ACHIEVEMENT OF GOALS SUBSEQUENT TO 
CONSTRUCTION OF WATER RESOURCES PROJECTS

by

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INTRODUCTION

History has shown that great civilizations develop where good quality water is abundant or can be made so by the efforts of man to meet the needs of man, and falter when usable supplies are inadequate or are grossly misused.

Most nations of the world, to the extent they have become involved in nationally sponsored and financed resource development activities, have historically given high priority to those functions and goals which lead to stronger national economic growth and stability. Currently, the goals of many nations, including the United States, are giving greater conscious emphasis to functions which contribute not only to economic growth but also to a better social and cultural quality of life for their people, and to protection and enhancement of the overall environment. All of these broad national goals relate directly or indirectly to a nation's resources and the projects that put those resources to work for the benefit of the people.

Resources

Water, land, and the atmosphere are the earth's three basic renewable natural resources from which all new wealth generates through the activities of a fourth all-important renewable resource--man. In general, all other
resources are extractable and therefore exhaustible. Of the renewable wealth-generating resources, water is the most limited and variable. In addition to its wealth-generating capabilities, it is the catalyst in development of the earth's expendable resources. Water combined in use and development processes with land, coal, oil shale, other minerals, and other natural resources tends to stabilize and enhance rural and urban life in established areas, to stimulate rural and urban growth in new areas, and to promote general economic development and expansion with far-reaching sociological benefits.

Planning and Construction

If a project is to achieve its goals subsequent to project construction, obviously it must have been formulated, designed, and constructed on a sound basis. Each of these aspects is an extensive subject in itself and cannot be covered in the limited time for this paper. Therefore, this paper deals only with achievement of goals subsequent to project construction and assumes, of course, that project formulation, design, and construction have been on a sound basis.

Multiple-purpose Projects

In most of the world, the day has long past when a nation can plan for single-purpose water development projects. The multiple-purpose approach is essential to meet modern day needs and demands of society and it offers many advantages. Foremost among these of course is the opportunity to integrate and coordinate water uses for the several competing functions in order to maximize overall benefits for people. More specifically, the multiple-purpose approach offers the opportunity to share costs among several
functions, to avoid costly duplication of facilities, to avoid costly modification of facilities for adding new functions after initial construction, and to minimize conflicts among project functional interests by setting up from the beginning long-range principles and criteria for coordination and integration of water uses.

Despite the advantages of the multiple-purpose project concept, there are inherent conflicts among the several purposes and these must be reconciled, frequently by compromise. For example, the season of high-water use for irrigation occurs at about the same time that the natural flow of the river drops off. These circumstances often cause a rapid drawdown of reservoirs during the season of greatest recreational use of the reservoir area. This is offensive to the recreationist because the rapid drawdown leaves exposed shoreline mud flats, exposed boat ramps and piers, and a shoreline devoid of vegetation. Similarly, fluctuating water releases for hydroelectric power production for peaking purposes may create undesirable conditions for sport fishing downstream. Integration and coordination of water management operation to serve multiple functions become complex from the legal, technological, administrative, financial, economic, social, political, and environmental standpoints. Management, to cope with these ramifications, is often beyond the capability of a local entity, particularly one oriented to a single function, and therefore must usually be dealt with under the broad authorities that prevail at the state or national level.
Organization

The type of organization required to manage a multiple-purpose project is usually established before the project is constructed. In the United States this may be a Federal bureau responsible for overall management of the multiple-purpose functions. Facilities serving single-purpose functions within a multiple-purpose project may be transferred for operation and maintenance to local or state organizations authorized to contract with the United States and with power to tax their members. If several such organizations are involved, a board of control or a joint operating organization of some type is established. If the project is international in character, the two or more nations involved must each be represented on some type of a joint committee or commission set up for the purpose of operating the project facilities pursuant to previously established guidelines and criteria. Such a board would employ an experienced manager, supplemented by a technical staff to the extent necessary to conduct the operation and management functions.

