CLASSIFICATION OF FLOODS

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Summary

Flood is a consequence of migration of the boundary between land and water bodies, reflecting the normal interaction of the atmosphere, hydrosphere and lithosphere. Two major factors are responsible for flood generation and impart specific features to it. The first is the physical process, which generates the change of position between the lithosphere, atmosphere and hydrosphere. Secondly, the flooded area, depth of inundation, and its duration, depend on the geographic situation in the region where the flood takes place. Due to the great variety in operation of the natural processes and the endless variation in the condition of the geographic arena where they act, many different kinds and scales of floods can be distinguished. There are at least 18 major kinds of floods of natural origin. Growing human influence is becoming evident from the increasing frequency of floods of anthropogenic origin.

1. Introduction

The area of the continents and islands of the Earth occupies only about 29% of the global surface area, The area of the World Ocean, plus the inland seas, rivers, lakes and reservoirs is therefore around 71%. These figures can be regarded as the area of two great spheres—the lithosphere and the hydrosphere. These spheres interact with the atmosphere and this affects the position of the borders between the land and the water masses of the hydrosphere. The water of the Earth's hydrosphere is characterized by extremely high mobility. Currents and waves are generated by gravity, changes of pressure in water and movements of air masses at the surface between water and the atmosphere. As a result, there is practically continuous movement of the borders between dry land and water masses. Movements of these borders, resulting in temporary flooding, can be called inundations.

The significance of flood as a natural phenomenon appears only in the context of human perception. Flood is commonly defined as an overflow of water onto lands that are used or are usable by man, and are not normally covered by water. Floods have two essential characteristics: the inundation of land is temporary; and the land is adjacent to and inundated by overflow from a river, stream, lake, or ocean.

Another, more general definition states that flood is determined as a general and temporary condition of partial or complete inundation of normally dry land areas from overflow of inland or tidal waters, or from the unusual and rapid accumulation or run-off of surface water from any source.

There is one important detail in the above definitions that remains vague, namely the short duration of flood. When considering this, one should take into account that one of the most important divisions of time scale for humans is a year. Numerous natural cyclic processes are completed during this period of time. The same concerns the individual and the social lives of human beings. In particular, climatic seasons change predictably over a period of one year. Large amounts of precipitation may be typical of a particular season and, accordingly, there may be a high probability or even inevitability of floods at that time. This is why floods and their negative effects on populations and economies are most pronounced in the time span up to one year.

Therefore, following the above arguments, floods are considered as short-term or seasonal events. For example, the inundation of coastal land caused by the rise in the

level of the Caspian Sea, which has taken place over the past decade, should not be regarded as flooding, but as a short-term transgression of the sea.

Another feature used in categorization of flood is the origin of flood-forming waters. Both underground water and precipitation can contribute to flooding. In urbanized areas, the area of which grows constantly throughout the world, rainstorm precipitation often generates rapid and powerful floods which inundate inhabited areas. Catastrophic floods can also be caused by melting of glacier waters, a different form of surface water. It is clear that inundations caused only by a single type of water, e.g. a river, lake, sea, or ocean, are merely a part of the range of possible kinds of floods.

Hence, a useful definition of flood can be formulated thus: Flood is a short-term or seasonal inundation of Earth's dry land areas by water from any source and due to action of different forces and under the influence of various factors.

It is known that the hydrosphere participates in continuous water exchange between the atmosphere and the lithosphere. Evaporation from water surfaces, initiated by solar energy, transforms a vast amount of water from oceans, seas, lakes, and rivers into atmospheric vapor. Water vapor transported by air streams is then a source of atmospheric precipitation over the land surface. Precipitation recharges water resources in the aquifers of the lithosphere and in water reservoirs of the land surface, and it generates river run-off.

The spatial and temporal distribution of precipitation over the land surface is uneven. Heavy rains occur periodically on different parts of the Earth's land area and cause flooding. Drainage of such waters is often slow and this increases the flooding effect.

Thus, fluctuation of the position of the boundaries between land and the waters of the hydrosphere on the Earth's surface is the essential cause of flooding. The migrating boundary between land and water reflects the "normal" interaction of the atmosphere, hydrosphere and lithosphere. This factor operates continuously, without normally changing the appearance of the landscape, but abnormally high activity and dynamics cause instability of the location of the boundary between land and water. Because of humans' limited capability to adapt, live, and act in conditions of very rapid environmental change, the inconstancy of these boundaries often becomes critical for human existence and economic development.

