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CONSIDERATIONS FOR IRRIGATION SYSTEM CONTROL

BY

Jack C. Schuster[1] and Duane F. Nelson[2]

SYNOPSIS--Considerations needed in planning for operating an irrigation system ranging from manual to centralized computer assisted control are discussed in general terms.

INTRODUCTION

Consideration of methods of controlling irrigation systems to improve service to water users, to increase the efficiency of operations, and to reduce the cost of operating complex systems should begin concurrently with project planning. Major decisions made early in the planning of a system may dictate the level of control and monitoring system required for satisfactory operation of the project.

Open channel, and in some cases closed, conduit water distribution systems are operated under less than optimal conditions. This is frequently caused by the difficulty of matching inflow and outflow of the system. Mismatches between diversions, storage, and deliveries can occur as a result of inaccurate regulation, unexpected changes in the inflow or outflow, lack of adequate storage, and the lack of compensation for time lag in flow of water inherent in conventional operation of canals. For example, many conventionally operated canal and river systems need a day or several days of water travel time for a change of flow to pass through the conveyance system. Proper planning for future operations and application of control systems can greatly decrease the effect of time lag, compensate for inaccurate regulation, and generally provide better service to water users with less water waste.

IRRIGATION PROJECT ELEMENTS

The facilities of a water system can be classified generally as storage works, diversion works, conveyance system, and distribution system (figure 1). The storage works include one or more storage reservoirs, generally having an outlet works for regulation of water releases, and a spillway for protection of the dam. The diversion works may include a diversion dam with headworks for controlling releases into the conveyance system, a sluice gate for streamflow regulation and a spillway for protection of the structure (figure 2). The structure may also include only a headworks or a pumping plant discharging into the conveyance channel. The conveyance system generally is an open-channel system with structures for control of flow in the system and for delivery into the distribution system; however, the conveyance

[1]Head, Hydraulics Research Section, Division of General Research, Engineering and Research Center, Bureau of Reclamation, Water Systems Automation Team, Coordinator for Research Division.

[2]General Engineer, Division of Water Operations and Maintenance, Engineering and Research Center, Bureau of Reclamation, Water Systems Automation, Team Leader.

