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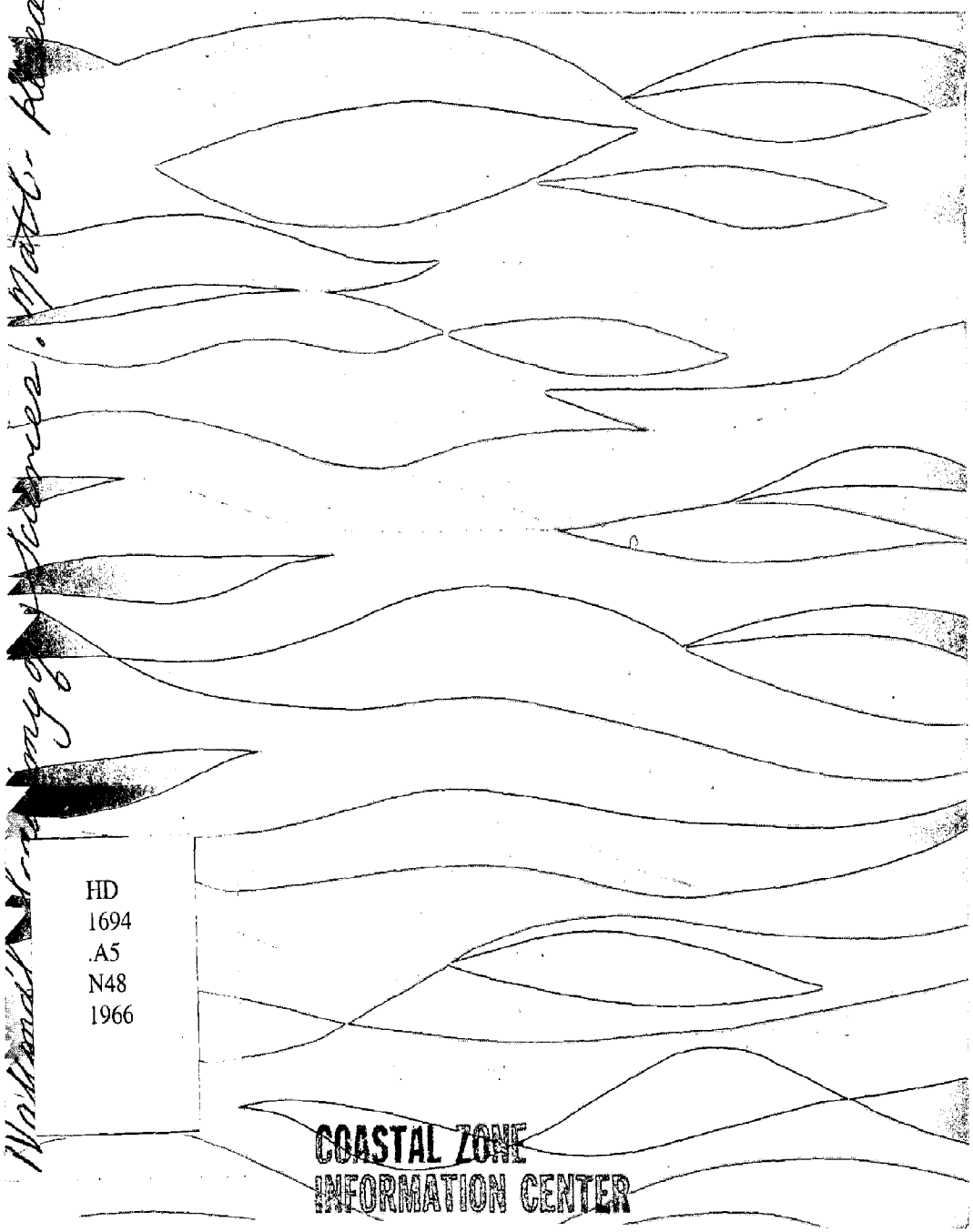

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ALTERNATIVES IN Water Management

A REPORT OF THE
COMMITTEE ON WATER
DIVISION OF EARTH SCIENCES
NATIONAL ACADEMY OF SCIENCES
NATIONAL RESEARCH COUNCIL

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Preface

The Committee on Water was appointed in 1964 by Frederick Seitz, President of the National Academy of Sciences. The Committee was to examine in some detail the important interactions between expanding knowledge concerning water resources and water use in the physical sciences, the social sciences, and engineering on the one hand, and increasingly complex decisions of public policy concerned with water-resource management on the other. This charge is so broad and the issues so extensive and complex that it seems likely that several reports will be required to give the several related topics the treatment their importance warrants.

The objective of this first report is modest. It identifies several principles that, in the opinion of the Committee, merit more attention than they are now receiving. In particular, the Committee, recognizing that the value of water varies among different groups in different places and at different times, believes that the management of water resources has evolved to a stage where planning should center upon the needs of people rather than upon water *per se*. This viewpoint implies that a broad range of alternatives must be considered before a decision is made to develop a water resource. To deal effectively with the increasingly complex nature of the decision process, new institutional arrangements may be needed to take account of intangible as well as tangible objectives.

Finally, the Committee recognizes that the future development of water resources requires better use of existing knowledge, and that the decision-making process itself must be responsive to advances in science and technology — advances that not only

increase the range of alternatives to be considered but also aid in evaluation of the alternatives.

The Committee hopes to develop more fully, in subsequent reports, several of the topics treated in this first report.

The Committee expresses its sincere appreciation to the National Science Foundation, the U.S. Army Corps of Engineers, the U.S. Weather Bureau, the U.S. Geological Survey, the U.S. Department of Agriculture, and the U.S. Department of Health, Education and Welfare, for their support.

Gilbert F. White, Chairman

May 1966

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More Science: Better Water

This report is not prompted by a national water shortage, for there is no nationwide shortage and no imminent danger of one. To be sure, there are serious regional shortages of usable water, many of which are becoming critical because of short-sighted planning or pollution of fresh-water supplies. The question of water quality is as important today as the question of water shortage.

This report is concerned with the rapidly growing need for more intelligent application of science to the use of water in the United States. Within the limits imposed by the natural distribution of precipitation, most of the pressing regional and local problems of water quality and distribution would be susceptible to informed and imaginative solution, not only in the United States but in other parts of the world.

While science and technology are enlarging the range of possible alternatives in water management, the nation's increasing affluence permits it to consider intangible values, and the need for doing so is widely recognized. But the nation lacks facility in dealing with intangible values. It also lacks facility in using the results of scientific and technologic investigation to formulate alternative ways of achieving multiple aims.

Changing Objectives

The Tide of Empire

At the sound of a pistol shot on April 22, 1889, men in buckboards, on horses, on burros started a race unique in American history. The race was unique but the force behind it was not. In the latter half of the nineteenth century a strong tide of empire was flowing westward. The people of the United States wanted their West developed rapidly. To this end they encouraged the farmer, the railroad man, and the miner to develop the resources of the West, holding out gifts of land as inducements — to the farmer, homesteads; to the first railroads, land grants; and to the miner, exclusive enjoyment of any mineral treasure he found and the land upon which he found it.

Even earlier than the Oklahoma land rush and the Homestead Act, "internal improvements" had been the theme, and such statesmen as Albert Gallatin and John Quincy Adams had urged the new nation to improve its natural waterways and to build canals as a means of joining the country in commerce and of breathing economic life into new regions. Later, when it was believed that the key to western development was water, the drafters of the Reclamation Act sought to make possible the development of small farms and communities by extending the help of the federal government in furnishing the vital water. Still later, in the dark days of the 1930's, plans to transform the valley of the Tennessee River were put into action to provide a new way out of a regional economic morass, and massive investment was made in water projects in other parts of the country, as in the Columbia, the Missouri, and the Arkansas basins.

The Basin Plan

While these major steps in land and water policy were clearly tied to economic growth and development, a host of laws and policies dealt with particular resources or with particular places, disregarding pleas by federal commissions as early as 1907 for integrated water development. Grazing permits on the public domain, land-conservation programs for agriculture, regulation of hydroelectric power, and investment in flood control are only a few reflections of the national interest in resources. Despite concentration on specific resources for single uses, it gradually became apparent that resources were interrelated, and a need was recognized for longer-range planning that would include multipurpose systems involving simultaneous development of several resources. If a dam could be built to retard flood waters, could it not also store water for irrigation, or periodically release water to produce power? Hoover Dam became the prototype for multipurpose water regulation.

The view developed that comprehensive plans could be designed for a basin or a region, with water as a unifying factor—basin plans which, if put into effect, would use resources more productively, with minimum waste and at minimum cost. Because water is widely distributed, is closely related to the utilization of other resources, and is usually managed in visible construction projects, planning for food, fiber, mineral, and land resources tended to be seen as related to plans for water development. The Tennessee Valley Authority became the popular prototype for comprehensive development of an entire drainage area; but similar systems or projects were taking shape in the Columbia River Valley, the Central Valley of California, and other basins.

To accommodate numerous federal and state interests, it became necessary to coordinate the activities of public agencies. National and basin programs were promoted through the National Resources Planning Board, and later through interagency committees.

