THE AUTOMATIC HYDROLOGICAL RADIO REPORTING NETWORK

NEW ENGLAND DIVISION, CORPS OF ENGINEERS[1]

By

Carleton H. Gray[2]

The New England rivers have frequently overflowed their banks since time immemorial. As the valleys were settled and flood plains became more densely occupied by industrial, commercial and residential developments, flooding problems increased. Rapid industrial and urban expansion for the growing population have greatly increased the potential for flood damages.

Major floods cause loss of life, damage to property and erosion of soil and beaches. The region is subjected to flash floods and storms in all seasons. Suffering and devastation wrought by such flooding is indelibly etched in the memory of many New Englanders. The storm and associated floods of November 1927, March 1936, September 1938 and August 1955 serve as grim reminders.

Following the major flood of 1927, the New England Division Corps of Engineers began studying flood problems and preparing preliminary surveys reports under the authority of the River and Harbor Act of 1927. The disastrous floods of 1936 and 1938 soon followed --one a spring type and the other from hurricane generated deluges. These dramatically demonstrated the need for comprehensive planning.

The two flood Control Acts that followed these disasters precipitated agressive action by the Corps in the in-depth study and implementation of flood control and construction projects.

The Corps studied the flood hazards of each river basin and recommended a comprehensive plan of protection. Many projects were authorized by Congress and constructed by the Corps. Protective works consisted of a combination of dikes and walls at major damage centers and upstream flood control reservoirs. The Corps built 35 flood control dams, 34 local protection projects and four hurricane barriers in New England at a total investment of some $300 million.
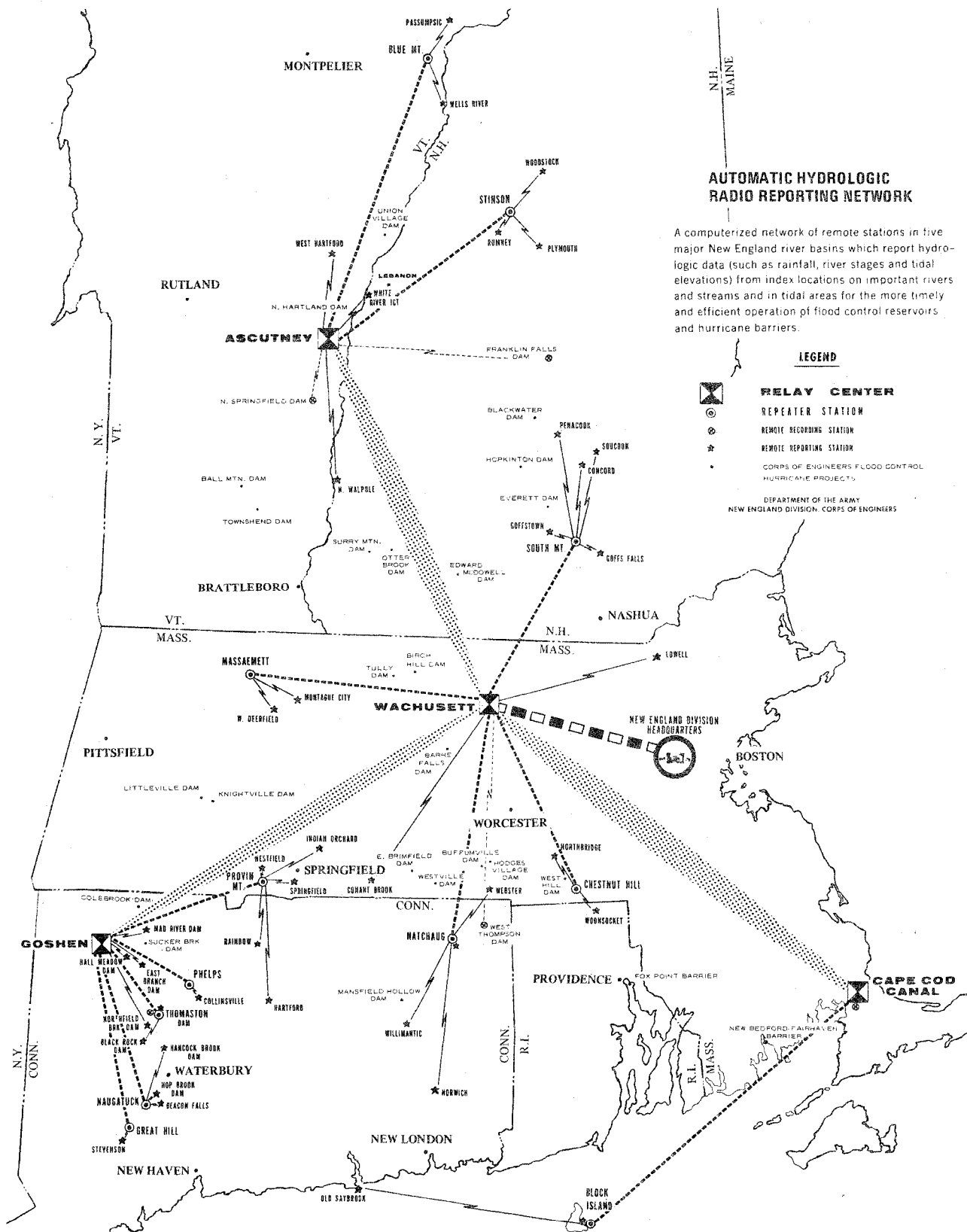
To achieve optimum benefits from this comprehensive protection system, the New England Division designed an automatic data collection network. The "Automatic Hydrologic Radio Reporting Network" assures maximum efficiency, economy and timeliness in the systems' operation by providing extensive hydrological data, including river, reservoir and tide levels, wind velocity/direction, barometric pressure and precipitation levels. This network, under computer programmed control, will immediately provide read-out information which is essential for flood regulation by the Reservoir Control Center at Waltham, Mass. (The system diagram shown in illustration No. 1 shows the complexity and area of the system). This assures accurate and timely regulation of the various dams and barriers.

