system to operate data networks. Five additional GOES sites were established, and evaluation and testing were continued for the land-line and Landsat sites. The Landsat satellite, operated by National Aeronautics and Space Administration (NASA), and the GOES satellite, operated by National Oceanic and Atmospheric Administration (NOAA), were used in these studies.

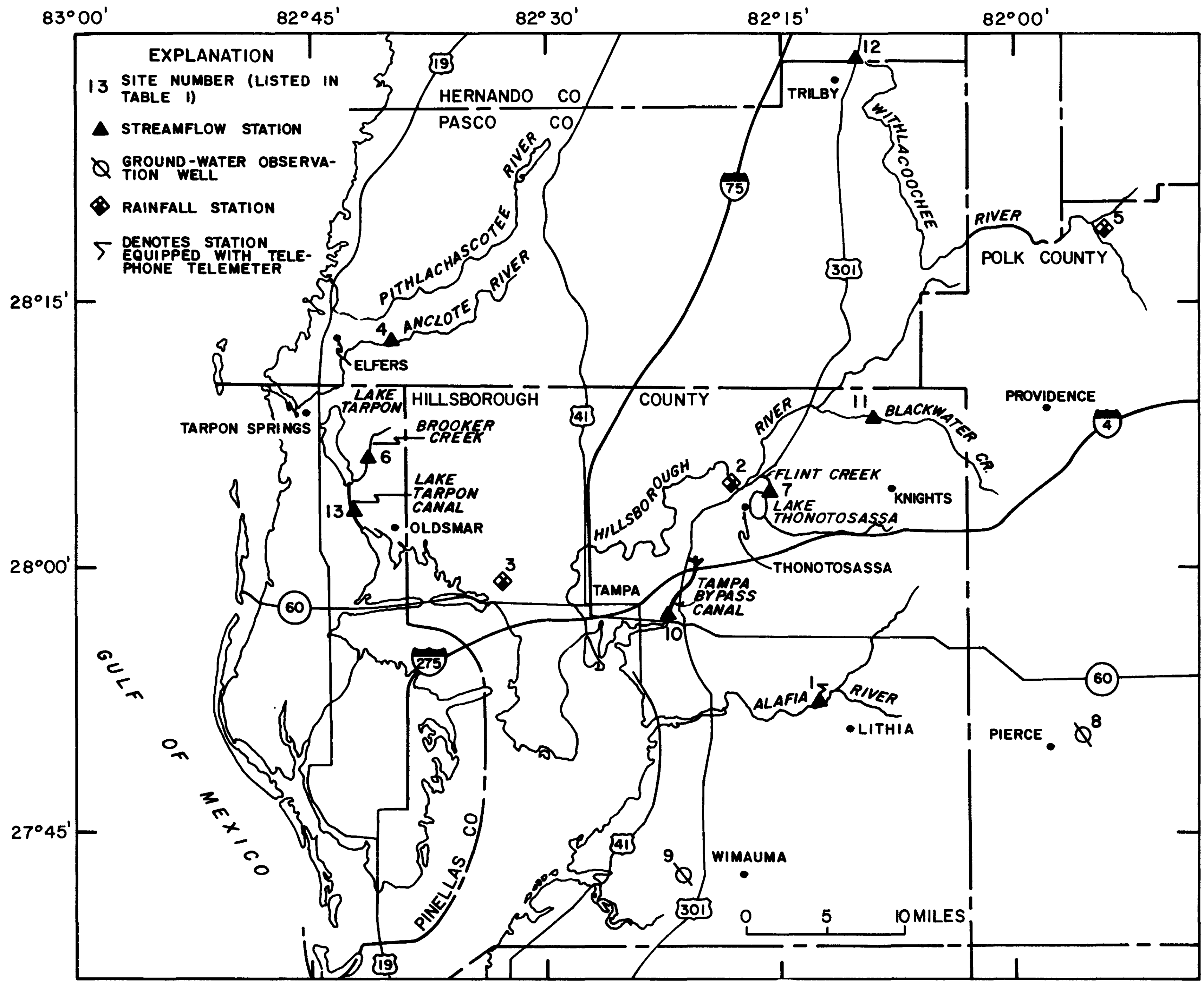
The data-collection sites used in the study are listed in table 1 and locations are shown in figure 1. The GOES data network evaluated in this study consists of two streamflow, two rainfall, and two ground-water stations. The streamflow sites are Brooker Creek near Tarpon Springs (site 6, fig. 1), located in a relatively flat basin with a low flood plain, and Flint Creek near Thonotosassa (site 7, fig. 1), located at a flood-control structure at the outlet of Lake Thonotosassa. The rainfall sites are Nature's Classroom rainfall near Thonotosassa (site 2, fig. 1), located near the Hillsborough River, a stream that is the major water-supply source for the city of Tampa, and Rock Ridge rainfall near Providence (site 5, fig. 1), located in a swamp that is a major recharge area. The ground-water monitoring sites are Pebbledale Road deep well near Pierce (site 8, fig. 1), located in a mining area, and ROMP 50 deep well near Wimauma (site 9, fig. 1), a regional monitor well located near a well field.

The GOES data network was modified in 1980. Several streamflow stations where flood-warning information was needed were added to the network, including Anclote River (converted from Landsat), Tampa Bypass Canal at Structure 160 near Tampa, Blackwater Creek near Knights, Withlacoochee River at Trilby, and Lake Tarpon Canal at Structure 551 near Oldsmar. Discontinued GOES stations included Brooker Creek, Flint Creek, Pebbledale Road well, and ROMP 50 well.

PURPOSE AND SCOPE

The purpose of this report is to provide results of the second-phase study, including determinations of cost effectiveness and reliability of the GOES system in operating data-collection networks in west-central Florida. Cost effectiveness is evaluated by determining the need for manpower and cost for the GOES system compared with manpower and cost required for conventional systems. The reliability of the GOES system is determined by the percentage of acceptable stage record obtained.