Unfortunately, planning and development of water

resources continued to be concerned mainly with specific needs, such as navigation, irrigation, and flood control. The strength of the nation's interest in these and other problems varied widely from decade to decade. While the economic well-being of communities, states, and regions may have been an underlying motif in investment policy, that motif often was buried within or masked behind specific laws and formulas designed to deal primarily with natural resources as such; the public tended to lose sight of the fact that many resource-development plans and policies were justified originally for their contribution to economic growth.

By the 1950's federal agencies had done much to improve and standardize methods of analyzing water projects and developments. Congress, which had usually belied its expressed belief in comprehensive planning by authorizing individual projects, took a giant step toward comprehensive national water-resources planning when it authorized the report of the Senate Select Committee on National Water Resources; that report, published in 1959-1961 in 32 sections, emphasized the pressing water needs of the next few decades. Efforts to establish machinery for coordinating the diverse interests represented by a large number of federal, state, and local agencies culminated in the Water Resources Planning Act of 1965, which established a Water Resources Council and provided financial assistance to improve state potentials for water planning. The Act further provided for the establishment of river-basin planning commissions made up of state and federal regional representatives.

The new Water Resources Council, composed of the Secretaries of the Departments of Interior, Agriculture, Army, and Health, Education and Welfare, and the Chairman of the Federal Power Commission, has the two principal opportunities to formulate policies to be followed by federal agencies in planning and developing water and related land resources and to review the plans developed regionally

for those purposes in cooperation with the concerned state and local groups.

Federal assistance in a great array of resource programs led to concepts of comprehensive river-basin planning. At the same time, dealing piecemeal with individual resource issues fostered a complex of laws, policies, procedures, and habits of thought that make it difficult to consider the nation's broad interests and objectives in any coherent scheme of policy and practice. Recommendations to solve water problems are made typically by agencies with responsibility for construction. Their appraisals understandably tend to lack breadth. It is difficult for the Bureau of Reclamation to be objective about irrigation either as an aspect of agricultural policy or as a justification for consumptive use of water, or for the Office of Saline Water or the Atomic Energy Commission to consider with total dispassion ways to meet water needs other than by giant desalting-power plants. The incentive to escalate agency programs is endemic. Moreover, there is always strong support for solutions that involve large expenditures and employment, even if temporary.

An important statement of federal water policies, standards, and procedures was printed in Senate Document 97, 87th Congress, and approved by President Kennedy in 1962. These policies and standards were intended to provide a common basis for federal agencies in the formulation, evaluation, and review of plans for the development of water and related land resources, and to reduce differences in practices. The standards set forth in Senate Document 97 encourage a comprehensive long-range viewpoint in planning, with full consideration of all types of water demands and development possibilities, and they stress the need to outline and present to decision-makers alternative solutions in order that variations in objectives, policies, timing, and other factors may be considered in adopting plans for action.

A Wider Concern

Yesterday the nation's interest in water resources was variously centered on irrigation, navigation, winning the West, and lessening the burden of natural disasters. Today the nation's concern is widening to include assurances that all regions share in the national growth, that individuals have an opportunity to enjoy the pleasures and beauties of the natural environment, and that the quality of that environment be protected and enhanced as the nation grows. Consequently, recreation, pollution abatement, wilderness preservation, and water development for Appalachia are important today. Protection against floods and droughts, as well as production of hydroelectric power and the promotion of navigation, must be examined anew in the light of modern America's demands and desires and its ability to pay for what it wants. Clearly, the list of socially desirable objectives in planning is growing.

A sharpened concern that all regions share in national growth poses prickly problems of allocating water among states and of allocating investment funds among regions. Every decision to store or transport water has implicit in it a set of judgments as to national and regional aims. If region A is running short of water for irrigation and region B still has supplies exceeding its prospective needs, one solution is to seek a transfer of water from B to A with the federal government providing financial support for irrigation, for power, and for recreational features of the project. An alternative is to support increased uses in region B, encouraging population growth there rather than in A. Putting aside knotty questions of contending water rights, it is difficult to disentangle fully the web of consequences that would result from pursuing one solution rather than the other.

A similar problem arises where region C suffers chronic unemployment that might be relieved temporarily by constructing new water projects largely at federal expense. The benefits may be short-lived unless the projects promote productive capacity, and it may even be that such an investment in public works will retard socially desirable

population emigration and economic adjustments that otherwise would take place more rapidly. Again, a policy toward population relocation may be inherent in the building of a dam. Such decisions and actions call for new consideration of national aims and, in turn, for deepened understanding of the effects of a change in water use on the whole fabric of society.

Momentous changes in society—rapid increase in population, in urbanization, in mechanization of daily life, in leisure time, and in disposable income—are causing large increases in the use of water, are bringing about serious decreases in the quality of water, and are putting heavy pressure on planners and managers to incorporate the recreational and aesthetic values of water into their formulas and systems. Accumulated experience with their environment enables Americans to be more sensitive to the full effects of their manipulation of water, soil, air, plants, and animals. At the same time, they increasingly realize that they can now afford to do things beautifully as well as efficiently.

The Planning Process

Tangibles and Intangibles

New dimensions of social and economic development in American society, characterized by fresh hopes and rapid change, call for continuing appraisal of the objectives and methods of planning for water resources.

While impressive advances broaden the outlook of planning and water management, present policy and practice limit consideration of alternatives and emphasize those aspects of development that are framed easily in terms of economic production rather than those aspects in which nonmarket values dominate. With increased emphasis on the national store of scenery, fish and wildlife, historic sites, and on other social values that cannot be expressed easily in economic terms, planning processes must change to take such factors into account.

During the past half-century the national desire for economic growth was considered to justify full development of resources as soon as the direct economic benefits could be demonstrated potentially to exceed the costs. Planning was viewed as a method of considering the development of resources at individual sites or in specific areas, of designing a feasible project or projects, and of determining the economic benefits and costs as measured by direct change in production. The best plan was one that provided the most economical way of developing a specific resource.

The benefits to the nation of developments for power, flood control, navigation, and irrigation should by no means be overlooked in the future planning of the use of water. Such developments have contributed materially to present productivity. However, at no time were the aims of public involvement solely economic. Public power was seen by some of its

proponents as a means of regulating private producers; flood control on the Ohio in the late 1930's was influenced strongly by determination to prevent loss of life; and irrigation from the outset of federal investment was directed toward building communities of family-size farms.

Events of the recent past reveal that social objectives considered desirable by society have been significantly broadened, and that certain objectives desired by society may not be consistent with the most economically profitable use of resources. The public interest in recreation, quality of environment, and aesthetics implies a willingness to forego opportunity or to spend money in a way that does not necessarily yield the highest benefit-cost ratio as we are now able to compute it: the public is willing to pay for intangibles. On the other hand, in order for the public to know what intangibles are available at what cost, and thereby to determine what it is willing to pay (including foregone benefits) for those intangibles, all practicable alternatives, including both tangible and intangible benefits and costs, must be presented. Consideration of such a broader range of alternatives implies greater demands on science to predict not only the immediate but the more remote consequences of resource development.

Hydrology, Society, Planning: the Potomac

Recent deliberations over the future of the Potomac River provide an excellent illustration of both the problem of exploring alternatives and the fundamental importance of biological, physical, and social knowledge that must inform such political discussion.

The Potomac is not a large river. With a mean annual flow of 11,000 cubic feet per second (cfs), it is characterized by great variability, with late-summer flows as low as 800 cfs and spring floods as high as 484,000 cfs. Much of the land of the Potomac basin remains open, as yet free of intensive development. Not only does the basin contain many monuments of the nation's history, including the Chesapeake and Ohio Canal which parallels the river for a hundred miles from Georgetown to Cumberland, but near Washington, D.C., the river

passes over the spectacular Great Falls and through an impressive colorful gorge. However, at and below the fall line where the free-flowing river becomes tidal, the nation's capital is the center of one of the rapidly growing metropolitan regions in the United States. The demand for water supply and for water to receive the effluent created by rapid growth has placed heavy demands on the available flow in the river. For over 50 years, the tidal river near Washington has been polluted; since 1800, deposits of mud have plagued navigators and irritated residents and visitors who value the beauty of the capital's waterfront.

Flood protection and water supply in the Potomac basin have long received attention. One study by the Corps of Engineers, directed primarily toward water supply and flood control for the Washington metropolitan area, suggested construction of a major dam a few miles above the city of Washington. More recently a report prepared by the Corps but representing the collective efforts of several federal agencies addressed itself to broader objectives for the basin as a whole. That plan, presented to the public in 1964, called for a dam a short distance above Washington, for 16 storage reservoirs primarily for low-flow augmentation to reduce pollution, and for 400 smaller upstream reservoirs to provide water supply and upstream flood protection. It left many questions unresolved about the aims and methods of managing the waters of the basin.

Because of the erratic and low flows of the Potomac, if the river is to provide dependable low flows for water supply and pollution control, storage must be provided somewhere. But a dam near the city would mar the woodland beauty of the gorge, drown a portion of the historical canal, and thus destroy a unique area. Moreover, reservoirs that must be drawn down present an unsightly appearance and reduce opportunity for recreation. It may be that low-flow augmentation is a relatively poor tool for pollution abatement, and enhanced treatment is a better answer.