Since the time of humans' first appearance on the Earth, and up to the present, land areas located close to water bodies have been attractive for settlement by people. These places include the sea and ocean coasts, riverside areas, and the shores of lakes and artificial water reservoirs. There are many reasons for this choice.

Access to water is very important for humans, as fresh water is one of the vitally essential materials for direct consumption. Waterside areas are exceptional for their increased biological productivity, both on land and in water. Water-borne transport links between remote regions of the world were very important in ancient times, as they are today. Valuable recreational and balneal resources are concentrated near land and water. The microclimate on coasts, and even on the shores of large rivers, is more comfortable

for living than in the inland parts of the continents. All this makes coastal areas attractive for locating human settlements and economic facilities. For example, in the early 1990s, more than 50% of the population of USA resided in maritime regions. A similar proportion of the population of Japan live in coastal areas and the same is true of many other countries. Coastal land is well suited for prime development of cities, as their location offers significant economic advantages for development, providing access to the resources of remote regions by water-based transport. There are similar benefits of proximity to water beside lakes, large water reservoirs, on rivers.

Thus humans have always favored land where the power of the hydrospheric, atmospheric, and lithospheric interaction is high and where the probability of natural hazards, including floods, is also high. So human attitudes to water and floods, as one attribute of a rapidly changing environment, is ambivalent. By nature, humans are terrestrial creatures. Because of their physiology, humans are not able to live in half-submerged dwellings or on swampy land. Similarly, human activity, economic infrastructure, and technology need to operate in the medium of air. At the same time, the existence and development of the human civilization is impossible without permanent and diverse use of water resources. Even human living and activity is most comfortable and effective at locations that are in direct proximity to water bodies.

The largest floods have been engraved on the memory of humankind. The human perception of floods—one of the most powerful manifestations of nature's forces—was reflected in the legend about the Flood. This has been disseminated among many nations of the World since ancient times. One of the earliest written versions is the shumer story about Gilgamesh, recorded in cuneiform inscription on clay plates in about the twenty-first century B.C. Accordingly to Gilgamesh's legend, the Flood occurred in extreme antiquity. Continuous rain which lasted seven days and winds of hurricane strength were the causes of the Flood. Only Utnapishty, who built the ark for his family and different animals, escaped death.

The shumer legend about the Flood found its reverberation in the Bible, in texts dated approximately from the ninth century B.C. While differing in certain details, both sources are identical on the main points——the catastrophic scale of the Flood and its place of origin on the Mesopotamian plain.

During contemporary history, legends about the Flood have been regarded as myths, as elements of the epic literature of different nations. They were not regarded by scientists as the reflection of real events, but were treated as consequences of the limited knowledge of ancient communities about their surroundings, and their understandable fear of natural phenomena such as flood. In reality, floods could have covered considerable parts of the world that was known to humans, but these were relatively small parts of the Earth, which had been settled by different populations.

Only recently, confirmation of enormous floods that occurred in the Holocene in Eurasia was derived by analysis of a large set of data. These floods extended over vast areas in western Siberia, the basins of the Aral, Caspian, Black and Azov Seas, and even approached the Mediterranean. The largest floods took place 12,000 10,000 and 7000

years ago. They caused tremendous transformation of the Earth's surface and changed river networks over vast areas.

2. Factors and Conditions of Flood Generation

Various factors, processes, and their combinations can induce floods. Generally, two major factors usually combine to generate floods and determine their specific characteristics. The first is the physical process that generates the change in the interaction of the lithosphere, atmosphere and water masses. The second depends on the geographic situation in the area where the flood takes place, and this determines the scale of a flood, such as the area and depth of inundation, and its duration. Regional specificity, including climatic conditions, determines the most characteristic features of floods and their recurrence. The role of the geographic situation in giving rise to floods is very important. For instance, heavy rains can be the cause of inundation in river valleys, but they never create floods on sea coasts. In the same way, storms generate surges on low-lying shores of seas and lakes, but never create surges on shores with elevated and steep coasts.

Floods can be classified by the factors and conditions of their generation. Thus, river floods comprise one large category, and inundations of shores of lakes and seas are another. Large scale floods that originate from, and are exacerbated by, human activity can be put into a specific group. Felling of forests, drainage of wetlands, and urbanization are the major causes of rapid increase in the flow of rivers, giving rise to floods. Reservoir construction, in addition to changing river flow regime can also trigger a number of other negative consequences that promote flooding. They are flood-flush to tail bays, under flooding of coastal lands, and flash flood waves caused by dam failure. Other kinds of flooding are deliberate land inundation for irrigation, and human-made tsunamis as a secondary effect of underwater nuclear explosions.

