# CHAPTER V

## LAND-USE MEASURES FOR THE PREVENTION AND MITIGATION OF FLOODS AND EARTHQUAKES

### Floods

#### (i) General

All rivers are liable to flood: it is the nature of a river to burst its banks from time to time and to spill out into its floodplain. The floodplain is an integral part of the river system, although used only intermittently to discharge peak flows. When not occupied by water, it forms part of the land system and is used for agriculture and rural settlement, urban and industrial activities. These rival claims to the floodplain have set the scene for many a flood disaster.

Coastal areas, too, may be subject to flooding, but the hazard is not as ubiquitous as in the case of river flooding in the sense that not all coastal areas face a significant flood risk. Most at risk are those low-lying coasts in the path of tropical storms (variously called cyclones, hurricanes or typhoons), according to whether they occur in the Indian Ocean, the Caribbean Sea and North Atlantic or the China Sea and western part of the North Pacific, respectively.

Another cause of coastal flooding is the tidal wave or "tsunami". A tsunami is a series of travelling ocean waves of extremely long length and period, generated by disturbances associated with earthquakes occurring below or near the ocean floor. In deep water, tsunami waves may reach forward speeds exceeding 1,000 kilometres per hour. As the tsunami enters the shoaling water of coastlines, the velocity of its waves diminishes and wave height increases. In these shallow waters tsunamis become a threat to life and property, since they can crest to heights of more than 35 metres and strike with devastating force. The tsunami associated with the 1960 earthquake off the coast of southern Chile travelled across the Pacific in 24 hours to kill 139 people and injure 872 in Japan.

#### (ii) Principles of land-use control

Land-use control for the mitigation of flood disasters acknowledges that high waters will occasionally invade the land, on river floodplains and along the coast, in spite of man's increasing efforts to hold them back. The purpose of control is to implement patterns of land-use which reduce danger to life and property when the inevitable inundations occur. Relevant controls may take a number of different forms: directing people and economic activity away from the most hazardous places; insisting on designs and construction techniques that make buildings and other structures comparatively flood-resistant; altering land-use patterns so that only those with low damage potentials occupy the high risk areas; and ensuring escape routes to higher buildings or higher ground for people in vulnerable low-lying areas.

One of the most important functions of land-use control is to ensure that flood hazards are made no worse by ill-conceived new land-uses. Especially where urban and industrial development is rapid, there is a strong possibility that damage potential will increase. Most obviously, new development may be put in the path of flood waters in ignorance or under-estimation of the danger. No less effective in increasing damage potential is the inadvertent blocking of a river flood channel by new buildings, bridges, roads, and so on. If very strongly constructed, these may themselves escape damage, but flood waters will be trapped upstream and overflow into areas formerly flood-free. Widespread land-use changes in a river catchment - such as deforestation - may also increase the flood hazards by hastening catchment run-off and simultaneously accelerating soil erosion, thereby also contributing to the silting of river beds. There are many examples of the application of controls to avoid these situations, some of which are cited below.

Another function of land-use control is the prevention of over-enthusiastic development in response to flood protection engineering. All over the world, excellent engineering works are reducing the physical risk of inundation in floodplain and coastal areas, but each project is designed to protect only up to a specific limit. While the professionals involved in design and construction recognize that floods greater than the design flood will overtop the work, many local people fail to understand this. To some, even the promise of an engineering project is enough to make the flood hazard disappear altogether. Such over-estimation of the benefits of flood protection is extremely dangerous: concentration of activity in the protected area may increase rather than diminish potential damages and loss of life. Land-use control can combat this by insisting on land-use patterns appropriate to the reduced but nonetheless ever-present residual hazard.

Finally, as we have discussed in previous chapters, land-use control can be employed to adjust existing uses to the recognized risk in areas where there is less drastic change in over-all land-use or physical hazard. Inevitably, this is a rather slow process, as it waits for the natural redevelopment of land and buildings, but it can be very effective in helping communities take a more realistic and positive view of their flood predicament. Controls designed to reduce susceptibility to flood damage will draw attention to those uses at present most vulnerable and so discourage their automatic perpetuation.