The remote reporting stations in five states are strategically located in five major river basins and at key coastal locations. Each contributes to a detailed, comprehensive hydrological picture by feeding information into division headquarters where it is stored in a programming and data collection center. The data is recorded for Corps use and then retransmitted in teletype code back through the same channels (except for several additional relays such as Bald Mountain) to one of several dams where it is used in the operation of the dam or hurricane structure. This automatic interrogating, programming and retransmission provides the required hydrological information on a 7-day 24-hour basis for use in operating the various structures.

Illustration #1 shows the complexity and the area of the system.

The central control station at Waltham consists of an interface between the radio equipment and a computer. It will automatically interrogate the entire network or individual stations at selected time intervals and provide a complete print-out in three minutes. The remote reporting stations respond with this information. Manual interrogation also may be initiated at any time.

The computer software provides automatic scheduling of remote station interrogations, in sequence, and converts river stage data to engineering units.

The interface unit connecting the IBM 1130 to the central station provides the capability for real time scheduling of programs within the computer. This unit outputs addresses and commands to the central station, accepts the indication that data is ready, and then accepts parallel data from the central station which has been received from the interrogated remote data site.

The Waltham computer has been programmed to operate continuously in a dedicated mode for the automatic acquisition of hydrological data. The operator may at any time interrupt this sequence and perform batch processing operations which are normal to the IBM 1130. The dedicated mode of this reporting system was dictated by the requirement for rapid, real time calculations of river flow in the five river basins throughout the New England area from the river stage readings taken at the reporting stations and from known stream bed cross-sections.

Several of these rivers have relatively rapid rise times from precipitation runoff and require real time management of their reservoir systems to prevent disastrous floods.

While the Waltham system has been designed to operate in a dedicated mode, relatively minor modifications to existing batch processing programs and use of a slightly different philosophy for the executive scheduling monitor would allow the data acquisition program to be continuously executed in the background in such a way it would appear to the normal batch processing user that he had full use of the computer. Computations on raw data received could be accomplished on a non-interference basis.