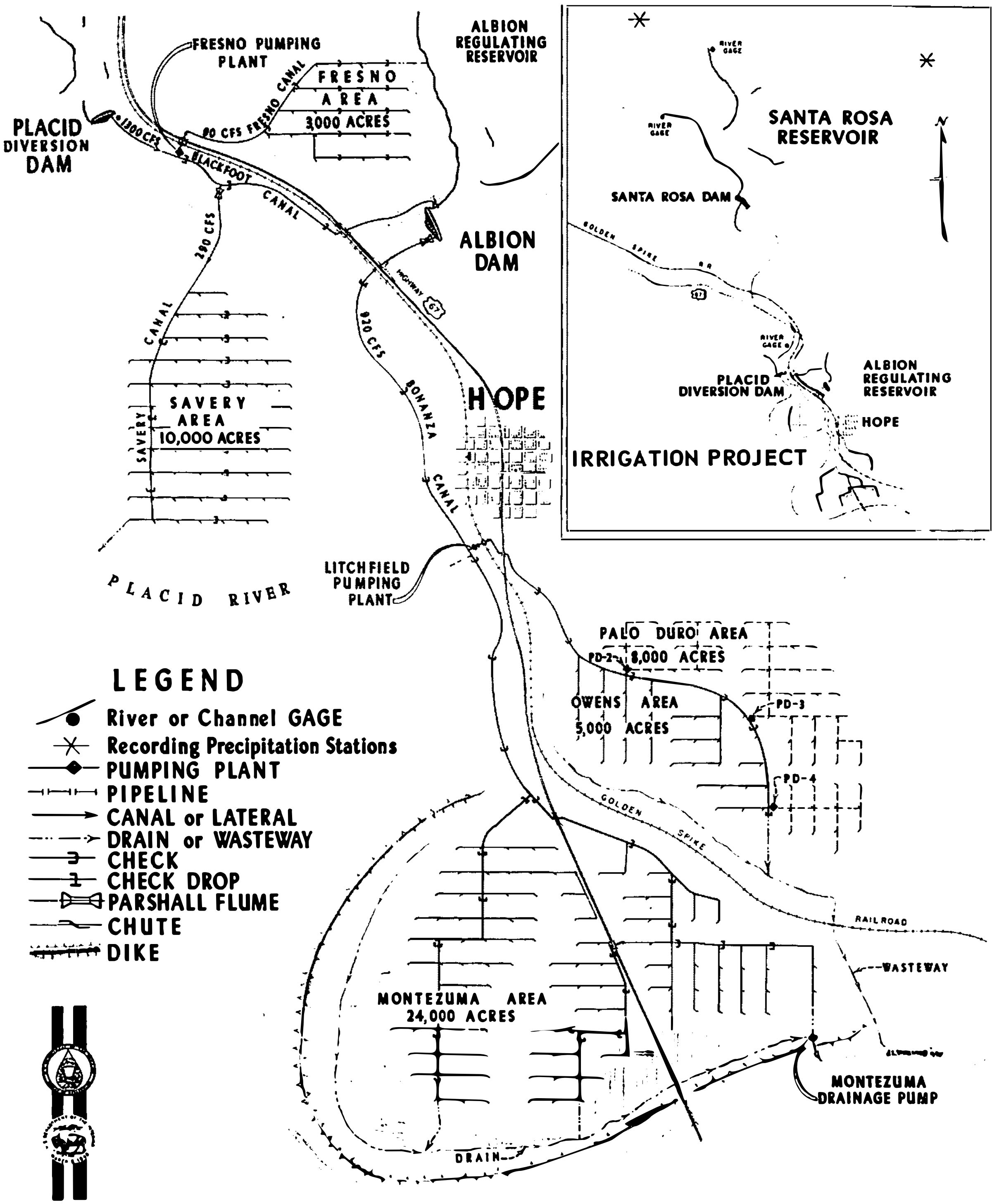

Figure 1. - Irrigation project elements.