The scales and power of floods are usually quantified in terms of their recurrence interval (their probabilities of recurrence). This is related to various characteristics such as depth of inundation in a particular location, height of stage in a river, etc. This can be explained using an example of occurrence of river floods in a river cross-section (Figure 1).

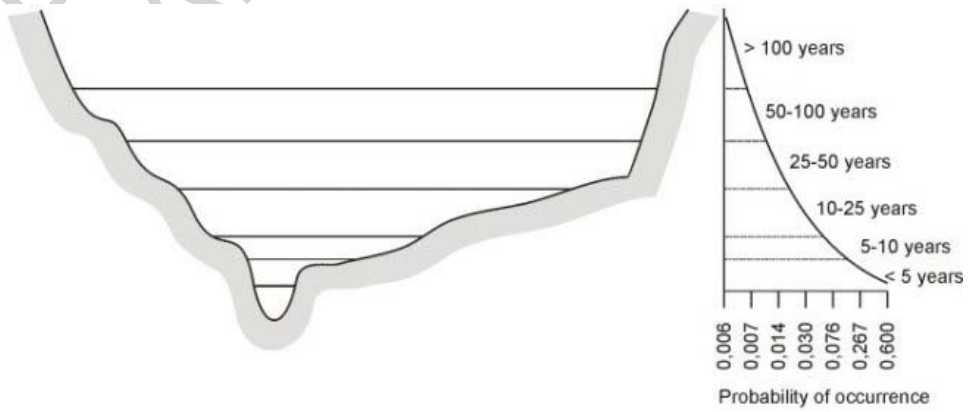

Figure 1. Floods in a river cross-section.

It is evident that high stage rise in a river and, accordingly, high depth of inundation, are rather rare events. Floods with low stage rise are the most probable. Such events can occur annually and even several times a year. For the specific conditions of a given river valley, flood recurrence is determined by the use of long-term hydrologic observation in the cross-section of the river under consideration, or by special calculation. A probabilistic approach is also used for estimation of the power of other flood categories whose causes and factors of generation are repeated regularly or periodically. The power of floods initiated by sporadic causes, such as dam destruction, volcanic eruption and the like, can only be assessed from observation of the single event. In such cases the criteria for flood assessment are not so strict and to some degree are more subjective.

The effects of a flood on the inundated land and the property located there will differ, depending on local factors and conditions, and where the flood originates. The main effects are from accumulation of water and the dynamic impact of flowing water during the movement of a flood wave. In specific conditions, the effects of a flood depend on a large number of additional circumstances, such as depth and duration of inundation, velocity of the flood's wave movement along the river, height and velocity of tsunami wave travel, and so forth. Accordingly, the protection and mitigation measures for floods vary greatly too. These are described for each kind of flood in the following sections.

3. River Floods

Inundations in river valleys are the most widespread and frequent type of flood, and they are caused by waves of high waters running downstream. Various mechanisms are responsible for generation of flood waves, but, despite their different proximate causes, they can all be attributed to removal of excess water from a river catchment.

The integrated characteristic of a flood occurring in any river is a hydrograph; this reflects the change in time of the flow rate and magnitude of run-off for a given river cross-section (Figure 2). A hydrograph is a flood "image", describing the distribution of flood volume over time. Its specific features are not the same for floods of different origins. Hydrograph volume and shape depend on the intensity and duration of rainfall or snow melt, the size and shape of the river watershed and the river network, topography, soil moisture, the type of vegetation cover, and land-use. The characteristic features of floods expressed by a hydrograph are maximum discharge, the duration of the flood rise and recession phases, the total volume of flood, and flood asymmetry, expressed as a ratio of flood rise to recession. The inundation caused by a flood, its scale and consequences for nature and humans, depend only on the flood rise rate, maximum discharge and duration.

As a flood wave moves downstream from its area of origin, the channel routing modifies the shape of the hydrograph, increasing the time of flood rise and the total duration, and decreasing its asymmetry. Flood rise is not steady along a river. It increases in narrow stream channels, and decreases along river reaches where the channel width is greater. The speed of a flood wave is slowed by obstacles, constrictions and dams in the river channel. These may include ice gorges, log dams, etc.