The direct connection of the telemetry system to the data processing computer provides "real time" data for computation processing and management without the manual transfer of data from the telemetry system to the data processing computer. The card and tape readouts become superfluous, since data can be automatically stored within the computer and ready for processing without human intervention.

With the Corps' key river gages and rainfall stations feeding data into this reporting network, computer information, which formerly required hours to compile, will be available in a matter of minutes. The computer-plotter combination allows analysis of a large store of data in a short time and expedites timely regulations. The real time printout on the computer will assure early warning to Division personnel of high stream flows and/or tidal surges for immediate operation of flood control dams and hurricane barriers.

The hydrological network has the capability of receiving technical data required for operation for other water resource purposes such as low flow augmentation, recreation, water supply, navigation and fishery enhancement. It can be expanded to 100 stations.

When the interrogation cycle is initiated, the readout of the data stations is performed automatically. Each remote data station has its own station address. However, because of the large geographical area from which the environmental data is being collected, the central station does not communicate directly with the data station. Messages directed by the central station to most of the remote data stations are sent by means of a multi-channel microwave radio repeater system (backbone repeater) and vhf radio intermediate repeater stations.

Also included in the system are satellite or remote recording stations. Their capabilities include the ability to record the data generated by certain remote data stations during emergency conditions without the help of the central station. This capability is limited to those remote data stations operating through a maximum of two intermediate repeaters and through the same backbone repeater station as the recording station.

In operation, several functions must occur before the central station receives a valid message from the interrogated data station.

Addresses of the individual stations are stored in BCD notation. The central station cannot address the data station directly, but must send the BCD data station address by way of the microwave radio repeaters. From the backbone repeater the data station address is received and retransmitted by the vhf repeater station.

Utilizing the microwave backbone, the system contains two subcarriers (multiplex) designated the control and data MUXES. Each MUX in turn carries a digital subcarrier consisting of a frequency-shift keyed carrier transmitting BCD data during interrogations, commands, or the transference of hydrological and meteorological information.

The data channel designates the hydrodata channel. This channel is used for teletype data (if a teletype is used as a readout), the addressing of any data station during interrogation, and the station reply.

The control channel transports all the addressing and commands sent to any backbone.

When the central station interrogates a data station, the central station generates an eight-bit binary message and transmits it over the control channel. The most significant bit or bit number one of the eight-bit message will unkey or key the backbone repeater.

Bit numbers two, three, and four are the backbone select addresses and bit numbers five, six, seven and eight are the repeater select code.

A typical interrogation includes the generation of the interrogate command and sending of individual station addresses to each of the remote stations. The radio transmitter is keyed and a neuter tone is sent for a period of from 0.2 to 2.0 seconds. This allows for activation of any repeaters and switchover from standby to receiver power at the remote location. The input encoder board at the central station then accepts the station address in a parallel form. This is read out by the encoder common board in serial form as a succession of marks and spaces (1's and 0's). These are converted by the frequency shift keyed transmitter (FSK) into high and low tones with a neuter tone between each bit. This tone sequence is used to modulate the radio transmitter.

In the event the interrogated station does not reply, the address sequence is repeated up to four times. If the addressed station still does not reply, an indication of no valid data received will be recorded and the next station will be interrogated.

When the remote station has received, checked, and compared its correct address, the remote radio transmitter is keyed and all of the data present on the attached encoders and/or alarm points is simultaneously read into the encoder input boards in parallel and held until read out in a serial manner. If the input data should change after the "read" pulse and during the serial transmission, no change will occur in the stored information being transmitted.

An encoder common board shifts out this information bit by bit, converts it into clocked mark-space pulses which are in turn converted to frequency shifted tones and transmitted via the radio.

The message is repeated four times to insure reception of a valid message even under poor signal-to-noise conditions. At the completion of the message repetition the station sequencer clears the input register and removes the power from all equipment except the radio receiver.

In routine operation, when a station does reply, each station in sequence will be interrogated after receipt and recording of the data until the roll call of all stations is completed.

When the system is in a quiescent state with no messages being sent or received, all data and intermediate repeater stations transmitters are off. However, the station receivers are in "standby" and the microwave system is in a carrier-on condition at all times.

