

## **DAMS AND RESERVOIRS**

### **Introduction**

1. Projects for building dams and their associated reservoirs are usually planned for one or more of the following purposes: hydroelectric power, irrigation, domestic and industrial water supply, and flood control. Policy and procedure BOAD on dams security issues dealing with projects including a dam that BOAD finance.

### **Potential Environmental Impacts**

#### General impacts

2. 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 because benefits from dams are outweighed by their social, environmental and economic costs, the construction of large dams is unjustifiable. Others think it is possible, in some cases, anticipate risks and to implement corrective measures that are cost-effective and reduce or avoid the costs to society and environment.
3. The area of influence of a dam project extends from the upper limits of the catchment of the reservoir to as far downstream as the estuary, coast and off-shore zone. It includes the watershed 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 wildlands, fisheries, climate and especially the human populations in the area.

4. The dam's indirect effects, which on occasion may be worse than the direct 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.
5. In addition to the direct and indirect effects of dam construction on the environment, the effects of the environment on the dam must be considered.) The major environmental factors affecting the functioning and life span of the dam are those caused by land, water and other resource use in the catchment above the reservoir (e.g., agriculture, settlement, forest clearing) which may result in increased siltation and changes in water quality in the reservoir and river downstream.
6. The benefits of a dam project are flood control and the provision of a more reliable and higher quality water supply for irrigation, domestic and industrial use. Dams may also provide an alternative to activities with potential for greater adverse impacts. Hydropower, for example, provides an alternative to coal-fired thermal power or to nuclear power. Intensification of agriculture locally through irrigation can reduce pressure on uncleared forest lands, intact wildlife habitat, and areas unsuitable for agriculture elsewhere. In addition, dams create a reservoir fishery and the possibilities for agricultural production on the reservoir drawdown area, which in some cases can more than compensate for losses in these sectors due to dam construction. Dam construction also helps to diversify agriculture, lengthen the period of production and reduce rural-urban

migration is a great evil for the Member States of the BOAD with their effects in the host cities.

### **Hydrologic and Limnological Effects**

7. Damming the river and creating a environment dam profoundly changes 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 in the river basin.
8. The decomposition of organic matter (e.g., trees) on the flooded lands enriches the nutrients in the reservoir. Fertilizers used upstream add to the nutrients accumulating and recycling in the reservoir. This not only supports reservoir fisheries, it also stimulates the growth of aquatic weeds, such as water lettuce and water hyacinth. Weeds and algal mats can be expensive nuisances when they clog dam outflows and irrigation canals, damage fisheries, curtail recreation, increase water treatment costs, impair navigation and substantially increase water loss through transpiration.
9. If the inundated land is heavily wooded and not sufficiently cleared prior to flooding, decomposition will deplete oxygen levels in the water. This affects aquatic life, and may result in large fish kills. Products of anaerobic decomposition include hydrogen sulfide, which corrodes dam turbines and is noxious to aquatic organisms, and methane, which is a greenhouse gas. The main gas produced, carbon dioxide, also exacerbates greenhouse risks. It creates air and water pollution.

10. Suspended particles carried by water settle in the reservoir, limiting its storage capacity and lifetime and robbing downstream waters of sediment. Many agricultural areas on floodplains have always depended on nutrient-rich silt to sustain productivity. As sediment composed of nutritious elements is no longer deposited on the floodplain downstream, the loss of nutrients must be compensated by fertilizer inputs to maintain agricultural productivity. The release of relatively sediment-free waters can result in the scouring of the downstream riverbeds. Sedimentation in the reservoir, however, provides higher quality water downstream for irrigation, industry and human consumption. Also, the use of fertilizers (uncertified) represents water pollution for other users.
11. Additional effects of changes in the hydrology of the river basin include altered levels of the water table both above and below the reservoir and salinization problems which have direct ecological impacts and affect downstream water users.

### **Social Issues**

12. The benefits of dams often accrue to urban dwellers, agricultural interests and others living some distance away from the dam, but less so or not at all to those who bear the heaviest environmental and social costs of the dam construction. The most affected people are those located in the plains downstream. The dam reservoir engulfing large areas of territory. Inevitably, local populations must be moved, the flora and fauna is embedded in the artificial pond and, in some cases, it is the same for some historical and cultural monuments. It is not easy to relocate the displaced populations as well, and find them a job, which leads to the increase in unemployment

and poverty. The inhabitants who remained in the watershed are often faced with difficulties of access to natural resources, land and water available.

