United States Department of the Interior
Geological Survey

TRANSMISSION OF DIGITAL DATA

by

Charles R. Showen

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FIGURES

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INTRODUCTION

The Geological Survey, Water Resources Division, established a pilot project to evaluate equipment that would transmit data recorded on 16-channel paper tapes over voice-grade telephone lines from field offices to the Washington, D.C., Automatic Data Processing Unit (A.D.P. Unit). Such equipment would allow computer-processed data for current-purpose hydrologic data stations to be made available in a more timely manner. The specifications for the equipment were prepared in March 1970; invitations to bid were solicited, a contract was awarded, and the equipment was delivered in November 1970. The equipment included two reader/transmitter units, and one receiver/recorder unit.

The reader/transmitter units transmit manually entered fixed information, i.e. station number, beginning date and time, and ending date and time, and photoelectrically read and transmit the 16-channel paper tape data. The receiver/recorder unit records the transmitted information on IBM-compatible magnetic tape.

This report summarizes the information gained from a year of pilot operation of the equipment, with and without a computer terminal at the field level, and makes recommendations for establishing a data-transmission system in the Water Resources Division.

EQUIPMENT

The reader/transmitter is capable of transmitting data from 16-channel paper tape over voice-grade telephone lines at a rate of 50 rows (200 binary coded decimal digits) per second. The receiver/recorder records the data on a 7-track magnetic tape, 1/2 inch wide, BCD, even parity, at a recording density of 200 bits per inch. The communications interface may be either a Bell System 202E2 data set or equivalent. This device will accept serial data at rates up to 1200 bits per second and

has reverse channel capability. The reverse channel allows the receiver to automatically halt the paper tape reader on the reader/transmitter and signal the transmitting operator when a transmission error, such as an odd number of characters has been transmitted or a parity error has been detected.

Reader/Transmitter

The reader/transmitter consists of a 16-channel photoelectric reader, a supply reel, a motor-driven take up reel, an eleven-digit assembly of decimal switches, solid-state control logic and a control panel. The complete system is housed in an instrument cabinet 9-inches high, 20 inches wide and 20 inches long. The reader/transmitter is shown in Figure 1.

The 16-channel paper tape (see Figure 2) is driven through the reader by a single sprocket wheel mounted directly on the shaft of a stepping motor. The sprocket engages the prepunched .100-inch-diameter holes located at .200-inch intervals along the center of the paper tape. Additional guidance is provided by metal edge guides. Each decimal digit (4 per row) is tested for invalid punch combinations. Any combination of punched holes other than those representing the digits 0 through 9 is invalid. If an invalid digit is detected, the reader stops, and an indicator light on the reader is turned on. The reader/transmitter operator then manually corrects the data.

The entry of fixed information is accomplished by manually setting the eleven switches mounted on the front panel of the reader/transmitter. These eleven switches, each of which may be set to one of the decimal digits 0 through 9, permit the input of data not contained in the 16-channel paper tape. The information entered by these switches is station identification number, beginning date and time of the record to be transmitted and the ending date and time of the record transmitted. The normal fixed data require 4 sets of 11 digits each, for a total of 44 digits. The fixed-data switches also are used to enter missing data items (4-digit items) and to correct erroneous data items.

Since the purchase of the original equipment, an optional 10-key keyboard has been provided for the entry of fixed information. The keyboard has been in operation for about