The basic remote station could be configured to recognize up to 99 addresses and to transmit only 16 bits of digital information. If the data is encoded in a BCD or excess -3 format, this corresponds to four decimal digits of information, or three decimal digits and one alarm.

Addition of one more card for each 8 bits can expand the capacity of the system up to a total of 128 bits or 32 decimal digits. Another card can also be added to extend the address capability or add control functions at the remote site.

Existing gage houses, used by the U. S. Geological Survey and the Corps of Engineers, were modified to incorporate the network equipment for the remote reporting stations. (Illustration No. 2 shows the interior of the gage house at Northfield Brooks Dam, Thomaston, Connecticut).

The equipment cabinet contains the solid-state "Dispatcher" radio, logic card cage, battery box and batteries. Mounted on the shelf is an encoder package containing a Baldwin encoder, 100 to 1 speed reducer, and a support casting connected by cable to the Baldwin encoder amplifier. The 100 to 1 speed reducer contains a special type of antibacklash gearing with stops to limit the output shaft rotation to the turn. The Baldwin encoder and amplifier units are gear coupled to the A 31 recorder. Thermoelectric generators are roof mounted to provide emergency power. Regulated propane tanks are used to maintain the line pressure to the thermoelectric generator at between 10 and 30 lbf/in^2.

Repeater stations consist of a standard 30 watt dc radio transmitter/receiver with multifunction subaudible tone control. (Illustration No. 3 shows the remote station at Natchaug State Forest.) With the radio equipment is a set of 11 Ni-Cad batteries and a charger. A thermoelectric generator is used for repeater locations having no ac power available.

The tide gages are installed at U. S. Coast Guard stations located at Block Island and Old Saybrook. The stations are unique in the form of their sensing equipment. Each station has four sensors: tide level, 3 digits, 00.0 to 35.0 feet; barometric pressure, 4 digits, 26.00 inches to 32.00 inches of Hg; wind speed, 3 digits, 000 to 150 mph; and wind direction, 3 digits, 000° to 359°. The information from the reporting station is available locally to the Coast Guard personnel as well as being telemetered. (Illustration No. 4 shows the Old Saybrook, Connecticut station.)

Satellite or remote recording stations (Illustration No. 5 shows the West Thompson Dam site in Connecticut) consist of a standing six-foot rack of logic equipment for encoding interrogation transmissions to remote data stations and for receiving and decoding replies from these data stations. Associated with each recording station is its radio (or GFE landline) and a teletype machine for logging the data received upon interrogation of selectable remote stations or upon receipt of data from the central station computer.

The New England system has proven that aerospace engineering and computerization can be successfully applied to the problem of flood control. To date, the system has justified its present use and opened the door to future potentials. Any data which can be expressed in digital form or as a function of shaft position or variable voltage can be encoded and transmitted over the system.

Such a system could be expanded to include a number of controls. As an example, one of the most pressing problems today lies in air and water pollution control. Water quality sensors could be installed downstream from possible contributors to river pollution. The monitoring system would detect a rise in the pollution level at any of its stations and appropriate action could be taken.

