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THE FLOODPLAIN AND THE SEASHORE*

A COMPARATIVE ANALYSIS OF HAZARD-ZONE OCCUPANCE

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THE United States is in danger today of embarking on a large-scale and costly program of coastal defense against storm hazard comparable with the program of flood control that has been operating in river valleys for the past quarter of a century. Federal legislation passed in 1936, and subsequently, has been largely the reason for the heavy investment in flood-control engineering works, to the neglect of possible alternatives. Yet appraisals of the flood-control program are in general agreement that despite federal expenditures of about five billion dollars, average annual damages from floods have continued to rise.[1] Nor is a brighter prospect held for the future. The Chief of Engineers stated in 1960 that at the present rate of expenditure flood protection will "just about keep up with the increase in flood damage that may be anticipated by 1980 as a result of flood plain development over the next two decades."[2]

A repetition of the same course of action with respect to coastal flood problems seems likely. The storm of March 5–8, 1962,[3] on the east coast of the United States (Fig. 1) focused attention on coastal storm damage. One informed official recently remarked that it seems unlikely Congress will be satisfied that it has done its duty by coastal constituents until an Atlantic Wall has been built from Maine to Mexico!

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[1] William G. Hoyt and Walter B. Langbein: Floods (Princeton, N. J., 1955), pp. 77–90; Gilbert F. White and others: Changes in Urban Occupance of Flood Plains in the United States, *Univ. of Chicago, Dept. of Geogr., Research Paper No. 57*, 1958, pp. 1–11; "Water Resources Activities in the United States: Floods and Flood Control," *Committee Print No. 15*, Select Committee on National Water Resources, U. S. Senate, 86th Congress, 2nd Session, 1960, p. 18.

[2] "Water Resources Activities" [see footnote 1 above], p. 29.

[3] For details of the storm see John Q. Stewart: The Great Atlantic Coast Tides of 5–8 March 1962, *Weatherwise*, Vol. 15, 1962, pp. 116–120. See also D. L. Harris: Coastal Flooding by the Storm of March 5–7, 1962 (U. S. Weather Bureau, unpublished manuscript).

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FIG. 1—Storm damage at Point O'Woods, Fire Island, N. Y., on March 7, 1962. (Photograph by United Press International.)

It is feared that more than one billion dollars could be spent on coastal protection by the federal government alone in the next fifteen to twenty years without any assurance that storm damage would be reduced; in fact, it might well be that average annual damages resulting from storms and saltwater flooding would be increasing by the 1980's. Because of long-term sea-level fluctuations and other factors, a program to "contain" the sea would seem to have as little chance for success as King Canute's attempt to command the waves.

Human Adjustments

A variety of human adjustments[4] have evolved in response to flood hazards in river valleys, of which engineering works are the most prominent. Others are permanent or emergency evacuation of population and property; bearing the losses with or without public relief; rescheduling of production so as to have low inventories at times of highest hazard; elevation of land; alteration of structures to make them flood-resistant; insurance; regulation and change of land use.[5] For prevention of flood damage a framework of human adjustments may be arranged as in Figure 2, a presentation widely used by the Tennessee Valley Authority.

Adjustments are also possible in coastal areas. The Chief of Engineers has declared that "in most cases, . . . on exposed reaches of shoreline, the principal reliance for reduction of damage from hurricane floods will probably have to rest with adequate warning service, proper building codes, evacuation plans and routes, and with the zoning of more hazardous areas."[6]

Thus there would appear to be a clear need for careful guidance in the human occupance of hazardous coastal areas. Such guidance will be more effective if based on studies of the rate of coastal development and the processes by which this development is advanced. The need for study applies to much of the United States coastal zone,[7] though public interest usually centers on areas of spectacular damage, such as the New Jersey coast, or on areas of controversy, such as Fire Island, New York, and Assateague Island, Maryland-Virginia, for which highway and bridge construction is being debated.

[4] The concept of human adjustment was first clearly proposed and developed in geographic literature by Harlan H. Barrows in his presidential address before the Association of American Geographers: Geography as Human Ecology, *Annals Assn. of Amer. Geogrs.*, Vol. 13, 1923, pp. 1–14.

[5] The classic statement of the range of human adjustments to flood hazard is Gilbert Fowler White's "Human Adjustment to Floods" (Dissertation, Ph.D., The University of Chicago, 1942; Chicago, 1945), pp. 128–204. Also published as *Univ. of Chicago, Dept. of Geogr., Research Paper No. 29.*

[6] "Water Resources Activities" [see footnote 1 above], p. 10.

[7] The Coast and Geodetic Survey estimates the total length of the tidal shoreline of the United States at 53,677 miles, exclusive of Alaska and Hawaii. If these states are included, the total is 88,633 miles.

