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The World's Largest Floods, Past and Present: Their Causes and Magnitudes

Circular 1254

U.S. Department of the Interior
U.S. Geological Survey

Cover: A man rows past houses flooded by the Yangtze River in Yueyang, Hunan Province, China, July 1998. The flood, one of the worst on record, killed more than 4,000 people and drove millions from their homes. (AP/Wide World Photos)

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Gale A. Norton, Secretary

U.S. Geological Survey
Charles G. Groat, Director

U.S. Geological Survey, Reston, Virginia: 2004

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Suggested citation: O'Connor, J.E., and Costa, J.E., 2004, The world's largest floods, past and present—Their causes and magnitudes: U.S. Geological Survey Circular 1254, 13 p.

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Conversion Factors

Multiply	By	To obtain
Length		
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
Area		
square kilometer (km^2)	0.3861	square mile (mi^2)
Volume		
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
cubic kilometer (km^3)	0.2399	cubic mile (mi^3)

Geologic Time Terms

Quaternary period: About 1.8 million years ago to the present

Pleistocene epoch: A division of the Quaternary period extending from about 1.8 million years ago to about 10,000 years ago. Also known as "The Great Ice Age"

Holocene epoch: A division of the Quaternary period extending from about 10,000 years ago to the present

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Introduction

Floods are among the most powerful forces on earth. Human societies worldwide have lived and died with floods from the very beginning, spawning a prominent role for floods within legends, religions, and history. Inspired by such accounts, geologists, hydrologists, and historians have studied the role of floods on humanity and its supporting ecosystems, resulting in new appreciation for the many-faceted role of floods in shaping our world. Part of this appreciation stems from ongoing analysis of long-term streamflow measurements, such as those recorded by the U.S. Geological Survey's (USGS) streamflow gaging network. But the recognition of the important role of flooding in shaping our cultural and physical landscape also owes to increased understanding of the variety of mechanisms that cause floods and how the types and magnitudes of floods can vary with time and space. The USGS has contributed to this understanding through more than a century of diverse research activities on many aspects of floods, including their causes, effects, and hazards. This Circular summarizes a facet of this research by describing the causes and magnitudes of the world's largest floods, including those measured and described by modern methods in historic times, as well as floods of prehistoric times, for which the only records are those left by the floods themselves.

Residents of Dhaka, Bangladesh, carry drinking water as they wade through floodwaters caused by three weeks of rain in 1986. Three rivers—the Ganges, Brahmaputra, and Meghna—left their banks, killing more than 1,000 people and stranding millions. (AP/Wide World photos)

Two complimentary types of information are used in this summary of the world's largest floods. The first is a compilation of the world's largest known Quaternary floods. (The Quaternary period extends from about 1.8 million years ago to the present.) Some of these floods are known only from geologic evidence and resulted from special circumstances during the course of Earth's history. Nevertheless, the records of such floods shed light on the great diversity and scales of flood-producing mechanisms and their particular settings on earth and over geologic time. The second source of information is historical measurements of the largest meteorologic floods on the largest river basins in the world. These floods, which are more within the realm of day-to-day human experience, provide a background for discussing the geologic, climatologic, and physiographic settings of large meteorologic floods on a global basis.

The Largest Floods of the Quaternary Period

Table 1 and figure 1 summarize the characteristics of 27 freshwater floods that had flows greater than 100,000 m^3/s (cubic meters per second) during Quaternary time. Undoubtedly, many more floods of these types and magnitudes have occurred but have not yet been studied or reported. Nevertheless, this admittedly partial list serves as a starting point for some basic inferences on the settings of the largest floods in Earth's history.

The largest known floods of the Quaternary period had peak discharges of nearly 20 million m^3/s and resulted from breaches of glacial-age ice dams that blocked large midcontinent drainage systems during ice ages. Most of the other largest documented floods resulted from breaches of other types of natural dams, including landslide dams, ice dams from smaller glaciers, releases from caldera lakes, and ice-jam floods. Only 4 of the 27 largest documented floods were primarily the result of meteorological conditions and atmospheric water sources. However, if only historic events are considered, the proportion of large meteorological floods still rises to only 4 of 10.