Staff

To achieve project goals, the manager and his top professional staff must represent technical expertise in all disciplines associated with the various project purposes. The number and classification of employees in each professional category will vary according to the operation and maintenance functions to be performed for each project purpose. Many irrigation districts in the United States have found it desirable to publish a handbook for their directors and staff which describes in some detail the project
goals, its physical facilities, the Board's legal responsibilities, its policies and standards, its management philosophy, and its programs for operation and maintenance.

MANAGEMENT OF STORAGE AND CONVEYANCE SYSTEMS

Operating Criteria

An integrated, or at least coordinated, operation of all units is essential to achieve the highest multiple-purpose use of the water resource and the greatest benefits for the greatest number of people. This requires promulgation of carefully worked out operating criteria.

Operating criteria may be defined as the long-range guide for operation of reservoirs, powerplants, and related facilities in a river basin consistent with the laws of the river so as to facilitate water regulation for the benefit of present and future water resource development in the basin, including protection and enhancement of the environment. Individual reservoirs in a basin development normally should not be operated as independent units or features.

Input into governing criteria must represent contributions from national, state, and contractual interests. Legislative, compact, treaty, and contractual restraints must also be observed. Parochial positions must give way to equitable treatment. The views of all interested parties must be given full recognition.

Criteria should be flexible with provision for periodic review among interested parties, and for revision whenever the need is indicated.

An annual report describing the actual operation for the preceding year and projected plan of operation for the current year should be a requirement.
Operational Techniques

The primary authorized functions of a reservoir usually dictate the management procedures for its operation. However, under a multi-purpose concept, this can become quite complex because of the different requirements for meeting competing interests and objectives. For example, the desire for empty storage space to insure flood control, the desire for a full reservoir to provide maximum irrigation and power generation benefits, and the desire for a nonfluctuating reservoir water level to maximize recreational benefits are basically in conflict. A compromise plan including proper priorities of interest is necessary. Although these conflicting interests are recognized in the planning process, those responsible for actual operation of a complex system are often subjected to pressure from special interest groups for modification of reservoir operation to enhance or give precedence to a particular function at the expense of another.

Frequently there is some flexibility in operations to recognize peculiar circumstances and to modify operations on a temporary basis to meet unusual or emergency conditions. However, the rule of operation must be fair and equitable treatment of all concerned in the light of authorized functions and established limiting operational criteria. Success in these operations requires good public relations which, in turn, require complete explanation to the users involved, the news media, and the public in general, as to the reasons behind operating decisions, the goals in mind, and the accomplishments obtained.

Water Quality

The success of many purposes served by a water project are dependent on good quality water. Conversely, these same functions may have adverse effects on water quality.
The greatest cumulative negative effect on water quality usually develops through the use and reuse of water as it moves progressively downstream from one reservoir or use to the next. Paradoxically, the greatest positive economic benefits from a given water supply are derived by the same use and reuse. By knowing the effects of various operations upon quality and the seasonal water quality demands for each multipurpose, operations can be adjusted to provide maximum benefits from a limited water resource.

For example, an irrigation project located on marine shale parent materials may have two negative effects, i.e., (1) a concentrating effect on total dissolved solids through evapotransformation; and (2) a "loading" of the drainage return flow with new salts leached from the parent material. Lining canals and laterals would decrease seepage, and improved farm irrigation efficiency would decrease deep percolation, both of which would otherwise leach salts from the soil and parent material.

Similarly, it may be possible to hold return flow of poor quality water in a regulating reservoir and use it for purposes where quality is not important, return it to the stream during periods of high flow, or return it to the stream at times when it will have the minimum adverse effects. For example, highly saline water for late season irrigation of cotton appears to have little adverse effect, while the same quality water would totally destroy a salt-sensitive crop at germination time.