### (iii) Definition of flood hazard areas and appropriate land-use controls

The foregoing arguments for land-use control pre-suppose that areas at risk from flooding can be clearly defined, along with desired land-uses compatible with the prevailing degree of risk. But these are major pre-suppositions which demand further consideration. Only if hazard zones can be located on the ground are land-use controls applicable at all, and only if the land-uses suggested are relevant in the context of the local economy are they likely to be adopted.

Most types of floods are indeed location-specific: one has a good idea of where they are going to occur. The principal exception is sheet run-off due to intense local rainfall, which though usually very restricted in area, may happen anywhere, in low-lying areas as well as on hillsides. The riverine flood hazard is particularly well defined area-wise. Any part of the floodplain may be inundated, having been fashioned by the river in flood for the very purpose of discharging high flows. Those portions of the floodplain close to the river will be affected by water more often and more seriously than distant portions adjoining higher ground, as floods of varying magnitude and frequency pass through the valley. Coastal areas prone to flooding from storm surges and tsunamis can also be defined in very much the same manner.

There are many useful methods for defining flood hazard areas along rivers. Where records of river discharges permit it, flood frequency analysis is an especially good indicator of both magnitude and frequency (recurrency interval) of probable flood events. Peak discharges may be estimated by means of various flood formulae which, while open to criticism, are often used for smaller river basins where the formulae are more reliable.14/ Once determined by either of these methods, flood discharges must be routed through the river valley to calculate the areas of channel overflow and so produce a flood hazard map. More direct methods of determining riverine flood areas include the recording of the outline of a large flood, by field survey or aerial photography, and the definition of the limits of the floodplain by detailed geomorphologic or soil mapping.

The flood risk, in terms of frequency of inundation, water depth, velocity and debris content, varies across the floodplain, and for this reason it is helpful to distinguish at least two separate zones of hazard: the floodway and the flood-fringe. The floodway is the central section of the total flooded area, the enlarged main channel that evacuates the flood discharge and has characteristically deep water, high velocities and much entrained debris. On either side of the floodway is the flood-fringe, an area of shallower, stiller water stored until levels in the floodway fall and it can drain back into the main channel. During this period of storage, sediments usually settle out and are deposited in the flood-fringe. This contrasts with the floodway, where erosion is much more common.

Because flood conditions vary according to the area, different land-use controls are appropriate to the two hazard zones. But flood severity also varies with time, and the floodway of a large and infrequent event may embrace the entire area affected by a smaller frequent flood. No absolute distinction can be made, therefore, and it is necessary to choose from the range of flood severities the one flood magnitude and frequency to be used to define the hazard zones for land-use control.

It is also possible to identify zones of hazard in relation to storm surges. Any low-lying area on a cyclone-prone coast may be vulnerable to floodings. As a tropical cyclone rapidly loses energy when it travels over rough ground, and the sea surge associated with it makes a limited inland penetration, severe damage may be confined to a relatively narrow coastal fringe, unless coastal lands are unusually low-lying, or even below sea-level. On a gently rising, wooded coastline, the hazard zone is narrower than on a coast of extensive, sparsely vegetated flats. But when a very long coastline lies exposed in a cyclone belt, such as the Bay of Bengal or the Atlantic coast of the United States, it is difficult to define areas of maximum hazard along the coastal strip.

Some cyclone tracks are fairly distinct and well-known, for instance where storm surges are funnelled into a bay, but in general, the point at which a cyclone will strike the coast is not predictable more than a few hours in advance. For safety's sake, land-use controls may need to be applied fairly consistently along the entire length of inhabited and vulnerable coastlines.

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14/ Disaster Prevention and Mitigation, Vol. II: Hydrological Aspects, UNDRO, Geneva, 1976.

The tsunami hazard is most pronounced in areas bordering the Pacific Ocean whose marginal areas are especially active seismically. Tsunamis reach their maximum height and inflict most damage where they meet embayed coastlines. Convergency of the energy of the wave and the seiche of the bay are the main factors increasing wave height. The strength of the generating earthquake is less influential on wave height than is the topography of sea floor and coastline. Bay-head locations are thus most prone to severe tsunami damage, although many hundreds of miles of coast may be affected less catastrophically.