Results of continued land-line and Landsat system testing during the second phase study are not included because these results are not significantly different from those obtained in the first phase study (Turner and Woodham, 1979). In addition, the land-line system is conducive to small networks and the Landsat system no longer supports the data-collection system.



Base from US Geological Survey, State of Florida map, 1:500,000.

Figure 1.--Location of telemetry sites, 1976-80.

Table 1.--Telemetry sites

Map site number 1/	Station ID number and name	Location	Type of unit	Type of data monitored
1	02301500 Alafia River at Lithia	At State Highway 640, Hillsborough County	DARDC	Stage
2	280510082200000 Nature's Classroom rainfall near Thonotosassa	Hillsborough River 6.4 miles downstream from Flint Creek, Hillsborough County	CDCP	Rainfall
3	275916082325100 Rainfall at Eisen-hower Boulevard, near Tampa	4710 Eisenhower Boulevard, Tampa, Hillsborough County	DCP	Rainfall
4	02310000 Anclote River near Elfers	At State Highway 54, Pasco County	DCP	Stage
5	281833081542500 Rock Ridge rainfall near Providence	Rock Ridge, northern Polk County	CDCP	Rainfall
6	02307359 Brooker Creek near Tarpon Springs	Tarpon Woods, Pinellas County	CDCP	Stage
7	02303300 Flint Creek near Thonotosassa	At Lake Thonotosassa, Hillsborough County	CDCP	Stage
8	275009081540901 Pebbledale Road Deep Well near Pierce	Near Pierce, Polk County	CDCP	Water level
9	274240082212701 ROMP 50 Deep Well near Wimauma	Sun City Center, Hillsborough County	CDCP	Water level
10	02301802 Tampa Bypass Canal at structure-160 near Tampa	Upstream from State Highway 60 at 78th Street, Tampa, Hillsborough County	CDCP	Stages above and below control struc-ture; and gate opening
11	02302500 Blackwater Creek near Knights	At State Highway 39, Hillsborough County	CDCP	Stage

Table 1.--Telemetry sites - Continued

Map site number 1/	Station ID number and name	Location	Type of unit	Type of data monitored
12	02312000 Withlacoochee River at Trilby	At U.S. Highway 301, Hernando County	CDCP	Stage
13	02307498 Lake Tarpon Canal at structure-551 near Oldsmar	Upstream from State Highway 586, Pinellas County	CDCP	Stages above and below control structure; and gate opening

Sites 1-9 in operation during study period.
Sites 2, 3, 6-9 discontinued in 1979.
Site 4 converted to CDCP in 1980
Sites 10-13 installed in 1980.
DARDC - Device for automatic remote data collection operated with existing telephone lines.
DCP - Data collection platform operated with Landsat orbiting satellite.
CDCP - Convertible data collection platform that can be operated with either Landsat or GOES systems.

1/ Map site number refers to station locations shown in figure 1.

CONVENTIONAL HYDROLOGIC DATA MONITORING SYSTEMS

The Survey collects and processes a variety of hydrologic data in accordance with prescribed methods and quality assurance standards. Methods used depend on use and variability of data. For some uses, a single observation may be adequate, whereas a nearly continuous record may be required for other uses. For example, streamflow may vary widely from day to day, particularly during flood periods, and require virtually continuous stage record. Similarly, streamflow releases below flood-control structures are subject to large changes and require nearly continuous monitoring. In areas undergoing rapid development, water levels in wells may fluctuate widely and rapidly, and nearly continuous water-level records may be required. On the other hand, water-surface elevations of most lakes and water levels of ground-water wells change gradually, and periodic measurements are adequate to monitor these changes. In some instances, current data are needed on a near real-time basis for regulatory purposes.

Hydrologic records for sites where rapidly changing conditions prevail are usually obtained with graphic or digital recorders. Records at other sites may be obtained from periodic readings by an observer. At most sites, only one hydrologic parameter is monitored, whereas at other sites, records of more than one parameter are collected. Single-parameter sites include most streamflow, lake, rainfall, and ground-water monitoring stations. Multiparameter sites include streamflow at flood-control structures, rainfall-runoff stations in urbanizing watersheds, and water-quality stations at critical sites, such as streams near public water supplies.

Records obtained by observers generally include a data value, date, and time of observation. The information is recorded on cards and mailed to the local Survey office. Similar records may also be obtained by Survey employees when visiting field sites. Observer data are reviewed and transcribed onto computer cards in a machine readable format.

Some multi-gate control structures have operators or observers who record gage and gate-opening data directly on a graphic chart or operator's log. The graphic record and log of gate-opening changes is used for manual computations of mean daily gage heights and discharge. Gage heights and discharge are then transcribed onto computer cards in a machine readable format. These special manual computation methods are all time consuming and require systematic checking.

Instruments used for obtaining hydrologic records include graphic and analog-to-digital recorders (ADR). Graphic records consist of a continuous trace of the hydrologic parameter with respect to time. Graphic records are generally visually interpreted and manually transcribed onto computer cards and entered into the WATSTORE files at the National Center computer system through terminal connection. Data in the WATSTORE files are reviewed periodically to assure accuracy.

In west-central Florida, the Survey currently uses the ADR almost exclusively at sites where nearly continuous records are required. The ADR record, a paper tape on which encoded data values are punched at a selected time interval, such as 15 minutes or an hour, is reviewed and prepared for transmission to the National Center computer system. Special programs are used to translate, edit, format, and store the data in appropriate water-data files.