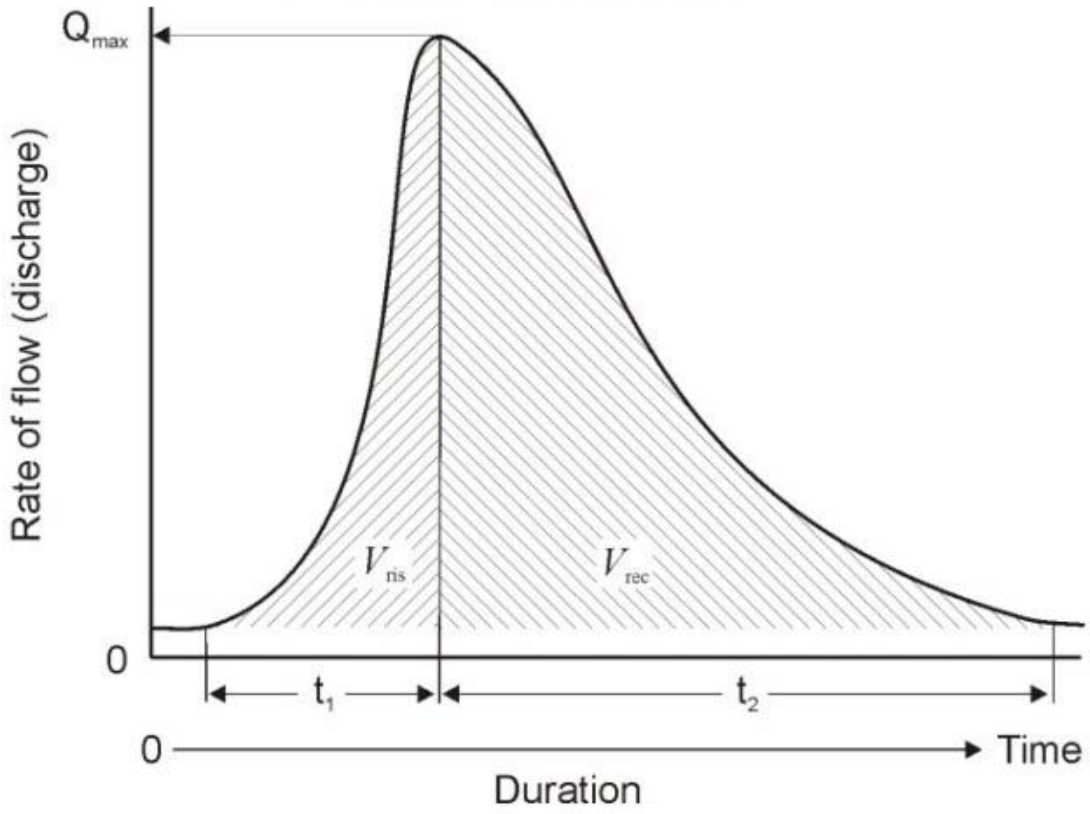

Figure 2. Basic characteristics of flood wave's hydrograph: t_1 - duration of the flood rising phase, t_2 - duration of the recession phase, V - flood volume ($V = V_{ris} + V_{rec}$), V_{ris} - volume of rising phase, V_{rec} - volume of recession phase, $Q_{\max}$ - maximum flood's discharge, υ - coefficient of flood hydrograph asymmetry (t_1 / t_2)

The characteristic features of inundation caused by floods, such as depth and duration of standing on any area are controlled by factors of flood origin and the conditions of its downstream passage. High flow occurs each year in many rivers of the world, causing inundation of their floodplains. Usually, high flow occurs in the same season, but meteorological conditions obviously change the rate and duration of river flow in a given year. Prolonged high flow leading to flood is caused by increased water input into the watershed system, caused by rain or snowmelt, usually during the wet season. In regions of temperate climate, this occurs in lowland rivers in spring due to the melting of snow accumulated in the watershed over the winter. Floods in sub-arctic rivers, caused by melted snow, begin in late spring and last through the summer. In rivers whose headwaters are in high mountains, melting snow and glaciers generate high flow in the summer months. In areas of monsoon climate, high flow occurs during the monsoon season, and in the tropical zones, the causes of increased run-off can be cyclones and zenithal rains.

Several kinds of river floods can be distinguished on geophysical grounds or from the conditions of their generation (Table 1). River floods in various areas differ as a result of different sources of river flow, time and conditions of flood generation, as set out in Table 1.