13.Changes in flow of a stream and reducing silt deposits due to the realization of a project impoundment, affect the riparian scale fisheries and flood recession agriculture. Floodplains of tropical rivers occupy large areas that benefit humans and animals. When they are shrinking and land use changes, these people are forced to move. In addition, water-borne diseases (malaria, schistosomiasis, river blindness and encephalitis, typhoid proud, for example) often increase in frequency and intensity with projects of reservoirs .

14.Social and environmental problems arise from the controlled and uncontrolled influx of other people into the area, such as construction workers, seasonal laborers for agriculture and other dam induced activities, and rural people who take advantage of increased access to the area provided by roads, transmission lines or improved river navigation. The consequences are health problems, overburdened public services, competition for resources, social conflicts. They have negative environmental impacts on the watershed, reservoir and downstream river basin.

### **Fisheries and Wildlife**

15.A reservoir fishery, sometimes more productive than the previous riverine fishery . However riverine fisheries usually decline due to changes in river

flow, deterioration of water quality, water temperature changes, loss of spawning grounds and barriers to fish migration.

16. In rivers with biologically productive estuaries, both marine and estuarine fish and shellfish suffer from changes in water flow and quality. Changes in freshwater flows and thus the salinity balance in an estuary will alter species distribution and breeding patterns of fish. Changes in nutrient levels and a decrease in the quality of the river water can also have profound impacts on the productivity of an estuary and can also have major effects on marine species which feed or spend part of their life cycle in the estuary, or are influenced by water quality changes in the coastal areas.

17. The greatest impact on wildlife will come from loss of habitat resulting from reservoir filling and land use changes in the watershed. Migratory patterns of wildlife may be disrupted by the reservoir and associated developments. Poaching and eradication of species considered to be agricultural pests have a more selective effect. Aquatic fauna, including waterfowl, reptiles and amphibians can increase because of the reservoir.



## OPERATIONAL GUIDLINES OF BOAD

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Negative effects on the environment	Possible measures to adopt
<p><b>1.</b></p> <ul style="list-style-type: none"><li>• air and water pollution generated by the construction and the discharge of waste;</li><li>• soil erosion;</li><li>• destruction of vegetation, health and hygiene problems in workcamp sites.</li></ul>	<p><b>1.</b></p> <ul style="list-style-type: none"><li>• fight against air and water pollution;</li><li>• care given to the location of camps, buildings, borrow pits, quarries and landfills;;</li><li>• precautions to control erosion;</li><li>• land rehabilitation.</li></ul>
<p><b>2.</b> Disruption of the communities residing in the flooded area</p>	<p><b>2.</b></p> <ul style="list-style-type: none"><li>• Reinstall the communities in appropriate areas, financially compensate for the loss of resources, provide health services, education and adequate infrastructure, and create employment opportunities.</li></ul>
<p><b>3.</b> Loss of land (agricultural, forest or pasture) and flooded wetlands to create the reservoir..</p>	<p><b>3.</b></p> <ul style="list-style-type: none"><li>• Locate the dam in order to avoid losses, reduce the size of the dam and reservoir;</li><li>• save or protect similar environments in the region to offset the losses.</li></ul>
<p><b>4.</b> Loss of historical, cultural sites or those with aesthetic appeal.</p>	<p><b>4.</b></p> <ul style="list-style-type: none"><li>• Locate the dam adequately, reduce the size of the reservoir to prevent or reduce losses;</li><li>• Save and protect cultural heritage.</li></ul>

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Negative effects on the environment Possible measures to adopt

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| 5. | Loss of natural areas and wildlife habitats and flora.   | 5. | <ul style="list-style-type: none"><li>• Locate the dam or reduce the size of the reservoir in order to avoid or reduce losses;</li><li>• Create natural parks or reserves in exchange;</li><li>• Rescue and relocate animals.</li></ul>   |
| 6. | Proliferation of weeds in the reservoir and its downstream, which affects the discharge of water from the dam during irrigation and navigation and endangering fisheries resources and increases water loss through evapotranspiration . | 6. | <ul style="list-style-type: none"><li>• previously remove woody vegetation in the area of flooding (nutrient removal);</li><li>• Provide weed control measures;</li><li>• Mow the grass and recycle it for compost for feed or biogas;</li><li>• Regulate the flooded area and manage water levels to curb the growth of weeds.</li></ul> |
| 7. | Deterioration of the water quality in the reservoir.   | 7. | <ul style="list-style-type: none"><li>• Previously remove woody vegetation in flooding area;</li><li>• Monitor the use of land, wastewater discharges and use of fertilizers</li></ul>  |