The writers have recently turned their attention to problems of coastal areas,[8] beginning with a reconnaissance of parts of the east coast of the United States from Boston to Cape May, New Jersey. A major conclusion emerging

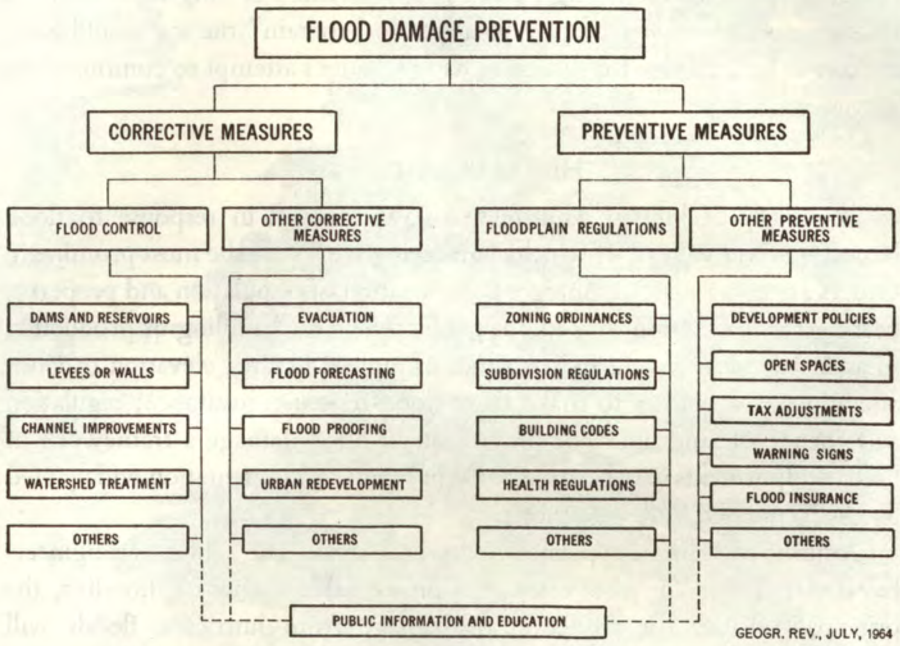

FIG. 2—A framework for flood-damage prevention, as formulated by the Tennessee Valley Authority, 1962.

from this work is that new damage potential is being created at an accelerating rate, by occupance of coastal areas subject to high winds, wave action, and saltwater flooding associated with storms. This occupance, however, is uneven and diverse. It appears to be influenced by a variety of factors, physical and cultural, but the relationships are poorly understood.

Basic to a better understanding of coastal occupance is some assessment of the rate of development in hazard areas. Indications may thus be obtained regarding rates of expansion over the next twenty to twenty-five years and the locations of areas of most rapid growth. A partial answer to the second of these questions is available. It seems reasonable to assume that the most rapid coastal development is occurring on the northeast coast in the urbanized area from Massachusetts Bay to the Potomac Valley, which Jean Gottmann

[8] For a guide to such study, the writers have drawn heavily on similar studies of flood-prone riverine areas. Two recent contributions are Ian Burton: Types of Agricultural Occupance of Flood Plains in the United States, *Univ. of Chicago, Dept. of Geogr., Research Paper No. 75,* 1962; and Robert William Kates: Hazard and Choice Perception in Flood Plain Management, *ibid., Research Paper No. 78,* 1962.

FIG. 3—Relative storm-surge potential of different coastal sections. Adapted from *National Hurricane Research Project Rept. No. 32*, U. S. Weather Bureau, Washington, 1959, Fig. 4 (p. 8).

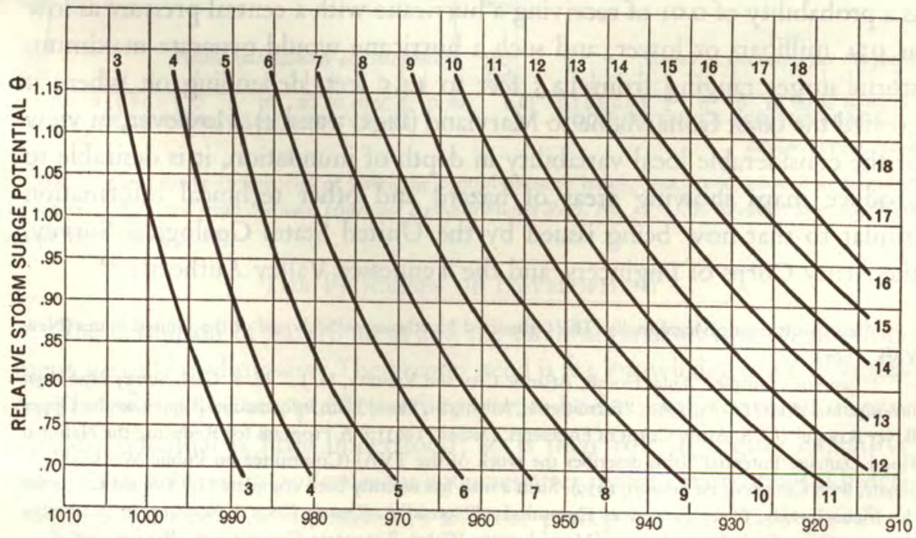

FIG. 4—Storm-surge prediction chart. Adapted from *National Hurricane Research Project Rept. No. 32*, U. S. Weather Bureau, Washington, 1959, Fig. 3 (p. 7).

has called Megalopolis.[9] Therefore, the need for better understanding of coastal occupance is probably nowhere greater than on the shores of this giant conurbation. It is not clear, for example, whether the rates of coastal development exceed those which might be expected elsewhere in Megalopolis or whether they are merely what might be expected in view of the rates of urban expansion being recorded in the conurbation as a whole.