Type	Name	Main factors of generation	Recurrence
River floods	Long duration spring floods	Spring–summer melting of snow and ice	Seasonal
	Short duration spring flood	Snow melting during thaws	Irregular
	Ice gorge floods	Accumulation of ice-floes in river channel during ice drift	Seasonal
	Ice jam floods	Congestion of river cross section during autumn ice drift or at the beginning of freeze-up	Seasonal
	Long duration storm floods	Precipitation in rainy season in tropics	Seasonal
	Monsoon floods	Precipitation of summer monsoon	Seasonal
	Flash floods	Rainstorms	Sporadic
	Floods of dam break	Break of dammed lakes; release of internal glacier water or moraine lakes; destruction of human-made dams	Sporadic
	Backwater floods	Flood wave hindrance at narrowing of river channel or its sharp turn, at barriers (log dams, etc.), due to stage rise in principal river or water body	Regular and irregular
	Mudflows	Rainstorms; rapid melting of snow and ice; break floods; availability of large volume of loose material on river watershed	Sporadic
	Icing	Outlet on surface of land or river ice cover and freezing of waters from river, lake or ground	Seasonal
Floods on coasts of open seas and oceans	Tides	Attraction of the Earth, Moon and Sun; latitude, depth of offshore sea and coastal line shape	Regular
	Surges	Strong and prolonged wind; lowland coast; water yield in river	Irregular
	Tsunami	Earthquakes with sources of origin in ocean or sea; landslides on slope of continental shelf; volcanic eruptions	Sporadic
Floods on coasts of inland seas and lakes	Surges	Strong and prolonged wind; lowland coast	Irregular
	Seasonal inundations	Seasonal change of water budget of endorheic lake	Seasonal
	Seiches	Wind surges; precipitation; air pressure change; seismic shake	Irregular
	Tsunami	Earthquakes and eruption of volcanoes in the region of a sea or a lake	Sporadic

Table 1. Types of natural floods

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Bibliography

Aleksyeev V.R., Savko N.F. (1975) *Theory of icing processes*, 204 p. Moscow, USSR: Science [In Russian. This book contains a comprehensive analysis of factors and processes of icing and ice gorges formation in rivers.]

Bolt B.A., Horn W.L., Macdonald G.A., Scott R.F. (1977) *Geological hazards*, 440 p., Berlin, Heidelberg, New York: Springer-Verlag. [This is an outline of natural hazards including many types of floods on the basis of scientific conceptions of their generation.]

Chromov S.P., Mamontova L.I. (1974) *Meteorological dictionary*, 568 p. Leningrad, USSR: Hydrometeorological Publishing House [In Russian. This is a comprehensive scientific dictionary of meteorological and related hydrologic terms.]

Grosswald M.G. (1999) *Cataclysmic mega floods in Eurasia and the polar ice sheets*, 118 p. Moscow: Scientific World. [In Russian. This is an an essay in geomorphologic analysis of continental paleohydrological systems.]

Nevada Division of Water Planning, *Water Words Dictionary*, http://www.state.nv.us/cnr/ndwp.home.htp [Accessed in April 2000. This is a detailed dictionary of water related terms including definition of flood that is currently in wide use.]

Pyaskovskyi R.V., Pomeranets K.S. (1982) *Floods*, 176 p. Leningrad, USSR: Hydrometeorological Publishing House [In Russian. This book describes the elements of physical theory of river flood, tsunami and wind surge generation.]

Vinogradov Yu.B. (1980) *Assays on mudflows*, 144 p. Leningrad, USSR: Hydrometeorological Publishing House [In Russian. The natural processes that cause mudflows are described in the book.]

Biographical Sketch

Anatoliy Fedorovitch Mandych was born in November 1936 in Ukraine. His initial professional education in hydrology was received in the Hydrometeorological College in Kharkov (Ukraine, 1951-1955). He graduated in the Geographical Faculty of Moscow State University (1955-1960), and later took a post-graduated course there (1963-1967). His specialty is that of geographer-hydrologist (science degree – Candidate of Science).

His professional experience was obtained through participation in hydrology related research at the Institute of Forest and Timber, Siberian Branch of USSR Academy of Sciences (Krasnoyarsk, 1960-1963), in Moscow State University, Geographical Faculty (1963-1967; 1972), in the USSR Research Institute of Hydrometeorological Information, World Data Center (1967-1972), in the Pacific Institute of Geography, Far Eastern Center of the USSR Academy of Sciences (Vladivostok, 1973-1978), in the Institute of Multidisciplinary Research (Khabarovsk, 1978-1984), and in the Institute of Geography, Russian Academy of Sciences (Moscow, from 1984 to the present). His key qualifications are as a hydrologist and landscape ecologist. His main fields of scientific interest are landscape hydrology, the hydrological cycle on the landscape scale, sediment transport by rivers, water resources and their transformation by human impact.

His current position is Head of the Center for Coastal and Barrier Geographic System Studies in the Institute of Geography. He has published over 80 scientific works and made over 60 presentations at scientific meetings.