Floods from Ice-Dammed Lakes

All known terrestrial floods with discharges greater than 500,000 m^3/s resulted from rapid release of water stored behind natural dams or within glaciers (table 1, figs. 1 and 2). During the Quaternary period, blockage of large river systems by continental ice sheets has been a primary source of landscape-shaping floods. These floods include the 17 million m^3/s Missoula floods along the Cordilleran Ice Sheet margin in western North America (fig. 2), giant floods along the margins of the Laurentide Ice Sheet in eastern and central North America, and more recently discovered giant Pleistocene epoch floods in central Asia. These large ice-age floods involved tremendous volumes of water, enough that their rapid discharge into the oceans may have affected oceanic circulation, and hence, global climate. These floods all resulted from rapid release of water impounded either in (1) preexisting river valleys dammed by ice or (2) proglacial lakes formed along glacial margins. Similar but much smaller floods have occurred historically, including the 1986 flood of 105,000 m^3/s resulting from the failure of the dam formed by Hubbard Glacier across Russell Fiord, Alaska (table 1).

In June 1986, Hubbard Glacier in southeastern Alaska closed off the mouth of Russell Fiord, creating "Russell Lake." When the lake breached the ice dam days later, the ensuing glacial outburst flood became the largest such flood in recorded history. (Photograph by Rod Marsh, U.S. Geological Survey)

Large ice-age floods occurred during glacial ages when ice sheets had advanced across preexisting drainage networks. Known cases are primarily from the northern midlatitudes, where the present geometry of land masses supported large continental ice sheets that advanced southward and disrupted large drainage systems. The largest floods (in terms of peak discharge) have been in areas of significant relief at ice-sheet margins, causing deep valleys to be filled by relatively tall ice dams that impounded very large lakes. When tall dams cataclysmically fail, such as the 600–1,000 m (meters) high ice dams for the Kuray and Missoula floods in Asia and North America (table 1), very large peak discharges result because of the exponential dependence of discharge on breach depth.

Table 1. Quaternary floods with discharges greater than 100,000 cubic meters per second

[Pleistocene, about 1.8 million to 10,000 years ago; Holocene, about 10,000 years ago to present. Peak discharge: $10^6 m^3/s$, million cubic meters per second]

Flood/River	Location	Date	Peak discharge ($10^6 m^3/s$)	Mechanism	Reference
Kuray	Altai, Russia	Late Pleistocene	18	Ice-dam failure	Baker et al., 1993
Missoula	Northwestern USA	Late Pleistocene	17	Ice-dam failure	O'Connor and Baker, 1992
Darkhat Lakes	Mongolia	Late Pleistocene	4	Ice-dam failure	Rudoy, 1998
Jassater Lakes	Altai, Russia	Late Pleistocene	2	Ice-dam failure	Rudoy, 1998
Yaloman Lakes	Altai, Russia	Late Pleistocene	2	Ice-dam failure	Rudoy, 1998
Ulymon Lakes	Altai, Russia	Late Pleistocene	1.9	Ice-dam failure	Rudoy, 1998
Katla	Iceland	1918	1.5	Subglacial volcanic eruption	Jonsson, 1982
Lake Agassiz	Alberta, Canada	Early Holocene	1.2	Proglacial-lake overflow	Smith and Fisher, 1993
Aniakchak	Alaska, USA	Late Holocene	1.0	Caldera-lake breach	Waythomas et al., 1996
Lake Bonneville	Northwestern USA	Late Pleistocene	1.0	Lake-basin overflow	O'Connor, 1993
Lake Regina	Canada/USA	Late Pleistocene	.8	Ice-dam failure	Lord and Kehew, 1987
Jökulsá á Fjöllum	Iceland	Early Holocene	.7	Subglacial volcanic eruption	Waitt, 2002
Indus River	Pakistan	1841	.54	Landslide-dam failure	Shroder et al., 1991
Amazon River	Obidos, Brazil	1953	.37	Rainfall	Rodier and Roche, 1984
Wabash River	Indiana, USA	Late Pleistocene	.27	Ice-dam failure	Vaughn and Ash, 1983
Toutle River	Northwestern USA	Late Holocene	.26	Landslide-dam failure	Scott, 1989
Amazon River	Obidos, Brazil	1963	.25	Rainfall	Rodier and Roche, 1984
Amazon River	Obidos, Brazil	1976	.24	Rainfall	Rodier and Roche, 1984
Columbia River	Northwestern USA	About 1450	.22	Landslide-dam failure	O'Connor et al., 1996
Lake Agassiz	Canada/USA	Early Holocene	.20	Proglacial-lake overflow	Teller and Thorliefson, 1987
Lena River	Kasur, Russia	1967	.19	Ice jam and snowmelt	Rodier and Roche, 1984
Lena River	Kasur, Russia	1962	.17	Ice jam and snowmelt	Rodier and Roche, 1984
Lena River	Kasur, Russia	1948	.17	Ice jam and snowmelt	Rodier and Roche, 1984
Lake Agassiz	Canada/USA	Late Pleistocene	.13	Ice-dam failure	Matsch, 1983
Porcupine River	Alaska, USA	Late Pleistocene	.13	Ice-dam failure	Thorson, 1989
Yangtze River	China	1870	.11	Rainfall	Rodier and Roche, 1984
Russell Fiord	Alaska, USA	1986	.10	Ice-dam failure	Mayo, 1989