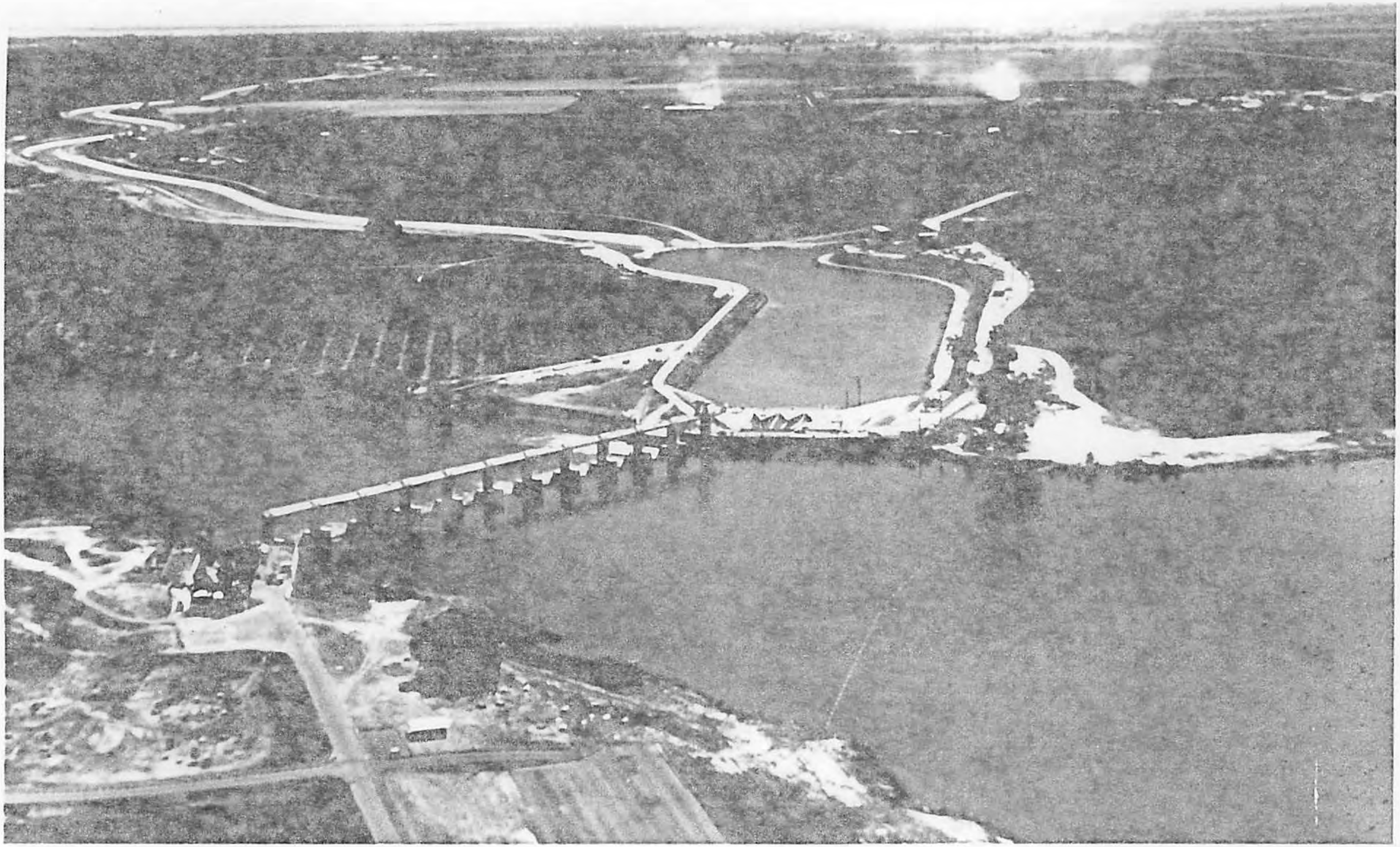

Figure 2. - A diversion dam project element with fish diverter and ladders, a sedimentation basin, fish spawning bed, and headworks for gravity and pumping plant supplied canals.

may be a pipeline with control and delivery structures. The distribution system is a series of open ditches or pipe laterals with a control structure and a delivery structure to the water user.

Each water control structure serves a specific function in a water system. Generally speaking, all of the structures control either a water surface elevation by regulation of a gate or pumping plant, or control the quantity of water being discharged through or into a particular structure. The type of control selected to accomplish a particular structure function or to operate a total water system depends upon the requirements and economics of the system.

PROJECT OPERATION STUDIES

Formulating an operation plan for a major project requires a study of all project requirements and consideration of alternative methods of operation for the selection of the optimal control method. Such operation plans need to be formulated and documented early in the planning and design stages of a project. Irrigation systems are becoming more complex and study must be made of the operating options offered by modern control systems. The need for an extensive, well-documented operations study is essential to finalizing the design of major projects. The lack of this type study and proper documentation increases the possibility of serious design errors.

An in-depth operations study requires manpower, time, and funds. The involvement of both office and field personnel is essential during all stages of the operations study. Although begun during the early stages of the planning of a project, the operation plan should continually be reviewed during design for incorporation of detailed and current design criteria before developing the final plan of operation. Although the ideal time to make an operations study is before final design is started, the study can be of great benefit to those projects under construction or completed to fully explore the benefits of modernization of the project. Below are steps that should be considered in conducting such a study for a major project.

Define System Constraints

Operational concepts and requirements impose restraints on the selection of a method of control. Thus, an early definition is required of both short-term and long-term general operating and maintenance objectives of a project. The economic, political, and physical constraints - water supply, operational, system configuration, communications, and maintenance conditions - should be identified for project planning. Economic constraints may limit the complexity of the control system for either part or all of the project system. These constraints may also affect the sequence and time for implementing a control system.

