HYDROELECTRIC PROJECTS

1. Hydroelectric projects include dams, reservoirs, canals, penstocks, powerhouses, and switchyards for the generation of electricity. The dam and reservoir may be multi-purpose; if watershed rainfall and stream flow characteristics and water and power usage patterns permit; hydroelectric reservoirs can also provide one or more of the following services: irrigation, flood control, water supply, recreation, fisheries, navigation, sediment control, ice jam control, and glacial lake outburst control. However, these are competing uses for the waters stored behind dams and each may imply a different diurnal or annual operating rule curve for the reservoir.

2. In a hydroelectric project, for example, the operator will maximize power benefits by varying reservoir level in accordance with a rule curve that is close to the reservoir trajectory in a very dry year. For flood control, an operator will draw down the reservoir to have maximum volume for flood retention available at the beginning of the rainy season. Irrigation reservoirs will be filled and releases made according to the growing seasons of the crops being irrigated. In project planning and development of the rule curve, any conflicts between competing uses should be resolved.

3. The hydroelectric projects require the construction of lines of transmission which distribute the electricity to the users. This aspect of the project is handled by the operational guidlines of the BOAD "Electricity networks"

Potential Environmental Impacts

4. The principal source of impacts in a hydroelectric project is the construction and operation of a dam and reservoir (see the section on "Dams and Reservoirs"). Large dam projects cause irreversible environmental changes over a wide geographic area and thus have the potential for significant impacts. Criticism of such projects has grown in the last decade. Severe critics claim that the social, environmental, and economic costs of dams outweigh their benefits and that the construction of large dams, therefore, is unjustifiable. Others sustain that in some cases environmental and social costs can be avoided or reduced to an acceptable level by carefully assessing potential problems and implementing cost effective corrective measures.

5. The area of influence of a dam and its reservoir extends from the upper limits of the reservoir to as far downstream as the estuarine, coastal and offshore zones, and includes the reservoir, dam and river valley below the dam. While there are direct environmental impacts associated with the construction of the dam (e.g., dust, erosion, borrow and disposal problems), the greatest impacts result from the impoundment of water, flooding of land to form the reservoir, and alteration of water flow downstream. These effects have direct impacts on soils, vegetation, wildlife and wild lands, fisheries, climate and human populations in the area. (See Table 10.8 at the end of this section for other examples and recommended mitigation measures)

6. The dam's indirect effects include those associated with the building, maintenance and functioning of the dam (e.g., access roads, construction camps, power transmission lines) and the development of agricultural, industrial or municipal activities made possible by the dam

7. In addition to the direct and indirect effects of dam construction on the environment, the effects of the environment on the dam must also be considered. The major environmental factors affecting the functioning and lifespan of the dam are those caused by land, water, and other resources available in the catchment areas above the reservoir (e.g., agriculture, settlement, forest clearing) which may result in increased siltation and changes in water quantity and quality in the reservoir and river downstream. These are usually thoroughly addressed in the engineering studies.

8. The electricity that makes possible a hydroelectric project is an undeniable advantage that allows developing the economy and improving the quality of life of the populations served. Hydroelectric projects are intensive labor and provide, therefore, employment opportunities. Roads and other types of infrastructure can provide the local people easier access to markets where will be sold their crops, schools, health centers and other social services. Furthermore, hydropower is a source of alternative energy for fossil fuels or nuclear energy, which corresponds to the energy demand while avoiding produce heated water, air emissions, ash or radioactive waste. If the tank is truly versatile, if the various functions contained in the economic analysis are really compatible, it will include other benefits such as flood control and a more reliable water supply, which will benefit users and agricultural and industrial operators. The intensification of agriculture at the local level due to irrigation helps mitigate the pressure on intact forests on

the remaining pristine habitats or land unsuitable for agriculture. In addition, dams allow the establishment of fisheries in reservoirs and provide opportunities for agricultural activities on the part of the subject to changes in the reservoir shore, which in some cases may more compensate for losses in these sectors due to the construction of the dam.

Special Issues

Hydrologic and limnological effects

9. Damming the river and creating a lake-like environment has profound effects on the hydrology and limnology of the river system. Dramatic changes occur in the timing of flow: quality, quantity and use of water, aquatic biota, and sedimentation dynamics in the river basin. Hydroelectric projects, in particular, are liable to create major changes in the river flow patterns downstream because storage and releases are managed in response to power demand cycles rather than the hydrologic cycles to which the downstream riparian environment is adapted.