Definition of Hazard Areas

In order that rates of encroachment may be established, the complex problem of defining the areas of hazard must be solved. As an interim measure, an arbitrary contour level may be selected, but a more satisfactory definition could be gained from a careful study of the factors that determined the height of surge in recorded storms. It may ultimately become possible to calculate theoretically the probable maximum elevation of tidal damage for given stretches of coast.

Storm-surge elevations at a given level of probability may be derived from empirical relationships established by the National Hurricane Research Project of the United States Weather Bureau (Figs. 3–5). Figure 3 represents the distribution of a topographic variable of storm surge Θ, which is based on the distance of the fifty-fathom depth contour from the shore. This variable Θ when related to the central pressure of a hurricane at the point of coastal entry provides an estimate of storm surge in feet (Fig. 4). Figure 5 introduces a probabilistic element by relating central pressure to frequency of occurrence. Thus the hurricane experience of 1900–1956 would suggest that there is a probability of 0.01 of receiving a hurricane with a central pressure as low as 931 millibars or lower, and such a hurricane would generate maximum storm surges ranging from 12.5 feet to 14.5 feet, depending on where it crossed the coast from Maine to Maryland (Figs. 3 and 4). However, in view of the considerable local variability in depth of inundation, it is desirable to produce maps showing areas of hazard and other technical information similar to that now being issued by the United States Geological Survey, the Army Corps of Engineers, and the Tennessee Valley Authority.[10]

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[9] Jean Gottmann: Megalopolis: The Urbanized Northeastern Seaboard of the United States (New York, 1961).

[10] See, for example, "Tidal Floods, Atlantic City and Vicinity, N. J.," *U. S. Geol. Survey Hydrologic Investigations Atlas HA-65*, 1962; "Farmington, Michigan, Flood Plain Information Report on the Upper River Rouge" (U. S. Army Corps of Engineers, Detroit, 1963); "A Program for Reducing the National Flood Damage Potential" [this describes the work of the TVA] (Committee on Public Works, U. S. Senate, 86th Congress, 1st Session, 1959). Such a map has recently been completed by Donald Crane for the Massachusetts Water Resources Commission (Donald A. Crane: Coastal Flooding in Barnstable County, Cape Cod, Massachusetts [Massachusetts Water Resources Commission, Boston, 1962]).