The nature of the flood hazard at any particular location is an important determinant of appropriate land-use controls but not the sole determinant, as will be seen below. Within the floodway zone of a river, it is desirable to restrict land-uses to those which do not obstruct the passage of flood waters, to direct building development elsewhere and to design bridges with adequate openings. This saves new development from excessive damage from fast-flowing water and also protects existing land-uses by making sure that the flood hazard is not aggravated by obstructions. In the flood-fringe area of the floodplain there is a much wider range of land-use possibilities, including settlements, provided these are raised above flood level or made flood-proof by some other means.

In areas at risk from coastal flooding, there are no floodway requirements, but on grounds of hazard magnitude it may be desirable to direct new development away from certain low-lying sections. In general, however, land-use controls for coastal areas are more like those for the riverine flood-fringe, and may permit intensive use. Where the local economy allows them, changes in building practice may render structures more flood-resistant. The provision of escape routes, either inland to higher ground or upstairs to a higher level in a building, will help substantially to reduce loss of life, especially when evacuation is part of an emergency procedure based on the receipt of a flood warning.

(iv) <u>Legal measures for land-use control: principles and examples of their application in relation to flood hazards</u>

Some of the different legal devices described in chapter 4 have been employed to control land-use in the interests of flood disaster prevention, some applied singly, some in combination. Certain of them acknowledge in detail the spatial variability of hazard just discussed, by defining zones of differing flood risk with different permitted land-uses within them.

(a) <u>Encroachment lines</u>

This is probably the simplest form of control, applicable even in areas where other aspects of land-use planning are rather rudimentary. On a river, the designated floodway is preserved free of obstruction by setting encroachment or "set back" lines on either side of the river channel, between which no building is permitted. The encroachment lines are defined simply as x metres back from the centre line of the channel, or drawn on a map. Encroachment lines may be used in coastal areas also, to prevent building close to the shoreline where occasional high water will have damaging effects on settlements.

The River Law of Japan establishes encroachment lines and gives the river administrator the power to control land-uses within the designated floodway. In the United States land-uses near river channels may be controlled by encroachment lines, as in the State of Connecticut.

(b) Zoning

This is a more comprehensive method of land-use control. A local government divides its area of jurisdiction into zones of permitted land-uses - residential, industrial, public open space, agricultural and so on - in order to provide for all desired uses, to separate those which are incompatible or conflicting, and to promote harmonious development. Controls to reduce the damaging effects of floods are incorporated into the over-all land-use plan, often as a set of special provisions within the general zoning regulations. Figures 1, 2 and 3 show the definition of one floodplain zoning district where data on the hazard are rather limited, and of two floodplain districts where data permit the differentiation of floodway and flood-fringe zones. Such zoning is necessary if a community wants to qualify for government-subsidized flood insurance.

Three floodplain zones are commonly defined in the United Kingdom - the floodway required to pass a major flood; the flood-fringe required for water storage; and a third, additional area at risk from floods of even greater magnitudes. The principles of control applied to each zone are, for the first, prohibitive, for the second, restrictive, and for the third, precautionary.