10. The decomposition of organic matter on the flooded lands creates a nutrient-rich environment. Fertilizers used upstream may add to the nutrients which accumulate and recycle in the reservoir. This process, not only supports an active reservoir fishery but stimulates also the growth of aquatic weeds, such as water lettuce and water hyacinth. Weeds and algal mats can be expensive nuisances which clog dam outflows and irrigation canals, negatively affect fisheries and recreation, increase water treatment costs, impair navigation, and substantially increase water loss through transpiration.

11. If the flooded grounds are much wooded and were not sufficiently cleared as a preliminary, the process of decomposition will exhaust the quantity of oxygen in the water which, in its turn, will influence the aquatic life, being able to result in the death of many fishes. The substances produced by the anaerobic decomposition understand hydrogen sulphides, which corrode the generating turbines and are harmful for the watery organizations, as well as methane, an explosive gas and for greenhouse effect.

12. Oxygen depletion typically occurs first in the deeper water where oxygen used by bacteria in decomposition is not offset by oxygen released by plant photosynthesis. When the intake for power generation is located at the lower level of the reservoirs, as is usually the case, water released from the turbines into downstream waters may be deficient in oxygen and may contain hydrogen sulfide. It may also be lower in pH and colder than the surface water. Releases of water with these characteristics can adversely affect plant and animal communities in the river below the dam.

13. Suspended particles carried by the river are deposited in the basin and, thus, limit the storage capacity and life while depriving downstream waters of these sediments. Many agricultural areas of floodplains have been based on the periodic supply of nutrient-rich silt for sustainable productivity. The lack of sediment supply means that we should use the fertilizer to maintain agricultural productivity. Spills almost devoid of sediment scour the riverbed may (can be both beneficial and harmful, depending on the circumstances)

14. The alteration of groundwater levels upstream and downstream of the reservoir as well as the intrusion of salt water in estuaries, including impacts on the natural environment are direct, affecting downstream users are among the other effects of hydrological changes in the river basin.

Social Issues

15. While, in many cases, remote communities and industries hydroelectric dam benefit the residents of the flooded area, which generally support the heaviest caused by the dam social and environmental costs, will not necessarily receive a fair share of revenue. The tank may involve the movement of people living on the land (in some projects, these populations reach hundreds of thousands or over a million people) and have a huge impact on these populations and those living in resettlement areas. It often happens that access to water, land and biotic resources is restricted for people who remained. Changes to the flow of streams and reducing silt deposits disrupt the riparian artisanal and traditional recession agriculture. Floodplains in tropical regions occupy large areas that benefit humans and animals. When they are shrinking and land use must undergo changes, these people are forced to move. In addition, water-borne diseases (malaria, schistosomiasis, onchocerciasis and encephalitis), if they are endemic in the region, they are likely to increase the frequency with the creation of a reservoir and management structures water associated there with.

16. The influx, controlled or uncontrolled, population groups in the region, consisting of workers employed in the construction works, the staff of the power plant, attracted by seasonal workers activities that stimulates the dam and population rural which, thanks to roads, transmission lines or improvement of navigation, now have access to the region, give rise to social and environmental problems (see guidelines "Development-induced" and "stand new land "). They result in health problems, overloading of

public services, and competition for resources, social conflict and a negative impact on the environment of the watershed, the reservoir and the river basin downstream.

Fisheries and wildlife

17. As already mentioned, due to flow alteration, deterioration of water quality, and the regression of spawning and physical barriers to fish migration, we can expect that fisheries resources are dwindling rivers. By cons, a fishery based on the tank is sometimes richer than previously fishery resources in the river.

18. In rivers with estuaries are biologically rich, fish and estuarine and marine crustaceans suffer changes in flow and water quality. The changes made to the flow of the water affect the salinity of the estuary, which in turn affect the distribution of species and the reproductive cycle of fish. The decrease in the amount of nutrients and degradation of river water quality can also have a profound impact on the productivity of the estuary. These changes can have major effects on marine species that feed or live there temporarily, or are sensitive to changes in the quality of coastal waters.

19. Habitat loss is the most serious as filling a tank impact and change in land use in the watershed have on wildlife. In addition, it is possible that the tank and related facilities disturb migratory patterns. Poaching as well as the destruction of harmful estimated for agriculture species have more selective effects. For cons, the creation of a reservoir can be conducive to the expansion of aquatic fauna which includes the birds, reptiles and amphibians

Induced seismicity

20. Although a link between the creation of reservoirs and seismic activity has been repeatedly established, it remains difficult to calculate the probability caused by a tank in an aseismic area seismic movements. In seismic areas, the creation of a reservoir may accelerate the advent of an earthquake and eventually give rise to more frequent but less destructive incidents. The assessment of environmental impacts should examine these two phenomena.