Release of storage water in the late irrigation season usually provides good quality water at a time when river flows would be low and of poor quality without the benefit of storage regulation.
The temperature of water in a stream below a dam to meet various purposes can be controlled within rather wide limits through the use of multilevel outlets.

The rate and timing of discharges from a reservoir have an important influence on the biodegradation assimilative capacity downstream. Large releases and increased flow velocity may so reduce the travel time to move a given organic pollutant downstream that it does not have time to undergo biodegradation. Peaking power releases may be particularly troublesome in this respect.

To achieve project goals, each operation for a given project purpose should be made with a full awareness of its effects on water quality as related to other project goals.

**Review of Maintenance**

Periodic review of all operating facilities is a necessity. It should be made at predetermined intervals by a team of experts in the maintenance of the particular facilities involved, whether they be dams, powerplants, pumping plants, canals, or mechanical systems related thereto. The purpose of such reviews, of course, is to discover, identify, and evaluate deficiencies in maintenance or operation and to establish schedules for their correction. The long-range objective is to insure effective, efficient, and safe performance of the facilities for their intended purposes.

**IRRIGATION**

**Sustained High Production**

The broad long-range objective of irrigation development is to establish a firm dependable base in support of local economies out of which will grow
numerous secondary benefits, both economic and social with far-reaching effects. The immediate objective, however, is agricultural production. Realization of the broad irrigation objectives depends upon the extent to which agricultural production is in fact developed and sustained at a high level. Experience of the Bureau of Reclamation has clearly revealed the following programs, tools, and aids which are very helpful in reaching both the immediate and long-term objectives.

Drainage

Ground-water levels associated with the irrigation of project land must be watched carefully in order that proper and timely corrective steps can be taken before serious drainage problems occur. With inadequate drainage a buildup of the ground-water level may drown the plant roots. Even with adequate drainage facilities accumulation of salts in the root zone may occur when insufficient water is applied during irrigation to leach the salts out of the plant root zone.

One significant source of salts is the irrigation water itself. It is not unusual for irrigation water to contain from one-half to three tons of salt (approximately 400 p.p.m. to 2100 p.p.m., respectively) per acre-foot. Many areas have irrigation applications of from 4 to 10 acre-feet annually. Another source of salt in the soil is from the parent material and is brought up to the root zone from lower levels with a rising water table or by piezometric pressures.

Drainage needs may occur a year or two after an area is first irrigated or may develop slowly and not become critical for many years after initial irrigation. This is controlled by the type of irrigation system and
irrigation practices which in turn determine the quantity of water that percolates to the ground water; and the soil and subsurface characteristics which establish the capacity of subsurface aquifers to hold water and to allow it to move away under natural or existing conditions.

Drainage factors are often so complex they cannot be completely predicted in the project planning stage. On projects where drainage was studied as part of project planning, information may be available on the original depth to water table, hydraulic permeability of soils, other soil characteristics, depth to impervious barriers, topography, and outlet conditions, all of which may be important in predicting what drainage problems may be anticipated.

Ground-water observation wells should be installed and read periodically to record changes in ground-water conditions. It is preferable that these wells be installed at least 2 years prior to initiation of irrigation, in order to record preproject conditions. In areas with significant seasonal rainfall, such data should be collected and correlated with ground-water conditions.

Periodic plotting of ground-water data is necessary to determine changes in conditions. This may be done by the preparation of maps and charts showing depth of ground water and seasonal changes in ground-water conditions. A good topographic map with contour intervals of about 1/2 meter or less is usually essential as a base for the preparation and layout of the data.