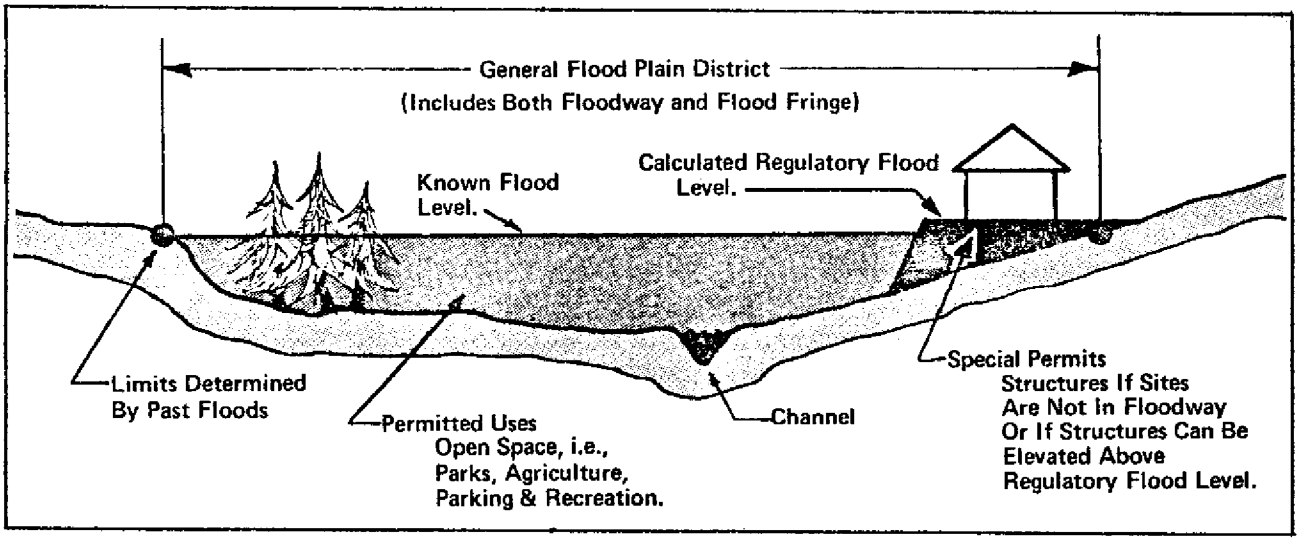
In the floodway, any obstructive development is prohibited and only open uses such as farmland or recreation are allowed. The purpose of this is to preserve a clear flood channel so that water can pass downstream efficiently, without backing up and increasing flood heights upstream. In the flood-fringe area the aim is to preserve adequate storage space for flood waters, so that the rate of discharge downstream is not accelerated by concentrating water into the floodway too rapidly. Development is restricted here, for instance, to essential public utilities or other developments for which compensatory storage can be provided. In the precautionary zone at the edge of the main flood hazard area, the water authorities may give advice on safe building levels or methods of construction, but in general they do not discourage development.

(c) Building codes