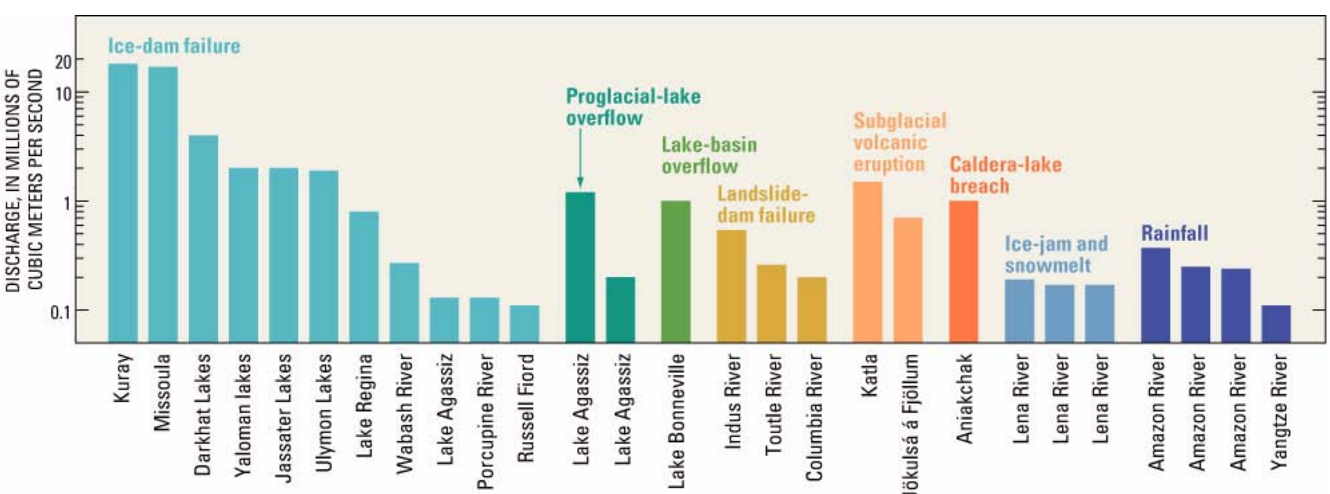


Figure 1. Most of the largest known floods of the Quaternary period resulted from breaching of dams formed by glaciers or landslides. See table 1 for details of each flood.

