Plan Formulation

The plan formulation process consists of identifying water-related needs and opportunities, developing alternative plans that provide for those needs and opportunities, and selecting the plan from among those alternatives that most effectively and efficiently provides for those needs and opportunities. Identification of the needs and opportunities is done primarily through public involvement, which includes the client and interested agencies. Plan formulation includes economic, social, environmental, engineering, hydrologic, land classification, legal, and institutional considerations.

Some of the more common water-related needs and opportunities are agricultural irrigation, municipal and industrial uses, power generation, flood control, instream flow augmentation, groundwater recharge, recreation, fish and wildlife habitat, and pollution abatement.

Plan formulation is an iterative process of comparing and selecting from alternative plans until the most acceptable plan is identified.

The following sequence of steps can serve as a helpful guide in plan formulation for a water resources study:

a. Preliminary identification of needs and opportunities.
b. Preliminary decisions on possible alternative plans for providing for the needs and opportunities.
c. Preliminary estimate of prospective differences among the alternatives, expressed in physical or nonmonetary terms.
d. Translation of descriptions of the differences among the alternatives into rough estimates of the benefits and costs in monetary terms, their times of occurrence, and their conversions to approximately equivalent values for a common time period.
e. Evaluation of nonmonetary effects of the plan, such as expected environmental and social effects.
f. Analysis and comparison of the rough monetary and nonmonetary estimates, and selection of those alternatives justifying further study.
g. Progressive refinements in physical, economic, environmental, and social evaluations; and selection of the more promising alternatives for more detailed study.
h. Progressive reexamination of problems and opportunities, alternative plans previously considered, and new alternatives that may be conceived in light of the results and refinements of progressive investigations and analyses.
i. Selection among the few remaining alternatives, giving consideration to more detailed studies, to comparative benefits and costs in monetary terms, and to differences among alternatives that are not readily reducible to monetary terms.
j. Selection of a single plan from the surviving alternatives, with further analysis using progressive levels of development to determine the optimum project size, and with consideration given to such concerns as pertinent laws, interstate compacts, and fiscal and administrative policies of relevant governing and financing organizations.

In practice, the relationships of engineering, economic, hydrologic, environmental, and social principles and criteria of plan formulation should be well understood. These relationships should be applied at all stages of the planning investigations and analyses from the beginning resource inventories and field inspections, through the increasing stages of refinement, to the time that one plan is selected for detailed investigation and evaluation.

The viability of proposed plans can be tested to a substantial degree by applying four tests: (1) completeness, (2) effectiveness, (3) efficiency, and (4) acceptability. These four tests are set out in the "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies," dated March 10, 1983, as published by the U.S. Water Resources Council. While the tests, as extracted from that document and stated below, are intended for guidance for Federal agencies, they are appropriate for the evaluation of any plan for use of water resources.

The four tests are:

(1) *Completeness.*—The extent to which a given alternative plan provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects. This may require relating the plan to other types of public and private plans if the other plans are crucial to realization of the contributions to the objective.

(2) *Effectiveness.*—The extent to which an alternative plan alleviates the specified problems and achieves the specified opportunities.

(3) *Efficiency.*—The extent to which an alternative plan is most cost effective in alleviating the specified problems and realizing the specified opportunities, consistent with protecting the nation's environment.

(4) *Acceptability.*—The workability and viability of the alternative plan with respect to acceptance by State and local entities and the public; and compatibility with existing laws, regulations, and public policy.

Ecological and Environmental Considerations

A. INTRODUCTION

2.1. ***Planning.***—Proper planning of dams requires a heightened awareness of our natural and human environment. Concern for environmental quality includes concern for the air and water, our natural ecological systems, and our cultural resources. Many laws and regulations now reflect this concern and require the consideration of environmental factors in planning.

Recent legislation and public concern require agencies to provide detailed statements of the significant environmental impacts of the proposed actions that can affect the quality of the environment. Reports meeting this requirement have become widely known as EIS's (Environmental Impact Statements). The demand for these reports has resulted in the establishment of numerous companies whose primary purpose is to develop technically adequate EIS's and extensive literature on environmental assessment methods [1, 2, 3, 4, 5, 6][1]. In many instances, the objective appears to be the development of an EIS; however, the goal is not better documents but decisions that better balance the use of water resources with the protection and enhancement of environmental quality.

