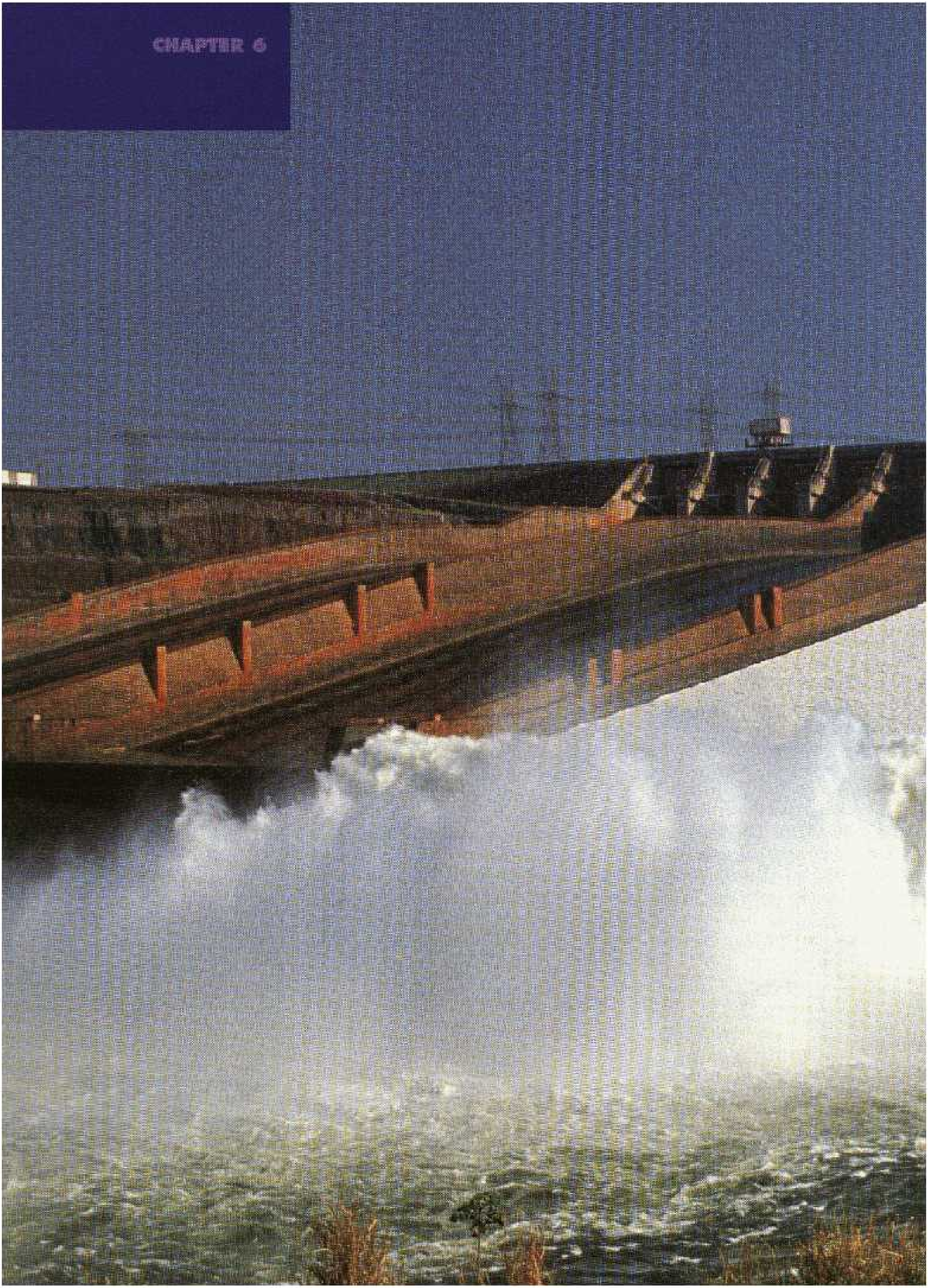