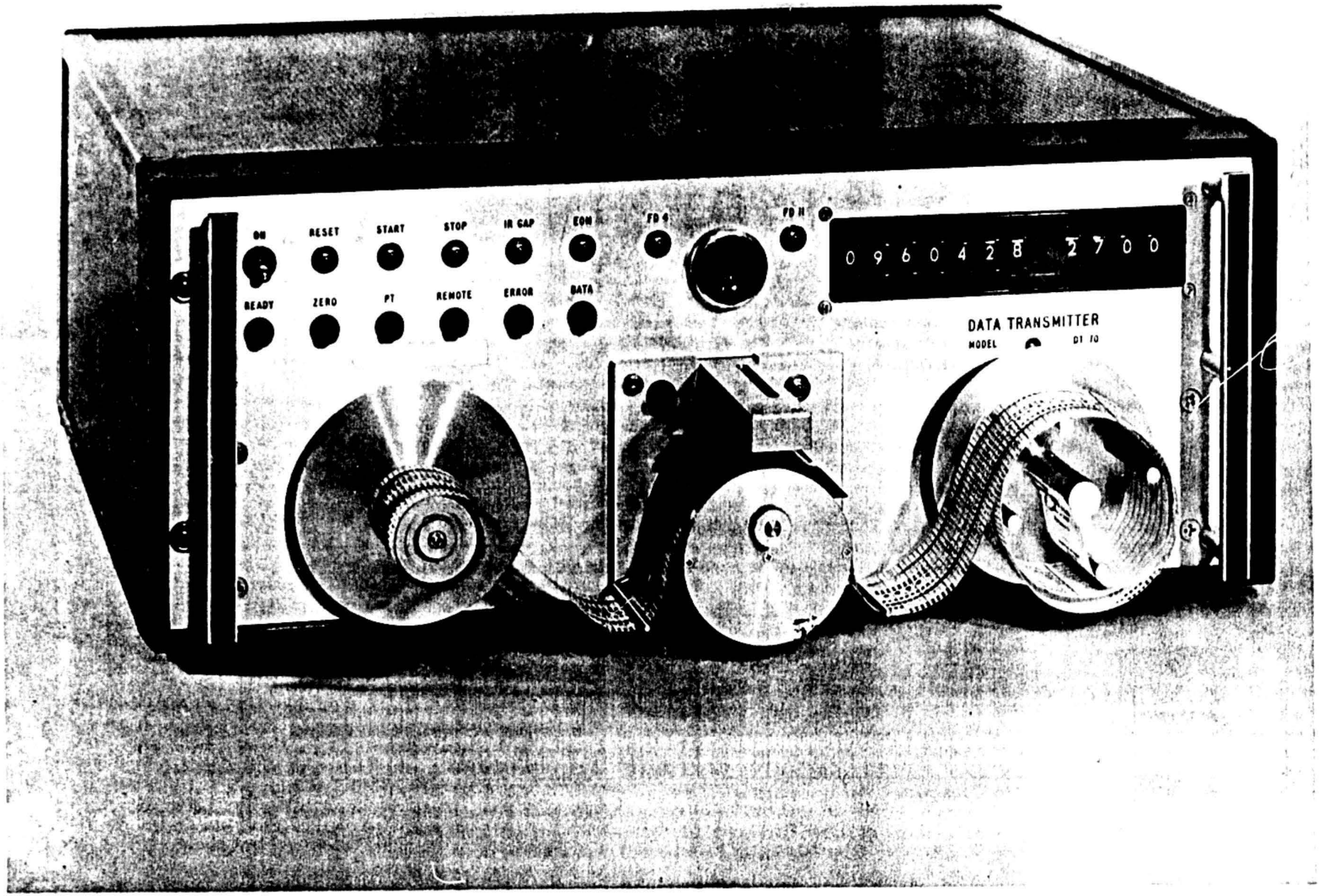

Figure 1. - Reader/Transmitter Unit

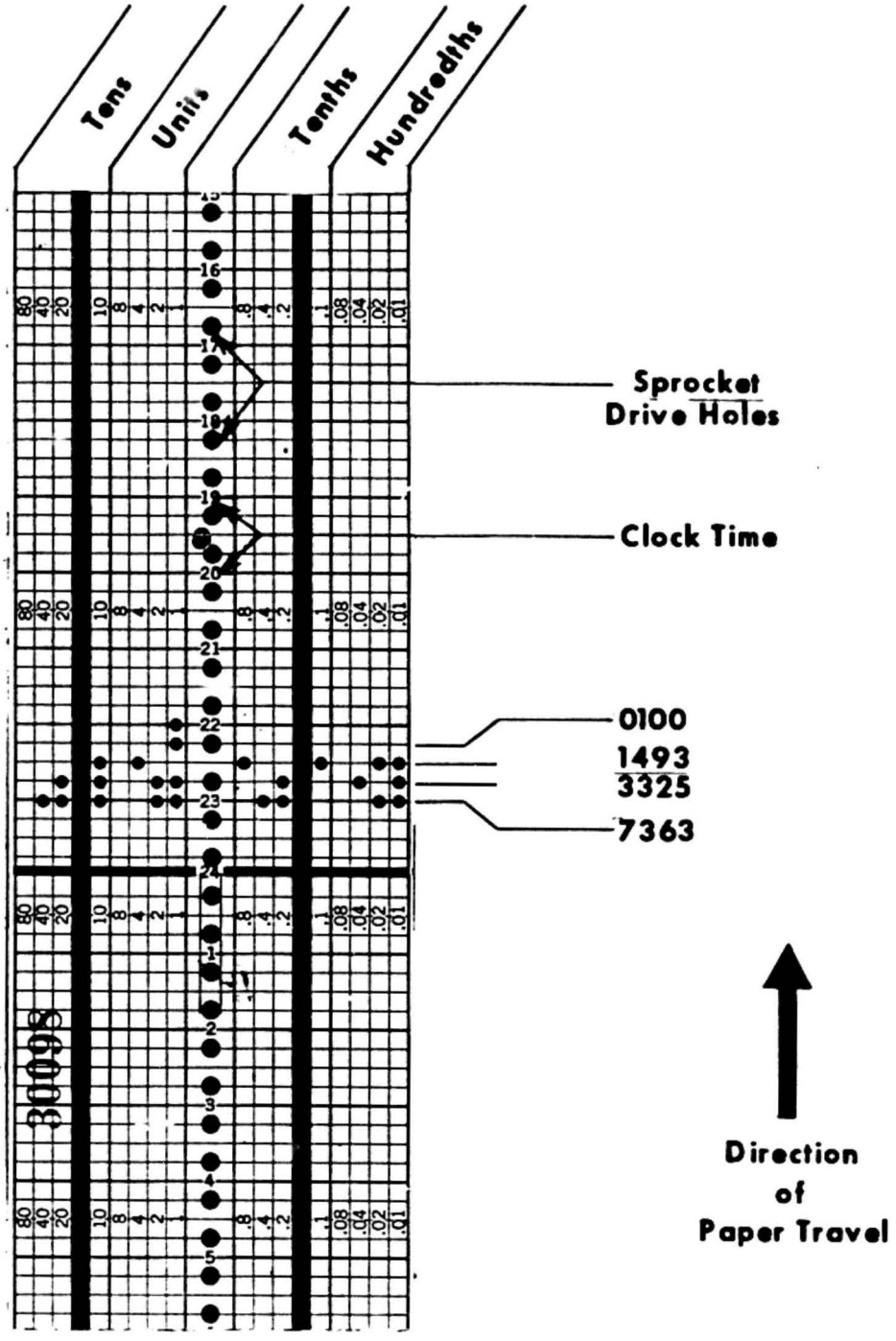

Figure 2. - Sample of 16-channel paper tape

two months and reduces the transmission time approximately 20% because the unit has a 44-character buffer which enables all the fixed information for a given set of input data to be entered into the buffer before transmission and then the whole of the fixed information is transmitted as one complete unit of data.

Normally, data read from the 16-channel tape are transmitted in blocks of 100 rows of 4 digits each. At the end of each block, the transmitter stops the reader for a period of 200 milliseconds which is sufficient time for an error signal to appear on the reverse channel line. If an error signal appears, the paper tape backspaces to row one of the block and retransmits the data; this occurs without operator intervention. A maximum of four automatic retries for a single block is provided. If errors are still encountered, the transmitting operator is instructed to make another telephone call to try for a better transmission line.

Receiver/Recorder

The receiver/recorder consists of an incremental magnetic-tape recorder, a control panel, and a solid-state control unit. The complete system is housed in an instrument cabinet 21 inches high, 20 inches wide and 20 inches long. The receiver-recorder is shown in Figure 3.

The receiver/recorder performs the following functions:

1. Tests each group of data for parity errors.