Legislation and public concern have fostered a multiobjective approach to water development and more serious consideration of the potential environmental consequences of development. Environmental aspects must be considered from the initial planning and design of a project through its construction and operation [7, 8]. This requires the actions of an interdisciplinary (and in some cases interagency) team representing a wide range of expertise, including economics, engineering, design, biology, recreation, hydrology, and sociology. The disciplines involved in each study should be based on the natural and physical resources involved in that study. It is through the effective interactions of the team members that arrangements are made to accommodate environmental concerns early in the planning rather than through mitigating actions after the project is completed.

The enhancement of existing resources and the complete avoidance of adverse environmental effects are not always possible. In addition, benefits to one resource may result in the loss of another resource; e.g., impounding a stream may create a dependable water supply but eliminate terrestrial resources within the permanent pool area. It is the job of a planning team to develop plans that result in impacts that are more positive than negative. In many cases, adverse environmental impacts can be reduced significantly through the careful design, construction, and operation of project features.

The purpose of this chapter is to describe ways to plan for environmental resources and to identify some practical solutions to the common environmental problems that frequently confront project planners and designers. Because each project presents unique problems, the reader is encouraged to consult the publications referenced in the bibliography at the end of this chapter (sec. 2.10) and other publications on this subject. Designers and planners are encouraged to consult experts in the environmental sciences to identify the opportunities for enhancing natural resources and to develop creative solutions for lessening adverse impacts.

[1]Numbers in brackets refer to entries in the bibliography (sec. 2.10).

B. GENERAL ENVIRONMENTAL ISSUES

2.2. ***Requirements.***—Subsequent sections of this chapter deal with the environmental issues generally encountered in all water resource development projects. A list of environmental factors that might be important in a specific project would be extensive. Therefore, each study should identify, or "scope," the environmental issues that could significantly affect planning. In many instances, these issues are specific legal requirements (local, State, or Federal regulations) that must be addressed. The appropriate agencies should be consulted for compliance procedures. In the United States, the appropriate Federal agencies include the Fish and Wildlife Service, Forest Service, National Park Service, National Marine Fisheries Service, and the Environmental Protection Agency. State agencies include game and fish, recreation, public health, historic preservation, and water resource organizations. Each study should involve a unique combination of agencies, depending on the resources involved.

2.3. ***Categories of Resources.***—The general categories of resources that should be considered include air quality, water quality, prime and unique farmlands, wild and scenic rivers, endangered species, wetlands, unique natural areas, wilderness areas, sound quality, visual quality, and geologic formations [9].

C. FISH AND WILDLIFE CONSIDERATIONS

2.4. ***General.***—Experience in Federal water resources development indicates that fish and wildlife resources may represent a major portion of the environmental concerns that should be addressed before project construction and operation. These resources include animal species with economic importance because of their uses as food and for commerce, species with recreational importance because of their uses in hunting and fishing, and endangered species with ecological importance because of the concern for their protection. Species that are indicators of environmental health and species with esthetic appeal should also be considered.

Because of the complexity of fish and wildlife resource problems that, on the surface, appear simple, it is imperative that professional fish and wildlife biologists be actively involved in project planning and design. Those professionals familiar with the resources in the planning area should be consulted early in the planning phase. The appropriate agencies can supply valuable information on local wildlife habitats and populations. Their involvement can result in the avoidance of critical resource areas, and their suggestions can help enhance particular resources. Where adverse impacts are unavoidable, they can recommend actions (designs and management methods) that can partially or completely mitigate project impacts.

Reservoirs can be of significant benefit to certain fish and wildlife species when the biological requirements of these species are considered during the planning, design, and operation of the reservoir project. The following sections discuss how fish and wildlife may be affected by dams and reservoirs, and describe certain features that can be incorporated into a project design to reduce adverse impacts or to directly benefit certain groups of species.

2.5. ***Ecological and Environmental Considerations for Fish.***—Impacts to fish and other aquatic life resulting from the construction of a dam and subsequent impoundment of water can be caused by the change from flowing to standing water conditions, by the modification of downstream flows, by changes in temperature and water quality conditions, or by the addition of physical barriers to both usptream and downstream movements.