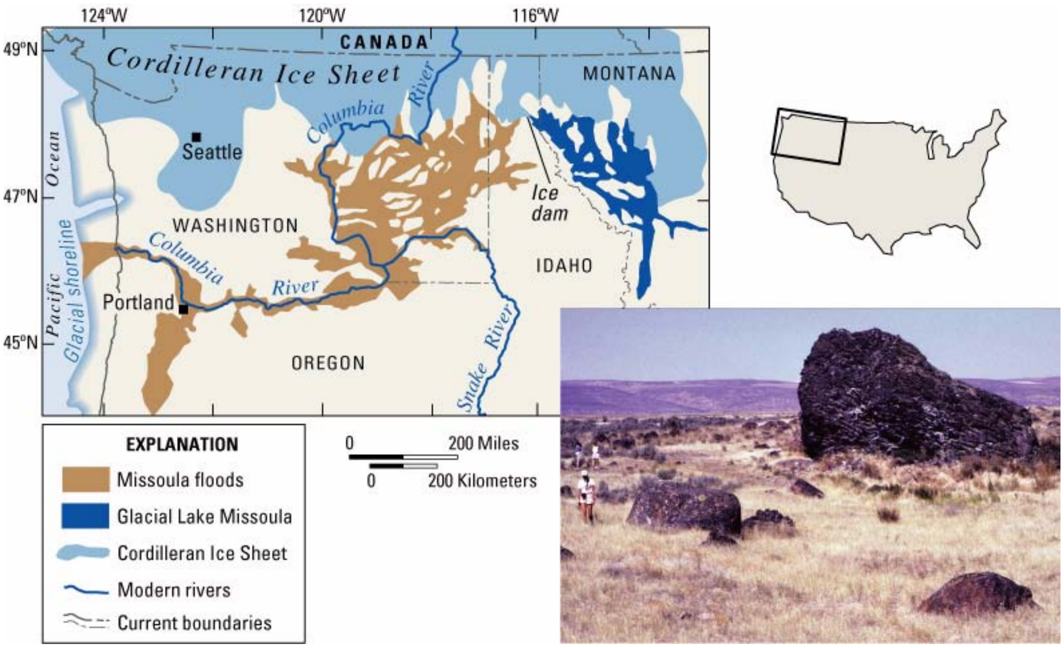


Figure 2. The late-Pleistocene Missoula floods in the Pacific Northwestern United States were some of the largest ever to have occurred on Earth. The floods resulted from the repeated breaching of an ice dam formed from a lobe of the Cordilleran Ice Sheet that blocked the present-day Clark Fork River and created an immense lake known as glacial Lake Missoula. The floods coursed across northern Idaho and eastern Washington, ripping up basalt flows and depositing large boulders along their paths. (Photograph by Jim O'Connor, U.S. Geological Survey)

Basin-Breach Floods

Filling and spilling of large closed basins can also cause immense floods. Several times during wetter periods of the Quaternary period, hydrologically closed basins have filled with water. Once a rising lake overtops its basin rim, spillover can cause rapid erosion, resulting in release of a large volume of water into adjacent drainages. Such was the case for the Bonneville flood of North America, which resulted from Pleistocene Lake Bonneville (the ice-age predecessor to Great Salt Lake, Utah) filling the Bonneville Basin, overtopping and eroding unconsolidated sediment that formed the drainage divide at Red Rock Pass, and the spilling northward into the Snake River Basin (fig. 3). Nearly 5,000 km^3 (cubic kilometers) of water was released at a peak discharge of about 1 million m^3/s during incision of about 100 m of the alluvial barrier. There is evidence for similar floods from the many other closed basins in the North American Basin and Range Province.

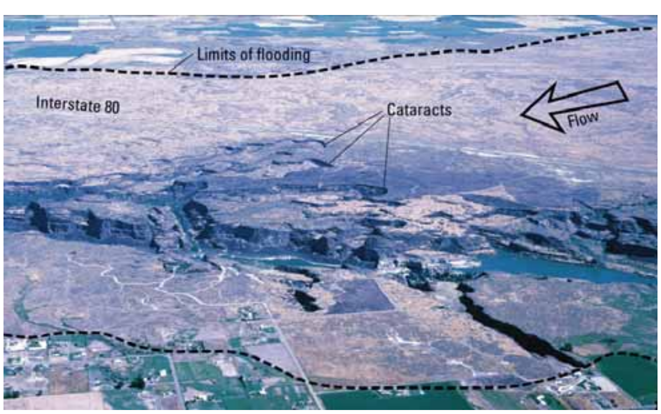
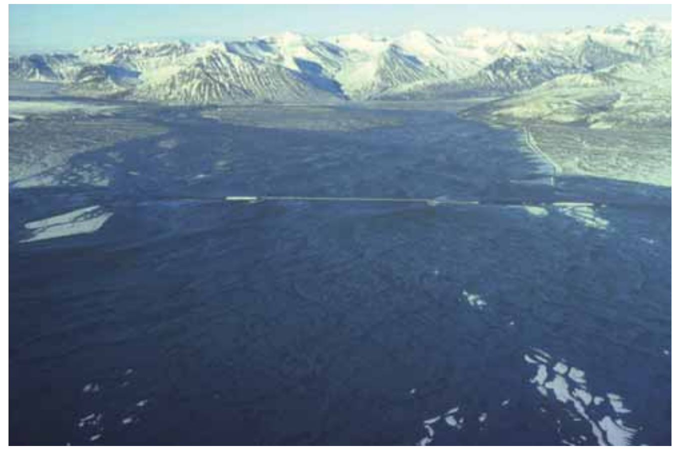