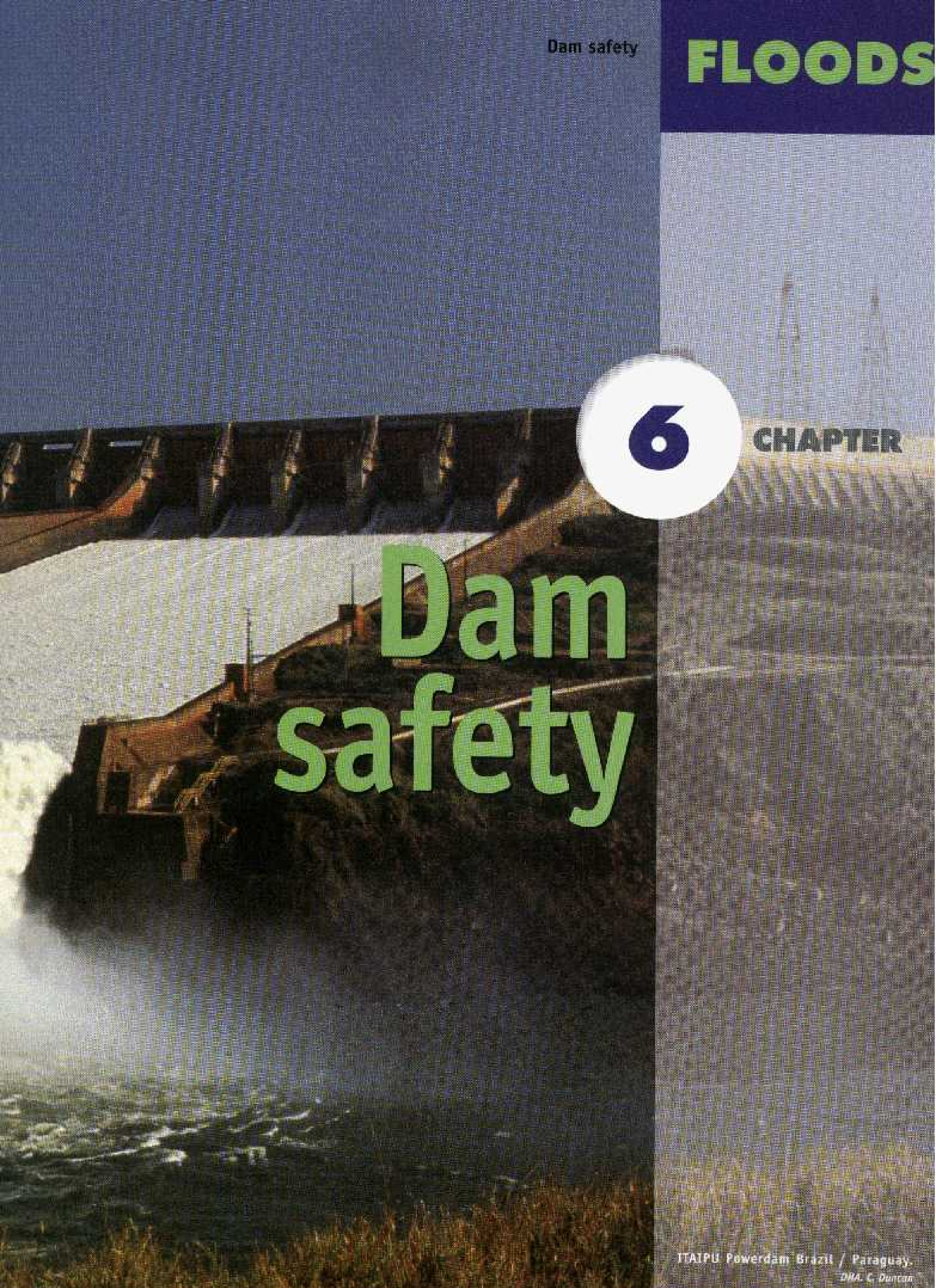
CHAPTER 6





