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Environmental Optimization in Hydrodevelopment of Tropical Forest Regions

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1. ENVIRONMENTAL INTERPRETATION OF DEVELOPMENT

This paper briefly considers both the energy supply and the development process itself. Hydroprojects in general and those in tropical forest regions in particular are then discussed.

Development projects seek to improve the quality of life. But improvement in the quality of life of a segment of population in any given area often is related to a concomitant deterioration of the quality of life elsewhere. Since some disadvantages inevitably will result in any developmental process, this paper attempts to show how planners can best cope with both the negative and the positive aspects of a project. Most disadvantages are environmental in nature and occur near the project, whereas the advantages frequently accrue largely to distant communities, and are usually economic rather than environmental. Though only environmental concerns are addressed in this paper, these concerns, wherever possible, are expressed in economic terms.

Development, the investment of capital, applies financial resources for the exploitation of natural resources. This, in turn, creates opportunities which, presumably, will improve the quality of life in an area. The goal of development is not to develop physical facilities, but rather to enable people to enrich and enhance their way of life. Environmental optimization protects financial investments, prolongs the profitable life of the project, accelerates amortization, prevents or mitigates disadvantages and increases both the benefits and the number of people gaining therefrom. Optimization -- admittedly an ideal -- makes the best possible use of the development project while at the same time acknowledging the impossibility of achieving totally positive outcome. Energy developments are of particular concern to ecologists because all other components of the ecosystem -- water, oxygen, and nutrients, for example -- are recycled in nature and are reused. Energy is the only resource which irreversibly flows in only one direction --

downwards, into uselessness out of the system.

2. EARLIER ENVIRONMENTAL CONSIDERATIONS

Before deciding what type of energy should be developed in a particular case, it is necessary to examine the overall environmental considerations of any given project (or development). Imbalances between supply and demand can be met either by increasing supply, or by stabilizing demand. Environmental optimization begins as soon as a future need is predicted. For example, when growth of the energy demand curve is projected to intersect total generating capacity in a period of ten years, national power authorities start to seek increased generating capacity. At this stage, basic environmental criteria should be addressed. Projections of energy demand are customarily catered to automatically. But no exponential growth can continue indefinitely, such as the demand for energy in over-industrialized regions. Though developing countries can raise living standards by supplying more energy, such an increase in energy supply in many other countries will still fail to improve the quality of life. North America's energy consumption is five times greater per capita over Japan (250 kw/cap/yr versus 50), yet it is not paralleled by a fivefold better standard of living, for example. In other words, increases in energy consumption beyond a certain level cannot be equated with an improved quality of life (1). Eventually, per capita energy consumption must become a constant. Although this level should be much greater than it is in most developing countries today, it is not too early to recognize the goal. Certainly per capita consumption can be reduced in many countries without crippling the economy and without lowering the quality of life.

The second environmental consideration to be addressed in environmental optimization is the potential for conservation of existing resources. Capital invested in promoting better use of public transportation systems, for example, may lessen the need for capital investment in increased generating capacity. Similarly, as

much as a wasteful two-thirds of the fuel consumed to generate electricity today is discarded as waste heat. The environmentalist helps to evaluate whether the investment should be applied to reducing such energy wastage or to generating more energy. No menas of providing energy, electrical or otherwise, is entirely free of environmental liabilities, and no form of pollution control is entirely effective. Thus although there always will be some environmental impact associated with energy production, conservation offers a double means of lessening the impact.

Assuming that it has been calculated that an increase in energy supply will improve the quality of life and that there is inadequate potential for conservation, only then should the need for increased generating capacity be admitted. Problems of electricity demand and the proliferation of power plants cannot be considered in isolation from the rest of the energy crisis. Electricity is only one form of consumption; often it can be beneficially replaced by other forms (2). The many ways of increasing generating capacity are customarily evaluated by economists and engineers. Since each energy system exerts different environmental impacts, the methods of providing the energy should be environmentally assessed.

The follwoing list of nine major types of energy systems is ranked in an approxiamte ascending order of environmental attractiveness:

NON-RENEWABLE CAPITAL

1. Nuclear fission
2. Bunker 'C' petroleum thermal
3. Coal-fired thermal

RENEWABLE 'INTEREST'

4. Geothermal
5. Solar conversion (photovoltaics)
6. Hydropower (pumped storage reservoirs, run-of-river, etc.)
7. Biomass energy (methane, ethanol, methanol, charcoal, fuel-wood)
8. Wind energy
9. Tidal energy

Although much could be discussed about such rankings, such discussion is academic unless it is related to a specific country or region. Clearly, any nation possessing stupendous resources of high-grade, low-sulfur coal which can be extracted cheaply and without damaging the terrestrial surficial (e.g. agricultural soil resources above the coal deposits), will prefer coal energy over photovoltaics for example. In general, however, renewable energy sources (geothermal, biomass, solar: nos. 4 through 9) are preferred environmentally over non-renewable energy such as coal, oil and atomic fission. Ideally, each region will be best served by a blend of generating devices, off-peak energy storage, and programs designed to increase base-load while dampening peak-load. Since hydropower represents the unpolluting harnessing of solar energy, ecological criteria favor hydro over fossil fuel energy generation. Endless hydropower represents a sustainable interest accruing from investment, whereas fossil energy represents a depletion of irreplaceable capital.

3. ENVIRONMENTAL DESIGN OF HYDRODEVELOPMENTS

Where engineering, economic and environmental criteria have determined that hydropower is the most rational means of development for the nation or region, both the type of hydroproject and environmental input should be evolved simultaneously. Three related generalizations are pertinent in this connection, or for that matter, in connection with almost any development project:

* "Environmental impact is directly related to the size of the project".
* "Environmental impact is inversely related to the narrowness of the project's goal".
* "Environmental impact is directly related to the tardiness of ecological input".

The size of the project -- i.e., the surface area of a reservoir -- determines

how much land is removed from agricultural or other actual or potential uses. The value of energy generated by the new project, therefore, must exceed the value of potential agricultural production prevented by the reservoir. If, in addition to the generation of energy, the reservoir can prove to be as productive in fish or other crops as the submerged agricultural land had been, the adverse impact of the reservoir is mitigated. Optimization achieves a system which would harvest a greater value of aquatic products from the reservoir, and of irrigated or recessional agricultural products near the margin of the reservoir, while at the same time creating sustained employment for a greater number of people than those who were displaced. In other words, greater multiple use of the reservoir mitigates the overall adverse impact.