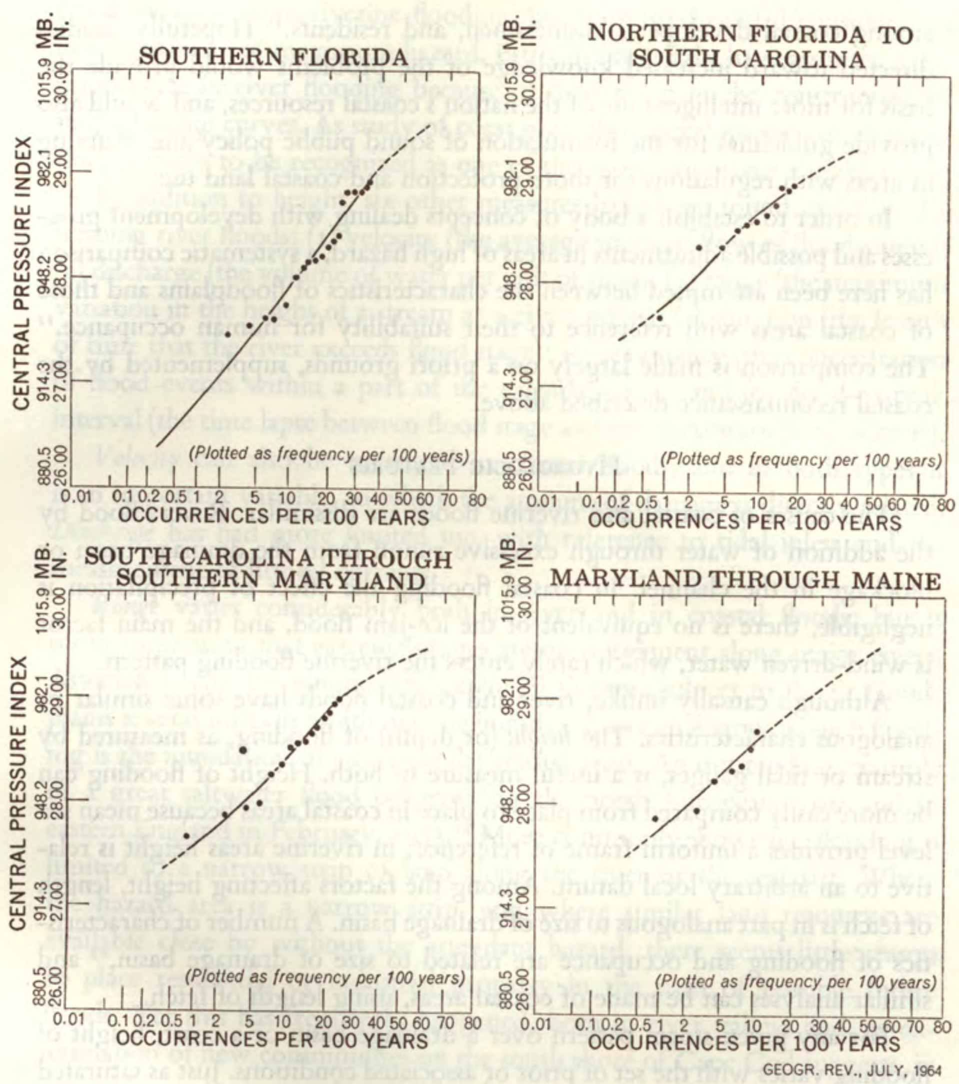

FIG. 5—Cumulative frequencies of hurricane central-pressure index, 1900–1956, plotted as frequency per 100 years. Adapted from *National Hurricane Research Project Rept. No. 33*, U. S. Weather Bureau, Washington, 1959, Fig. 4 (p. 23).

THE PROCESSES OF DEVELOPMENT

The definition of hazard areas and the establishment of rates of development are only preliminary. The greater need is for knowledge of the processes. The role of private, public, and corporate bodies in the creation of new damage potential is little understood; so is their role in urging expensive protection policies on government agencies after major catastrophes. Understanding is lacking of the attitudes and the perception of hazard prevalent among coastal developers, businessmen, and residents.[11] Hopefully, studies directed toward increased knowledge of the problems would provide the basis for more intelligent use of the nation's coastal resources, and would also provide guidelines for the formulation of sound public policy and planning in areas with regulations for shore protection and coastal land use.

In order to establish a body of concepts dealing with development processes and possible adjustments in areas of high hazard, a systematic comparison has here been attempted between the characteristics of floodplains and those of coastal areas with reference to their suitability for human occupance.[12] The comparison is made largely on a priori grounds, supplemented by the coastal reconnaissance described above.

Hydrologic Features

The causes of coastal and riverine floods are dissimilar. Rivers flood by the addition of water through excessive runoff from the drainage basin or blockage in the channel. In coastal flooding the effect of precipitation is negligible, there is no equivalent of the ice-jam flood, and the main factor is wind-driven water, which rarely enters the riverine flooding pattern.

Although causally unlike, river and coastal floods have some similar or analogous characteristics. The *height* (or depth) of flooding, as measured by stream or tidal gauges, is a useful measure in both. Height of flooding can be more easily compared from place to place in coastal areas because mean sea level provides a uniform frame of reference; in riverine areas height is relative to an arbitrary local datum. Among the factors affecting height, length of fetch is in part analogous to size of drainage basin. A number of characteristics of flooding and occupance are related to size of drainage basin,[13] and similar analyses can be made of coastal areas, using length of fetch.

For any given storm pattern over a drainage basin or a coast, height of flooding varies with the set of prior or associated conditions. Just as saturated or frozen ground increases runoff and produces a greater depth of inundation, so the coincidence of storms with high tides increases coastal flooding. Tidal fluctuations can be predicted with greater precision than associated or prior

[11] A discussion of the present state of knowledge may be found in Ian Burton and Robert W. Kates: The Perception of Natural Hazards in Resource Management, *Natural Resources Journ.*, Vol. 3, Albuquerque, 1964, pp. 412–441.

[12] A selected bibliography of floodplain literature is included in Gilbert F. White, edit.: Papers on Flood Problems, *Univ. of Chicago, Dept. of Geogr., Research Paper No. 70*, 1961, pp. 222–228.

[13] See, for example, Wolf Roder and Brian J. L. Berry: Associations between Expected Flood Damages and the Characteristics of Urban Flood Plains: A Factorial Analysis, *in* Papers on Flood Problems [see footnote 12 above], pp. 46–61.

conditions related to riverine flooding, but both need careful consideration in any estimate of maximum hazard. Estimates of height have assumed great importance in river flooding because of their value in the construction of stage-damage curves. As study of coast protection develops, height of storm tides is likely to be recognized as one of the more important variables.

In addition to height, six other measures have been found useful in describing river floods: (1) velocity (the average speed of flow of floodwaters); (2) discharge (the volume of water per unit of time); (3) range (the maximum variation in the height of a stream at a given point); (4) duration (the length of time that the river exceeds flood stage); (5) seasonality (the concentration of flood events within a part of the calendar year); and (6) flood-to-peak interval (the time lapse between flood stage and the maximum peak or crest).

Velocity can also be measured in coastal floods, and in both types it is an important variable, to which the amount of damage is directly related. *Discharge* has had more limited use, with reference to tidal inlets and the measurement of littoral currents.

Range varies considerably both in river and in coastal floods, but it is our impression that extreme ranges are more frequent along major rivers. Associated with the range is the extent of the area subject to flood. Floodplains several miles in width may be inundated, and analogous to such flooding is the inundation of extensive flat coastal areas. An outstanding example of a great saltwater flood occurred on the north European coast and in eastern England in February, 1953.[14] More commonly, however, flooding is limited to a narrow strip of land along the river or the seacoast. Where the hazard area is a narrow strip, and where similar land resources are available close by without the attendant hazard, there seems little reason to place residential or industrial property in the path of possible future floods. Yet this has frequently happened, both in river valleys and, as examination of new communities on the south shore of Cape Cod suggests, in coastal areas. Some purchasers of such property have been ignorant of the risk or have underestimated it.