6 CHAPTER

Dam safety

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Dam safety

The consequences of a dam failure can be extremely serious. The failure releases the contents of the reservoir in a great wave that can overwhelm communities in the valley below with little warning. The disaster is due entirely to the presence of the dam and could, in principle, have been avoided if the dam had been properly designed, maintained and operated. The problem of dam failure is a significant one. There are between 10 and 100 deaths due to dam failure in the United States each year. A census of serious accidents to dams for the twenty-year period 1964 to 1983 lists 43 failures of large dams (height 15 m or more by the definition of the International Commission on Large Dams, ICOLD). Fifteen of these failures resulted in loss of life with a total death toll of 2,572, though 2,000 of these were recorded in one incident, the overtopping of the 26 m high Machhu II earth dam in India in August 1979. About a quarter of these failures occurred during construction and another quarter on first filling or during the first five years of service. Overtopping of the dam by a flood was the commonest cause of failure. A landslide into the reservoir, displacing water over the dam, was the cause of several other failures. This may be due to the raising of the water table in the land surrounding the reservoir following the construction of the dam making the soils weaker. One of these landslides followed an earthquake, but surprisingly no other earthquake failures were reported in the census. By far the most failures (83 per cent) reported in the census were of earth or rockfill dams. When these dams are overtopped they erode rapidly leading to a progressive collapse and release of the reservoir contents. Concrete dams, whether of the gravity or arch type, can better withstand overtopping. Even though there may be considerable damage to installations immediately below the dam such as hydropower stations or water treatment plants, the dam itself will not collapse.

Old earth dams, particularly when poorly maintained, are prone to failure by piping (see chapter 4) or by erosion of the front face by water seeping through the dam. Many dams built for the early European canal systems some two or more centuries ago are still in use and from time to time develop these problems.

To prevent these disasters many countries have adopted dam safety regulations governing the design, construction and maintenance of dams and some have also surveyed existing dams to see whether they meet modern safety criteria, often with very disquieting results. The United States National Dam Inspection Program, carried out by the United States Army Corps of Engineers, found that a third of the 9,000 dams inspected, all in high hazard situations, were tentatively classified as unsafe. The cost of improving these dams to meet current safety standards would be prohibitive.

The safety criteria to be adopted for a dam usually depend on the hazard that it presents. For example, a dam built upstream of a town would have to meet more stringent criteria than one built where failure would not endanger human life. There are objections to this simple hazard rating as it can only be applied when the dam is built and subsequent development, such as the building of new housing in the valley below, may increase the hazard that the dam presents. It should be remembered that dams are very permanent structures with a life of decades if not centuries.

A hazard classification for dam safety is used in the United Kingdom. Dam safety in the United Kingdom is entrusted to members of a statutory panel of engineers deemed to be qualified to design and inspect impoundments. Each such "panel engineer" is responsible for the safety of the dams he is hired to supervise and to assist these engineers in meeting their responsibilities, the United Kingdom Institution of Civil Engineers appointed a Working Party on Floods and Reservoir Safety that reported in 1978. The working party's guidelines divide reservoirs into four hazard-based categories:

A. Reservoirs where a breach will endanger lives in a community;

B. Reservoirs where a breach (i) may endanger lives not in a community or (ii) will result in extensive damage;

C. Reservoirs where a breach will pose negligible risk to life and cause limited damage;

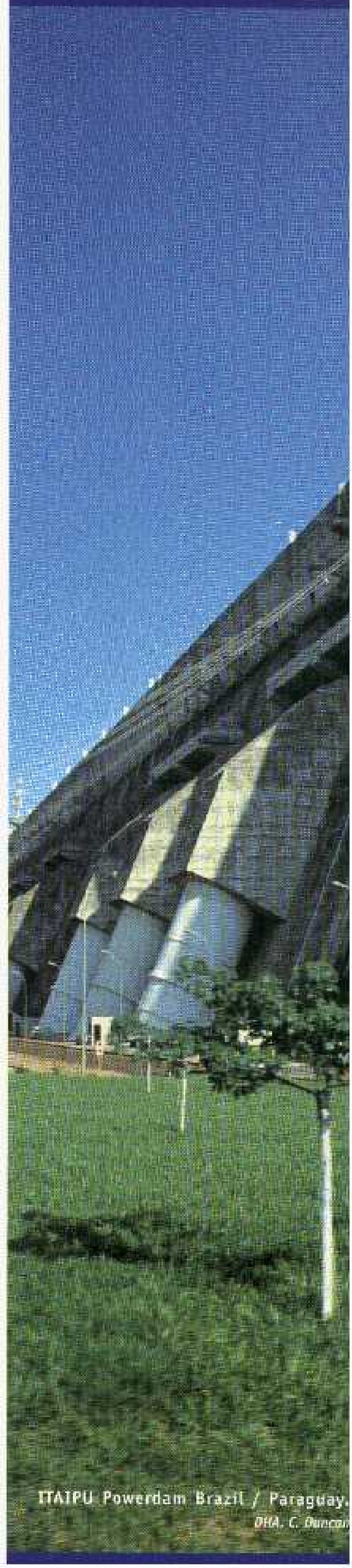
D. Special cases where no loss of life can be foreseen as a result of a breach and very limited additional flood damage will be caused.