2. Interrogates the error registers. An error in one of the registers signals the transmitter that an error has been detected. Data which contain errors are not recorded but action is taken to cause retransmission by the reader/transmitter. Errors detected are communications (parity) errors, memory-cycle errors, transmittal of an odd number of characters, a group of data exceeding the maximum permissible data-record length, and certain operator errors.

3. Records valid data on magnetic tape. The magnetic tape recorder is an incremental stepping recorder which writes data at a density of 200 bits per inch at any rate up to 300 characters per second. Data are written


DATA RECEIVER

on 1/2-inch tape which is compatible with the IBM series computers. Of the 7 available tracks only tracks 1, 2, 4, 8, and parity are used. Because data are all numeric, tracks A and B should never contain "one" bits.

Data transmission may be interrrupted at the receiving station at any time by the operator pressing the stop switch. Pressing the stop switch does not cause any loss of data; it permits verbal communications between the transmitter and receiver operators in order that equipment may be adjusted or data entry corrected when required.

SELECTION OF READER/TRANSMITTER SITES

The primary consideration in selecting the districts for trial of the reader/transmitters was that they have appreciable numbers of stations that require current-purpose computations. A secondary consideration was that one of the districts have access to a computer terminal which could teleprocess with the Geological Survey's IBM 360/65 computer in Washington, D. C.; the other district would not have access to a computer terminal. Using these criteria, the Arizona and Indiana districts were selected to participate in the project.