Watershed management

21. It is not uncommon for areas upstream of the dam have to face increased pressure due to the planned population from flooded areas or spontaneous influx of newcomers in the watershed resettlement. The environmental degradation of these areas and water quality , as well as increased sedimentation in the reservoir, from the clearing of forests for agriculture , increased use of land for grazing , the use of agricultural chemicals and the cutting of trees for the production of timber or firewood. Changes in land use affect the downstream dam, in the same way, the quality and quantity of water supplied to the stream. For all these reasons , it is essential that the design and project management of dams in the context of watershed management or national or sub-regional development plans, covering lands both upstream that downstream of structure.

Alternatives to projects

22. There are a number of alternatives to hydropower projects may, separately or in combination, influence the size, location and conduct of the proposed project.
    a) Change in energy demand through conservation measures and improved efficiency or restrictions on regional growth.
    b) Use of thermal power or alternative energy sources, including cogeneration, by industry, from small hydro and biogas.
    c) Examine the possibilities of locating the dam on a river dammed already diversifying the functions of an existing dam.
    d) Locate the dam in a place where negative and social impacts will be as minimal as possible.
    e) Adjust the height of the dam, the extent of the flooded areas and modify the design of the dam to mitigate the negative impacts on the environment.

Management and Training

23. Management of a hydroelectric project which sole purpose is to generate electricity is generally for a public or private electrical service. Impoundments multiple-use may be administered or monitored by government agencies with broader authority.

24. The agency responsible for the operation of the dam and the impoundment should be responsible for the collection of data, the construction and management of the dam, the overall strategy of the water allocation accompanied by management plans required for the regulation of restraint and the fight against vectors of disease transmission. The practice became common and often is recommended that the agency establish an operating unit of environmental management throughout the project. The organization responsible for the operation should also be consulted in the planning of the municipal water supply and treatment facilities , and should inform and enable him to give his opinion about requests for a permit to major water and wastewater discharge upstream samples.

25. It would be important that a program of environmental monitoring and economic issues is established. The implementation of this monitoring could be performed by an executive agency and the organization responsible for the operation or, if it exists, by the authority of the river basin. Among the areas of expertise required for the development of this program and the interpretation of results could include hydrology, limnology, areas on fishing, forestry or botany, ecology, flora and of wildlife, livestock management and grazing, rural sociology and health.

26. It should be, to the greatest possible advantage of the benefits offered by the training, the project staff responsible for the environment is made early and participate in the evaluation of environmental impacts, the determination of mitigation measures, development of program monitoring and supervision of construction. In this way, it will be able to understand the aspects of the project on the environment and carry out the monitoring and management of the environment.

Monitoring

27. Although there is no standard monitoring program for a hydroelectric project, the assessment of environmental impacts should include a program designed specifically for the project. The choice of the following aspects of those who will be covered by the monitoring program depends on the needs of management information:
    - precipitation
    - volume of water in the tank
    - Annual volume of sediment deposited in the reservoir
    - water quality level of the dam and at various locations of the stream, taking into account:
    - salinity
    - pH
    - temperature
    - electrical conductivity
    - turbidity
    - dissolved oxygen
    - suspended solids
    - phosphate
    - nitrates
    - Speed at various points downstream of the stream
    - volume of water used, by type of assignment, the basin and downstream
    - generation of hydrogen sulfide and methane at the dam

- Limnological sampling of microflora, microfauna, aquatic weeds and benthic organisms
- evaluation studies of fishery resources (species population size) in the river and reservoir
- wildlife (species, number, distribution)
- livestock (species, number, distribution, State)
- changes in vegetation (cover, species composition, growth rate and biomass) in the upper part of the watershed, in the lower area of the reservoir and downstream
- impacts on wildlife species or ecologically distinct plant communities
- Public Health and vectors of disease transmission
- emigration or immigration of populations in the region
- changes in economic and social conditions of displaced populations and those who remained in the watershed.