Duration of flooding on floodplains is related to size of drainage basin and may be several days or even weeks, as in the backwater flooding in the delta of the Mississippi River. In a coastal area, "duration" may have the same meaning as in riverine areas with respect to slow-draining tidal marshes or a somewhat different meaning with respect to tide changes. Since a

[14] Hilda Grieve: The Great Tide: The Story of the 1953 Flood Disaster in Essex (Chelmsford, 1959). See also the Report of the Departmental Committee on Coastal Flooding (Waverley Report), [*British Command Paper*] *Cmd. 9165*, London, 1954.

storm tide represents an increment over normal high tide (storm surge), maximum damage and inundation accompany high tides. Storms that persist through several tidal changes are exponentially more severe than those of shorter duration. The duration is shortest with hurricanes and longest with extratropical storms. Thus it was the duration of the storm of March 5–8, 1962, through three successive high tides rather than the height of the storm surge that was the major damage factor.[15]

The duration of a flood affects occupance in a variety of ways. In urban areas prolonged floods increase indirect losses, such as the loss of business and wages resulting from delays, and the loss due to continued submersion, which weakens structures, warps floors, and the like. Duration is of even greater importance in agricultural areas, since crops that might have been partly salvaged after a short flood become total losses if the floodwater does not drain rapidly away.

The recoverability of losses due to the duration of a flood is a matter of considerable dispute. The business of a retail store in an urban area on the floodplain may be interrupted for several days, but when the flood has receded, the lost business may be recovered, since sales may be above normal for a period. But the manager of a business in a coastal resort who is forced by flood damage to close early in the season cannot recover his losses in the same way. "Purchase" of the commodity he supplies has been diverted elsewhere or prevented, and not merely postponed.[16]

Seasonality of floods permits adjustments, which may reduce damages, provided the seasonality is recognized and understood. For example, some farmers make deliberate adjustments by late planting or early harvesting to avoid having valuable crops in the ground during known periods of high hazard. A similar opportunity is provided by a well-defined season of hurricanes on the east coast, from August 1 to September 15, which contained 60 percent of the recorded occurrences from 1887 to 1956.[17] For example, those who wish to have a summer cottage on the beach in an exposed part of the coast could use a trailer or mobile dwelling, which would be removed to a safer place with the onset of the hurricane season or

[15] "Improvement of Storm Forecasting Procedures, Hearing before the Subcommittee on Oceanography of the Committee on Merchant Marine and Fisheries" (U. S. House of Representatives, 87th Congress, 2nd Session, 1962), pp. 2–3 and 22.

[16] From the national view many indirect losses are simply transfer payments from flooded to non-flooded areas, rather than actual losses of goods and services. However, when no alternative amenity is available to recreation seekers, a real loss of the amenity is experienced for a time.

[17] "Survey of Meteorological Factors Pertinent to Reduction of Loss of Life and Property in Hurricane Situations," *National Hurricane Research Project Rept. No. 5*, U. S. Weather Bureau, 1957, p. 16.

with early warning of an approaching hurricane. The danger lies in the unexpected, out-of-season storm, which may increase damage by catching floodplain or coastal residents unaware. However, improved forecasts and their dissemination seem to be reducing this danger.

A long *flood-to-peak interval* provides the time needed for pressing into action a variety of emergency adjustments to river floods. It also permits extended measurement and observation, leading to greater accuracy and dissemination of flood forecasts. Conversely, flash floods give little or no warning, and damage may be correspondingly increased, with possible loss of life. In coastal areas the growing threat of an offshore hurricane compares with a rising flood in major rivers, and an extended period of observation permits hurricane warnings to be widely disseminated well in advance. In some coastal areas, however, especially where storms may develop quickly and unexpectedly, tidal inundations occur much more rapidly and may in effect be almost instantaneous, a situation comparable with flash flooding.

Geomorphic Factors

The hydrologic characteristics of floods are affected by the configuration of the land surface. It is helpful, therefore, in examining flood-hazard areas to be able to classify them according to their geomorphic characteristics. Ohya and others working at the Ministry of Construction in Japan have developed a classification of flood types on this basis.[18] A classification of types of agricultural floodplain occupance in the United States has also been formulated.[19] Here we have attempted to classify coastal types and to relate them to their floodplain equivalents or analogues (Fig. 6). The typology is unlike other coastal classifications in that it is based on those characteristics which seem to us to be important for human occupance. To the coastal geomorphologist it will probably appear meaningless. Nor is the comparison with river floodplains intended to have genetic or morphological implications. This is a purely anthropocentric typology believed to have significance for present and potential occupance. It is not comprehensive, but merely representative of some of the more common kinds of floodplain and coastal terrain. It is based mainly on width and slope of the flood-prone area and presence or absence of natural protection, such as levees and dunes or terraces and raised beaches. Each main type can be subdivided by size class of material (boulders, gravel, shingle, and so on) or susceptibility to erosion, factors that have important implications for occupance.