Information on soil and geologic conditions is essential to predicting requirements for drains, determining drain locations, and in estimating
The Bureau of Reclamation Designs principles for drainage as an integral part of the
framework. Emphasis must be given to the principal
backbone element of the drainage system,
not the minor or auxiliary construction of the
regulation, supply and distribution systems.
Extensive drainage systems and the addition of lateral drains may be
depended upon until experience dictates more precisely their need and proper
location.
their effectiveness when installed. This includes information on the 
permeability of the soils and the depth of permeable material that overlies 
a drainage barrier. While it is necessary to have a general idea of soil 
permeability of an area, the best measurement can be made by bailout-type 
tests conducted under high water table conditions.

Proper drainage can be accomplished only with the knowledge of the 
source of the water that is causing the problem. Modified irrigation 
practices to reduce deep percolation and lining of canals to stop seepage 
are often cheaper corrective measures than installing drains.

Settler Assistance

Engineering. Often irrigators on new projects are inexperienced. 
Assistance in preparation and management of farm units will help in attaining 
high crop productivity in initial stages of development. It will prevent 
considerable expense and loss of productivity that occur when crude systems 
must be rebuilt after farmers find that they are inefficient and must be 
redone.

Proper layout of farm unit is essential to maintaining high productivity, 
providing good control of irrigation water, and in keeping farm labor 
requirements within reason. Design of farm fields depends on the type of 
irrigation to be practiced. In gravity irrigation, consideration must be 
given to the head of water available, the slope of fields, and length of 
the irrigation run so that water can be applied in proper amounts to the 
soil root zone to satisfy the need of the crop being grown without wasting 
water, eroding the soil, or causing high labor requirements.

In sprinkler irrigation systems, less consideration need be given to 
topography in the farm layout, but peak water requirements of crops, labor
requirements in moving the systems, and power costs of providing pressure to the sprinkler irrigation system are of prime importance.

Design of farm ditches to deliver water to farm fields and surface drains to carry off excess water needs to be considered in the development of the farm unit. Proper slope, capacity, and elevation of water in ditches as related to that of farm fields is essential to the control of irrigation water.

**Agronomic.** Changes from dryland agriculture to irrigation often involve training and education in farming practices.

Proper irrigation practices are essential. It is often difficult, even for people who have had irrigation experience, to understand the soil-plant-water relationships that are necessary for proper irrigation. Farmers need an understanding of the water-holding capacity of the soils, the conditions under which plants extract moisture from the soil, and what happens when excess water is applied.

As compared to dryland farming, new crop varieties often provide higher production under irrigated agriculture. In the United States information on new crop varieties can be obtained from agricultural experiment stations. Often the availability of water allows for changes in planting dates or may permit more than one crop to be grown during a year.

To accomplish desirable agronomic adjustments, the Bureau of Reclamation frequently, as part of its project costs, employs or finances the employment of skilled agronomists and irrigation engineers to assist farmers individually in farm unit layout, cropping patterns, and irrigation methods.
Financial. Farm development costs are often beyond the financial capacity of the farmer. Full production from irrigation agriculture can be obtained only if timely financing is available for proper farm development, farm equipment, and farm operating costs. Often it is not feasible for farmers to own individually all of the needed specialized equipment. Thus, arrangements should be considered under which several farmers can share equipment, possibly through cooperatives or equipment pools so that farmers can obtain the use of needed equipment at reasonable costs.

Development Farms. Development farms are an effective tool in settler assistance. Their principal value is during the early years of a project to demonstrate to new settlers and project water users practical irrigation methods and agronomic practices best suited to local conditions. The farms also provide a centralized location where all interested local, State and Federal agencies can cooperatively carry on needed research. It is imperative that sites selected represent the prevailing project conditions.

Research conducted under such conditions usually is under the direct supervision of agricultural experts supplied by the State or Federal government. However, an advisory committee representing Federal and local interests usually participates in guiding demonstration farm programs for Reclamation projects. Demonstration farms may be on land in a project area and farmed by the landowner or tenant, in accordance with the plans of the supervisor and committee; or may be on Federal or State land and operated and managed by a full-time Federal employee, also under technical supervision.
Frequent demonstrations, to which local settlers are invited, are held at the field level to illustrate improved irrigation and farming methods. The Bureau of Reclamation has found from experience that demonstration farms are extremely helpful in expediting the attainment of irrigation project goals.