Power generators are now being designed for ever-increasing outputs, since they are cheaper in terms of immediate capital cost per megawatt of generating capacity. For example, choosing a 1000 MW unit instead of a 500 MW unit reduces the capital investment per MW by ten percent and the labor requirements by eighteen percent. The hidden cost of bigness is unreliability: the bigger the rating, the more time it spends idle due to faults, and the more serious the outage becomes. For example, units in the 390-599 MW range are "available" to generate only 74 percent of the time, whereas this figure increases to 84 percent for the 130-199 MW size.

Most adverse environmental consequences are a simple function of the size of the reservoir: the area of fertile soil removed from annual production by flooding; the number of people displaced by, and houses and infrastructure lost to the reservoir; the opportunities for proliferation of aquatic disease vectors (e.g.: malarial mosquito, schistosomiasis snail) and nuisance organisms (e.g. water hyacinth, gnats); voluminous reservoirs trigger or exacerbate the perils of induced seismicity; large reservoirs produce less fish per unit volume than small reservoirs; water quality

deteriorates gravely in large reservoirs while remaining acceptable in small ones. Environmental optimization therefore seeks high "power per area" ratios of reservoirs, such as kilowatts per hectare (3).

These examples should suffice to demonstrate that customary short-term economic criteria are woefully inadequate when determining the size of a project. Economics excludes consideration of such adverse consequences -- frequently referred to as "externalities" -- from customary evaluations. The time-frame of economic thinking is so short-sighted, and the perspective of economic vision is so narrow, that such criteria frequently act to the detriment of the environment. In the final analysis, anything environmentally unsound can never be economically healthy. One of the most effective methods of ensuring environmental rationality and health is to "internalize" these "externalities". In other words, potential environmental impacts should be considered as integral factors in all economic evaluations. While acknowledging the supreme importance of this topic, however, it is not centric to the main theme of this paper, so will not be discussed further here.

The inverse relationship of size to reliability of power generation creates further disadvantages, since the outage of a large generator wreaks proportionately more harm than the outage of a small generator. The area affected is larger, and therefore the possibility of importing power from neighboring regions is more remote. "Civilization can be measured by the degree of helplessness when the electricity goes off".

The prevention or avoidance of environmental problems is infinitely less expensive than their cure. Not only is prevention much better than cure, but cures of environmental ills frequently do not exist. Remediation and even palliation is expensive and ineffective. Since amelioration and prevention is achieved principally by modifying designs and adapting plans, the earlier the problem is predicted the more effective and less onerous will be the preventive measures. In my experience, prevention can be achieved frequently by doing the same thing in a slightly

different way or with minor changes in timing. In these cases, prevention requires no added investments and causes no decrease in product (e.g. energy). For prevention to be effective, environmental assessment and environmental planning criteria must be integrated as early as possible. For example, an epidemic of disease may be avoided by minor drafting alterations to the blueprint of the spillway. The cost of deaths or disability caused by an epidemic of the disease and the cost of curing the disease can rapidly exceed the cost of the project. Thus, the later the environmental input, the greater the impact will be.

These, then, are the reasons that discussion of the size of hydroprojects is so important in their optimization. The relative merits and demerits of a few large dams, as opposed to many smaller dams, or a still greater number of axial tube turbines, thus provide an essential contribution to the development decision. Axial tube turbines cause practically no environmental problems since little or no reservoir is created. These cheap, low-maintenance, sparkless sources of power are easy to manufacture in the 100 KW to 1,000 KW range, and 20 MW to 100 MW sizes also can be feasible with minor environmental impact.

Ideally, the site for the future hydroproject -- traditionally selected solely by engineering, geological and financial criteria -- should be determined by a procedure in which environmental considerations figure significantly. All the sites at which it is technically and economically feasible to generate the required energy should be ranked in an order of environmental acceptability. This ranking can be based on an environmental cost/benefit analysis, or the environmental "externalities" can be integrated as factors in economic equations. Although difficult to gauge accurately, it is not impossible to assign some financial value to the "externalities" of a hydroproject. Increasing the probability of a malarial, yellow fever or bubonic plague epidemic, or the flooding of a large, densely populated and highly productive agricultural community, are examples of external components which should be internalized and this cost accounted for. The site ultimately agreed

upon will be the compromise producing the most power with the least environmental problems, and the greatest multiple use potential, requiring the least capital investment.

Another aspect of site selection concerns the nation or region as a whole. Most people today accept the thesis that it is advisable to preserve at least some of the nation's rivers running free, and going one step further, increasing numbers of people are convinced that it is economically worthwhile to maintain a proportion of rivers undammed. Ideally, a nationwide energy master plan should identify which rivers should be dammed during the next 25 or 50 years or even longer, and which should be left in their natural states in order to maximize the economic benefits of undammed fluvial resources. Optimization of a nation's resources and investments can be achieved only after a long-range, integrated energy master plan identifies objectives and establishes priorities.

Although singleness of purpose may be admirable in many pursuits, it is deleterious for most development projects, and even dangerously counter-productive in hydropower developments. The corollary of the generalization on the narrowness of the goal demonstrates that the wider the hydroproject's goals and the more multi-purpose the reservoir, the less will be the environmental impact and the more beneficial will be the development itself.

For example, the extent to which the project creates gainful employment for the people of the area, particularly those displaced by the reservoir, is a measure of the value of the development. Significant in this regard is the fact that with prior comprehensive planning, most economically profitable multi-purpose opportunities can be exploited with little, if any, additional investment. Multi-purpose uses of hydroprojects and reservoirs include fisheries in both the lake itself and downstream, recessional agriculture (in periodically exposed perimeters), irrigation, water supply, navigation, transport and communications, reforestation of the lake-side marginal strip, and watershed management (<u>vide infra</u>), production of waterfowl,

aquatic animals and aquatic plants, and such varied recreational activities as boating, yachting, sport fishing and swimming.

4. ENVIRONMENTAL ASSESSMENT OF HYDROPROJECTS

As soon as the type, size, and site of the hydroproject have been determined -- incorporating the environmental contributions outlined above -- the project itself should be examined environmentally in order to identify three important aspects:

*Environmental problems:	their prevention, mitigation or remediation.
*Environmental opportunities:	their maximum exploitation.
*Environmental monitoring:	to design effective plans and for early warning of problems.

Environmental assessment of a proposed hydroproject is an examination of the entire project in all its ramifications, which predicts or projects both problems and opportunities which might arise as a result of the project. The assessment identifies and pinpoints areas where more specific information is needed in order to solve the problems or to exploit the opportuntities. To this end, the assessment will propose a program of environmental monitoring. This will confer the added advantage of establishing base-line data against which changes may be detected and warning trends discerned in time for preventive steps to be taken.