Political constraints may be diverse and impose unique restrictions on an individual project. Environmental aspects of a project and the impact on sociological changes of an area may be the basis for political constraints.

Physical constraints are imposed by the amount of water available, the type of water delivery system, the operating characteristics of the control facilities, and the expected maintenance conditions. Considerations of physical constraints require an analysis of short- and long-term cropping patterns in the service area, analysis of irrigation practices and possible improvements, the type of irrigation distribution system, and the control characteristics. The consideration should include an evaluation of the expected operating conditions for irrigation and nonirrigation season operations, under normal and abnormal circumstances. Detailed consideration of the water system physical constraints should help narrow the number of control alternatives.

Develop Operating Criteria

In developing operating criteria, information should be collected on location, size, and pattern of deliveries expected for new projects or the present and projected delivery patterns for existing projects. Projected demand and scheduling of water to the delivery points, size of the main aqueduct, lateral sizes, and pumping requirements in nongravity systems are a few of the factors requiring consideration in developing criteria for evaluation of system controls. Hydrographs representing flow conditions at critical points of delivery should be constructed to assist in evaluating the control method. Normal flow requirements should be investigated using computer simulation programs based on farm turnout requirements.

Formulate Optimal Operating Policy

Operating strategies over specified time periods (e.g., daily, weekly, monthly, yearly) should be developed. The extent of this effort depends on the complexity of the project. The major concern is to optimize storage releases over a given time period subject to the various system constraints. This generally involves maximizing benefits or minimizing costs while considering such factors as power generation; pumping costs; off-peak/on-peak power operation; pump/generator operation; irrigation, municipal and industrial demands; fish and wildlife requirements; water quality requirements; recreation requirements; and physical limitations. Because each project is unique, an individual optimization model is required; however, certain techniques developed for one project may be applicable to many other projects.

Control Concepts to Consider

Options to consider for control of irrigation systems include:

1. Local manual control
2. Local automatic control
3. Remote manual centralized control
4. Semiautomatic or open-loop centralized control
5. Fully automatic or closed-loop centralized control

Option (4) uses computer equipment in an advisory capacity and (5) uses computer equipment for complete control of the system.

Variations or combinations of the options may need to be considered for a particular project in the selection of a controlling method. The type of operation (demand at the will of the users or schedule from prior orders), control and measurement requirements (rate, range, precision, repeatability, and environment) and telemetry requirements for monitoring the system as to status, including alarms, must be considered in selecting a control method.

Unsteady flow conditions caused by the adjustment of the control structures or those occurring from emergency conditions should be investigated using a hydraulic transient mathematical model programed for the computer. By simulation, the feasible project operations schemes of control can be compared in selecting the best control method.

Local Manual Control -- Local manual control may be defined as direct onsite control and supervision of all control features in the system. Operators make the physical control manipulations required at the sites for achieving the operational objectives.

In the open channel parts of a project, water operators are required to regulate canal checks and maintain correct flow rates through the service area. The operators would be responsible for operating assigned reaches of a canal involving such tasks as raising and lowering check gates to maintain a near-constant water surface reading, recording the values from staff gages and measuring and setting the flow rate in the canal. Operators are responsible, from a provided schedule, for setting turnouts to deliver the required flow from each turnout in their areas of responsibility. Their duties may also include the maintaining and servicing of the onsite recording devices. Records are normally delivered to project headquarters for processing into statistical information and for charging the water users.

In systems having power generation or pumping facilities the operator operates and monitors the generator or pump units from information displayed on control boards.

On large systems, manual control requires a large number of operators throughout the system and provides jobs for many people. These operators, in order to achieve efficient operation of complex systems, require considerable training for normal and for emergency operations. Use of manual operation for complex systems requires the documenting of procedures and the training of operators in the use of the procedures to be used in emergencies. These procedures reduce operational errors in the system. A reliable voice communication system is necessary for local manual control for normal operations but is especially needed for emergency operations.