Table: Summary of Impacts and Mitigation Measures of hydropower projects

	Potential negative impacts	Mitigation measures
Impacts directs		
1	Negative Effects of books on the environment: • pollution of air and water generated by the construction and the discharge of waste • soil erosion • destruction of vegetation • health problems and health workers from camps	Adopt the following measures to mitigate the impacts: • fight against air pollution and water • care given to the location of camps, buildings, borrow pits , quarries and landfills • precautions to restrict the erosive action • reclamation of land
2	Disruption of the quality of life of communities living in the flooded area	• Reinstall the communities in appropriate areas. • The financially compensate for lost resources. • Provide infrastructure and adequate health services and employment opportunities.
3	Loss of land (agricultural, forestry, pasture and	• Locate the dam in order to avoid losses.

	wetland areas) flooded to create a reservoir.	• Reduce the size of the dam and impoundment. • Protect the area of land with an area equal to the losses. • Making use of land that was not previously in order to compensate for losses.
4	Disappearance of historical, cultural and aesthetic appeal with sites.	• Locate the dam or reduce the size of the tank in order to prevent or reduce losses.
5	Disappearance of spaces and natural habitats.	• Protect cultural heritage and, failing to do so, provide rescue operations. • Locate the dam and reduce the size of the tank in order to prevent or reduce losses. • Create parks or reserves in compensation. • Rescue and relocate animals.
6	Proliferation of weeds in the reservoir and downstream of it, which hinders the discharge of water from the dam, irrigation and navigation, and endangering fisheries resources and increased water losses caused by the process perspiration.	• Clearing the land previously woody vegetation in the area that will be flooded (nutrient removal). • Provide weed control measures. • Faucher weeds and recycle compost, feed or biogas. • Regulate the discharge of the dam and control water levels in order to stop the growth of weeds.
7	Deterioration in the quality of the water in the	• Clearing the land previously woody vegetation in the area that will be

	tank.	flooded. • Monitor the use of land, wastewater discharges and application of fertilizers and pesticides in the watershed. • Limit the retention time of water in the tank..
8	Sedimentation tank and the reduction of its storage capacity.	• Provide multi-level spills to prevent the anoxic water spill. • Monitor the use of land in the watershed (to avoid, in particular, the conversion of forests to agricultural land). • Reforestation or adopt soil conservation measures in the watershed (limited effect). • Remove sediment hydraulically (cleaning, winnowing, trigger current density). • Use tank to avoid possible sedimentation (responsible for energy losses).
9	Accumulation of sediment into the reservoir, causing discharge , flood or flooding upstream.	• Remove sediment methods of cleaning and winnowing.et de vannage.
10	Scouring the bed of the river below the dam.	• Develop an effective method of trapping and release of sediment (sludge and sediment winnowing) to increase the salt content of water discharged
11	Decline of recession agriculture.	Set spills dam to reproduce at best the natural flooding.
12	12Salinization of floodplain.	Regulate flows to mitigate the consequences.

13	Saltwater intrusions in the estuary or mouth.	Ensure a minimum flow to avoid ski.
14	Disruption of reverie fisheries due to changes in the flow of the river, barriers to fish migration and degradation of water quality and its limnological characteristics.	• Provide a minimum flow for fisheries • Provide passes or other means of fish passage. • Protect spawning grounds. • Develop and establish aquaculture fisheries on the tank to compensate for losses.
15	Damage to fishing nets by submerged vegetation in the reservoir.	Selectively clear vegetation before flooding.
16	Increase in water-related diseases.	• Develop and operate the dam to control the habitats of disease vectors • Control of disease vectors. • Prophylaxis and treatment of diseases
17	Conflicting requests use of water resources.	• Plan and manage the dam from the regional development programs. • Equitable distribution of water resources between large and small users and between different sectors of the valley.
18	Social disturbance and decreased quality of life for displaced communities.	• • Maintain the quality of life of people in ensuring that available resources are at least equal to those which they had access. •They provide social and health services.
19	Environmental degradation caused by increased pressure on the land.	• Choose a site resettlement avoiding exceed the carrying capacity of the land.

		• Increase productivity and improve the management of land (agricultural, pastoral and forestry) to accommodate growing populations.
20	Disturbance or destruction of tribes or indigenous groups.	Avoid acculturation and, if necessary, relocate populations in an area where they can preserve their way of life and traditions..
21	Increase in humidity and increase the frequency of fog creation of conditions conducive to the proliferation of insects, disease vectors (mosquitoes and tsetse flies).	Control vectors of disease transmission.
Indirect impacts		
22	Spontaneous migration of populations in the region made accessible by roads and transmission lines.	Restrict access to the area of rural development activities and provide health services to mitigate the possible impacts.
23	Environmental problems created by induced development (irrigated agriculture, industry and urban growth)	Develop an integrated watershed management in order to avoid misuse Plan, misuse or use conflicts of water and land.
External impacts		

24	Mismanagement of land in the watershed upstream of the reservoir causing silting of the reservoir and alteration of water quality.	Focus efforts on the management area, particularly in the watershed upstream of the dam