Successful environmental assessment is promoted by judicious "Terms of Reference", the design of which can facilitate or impede the assessment. The terms of reference must be as wide, catholic and all-embracing as possible from the very beginning of the study. One valuable albeit brief initial step in all such assessments takes the following form: "The environmentally sensitive and potentially significant topics a, b, c and d were examined in sufficient detail to determine that, for the purpose of this project, these topics need not be considered further. They are most unlikely to cause problems in this project for the following reasons..." Examples of effective terms of reference are appended (4) for the environmental assessment of hydroprojects.

The scope of the assessment must include anything affecting the project or affected by the project. It is, therefore, important to delimit, in general terms, the area to be studied. The geographical area in mutual interaction with any given project is much larger than the immediate vicinity of the project. The entire watershed or catchment basin above the dam constitutes most of the area to be addressed. Clearly, events anywhere within the watershed upstream may affect the reservoir or dam. Sedimentation from large-scale opencast mining anywhere upstream can curtail generating capacity, for example. The size of the area to be embraced in the assessment will necessarily be larger than the watershed upstream, however. The dam and reservoirs create significant changes in the rivers below the dam; the released water is colder, less propitious for fish, and more erosive, for example. Thus the entire watershed of both the river and its tributaries must be considered in the assessment. Furthermore, since estuaries and deltas play such an economically and ecologically influential role, these areas also must be included. Similarly, the power transmission lines and their construction, access and maintenance roads must be considered, in addition to any other roads and settlements built for the project. New consumers of the energy generated by the project, especially if these are large industries (e.g. an alumina smelter or an electrified railroad), also should be included in the assessment. Thus, the use to which the energy will be put is an important consideration in relation to the environmental impact. The area to be assessed, therefore, is composed of the watershed above the dam, the watershed below the dam (including any affected estuaries) and the areas affected by or affecting the powerline route, project roads, and new energy-consuming projects. Furthermore, some projects may interact with areas outside their watersheds. For instance, smoke or gaseous effluent from a polluting industry affects regions downwind. Or creation of an extensive reservoir in a dry region increasing humidity downwind can, in turn, exacerbate fungal pathogens of crops such as coffee rust and banana blight.

Conversely, large-scale modifications of any landscape whence weather patterns originate also cause changes in the project area. In ceratin cases, therefore, the "airshed" of the project should be surveyed both up and downwind. The airshed of a project encompasses that area determining the air (and weather) received by the project, together with the area receiving air (and weather) from the project.

The combined watershed and airshed of the entire project may encompass an enormous area, but this will not dilute the effectiveness of the assessment. Although the watersheds and airsheds must be accepted as legitimate and essential components of optimal environmental assessment, much of this area can readilty be dismissed from further consideration. The area to be considered is large but the attention devoted to it is never uniform. Little attention will be paid to most of the area, while close attention will be devoted to significant or critical, albeit small, sub-areas. The whole waterhsed receives sweeping general attention, for example, while the reservoir perimeter will be subjected to varied and minute scrutiny.

There are many meritorious ways of codifying environmental assessments, and each assessment should be tailored to a specific development. In any case, there are three broad sections which, by and large, will be incorporated in most environmental assessments:

*Human Ecology:	Waterborne diseases, nosogeography, resettlement, tribal peoples, cultural aspects,
*Environmental Ecology:	Water quality, siltation, watershed management.
*Bio-Ecology:	Resource inventory, biotic salvage, endangered species.

Human ecology is usually the most important section of any assessment, and it examines what diseases could be expected to increase due to the project, and how epidemics can be avoided. Waterborne diseases, vector ecology, and integrated pest management (sometimes referred to as nosogeography), also figure prominently in this section. Harmonious resettlement of people displaced by the reservoir can be as difficult and time consuming as construction of the project itself. Community structure, employment, cadastral survey and censuses, fair indemnification and assistance for displaced agriculturists without title to lands, are the prime concerns of this topic. Any tribal people -- Amerindians for example -- affected by the project, certainly warrant especial attention. Archaeological, cultural, historical and esthetic values, plus possibilities for increased recreation and tourism, all may usefully be included in this section.

Environmental ecology treats the chemical and physical effects of the project. What will happen if the newly-filled reservoir inundates one thousand square kilometers of tropical wet forest, for example? Changes in water quality in relation to anticipated water use will be assessed. Erosion, siltation and possible curtailment of energy generation and fish production is examined, as is the need for watershed management in general. Pre-impoundment treatment of the future reservoir area is planned, and selective clearance programs of lake-bed and transmission line corridors are formulated. The potentials are assessed of induced seismicity, climatic and hydrological modification, and impediments to navigation.

Bio-ecology deals with any natural resources affected by the project. Special tracts, such as national parks and biological reserves, are considered within this framework. Rare and endangered species of plants and animals receive attention here together with any special habitats. Biotic salvage, the rescue of animals flooded out by the project, and programs to avoid problems with dangerous or

poisonous animals are assessed. The optimal exploitation of resources in the area of the future reservoir receives careful attention.

Other parts of the environmental assessment include environmental aspects of the engineering itself: the routing of the power corridor, the deployment of the operators' settlement in relation to the dam, the location and treatment of borrow areas, and the operation schedule of the reservoir, for example.

5. ENVIRONMENTAL MANAGEMENT

Once a hydrodevelopment has been environmentally assessed, the many recommendations are implemented -- a process that can be described as environmental management. Ideally this process begins several years before closure of the dam, and continues not only throughout the life of the project at varying levels of activity, but also after the project ends and is dismantled.

Environmental management implements the recommendations concerning activities which must be finished before impoundment begins, especially treatment of the area to be flooded. In certain cases, effective treatment can be designed only following a study or inventory. Thus, a site-specific reservoir forest clearance plan can be formulated and implemented only when the nature and composition of the forest has been inventoried. Similarly, productive fisheries can be designed only when water quality measurements, fish data, and limnological studies provide adequate data.

In addition to implementing the manifold recommendations of the assessment, environmental management includes surveillance of the project in order to detect problems not perceived during the assessment. Base-line data and periodic, systematic monitoring of environmental factors will alert the environmental managers to any significant changes in ample time for preventive or remedial action to be taken.

6. PRE-IMPOUNDMENT CLEARANCE OF TROPICAL FOREST

This paper deals in generalities only, because all projects vary to such a degree that environmental optimization must be individually tailored to each project. One topic will be mentioned here as an example of a specific environmental concern in order to illustrate how pre- and post-impoundment activities closely relate to each other, and as a case study of major and increasing economic significance for future tropical hydroprojects. This case concerns reservoirs projected to inundate large tracts of luxuriant tropical forest.