In the open-channel portions of an irrigation system, indications would be not telemetered to a common location should an emergency condition arise and the time lapse between the occurrence of an emergency and detection could be great. After the emergency condition becomes apparent, the required travel time of the water operator to correct the situation extends this period.

Control of a large irrigation system may be coordinated through area control centers. These area control centers have radio contact with water operators on the distribution system, as well as radio or telephone contact with pumping plant operators if they are not at an area control center. At these area control centers, system dispatching and data logging are accomplished by manual means after reception of the daily master schedule from a project control central.

Local Automatic Control -- This method uses onsite control equipment. For example, within a pumping or generating plant, control equipment allows the plant operator to automatically start or stop units from a control room within the plant. In addition to startup and shutdown operation, the control equipment also monitors conditions during operation. These monitored quantities are displayed on a control panel located in the control room of the plant.

Control of the checks and turnouts in open-channel portions of a system utilizes equipment to provide local automatic control. From a sensed variable such as water level or flow, the check or turnout is regulated automatically at the site with other equipment. An operator inserts a water level setpoint into the controlling device which controls the water level about this setpoint until readjusted.

In emergency situations, the local automatic control equipment functions to protect the pumping and generating units from malfunction. However, should the control equipment malfunction, the plant operator may take complete and direct manual control of each unit. Because these failures occur infrequently, operating personnel should periodically receive training on procedures to implement in emergency situations.

Should power failure occur at a pump turnout, the resultant rejected flow causes the water surface to rise in the canal. As the water surface rises, an upstream automatic control device at the canal check increases the gate opening to maintain a constant water surface upstream from the check. As the check opens, the downstream flow increases. Rejected flows proceed downstream until the capacity of the canal is no longer able to contain them, at which time water must be released through wasteways or canal overflows. An automatic downstream control device at a check decreases the gate opening in the check immediately upstream to reduce the flow and prevent waste.

The same condition could exist at a gravity turnout; if there is a control device malfunction or scheduled water is not taken by the user. The device itself is unable to indicate such a malfunction or change of schedule to the operator or apply temporary corrective measures. Warnings of turnout malfunctions might come from sources other than the project operation staff.

Remote Manual Centralized Control -- This method of control utilizes display, measurement, telemetry, and control equipment in pumping or generating plants, and along open-channel portions of a water delivery system that is controlled from a remote central location. The project elements are controlled by an operator located at the control center using either radio or land-line communications to receive and transmit control data instructions.

Upstream reservoir outflows may be controlled remotely from a generating plant control room. Water surface levels, gate positions, and quantities of flow are displayed in the control room for use by the operator. Equipment used in transmitting these data includes floats or other water surface measuring devices equipped with telemetering units. Pumping and generating plant units may be controlled by operators using similar control equipment.

Remote control of conveyance structures requires equipment at checks and turnouts that responds to remotely transmitted signals. This equipment has the capability of recognizing a transmitted instruction, converting that instruction into an action by the control device, and transmitting back to the initiating location confirmation that the instruction was received and that action had been taken.

With remote control, the ability to react to emergency situations is greatly enhanced over that of the methods previously discussed. Indications of generating or pumping unit status are immediately available at all times at the control center. Should the indicators show that an emergency situation is impending, the troubled unit can be shut down, system adjustments made to compensate for the change of flow, and a maintenance man can be dispatched to find the cause of the emergency alarm.

In the irrigation system, foreseeing an impending emergency condition is possible through the use of remote indication. In an emergency, such as a power outage at a pump turnout, an indication of the failure may be remotely displayed at the control center and, therefore, can provide rapid notification of power loss to the water operator. The operator is then able to cope with the rejected flow by the regulation of checks upstream and downstream from the pump turnout.

In case of a failure of onsite communication equipment for receiving and transmitting messages to and from the control center, the operator receives an instantaneous notification and can send a technician to repair the equipment.

Semiautomated or Open-loop Centralized Control -- Semiautomated centralized control of an irrigation system uses the capabilities of digital monitoring and control equipment to assist in control of storage reservoirs, generating plants, and pumping plants, checks, valves, and turnouts in the system. A computer interrogates onsite sensors to obtain data, analyze system status, and provide guidance for the operator in the control center.