OPERATION

The Arizona district requires current-purpose streamflow computations for about 50 stations. Because there was a computer terminal in Flagstaff, this district was selected as one of the reader/transmitter sites. After the 16-channel tapes were removed from the field recorders they were airmailed to Flagstaff. Upon receipt, the data from the 16-channel tapes were transmitted via the reader/transmitter using voice-grade telephone lines and recorded on a receiver/recorder in the Water Resources Division's A.D.P. Unit in Washington, D. C. The Flagstaff WRD office prepared the supplemental data (rating tables, shift or datum corrections) on punched cards for entry to the IBM 360/65 computer in Washington through the Flagstaff terminal. A part of the entry procedure was the instruction to the computer operator to mount the magnetic tape which holds the data from the proper group of 16-channel tapes. The data were then processed by the central computer; the master file of daily discharges in

Washington was updated; and the printout (primary computation sheets) telecommunicated to the printer at Flagstaff. The data were usually processed with over-night turnaround priority and the completed results were available in Flagstaff the following morning. (It is possible to obtain turnaround in less than two hours at extra cost by requesting a higher-priority handling). The primary computation sheets were then airmailed from Flagstaff to the various WRD field offices in Arizona.

The Indiana district operates from 30 to 60 current-purpose stations. These include streamflow, ground-water level and water-quality digital-monitor stations. After the 16-channel tapes were removed from the field recorders and brought to Indianapolis, the tapes were transmitted via the reader/transmitter and recorded on the receiver/recorder in the A.D.P. Unit in Washington, D. C. The Indiana district has a facsimile machine which can both send and receive page image via a voice-grade telephone line to or from the A.D.P. Unit. This equipment was used to send new rating tables, shifts and/or datum corrections to the A.D.P. Unit. The A.D.P. Unit then punched new rating cards, shift or datum cards and assembled the data for an overnight run on the computer. The output (primary computation sheets) printed at Washington were then returned to the district via airmail or sent to the district on the facsimile machine depending on the timeframe in which the data were required. Return by airmail took 3 or 4 days, whereas return by the facsimile machine took only about 5 minutes per page of data. Turnaround via the computer and facsimile machine in approximately two hours was possible at extra cost, if required.

EQUIPMENT PERFORMANCE

For the most part, the reader/transmitter equipment performed as anticipated. However, a number of minor changes were required in the receiver/recorder hardware since the project began. Most of these changes were made to provide the reader/transmitter operators with better error indicators in order to enable them to detect omissions before the actual transmission was completed.

OPERATOR TRAINING

Six to 8 hours of training and orientation were needed before an operator became reasonably proficient in the transmission of 16-channel tape data. This training and orientation was provided by personnel of the A.D.P. Unit in Washington.

In a district that either has or is acquiring a computer terminal using card input, a key-punch/verifier operator also is required. Commercial training is available for key-punch operators and a basic course requires about one week. Other key-punch training courses are available which provide on-the-job training and require 6 to 8 weeks to complete.

SYSTEM COSTS

The associated costs for equipment purchase, data transmission, and data processing are given below.

Equipment and Data Transmission Costs

The reader/transmitter units are on the Federal Supply Schedule and the purchase price is $4,860. The Bell System Model 202E2 data set may be leased from the local telephone company. The cost for the data set is $12.00 to $20.00 per month depending on the telephone company plus a nominal one-time installation charge.

The pilot project used the Federal Telecommunications System (FTS) telephone lines to transmit the data. Costs for transmitting data over the FTS network were billed directly to the project at a rate of $0.14 per minute. The time required to transmit one station-month of data for one parameter collected at a 15-minute punch interval varied from 3 to 4 minutes depending primarily on the skill of the operator. The transmission time of 3 minutes per month may be the optimum whereas the transmission time of 4 minutes per month appears more realistic.

If a computer terminal is not available, additional costs are incurred for a facsimile machine and the FTS charges for transmitting the computer output. There are various facsimile machines available which lease from about $38.00 to

$50.00 per month. The facsimile machine used in the pilot project leased for $42.75 per month. The time required to transmit one page of computer output via the facsimile machine is about 5 minutes.

Processing Costs

For those districts that use the data transmission system and/or a district terminal, an adjustment in the processing charge per station is required. The adjustment in charges is shown in the table below:

Category	Description of services provided	Billing Rate (% of standard processing charge)
1.	Translation, primary, updates, and tables by the A.D.P. Unit. (This is the present situation where the A.D.P. Unit does the complete job for the district.)	100%
2.	Translation and primary by A.D.P. Unit. All updates and tables initiated from the district computer terminal.	85%
3.	16-channel tape data transmitted to A.D.P. Unit via reader/transmitter. Primary, updates and tables made by A.D.P. Unit.	80%
4.	Data transmitted to A.D.P. Unit via reader/transmitter. Primary, updates, and tables initiated from the district terminal.	30%

The processing charge to the district in Category 4 is for their share of maintaining the system (disk rental, data security, etc.). All other costs (card punching, translation, computer costs) are paid directly by the district.