Up until the present time, all of the world's major reservoirs have been created in desert, savanna, or agricultural regions -- all areas where the biomass of the submerged vegetation has been small. The six largest man-made tropical lakes (Owens Falls in Uganda, High Aswan in Egypt, Kariba between Rhodesia/Zambia, Akosombo in Ghana, Cabora Bassa in Mozambique, and Sobradinho in Brazil) are of this type, in which the decomposition of the vegetation is relatively insignificant (5). In 1964, Lake Brokopondo submerged 1,500 km^2 of intact forest in Suriname. Since this was the first time a large tract of tropical forest had been inundated, the project was scientifically monitored from shortly before closure for the first few years (6).

The expenses incurred already in remedying problems related to flooding the intact forest rapidly exceeded US $4 million, a huge seven percent of the total cost of the project. In retrospect, it would have been advisable to invest substantial funds in preventive measures in order to avoid the much larger expenditures subsequently imposed to mitigate the resulting problems. Most of the adverse consequences -- fish kills, corrosion, hydrogen sulfide production, enormous expanses of waterweed -- would have been mitigated or completely prevented by selective removal of some of the forest before impoundment. We can learn from

this experience that much less than the seven percent invested in prevention beforehand would have saved a great deal of scarce financial resources and would have significantly reduced the economic cost of the project.

Now that several major hydroprojects are either being planned or are under actual construction in tropical forested regions, there is greater awareness of this problem and this topic, therefore, has become economically crucial. Completion of Brazil's largest hydroproject -- Tucurui -- the first of many planned for Amazonia, is scheduled for 1983. The Tucurui reservoir will cover what is now 2,160 km^2 of tropical forest. Suriname's second hydroproject after Brokopondo -- and much larger -- is at Kabalebo, which will flood 1,450 km^2 of wet forest. The Mazaruni project in neighboring Guyana is projected to inundate possibly as much as 2,590 km^2 of wet forest (7).

Most assessments of hydroprojects are based on prediction or projection from admittedly inadequate data tempered by experience with other hydroprojects. The environmental consequences can be predicted with reasonable reliability or, if not, then enough is perceived to call for urgent and detailed study. In the case of forest flooding, even guesses are difficult. Since detrimental consequences are more likely, costly and important than any neutral or beneficial changes, the whole topic warrants thorough and urgent treatment.

Major adverse chemical, physical, biological and human effects of forest flooded by reservoir are outlined (8) as far as possible. The consequences, such as explosions, damage to machinery, curtailment of power generation, loss of water, fish kills and many others, are so serious that preventive measures are essential. These consequences are exacerbated in projects where the reservoir is deep and still, retention time long, and the spillway rarely used. Turbulent or shallow reservoirs with rapid circulation and brief retention, and run-of-river projects will suffer much less from such problems.

Preventive measures devolve largely on the removal of as much biomass from selected regions of the projected reservoirs or even from the reservoir itself, as can be shown to be economically feasible. The necessary cost/benefit analysis attempts to quantify remediation of the predicted problems against the cost of forest clearance. Where it is found expedient to remove certain areas of forest, then a specific clearance plan may be formulated (9). In conclusion, it may cynically be observed that an expensive clearance proceeds with no precedent, based on a plan similarly without precedent, in order to avoid predictions (based on inadequate evidence) of largely unknown consequences. Such is the state of the art today: "To those who believe, no explanation is necessary. To those who do not believe, no explanation is possible!"

1. The lack of a relationship between the consumption of energy and the quality of life for several countries is exemplified by comparing the annual per capita energy consumption with the gross national product per capita. The per capita ratio of energy/GNP is tabulated in figure 1, based on data taken from the UN Statistical yearbook of 1969. Even in countries where energy demand is proportioned to the product of population and real GNP per capita, the relationship with standard of living fails to hold.

2. Much of this material is extracted from Holdren and Herrera (1971) who provide more details on these topics. The points raised in this section are amplified in Clark (1974), Fowler (1975), Gatts et al. (1974), Hammond et al. (1973), Kenward (1976), Meador (1974), Morris (1972) and Thirring (1974).

3. Power generated per area of land is expressed in a kilowatts per hectare ratio in figure 2. The "normal" area of the reservoir used in this calculation is the mean level or midway between normal low and normal high as far as these figures could be obtained from the literature. From the point of view of induced seismicity, the weight of water is critical, so that depth and volume measurements should be used in assessing tectonic modifications. From a fish production point of view, large surface area is more influential than depth or volume since most fish avoid water below twenty meters.

4. Terms of reference for environmental assessment, environmental impact reconnaissance or impact statements from the World Bank (1974), Western Suriname (1977), and elsewhere. Environmental effects of tropical reservoirs and hydro-projects are treated in detail in eight books: Ackermann et al.(1973), Lagler (1969), Beadle (1974), Lowe-McConnell (1966), Obeng (1969), Rubin and Warren (1968), Stanley and Alpers (1975), SCOPE (1972),brought up-to-date by the recent review of Baxter (1977). Environmental assessments of individual hydroprojects are few and difficult to obtain but most instructive, since all projects present interesting --

and often critical -- differences. Assessments of individual hydroprojects are contained in the bibliographies of the above references supplemented with Freeman (1974), Jackson and Davies (1976), Hall et al. (1976), Goodland (1971-1978), Challinor (1973) and Visser (1970). Useful related information can be found in Dasmann et al. (1973), Dee (1972), EPA (1972), IUCN (1975), McJunkin (1975), and Mitchell and Mitchell (1972).

5. Some environmental data on tropical reservoirs worldwide has been tabulated to form figure 4. The data are taken from Ackermann (1973), Beadle (1974), Rubin and Warren (1968), and from Paiva (1976b).

6. The most recent publication on Brokopondo in the most useful work of Paiva (1977). Leentvaar (1966, 1973, 1975) reviews the large amount of literature on Brokopondo.

7. The 3000 MW Tucurui hydroproject, the largest in Brazil and the first (probably of many) in Amazonia is scheduled for completion in 1983. The first two sources of information available so far are Elétronorte (1976) and Goodland (1978). The Kabalebo scheme is outlined in Kabalebo (1975), and the environmental aspects in Western Suriname (1977). The Mazaruni project in Guyana is described in Steward (1976), Goodland (1976b), Energoprojekt (1974), Harza (1974), and SWECO (1976).

8. Although the major adverse effects of flooding forest can be listed (figure 5) they are not yet understood nor amenable to ranking, let alone quantification. Each reservoir will support different proportions of aerobic and anaerobic decomposition of the forest depending on the project (figure 6). What little is known concerning this topic can be found in Addo-Ashong (1969), Ball et al.(1975), Branco (1971), EPA (1973), Fast (1972), Hall and Smith (1955), Goodland (1975), Jenkins (1976), and Paiva and Salles (1977).

9. All reservoir clearance plans must be tailored to the individual project. Clearance criteria and requisites are outlined in figures 7 and 8 together with notes on what sorts of areas should be cleared for specific purposes (figure 9).

