CHAPTER 8

FLOOD CONTROL

The purpose of the present chapter is to explain how various devices may be employed in order to control an excess flow of water so that a flood may be prevented or, at least, its worst effects reduced. These devices include engineering works, embankments, detention reservoirs, the adaptation of river channels and facilities for flood diversion. The possibility of storm surges further complicates the problem of flood control.

Engineering works

Over the years, in many parts of the world, different types of engineering work have been developed to protect man and his property from floods. These works can be placed in two categories – those controlling water in the river-channel phase and those controlling it in the land phase

There are various ways of effecting control in the river-channel phase. Land can be protected from inundation by embankments and river channels can be straightened, widened or deepened to lower flood levels by creating more efficient flow conditions. Excess water in the main river channels can be diverted into by-passes and diversion channels. Natural or man-made reservoirs can be used to hold back excess water temporarily from the river, the stored water being released later at such rates and times that it can be carried safely by the river. Pumping stations can be installed to dispose of water from the protected areas behind an embankment.

In the land phase, control can to some extent be exerted by proper management of the upstream areas of the watershed and by reafforestation and soil conservation to reduce the rate of runoff and sedimentation.

Usually the construction of embankments and the associated works results in a general increase in flood stages along a river unless reservoirs are constructed or extensive channel improvement takes place. Upstream local protective measures, such as levee construction and channel improvement, may increase the magnitude of floods at points downstream. These measures, as well as reservoir construction, should therefore be looked upon as part of the flood-control works within an overall water-resources development programme for the whole river basin. They must be planned and executed with care so that the benefits at one place are not offset by increased damage elsewhere. The type of structure used should be carefully selected to offer the maximum protection at the minimum cost. Funds for maintenance and repair must also be provided to ensure that the structures function efficiently when brought into use

It should also be recognized that failure or collapse of flood protection structures can frequently be caused by major floods or through rubbish being jammed against a bridge and causing an unexpectedly high stage or, sometimes, because of the occurrence of floods greater than the design flood. Another risk of a different kind is that the construction of engineering works tends to give a false sense of security to people living in the protected area. It is therefore essential that these flood-control measures should be accompanied by the other measures necessary, such as land-use control, building codes, etc., in a comprehensive approach to the effective protection of life and property.

Embankments

Embankments (also called dikes, levees or bunds) on alluvial plains and in river deltas were originally constructed by groups of villagers and farmers seeking to defend their small holdings. They could be built at low cost with labour and materials available along the river. Earthen embankments are one of the oldest and most widely used measures to protect land from flood waters. In the lower reaches of large rivers, embankments are the only feasible method of preventing inundation and are, perhaps, the cheapest structural protection against floods. Old dikes have been raised and strengthened and new dikes have been constructed over the years. It is reported that, in India,* the total length of embankment constructed before 1947 was 5300 km and that about 7000 km was constructed between 1954 and 1969. A major portion of this length, about 3000 km, was constructed on the Brahmaputra River. Along the Kosi River, a total length of 240 km was completely embanked during the period 1953-1959.

Water that would normally drain freely across the flood plain into the river will accumulate behind the embankments. It is accordingly necessary to have an adequate system to drain this water into the river through sluice gates and pumping stations. Drainage and sewerage from urban areas may require pumping during high flood stages. Tributaries joining the main river in an embanked reach must be given special attention as floods in the main river will back up the tributaries and, to offset this effect, backwater embankments may be necessary.

Normally no flood-control structures or embankments are designed and constructed to afford complete protection against infrequent and extraordinary floods, as the cost of such works would exceed the economically justified benefits. Projects for the control of floods in urban or built-up areas should, however, provide a higher degree of protection than for rural or agricultural areas.

In India, for example, embankments in agricultural areas are designed in general to protect against a 25-year flood frequency, whereas those protecting important urban areas are against 50-year floods. In Japan, the long-term flood-control programme specifies that projects for the major 108 rivers should be undertaken to give protection against floods which have a probability of occurrence of once in 100 years, in certain cases once in 200 years; projects for urban and other rivers give protection against once-in-50-year floods but, in special cases, against floods having a frequency of once in a hundred years.