[18] Fumio Tada and Masahiko Ohya: The Flood-Type and the Classification of the Topography, *in* Proceedings of IGU Regional Conference in Japan 1957 (Tokyo, 1959), pp. 192–196.

[19] Burton, *op. cit.* [see footnote 8 above].

Wide type. In an analysis of data from 104 cities with flood problems it was found that width of floodplain was directly related to size of city but inversely related to frequency of flooding.[20] It seems likely that the reverse

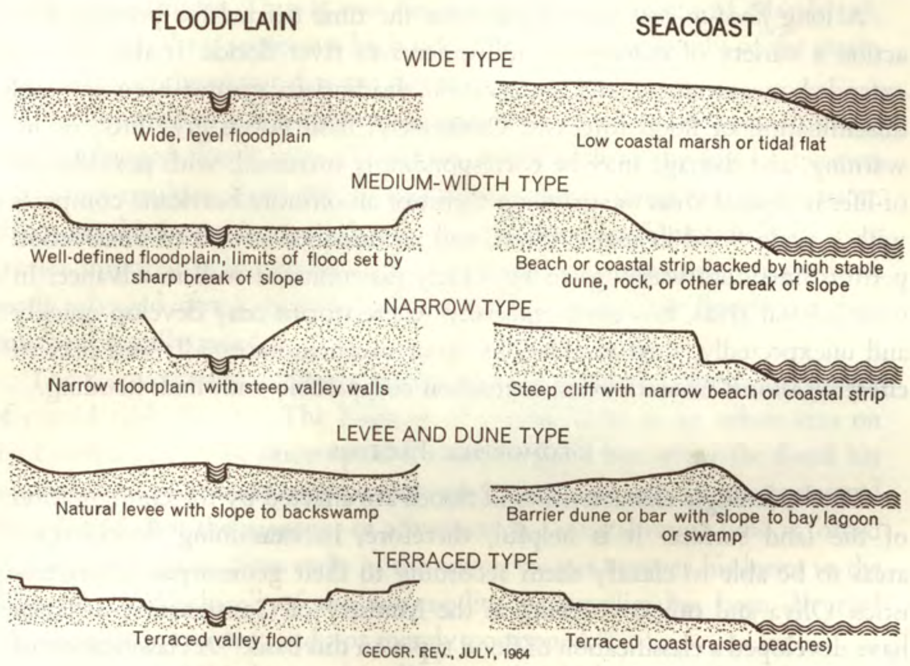

FIG. 6—A comparative typology of floodplains and seacoasts.

obtains in coastal areas; that is, where the coast is low and flat and the area subject to flooding is extensive, floods may be expected to occur more frequently, and large cities are noticeably absent. Floodplains and seacoasts of the wide type may be expected to share problems of high water table and poor drainage.

Medium-width type. Where hazard zones are smaller and well defined, it is surprising to find their use expanding and little concern apparent. Such, however, has been the case on urban floodplains and, though not yet observed, could conceivably be in process in coastal areas also. An example of the medium-width type is the stretch of coast included in the Cape Cod National Seashore. The high stable dunes provide a splendid view for the residents who live on top of them, without flood hazard. However, no evidence has been observed of expansion down the front face of the dune in such areas or onto the beach itself.

[20] Roder and Berry, *op. cit.* [see footnote 13 above], p. 48.

FIG. 7—Hazard, Kentucky, lying in the narrow valley of the North Fork of the Kentucky River, was inundated by floodwaters in March, 1963. (Photograph by Billy Davis, courtesy of *The Courier-Journal*, Louisville.)

FIG. 8—A levee successfully holds back floodwaters of the Mississippi River on the wide floodplain of the Yazoo Basin, May 29, 1961. (Photograph by the U. S. Army Corps of Engineers.)

Narrow type. The narrow floodplain in the steep-sided valley is difficult of access and often remains free from dense settlement. When settlement does take place under the press of local circumstances, buildings are crowded on the floodplain, and the potential for a devastating flood is created (Fig. 7). An example is the village of Lynmouth in north Devon, England, a small community crowded into the mouth of a narrow valley, which was virtually wiped out in August, 1952, by the rapid rise of a small stream following a torrential storm concentrated over its small watershed. Settlement is normally absent from the analogous coastal type, though the village of Hallsands is situated in such a position on the south Devon coast, and has suffered severe storm and flood damage, perhaps associated with increased hazard due to offshore dredging.[21]

Levee and dune type. Levees, dunes, and bars afford a degree of protection against high water levels, but they are not invulnerable, and severe damage may result when they are breached by man or nature. Property on the crest is destroyed in the area of the breach, and considerable volumes of water may flow through and inundate large areas. One characteristic of coastal occupance appears to be unique: there is no riverine analogue to the prevalent and continued destruction of coastal dunes to provide improved scenic views or building sites.

Terraced type. Terraced river valleys are common and provide safe sites for human occupance. Only the lowest terraces are subject to flooding, and that infrequently. Less common, but equally valuable as safe sites, are marine terraces, which may command a view of the ocean without undue exposure to its dangers.