If the water in the river is to be fresh for

swimmers and fish, it cannot receive untreated or partially treated wastes as it does today. At low flows, the level of waste treatment must be high, higher even than current standard treatments can provide. In the tidal river and estuary a high nutrient level promotes exuberant algae growth, despite the inhibiting effect of high turbidity.

Many pressing scientific and technical questions remain unanswered in this Corps report. Most of them cannot be answered today. They include:

(1) Can waste-treatment technology be significantly improved, thus lessening the need for storage to provide low flows for waste dilution?

(2) How will stream biota react to varying periods of low flow?

(3) What is the recovery rate of desirable fish and flora subjected to damaging diminution of flows?

(4) Will improved treatment lower the nutrient content of flows to the tidal river?

(5) Will algae growth decline proportionately with nutrient decline?

(6) Will the species of algae change with changes in water quality?

(7) What is the quality of water contributed by agricultural, forest, and urban areas?

(8) Can sediment inflow from vast agricultural areas and from urban lands experiencing construction be reduced significantly?

(9) How much reduction will be required to change the turbidity in the tidal river?

(10) Will algae multiply as turbidity declines, and in what ratio?

(11) Will urban storm run-off produce wastes that impair the quality of water for swimming, even in the face of complete treatment of sanitary wastes?

(12) If other solutions are available, should $100 million be spent to treat and transport wastes from an estuary to make the area fit for swimming?

(13) Will the area meet the aesthetic and health standards after the money is spent?

(14) Must dams be erected in the most magnificent river gorges in a basin to impound water to be used to augment the trickle nature provides, if that trickle is enough to keep most of the fish alive all but a few years of every fifty?

(15) What is the minimum number of dams required today, tomorrow, and in the future?

These questions, and others, must be answered before sufficiently informed decisions can be made.

In the face of the controversy over ends and means in the Potomac, President Johnson, emphasizing the concern for natural resources expressed in his message on natural beauty, made the Secretary of the Interior responsible for developing plans that would make the Potomac River a model of conservation for the nation. The Secretary established task forces made up of federal personnel, appointed a committee of architects to consider land-planning aspects, and called a conference of the governors of the interested states who have themselves established an advisory committee on the Potomac. An interim report by the federal task force and state advisory committee was made in early 1966, without benefit of public discussion of its recommendations for extensive commitment of resources or evidence that alternatives had been considered in the light of long-range objectives and possibilities.

Because the federal agencies have specific missions defined by law, and because, in addition, specific provisions of federal financing make certain alternatives in water development, such as dam construction, more readily operable and often more desirable in the eyes of local beneficiaries, the task of developing meaningful alternatives in the Potomac basin is exceedingly difficult. Moreover,

objectives have not been well defined by Congress, planning staff has not increased in proportion to the task, and basic studies have been hampered by demand for speedy decisions.

The evolution of planning for the Potomac is evidence of a need for development of broader views of planning objectives and alternatives. Furthermore, it shows the necessity of better fundamental scientific knowledge and improved technology in exploring the alternatives and in weighing the choices.

Centering on Human Needs

Up to now, most plans for water-resource development and management, in areas beyond the Potomac, have been tied to individual projects or to basin development, and they have been narrowly concerned with water per se. When New York sees its use of water approaching the limit of its supply, it typically begins looking for additional pure sources, and unless threatened by a crisis, it pays less attention to possibilities of reducing excessive consumption, reusing waste water, or abating pollution of nearby streams. Planners tend to ignore alternatives that involve changes in human habit, preference, or aspiration. In the case of individual projects, the consideration of valid alternatives often has been prevented by the rigidity of the mission of the agency proposing the project, by imperfect apportionment of costs, by neglect of nonmarket benefits and social costs, and by a simple lack of awareness of available alternatives.

Although the drainage basin provides a coherent hydrologic unit relevant to water control, it is not necessarily, or even usually, coincident with the appropriate social, political, or economic region within which society functions. Water planning should relate more to man's activities, needs, desires, and ability to manage water than to the water itself. The drainage-basin master plan as often practiced is focused on water.

The types of plans that have been developed over the years are becoming less useful, because of the broadening of objectives, the increase in actual

and potential uses, the realization that in planning, water should not be isolated from other resources nor regarded as indispensable in all its present uses, and the growing recognition of the necessity to maintain flexibility to meet future needs.

Improving the Process

In summary, the past century's experience and the prospect for science point to a need for water planning that will maintain flexibility for the future, that will foreclose as few alternatives as possible, that will put new demands on science to predict conditions and consequences and to provide new alternatives for changing needs.

Several attributes are fundamental to the planning of water resources if the full fruits of America's generous resource base and scientific capacity are to be gathered. First, the process must generate and evaluate alternatives for consideration by the people of the United States and their representatives. Second, it must report and disseminate such alternatives and evaluations for the broadest possible discussion in the political arena. Third, it must strive to assay as well as possible the values that all segments of society place upon specific uses, abuses, enjoyment, or appreciation of water resources. Fourth, the appraisal of values must include an attempt to ascertain how values develop or degenerate with the passage of time, either because action is too slow and advantage is lost or because action is so precipitous that future opportunities are foreclosed. Fifth, the process must recognize that all concerned private, local, state, and national groups can and should contribute to the planning and development of water resources.

After public discussion of alternatives has brought out the relative values placed by different groups on different objectives and on different social or nonmarket costs and benefits, the administrators who are concerned should be better prepared to act. In their recommendations to the Congress, a state commission, a city council, or an industrial executive, they should know, far more fully than they now do,

which groups desire which objectives and, to a greater extent than formerly, what these groups consider to be the relative values involved.

Public discussion of alternatives, properly conducted, would tend to eliminate the problems that arise when the public belatedly realizes the consequences of a decision already made. It also should provide a healthy amelioration of the institutional hardening and the practice of dealing with a restricted or local clientele that characterize some public agencies. The difficulties of reconciling diverse aims would still be immense, but whatever reconciliation is possible would be effected in a more rational and acceptable democratic framework than at present.

Much hinges on accurate prediction of conditions and consequences. While the accuracy of prediction is greatly enhanced by studies of the effects of past decisions, there has been surprisingly little analysis of the effects of water-use decisions of the past. The full impacts of the Tennessee Valley Authority on the productivity and life of that region are extremely difficult to sort out from economic changes that were shared more widely by areas outside the Authority's program. And while the effect of dams upon stream flow is well known, their effect on water quality, down-stream channel erosion, and biota is less clear. It is important to state that no major water project in the United States has been studied with sufficient care and precision to determine its full effects on the systems of water, soil, plants, and human activity which it has altered. Few smaller projects have been examined in enough detail to judge whether they have attained the purposes for which they were intended. When a new technique, such as weather modification or a powerful pesticide, is introduced there is a flurry of public concern about the likely consequences and considerable investigation of them; but unconcern and ignorance continue to exist in regard to the effects of more conventional measures.

More analysis is needed of the effects, both on the environment and on the economy, of actions taken in the development of water resources.

Objectives and Alternatives

Alternatives in Planning

There are several kinds of variable factors in water-use planning, each of which requires consideration of alternatives. They are:

Alternatives of objective: A canyon can be exploited as a reservoir site or preserved for its scenic and recreational values.

Engineering alternatives: Flood control and power production may be achieved in a certain reach of river by three dams or one large dam.

Management alternatives: Flood losses may be reduced by dams and reservoirs alone or by flood-plain regulation.

Institutional alternatives: Related to management alternatives, they involve the political structure through which the resources are to be managed; irrigation waters, for example, may be managed by the Bureau of Reclamation according to the relative strength of individual water rights, or they may be managed through a conservancy district to which all rights are conveyed in return for proportionate water allocations.

Timing and size alternatives (which are closely interrelated): Based on predictions of future conditions and needs, a dam constructed to the full potential of a site might provide facilities that exceed present needs. Alternatively, it might be possible to construct an initial dam to a lower elevation, with provisions for future raising, if needed. Such stage construction is to be preferred to overdesigning in terms of near future needs, because the anticipated distant needs may never develop. If stage development is not feasible, it may be better to delay construction until the need approaches the site

potential. With respect to timing alternatives, the best engineering, management, and institutional alternatives today may not be the best tomorrow. Technological breakthroughs, value shifts, and government actions may so change the priority of alternatives that starting tomorrow may prove wiser than starting today.

Alternatives of location: Each of these may lead to a different set of physical and social impacts on the region affected.

Some alternatives may involve broad national policy, as reflected in federal statutes, regulations, and practices. In illustration, national policies in pollution abatement, reclamation, and flood-loss reduction are discussed briefly here in the context of their effects on alternatives and choice in water management.