HYDROELECTRIC POWER

General

Electric power is derived as a byproduct of Reclamation's western multiple-purpose river developments. Being a byproduct, power generation is determined by the amount of water passing through the storage system. The Bureau of Reclamation's involvement in the power field is largely for the purpose of financing those reimbursable costs of other multiple-purpose functions of water resource projects that are beyond the ability of those functions to repay. Power managements' objectives are comparable to those of any other business; that is, to perpetuate the organization so that its mission and financial objectives can be achieved. Because of the Bureau of Reclamation's mandate and desire to run its electric system in the most economical manner possible, efforts are continually made in evaluating economies that might be achieved by adopting new practices, new procedures, new products, and new technology, not only in the planning of new power developments but also in the redesign, operation, and maintenance of older plants.

There are few, if any, manufactured products or processes that reach a greater number of American consumers than electric power. Because of this, the industry is subjected to microscopic examination by the public, the press, and other communication media in addition to regulatory agencies.
This became particularly pronounced when the Northeast sector of our country suffered from an extensive blackout in November of 1965. This marked the start of a period in the industry when the key word became "Reliability."

Reliability

Translating reliability from the word to action has required installation of much new equipment and establishment of many new procedures. New emphasis on reliability has also resulted in the formation of coordination councils and organizations which now display a degree of cooperation that has not previously prevailed in the industry. The Bureau of Reclamation has taken a leading role by coordinating the operation of its interconnected power system through development of relay and control devices for improvement in interconnected power system operation and has joined all available reliability and coordinating councils to which we can contribute our expertise. We are an active member of the Western Systems Coordinating Council which serves 36 million people with an electric power demand of approximately 49 million kilowatts.

Implementation of Goals

The Bureau of Reclamation is facing and meeting the challenge to provide reliable, high quality, low cost electric power for the ever-increasing demands of customers by numerous means. Now under construction is the "third powerplant" at Grand Coulee Dam on the Columbia River in the State of Washington. The existing generating capacity at Grand Coulee Dam is about 2 million kilowatts. The six units to be initially installed in the new plant will add 3,600,000 kilowatts, with an anticipated ultimate capacity in the third powerplant alone of 7,200,000 kilowatts. The Bureau of
Reclamation recently participated in the construction of extra high voltage ties between the Pacific-Northwest and the Pacific-Southwest. Those ties are in the 500- to 750-kv. range and involve d.c. as well as a.c. transmission.

**Peaking Power**

Hydro powerplants are uniquely well adapted to generation of peaking energy. Since the power industry by its very nature is one of growth and change, the Bureau of Reclamation is exploring opportunities to maximize use of all hydro installations for peaking power production to augment the thermal power baseloads of the West. The Bureau of Reclamation is also investigating the further development of so-called pump-back storage for hydro peaking capacity to make the maximum use of our water resources.

However, even with all the new developments in systems analysis and control, the formation of large power pools, combined operating areas, the construction of extra high voltage ties and high capacity generation, and the greatly improved computer capability and use, the human element cannot be overlooked. Personnel understanding and guidance must be thoroughly geared to the achievement of the goals being sought.

**FLOOD CONTROL**

Under the multiple-use concept most reservoirs are now planned and constructed to provide flood control by allocation of some storage space, either exclusively or jointly, to the flood control purpose. Even when this is not one of the primary objectives, the incidental flood control benefits in connection with other uses such as irrigation and power are often quite significant.
Flood Operating Criteria

In order to obtain maximum flood control benefits operating criteria based upon rule curves as related to snowpack surveys, runoff forecasts, seasonal temperatures, historical records, and other meteorological information are necessary. Criteria often are developed in the planning stages, and should be revised as operating experience indicates is necessary or desirable.