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Figure 1. ENERGY CONSUMPTION AND THE QUALITY OF LIFE

Country	Annual Energy Consumption Per Capita (MW hours per capita)	Gross National Product per Capita (Thousand US dollars)	Ratio of MW hrs/cap. to GNP/cap.
Switzerland	24	2.8	8.7
New Zealand	22	2.0	10.7
Japan	20	1.4	14.3
Norway	34	2.4	14.4
USA	83	4.4	18.9
Canada	68	3.0	22.6
USSR	33	0.9	35.0

(after: UN Statistical Yearbook, 1969)

Figure 2. HYDROPOWER GENERATED PER AREA INUNDATED
(Note: Additional relevant data are included in Figure 4.)
(These data are approximate only.)

Project	Country	Rated Capacity (Kilowatts)	Normal Area of Reservoir (Hectares)	Kilowatts per Hectare Ratio
Paulo Afonso	Brazil	1,299,000	7,520	173
Sayanskaya	USSR	6,400,000	80,000	80
Churchill Falls	Canada	5,225,000	66,500	79
Itaipu	Brazil/ Paraguay	10,500,000	135,000	77
Grand Coulee	USA	2,025,000	32,400	63
Jupiá	Brazil	1,400,000	33,300	42
São Simão	Brazil	2,680,000	66,000	41
Tucurui	Brazil			
	Ultimate	6,480,000	216,000	30
	Initial	2,115,000	216,000	10
Ilha Solteira	Brazil	3,200,000	120,000	27
Mazaruni	Guyana			
	Projected Ultimate	1,000,000	39,000	26
	Projected Initial	3,000,000	259,000	12
Guri	Venezuela	6,000,000	328,000	18
Paredão	Brazil	40,000	2,300	17
Cabora Bassa	Mozambique	4,000,000	380,000	14
Furnas	Brazil	1,200,000	135,000	9
Samuel	Brazil	110,000	15,000	7
Kabalebo	Suriname (ultimate)	800,000	145,000	6
Aswan High	Egypt	2,100,000	400,000	5

Figure 2. (Cont.)

Curuá-una	Brazil	40,000	8,600	5
Três Marias	Brazil	400,000	105,200	4
Kariba	Rhodesia/ Zambia	1,500,000	510,000	3
Sobradinho	Brazil	900,000	450,000	2
Balbina	Brazil	250,000	124,000	2
Volta	Ghana	833,00	848,200	1
Brokopondo	Suriname	30,000	150,000	0.2

Figure 3. TERMS OF REFERENCE FOR ECOLOGICAL RECONNAISSANCE OF HYDROELECTRIC SCHEMES (after: World Bank, IBRD, 1972)

The objective of an ecological reconnaissance to be carried out in connection with a proposed hydro-electric power scheme is to determine in a general way the possible impact of the project on the environment, public health, and social welfare of the peoples affected by the scheme. The study should include as a minimum, but not necessarily be limited to:

(1) The scenic and aesthetic qualities of the area likely to be affected by the project's presence or operation. Present and future tourism values that may be created or injured should be considered.

(2) The nature and extent of the biotic community existing within the project area likely to be affected by the construction, presence or operation of the project, paying especial attention to the impact of the project on those life forms that are classed as economically or aesthetically desirable, ecologically unique, or among the endangered species. The impact of the project on fish and wildlife resources, their presence, abundance, reproduction and distribution should be considered.

(3) The effects of the project on agricultural and forestry potential of riparian lands; the bio-physical alterations or changes (permanent or episodically transient) to be expected in the impoundment area and downstream; the potential for the influx of aquatic vegetation and its effects on the uses of the impoundment and the purposes of the project; the effects of the project's presence or operations on nuisance organisms and disease-bearing vectors and on the pattern and distribution of diseases.

(4) The possible impact on the people occasioned by the project, including requirements for resettlement. If resettlement is necessary, the adequacy and sufficiency of the relocation plans should be assessed with regard to the culture, ethnic origins, life styles, living patterns, social customs and related socio-cultural factors of the affected populace.

(5) The impact of people on the project should be evaluated, including the potential for squatter settlements, unplanned land-use activities in the catchment area especially with regard to erosion and pollution, and new economic activities that might affect the project.

(6) Plans for the protection and management of the catchment area should be examined or initiated with a view to preventing utilization of the watershed area in ways detrimental to the project's intended use and longevity.

(7) The presence of any artifacts or sites of archaeologic or historic significance, and the adequacy of the plans for protecting or salvaging them.

(8) The possible effect of the project on the multiple-use capabilities of the area particularly with regard to fore-closing any future resource-use options by virtue of the project's presence or operation. Conversely, the multiple-use possibilities afforded by the project should be examined, such as establishing a commercial or sport fisheries, tourist facilities and recreation, etc.

(9) If this project is one of several planned or in being on the river system, a general assessment of the combined impact is important.

Upon completion of the reconnaissance a full report of findings should be prepared to include detailed information on the foreseeable environmental and human ecologic consequences of the project; the nature, scope, and timing of any additional studies required; the nature, dimensions, and timing of any serious problems should be highlighted, along with recommendations as to how they can be prevented or mitigated. Likewise, opportunities for environmental or human ecologic enhancement should be stressed with recommendations for achieving their implementation.

Figure 4. TROPICAL HYDRO RESERVOIRS: ENVIRONMENTAL DATA

(After Paiva, 1976b; Ackermann et al., 1973; Beadle, 1974; Rubin and Warren, 1968; P = Planned; UC = Under Construction)

Country	Name of Dam	Name of Reservoir	River	Year of Closure	Mean Surface Area (km^2) approx.	Maximum Drawdown (m)	Vegetation
Ghana	Akosombo	Volta Lake	Volta	1964	8,482	3	Savanna
S.Rhodesia/Zambia	Kariba	Lake Kariba	Zambezi	1958	4,300	3	Bush
Nigeria	Kainji	Kainji	Niger	1968	768	10	Savanna
United Arab Rep.	Sadd-el-Aali	Nasser-Nubia	Nile	1964(7?)	6,000 (max.)	-	Desert
Egypt	Aswan High	Lake Nasser	Nile	1969	3,074 ('70)	?	Desert
Moçambique	Cabora Bassa	Cabora Bassa	Zambezi	1974	2,700	?	?Woodland
Suriname	Afobaka	Lake Brokopondo	Suriname	1964	1,500	3	Wet Forest
Brazil	Tucurui	Tucurui	Tocantins	1981	2,160	14	Wet Forest
Brazil	Coaracy Nunes	Paredão	Araguari	1975	23	5	Savanna
Brazil	Curua Unã	Curua Unã	Curuá-Una	1977	86	?	Wet Forest
Brazil	Balbina	Balbina	Uatumã	P	1,240	?	Wet Forest
Brazil	Samuel	Samuel	Jamarí	P	150	?	Wet Forest
Brazil	Ilha Solteira	Ilha Solteira	Paraná	1973	1,231	?	Savanna
Brazil	Furnas	Furnas	Grande	1963	1,400	?	Savanna
Brazil	Jupiá	Jupiá	Paraná	1968	352	?	Savanna
Brazil	Sobradinho	Sobradinho	São Francisco	1978?	4,500	12	Semi-desert
Brazil	São Simão	São Simão	Paranaiba	1978	660	minor	Savanna
Brazil	Itumbiara	Itumbiara	Paranaiba	1980?	765	?	Savanna
Brazil	Três Marias	Tres Marias	São Francisco	1961	1052	12	Savanna
Brazil	Boa Esperança	Paraibuna	Paraitinga	1969	430	?	Savanna