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Negative effects on the environment	Possible measures to adopt
	and pesticides in the watershed; • Limit the period of retention of water in the reservoir; • Provide multi-level releases to prevent the anoxic water spill.
<b>8.</b> Sedimentation in the reservoir and decrease its storage capacity	<b>8.</b> <ul style="list-style-type: none"><li>• Monitor the use of land in the watershed upstream of the dam (to avoid, in particular, the conversion of forests to agricultural land).</li><li>• Reforestation or adopt soil conservation measures in the watershed (limited effect).</li><li>• Remove sediment hydraulically (cleaning, winnowing, triggering current density).</li></ul>
<b>9.</b> Sediment at the entrance of the reservoir causing a discharge of water, flood and upstream flooding.	<b>9.</b> <ul style="list-style-type: none"><li>• Remove sediment through cleaning and winnowing.</li></ul>
<b>10.</b> Scouring the bed of the river downstream of the dam	<b>10.</b> <ul style="list-style-type: none"><li>• Develop an effective method of trapping and release of sediment (cleaning and winnowing of sediments), in order to increase the salt content of the water discharged from the dam</li></ul>
<b>11.</b> Decline of recession agriculture.	<b>11.</b> <ul style="list-style-type: none"><li>• Set the release of water from the dam to reproduce at best the natural flooding.</li></ul>



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Negative effects on the environment	Possible measures to adopt
<b>12.</b> Salinization of floodplain	12. <ul style="list-style-type: none"><li>• Regulate the flow in order to reduce the consequences.</li></ul>
<b>13.</b> Rising sea water in estuaries and upstream.	13. <ul style="list-style-type: none"><li>• Maintain a sufficient flow to prevent upwelling</li></ul>
<b>14.</b> Disruption of fisheries resources of rivers, due to changes in flow, stop in fish migration and impairment water quality and its physical and biological aspects.	14. <ul style="list-style-type: none"><li>• Maintain at least a minimum flow for fisheries resources;</li><li>• Provide fish ladders or other means of passage and protection of spawning grounds;</li><li>• Developing aquaculture and fish tanks to compensate for losses.</li></ul>
<b>15.</b> Tearing of fishing nets in overgrown ponds	15. <ul style="list-style-type: none"><li>• Remove, selectively, vegetation before flooding</li></ul>
<b>16.</b> Increase in water-related diseases.	16. <ul style="list-style-type: none"><li>• Develop and maintain the dam to restrict the conditions that make favorable disease transmission;</li><li>• Control of disease vectors;</li><li>• Implement measures of prophylaxis and treatment of diseases.</li></ul>
<b>17.</b> Conflicts in the request for the use of water resources.	17. <ul style="list-style-type: none"><li>• Plan and manage the dam in accordance with the regional development programs;</li><li>• equitable distribution of water resources between large and small</li></ul>



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Negative effects on the environment	Possible measures to adopt
<b>18.</b> Social disruption and loss of quality of life for displaced communities.	18. • landowners and between the various sectors of the valley. • Maintain the quality of life of people in ensuring that available resources are at least equal to those which they had access; • Provide them with social and health services.
<b>19.</b> Environmental degradation caused by increased pressure on the land.	19. • Choose a site for resettlement of populations where the capacity of land is not exceeded; Increase productivity and improve the management of land (agricultural, pastoral and forestry) to meet growing populations.
<b>20.</b> Disruption or destruction of tribes or indigenous groups.	20. • Avoid social dislocation and, in case of force majeure, relocate populations in an area where they can preserve their way of life and traditions.
<b>21.</b> Elevation of the moisture in the air and increase in the frequency of fog in the area, creating an environment conducive to the proliferation of disease-carrying insects (such as mosquitoes and tsetse flies).	21. • Control disease transmission vectors.