To use the above table, consult the yearly processing charge table sent to the districts each year by Water Resources

Division Memorandum and multiply the charge by the percentage indicated in the table to determine the adjusted yearly processing charge.

IMPACT ON PERSONNEL

The use of the reader/transmitter with or without terminals in field or district offices may require an overall increase in total Survey personnel. The use of the reader/transmitter achieves faster turnaround, but an additional 1/4 to 1/2 man-year effort will be required at the district level to process 150 stations. This estimate of man hours is made without regard to the skills or grade level of these individuals involved.

As the use of computer terminals at field offices for initiating processing jobs becomes more widespread, the overall personnel requirements of the Washington A.D.P. Unit will become smaller. However, the necessary skills of those in the A.D.P. Unit will be greater because the problems and questions from the district personnel will require A.D.P. Unit personnel with more intimate knowledge of the entire system.

As more districts indicate an interest to adopt these techniques for data processing a considerable amount of advance planning must be done in order that adjustments in personnel requirements at the central location may be achieved.

SUMMARY OF PILOT PROJECT

The use of the reader/transmitter and receiver/recorder in conjunction with voice-grade telephone lines to transmit current-purpose hydrologic data from 16-channel paper tapes is entirely satisfactory. The reader/transmitter, in conjunction with a computer terminal, has great advantages in reducing the turn-around time for processing digital-recorder records. This combination of equipment allows the processing to be initiated by the field offices at a time and priority of their choice. Using this technique, the Geological Survey is able to provide high-quality hydrologic information to cooperating agencies in a rapid timeframe.

The use of the reader/transmitter in conjunction with the facsimile machine for transmission of computer output is also an acceptable alternate for small amounts of data.

However, this combination of equipment requires considerably more manual work by the Washington A.D.P. Unit and therefore would be subject to backlogs caused by shortage of personnel in the A.D.P. Unit. Still this alternative can reduce the time required to transmit, process, and receive computer output to about 2 hours, when required.

RESULTS OF DISTRICT OFFICE SURVEY

A preliminary report on the pilot project was sent to the Water Resources Division District offices in April 1971. Each district was asked to express its interest in obtaining the reader/transmitter equipment and whether or not the pilot system should be expanded to handle all 16-channel tape data from a district rather than just current-purpose data.

Of the 47 district offices in the Water Resources Division, 39 responded to the inquiry. Only 8 districts indicated a need to process current-purpose data and an interest in the purchase of a reader/transmitter. However, 25 districts felt that the pilot project should be expanded to handle all 16-channel tape data from a district rather than only current-purpose data.

Several districts also commented that serious backlogs would likely occur in the A.D.P. Unit if the data transmission system were adopted nationwide unless most of the districts also had computer terminals so that their card input data could be prepared locally and the processing jobs could be initiated by the districts.

RECOMMENDATIONS

Based on the results of the district office survey, it appears that there is not a great enough need for current-purpose data processing to justify establishing a national data-transmission system at the present time. However, for those districts that have access to a computer terminal which can teleprocess with the Geological Survey's IBM 360/65 computer in Washington, D.C., the benefits are great enough to warrant their acquisition of the transmission equipment, as funds permit, to process all their 16-channel tape data.

For those districts that do not have a computer terminal, the system has advantages only for processing current-purpose data. The use of the system to process all 16-channel tape data for these districts would probably cause a serious backlog in the A.D.P. Unit in the preparation of the supplemental data (rating cards, shift-correction cards and datum-correction cards) and thereby cancel any benefits which might be achieved by rapid transmission of the tape data.

It is recommended that reader/transmitter units be installed at the Water Resources Division processing centers in Denver, Colorado, and St. Louis, Missouri. These reader/transmitter units would enable districts without terminals to reduce the turnaround time now required for processing of current-purpose data. An additional receiver/recorder will be needed to handle data at peak load times which are near the first of each month. When these recommendations are implemented, it probably will be necessary to assess a premium charge for computing current-purpose data to cover the additional costs involved. To process current-purpose data in this manner will probably increase the standard processing charge by about 15%.

As additional reader/transmitter units are installed at the district level, it will be necessary to schedule transmission times and limit the amount of time for each transmission. This will be required primarily to accommodate current-purpose data in proper priority. The remainder of the 16-channel tape data can then be processed during off-peak times.