Figure 3. The Lake Bonneville flood of about 14,500 years ago resulted from nearly 5,000 cubic kilometers of water spilling out of the Great Basin and into the Snake River drainage. At a sustained peak discharge of about 1 million cubic feet per second, the flow filled the 100-meter-deep canyon and overflowed the basalt uplands of the Snake River Plain in southern Idaho, stripping soil from a 5-kilometer-wide swath and carving immense cataracts where flow reentered the canyon. (Photograph by Jim O'Connor, U.S. Geological Survey; view looking north)

Geologic records also document tremendous marine floods into tectonically closed basins. The largest known example is the flooding of the Mediterranean Basin through a breach developed at the Straits of Gibralter—an event now recognized to have caused the faunal upheaval used by early geologist Charles Lyell to divide the Miocene and Pliocene epochs. More recently, William Ryan and Walter Pitman, of the Lamont Doherty Earth Observatory, proposed that the Black Sea Basin was flooded about 7,500 years ago by water from the rising Mediterranean Sea when it overtopped and eroded a divide at the present-day Bosporus Strait. Ryan and Pitman (1999) further speculated that this event was the biblical Noah's Flood.

A common element of these floods from and into hydrographically closed basins is that they all occurred in semiarid environments during times of radically changing hydrologic conditions. Enormous terrestrial freshwater floods are generally associated with sustained wetter periods that cause basins to fill. Likewise, marine floods into closed basins such as the Black Sea are most likely during times of rising sea level due to global warming and deglaciation. Large closed basins are preferentially located in tectonically active regions within the arid subtropical belts. In these regions, long periods of negative water balances allow basin development to proceed without continuous overflow and incision of the flanking topographic divides, thus creating the potential for large water volumes to accumulate before descending over and eroding basin rims during rare times of basin filling. Likewise, episodes of marine floods into closed basins are mainly in semiarid areas, where high evaporation rates keep water levels well below sea level, thus providing the necessary elevation difference for cataclysmic inflow of marine water.



This 1996 jokulhlaup (literally "glacier-burst") in southeastern Iceland (top) was caused by a volcanic eruption under the Vatnajokull glacier (bottom). The glacial meltwater produced by the eruption poured into a nearby subglacial caldera lake and subsequently floated the overlying ice cap sufficiently to quickly release about 3.6 cubic kilometers of water. Discharge at the time of this photo was about 50,000 cubic meters per second. The largest jokulhlaup in recorded history, in Katla, Iceland (table 2), had a discharge of 1.5 million cubic meters per second at its peak, 30 times as large. (Photographs by Magnus Tumi Gudmunsson, University of Iceland)

Floods Related to Volcanism

Volcanism has been directly or indirectly responsible for 5 of the 27 largest global floods (fig. 1). Some of the largest volcanic floods resulted from eruptions melting substantial snow and ice, including the largest known historic flood, of 1.5 million m^3/s, which accompanied a subglacial volcanic eruption at Katla, Iceland, in 1918 (table 1). Similarly, a 700,000–1,000,000 m^3/s flood down Jökulsá á Fjöllum, Iceland, was caused by a subglacial eruption about 7,000 years ago.