Building codes complement land-use zoning. They control building design and methods and materials of construction. They are applicable both in coastal regions and in river floodplains outside the main floodway. Special building standards intended to limit flood damages include elevation on fill, piles or stilts, construction in water-resistant materials, provision of bulkheads to close low-level entrances, and provision of refuge rooms with access from lower levels in the buildings.

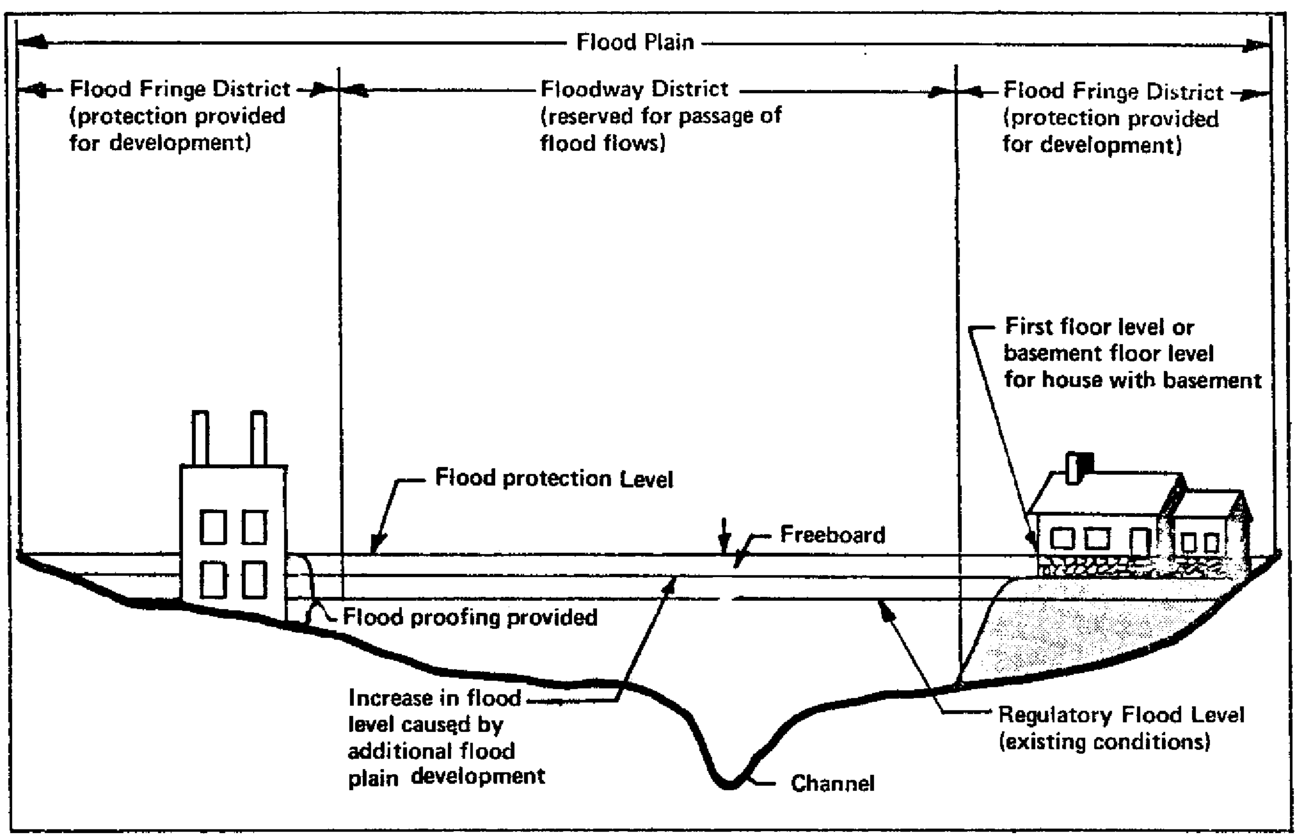
The coastal city of Nagoya, Japan, gives an example of the use of building codes to reduce flood damages and save lives. In September 1959 Nagoya was devastated by the Isewan cyclone. Over 5,000 people were drowned in the city and surrounding region. Areal differences in flood and damage characteristics, due mainly to topographic differences, led the city authorities and the Ministry of Construction to divide the region