Field and office effort required for collection and preliminary processing of streamflow records used in the study are shown in table 2. Inspection of a field station requires ADR servicing (removing record, replacing batteries, replacing paper supply, reading reference gages, making minor adjustments, and restarting ADR), nonroutine visits to collect current data, and measuring discharge. Average time required per station is 30 hours per year. In this study, an average of 12 visits per year (monthly) was used for comparative purposes. Daily monitoring afforded by the GOES system allows scheduling of field visits to coincide with hydrologic conditions. Preliminary office effort includes manual review of ADR record, preparing instructions for translating and transmitting the record to the National Center computer system, and computing preliminary discharges from the transmitted record and current stage-discharge ratings. The average time required for preliminary office processing is 5 hours per station per year. Total time requirements for operation of GOES sites are discussed in a later section of this report.

Reliability of the conventional system was evaluated by determining the completeness and accuracy of ADR stage records obtained. Reliability is dependent on the operation of the ADR, timer, battery, and field conditions.

An analysis of ADR stage record obtained for each site is provided in table 3. Included are maximum possible number of observations (col. D), the number recorded by the ADR (col. E), and the percent of usable observations (col. I). The conventional system provided a combined average of 98 percent of possible usable observations from the six sites during their periods of operation.

During the 85-month cumulative test period for the six sites, there were 45 days when the ADR was stopped and 12 days of unusable record. The ADR at Nature's Classroom (site 2, fig. 1) and ROMP 50 (site 9, fig. 1) failed to punch at times for short periods. The Brooker Creek station (site 6, fig. 1) had erroneous punches at times due to ADR malfunction. Manual computations were required to correct the data. Failures were due to ADR malfunction, low battery voltage, or faulty battery. Performance of the ADR at each site is shown in figure 2.

Disadvantages of the conventional system include: (1) necessity to visit sites to monitor instrument operation, (2) manual processing to compute and store data in WATSTORE, (3) expense of extra visits to obtain current reporting data, and (4) lost record. These disadvantages can be partly resolved by satellite telemetry such as the GOES system.

GOES DATA MONITORING SYSTEMS

The GOES data monitoring systems relay data from field sites by means of Geostationary Observational Environmental Satellites (GOES) operated by NOAA. The GOES used in this study has an orbit over the Earth's equator at an altitude of about 22,000 miles. Satellite coverage remains in the same approximate geographic area over the earth at all times.

Table 2.--Field and office manpower requirements for operation of conventional and GOES systems

Requirement	Required for:								
	Conventional method			GOES method					
				Trip frequency equal to conventional			Assuming trip reduction		
	Time to execute (man-hours)	Number times per year	Time per year (man-hours)	Time to execute (man-hours)	Number times per year	Time per year (man-hours)	Time to execute (man-hours)	Number times per year	Time per year (man-hours)
Field:									
ADR service	0.33	12	3.96	0.33	12	3.96	0.33	8	2.64
Nonroutine visit (to obtain current data)	2.0	1	2.0	--	--	--	--	--	--
CDCP service (in addition to ADR service)	--	--	--	1.0	2	2.0	1.0	2	2.0
Discharge measurement	2.0	12	24.0	2.0	12	24.0	2.0	8	16.0
Subtotal			29.96			29.96			20.64
Office:									
Manual tape review	.25	4	1.0	.25	1	.25	.25	1	.25
ADR tape transmission	.50	4	2.0	--	--	--	--	--	--
Primary processing (computer application)	.50	4	2.0	.50	4	2.0	.50	4	2.0
Subtotal			5.0			2.25			2.25
Total			34.96			32.21			22.89

Table 3.--Reliability of data collected by conventional and GOES systems

Map site number[1/]	Site name	Evaluation period	Number of 15-minute observations					Reliability		
			Conventional		GOES			Conventional	GOES	
			Maximum possible	Recorded by ADR[2/]	Transmitted from CDCP (including observations repeated in later transmissions)	Received at USGS computer (including observations repeated in later transmissions)	Processed (including observations used for missing data obtained from later transmissions)	Percent of observations that were useable (E÷D)x100	Percent of transmitted observations that were received (G÷F)x100	Percent of possible observations processed (H÷D)x100
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
2	Nature's Classroom rainfall near Thonotosassa	Oct. 4, 1976 to May 31, 1979	93,060	88,469	372,240	316,464	84,924	95	85	91
5	Rock Ridge rainfall near Providence	June 7, 1978 to May 31, 1979	34,416	34,416	135,168	126,528	32,832	100	94	95
6	Brooker Creek near Tarpon Springs	Aug. 3, 1978 to May 31, 1979	29,031	27,879	116,124	108,528	28,056	96	93	97
7	Flint Creek near Thonotosassa	July 20, 1978 to May 31, 1979	30,264	29,909	119,520	77,808	24,924	99	65	82
8	Pebbledale Road Deep Well near Pierce	July 24, 1978 to May 31, 1979	29,878	29,878	119,520	111,840	29,878	100	94	100
9	ROMP 50 Deep Well near Wimauma	June 15, 1978 to May 31, 1979	33,636	33,587	134,544	127,440	33,552	99	95	99
Total and Average			250,285	244,138	997,116	868,608	234,166	98	87	94

1/ Refers to table 1 and figure 1.
2/ ADR was dependent on CDCP for timing.