The most dramatic impact is caused by the conversion of a portion of a free-flowing stream or river system to a standing-water system. Depending on the numerous physical and chemical variables of the site, the temperature and water quality conditions could change so as to significantly affect project uses, including fish and wildlife and recreation. Water quality issues in reservoir design are discussed in greater detail in part E of this chapter.

In most instances, either the species of fish that occupy the new reservoir are different from those in the stream, or the ratio of the various species contributing to the total population is significantly changed. If a significant fishery exists in the stream or if the project is to provide fishing opportunities, the planning study needs data accurate enough to assist in the design of alternatives that will maximize fishery benefits in the new reservoir, but will avoid adverse impacts downstream. The agencies responsible for fish management should be consulted for such a project.

Assessment of existing and potential fishery resources may, depending on the significance of the resource and the amount of available data, require sophisticated population or habitat studies. Where migratory species (salmon, trout, shad, striped bass, etc.) are important, tagging or radio-tracking techniques may be necessary. In recent years, there has been an increased emphasis on more accurate determination of the flow conditions that optimize fish habitat for the various life stages (spawning, fry, juvenile, and adult) [10, 11, 12]. Depending on the resource involved, the study methods can vary in the amount of time, money, and technical expertise needed to obtain adequate information. Predictions of reservoir populations are often made by comparing the physical and chemical properties with those of other reservoirs in the same area [13].

In cases where stored water will be used to generate hydroelectric power in a peaking pattern, the installation of a reregulation dam downstream from the discharge point should be considered if a significant fishery resource exists, or high recreational use is expected. This reregulation structure should balance high and low flow conditions which, if unregulated, could strand fish and recreationists, expose spawning areas, and scour the stream bottom, possibly reducing the production of aquatic food.

In relatively small rivers and streams, it is often possible to create habitat conditions that increase fish populations. Where pools are limiting, the construction of bank deflectors or small dams can direct the current so that scour holes are developed [14, 15] (see fig. 2-1). These structures can be very effective, yet they require little maintenance if properly located and constructed. Wing deflectors can be placed to direct the stream current to avoid excessive erosion, permitting the area to stabilize and reducing the amount of sediment entering the stream. Riprap and rock-filled gabions can also effectively control erosion. Underbank (escape) cover can be developed through the construction of overhanging structures: using logs securely anchored into the bank and covered by planking and sod (fig. 2-2). Where spawning habitat is limited or inaccessible because of the dam, construction of spawning channels and riffle areas have sometimes been beneficial (fig. 2.3).

When the construction of a dam will create a barrier to upstream and downstream fish movements where fish populations are an important resource (e.g., salmon), the design should include facilities for fish passage. Several design features are possible alternatives. Although none of these are completely effective in passing fish, they can reduce adverse impacts significantly. The types of structures include fishways (or ladders), conduits, and turbine bypasses [14]. At some facilities, trapping and hauling have been selected as the most cost-effective solution.

The fish ladder is perhaps the most common method used to facilitate fish passage. These structures generally consist of a series of stepped pools separated by weirs. Another type of passage structure, the Denil-type fishway, consists of a chute with energy dissipating vanes in the sides and bottom that reduce the water velocity enough to permit fish to ascend. Figure 2-4 shows yet another design, the Alaska steep pass fishway, at Ice Harbor Dam in Alaska. [14].

To direct fish to passage areas and to reduce the possibility of their entry into intake structures, several types of excluding devices have been used. These devices include stationary and moving screens (fig. 2-5), louvered deflectors, and electric weirs [14]. Where specific requirements for fish passage or exclusion are required, designs may be developed with the help of the U.S. Fish and Wildlife Service or the State fishery agency.

Within the reservoir, there are several factors that should be considered and evaluated to enhance the value of the anticipated fishery. Results from water quality and temperature studies should indicate whether the reservoir will thermally stratify. If stratification is expected, the reservoir may be suitable for management as a "two-story" fishery, with warm-water species occupying the upper layer (epilimnion), and cool or cold-water species established in the lower layer (hypolimnion). Management of the hypolimnion assumes that oxygen will be available in an acceptable concentration, which is determined in the water-quality studies. In stratified reservoirs, the installation of a multilevel intake structure may be desirable for both reservoir and downstream management.

When preparing the reservoir area, it is often advantageous to leave some trees and shrubs in the