Figure 1 Land-use zoning with one floodplain district



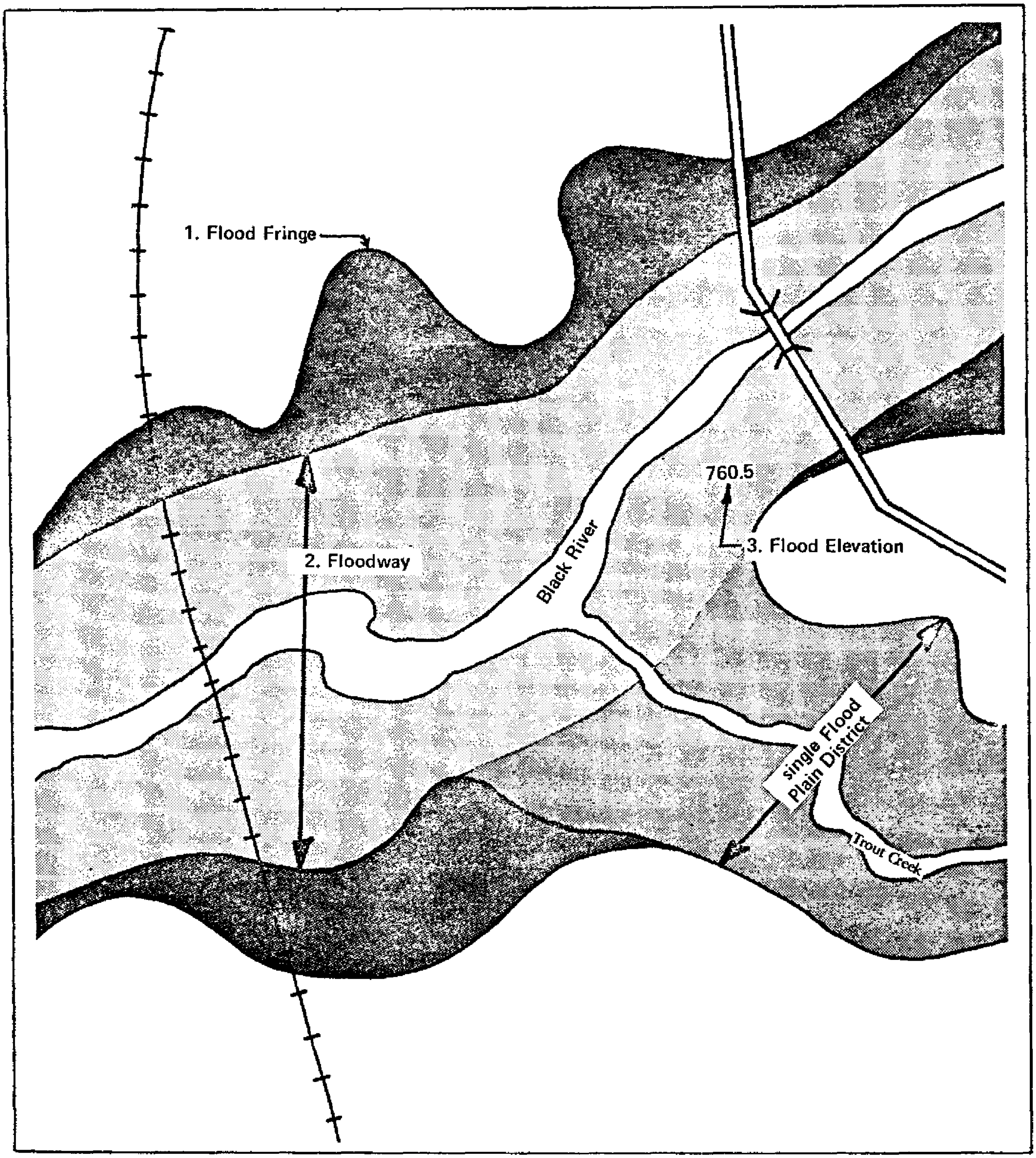

(from Kusler and Lee, 1972, p 45)

Figure 2 Land-use zoning with two floodplain districts




(from Kusler and Lee, 1972, p 44)

Figure 3 Land-use zoning on the Black River and Trout Creek




**On the Black River the two districts are used because data are available for determining the flood fringe (1) and floodway (2) and the flood elevation (3). On Trout Creek the single flood plain district is appropriate because data are unavailable for defining flood fringe, floodway, and flood elevation.**

(from Küsler and Lee, 1972, p 57)

into five flood zones and issue different building codes for each (see figure 4). These controls applied in the immediate reconstruction period and for longer-term development in the city.

To reduce flood damages and the danger to life, four measures are incorporated in Nagoya's building codes:

(i) Control of the elevation of the building site. For example, in area 1 around the Port of Nagoya, the minimum permitted elevation of building sites is 0.5 metres higher than the natural land surface and 1.5 metres above mean high tide in Nagoya Port.

(ii) Control of building materials and types of structural repairs. In certain zones wooden buildings are prohibited, and construction in concrete is insisted upon in particularly vulnerable places.

(iii) Control of the height of the ground floor and provision of refuge rooms. The purpose here is to provide safety for inhabitants and their movable possessions in time of flood.

(iv) Prohibition of houses, hotels and other residential buildings within a certain distance from the sea or river, for example, 50 metres in area 1. The purpose here is also to preserve life, keeping people away from the most dangerous areas.