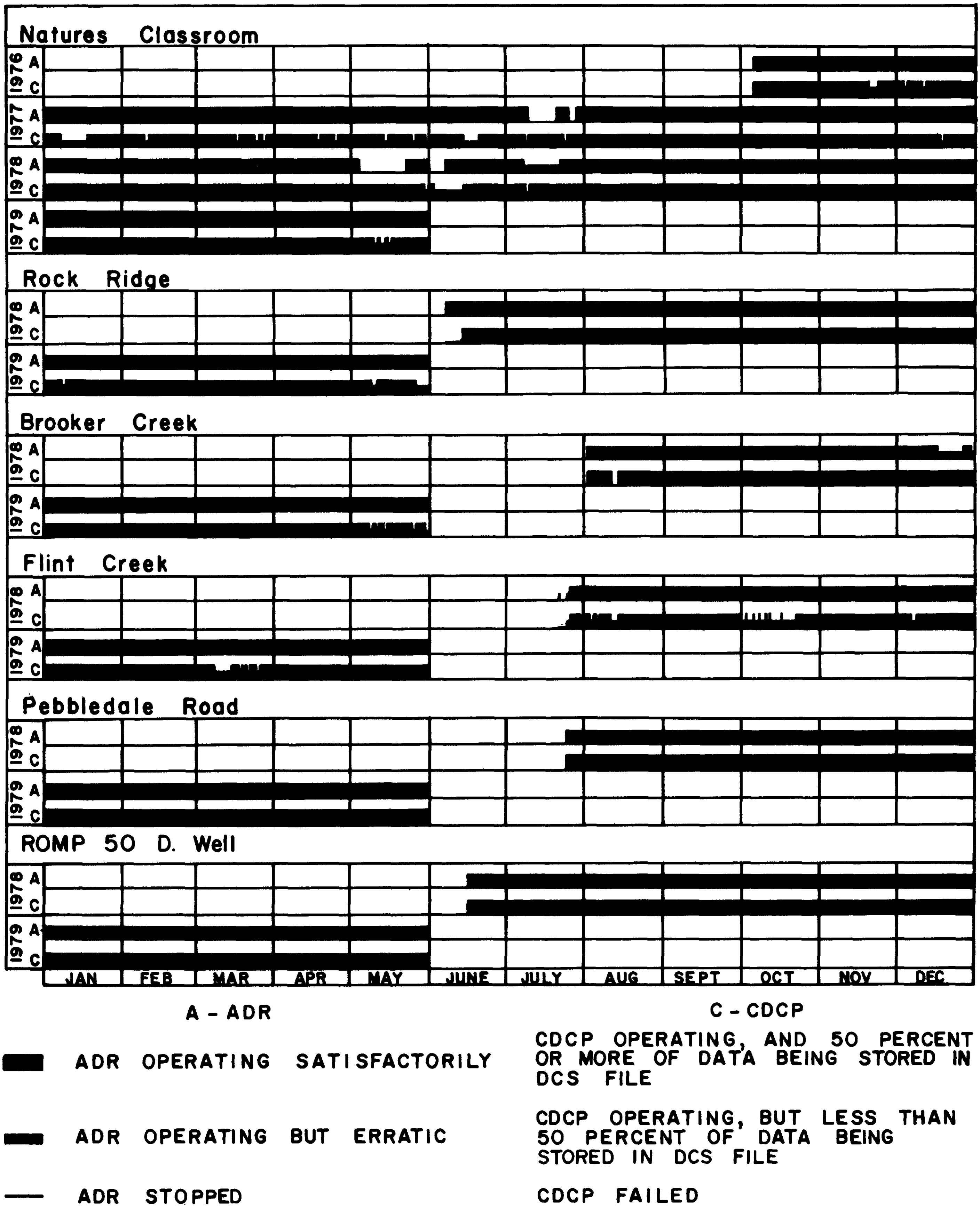


Figure 2.--Performance of instrumentation at GOES stations.

GOES system telemeters used at field sites in this study are referred to as Convertible Data Collection Platforms (CDCP's) made by the LaBarge Corporation.[1/] The CDCP's transmit data from field sites to the GOES, which in turn relays the data to a receiving station at Wallops Island, Va. The data are subsequently relayed over land lines to the World Weather Building in Camp Springs, Md., and then to the National Center computer system in Reston, Va. The exact schedule for relay of data from Wallops Island to the National Center computer varies, but the relay is normally accomplished several times a day. Data from the National Center are generally available to the user on an approximate 6-hour basis. Raw, unprocessed field-site data can also be retrieved from Camp Springs, Md. However, local processing to translate the data into engineering units is required.

At field sites, sensor data are punched on paper tape by an ADR every 6 or 15 minutes, or multiples thereof. The CDCP accepts sensor data at these time intervals and stores current values while retaining some preceding values. Updates occur as new data are sensed, punched on paper tape, and stored sequentially in the CDCP memory.

The CDCP operates under control of a built-in precision timer that is accurate to about 30 seconds per year. In this study, CDCP's were precisely timed to transmit to GOES every 3 hours. Following each data transmission, the CDCP returns to standby condition for minimum power consumption from the battery supply.

Data transmissions from the CDCP to GOES include stored data for each parameter and the CDCP identification number. Data reference times determined from times that transmissions are received are stored with sensor data.

Manpower requirements for collecting and preliminary processing of records at a streamflow station using the GOES system are outlined in table 2. Field service requirements for GOES sites are about the same as for conventionally operated sites except for CDCP service, which requires an additional 2 hours per year (1 hour for each of two visits); however, nonroutine visits to collect current data are not required. ADR service and frequency of discharge measurements vary from site to site. Daily monitoring of GOES sites affords the opportunity of scheduling site visits to coincide with current changes in hydrologic conditions. While this may result in more visits to some sites, it also presents the possibility of overall reduction in total visits for the network and improved records. A possible reduction in ADR service and frequency of discharge measurements from 12 per year to 8 or less per year is discussed in a later section. Annual office and field effort required to collect and process hydrologic records by GOES and conventional systems are summarized in table 4.