Effect of Policy: Pollution Abatement

The need to clarify the real objectives of private and public water management in order to elicit alternative courses to achieve those objectives is seen in two common elements of most water-resources plans—pollution abatement and flood-loss reduction. In recent years the Congress has agreed that storage may be provided in reservoirs at federal projects, without cost to local beneficiaries, for low-flow releases to meet pollution-dilution requirements. The objective, of course, is cleaner water for domestic, industrial, and recreational purposes. Clearly, however, this approach is not the only way to meet the objective. More effective treatment systems, elimination of pollutants by manufacturing process changes, in-stream treatment, and relocation of waste discharges are alternatives. An effective enforcement program can be a very important element in pollution control and can determine the applicability of alternatives. It must be remembered that industry and local governments are responsible for waste disposal under state and interstate regulation. Waste-water reclamation would not only control pollution, but would augment the supply of usable water. At the present time, however, not only does federal

financing lean heavily toward low-flow augmentation, but river-basin planners are unlikely to consider the other alternatives because they are not within the "authorized tool kit" available at the federal level. With planning oriented toward the project rather than the purpose, planners tend to concern themselves more with "benefits" that will justify the project than with alternatives that will solve the problem. Needless to say, this tendency occurs in most water-project planning, not just in planning for pollution abatement.

Effect of Policy: Flood-Loss Reduction

Detailed studies have documented the fact that flood damages continue to rise year after year even as expenditures for flood control climb. People live and work on flood plains for many reasons, and those who live and work there view the flood hazard differently from the engineers designing works to control flood waters. While federal agencies have been authorized to assist communities in evaluating flood hazard and in developing alternative methods of reducing unwarranted damages—methods such as flood-plain zoning, building codes, subdivision regulations, flood proofing, and warning systems—the financing provisions for most federal participation favor control measures such as dams and levees.

The federal reimbursement policy on flood control in effect transfers part of the cost of floods from the direct beneficiaries to the taxpayers of the nation. Other opportunities for individuals to use flood plains without heavy public cost or for public agencies to encourage recreational and wildlife uses often are neglected. Because many communities, given the option, will choose the alternative that costs them least and is readily available, alternatives to structural measures of flood control rarely receive serious consideration by those who have the power to initiate them, despite the fact that engineering structures can never guarantee complete protection. To minimize efficiently losses from floods requires land-use planning as well as water planning, and it calls for helping individual property

owners to assess their hazard and possible ways of dealing with it. Although flood insurance has been proposed as an additional means of deterring flood-plain occupancy and of reimbursing losses, it has yet to receive a thorough trial on a national scale. Federal agencies now are moving toward a broader view of possible means of fostering wise use of flood plains.

Adoption of a full-alternative method of planning for flood-loss reduction would be advanced by a more searching evaluation of the reasons why persons choose to locate on flood plains, and of the probable effects of various ways of providing incentives to adopt alternatives, other than structural or control measures, for reducing losses from floods.

Effect of Policy: Reclamation

Irrigation in the West may have substantial impact on the nation's agriculture, yet the reclamation policy may run counter to the agricultural income-support policy. Though it is often pointed out that reclamation costs are reimbursable and that, in the long run, the water user repays the federal government for its investment, it is not always understood that there is an important subsidy associated with the reclamation legislation (as there is with flood-control, navigation, and soil-conservation legislation). First, the capital investment made by the federal government for irrigation is repaid over a period of many years without interest. The capitalized value of this interest is in effect a subsidy of about one half the cost of putting water on the land. Furthermore, the sale of electricity produced by reclamation dams, and even by dams that have no utility for water control, provides revenue that helps pay the costs allocated to irrigation water.

These subsidies were an inducement to settlement and development of the West, and added to the agricultural production of the United States. In addition, Congress limited to 160 acres the size of land-ownership units that could receive irrigation water from reclamation projects; this limitation reflected

a desire to people the land with independent farmers on family-size farms.

Although these were laudable objectives for the Reclamation Act when it was passed in 1902, over the years since that time they have led to some curious conflicts. In some instances, crops grown on irrigated acreage subsidized under the reclamation program have been supported under government price-support programs. Elsewhere irrigated acreage simply has added to the agricultural production capacity.

Not only is the necessity for the subsidy to be questioned, but it must also be recognized that irrigated crops place heavy consumptive demands on the water resources in a region of relative scarcity. Last, it is increasingly apparent that in many regions improved technology and prevailing prices for agricultural products are making it impossible for a farmer to earn a living on 160 acres.

In view of these changes and the fact that the irrigation subsidy on federal reclamation projects greatly influences decisions on uses of water in the West, the Committee believes that a review of the federal reclamation policy as part of a general review of water policy, in the light of present and future competing needs for water and agricultural products, is a critical requirement. Such a review would examine cost-sharing and reimbursement as they shape public interest in different water uses.

Restriction of Use: a Reasonable Alternative?

Conservation of use, in the sense of planned restriction of water use, often has been regarded as a desperation measure rather than a reasonable alternative. This attitude is largely the result of many years of thinking of water as a free good. The free-good concept combines with a tradition of promotional rates to produce the pricing policies peculiar to water—policies whereby the consumer may pay only a fraction of the cost of delivering water to him.

Restriction in use of water could be effected through more rational pricing, and by restricting

or controlling devices or practices that waste water. In the pricing policy, surcharges might be considered for peak use (in some cities peak demand for lawn watering in the summertime is five times the mean use). As an aid to improved planning, modification of the laws and charges on water should be considered, so that individuals would have an incentive to economize. Changes in water-using equipment and user behavior can bring significant improvement in the use of water.

Benefits Foregone and Options Preserved

In a rapidly changing society, in which the specific needs of the future are impossible to forecast and where technology provides many alternatives, a primary tenet of planning should be to maintain flexibility for the future. This statement is not defense of inaction. Reasoned delay may be better than action for which the need has not been demonstrated thoroughly and the effects of which have not been evaluated adequately. Because choice is preserved at the cost of immediate benefits, the reasoning behind this view needs to be stated clearly.

First, reservoir sites and specific natural environments are finite in number, fixed in position, increasingly scarce, and irreplaceable.

Second, the values placed on the several uses are continually changing while the competition among users is increasing, which is another way of saying that needs change with time.

Third, most decisions except those that require preservation of the status quo, once implemented, are irreversible.

Fourth, there are instances in which inadequate design information and inability to predict consequences of construction make delay desirable. We create great reservoirs that stop the migration of fish and then provide costly fishways, hatcheries, and other devices to maintain the fishery, and with no certainty of success. We impound water without knowing the effects of that impoundment on its quality. We build an irrigation project and then find salinity increasing dangerously in the river

downstream. We eliminate high-flood peaks by reservoir storage, but downstream from some reservoirs we see unpredicted erosion, sedimentation, bank-cutting, and other effects, even unto, as in California, the loss of beaches along the seacoast, starved of their supply of sand.

Finally, new engineering, management, and institutional alternatives will continue to appear, offering new and perhaps better ways of meeting needs. The pace of scientific research and technological application is quickening. It may have been reasonable in 1920 to assume in designing pollution-abatement works that both waste and the technology of its treatment would remain little changed over 25 years (and indeed, municipal waste treatment did improve only modestly over that period). But it now seems realistic to assume that the composition of waste will become immensely more complex and that radical improvements will occur in biological and chemical methods for treating waste.

Decisions as to whether to proceed with water-resource development should be based on a thorough comparison of the need for action with the dangers of undesirable changes in the environment and the virtues of retaining options for the future. If undertaken, the development should be designed to maintain the widest practicable choice for future action. Partial development should be recognized as one means of preserving options. In reaching for decision, we should not delude ourselves that benefits foregone are unreal; every effort should be made to evaluate such benefits. We should likewise try to ensure that decisions made now will minimize deleterious effects and will not induce cost dislocations that might have been avoided had decision been deferred or made in such a way as to retain flexibility for future action.

The choice of lands to be reserved as noncompetitive with other types is not an easy one and the decision as to whether to proceed or delay may be painful. Present organizational

arrangements are not satisfactory for this purpose: persons whose interest lies in preservation of scenic areas, recreational activities, and similar pursuits are not adequately represented at the federal level when compared with those whose interest lies in irrigation, flood control, and power development. Consequently, the former rely primarily on Congressional hearings and appeals through public media. Institutional changes are required to correct the imbalance. However, care should be taken to assure that institutional changes do not create an imbalance in the opposite direction: unilateral judgments by those interested in preservation of scenic attractions should not be the sole basis for reservation of such sites.

Wherever feasible, the experimental approach should be tried, before an irreversible decision is made, as with pilot projects in irrigation or in combined disposal of urban storm and sanitary drainage.

Design for Consideration of Alternatives

Formerly a full-development plan usually was based primarily on economic and financing considerations, with limited examination of alternative use of the resource for other purposes and with little public review of the alternatives available. Institutional and conceptual constraints often precluded consideration of certain of the better alternatives. Now the ideal would be to present the public with information about practical and coherent alternatives, both in development and objectives, so that the people might have a chance to discuss those alternatives and, through their representatives, to express their preferences before a final choice is made.

The ordinary procedure for bringing a proposed sewer extension to a city council is for the responsible engineering staff or consultant to canvass possible solutions and to recommend the project that appears to be most economical or effective. Even for a single sewer extension for an isolated town the considerations in choosing between different routes and between a public sewer and

private septic tanks are bound to be complex. The engineer or planner resolves in his single recommendation a whole series of judgments of the facts of community growth and values with respect to the quality of the community and its landscape, which in the final decision may be obscured from the view of the public representatives.