In the operation of upstream reservoirs and generating plants, the central processor schedules water releases for generation from a control center master schedule. The central processor may also function through local digital control equipment to schedule and operate the pumping plants located throughout the system.

Open-channel portions of an irrigation system are controlled by an operator receiving guidance from a programed central processor. The processor receives data from sensing devices at the control structures in the distribution system, analyzes the data, and makes information available for use by the operator. Final control responsibility would be placed in the hands of the operator.

The concept of semiautomated centralized control provides for response to emergency conditions in the system. The central processor receives data relating to operation problems from the control equipment located at generating and pumping plants. These data provide for an analysis by the processor and may be followed by a diagnosis of the impending emergency condition. By utilization of the processor's capability to schedule the pumping units, not only for operation but maintenance purposes as well, conceivable emergency conditions may not occur as frequently as under the previously discussed concepts of control.

Fully Automatic or Closed-loop Centralized Control -- Fully automated centralized control, a concept of the future for irrigation systems, involves the introduction of closed-loop, on-line control computers or processors as controlling devices into all control loops required for complete operation of the irrigation system. The extent to which operators enter into actual control of facilities is limited even in extreme emergency cases. The central control computer supervises the functions of local computer equipment near major structures for pumping, generating, and regulating large flows.

Area control centers could be programed to supervise the operation of a designated portion of the system or the project control center could supervise all operations. If area control centers are used, an operator would be on duty at these area control centers at all times as would operators (water and power dispatchers) at the project control center.

Data from the system would be examined, processed, and analyzed; system deviations noted; commands issued to correct those deviations and prevent future occurrences; and data recorded for essential project records.

Research and Development

In considering the control options, a research and development program could be found necessary. New and existing projects, whether large or small, may require knowledge of new techniques of control. Local automatic controller development may be required to meet the needs of small projects not having funds for expensive centralized control systems. In the development of a control methodology, particularly for systems having open channels, the prediction of the hydraulic stability and the analysis of hydraulic transients can be accomplished through computer simulation. Thus, research and development of control options can be considered by using computer simulation of parts or all of the water distribution system. A hydraulic transient computer model can be a valuable tool in the development of the optimal control plan for a water system.

Analysis and Cost Comparison

Control options can be considered for an irrigation system on the level of need and on performance capability. Each option or tentatively selected options, may be considered on several performance factors and requirements of the system. Some of the factors are:

- Manpower availability
- Power availability and type
- Communications availability
- Control reliability
- Necessary response of controlling
- Degree of control
- Effect on optimal operations
- Precision of control
- Water user services
- Emergency warning capability

From an analysis of the control options, information should be derived for assessment and comparison of the methods of control. Operational benefits and limitations can be determined for an economic analysis. A detailed estimate of structure, equipment, manpower, and related costs will be necessary for a comprehensive comparison.

The cost for one option could be used for a base cost. Other options can then be compared in terms of costs for equipment, personnel requirements, communication systems, and operational benefits. For example, considerations for Local Automatic Control could include activities in the following categories:

General Maintenance Unit

Plant maintenance
Canal maintenance
Ground and reservoir maintenance

Operations Unit

Plant operation
Conveyance operation

Administrative Unit

Cost for establishing the units include:

Salaries
Equipment
Supplies, materials, and tools
Administrative and general expenses

A similar evaluation made for other options allows a comparison and way of choosing the possible short-term and long-term optimal method of controlling the irrigation system.

<u>Finalize Plan</u>

A recommended final plan can be developed from the comparisons among the control method options. Details and justification given for selecting a particular plan can be used for consideration by the planning organization. After review, comment, and acceptance, the document can be used by design and field personnel for designing, scheduling, constructing, and operating the distribution system.

A comprehensive operational study considering the options for optimal control of the distribution system will give assurance of efficient service to water users on the system with less water wastage.