The Role of Engineering

In certain river and coastal situations engineering works can be constructed to protect vulnerable areas. Where earth or sand can be used, artificial levees and dunes can be constructed. Floodwalls in some cities, and seawalls on some coasts, protect high-value property against damage. The dam has no exact equivalent in coastal engineering, though a hurricane dam is under construction at the mouth of the Providence River to protect the city of Providence, Rhode Island, and a plan is under study to build such a dam at the mouth of Narragansett Bay.[22] Coastal harbor walls and jetties are more common, but they do not strictly compare with dams.

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[21] See also Thomas Sheppard: The Lost Towns of the Yorkshire Coast (London, 1912).

[22] John B. McAleer: Hurricane Protection of Narragansett Bay, *Military Engineer*, Vol. 54, 1962, pp. 112–115.

It is worth stressing that there are great technical unknowns in both riverine and coastal engineering. The effects of a dam on a downstream river channel, or of a groin on a beach from which the littoral current is being deflected, are only partly understood. However, there appears to be greater uncertainty in coastal engineering, related in some fundamental way to the magnitudes of energy that can be dissipated on the coasts.

One conclusion emerging from studies of river floods is that protection against floods of a low order of magnitude but high frequency of occurrence may encourage more rapid development in hazardous areas and thus increase the damage potential for less frequent but higher-order floods. It is possible, therefore, that where protection in coastal areas is not accompanied by new zoning laws or building codes, further encroachment may be stimulated there also.

However, our coastal reconnaissance leads us to suggest that the reverse may likewise be true. If removal of a barrier dune (levee and dune type) increases the amenity of a coastal site by giving more houses a view of the ocean, further development may take place, with a resultant increase in the frequency of damage. Conversely, the obliteration of an ocean view by construction of an artificial dune may reduce amenity value and slow up development.

Construction of levees in agricultural areas may have what has been described as the "levee effect." Managers of farms severed by the levee may be tempted to farm the land between the levee and the river on a speculative basis, and may be better able to do so because of more secure farming behind the protection of the levee (Fig. 8). A coastal analogue is the construction of a house on the sea slope of a barrier dune, especially where this is a speculative venture in the hope of quick returns from high rents during a few storm-free seasons.

Watercourses are canalized in both coastal and riverine areas. Ditches pierce natural levees to provide improved drainage for backswamp areas, but they may also act as inlets for water from the main river, which flows into the backwaters and accentuates the flood problem. A coastal analogue is the construction of canals to provide waterfront sites for dwellings that may be hundreds of yards or even several miles from the open ocean; in this manner many more coast dwellers are able to keep a boat close to the house and sail out to sea. These same canals, however, provide avenues up which seawater can be wind-driven far inland and cause severe flood damage in previously safe localities.

Cultural Features

In an assessment of what adjustments should be made in floodplain settlement to minimize flood damage, the factors must be considered that induce men to settle on floodplains and remain there in spite of a demonstrated hazard. It is helpful, therefore, to compare the locational advantages of floodplain sites and coastal sites.

River valleys have played a traditional role as corridors, particularly through dissected terrain. They provide low-incline routes for highways and railroads as well as the medium for waterborne transport. Installations associated with these transport arteries, and activities benefiting from nearness to them, have tended to locate close to the river, and often on flood-prone land.

Coastal margins rarely provide such convenient paths. More normally, coastal settlements serve as termini. Coastwise movement of people and goods may result in the development of ports, but these are isolated settlements, and their sites are often selected for shelter from the ocean, so that storm damage is low. So far as transport utility is concerned, coastal settlements have a greater opportunity for judicious selection of sites, and by virtue of the nature of their business and their high degree of awareness of the potential force of the sea, they have a strong motive for seeking out places where they are protected from its full force.

The association with transport is only one of the locational advantages of rivers and coasts. In the case of rivers, easy disposal of waste, the supply of water, the opportunity to develop power, and the comparative advantage of level land for building have historically influenced settlement. With the deterioration in the quality of river water, the reduction in the adequacy of waterpower for modern industrial needs, the substitution of other modes of transport, and the advent of earth-moving machinery, much of the historical motivation for floodplain settlement has declined or even disappeared. Settlement itself has not declined, however, and continues, by inertia, to expand from its original foci.

Coasts possess some of the same advantages. Easy disposal of waste is an increasingly important asset of coastal location. The waste products from human activity, though still small in relation to the capacity of the ocean, present a growing problem, especially in estuaries and bays that provide a terminus for river-borne waste.

In most places the ocean is not considered a source of water supplies. Continuing technical advances in the process of desalinization, and the rising

FIGS. 9–11—Human adjustments to coastal hazards. (Captions opposite.)

cost of "fresh" water, suggest circumstances in which coastal locations could become highly favored, though not in the near future. Opportunity to develop power has also been absent in coastal areas. Modern technology, however, is changing this assessment of coastal resources. In the Rance estuary of northern France power stations are under construction that will use tidal fluctuations to turn the turbines.[23] Similar plans have been developed for Passamaquoddy Bay, on the Maine–New Brunswick border.[24]

The comparative advantage of level land cannot be said to exist to any great extent in coastal areas. But two other inducements are of great significance—access to the resources of the sea, and recreation. Fishing is of paramount importance and leads to the settlement of coastal areas that would otherwise be devoid of human habitation. As in the location of coastal settlements directed primarily to trade, sites were formerly selected that would minimize the effect of storms. Advances in coastal engineering now permit greater flexibility and attention to markets in the construction and expansion of port facilities.