Category A is established because it is considered that public opinion will not accept conscious design for a specific threat to a community. Category B (i) applies to isolated houses or plant operators in a water treatment works or hydropower plant immediately below the dam. These situations lend themselves to reducing the danger by taking measures to buy out the isolated property or to arrange flood escape routes. Category C includes cases such as playing-fields or footpaths across flood plains that are occupied only occasionally. Category D includes low earth dams, typically for ornamental lakes, that cause no real problem except that of replacement if washed out. A flood large enough to wash out the dam would, in most cases, have caused damage, even before the ornamental lake was built.

The guidelines require that category A reservoirs should in general be designed for the probable maximum flood, though a lower standard is permitted if the dam can withstand rare overtopping. The general standard for category B is the 10,000-year flood and for category C the 1,000-year flood, while category D reservoirs need be designed for only the 150-year flood. The guidelines also specify an allowance for wave surcharge and the initial reservoir contents before routing the specified flood through the reservoir.

This is a relatively complicated system, but represents a real attempt to grapple with the complexity of the issue. The inherent difficulties of public perception of and reaction to risk are well known. To these are added here the technical uncertainties of the probable maximum flood, which according to a United States National Research Council report (see next paragraph) "does not necessarily provide absolute assurance that a dam is safe for every possible flood".

The practice in the United States has also been for high hazard dams to be designed for the probable maximum flood, and a committee of the National Research Council that reported on dam safety in 1985 recommended that this should continue, while recognizing that a lower standard could be justified if failure during a flood of PMF magnitude would cause "no significant increase in potential for loss of life or property damage". This emphasis on the increased damage due to a failure of the dam is interesting. A flood of the size to destroy a dam is obviously going to cause extensive damage, whether or not a dam fails. In contrast to the United States system, the United Kingdom classification system for dam safety considers incremental damage only for category D dams.



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The full analysis of the safety of a dam should consider the consequences of its possible failure. The United States National Weather Service has developed two computer programs for simulating the movement of a flood wave following the failure of a dam. The program BREACH calculates the flow through a breach in an earth or rockfill dam and the consequent widening of the breach by erosion. It provides input to the second program, DAMBRK, that calculates the passage of the flood wave down the valley. These two programs can give valuable information on the extent of flooding and the properties and lives at risk should the dam fail. The programs have been used in many parts of the world and can be obtained through HOMS, the WMO system for technology transfer in operational hydrology.

The problem of dam safety is a difficult one and requires the careful balancing of project benefits, construction costs, social costs and public safety. The current state of knowledge does not permit the balancing of all these factors with full confidence. At the design stage a careful hydrological and economic analysis of the project is needed, which may well lead to the abandonment of the project if safety requirements cannot be met. Countries should develop national guidelines so as to ensure consistent decisions on dam safety. During the life of a dam, which can be long, the safety of the dam and developments downstream that could alter its hazard rating need to be monitored regularly. As a result of this monitoring the dam owner may have to face, at longer or shorter intervals, further expenditure to maintain safety levels. The publication of the United Kingdom guidelines led to enlarged spillways being built on a number of dams.

A number of developing countries face particular problems of dam safety. Many have built dams in recent years for irrigation or hydropower to further their development. These have been funded by different aid donors and in the absence of national standards the donor has usually applied his own country's standards. The inconsistency of standards that results has caused concern in some tropical countries in recent years.