Figure 5. MAJOR ADVERSE EFFECTS OF FOREST FLOODED BY RESERVOIRS

CHEMICAL EFFECTS

Aerobic Decomposition

Anaerobic Decomposition

Oxygen Reduction

Production of Methane

Production of Hydrogen Sulfide

Production of Hydrogen

Chemical Precipitation

Eutrophication

Increased Acidity

Increased Corrosion

PHYSICAL EFFECTS

Reduction of Reservoir Volume

Reduction of Vertical Circulation

Temperature Polarization

Decreased Erosion

Mechanical Interference with Dam

Mechanical Interference with Multiple Use

BIOLOGICAL AND HUMAN EFFECTS

Loss of Environmental 'Services'

Loss of Timber Resource

Loss of Wildlife Habitat

Proliferation of Waterweeds

Curtailed Multiple Use

Impediment to Access

Increased Disease Vectors

Impaired Water Quality

Figure 6. DECOMPOSTION OF FLOODED FOREST

Characteristics of the Water	Environmental Conditions in the Reservoir Aerobic Decomposition	Anaerobic Decomposition
Depth	Shallow	Deep
Circulation (Retention time)	Turbulent (rapid)	Stagnant
Light	Intense to shaded	Dark to aphotic
Temperature	Warmer	Colder
Oxygen	Rapidly depleted unless replenished by aerated water	Anoxic: oxygen removed and not replaced
Acidity	Increases slightly	Increases significantly; corrosion exacerbated; blockages e.g. by precipitation of insoluble sulfides. H_2S+Fe or Mn $\longrightarrow$ FeS or MnS
Inorganic Nutrients	Rapidly released from soft organic matter or cellulose	Less concentrated; not released; only added by falling detritus
Rate of Decomposition	Fast	Slow
Eutrophication	Could accelerate eutrophication	Eutrophication could slightly increase anaerobic production
Duration	Brief; few years only, then ceases	Forever in organic sediments; Protracted in lignin
Gas Production	Carbon dioxide, much (increased acidity) $(CH_2O)_x$+O_2 Aerobic bacteria $\rightarrow$ CO_2+H_2O Cellulose 1 g. C depletes 3g.O_2 from the water	Carbon dioxide (increases acidity) (Any organic acid) CH_3COOH Methanobacterium, Methanobaccillus Methanococcus, Methanosarcinus $\rightarrow$ CH_4+CO_2 Methane (inflammable) Proteins (S) Desulfovibrio $\rightarrow$ Hydrogen sulfide H_2S (malodorous, poisonous) $(CH_2O)_x$ Clostridium, Achromobacter Bacillus, Bacterium $\rightarrow$ H_2+CO_2 Hydrogen (explosive) or CH_3COOH

Figure 7: RESERVOIR CLEARANCE CRITERIA

Clearing Versus Not Clearing

Example of Increased

Costs of Not Clearing	versus	Benefits of Clearing
Waterweed control		Improved transport
Disease vector control		Improved fishing
Nuisance insect control		Improved recreation
Increased undesirable decomposition		Benefits from use of draw-down zone
Reduced water quality downstream		Improved water quality
Increased log removal		
Increased mechanical protection for turbines		

RESERVOIR ZONATION CRITERIA

The entire area of the future reservoir should be zoned based on the following criteria. This zonation will be integrated with the reservoir protection and watershed management plans:

*Contemplated use for each area, such as fishing.

*The timing of whatever treatment is found necessary in order to avoid regrowth where it would be undesirable, but to complete priority timber removal before flooding begins.

*The configuration of the site: slope, embankments, etc., with respect to control of erosion.

*The location of each area with respect to use of the reservoir margin -- near settlements for example.

*Reservoir bathymetry: tree height superimposed on detailed contour map showing extent, frequency and duration of drawdown.

Figure 8: PRE-REQUISITES FOR THE SPECIFIC CLEARANCE PLAN

1. Forest Inventory

   Major categories of forest, their areas and locations
   Species composition of major categories
   Density of abundant species: proportion lighter and heavier than water
   Areas to be permanently submerged
   Areas to be seasonally exposed
   Areas to be occasionally, but shallowly flooded
   Flood-tolerant species to be protected and expanded
   Biomass per hectare in relation to duration of submersion
   Canopy height, trunk length, tree density
   Permanency of stumps: rooting characteristics

2. Timber Quality and Marketability

   Species improving with submersion
   Valuable species deteriorating with submersion
   Floating species worth felling and leaving
   Sinking species worth subsequent salvage
   Exploitation of seasonally exposed timber

3. Market and Use of the Forest

   Selective harvest of top-quality species
   Harvest of valuable species in the more accessible sites
   Establishment of an export charcoal industry
   Treatment of selected species for collection from lake
   Establishment of small mobile or floating sawmills
   Extraction of sunken species
   Collection of floating species
   Exploitation of water-cured intact trees
   Preparation of rafts of valuable sinkers tied to floaters
   Color-coding commercial species in seasonally accessible zones

4. Reservoir Bathymetry or Morphometry

   Detailed topographic map (ca. 5 m contour interval) at least around critical sites
   Tree height and density superimposed
   Depth, frequency, and duration of drawdown superimposed

Figure 9. AREAS TO BE CLEARED FOR SPECIFIC PURPOSES

1. DAM STRUCTURE CLEARANCE - Area just above dam and above any shallow lateral dams to be cleared to avoid mechanical interference, potential gas problems, and offensive smells.

2. CLEARANCE FOR SETTLEMENTS - If any settlements are to be located on or near the reservoir margin; treatment for access to lake, avoidance of insect nuisance, disease vectors and smells, treatment to permit exploitation of drawdown stip.

