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ORGANIZING SCIENTIFIC INVESTIGATIONS TO DEAL WITH ENVIRONMENTAL IMPACTS

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A puzzling aspect of many development projects is why they are not accompanied by more searching scientific investigation of their ecological consequences. To what conditions can we trace the lack of attention given to fisheries studies in a hydroelectric reservoir project? The same question can be directed to irrigation projects and schistosomiasis, flood control schemes and soils, the effects of pesticides or fire control, and a host of other relationships of the type canvassed in the case studies of this conference.

Often the answer which is offered, now indignantly, now peevishly, now sadly, is simple in form. The trouble, we say, is ignorance, or stupidity, or greed, or the lack of an agency to put things right. And the correctives, also put simply, range from more research and more education to running the rogues out of office and to setting up new offices for angelic practitioners of science. Whatever the corrective measures, we are not doing conspicuously well with them. There is good reason to think that development projects are spreading faster than efforts to anticipate their full consequences. Perhaps we can gain in competence in coping with this trend by taking an unconventional look at experience with one type of project. The type of project is the large tropical reservoir. The perspective is that of a geographer concerned with ways in which man perceives his interventions in natural systems and with his modes of adopting to them.

We can narrow the question by inquiring why more explicit and sensitive attention has not been given to the ecological impacts of reservoir development in the tropics. Analysis begins with a brief review of the theoretical relationships which are involved in reservoir development. It moves on to what might be considered a proper study agenda in connection with the planning of any tropical reservoir. This is compared with actual studies at three large reservoirs. Then it comes to the issue of whether or not there is any myopia on the part of the engineering, scientific, and administrative fraternities in dealing practically with those relationships. It examines some of the current explanations for past distortions or delinquency and suggests their implications for public action.

Recognizing man to be often ignorant and sometimes stupid, we may nevertheless assume that when he systematically avoids facing up to consequences as he has in the case of certain African reservoir projects, there may be reasons which seem persuasive to substantial sectors of the family. In understanding these reasons the ground may be prepared to deal with them in future.

Theoretical relationships

We begin with a reservoir as one element in a water management system in a river basin, not because it is in any sense comprehensive, but because it is one of the few convenient and readily isolated units in water management and because there has been more study of reservoir problems than of other units of management such as channel regulation and irrigation distribution systems.

The reservoir is a human creation, intended to affect the place of water in time and in elevation. Impoundment has the result of modifying the regimen of a stream in some respect. As a minimum, it changes the elevation of available water in a channel. At maximum, a dam completely alters the distribution of water over a large area while radically changing the downstream regimen. In all but rare cases, there is daily, seasonal, and annual fluctuation in reservoir levels and in the exposed margins.

Confining attention to the reservoir itself and excluding effects of alterations downstream, the possible range of impacts of creating a reservoir may be outlined as shown in Figure 1. Obviously, these are sketchy, and they will be described in more detail in another publication. Others of less general significance are omitted. It is sufficient here to note their complexity and to call attention to a few features of the relationships.

The eight systems which are defined consist of two physical systems of air, water and sediment movement, three distinct biological ecosystems, and three human systems. It is impossible to erect a large dam without causing some impact upon each of the others.

One useful way of classifying impacts is by the systems affected. Indeed, the common way of referring to reservoir projects is in terms of the primary human activity to be changed: a storage dam for hydroelectric energy production, a regulating reservoir for water transport, a detention reservoir for flood control. In describing and building projects in those terms, other, secondary relationships, may be ignored or obscured.