In the future, two distinct phases will need to be cultivated. In the first phase, the public would be presented with a number of technically feasible alternatives for meeting particular objectives and the related costs and benefits, both tangible and intangible, for each alternative. In the second phase, the course of action would be decided in the public arena. Each of these phases influences the other.

Although no specific organizational change is recommended by the Committee, a mechanism for formulating a range of practicable alternatives and of presenting them dispassionately to the representatives of the public for evaluation needs to be evolved in each agency charged with decisions concerning water. At the regional level, the new Water Resources Council and its federal-state regional commissions could play such a role. Hearings would be a useful mechanism to develop and present water-use alternatives, and to air conflicting views on aims, alternatives, and values. Inevitably, the more difficult and acute issues will find their way into the political arena. At the federal level there will be hearings and investigations, Congressional and other. At that stage, the issues should be sharply defined and the relevant evidence should be at hand; in addition, agency or institutional bias would be revealed.

After a reasonable time for public consideration of alternatives, the second phase might begin. In this phase, decision would be reached on what needed to be done then and what possible courses of action could and should be preserved for future decision. In large basins, the two phases would develop concurrently as one project reached construction and others were first reviewed.

Just how and where decision would be reached would depend to a considerable degree upon the nature of the mechanism established. At all levels the adoption of a sequence of planning that includes public presentation of a full range of alternatives is more important than the question of where in the planning structure the decision is reached on what to present to the municipal, state, and national legislative body. It should be emphasized that the Committee is not recommending a planning mechanism that would produce one "perfect" plan for legislative adoption or rejection; the leading alternatives, tempered and perhaps ordered by public discussion, would be presented.

Not All Values are Measurable in Dollars

Water Values

In a democratic society, the political process weighs incommensurate values and makes choices. Throughout the nation's history different weights have been given to different values in water-resource development. When much of the country was still wilderness and when all the nation sought economic advantage, priority in the halls of Congress, as in the minds of the people, was given to land settlement, navigation improvement, and the exploitation of tangible resources. Now that the wilderness has all but disappeared, now that many of the people have both comfort and leisure, there is a greater appreciation of, and a willingness to pay for, certain qualities of the environment which formerly were more common and therefore less valued than they are today.

The change in concept of the natural environment from that of a workshop to that of a temple and the conflicting existence of both concepts presents the resource planner with his most sensitive task: drawing a line between workshop and temple, or attempting to merge them.

Current approaches to analysis and evaluation of resources employ sophisticated processes for determining the combination of projects that can be constructed with optimum net economic benefits. The alternative measures that are project ingredients are programmed for a computer, and various combinations are compared in a search for the combination that

best reflects an agreed-upon set of economic objectives. These mathematical approaches provide important new techniques for analyzing the available information. Valuable as they are as planning aids, they will not, by themselves, provide a philosophy for dealing with the social benefits and costs fundamental to water-resource analysis. In other words, a computer alone will not solve all our resource problems. It may, however, through its requirement of a precise statement of values, force a clearer definition of what society prefers.

Guides that Mislead

The value of water is infrequently its selling price. Almost everywhere in the United States, it is underpriced in relation to what an industry or an individual would be willing to pay for it. What this amount is can be determined, however, only if pitfalls are avoided in the calculation. Do we mean the maximum amount that would be paid for the total amount of water used? No, the value needed for planning is what would be paid by a user for an extra gallon of water. But this payment depends on the amount of water being taken. As an example in which quantity available is fixed, it may be possible to get an idea of the market value of a canyon view by the amount of earnings the public is willing to forego if a dam is not constructed on the site. But a reliable method is seldom available for estimating what this amount is. Because water is critical in life processes on our planet, there is a tendency to view water needs as physically determined. Yet purely physical requirements cannot be separated from social and economic demands.

The absence of an effective market mechanism in the allocation of water leads to many unreasonable claims of "need". How, for example, can irrigated agriculture in the West "need" more water when it cannot bear the full cost of its delivery? Once people "need" to live in Los Angeles they "need" water, but to what extent does the nation need to

subsidize the delivery of water to Los Angeles?

The aim of resource planning is a maximum social value, which unfortunately remains difficult to put in quantitative terms. In practice a categorization of objectives often takes place because the benefits and costs which are readily measurable are those that can be expressed in monetary terms. The nonmonetary costs and benefits, though admitted to be real, are thereby relegated to a lower priority.

Even where monetary values are assigned to recreation and to fish and wildlife, these values may not reflect the essential element of quality. Faced with these difficulties, especially if we are impressed with the desirability of preserving the natural environment, it is easy to take the view that nonmonetary benefits should be overriding. There is an illogical schism between those who tend to place sole reliance on either market or nonmarket values. Both types of benefits exist and are important. What is needed is a balancing among benefits. We need to get on with the task of finding satisfactory ways of deciding among objectives, of determining values that should be placed on them, and of comparing and contrasting values and objectives.

Precepts for Improvement

Much progress has been made in devising objective measurements of water-project effects in dollar terms. These measurements have affected significantly decisions about individual projects, and they have influenced the general direction of water policies. A first precept is to maintain and build on this progress, carefully using dollar market values to the full extent to which they are appropriate.

With increasing importance attached to leisure and aesthetics as the nation develops, the neglect of effects not accurately reflected in market values has become more serious. A second precept, already stressed, is that neither zero nor infinite value should be placed on these nonmarket effects. Rather, methods should be explored for weighing

explicitly nonmarket benefits together with benefits for which dollar market values are available.

Because of the long life of most water projects, time is a major consideration in water planning. (A key factor in good planning is the selection of an appropriate rate of discount for comparing values in different time periods.) A third precept is that more thorough exploration of alternatives, giving explicit consideration to the long-lasting effects of water decisions, is needed. This exploration of alternatives should reflect concern with how uncertainty about the future may affect the most desirable course of action, as well as how account should be taken of irreversible actions.

The effects of water decisions considered thus far have to do with the total net benefits to society, regardless of who receives benefits or who is adversely affected. A different dimension, too long neglected as a matter of systematic analysis, has to do with the distribution of benefits among persons and among areas. A fourth precept is that there should be explicit consideration of the distributional effects of water decisions.

Below, the meaning of these precepts is considered more fully.

Market Values and Social Values

Corn is corn, and it is grown in every state. When the product of water is something that is commonly producible in a market setting—as are agricultural crops—the value of providing the water can be estimated with confidence by relying on observed dollar magnitudes. Most often, the net benefits from producing marketable commodities is the saving made possible by being able to produce the commodity less expensively with the water provided than it can be produced elsewhere. The use of market values can be applied validly and widely to water decisions, especially those taken at the federal level. Notably amenable to this approach is production made possible by flood control, reclamation, hydroelectricity, and navigation.

Market valuations can sometimes be used even

when the outputs made possible by water management are difficult to value. They can be used by estimating benefits as the saving in costs of providing the output by a proposed project instead of providing it by the least-cost alternative. One proviso, necessary if this approach is to be used, is that the output by the alternative means would in fact be economical or otherwise justifiable to produce. Another proviso is that an earnest search be made among the alternative ways to find the means that costs the least. These provisos are violated if the benefits from pollution abatement provided from low-flow augmentation by a dam are estimated as the savings in treatment costs if those treatment costs are in fact higher than would be considered justifiable. Similarly, the provisos are violated if benefits from additional water to Los Angeles are estimated to be the savings in costs over bringing in water by barge from the North Pacific Coast if this means would not be considered feasible.

Balanced Recognition of Nonmarket Values

Shortcomings of relying solely on market values, indispensable as they are for a wide range of benefits, have already been noted. The list of shortcomings could be extended greatly. Until recently, we have assumed it was worth doing little about unsightly, foul-smelling, or unhealthy nuisances in the environment, unless someone could conveniently collect bills for doing so from those being harmed. Decision-making still gives undiscriminating weights to property values regardless of whether this weighting is to the benefit of society at large. Such weighting is likely to be particularly unfortunate when sizeable enhancements in land values will result from water decisions, and the land happens to be owned by persons important in a political power structure.

On the other hand, the absence of objective criteria for evaluating nonmarket benefits has led occasionally to decisions which overvalue nonmarket effects. The zeal for controlling water runoff to prevent soil erosion in some cases has

led to an installation without analysis of whether it is worthwhile. It is simply assumed that all activity of this kind produces market and nonmarket benefits in excess of costs. Careful analysis might lead to the conclusion that expensive terracing often is not worth its cost, especially when a less costly alternative may be available for conserving the soil—such as allowing the natural growth of pine trees, an example pertinent to large areas of the South.

In short, failing to do a better job of scrutinizing objectively nonmarket benefits has led to inconsistent behavior, most often to underestimation of the importance of nonmarket effects but sometimes to overestimation of them.