In most cases the criteria for the design of embankments are based on the maximum recorded flood. As more hydrological data become available for longer periods, and as past maximum floods are replaced by new and larger floods, the planning and design criteria are changed accordingly. In the initial stage in India, the crest width of embankments was generally 3 m but it has now been increased to 5 m. Free-board was 1-1.5 m above the observed high flood level. Side slopes were 2:1 on the river side and 3:1 on the country side. In Japan, a crest width of 5-7 5 m is employed and free-board is 1.5-2 m in general.

Erosion along the embankment and natural banks is one of the serious problems that must be resolved in flood-control and river-improvement works. Over the years, numerous methods have been tried in many countries to prevent bank erosion along river courses, for example, in the Brahmaputra River and the Yellow River. Revetments, spurdikes and groins vary considerably and it is clear that each river should to some extent be regarded as a separate problem.

Channel cross-sections and longitudinal bed profiles can be determined by making assumptions based upon measurements of the flow discharge and sediment transportation. The long-term variation of the river behaviour should be taken into account when planning anti-erosion and flood-control works. Thereafter river behaviour should be monitored so that if any need for additional works arises, it will be recognized in good time.

Storm-surge protection

Coastal embankments susceptible to storm surges should be designed specifically to withstand the expected storm-surge water heights and forces, the combined action of wind and waves, and overtopping from the storm-surge water. Furthermore, coastal embankment projects in deltaic areas should be planned in conjunction with other development projects such as highways, harbour and reclamation projects in order to avoid duplication of investment costs.

*J. P. Maegamvala and R. B. Shah, "Review of river training measures in India". *Report of Eighth Congress on Irrigation and Drainage, 1972.*

In Bangladesh, a coastal embankment project consisting of 3090 km of embankment with 625 sluices for the protection of 648000 hectares of low-lying land along the head of the Bay of Bengal was completed by June 1970. Total investment in the project amounted to US $200 million. Embankment standards were designed to provide protection against normal storm-surge heights. The tropical cyclone of November 1970 resulted in a catastrophic storm surge which completely destroyed about 65 km of embankment in an area close to that traversed by the centre of the cyclone. Varying degrees of damage were sustained by another 390 km of embankment.*

An example of storm-surge protection

An advanced and carefully planned system of storm-surge protection has been developed at Osaka, Japan, in one of the most densely populated areas of Asia.

Osaka is built on soft clay and gravel sedimentation deposited by the Yodo and Yamato Rivers. About forty years ago, remarkable land subsidence began to appear, caused by excessive pumping of the groundwater necessary for industry and air-conditioning. The maximum total land subsidence over the period from 1936 to 1967 amounted to about 280 cm in the coastal areas and most of western Osaka is now lower than sea-level.

Severe damage was caused in Osaka by the Muroto typhoon in 1934 and again by typhoon *Jane* in 1950 when one-third of the city was flooded by the associated storm surge. As a consequence of this event, storm-surge protection works were immediately planned and put into effect. However, land subsidence caused the storm-surge embankments to sink as well as the city itself. To protect the lives and property of several million people it became urgently necessary to raise the embankments to the height required to withstand the maximum storm surge previously experienced.

The present storm-surge prevention project consists of the construction of embankments, locks, pumping stations and the lifting of bridges lowered by land subsidence. The large locks that now protect Osaka from a storm surge caused by a typhoon were constructed between 1965 and 1970. These locks were planned and constructed as an alternative to raising the height of the existing embankment for reasons of cost and time, and to minimize the effects on traffic and urban appearance. This project is shown in Figure 8, the solid circles indicating the large locks.

Detention reservoirs for flood control

Flood protection can be effected by providing reservoirs to retard or delay excessive runoff for the purpose of reducing flood heights downstream. In general, this is accomplished by constructing dams on the main stream and/or its tributaries and, in some cases, by constructing retarding basins in the middle of rivers. When properly operated, and when combined with efficient flood-forecasting systems, reservoirs offer the most dependable form of flood-control structure.