[1/] The use of brand names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

Table 4.--Manpower and related costs for data collection by conventional and GOES systems

Function number	Collection or processing function	Site 6 (daily discharge)			
		Conventional		GOES	
		Total time per year (hours)	Cost per year[1/] (dollars)	Total time per year (hours)	Cost per year[1/] (dollars)
(A)	(B)	(C)	(D)	(E)	(F)
1	ADR service	3.96	74	2.64	50
2	Nonroutine visit (to collect current data)	2.0	38	(3)	--
3	CDCP service (in addition to ADR service)	(3)	--	2.0	38
4	Travel mileage	(300mi)	51[2/]	(200mi)	34[2/]
5	Travel time	12.0	225	8.0	150
6	Discharge measurement	24.0	450	16.0	300
7	Transmission of ADR tapes	2.0	38	(3)	--
8	Satellite-relay data entry to HYDRECS and daily storage in unit values file	(3)	--	--	511[8/]
9	Review ADR tape	1.0	19	.25	5
10	Primary processing (includes computer application)	2.0	38	2.0	38
11	Rating analysis	40.0	750	40.0	750
12	Special manual computation methods	(3)	--	(3)	--
13	Manual discharge entry to computer	1.0	19	1.0	19
14	Record check	24.0	450	12.0	225
15	Table retrieval/update (includes computer application)	1.0	19	1.0	19
16	Typing	3.0	56	3.0	56
17	Review	3.0	56	3.0	56
18	Miscellaneous (reruns, repairs, delays)	14.0	262	14.0	262
19	Requests	8.0	150	8.0	150
20	Station levels	2.0	38	2.0	38
21	Line supervision	4.0	75	4.0	75
22	Management supervision	4.0	75	4.0	75
Total	Hours and dollars	150.96	2,883	122.89	2,851
Total	Days and savings	18.9	--	15.4	32
Percent savings				19	1

Footnotes are at end of table.

Table 4.--Manpower and related costs for data collection by conventional and GOES systems--Continued

Function number (A)	Collection or processing function (B)	Sites 2,5 (daily rainfall) Conventional: Total time per year (hours) (G)	Conventional: Cost per year[1/] (dollars) (H)	GOES: Total time per year (hours) (I)	GOES: Cost per year[1/] (dollars) (J)
1	ADR service	3.0[4/]	56	1.5[4/]	28
2	Nonroutine visit (to collect current data)	2.0	38	(3)	--
3	CDCP service (in addition to ADR service)	(3)	--	2.0	38
4	Travel mileage	(150mi)	26[2/]	(100mi)	17[2/]
5	Travel time	6.0	112	4.0	75
6	Discharge measurement	(3)	--	(3)	--
7	Transmission of ADR tapes	2.0	38	(3)	--
8	Satellite-relay data entry to HYDRECS and daily storage in unit values file	(3)	--	--	511[8/]
9	Review ADR tape	1.0	19	.25	5
10	Primary processing (includes computer application)	2.0	38	2.0	38
11	Rating analysis	(3)	--	(3)	--
12	Special manual computation methods	(3)	--	(3)	--
13	Manual discharge entry to computer	(3)	--	(3)	--
14	Record check	4.0	75	2.0	38
15	Table retrieval/update (includes computer application)	2.4	45	2.4	45
16	Typing	2.4[5/]	45	2.4[5/]	45
17	Review	1.2	22	1.2	22
18	Miscellaneous (reruns, repairs, delays)	10.0	188	10.0	188
19	Requests	(6)	--	(6)	--
20	Station levels	(3)	--	(3)	--
21	Line supervision	1.0	19	1.0	19
22	Management supervision	1.0	19	1.0	19
Total	Hours and dollars	38.0	740	29.75	1,088
Total	Days and savings	4.8	--	3.7	-348
Percent savings				23	-47

Table 4.--Manpower and related costs for data collection by conventional and GOES systems--Continued

Function number	Collection or processing function	Sites 8,9 (ground-water level)			
		Conventional		GOES	
		Total time per year (hours)	Cost per year[1/] (dollars)	Total time per year (hours)	Cost per year[1/] (dollars)
(A)	(B)	(K)	(L)	(M)	(N)
1	ADR service	1.6[7/]	30	.8[7/]	15
2	Nonroutine visit (to collect current data)	2.0	38	(3)	--
3	CDCP service (in addition to ADR service)	(3)	--	2.0	38
4	Travel mileage	(100mi)	17[2/]	(50mi)	8[2/]
5	Travel time	4.0	75	2.0	38
6	Discharge measurement	(3)	--	(3)	--
7	Transmission of ADR tapes	1.2	22	(3)	--
8	Satellite-relay data entry to HYDRECS and daily storage in unit values file	(3)	--	--	511[8/]
9	Review ADR tape	1.0	19	.25	5
10	Primary processing (includes computer application)	2.0	38	2.0	38
11	Rating analysis	(3)	--	(3)	--
12	Special manual computation methods	(3)	--	(3)	--
13	Manual discharge entry to computer	(3)	--	(3)	--
14	Record check	6.0	112	3.0	56
15	Table retrieval/update (includes computer application)	.8	15	.8	15
16	Typing	1.5	28	1.5	28
17	Review	1.5	28	1.5	28
18	Miscellaneous (reruns, repairs, delays)	12.0	225	12.0	225
19	Requests	3.0	56	3.0	56
20	Station levels	1.0	19	1.0	19
21	Line supervision	2.0	38	2.0	38
22	Management supervision	2.0	38	2.0	38
Total	Hours and dollars	41.6	798	33.85	1,156
	Days and savings	5.2	--	4.2	-358
Percent savings				19	-45

Table 4.--Manpower and related costs for data collection by conventional and GOES systems--Continued