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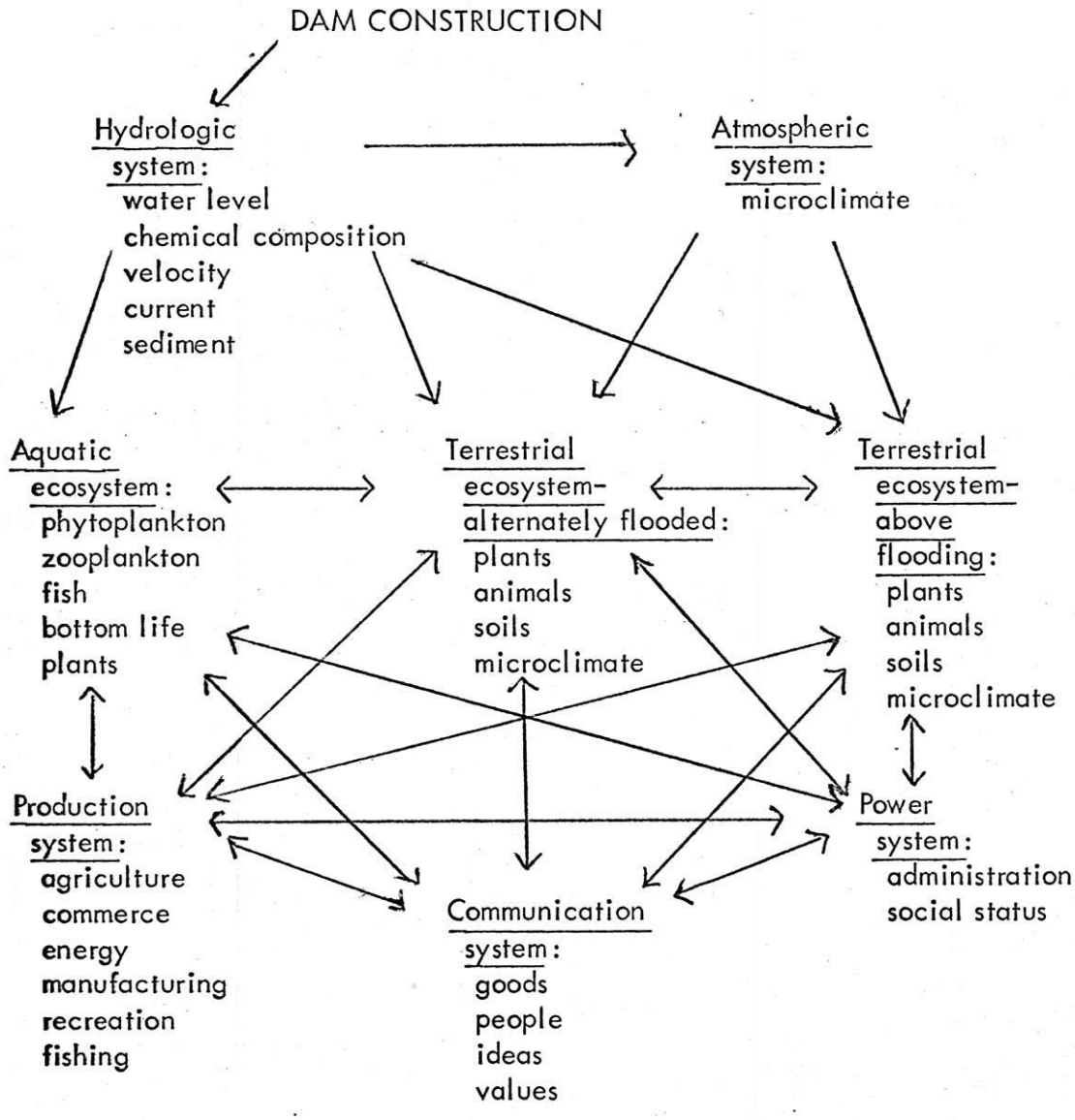

Figure 1. Schematic diagram of the major possible effects of a reservoir impoundment.

A second useful classification is according to the degree of directness of connection between reservoir construction and the system impact. Thus, the level of water in a reservoir may have a direct impact on the availability of fishing grounds to fishermen, but an indirect impact on fish productions as the aquatic ecosystem changes. It may have an indirect impact upon the microclimate of the nearby area by virtue of movements of air and moisture. The number of inter-connections is immense.