Communication

The efficiency of flood control operations is enhanced considerably by complete and fast communication of the latest hydrological data within the drainage basin of the project. As many interests, both Government and non-Government, are concerned with flood control activities cooperative arrangements among such interests are often used in obtaining and relaying current rainfall data, river stages, and other information useful in flood control operations.

RECREATION AND FISH AND WILDLIFE

Through desirable combinations of water, land, and aesthetic resources the storage features of water development projects usually have high potential values for recreational use. Because such projects usually utilize public lands, public waters, and public financing, the resulting recreational benefits should accrue to the general public, rather than to special interest groups. Accordingly, recreational management responsibility should be assigned to a qualified governmental entity.

The first requirement to be met in connection with recreational interest in project features is to protect the project from damage incident to public use and to provide at least minimum facilities for protection of the health
and safety of the public. Such facilities are clearly the minimum required and usually are highly inadequate to accommodate the full public recreational potential.

To maximize public benefits consistent with other project requirements and needs for environmental protection, development and use of a reservoir area for recreation should be undertaken in accordance with a soundly conceived development and management plan which brings together in one document information needed to coordinate all pertinent reservoir needs and uses. Such a plan can be updated as necessary to meet changing needs. It contains a ready source of information to provide guidance to all appropriate interests.

Fish and wildlife values of a project fall into two readily identifiable categories; i.e., (1) those that provide direct recreational benefits (such as hunting, fishing, camping, picnicking, and nature study) in the project area, and (2) those requiring use and management of project features or facilities for mitigation of losses or enhancement of fish and wildlife resources.

MUNICIPAL AND INDUSTRIAL WATER SUPPLIES

Water is the lifeblood of a country's cities and industries. Therefore it can be expected that municipal and industrial water usually receives priority over all other uses as to both quantity (the sharing of water shortages) and quality. However, the degree to which this is done is usually spelled out in the operating criteria.

Water quality, including taste and odor as well as salt concentration, is extremely important. Every effort should be made to keep the reservoir and distribution system (including open canals and pipelines) from becoming
polluted. Pollution can occur from the action of man, animal, or nature. Controls must be exercised to prevent the detrimental effects of sewage and indiscriminate use of pesticides adjacent to water supplies. Heavy use of an area by wildfowl can result in undesirable concentration of nitrates or biological pollutants. Flood runoff into canal systems serving municipalities may result in turbidity and siltation problems.

Federal and local health and environmental control agencies often are helpful in policing municipal and industrial water supplies to keep out pollutants. They also can control the activities of the project system operators. Therefore a good working relationship among personnel of the agencies is essential. Health agencies can compel operators to take certain safety precautions as well as limit them in the use of chemicals to control algae, insects, or weeds in a water supply area. In some instances, fish and wildlife agencies prohibit use of copper sulphate to control undesirable taste producing algae because the CuSO₄ kills fish. In other instances, public health service agencies will not allow the use of DDT to control mosquitoes or 2,4,5-T to restrict certain plant growths around water supplies because of possible ill effects on water users.

CONCLUSION

Water is essential to the very existence and survival of man. Therefore, it should be emphasized that the fundamental objective of any water resource development project must be to improve the quality of life for people. Accomplishment of that objective requires more than mere construction of the physical facilities for water control and delivery.
It requires skilled management and a technically competent operation and maintenance staff that fully understands the short- and long-term effects and relationships of operations among and between the several project purposes; it requires carefully developed ground rules to assure equitable integration and coordination of all authorized project functions; it requires adequate and sound advice, assistance, and financing for project water users; and it requires continuous review and updating of operating procedures and criteria to keep them fully, efficiently, and effectively responsive to the basic objective of improving the quality of life for people—not only those now living but also those generations yet unborn. Like government itself, both philosophically and actually, an appropriate motto would be that water resource development must be "of the people, by the people, and for the people."