Function number	Collection or processing function	Site 7 and proposed sites (multigate dam; daily discharge)			
		Conventional		GOES	
		Total time per year (hours)	Cost per year[1/] (dollars)	Total time per year (hours)	Cost per year[1/] (dollars)
(A)	(B)	(O)	(P)	(Q)	(R)
1	ADR service	2.0	38	2.4	45
2	Nonroutine visit (to collect current data)	2.0	38	(3)	--
3	CDCP service (in addition to ADR service)	(3)	--	2.0	38
4	Travel mileage	(150mi)	26[2/]	(150mi)	26[2/]
5	Travel time	6.0	112	6.0	112
6	Discharge measurement	8.0	150	8.0	150
7	Transmission of ADR tapes	(3)	--	(3)	--
8	Satellite-relay data entry to HYDRECS and daily storage in unit values file	(3)	--	--	610[8/]
9	Review ADR tape	(3)	--	1.0	19
10	Primary processing (includes computer application)	(3)	--	8.0	150
11	Rating analysis	40.0	750	40.0	750
12	Special manual computation methods	125.0	2,344	30.0	562
13	Manual discharge entry to computer	8.0	150	1.0	19
14	Record check	75.0	1,406	20.0	375
15	Table retrieval/update (includes computer application)	1.0	19	1.0	19
16	Typing	4.0	75	4.0	75
17	Review	4.0	75	4.0	75
18	Miscellaneous (reruns, repairs, delays)	20.0	375	20.0	375
19	Requests	8.0	150	8.0	150
20	Station levels	2.0	38	2.0	38
21	Line supervision	8.0	150	8.0	150
22	Management supervision	4.0	75	4.0	75
Total	Hours and dollars	317.0	5,971	169.4	3,813
	Days and savings	39.6	--	21.2	2,158
Percent savings				46	36

1/ An 8-hour day is assumed to cost $150.00 ($18.75 per hour).
2/ Average cost for travel is assumed to be $0.17 per mile.
3/ Not applicable.
4/ Additional time required to drain (pump) rain gage.
5/ Monthly transmittal letter required.
6/ Included in 14 and 15 above.
7/ Manual tape-down required.
8/ Average cost for daily data entry to HYDRECS is $21.00 per month per site. Average cost for daily data entry to unit values file is $0.09 per parameter plus fixed charge of $0.62 or $0.71 per day for single-parameter sites. An additional charge, not included here, is made for on-line storage while data are being accumulated on the unit values disk file. No charge is made for backfile storage.

Reliability

Reliability of the GOES system was evaluated by comparing stage data collected and processed by the GOES and conventional systems. Three reliability factors were selected: (1) percentage of data transmissions successfully completed, (2) accuracy of relayed data, and (3) quantity of data acquired. Reliability of the GOES system is dependent on operation of instrumentation at the field site, onboard the satellite, at the ground-receive site, and at the National Center computer system.

An analysis of completed data transmission for each GOES site used in the study is provided in table 3. Included are maximum possible number of observations (col. D); number of observations transmitted by the CDCP, including observations repeated in later transmissions (col. F); number of observations received at the National Center computer system, including observations repeated in later transmissions (col. G); and number of observations processed, including those used for missing data obtained from later transmissions (col. H). Percentages of CDCP transmissions received at the National Center computer center and the percentage of all possible observations processed for the analysis period are also shown (cols. J and K).

The GOES system relayed a combined average of 87 percent of all CDCP transmissions from the six sites during their periods of operation. Because of the CDCP data redundancy feature (repeating previously transmitted observations in two to four subsequent transmissions), 94 percent of all possible observations from the sites were processed.

Average cumulative frequency distribution of successfully relayed data transmissions by the GOES system are shown in figure 3. Ninety-eight percent of the time, at least one data transmission was completed each day for each site, and 85 percent of the time, all 8 transmissions were completed each day.

Performance of CDCP at the GOES sites is shown in figure 2. During the test period for the six sites, which included 85 site-months, there were 39 days when CDCP transmissions were not completed. Some transmissions were not completed because the satellite was turned off temporarily due to solar eclipse or equipment malfunctioned at the ground-receive site. Some transmissions were not completed during periods when satellites were launched (system problem). For several sites, the ADR malfunctioned for short periods and failed to update the CDCP memory; the CDCP operated properly at these times. A CDCP malfunction occurred at the Nature's Classroom site when an internal transmit counter failed to register properly and shifted the assigned transmit time. Low voltage from a faulty battery caused a time shift at the Brooker Creek site and failure of the CDCP and ADR at the Flint Creek site. The CDCP's operated properly when restarted with fresh batteries.

Accuracy of GOES data that were relayed, edited[1], and stored in the National Center computer system was 100 percent. However, one site, ROMP 50, had erroneous data transmitted due to spurious ADR telemetry switch operation. There were no erroneous data transmissions due to GOES system malfunctions. About 5 to 10 percent of the GOES data entered in the computer system were deleted because of processing errors.