Volcanic eruptions have also caused floods by means other than direct melting. Debris dams formed during volcanic eruptions by lava flows, lahars, pyroclastic flows, and landslides have blocked drainages, allowing lakes to form and breach. A flow of about 260,000 m^3/s coursed down the Toutle River, Washington, about 2,500 years ago when a landslide associated with an eruption of Mount St. Helens blocked a river valley and the resulting ancestral Spirit Lake breached cataclysmically. Similar floods would have been likely after the 1980 Mount St. Helens eruptions if mitigation measures had not been undertaken as the modern Spirit Lake rose against the 1980 debris avalanche. Large floods from breached volcanogenic blockages also resulted from the eruption of Tarawera Volcano, New Zealand, about 700 years ago, and from the Mount Mazama eruption in the Oregon Cascade Range about 7,700 years ago. Large historic floods in conjunction with volcanism have been reported in southern Mexico, Japan, and Alaska. Additionally, at least two large Quaternary floods on the Colorado River in the Grand Canyon, Arizona, resulted from breaches of lava dams.

Floods from breaches of water-filled calderas and craters have also caused large flows, including a late Holocene epoch flood of about 1 million m^3/s from Aniakchak Volcano in Alaska, a flood 1,800 years ago from Lake Taupo, New Zealand, and a late Holocene flood from Newberry Caldera in Oregon.

Floods from Breached Landslide Dams

Failures of landslide dams not directly related to volcanic activity were the cause of 2 of the 27 largest floods (table 1). Dam-breach modeling indicates that a flood with a peak discharge of about 540,000 m^3/s resulted from breaching of an 1841 rockslide that temporarily blocked the Indus River within the western Himalaya, Pakistan. Similarly, there is stratigraphic evidence of a flood of about 220,000 m^3/s from breaching of a landslide dam across the Columbia River in western Washington about 500 years ago (fig. 4).