But to suggest a relationship from either theory or observation is not to specify our knowledge of it, and much of what is outlined in the diagram is so tenuous or speculative that we cannot assert the relationship with a high degree of confidence. It is possible to estimate the effect of a storage impoundment on potential electric power production with considerable accuracy. The effects of reservoir fluctuation on the soils and plant population of marginal lands is much less certain. The effect of storage on a schistosome vector or on aquatic plants is even less predictable. Some of these have been described in the Institute of Biology symposium (Lowe-McConnell, 1966) and others in the Accra symposium (Ghana Academy, 1968). Scudder examines part of the complex perturbations generated by the building of Kariba.

With few exceptions the relationships are reciprocal. For example, the amount of water used for electric power production changes stream regimen, and also controls water levels on the margins, in turn, affecting the growth of aquatic plants.

Desirable study agenda

When consideration is given to building a dam there must be at least one impact which is sought, and generally it is power production, agricultural production, goods movement, domestic water supply, or some combination of them. Human manipulation presumes human ends to be served. These ends commonly are ambiguous and confused in water development, but it may be helpful to sort them out according to the method used in the recent analysis of Colorado Basin development (National Academy of Sciences, 1968) as being:

national economic efficiency,
income redistribution,
preservation and esthetics,
political equity, and
environmental control.

Only the last two of these requires explanation. By political equity is meant the satisfaction of social commitments without primary regard for income flows or environmental quality. By environmental control is meant that special, oftentimes inarticulate, and widespread motivation to harness a stream or some other natural process because man knows how to do it.

It is usual to give national economic efficiency as the primary aim for national investment. Yet, the record is loaded with projects in which regional claims or political equity or the aspiration to create a monument to man's mastery of nature have figured in the final choice.

To decide what should be studied in a proposed dam construction requires, then, a conscious or tacit definition of aims, and for our analysis we shall

assume that these are a combination of national economic efficiency and environmental preservation, aims that may be in conflict but are susceptible to reconciliation. Desirable plans of study would seek to explore each of the possible relationships to see how they would be affected by the construction and how this in turn would advance or detract from the stated aims.

At once, a value judgment is required. How significant must the effect promise to be before it is investigated? One way of meeting that requirement is to specify that all possible effects shall be studied to the point of estimating the order of magnitude of impact insofar as man is capable of identifying them.

On theoretical grounds the agenda also would include an investigation of alternative means of reaching the same goals. This would canvass as well as the variety of possible water management measures, the non-structural measures promising similar results. Hydroelectric power would be compared with thermal sources; irrigation would be compared with fertilizer and seed programs (National Academy of Sciences, 1966).

Actual study programs

A study program which examined alternatives and gauged the weight of possible impacts might satisfy the ideal agenda. We must admit at once that no such study has ever been made. Experience with the planning of three reservoirs helps us see some of the reasons.

The three projects are the Kainji on the Niger, the Volta River dam, and the Sadd el Ali (High Aswan) on the Nile. Their physical and fiscal size is indicated in Table 1. Each is a national project supported by international financing. Each has power production as a primary purpose as a means of advancing national economic efficiency, although Sadd el Ali includes irrigation water storage as a primary purpose.

Perhaps the closest that any study of an African reservoir project has come to recognition of such a set of relationships is in the Volta River Preliminary Commission investigations. Over a period of five years they sought to clarify a large number of problems involving physical, biological, and social processes. This is shown in Table 2 which outlines aspects of the Volta project embodied either in the investigations or in the final report of the preparatory commission.

No other reservoir approaches the Volta investigation in concept or in detail. Yet, it later required as much salvage type of activity as did the other two projects.

Without attempting to review the history of project planning in each case it is possible to enumerate some of the principal points at which the studies leading to construction fell short of the desirable study agenda. A rigorous way of going at the deficiencies would be to compare the actual studies with the ideal agenda. Comparison is hindered by the lack of any complete history of the planning studies. We know from the available reports

what findings were brought to the public or responsible officials; we cannot reconstruct the lines that were considered and then abandoned. It is easier to list those relationships which after construction was well under way were selected for further study. Kainji and Volta lakes and Lake Nasser, the portion of the Sadd el Ali reservoir in the United Arab Republic, are the subject of detailed studies by teams of international experts financed jointly by the respective countries and the United Nations Development Programme.