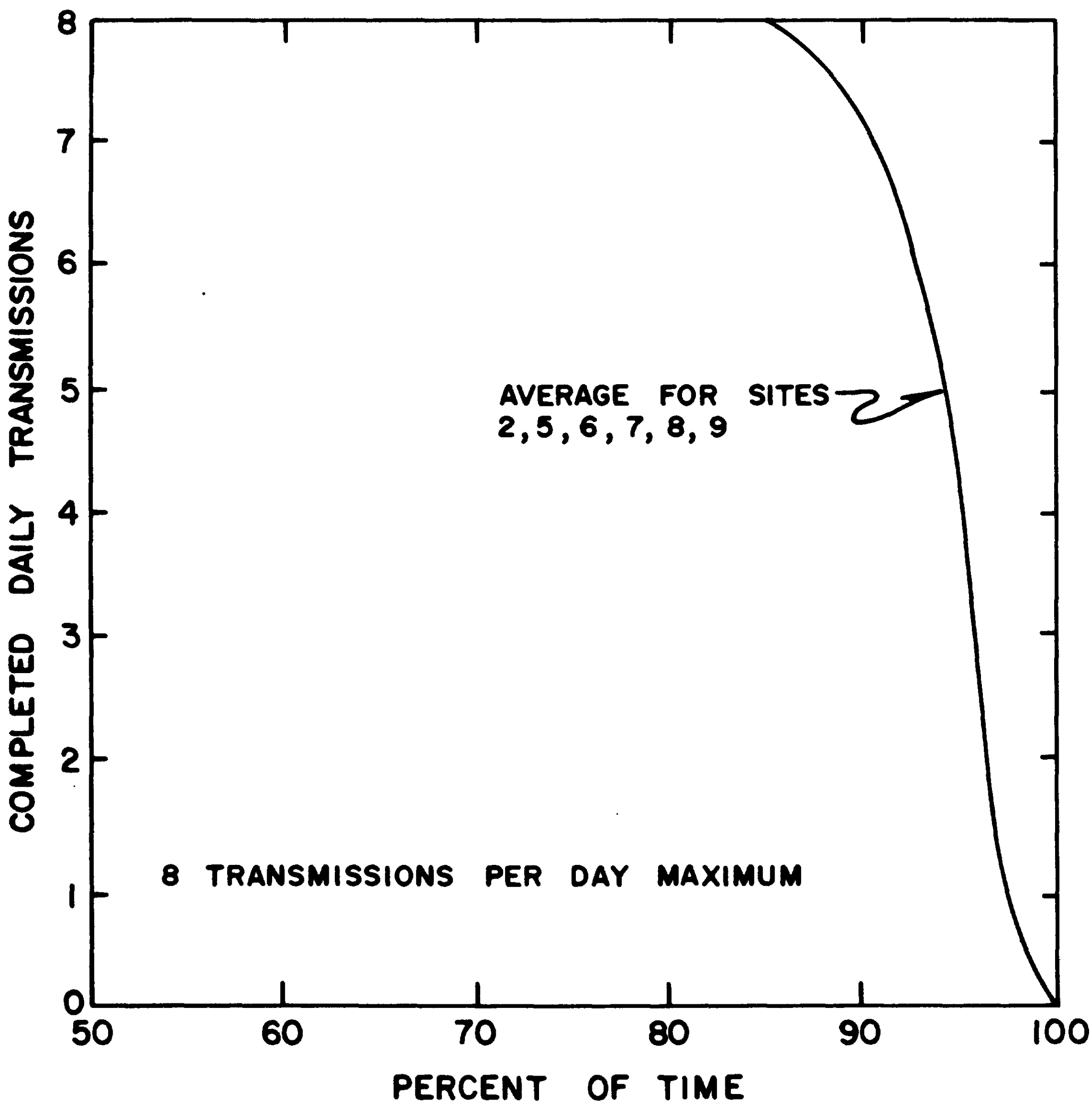


Figure 3.--Average cumulative frequency distribution of successfully relayed data transmissions for GOES (CDCP) stations.

The GOES system allows monitoring of station status by retrieval of current data. Non-routine visits to service instrumentation was required once at the Flint Creek and Brooker Creek stations, twice at the Pebbledale Road well, the ROMP 50 well, and the Rock Ridge rainfall station, and four times at the Nature's Classroom rainfall station, resulting in an average of 1.7 times per year per site.

Undesirable features of the GOES system include (1) precise time of transmission requirements that can cause interference with transmission from other sites if time drifts and (2) delays of 6 hours or more in relaying data from ground-receive sites to the National Center computer system.

Cost Effectiveness

Manpower and operation costs of maintaining, collecting, and processing hydrologic records with the conventional and GOES systems at six single-parameter sites were evaluated. Total effort required to operate each data-collection system, in terms of days per year, was used as the basis for comparison. Equipment costs were not considered in the analysis because a different method would be used to obtain equipment for a national telemetry program. The functions required to process records using the conventional and GOES systems are listed in table 4 (col. B). Salary costs, average driving time, and average one-way mileage (visits usually made to more than one site) to field sites were considered as necessary expenses.

Work elements that would be replaced or reduced by the GOES system are considered in the cost study. Considering the processing of daily discharge records for site 6 (table 4, cols. C-F), 19 of the 22 functions listed are required for the conventional system. Eight of these functions are eliminated, modified, or added in the GOES system. These functions are: (1) ADR service; (2) nonroutine visits to collect current data; (4) travel mileage; (5) travel time; (6) discharge measurement; (7) transmission of ADR tapes; (9) review of ADR tape; and (14) record check. Average annual cost for these functions is $1,345 using the conventional system.

Functions listed in table 4 are also necessary for the GOES system. These functions are the same as for the conventional system, except that CDCP service (function 3) and satellite-relay data entry to HYDRECS (function 8) are required. However, transmission of ADR tape data to the National Center computer system (function 7) and review of ADR tapes (function 9) would be virtually eliminated, nonroutine visits to collect current data (function 2) would be eliminated, and record check (function 14) would be greatly reduced. Additional time would be required for servicing the CDCP, but this function normally would be accomplished during routine field inspection visits. Additional travel time and mileage are not considered necessary for this function. Annual cost of these eight functions is $1,308 for the GOES system--a reduction of $37 or 3 percent compared to the conventional system.

Results of similar analysis for single-parameter rainfall and ground-water well sites are also given in table 4 (cols. G-N). Total annual cost increase for these types of monitor sites is about $350 or 46 percent. Manpower, however, is reduced by about 21 percent.

Manpower required for daily discharge stations by the conventional system is 18.9 days per year and 15.4 days per year for the GOES system, or a reduction of 3.5 days (19 percent). Cost reduction amounts to about $32 per year for a single-parameter streamflow site.

From 5 to 10 percent of the streamflow stations in west-central Florida could be classified as multiple-parameter sites because they require complex computations to determine discharge affected by operation of multiple-gate control, slope, or tide. Discharge for multigate controls is currently computed manually using graphic or ADR record and special computation forms for subdivision of daily record. The GOES system would greatly enhance computation and storage of discharge data at these sites. A cost analysis for multiple-parameter sites is also given in table 4 (cols. O-R). Use of the GOES system virtually eliminates manual processing, resulting in annual cost reductions of $2,158 (36 percent) for each site. Manpower is reduced 46 percent.