Lake Tahoe will turn from blue to green unless costs are borne to stop sewage from being dumped into it. Let us find out how great the costs are before prejudging that it is or is not worth letting the lake turn color. If it will cost $5.00 per hour of viewing time for anyone who will ever see the lake to keep it blue, one may conclude that there are better alternatives for these expenditures. But if the cost would amount to only a fraction of a cent per person visiting the lake and if the cost of alternative means of disposal of the sewage would raise the cost of living of the polluters only slightly, one might rationally conclude that it would be a wise action to keep the lake blue.

The fact that the aesthetic uplift and physical improvement of the individual recreationist cannot be expressed easily in monetary terms does not diminish the fact that they represent a value to society, and one which may be peculiarly diminished in quality as recreational areas become overcrowded.

Scenic gorges, river valleys, fish-spawning grounds, and wildlife habitats present difficult problems in valuation. In attempting to place a monetary value on a resource, we are concerned often not only with the costs and benefits, but with identification of the beneficiaries and those who should share the costs. It should be noted, however, that inability to identify or

assess beneficiaries does not indicate an absence of benefits. For example, the migratory habits of fish and game birds pose exceedingly complex problems in designating the beneficiaries of habitat protection; yet the difficulty of the task should not cause us to conclude that because the benefits are diffuse and difficult to appraise, they are negligible.

Tomorrow in Today's Planning

Perhaps nowhere is the lack of consideration of alternatives in water planning greater than in provision for future water uses. A great amount of attention to the choice of a proper discount rate, needed to compare present and future benefits, has obscured other considerations relating to the future. Discount rates should be more uniform among water-planning agencies at various governmental levels. There is question about the federal discount rate; however, better provisions for the future can be accomplished even if discount-rate procedures remain imperfect.

One need is to convert all possible future events to a risk basis and to reach decisions about the amount of risk reduction to be undertaken. Every decision related to the modification of the timing or magnitude of events in the hydrologic cycle involves an appraisal of risk. Risk, insurable, is distinguished from uncertainty, not insurable. Risk in water development involves frequency of drought and floods; uncertainty involves, for example, the time such events will occur, the rate of population growth, and technological breakthroughs. Repeatedly above, the principle of flexibility has been recommended in the face of uncertainty. Preservation of wildlands and urban open spaces and delay in building large structures apply this principle. But a surprising amount about the future can be quantified in terms of probabilities and can be subjected to precise risk analysis.

A decision to provide storage sufficient to sustain a metropolitan region through the severest

drought on record without resort to rationing places an exceedingly high value on not running out of water. Values must be placed on reducing the risk by making the water system capable of meeting a very unusual drought or the flood control works capable of protecting against floods expected only once every few centuries. In both situations, it must always be recognized that we probably cannot provide a New York water supply adequate against all possible droughts or flood control at Chattanooga to protect against all conceivable floods. In each case, a value is placed upon the risk taken or not taken. There is a substantial subsidy and a very high social cost if we try to protect everyone absolutely. By applying probabilities, the expectation of occurrences can be calculated and an explicit rational decision as to the benefits from risk reduction can be made.

Implicit in decisions to develop or to manage a water resource are projections and assumptions concerning future trends in demand and in the quality of the resource. Not infrequently such projections determine the level of public concern and the direction and magnitude of public investment in management and research. Explicit statements of the assumptions underlying both decisions and projections are essential if proper evaluations of future alternatives are to be made.

Irreversibilities abound in water-development plans. They too, exemplify the lack of consideration of alternatives precluded by the one-and-only plan usually presented for consideration. Consider the failure to reserve land as wildlands or open spaces in and near cities. Often little expense results from deciding to reserve lands beforehand. Yet the benefits of reservation precluded by a planning decision ordinarily are not mentioned, much less quantified. The benefits do not have to be great to make reservation of land worthwhile, if the lands have not been committed to other uses. But if they have been committed, undoing the commitment and restoring them is likely to be too costly to justify.

Distribution of Benefits

In pursuing the purpose of water policy to contribute to the well-being of people, franker consideration should be given to whose well-being is affected. Traditionally, the effects on people of different incomes has not been a concern in decisions about water. In view of the recognition now given to combatting poverty, there is special need to initiate the practice of estimating effects of water proposals on people of different incomes.

The importance of the geographical dimension has long been recognized. Prominence is given to secondary benefits that show the increases in income from a project to a local area and, incidentally, fail to show how much of the income is simply taken away from the rest of the economy, thereby bringing losses to other localities. Calculation of secondary benefits is consistent with the aim of fostering a desirable pattern on activity spatially. However, secondary benefits inadequately measure the contribution of water projects to this aim.

To the extent that water-development projects employ persons who would otherwise be unemployed or underemployed and to the extent that low-income people are benefitted, there is no problem of reconciling the regional and national points of view. But deciding to construct a project usually constitutes a choice between amounts of development in different regions, and it does so in a way that affects the over-all growth of the national economy. As a nation, we have been slow to face the regional choice openly; one of the results has been that we have acted inconsistently. On the one hand, for many policies (such as defense spending) it is pretended that geographical impact is a matter of no concern at all. On the other hand, slavish concern with secondary benefits in public-works projects implies that the impact in one particular region is all that matters.

The geographical distribution of economic activity does matter, particularly when some regions are in decline. Aside from the high incidence of low incomes and low productivity

in declining regions, public services, particularly education, tend to be inferior there. Children growing up in these regions and adults who are ill prepared to move do not have opportunities equal to those enjoyed by most Americans.

Primary benefits approximate the contribution of projects to production of goods and services of the nation, irrespective of who receives the benefits. Choices may be made to trade off some primary benefits to contribute to a desirable distribution of benefits among persons of different incomes and among regions. To do so rationally will require enunciation of a national economic-development policy which among other things spells out income-distribution and population-distribution objectives. Water planning should be integrated with this national economic-development policy, and benefit measures should be redesigned to show the contributions of specific projects to the national aims.

Persons, States, and Nation

Levels of Planning

In discussions of the water resources of the nation there is a tendency to assume that the federal government holds full sway in this domain. This assumption is not true, nor would the nation be served well if it were.

The federal government can and does exercise a powerful influence in water development and management, largely by virtue of its sovereignty over navigable waters and those rising on public lands as well as its predominant interest in protecting the welfare of the people and promoting the development of the country. Nevertheless, the greater part of the planning, construction, operation, and supervision in relation to water resources is done by private corporations and by state and local governments. More than half of the hydroelectric-power capacity of this country has been developed by projects financed by private capital. The federal budget for water development is currently about $2 billion, while the nonfederal water-development budget is about $10 billion. Although the discussion in this report of planning principles deals chiefly with the federal government, the Committee emphasizes that these principles apply at all governmental levels.

From the day federal planning begins, state and local representatives should be involved on a continuing basis. Such involvement will require staffs that some of the states do not now have. It is not enough to be able to review or even veto a report. It is far more important to have a say on what is studied and how it is studied.

Because of its heavy support of bilateral-aid

programs and the participation of its experienced people in other overseas resource-development programs, the United States has a significant influence upon the quality of water management in some other countries. Any improvements in method or organization in this country will affect planning and operations in other parts of the world. In turn, we can learn from the work of other nations ways of handling water at large dams, in small projects, on the land, and in the city. New research programs should be designed both to aid and to benefit from overseas activities.

Influences on Water Allocation

Although economists long have emphasized the importance of the market in mediating competing claims upon resources, there is no industrialized society in which a free market in water is organized or tolerated. Pricing is only one of the means by which choices are made.

Pricing could be used much more widely as a device of water management. It has been found that levying water charges can induce people not to waste water, without imposing hardship on them. The traditional market functions of prices are to ration demand and constrain the allocation of resource to production within the bounds of social valuation of the product. Pricing of water in practice, however, seldom rations either demand or supply. Fixed prices, not always set to recover full costs, are a characteristic feature of water supplies. The cost of major supply installations frequently determines price, and the institutional structure of supply is such that it may be difficult to determine whether costs are fully covered by charges. Critics of large-scale water projects sponsored by the Corps of Engineers, Bureau of Reclamation, and certain state agencies insist, for example, that the true cost of capital is not now charged to the projects.

At best, the markets for water will be localized. Users of large amounts of water will tend to move toward the water, where they can purchase water on local-supply terms. Unevenly distributed by

hydrologic events, water will have varying supply prices at different locations. There will be, then, a number of nested markets rather than a single market in which all preferences are resolved by a price system. The management of the entire system, on a national scale, will continue to be an administrative task.

While the possibility of achieving better use of water through greater reliance on user charges is resisted needlessly, pricing of water is not a panacea. Although installation of water meters is important if one is to establish a pricing policy based on use, and, if certain losses in a distribution system are to be detected, simply installing meters will not solve our water problems. It will be neither feasible nor desirable to depend entirely upon prices to determine use.

In the public allocation process it is unlikely that society will welcome widespread and strict allocation of water. Water is regarded as a birthright of Americans — a common holding in which there are common stakes. Other commodities are not so regarded; water is singled out for special consideration. Therefore the planners must devise acceptable guides to allocation.