At Lake Nasser the investigations, with a total cost of $2,600,000 over 5 years, include fishery biology, limnology, fishing gear technology, fish processing technology, fisheries economies; vectors of malaria, bilharziasis, and other human diseases; vectors of animal diseases; soil, agronomic, horticultural, and economic aspects of lake shore agriculture; afforestation and wildlife conservation; geo-hydrology; and social and economic analysis of adjustments in community life. At Kainji, a total expenditure of $2,000,000 over 6 years will be divided among limnological and fish species; socio-economic studies related to the continuation of resettlement; vectors of malaria, schistosomiasis, and onchocerciasis; and conditions for establishing a wild-life conservation zone. At Volta, a three-years investigation costing $2,700,000 is concentrating on investigations relating to fisheries and hydrobiology; resettlement; and public health.

Why the omissions?

Two broad sets of explanations may be advanced for the omission of these problems from the earlier project investigations. One is that those people responsible for deciding to go ahead with the projects were unaware of the consequences to which later studies were addressed. The other is that they were aware of possible consequences but thought it unwise to study them.

Lack of awareness surely there was in some quarters. Much of it could be attributed to deficiency of information, either because the basic reports failed to identify the possible relationships or because the readers were insufficiently prepared by training or outlook to ask about them. In some instances the scientific basis for an intelligent question was lacking, as in the case of micro-climatic impacts.

To an unknown degree there must be perceptual distortion in dealing with these impact problems. We know that in thinking about the occurrence of floods or the hazard of drought or the recreational use of a domestic water supply reservoir resource managers are shaped by their prior views of what is practicable to do (Kates, 1962; Saarinen, 1966, Bauman, 1968). People who feel themselves unable to cope with a situation see it as less severe than others. A sense of efficacy in handling complexity may be a powerful aid to awareness.

If certain officials were unaware of the complications of building the dams it was because engineers and other technicians who recognized the problem chose to treat it as insignificant. In good faith and feeling themselves

loyal to their professional training and traditions, they decided that questions need not be raised in overt fashion in their reports and advice to those higher up. As with so much natural resource management, many of the basic decisions as to policy are made tacitly or unconsciously by the investigator who decides which problems he will study, which options he will probe. By the time a recommended project reaches the top officials or the public arena these assumptions are plowed so deeply into the soil of the program that they are barely discernible or are covered entirely by the construction design.

The preponderant number of decisions to exclude consideration of the full set of theoretical relationships may be attributed to conscious judgment that the social cost of neglecting the relationships would be smaller than the cost of attacking them frontally. Two economic considerations may be relevant. With respect to most of the relationships, the scientific precision of understanding is such that there is a high degree of uncertainty as to the probable effects of investment in studies or in subsequent management. Take the case of fresh-water fisheries on new reservoirs. Although a considerable body of evidence has accumulated as to the nature of the change in thermoclime once a reservoir impoundment begins, scientific information on effects of those physical changes upon the biological population of the reservoir is so meager that it rarely is practicable to indicate in advance the management measures which should be taken to increase fishery productivity. Prediction of the new ecosystem is not sufficiently confident to warrant a firm decision to introduce new species

of fish or other life into the reservoir. It is necessary to wait and see what happens. Certain fishery experts argue the wise course of action is to make observations of reservoir conditions while the reservoir fills, and then hold off on any preliminary activities until the first biological bloom has passed, and the aquatic system approaches a new equilibrium. At that stage the scene is set for more intelligent management measures involving stocking, fishing control, and measures to promote marketing and processing of whatever variety of fish seem to be most promising. To follow such a course would imply that the government would take negative steps to prevent undue fishing on the part of the local fishermen: it would discourage mechanical development, it would not introduce new gear, and it would try to hold the fishing industry to the existing number of fishermen and fishing boats. In these circumstances, it is asserted the most efficient strategy for the government to follow is to do nothing during the preliminary study period with respect to fishing, to follow a modest program of observation while the reservoir is filling, and then to make a heavy input of professional study and advice after the reservoir is full. To those who insist upon baseline studies, they would reply that such studies would be useful but in such limited degree they would not justify the expense.