Undoubtedly the main attraction of coastal areas today lies in their opportunities for recreational use.[25] This is a relatively minor factor in riverine situations, but on the coast it is the dominant reason for the rapid expansion of settlement in the past decade. An important aspect of the recreational amenity is proximity to the sea. The most favored sites overlook a fine sandy beach, with easy access to warm, calm water. There is a

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[23] Information on the Rance Tidal Power Station may be found in the French *Technical Bulletin No. 2,* 1962, pp. 1–11, issued by the French Embassy, Ottawa. See also R. Gibrat: L'exploitation d'une usine marémotrice en régime d'économie de charbon, *Bull. Soc. Française des Électriciens,* Vol. 2, 1962, pp. 136–143.

[24] "The International Passamaquoddy Tidal Power Project and Upper Saint John River Hydro-electric Power Development: Report to President John F. Kennedy . . . [by the Passamaquoddy-Saint John River Study Committee]" (U. S. Department of the Interior, 1963).

[25] The coastline of England and Wales has been thoroughly studied and classified according to quality of scenery, character of the coastal morphology, and patterns and type of human occupance. See the reports by J. A. Steers: Coastal Preservation and Planning, *Geogr. Journ.,* Vol. 104, 1944, pp. 7–27, and Vol. 107, 1946, pp. 57–60. See also "Seashore Preservation: Recreation Opportunities and Storm Damage" (U. S. Department of the Interior, National Park Service, Region 5, 1962).

FIG. 9—The value of deep-piling construction is well illustrated in the case of this $80,000 home, which before the storm of March 5–8, 1962, was firmly sited atop a sand dune. (Photograph courtesy *Eastern Shore Times,* Berlin, Md.)

FIG. 10—Branches and boards protect a clay dike at Bethany Beach, Delaware, and help hold the accumulation of sand. The dike was built by the State Highway Department. (Photograph by Robert W. Kates.)

FIG. 11—Sand fences erected by the National Park Service at Cape Hatteras National Seashore, North Carolina. This view shows a six months' accumulation of sand. (Photograph by Robert W. Kates.)

large extent of such seacoast in the eastern United States, and a thin ribbon of settlement (only in specially favored places is coastal settlement dense, and rarely does it extend far inland) tends to spread out along it. A situation is rapidly being reached, therefore, in which all seafront lots suitable for recreational use will be developed to some degree, so that wherever a storm or an exceptionally high tide strikes, some damage will result.

In both riverine and coastal locations the particular damage patterns we have observed appear somewhat random. There is a systematic variation in some of the factors at a particular place, but when all factors are considered, a random pattern is perhaps the most accurate description of the resulting damage.

The effect of flood damage on property values and on the social and economic status of the communities affected is complex. There is evidence to indicate that after heavy damage a community may never completely recover its former status. Examples are the decline of Narragansett Pier, which is attributed to the hurricane damage in 1938, and the more rapid decline of floodplain neighborhoods reported by Roder in his study of Topeka, Kansas.[26] On the other hand, rather poorly constructed buildings or sea defenses may be replaced by more substantial structures after a storm. Evidence of high-quality reconstruction after the March, 1962, storm was seen along the New Jersey coast in August from Cape May to the Barnegat Light.

It has been observed[27] that on river floodplains awareness of flood hazard is, in part, a function of the number of floods experienced. Also, farmers are known to have a keener awareness of hazard than city dwellers.[28] Our impression, after interviews with a number of managers of coastal property, is that they too have a greater awareness of the hazards of storms than is common among city dwellers on river floodplains. Even the seasonal coast dwellers, who see the sea only in its usually more placid summer mood, seem to share this heightened awareness. The presence of the sea, the impact of the tide on the imagination, the increasingly widespread ownership of boats, and the minimal knowledge of the weather that may be associated with such ownership all contribute to this awareness. The city floodplain dweller with no knowledge of flood hazard is common. The coast dweller without a little knowledge of storm potential has not been found.

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[26] Wolf Roder: Attitudes and Knowledge on the Topeka Flood Plain, *in* Papers on Flood Problems [see footnote 12 above], pp. 62–83.

[27] Kates, *op. cit.* [see footnote 8 above].

[28] Burton, *op. cit.* [see footnote 8 above].

Nevertheless, coast dwellers, while showing a more realistic appreciation of what is possible, tend to be optimistic in their assessments of the frequency, likelihood, or probability of storm damage. They also tend to underestimate the possible severity of such damage. It might be safe to forecast that increased coastal protection will develop an even greater sense of confidence, without a corresponding increase in security.

If our appraisal of the coastal flood problem is correct, it follows that there is urgent need for further research and for greater understanding not only of the nature and degree of the hazard itself but, especially, of the process and rate of settlement in hazard areas. Such understanding may help to promote a more rational approach to the management of coastal lands.

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