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Negative effects on the environment	Possible	measures	to	adopt
<b>22.</b> Uncontrolled migration of people in the area made accessible by roads and transmission lines.	22.	<ul style="list-style-type: none"><li>• Restrict access, development of rural activities and provide health services to minimize the impacts.</li></ul>		
<b>23.</b> Environmental problems created by development induced by the construction of the dam (irrigated agriculture, industries and urban growth).	23.	<ul style="list-style-type: none"><li>• Develop an integrated watershed development plan in order to avoid wastage, abusive practices and conflicts of use of water resources and land.</li></ul>		
<b>24.</b> Poor land management in the surface water catchment, upstream of the reservoir, causing excessive siltation and impairment of water quality.	24.	<ul style="list-style-type: none"><li>• Increase efforts on land use and watershed.</li></ul>		

### **Seismic Threat**

18. Large reservoirs may alter tectonic activity. Though the probability that they will induce seismicity is difficult to predict, the full destructive potential of earthquakes, resulting in landslides, damage to dam infrastructure, and possible dam failure must be considered.

### **Watershed Management**

19. Increased pressure on upland areas above the dam is a common phenomenon caused by the resettlement of people from the inundated areas and by the uncontrolled influx of newcomers into the watershed. On-site environmental deterioration as well as a decrease in water quality and increase in sedimentation rates in the reservoir result from conversion of forests to agricultural land, grazing pressures, use of agricultural chemicals, and tree cutting for timber or fuelwood. Similarly, land use in the watershed of the lower river basin affects the quality and quantity of water entering the river. For these reasons BOAD recommends that dam projects be planned and managed in the context of overall river basin development plans, including both the upland catchment areas above the dam and floodplain, and watershed areas downstream.

### **Project Alternatives**

20. A variety of alternatives, such as the following, exist for the design and management of dam projects:

- avoid or postpone the need for dam construction altogether by reducing demand for water or energy by conservation measures, efficiency improvements, fuel substitution, or restrictions on regional growth;
- avoid construction of a dam whose primary purpose is for irrigation by expanding and/or intensifying agriculture on the river's floodplain or outside the watershed;
- investigate possibilities for siting the project on an already dammed river by diversifying the functions of that dam;
- site the proposed dam on the river where it will minimize the negative and social impacts;
- adjust dam height, inundation area, dam design, and operational procedures to minimize negative environmental impacts;
- install several small dams instead of a single large one.

### **Management and Training**

21. Responsibility for management of the dam project should be vested in a river basin authority or other centralized entity, which will:

- collect baseline data
- build and manage the dam
- produce a water-use master plan with management strategies for regulation of the reservoir
- .approve permit requests for major withdrawals and wastewater discharges
- coordinate disease vector control
- plan for population water supplies and water treatment facilities

22. Intersectoral cooperation should be ensured at both the policy and field levels with government ministries responsible for agriculture, fisheries, forestry, range and livestock, health, wildlife, tourism, municipal and industrial planning, and transportation.

23. Environmental and socioeconomic units should be established within the river basin authority and on the project site. The units should be staffed by professionals in physical (e.g., pollution control), biological (e.g., disease vector control), and social (e.g., involuntary resettlement) disciplines.

Guidance for the river basin authority can be provided by an advisory panel of international environmental specialists to advise on environmental aspects of the project and on training and management needs.

24. Training should be provided where needed to assure that the above mentioned disciplines are adequately represented.

### **Monitoring**

25. Factors to be monitored should include:

- rainfall
- stored water volume in the reservoir
- annual volume of sediment transported into reservoir
- water quality at dam discharge and at various points along the river (such as, salinity, pH, temperature, electrical conductivity, turbidity, dissolved oxygen, suspended solids, phosphates, nitrates)
- hydrogen sulfide and methane generation behind dam
- limnological sampling of microflora, microfauna, aquatic weeds and benthic organisms



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- fisheries assessment surveys (species, populations. etc.) in the river and reservoir
- wildlife (species, distribution, numbers)
- vegetation changes (cover, species composition, growth rates, biomass. e.) in the upper watershed, reservoir drawdown zone, and downstream areas
- increases in erosion in the watershed
- impacts on wildlands, species or plant communities of special ecological significance
- public health and disease vectors . in and out-migration of people to area
- changes in economic and social status of resettlement populations and people remaining in the river basin