In the conventional system, special trips are often made to field sites to obtain current data. In these cases, the total effort for the conventional system may be increased by 2 hours to 2 or more days per year for single-parameter sites. The GOES system normally provides current data within a few hours, resulting in additional manpower savings.

Results of this study are a product of small network size and present technology; therefore, savings shown may be a conservative indicator of savings that may be attained with fully developed systems applied to large networks. Improved systems are expected to be implemented as a result of this and other studies. A pilot study is currently being implemented on a national level to test the feasibility of contractor supplied and operated systems. Evaluations of that system will also help to define future systems.

Data handling procedures are expected to be greatly improved and modified as new systems are developed. The need for annual data publications would be diminished as data requests could be handled at the local level with current data evaluated on an as needed basis.

Suggested Improvements

Some of the possible improvements in the GOES system are as follows:

(1) The precise transmission schedule could be eliminated by allowing random transmissions with lagged secondary transmission to insure complete data reception;

(2) The transmission interval could be shortened to 1 hour or less, with provisions for more frequent transmissions during periods when critical hydrologic conditions occur;

(3) The GOES system files in the National Center computer system could be updated nearly instantaneously;

(4) Micro-processors could be used for on-site computation and storage of data on magnetic devices, allowing transmission of final data;

(5) Use of local ground-receive sites would assure real-time data reception, particularly in times of severe storms and flooding when telephone systems may fail. This would eliminate dependency on telephone systems between the National Center computer system and local offices.

(6) ADR instrumentation needs to be improved. Table 5 shows an example of incorrect data due to telkit malfunction. When the ADR is in operation, proper data codes are punched on four channels of 16-bit paper tape and stored by telkit switches. Values punched can range from 0 to 9999. Each channel can have correct values that range from 0 to 9. Four binary bits in each channel have the values 1, 2, 4, or 8. Combinations of these bits produce sensed values. A punched bit of 1 plus a bit of 4 would produce a value of 5 in one of the four channels. While the punched values are rarely in error, the stored values can be different than the ADR punched value because of bounce and chatter of an improperly adjusted telkit. That is, some switches may close that should not, or some may fail to close that should. ADR telkit switch stabilization is presently being accomplished by proper but tedious, time-consuming adjustments.

SUMMARY AND CONCLUSIONS

Automated data-acquisition systems, including a land-line and GOES and Landsat satellite systems, were tested during 1976-79 in the Southwest Florida Water Management District. Results of cost effective and reliability studies indicate that the GOES system is a feasible alternative to conventional systems. The GOES system was found to be nearly as reliable but more cost effective than conventional systems.

The GOES system was tested at two streamflow sites, two ground-water wells, and two rainfall sites for a cumulative period of 85 months. During this period, an average of 87 percent of all CDCP transmissions from the sites was relayed by the GOES system to the Geological Survey computer system, which resulted in successful processing of 94 percent of all possible observations. The conventional system ADR, tested at the same sites and periods, obtained 98 percent useable observations. This high percentage may be attributed largely to the CDCP that controlled data acquisition by the ADR.

GOES data were normally available from the Geological Survey computer within 8 hours after recording at the field site and were about as accurate as ADR records processed routinely. ADR records are normally available only after obtaining them from the field at 4 to 8 week intervals or by making a special trip.

The satellite system allows nearly direct computer storage of relayed data in the National Center computer system, Reston, Va. Automatic storage of data by the GOES system for single-parameter sites results in cost increase of 46 percent to a savings of 1 percent per year over conventional methods of collection and processing. Savings of 36 percent, or more, are indicated for multiple-parameter sites where complex manual computations are presently used as part of the conventional system. The GOES system is more cost effective when accounting for real-time data needs. Implementation of suggested improvements and large networks would reduce costs further.

Table 5.--Sample of incorrect data due to ADR telkit malfunction

[These conditions or similar ones were observed while bench testing ADR telkits. A plus(+) indicates that a telkit switch contact was made which should not have been made, and a minus (-) indicates that a contact was not made which should have been made. The test punch value "2222" caused the "2" bit in each channel to punch the paper tape correctly but improper telkit adjustment caused the "1" bit in the tens channel and the "4 and 1" bits in the hundredths channel to make contact and store the value 3227 in CDCP memory (2+1=3 and 2+4+1=7). Hexidecimal characters A-F, equivalent to numbers 10-15, indicate bit combinations which cannot be recognized as valid data. Values in any channel cannot be greater than 9.]

ADR test punch value	Hexidecimal value stored in CDCP memory	Incorrect binary bits (1, 2, 4, 8) in:			
		Tens channel	Ones channel	Tenths channel	Hundredths channel
0000	0001	----	----	----	+1
1111	1301	----	+2	-1	----
2222	3227	+1	----	----	+4, +1
3333	3333	----	----	----	----
4444	4446	----	----	----	+2
5555	5757	----	+2	----	+2
6666	7646	+1	----	-2	----
7777	F7FF	+8	----	+8	+8
8888	8A89	----	+2	----	+1
9999	F988	+4, +2	----	-1	-1

Improvements are needed in the GOES system. ADR instrumentation (telkits) needs modifications to improve data quality. Precise time-of-transmission requirements could be eliminated by using random transmissions (within specified time intervals) with a subsequent follow-up transmission.

All systems tested are dependent on telephone lines for data retrieval. Real-time data availability would be affected by line failure during storms. Local receive sites could be established to assure availability of data during hurricane periods and severe storms.

REFERENCE

Turner, J. F., and Woodham, W. M., 1979, Remote data-acquisition systems, west-central Florida: U.S. Geological Survey Water-Resources Investigations 79-102, 69 p.

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