The Corps of Engineers is currently evaluating the performance of this system with close attention and great interest as we consider the installation of similar systems in other regions.
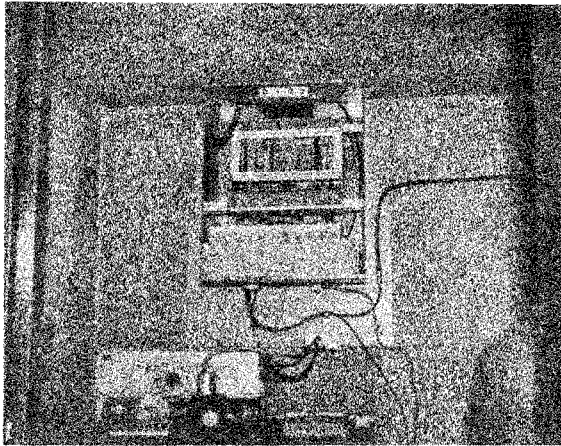
Illustration #2 shows the interior of the gauge house at Northfield
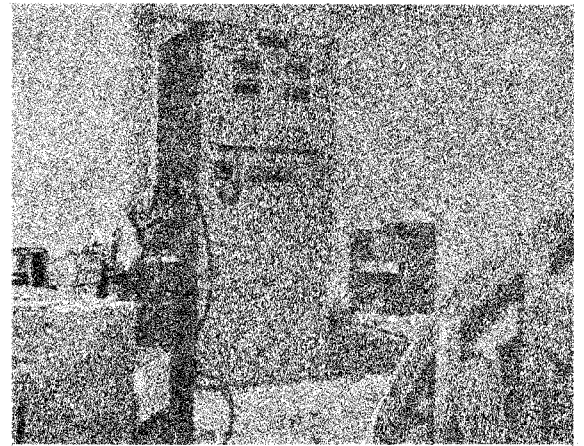Brook Dam, Thomaston, Conn.

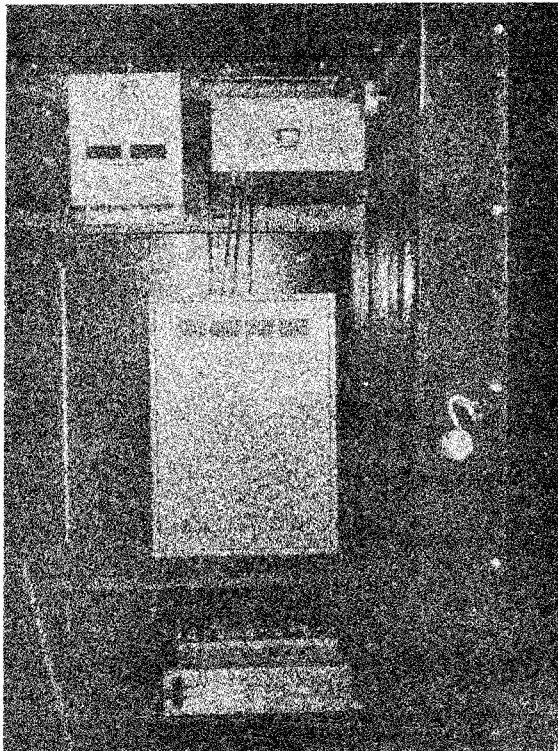Illustration #4 shows the reporting console at Old Saybrook, Conn.

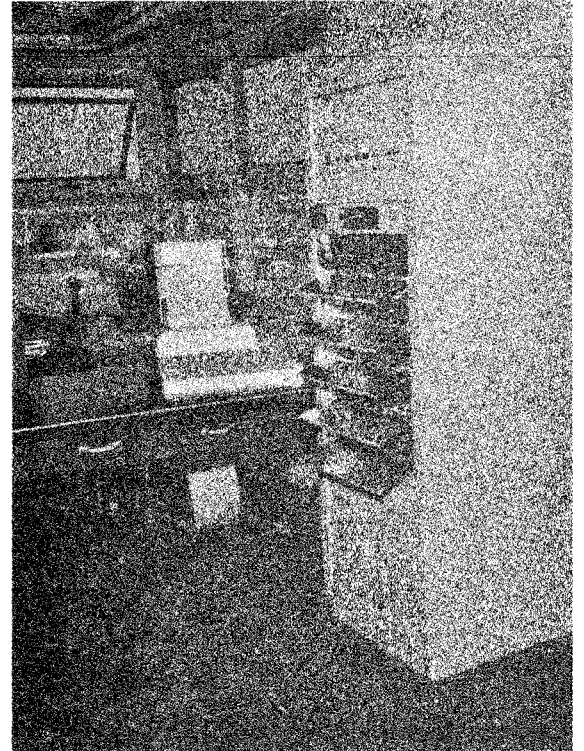Illustration #3 shows the transmitting equipment at the Natching State
Forest site.

Illustration #5 shows the interior of the West Thompson, Conn., station.