Construction of a storage dam of large capacity calls for a favourable site and the investment of substantial funds. In inhabited areas, the construction of a dam is apt to disrupt the social and economic life of the people. Resettlement, particularly of those engaged in agriculture, is often very difficult in countries where the pressure of population is high. It is accordingly a general practice to build multi-purpose projects, with flood control as one of the objectives, and to make good use of the few good storage sites available in a river basin. In most multi-purpose water-resources development projects there are apparent conflicts between the desire to keep the reservoir empty to accommodate unpredicted flood waters and the need to store water for hydro-electric power, irrigation, navigation, etc. When there are several flood-control reservoirs in a river basin, their operation must be carefully regulated so that the cumulative effect of releasing flood waters does not create a dangerous situation downstream.

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*Walter G. Schultz, "Introduction to irrigation and related institutional arrangements in the Ganges-Brahmaputra-Megna delta". *Report of Eighth Congress on Irrigation and Drainage, 1972.*

Plate II – Flooding in Philippines caused by Typhoon "OLGA", 18 May 1976. *(Photo: League of Red Cross Societies)*

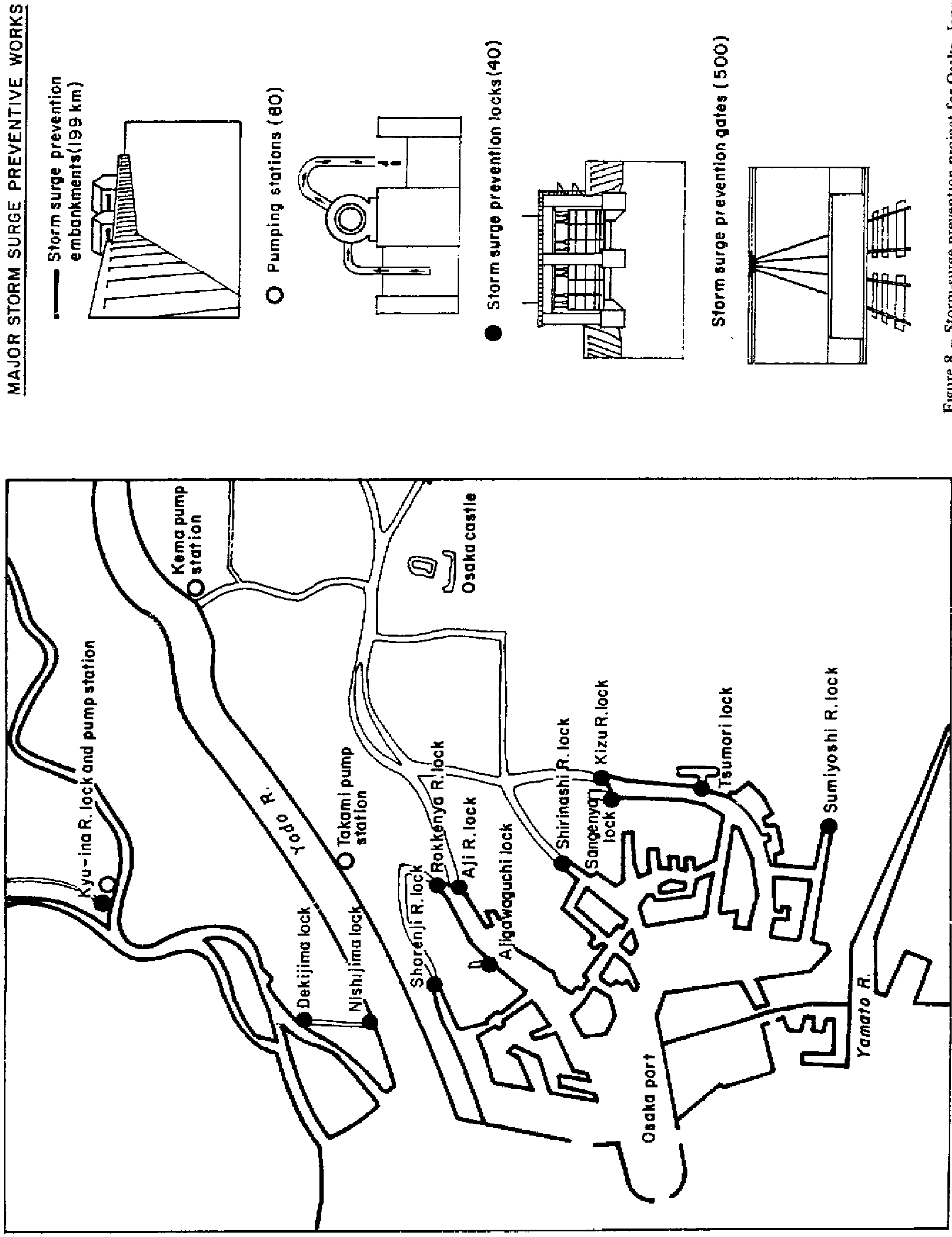

Figure 8 – Storm-surge prevention project for Osaka, Japan

Many reservoirs, even if properly maintained through watershed management and erosion control work, gradually fill with sediment which reduces the storage capacity and affects the behaviour of the lower part of the river. Despite their physical, economic and social limitations, many dams and flood-control reservoirs have been constructed and will be constructed in the future because water stored during the rainy season can be used effectively in the dry season to meet many water-use purposes.

The swamps and lakes often found in alluvial areas can be used as flood-retarding basins and can thus serve a purpose similar to that of flood-control reservoirs. As the depth available for water storage is normally no more than a few feet, the area of the basin needs to be large if this method is to contribute greatly to flood prevention. Out of the flood season the land can be used for cultivation and recreational purposes or, sometimes, to store water that can later be fed into the normal water supply system.

River-channel improvement and flood diversion