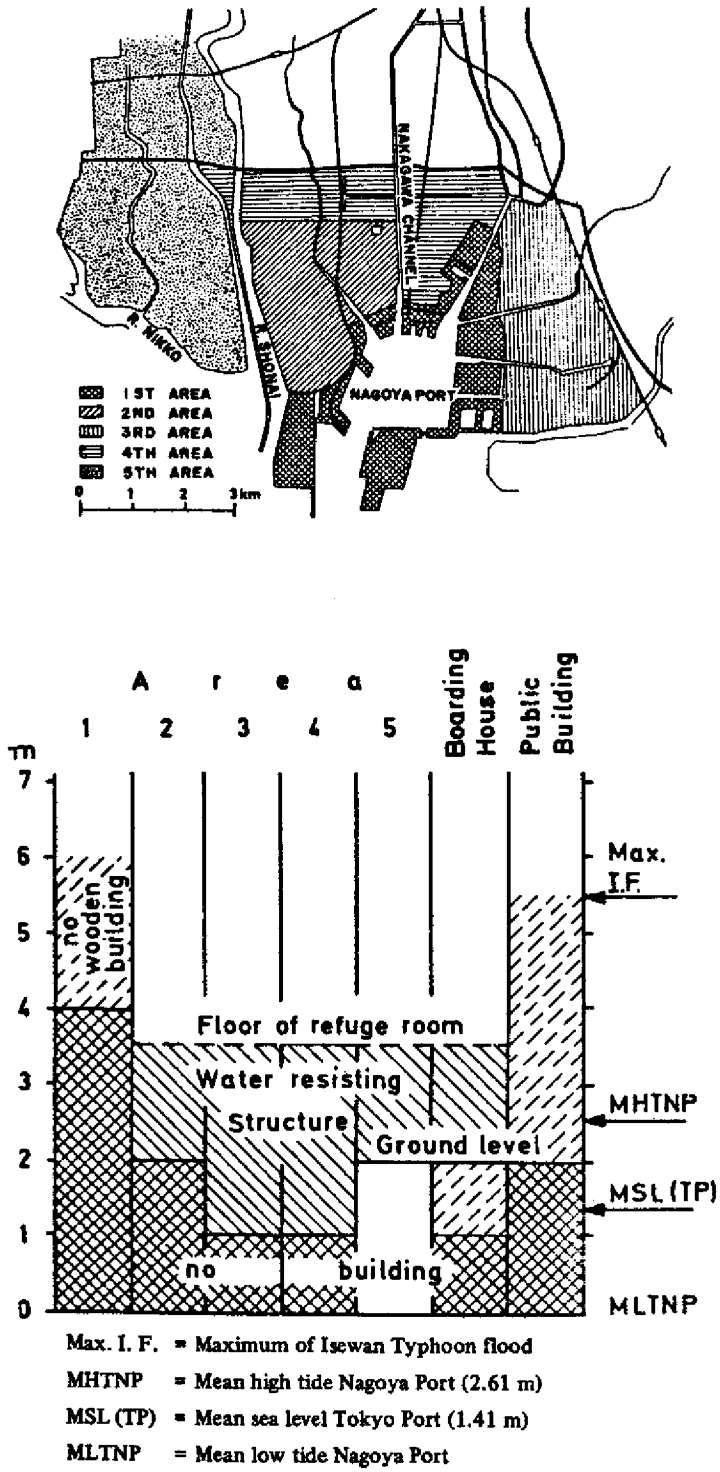
Such building codes are relevant where intensive development is required, as in Nagoya, which is a major port and industrial centre. On river floodplains, however, building codes alone will not suffice. In addition to the design of flood-proof buildings, an unobstructed floodway must be preserved free of all construction. On river floodplains building codes are thus most appropriate in the flood-fringe and precautionary zones.

(d) Public acquisition or purchase

The legal controls discussed above all refer to separately owned land. In the public interest they limit the landowner's rights to do as he likes with his land. As has been extensively discussed in previous chapters, in some cases such restriction would deprive the owner of any profitable private use, and here the government may choose to buy the land itself, compensating the owner and developing a worth-while public use where no private use is possible. A government may also choose to take responsibility for land because it is particularly suited to public use, for instance, as a nature reserve or parkland.

In Japan the central government contributes to a fund for the purchase and preservation of parkland areas along certain rivers, these open spaces serving as flood storage in times of high river flows or intense local rainfall. Hurricane Hazel in 1954 caused great destruction of property and the loss of 81 lives in Toronto's small, ravine-like valleys. The flood waters cleared away many obstructions and seriously damaged properties were not rebuilt. The Metropolitan Toronto and Region Conservation Authority is now buying this land, with

Figure 4   Flood zones and building codes in Nagoya, Japan




(from Oya, 1970, p 30)

federal, provincial and local government sharing the costs. Part of the total acreage is already in public ownership, and land-use zoning is a curb on development in areas scheduled for parkland but still in private hands. Toronto has a programme for progressive purchase of 7,500 acres of valley land to be used for recreational purposes.

(e) Re-location of flood-vulnerable settlements

This is not a separate legal device for land-use control, but several of those already discussed can be used to effect the relocation of especially vulnerable settlements, either through permanent evacuation to an alternative site on higher ground (lateral relocation) or through the raising of buildings above flood level on-site (vertical relocation). Zoning regulations can define the areas from which buildings should be moved and ensure the phasing out of nonconforming uses. Building codes can specify appropriate building levels and construction materials at the new site. Public purchase of land can provide the new site or put the abandoned old one to a beneficial use.