The administrative guides of the planners are their standards. The components of standards include technical analyses of requirements, estimation of social norms and acceptability, codification of previously acceptable practice, and professional regard for "better" practice. In the case of municipal water supply, for example, standards are set partly on grounds of health protection (scientific analysis of the tolerance of human beings to disease-producing organisms and toxicants), partly on estimates of the acceptibility of aesthetic factors (color, taste, and odor), partly on costs of obtaining quality goals through available methods of treatment, and partly out of a desire to continuously upgrade the product.

The usefulness of zoning to control flood-plain occupance was mentioned earlier. The technique of zoning is also appropriate to many cases

involving nonmarket values. National parks, monuments and wilderness areas have been established in recognition of special aesthetic, historic, and wilderness characteristics. Consideration is being given to the preservation of wild rivers. In view of the disappearance of natural areas and the increasing value that people are placing on them, further reservation of lands and rivers is surely appropriate.

Land reservation or zoning must be viewed as a way of achieving certain values. Contrary to much public misunderstanding, preservation does not preclude management. The current plight of the Everglades National Park underscores this point; the land area was reserved, but insurance of the fresh-water supply on which the uniqueness of the Park depends was not provided. At the same time, it is true that to make the best use of a unique or striking scenic, historic, or wilderness area, use must be structured and controlled.

Legal rights to water will continue to play an important role in determining water use. The methods commonly used to buy and sell land and rights to its use can and should be applied to water. The task is only somewhat more complicated by the effects on third parties, that is, persons such as downstream users who are not involved in a transfer or contractual arrangement of two parties upstream but are nevertheless affected by the upstream use. This general type of situation arises for land, too. For land transfers, courts have managed to develop principles of adjudication. In short, a desirable direction for water law — contrary to many current trends and requiring careful study — is toward market salability of water rights with reasonable security against unforeseen adverse consequences to those directly or indirectly involved in water use.

There is another way in which legal improvements are needed in connection with water. Years of delay in obtaining court decisions have led to development of costly alternative sources of supply and other

departures from good water use, which could be avoided if court procedures were streamlined to arrive at prompt decisions.

Sharing Responsibility

Planning carried out in concert — if not always in harmony — among federal, state, local, and private interests would not only provide a larger input of diverse views but would as well encourage responsibility for decision. The states, had they fully exercised their voices in development decisions and had they not allowed themselves to be bypassed by federal agencies, might have enlarged and upgraded the staffs and programs of their water agencies, and improved their performance in regulation. Full participation by local governments, especially if cost-sharing reforms come to pass, might reduce the tendency to look for federal and state "handouts." Greater participation by the private sector could result in better planning and more responsible criticism of public projects.

Earlier references to deficiencies in the way water is managed for reclamation, pollution abatement, and flood control point up the fact that federal emphasis on a particular kind of water use or for a single way of solving a water problem skews planning toward those conventional alternatives that will be least expensive to the beneficiaries, although those alternatives may not be the ones that would be least expensive to the nation in the long run.

Public measures affecting the course of water development extend far beyond investment policy. Direct federal regulation of navigable channels and power sites, state regulation of public water supplies and waste discharge, and city regulation of land use and drainage exercise powerful constraints on new development. The whole fabric of water law sets the terms on which water may be transferred, allocated, and priced. The kind of technical assistance that is available to towns or individuals will influence their capacity to put down new wells or to preserve natural stream courses. The quality and scope of scientific research set the limits of their opportunities for action and the horizons of their aspirations.

Potential of Science

Need for Better Information

This report is predicated upon the proposition that change is the most predictable feature of future developments in the field of water resources. While the prediction of rapid change has become almost a cliché, it is true, nevertheless, that changes in the interest and demands upon the water resource by society, coupled with changes in scientific knowledge and technology, place continuing pressure upon both the natural and social sciences to provide better information and understanding not only on how the natural water system works but on how society can reconcile the system and its demands.

Water Budget of the Nation

We are not facing a countrywide shortage of water. A national average, of course, does not reflect the fact that there are some areas in which the local supply may be insufficient to support the demand. Similarly, the growing interest in the quality of water within rivers and lakes is not reflected in volumetric estimates of supply and demand. Water-quality deterioration may place pressures upon users and observers despite the fact that the quantity of water available is sufficient. To cope with regional shortages in quality and quantity of water, and to improve planning for use and preservation of water in an environmental sense, an expansion is needed in our knowledge. This needed knowledge consists of the results of conventional research in the physical, biological, engineering, and social sciences, as well as information derived from discussions among scientists, engineers, public officials, and informed citizens.

Fields of Needed Research

Simply stated, there are three fields in which research in the natural and social sciences and improvements in technology bear upon the problem of defining and considering alternatives in water management. The Committee uses the word research in a broad sense—to include a variety of studies designed to result in new knowledge of facts, data, actions, views, and procedures related to water planning and development.

(1) Research on the behavior of the water resource and the way in which changes in the environment, including such wholesale factors as reduction in evapotranspiration or increasing urbanization of large land areas, affect the resource itself.

(2) Research on new technology in such processes as waste treatment, desalting, cooling water, industrial and other uses, including substitutes for water.

(3) Research on the decision process, including research on the economic characteristics and social behavior fundamental to planning in a democracy. An important direction of such research is toward estimates of broad trends and the shape of probable changes in our society, including wholly new technologies and changes in human demands.

The Potomac Basin

The significance of a local or regional water problem is well illustrated by the Potomac Basin described earlier in this report. Research in both the natural and social sciences is essential to the solution of most problems on the Potomac. An informed decision on future uses of the estuary of the Potomac is dependent upon the emergence of new knowledge about the behavior of biological organisms under changing conditions of nutrients, light, and circulation in a complex tidal river.

Governmental agencies must be developed that can provide the framework for reaching desired objectives. As with rivers in most metropolitan regions, the Potomac at Washington, D.C., is a concern of a number of county governments, planning

groups representing adjacent counties, several states, and the federal government. Proposals to reserve reservoir sites for possible future use, as well as proposals for joint operation of public works facilities, require administrative mechanisms that are both administratively sound and responsive to democratic and voter control. Metropolitan authorities, interstate compacts, federal agencies, and private development are among the many devices that are appropriate to specific areas and problems. Machinery for stimulating and recording the feedback of public opinion as well as conventional analysis in the social sciences is essential to the evolution of appropriate administrative and political framework.

The Potomac example illustrates also how the various alternatives have not been delineated or perhaps even thought of. At least they have not been elucidated publicly in equal detail. Some choices have been made and announced without the public being made aware of the range of choice and associated costs, effects, and implications. No period of public discussion of possible alternatives was provided. Furthermore, choices were made in the face of our present inability to forecast the results that will stem from the large expenditures implied by the choices. Thus, the Potomac example illustrates a major theme of the present report: the need for public discussion of alternatives before choices are made.

The problem of value is central to the analysis of water use and development. In the Potomac the pressures for development, on the one hand, and preservation or reservation, on the other, must be resolved in making decisions for future uses of the water resources and lands. Unique scenic gorges provide scenes unmatched in the valley and, at the same time, provide attractive sites for dams and storage reservoirs. Better econometric techniques are needed to help in appraising the relative importance of such diverse demands as well as in evaluating the magnitude of benefits to be received and in identifying beneficiaries and their location.

Alternative pollution-abatement techniques

also must be evaluated both economically and technologically. Analysis is needed to determine the circumstances in which new techniques will be adopted and how beneficiaries who are widely distributed along the river might best reimburse those who incur the cost. Not infrequently, as in the case where wastes are carried downstream from a town or industry, those who pay may not, indeed, be the direct beneficiaries. Until such evaluations can be made, it is difficult to consider adequately the best means for achieving a set of objectives.

Other Illustrations

Another set of problems calling for somewhat different emphases in research is presented by the southwestern United States where water supplies are, indeed, short of demands at prevailing prices. Here research in engineering costs and alternatives can help to clarify the terms of public choice. Supplies can be increased by transporting water from areas such as Northern California or the Pacific Northwest, by local desalting works in favorable areas, or supplies might be increased to some users by making less water available to others in the same area. Here again, new knowledge from the natural and social sciences can contribute to choice of solutions that are efficient and acceptable.

In deciding upon alternatives at the simplest level, for example, the choice of supply, it is necessary to know costs of desalting compared with costs of transport. Obviously, as techniques for desalting are improved, or as pumping and transmission are altered, the weighting of these alternatives is altered. At the same time, research in the methods of appraising the relative importance of such diverse demands, in evaluating benefits to be received and in identifying beneficiaries and their location is essential.

On the Colorado River and elsewhere in the nation, technological improvements in the production of power may affect both the value of hydroelectric power and the alternative value of power generated from coal or atomic fuels. As the

significance of hydroelectric power changes, this in turn may affect markedly the evaluation of the costs of developing the river for other uses. To assume that comparative power techniques will not change is to ignore both the prospect and the opportunity to shape it.

Conversion from one water use to another is strongly influenced by both the legal framework and the valuation of the resource made by individual users. Much inquiry is needed into the way in which complex legal frameworks of local, state, and federal law influence decisions in water management. Some evidence suggests that unduly restrictive laws tend to retard desirable changes in water use and valuation where rapid social and economic change would make such transformations particularly important.