The second economic consideration is the high risk and uncertainty attaching to secondary impacts. When a water planning agency is dealing with probable returns from sale of hydroelectric power which promise yields of at least 5 or 6 per cent per annum with what at the moment of study approaches

certainty, the probable savings of negative costs or probable gains of positive benefits from the management of secondary benefits may seem relatively insignificant. Given the high risk involved, it seems wiser to some managers to forego consideration and take the consequences rather than to invest heavy components of money and personnel in basic investigations.

There are administrative obstacles. The agency responsible for planning a new dam typically does not have competence in either biological matters or those related to social organization and process. In these circumstances, it oftentimes finds it easier to omit consideration of those topics than to try to enlist new personnel from a foreign environment or enlist the cooperation of other agencies in the government to share their funds. The simple bureaucratic complications of shifting funds or of supervising unfamiliar personnel may lead to a conscious decision to exclude the accompanying activities.

The same kind of difficulty arises with international administration of integrated resource studies. It is extremely cumbersome for two or more specialized agencies in the international family to collaborate in carrying out studies. The FAO, which has been primarily responsible as the executing agency for the African reservoir studies, has worked out agreements for collaboration with WHO in the health field. It has had more difficulty in working cooperatively with UNESCO which asserts a basic responsibility for scientific research education and training. The same kind of difficulty reflects itself at the national level. A ministry of agriculture hesitates to enter into an

investigation which also will involve a ministry of public works, and vice versa. Each of the ministries characteristically has its counterpart in the international specialized agency. Agriculture ministries prefer working with FAO. A ministry of public works prefers to work with the World Bank. As a result, each proposes a project or an investigation scheme narrow enough in concept so that it avoids the problem of overlapping at either the national or international level.

In a sense, correlation of separate administrative responsibilities reflects differences in approach among scientific disciplines and their accompanying professional cadres. On a reservoir project, the coordination of limnologists, wildlife ecologists, sociologists, and economists may be equally as sticky in terms of developing cooperative approaches to common problems as the coordination of administrative agencies. The finger of responsibility should be pointed toward the points of view of professional groups and to administrative agencies reflecting their orientation.

In the case of the Volta project the negotiations for foreign financing dragged on a long time, and once they were concluded the government felt impelled to get construction under way without delay. In the bargain it found itself short of funds. Consciously and with questionable wisdom it pushed resettlement, cut out expenditures for reservoir clearing and public health investigations. Studies of basic biological changes and of potential use of the reservoir margins awaited financing through the University and

with foreign assistance. Moreover, the concentration of attention on building the dam and selling the electricity led the Volta River Authority to shed its responsibility for such auxiliary activity as agricultural development. When it returned to that unified role it took up its interest in supporting the basic research on biological and social problems.

We may draw on the Volta experience as a kind of prototype. In a number of ways the Volta River Authority failed to use the data and findings from its preliminary study activity in the final operation and construction of the reservoir. The resettlement program was initiated before the results of the resettlement study were completed. Plans for clearing the reservoir for fishing purposes were altered and eliminated, except for a small demonstration area in a stretch of about two miles immediately adjacent to the dam. Public health measures in the reservoir area were not taken. No detailed investigations or pilot operations were undertaken in the foreshore with its seasonal inundation of potentially useful agricultural land. Inadequate measures were taken to look into possible impacts of the reservoir upon transportation in the area or to experiment with simple means of maintaining either passenger or freight transport on the new lake.