3. DISEASE VECTOR AND WATERWEED - Health workers will identify sites where disease vectors and waterweeds may proliferate. These should be zoned for special treatment both before and after filling, as necessary.

4. ACCESS LANES - Access from settlements to the lake, especially during seasonal drawdown. Possible need for provision of cleared and slightly elevated paths for boat and cargo haulage, and for agricultural access.

5. NAVIGATION LANES AND THEIR DEMARCATION - Local communications, as well as fluvial transport requirements and ferry crossings should be planned.

6. FISHING LANES - Fisheries personnel should design the orientation, width, number, location, and depth of lanes necessary for the various phases of the fish breeding cycle. Access to the lanes and to the fish development station. Relation of settlements and salting, smoking, pickling, and drying sites to transport and markets.

7. FISH AND ANIMAL PRODUCTION SITES - Shallow embayments offering improved opportunity for the production of certain species of fish and other animals (e.g.: manatee, crocodilians capivara, turtles, waterfowl, domestic ducks and geese). The entrance or mouth of certain of these "finger lakes" should be sealed by a short earth berm or isolated with a protective net to optimize such production. Specialist groups all should be given a choice of these special areas. Agricultural officers may cooperate on a wet rice - fish - duck ecosystem, or waterweed - fertilizer production.

8. AGRICULTURAL EXPLOITATION OF DRAWDOWN STRIP - "Recession Agriculture" depending on compromise between operating schedule of the dam and time to harvest the crop. Irrigation potential; earth berms to retain water for use during the early part of the dry season.

9. SILT-DEPOSITION AREA - Where fertile silt will be deposited in the aggradation zone of the shallow tail of the reservoir, agricultural possibilities should be explored. Pre-treatment of sporadically flooded zones, especially for rice cultivation.

10. ISLANDS AND PROMONTORIES - The agricultural, forestry, and other special potentials of islands and promontories should be explored.

11. PROTECTIVE FOREST MARGIN - Areas of steep slopes or those susceptible to bank slump or erosion by current should be incorporated in the reservoir margin protective strip.

LITERATURE CITED

Ackermann, W. C. et al., 1973.
Man-Made lakes: their problems and environmental effects.
Washington, D.C., American Geophysical Union. 847 p.

Addo-Ashong, F. W., 1969.
The effect of flooding on the decomposition of wood (292-297) in Obeng, L.E. (ed.). Man-Made Lakes.
Accra, University Ghana Press. 398 p.

Ball, J., et al., 1975
Effects of original vegetation on reservoir water quality.
Texas A & M University, Texas Water Resources Inst. (Tech. report no. 64).

Baxter, R. M., 1977.
Environmental effects of dams and impoundments.
Annual Review Ecology Syst., 8:255-283.

Beadle, L. C., 1974.
The Inland Waters of Tropical Africa.
London, Longmans. 365 pp.

Branco, S. M., 1971.
Limpeza prévia de reservatórios de acumulação: Estudo conceitual.
São Paulo, Revista D. A. E.: 38-47.

Challinor, D. (ed.), 1973.
Some environmental considerations for the Mekong Basin project.
Washington, D. C., Smithsonian Inst., 192 p.

Clark, W., 1974.
Energy for Survival.
New York, Garden City, Anchor Books, 652 p.

Dasmann, R. F., Milton, J. P., Freeman, R. H., 1973.
Ecological principles for economic development.
New York, Wiley. 252 p.

Dee, N., et al., 1972.
Environmental evaluation for water resource planning.
Batelle Columbus Lab for USDI Bureau of Reclamation. NTIS: 189 p.

Elétronorte, 1976.
Usina Hidreletrica de Tucurui: Projeto Basico, Relatorio Condensado.
Brasília, Centrais Elétricas do Norte do Brasil S. A. (January): 114+ p.

Energoprojekt, 1974.
Feasibility study of Upper Mazaruni Hydroelectric project.
Yugoslavia, 3 vols.

EPA, Environmental Protection Agency, 1972.
Environmental Assessments for Effective Water Quality Management Planning.
Ohio, Battelle Columbus Laboratories, 24 p.

EPA, Environmental Protection Agency, 1973.
Measures for the Restoration and Enhancement of Quality of Freshwater Lakes.
Washington, D. C.,E. P. A.: 238 p.

Fast, A. W., 1972.
The effects ofartificial aeration on lake ecology.
Environmental Protection Agency, Project No. 16010.

Fowler, J. M., 1975.
Energy and the Environment.
New York, McGraw-Hill, 496 p.

Freeman, P. H., 1974.
The Environmental Impact of a large tropical reservoir (Lake Volta, Ghana).
Washington, D. C., Smithsonian Institute, 86 p.

Gatts, R.R., Massey, R.G. and Robertson, J.C., 1974.
Energy Conservation Program Guide for Industry and Commerce.
Washington, D.C., National Bureau of Standards, 212 p.

Goodland, R., 1971.
Ecological Reconnaissance of the São Simão Hydroelectric Project, Rio Paranaíba, Brazil.
Washington, D.C., World Bank, 53 p.

Goodland, R., 1972a.
Itaipu (Rio Paraná) Hydroelectric Project. Environmental Assessment. Comisión Mixta Técnica.
Rio, Eletrobras,and Asunción, ANDE, 95 p.

Goodland, R., 1972b.
Itumbiara Hydroelectric Project, Brazil: Environmental Impact Reconnaissance.
Rio de Janeiro, Furnas Centrais Elétricas, S.A., 90 p.

Goodland, R., 1973a.
Sobradinho Hydroelectric Project, Rio São Francisco, Brazil: Environmental Impact Reconnaissance (English or Portuguese).
Rio de Janeiro, Companhia Hidrelétrica do São Francisco, CHESF: 105 p.

Goodland, R., 1973b.
Cerron Grande Hydroelectric Project,Rio Lempa, El Salvador: Environmental Impact Reconnaissance.
Washington, World Bank, 96 p.

Goodland, R. (ed.), 1973c.
Power Lines and the Environment.
New York, Millbrook, Cary Arboretum, 170 p.

Goodland, R., 1974.
Salto Santiago Hydroelectric Project, Iguaçu River, Brazil: Environmental Impact Reconnaissance. (English or Portuguese).
Curitiba, Elétrosul, 124 p.

Goodland, R. and Tillman, R., 1975.
Guatemala, 25-year National Energy Master Plan: environmental assessment.
Guatemala, INDE: Instituto Nacional de Electricidade, 121 p.

Goodland, R., 1975.
Foz do Areia Hydroelectric Project, Rio Iguaçu, Brazil: Environmental Impact Reconnaissance. (English or Portuguese).
Curitiba, Comp. Paranaense de Energia Elétrica, COPEL: 84 p.