In such disparate hydrologic regions of the United States as the Northeast and Southwest, research is needed into social values as well as technologic possibilities. Further, an open inquiry into the appropriate administrative and judicial framework for the relocation of water from a given source during recurring periods of scarcity should be encouraged. The recent drought in the Northeast posed fundamental problems in the distribution of water among claimants from the Delaware River. These same problems have repeatedly arisen in the allocation of the limited waters of the Colorado River.

Knowledge Needs

We need to know more about the regional effects of water development. Regional water-resource development may promote relative economic growth or decline as well as population redistribution. New tools of social-science research are evolving which can help to provide measures of the probable extent of the regional changes that will accompany varying amounts of investment and levels of development in different regions. Such measuring tools will again broaden the range of alternatives that may be considered when decisions are made to achieve specific economic and social

goals for various parts of the population dwelling in different regions. Usually, the aims are mixed: relief often is linked with long-term development. If objectives are stated clearly, it may well be that public investment in sectors as diverse as education, highways, or recreation, in fact, may be substitutes for or partners with investment in water resources in achieving economic and social well-being.

We need to know more about how society adopts new technology. While considerable emphasis today is placed upon technological change in developing countries, it is equally clear that the process of technological change needs to be better understood in our industrialized society. Research is needed, for example, on the circumstances under which industries alter both the volume of water needed in their operations and the character of the waste products discharged to natural water courses. Expenditures by industry for water in Pittsburgh or Chicago constitute a small proportion of total expenditures in product manufacture. In attempting to predict future water demands and water condition, it is especially important to understand those forces that will lead to changes in water use and waste treatment in the metals, petroleum, chemical, food, and pulp and paper industries. Here again, technology is intimately associated with political process. Enforcement of pollution-control measures is linked with the costs to users, with their perception of alternative ways of handling waste, and with the value that local areas place upon the importance of particular industries to the economy. Effective regulation of pollution is predicated on detailed knowledge of the technology of use and treatment, the economic evaluation of benefits and costs, and the likely responses of those who discharge waste and those who look for clean water.

We need to know more about how people make choices. The process of decision making involves the accumulation of information, evaluation of alternatives, and finally, judgment in weighing alternatives having values that may appear

stubbornly incommensurate. Regardless of the level of scientific understanding or technology, judgment in selection of choices will always be required, and in the face of diverse and conflicting demands. Responsibility for water-use decisions in the United States is spread over a large number of people and agencies, ranging from farmers who decide quite independently to put down a new well to legislators who delicately reconcile regional interests in setting a new pollution-abatement policy. While the types of decisions are well known, there is little precise understanding of the circumstances in which people make their choices and of the factors that affect their decision to overirrigate a crop, or to permit a stream to become unsafe, or to drill to a fresh supply of ground water. Because public policy often is based upon belief as to how such decisions are made, a better understanding of their determinants and rationale could assist in the formulation of sound policy.

We need to improve the decision process. The present report does not present in detail all the ways in which research might improve consideration of alternative actions. Much more can and should be said on this matter but adequate treatment of the subject is beyond the scope of this report. The Committee wishes to emphasize that there is a constant interaction of changing technology with human needs and desires. The planning process needs to be brought abreast of knowledge that is now available, and it needs to be altered toward the end of encouraging new knowledge and utilizing that knowledge as it becomes available.

Essential to this progress is cultivation of the distinct phases mentioned earlier. In the first phase, the alternatives need to be studied in greater depth than they are in present practice. Alternatives need to be explained in equal detail. They should be presented to the public so they can be considered. In a second, later, phase the course of action or choices among alternatives would be made, reflecting public reaction to the earlier presentation.

Summing Up

A New Emphasis

A review of current efforts to manage water to serve the needs and desires of man reveals that all aspects of water management would be improved by planning that would maintain flexibility for the future, foreclose as few choices as practicable, and put fresh demands on science to predict consequences and to provide alternatives to meet changing needs. Specifically, such an emphasis would call for applying more intensively present knowledge of the behavior of water, land, and man in two ways: first, by identifying all available alternatives for coping with water problems and taking systematic steps to discover new alternatives; and second, by improving methods of recognizing the social as well as the physical consequences of water management and of weighing alternatives.

Lines of Action

The Committee sees need for action along three major lines. First, all organizations, public and private, engaged in planning for the use of water, should give increased attention to alternative approaches and courses of action, to the appraisal of social costs and benefits, and to the use of research as one of the means by which new effective solutions could be reached. These aims will be achieved only as fast as the men who prepare new water-development plans for private and public organizations adopt and practice a broadened view.

Some reorganization of public agencies for water planning will be necessary to translate the shifted emphasis and new knowledge into studies and plans. The Committee does not propose specific organizational changes; but without some changes the quality of research and planning will suffer. The present

framework for decision, although revised in recent years, still leaves much to be desired. The gap between scientific knowledge of optimal methods and their application by farmers, manufacturers, and government officials is large and widening. Man's ability to forecast streamflow, store water, transport it long distances, alter its quality, and extract it from great depths is growing more repidly than his skill in fitting the improved technology to his needs and aspirations.

Second, concerned citizens' groups and the elected representatives of the public should be encouraged to ask that practicable alternatives be presented for their consideration and evaluation. The public, through its representatives, should maintain responsibility for the value judgements inherent in water-use decisions. Both the "single best plan" and the "quick fix" should be shunned.

Third, the scientific community should recognize the need for extension of its research efforts into a broad and diverse group of physical, biological, and social problems related to water. The scope of research should expand to identify and evaluate the factors that influence water-resource decisions, and to seek answers to questions that emerge from studies of alternative solutions to water problems.

Breaking with the "Quick Fix"

There is little need to repeat the descriptions of water supply, distribution, and requirements that appear in published reports. The essential facts now are becoming well known, and the basic hydrologic problems have been defined. Still lacking is a broad recognition by scientists and engineers as well as policy makers that advances in the knowledge of water and its possible uses not only have changed the character of water problems, but have made it possible to deal with these problems in a greater variety of ways and more effectively than in the past. Such recognition by engineers, administrators, and citizens organizations would change the character of research, of planning studies, and of the public discussion of programs and policies.

The broadening of thought and action recommended by the Committee would be a fundamental break with

the rigid technological ("quick fix") outlook that has dominated U. S. water planning and management over the past century. In many instances, that outlook has been justified, because economic growth was a major aim. In other cases, this approach has been of questionable validity. The technological tradition has its most recent and dramatic expression in the heavy emphasis upon improving the production of fresh water from salt water. Typically, it answers the problem of impending water shortage by seeking more water at least cost—from a distance, from underground, from the clouds, or from the sea—and it encourages commitment to a single engineering solution to the exclusion of other alternatives. The Committee recognizes that a cheap, reliable method of desalting would provide another option to those responsible for increasing the supply of water. However, it is concerned lest too heavy a commitment to a single engineering solution may tend to exclude other alternatives.

The outlook that better expresses man's growing sensitivity to his environment and makes use of his expanding scientific insights is one that calls for careful weighing of the whole range of devices, both technologic and social, that are open to him to support and refresh his body and spirit.

More Sensitive Evaluation

The values that we put on water cannot be expressed entirely in dollars. We value water for the life it sustains, for its role in our economy, and for the lift it may give our spirits. We look upon it differently at different times and in different places. It has both tangible and intangible, both market and nonmarket, values. If we are to be good stewards of the nation's water resources, we must search for ways of realizing values held in varying esteem by different people in different places. As these values increasingly reflect a concern for improving the quality of our environment, the process of evaluating and of incorporating them into water-use decisions becomes more difficult.

Kinds of Information Needed

Wise solutions to water problems require accurate information about water and the immense diversity of conditions under which it occurs and is used; they call

for clarity in judging the value of water and associated resources. These solutions can be reached only when the organization of planning permits balanced consideration of the choices and values involved.

Information needed is of three kinds: (1) information on the behavior of water and on the ways in which environmental changes affect water as a resource; (2) information on new and more efficient processes of waste treatment, desalting, and water use; and (3) information on user behavior, on the planning and decision processes, and on probable changes in water use as a result of changes in our technology and in our style of life.

There is much information on how water moves in the hydrologic cycle, and on how to construct dams, canals, and purification works. Less is known of the biological and social effects of such constructions. Much remains to be learned of the way water-use decisions are reached at the various levels of government and in the private sector. We especially need information that will help increase the number of feasible alternatives and improve water-use decisions.

Research as a Part of Management

Even though enough water is available to the nation to meet present and foreseeable requirements, the demands on that water necessitate thorough planning and efficient management. Beneficial management in turn depends upon sound planning; sound planning depends upon accurate prediction of conditions and consequences; and accurate prediction depends upon good records and perceptive analysis of past experience. The process is continuous and unending. It calls for scientific examination of the way decisions are made (why a farmer knowingly chooses to overirrigate, for example, or why a city chooses to build another dam instead of metering water), of the tools that can aid in reaching decisions (how a wild river is valued or how account is taken of drought risk), and of the physical and biological possibilities for new methods of management (how the loss of water from soils could be altered or how toxic wastes could be eliminated). Imaginative research, as an integral part of the management process, can expand immensely the nation's ability to handle water for the public good.

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