River-channel improvement by clearing, straightening, widening and deepening can be undertaken to decrease the length of the river and to improve its conveyance ability. Work to increase the effective slope of the channel or to reduce bed and bank friction by the elimination of bars, smoothing bank contours, the enlargement of the natural channel by dredging, and the removal of obstructions or bends are all beneficial in increasing the velocity of the river flow and, consequently, in lowering the flood stage.

Diversion floodways provide a means for the escape of flood water in excess of the carrying capacity of the main channels into emergency or auxiliary channels. They can be used to control unusual floods around cities in the lower reaches of a river near the sea. Diversion of excess water from one river to another is practicable only if the flood flow can be safely conveyed into the second river. In deltaic areas it may also be possible to divert flood waters directly into the sea.

As with embankments, proposals for channel improvement and flood diversion should be considered as part of a flood-control programme for the whole river and so planned and effected that the benefits at one point are not offset by increased damage elsewhere.

Watershed management

Proper watershed management reduces flood damage on small streams during minor floods by affording some degree of control over water in the land phase of the runoff cycle. Watershed management measures can be grouped broadly under two headings. The first is concerned with improvement of the vegetation mantle in crops, grasslands and forests and includes such measures as suitable rotation of crops, grass cultivation, tree planting and reafforestation. The effect of these measures is to increase the water infiltration capacity of the soil.

The second heading includes engineering works such as terracing, contour bunding, contour cultivation and cropping, gully plugging, sediment check dams, outlet structures, spurs, groynes and similar works to prevent hillside erosion and landslides, and to reduce the sediment load in streams.

Landslides in mountainous areas, or landslips on steep hillsides, can be the cause of heavy loss of life and tremendous damage to property during periods of heavy rainfall. A recent example was the loss of more than 80 lives in the Hong Kong landslips of June 1972.

The threat of landslides can be controlled by soil removal, surface and underground drainage, the interception of groundwater, the use of piles, and retaining walls. These counter-measures call not only for direct expenditure in civil engineering works but may also, in some cases, require the purchase of land or the denial of its use for other purposes.