In India very large numbers of settlements have been shifted laterally or vertically. The government of the State of Gujarat has recently relocated on nearby higher ground about 300 villages lying in low areas along the Narmada and Tapti rivers, following catastrophic floods there in 1970. For lateral relocation to be feasible there must, of course, be higher ground nearby to receive the evacuated community. Villagers are reluctant to abandon fertile agricultural land, and relocated villages must be near enough to the floodplains to allow continuance of cultivation. Otherwise, the new villages will be abandoned or not occupied in the first place.

In regions of very wide, low floodplains the raising of villages may be possible where lateral relocation is not. In the State of Uttar Pradesh about 45,000 villages were raised during the Third Indian Five Year Plan (1961-1966). In some cases entire villages were raised above flood level. In other cases more limited raised platforms were constructed, on which the villagers can shelter along with their movable property and animals. Where a number of villages are located together, a common platform serves several of them. The raising of the ground level is an engineering task, not a matter of land-use regulation, but land-use regulation is an important adjunct, as it can limit building in unprotected areas, control building techniques and materials on the platforms, and safeguard lines of communication between settlements.

(f) Conservation

Finally, we consider land-use controls which preserve the existing vegetation cover in the interests of flood disaster mitigation. In a river catchment, especially in hilly or mountainous country, the control of run-off and erosion through programmes of water and soil conservation can have extremely beneficial effects downstream. In coastal areas, too, a tree cover can reduce the inland penetration of wind and water, as well as giving some brief refuge from a rising tide.

Malaysia's Land Conservation Act (1960) restricts forest clearing, cultivation and building in declared hill areas, except where special run-off and erosion controls are applied. These may cover the extent of the area to be cleared at any one time, the provision of flood storage basins and silt traps, and the depth and degree of compaction of builder's fill. The Forest Enactments and Rules also can control disturbance of the forest cover by regulating buildings, plantations, and tree felling and firing. In Bangladesh the coastal Sundarban forest, fringing part of the Bay of Bengal, plays an important role in cyclone damage prevention, and controls are in force to stop indiscriminate felling of trees.

(v) Socio-economic factors and the feasibility of land-use control

The type of land-use control appropriate in any particular area depends partly on the degree of physical hazard. It also depends on numerous human factors which have to do with the inhabitants' perceptions of the hazard they face and of the available means of altering the incidence of damage. The established way of life, existing land-use patterns, and pace of social and economic change will determine to a greater or lesser extent what regulated uses are to be recommended. By way of illustration, we consider two areas prone to severe coastal flooding - the Nagoya region of Japan and the coastal region of Bangladesh. The physical hazards are not dissimilar, but socio-economic factors lead to very different land-use responses.

We have already mentioned Nagoya's building codes designed to reduce flood damages. These must be seen in the context of large-scale reconstruction and expansion of economic activity, as reconstruction was associated not only with the local flood disaster but also with the national economic effort in the period of post-war development. The resulting building codes are sophisticated, recognizing locational differences in hazard characteristics and permitting intensive but safe land-use through an insistence on comparatively costly changes in building practice. Clearly, such codes would be less suitable where economic growth is very slow or where intensive land-use is not required.

Development plans for the Nabeta Polder near Nagoya illustrate another related point, that land-use change and control are fairly easy when development is large-scale and comprehensive. This approach, including methods of financing, have been described in the preceding chapter. The Nabeta Polder (figure 5) is a reclaimed area at the mouth of the Kiso River, where construction of sea dykes started in 1946. There were more than 100 farmhouses on the Polder before the 1959 flood, mostly single-storeyed and made of wood, strung out along the main roads. The slightly higher, inland portion was not settled, but used for upland crops. Of the Polder's 288 inhabitants, 125 were drowned by the cyclone. Houses and crops were destroyed and much of the surface soil was washed away. The fact that all the land was in public ownership facilitated restoration of the Polder with a quite different settlement pattern. Apparently little or no conflict of private interests disrupted the concept of a land development which was economically effective and advantageous for all concerned.

All farmhouses and public buildings are now concentrated in the north-west corner, where higher ground gives access inland. Houses are of reinforced concrete and three-storeyed. Shelter belts of trees have been planted to