Goodland, R., 1976a.
The environmental case for retaining most of the vegetation in the future São Simão hydro-reservoir and guidelines for selective clearing.
Brazil, Belo Horizonte: CEMIG, Centrais Elétricas de Minas Gerais, S.A.: 59 p.

Goodland, R., 1976b.
Environmental aspects of the Upper Mazaruni hydroproject, Guyana. A proposal towards environmental development.
Paris, UNESCO, Div. Ecolog. Sci., No. SC/ECO/Misc./FF-1:55 p.

Goodland, R., 1976c.
Rio Cauca regulation project: preliminary environmental assessment.
Colombia, Cali. Corporación Valle del Cauca, CVC (and UN-PAHO): 65 p.

Goodland, R. (ed.), 1976d.
Buildings and the Environment.
New York, Millbrook, Cary Arboretum, 263 p.

Goodland, R. et al., 1977.
Salto Grande Hydroproject, Uruguay-Argentina: Suggestions towards strengthening the environmental development program.
Buenos Aires, Oficina Pan Americana de la Salud, 20 p.

Goodland, R., 1978.
Environmental Assessment of the Tucurui Hydroelectric Project, Rio Tocantins, Amazonia.
Brasília, Elétronorte, LC No. 77-93947: 250 p. (in press).

Hall, A.; Davies, B.R. and Valente, I., 1976.
Cabora Bassa: some preliminary physiochemical and zooplankton preimpoundment results.
Hydrobiologica. 50: 17-25.

Hall, T.F. and Smith, G.F., 1955.
Effects of flooding on woody plants.
Journ. Forestry, 53:281-285.

Hammond, A.L., Metz, W.D. and Maugh, T.H., 1973.
Energy and the future.
Washington, D.C., American Association Advanc. Sci., 184 p.

Harza, 1975.
Environmental appraisal of the Upper Mazaruni hydroelectric project.
Chicago, Harza Engineering Co., v.p. 5 chapters.

Holdren, J. and Herrera, P., 1971.
Energy: A crisis in power.
San Francisco, Sierra Club, 252 p.

IUCN, 1975.
The use of ecological guidelines for development in the American humid tropics (Proc. Internat. Meeting Caracas, Feb. 1974).
Morges, Switzerland, Internat. Union Conserv. Nature & Nat. Resources, IUCN, No. 31:349 p.

Jackson, P.B.N. and Davies, B.R., 1976.
Cabora Bassa in its first year: some ecological comparisons.
Rhod. Sci. News 10:128-133.

Jenkins, D.W., 1976.
Alternatives to the problem of flooding forests in tropical reservoirs.
Georgetown, Guyana. National Science Research Council, Seminar on Hydropower and the Environment, 12 pp.

Kabalebo, 1975.
Feasibility study of hydroelectric development in Western Suriname, Vol. 1.The Kabalebo Hydroelectric scheme Part I, Main Report.
Oslo, Norconsult and Zurich, Electro-Watt, v.p., 13 chs.

Kenward, M., 1976.
Potential Energy: an Analysis of World Energy Technology.
Cambridge, Cambridge University Press., 227 p.

Lagler, C., 1969.
Man-Made Lakes.
Rome, F.A.O., 71 p.

Leentvaar, P., 1966.
The Brokopondo research project, Suriname (33-42) in Lowe-McConnell, R.H. (ed.) Man-Made Lakes.
London, Academic, 218 p.

Leentvaar, P., 1973a.
Lake Brokopondo (186-196) in Ackermann, W.C., et al. (eds.), Man-Made Lakes: their problems and environmental effects.
Washington, D.C., American Geophysical Union, 847 p.

Leentvaar, P., 1975.
The Brokopondo Research Project (179-191) in Stanley, N.F. and Alpers, M.P. (eds.) Man-made Lakes and Human Health.
London, Academic Press, 495 p.

Lowe-McConnell, R.H. (ed.), 1966.
Man-made Lakes.
New York, Academic, 218 p.

McJunkin, F.E., 1975.
Water, Engineers, Development and Disease in the Tropics.
Washington, D.C., U:S. Agency for International Development AID/csd-1888:182 pp.

Meador, R., 1974.
Future Energies.
Ann Arbor, Michigan, Ann Arbor Science, 66 p.

Mitchell, B. and Mitchell J., 1972.
The watershed as a resource management unit.
Council of Planning Librarians, Exch. Bibli., No. 284:26 p.

Morris, D.M., 1972.
Future energy demand and its effect on the environment.
Santa Monica, California, Rand Corp., 46 p.

Obeng, L. E. (ed.), 1969.
Man-made Lakes.
Accra, Ghana University Press, 398 p.

Paiva, M.P., 1976.
Estimativa do potencial da produção de pescado em grandes represas Brasileiras.
Rio de Janeiro, Eletrobras (stencil):23+ p.

Paiva, M.P., 1977.
Algumas considerações sobre a represa de Brokopondo, Suriname.
Rio de Janeiro, Eletrobras, 61 pp.

Paiva, M.P. and Salles, P.V., 1977 (n.d.).
Desmatamento de represas hidrelétricas no Brasil.
Rio de Janeiro, Eletrobras, 28 pp.

Rubin N. and Warren, W.N., (eds.), 1968.
Dams in Africa: an interdisciplinary study of man-made lakes in Africa.
London, Cass, 188 p.

SCOPE, 1972.
Man-made lakes as modified ecosystems.
Paris, Inernat Council of Scientific Unions, 76 p.

Stanley, N.F. and Alpers, M.P. (eds.), 1975.
Man-Made Lakes and human health.
London, Academic, 495 p.

Stewart, R.K., 1976.
Ecological reconnaissance: Guyana hydroelectric power survey.
Montreal, Montreal Engineering Co., Vol. 6, (appendix 12):1-57.

SWECO, 1976.
Republic of Guyana, Upper MazaruniDevelopment Authority. Final Engineering Report.
Stockholm, Swedish Consulting Group, 3 vols.

Thirring, H., 1974.
Energy for Man.
Westport, CT., Greenwood Press, 409 p.

Visser, S.A. (ed.), 1970.
Kainji,A Nigerian Man-Made Lake
Ibadan, Ibadan University Press, 126 p.

Western Suriname Environmental Work Group, 1977.
Terms of Reference of Proposed Environmental Studies and Suggested Health Care Measures (related to the Kabalebo hydroproject including diversions of the Lucie and Corantijn Rivers and dams near Devis Falls and Kabalebo).
Paramaribo, Min. Devel., W. Suriname Envt. Work Group. (v.p.) 10 chapters.

World Bank, 1974.
Environment, health and human ecologic considerations in economic development projects.
Washington, World Bank, IBRD:172 p.