Resources, Economy, and Population

A similar and related problem is the coordination of natural resource development with national economic policy. There is little point in preparing comprehensive basin plans unless they are harmonized with broader national efforts to reach national goals.

Even more sensitive is the coordination of resource development with population policy as an essential ingredient--explicit or implied-- in economic programs. It is evident that much resource manipulation is intended to offset demands created by growing numbers of people to be fed, clothed, and housed. Thus, an irrigation component in reservoir storage is intended to provide water to support a future population. A sober canvass of alternatives would note the opportunities and limitations in influencing the options open to individuals in that regard as well as in farming.

This brings us to what may well be the crucial aspect of resource intervention in the developing world today. It may be put as the degree to which management decisions are shaped so as to take account of the theoretical range of choice open to each society.

Some remedies

Against this record of action in omitting and then attacking secondary impacts of reservoir development, a few remedies seem promising.

If something approaching a desirable plan of study is to be achieved in the near future for the major projects, a kind of early warning service must operate. The United Nations Development Programme is the appropriate agency to do this in developing countries for it either funds or is aware of larger pre-investment studies. By identifying the emerging problems before construction planning is complete it should be able to prevent later salvage operations. Its field offices now are alert to the need for doing so.

UNDP and FAO also have initiated in the African reservoir studies a systematic attempt to assess the social gains and losses from studying or ignoring the secondary impacts. Methods are as yet imprecise, but rough estimates are being made, and from such appraisals may come a clearer view of what payoff in understanding of environmental change may be expected from different scales and type of investigation.

We must remind ourselves that relatively little is known of the success or failure of reservoir projects in achieving their stated limited and primary aims. The practice is to spend huge sums on normative studies of proposed construction schemes, and little or nothing on appraisal of what happened after the bulldozers withdrew. There are only a handful of searching evaluations, and these are primarily on the economic and fiscal aspects of the projects (King, 1967; de Wilde and others, 1967). The appraisal of non-economic consequences is even less advanced.

The FAO has just completed a rudimentary sort of manual pointing out the chief classes of secondary impacts which have plagued reservoir development in past (FAO, 1968). It should be clear, however, that neither manuals nor performance evaluation can in themselves shift the prevailing approach of technical agencies to project planning. The early warning service may be expected to command attention. This must be supported by evidence of impacts in concrete situations and by practical suggestions as to how the complicated and often speculative investigations of such impacts can be reconciled at reasonable cost with the studies of primary impacts.

Imposition of a special review agency or of a special study group in connection with ecological impacts of massive new projects of this nature does not seem a promising line of action. Administrative and professional resistance would be severe. Yet, means must be found to take account of the full range of consequences, and it may be that the steps already taken are in the right direction.

TABLE 1

CHARACTERISTICS OF THREE AFRICAN RESERVOIR PROJECTS

Name	Area of Reservoir in Square Miles	Estimated Generating Capacity in KW	Estimated Cost in Dollars	Construction Period
Kainji	480	320,000-880,000?	140,000,000	1964-1968
Volta	3,275	512,000-882,000	156,000,000	1962-1965
Aswan	1,900	2,100,000	>320,000,000	1960-

TABLE 2

OUTLINE OF
MAIN TOPICS FOR INVESTIGATION BY THE
VOLTA RIVER PREPARATORY COMMISSION

Technical aspects
- Dam and power installation
- Power markets, including bauxite and alumina treatment
- Landscaping
- Transport network
- Effect of reservoir on communications
- Sources of materials

Human factors
- Manpower requirements and supplies
- Productivity, health, training of labor force
- Living conditions in new communities
- Impacts on urban communities

Effects of the dam and reservoir
- Ecology, demography, and livelihood in reservoir area
- Compensation
- Resettlement and its administration
- Effects on downstream communities (agriculture, fishing, health, water, communications)
- Health and sanitation
- Agriculture, forests and fisheries

Financial and economic aspects

Other factors which could influence the projects (financial resources, overseas investment, Togoland administration, headwaters control, future of aluminum, nuclear power)

Administrative and legal framework

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