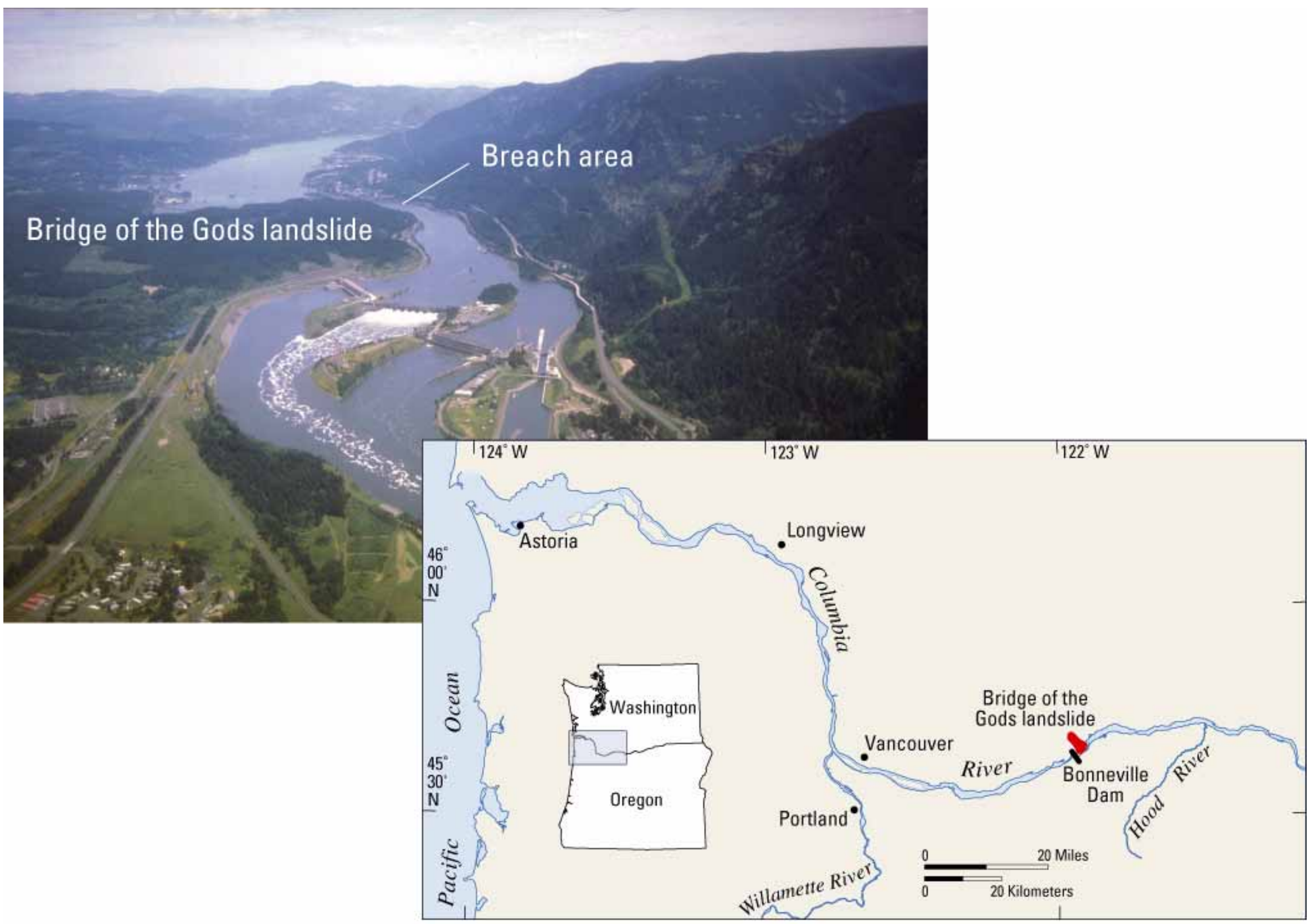


Figure 4. The Bridge of the Gods landslide slid down from the north wall of the Columbia River Gorge sometime between 1400 and 1465 A.D., blocking the Columbia River to a depth of 70–80 meters. Breaching of almost the entire thickness of the landslide dam caused a flood of about 220,000 cubic meters per second, about six times larger then the largest meteorological flood of the last 150 years. Deposits from the flood form a distinctive marker bed all the way to the Pacific Ocean. The last remnant of the dam was bouldery Cascade Rapids, the namesake of the Cascade Range, now drowned in the pool behind the 24-meter-high Bonneville Dam. (Photograph courtesy of the U.S. Army Corps of Engineers)

Landslide dams can form in a wide range of physiographic settings, from high alpine debris avalanches to quick-clay failures in wide valley floors. The most common mechanisms triggering dam-forming landslides are rainstorms, rapid snowmelt, and earthquakes. Landslide dams can be unstable and subject to failure because they have no controlled outlet. The vast majority of dam failures and ensuing floods result from overtopping and incision of the blockage, generally beginning soon after impounded water first reaches the low point of the blockage.

Despite representing only a small percentage of the world's largest floods, breaches of landslide dams are a significant hazard. There have been at least six historic landslide dam floods with peak discharges greater than 10,000 m^3/s. Most of these large floods were associated with tall blockages of large rivers, including cases where breach depths ranged up to 150 m through landslide dams that were as high as 250 m. Similar to the case of glacial dams, the potential peak discharge through a landslide dam increases exponentially with blockage height. Consequently, landscapes that generate large landslides that in turn form tall blockages in confined valleys have the greatest potential for extreme floods.

Landslide dams can dwarf human-constructed dams and therefore produce much larger floods. The largest landslide dam on Earth is the 550 m high Usoi landslide dam in Tajikistan, which created Lake Sarez. The dam formed as a result of a large earthquake in 1911.

Usoi Dam in Tajikastan, formed by a landslide in 1911, created 16 cubic-kilometer Lake Sarez, the largest lake in the world resulting from a landslide. Five million people live in the valleys downstream of the dam. Even partial breaching of the dam could cause catastrophic flooding. Complete failure of the dam could result in the deadliest natural disaster in human history. (Photograph courtesy of NASA)

This dam is nearly twice the height of the largest constructed dam in the world today, the 300-m-high Nurek rockfill dam, also in Tajikistan. The largest flood documented from failure of a constructed dam is the Teton Dam, Idaho, which failed in 1976 by piping (erosion through the dam) and for which the peak discharge was about 70,000 m^3/s, less than half the peak discharge of floods resulting from the landslide dam failures listed in table 1.

Ice-Jam Floods

Three of the world's largest 27 recorded flows were ice-jam floods on the Lena River, Russia—and this does not include the "unprecedented flooding" of May 1998 for which we have been unable to obtain discharge information. Floods on large rivers from ice jams result from "breakup jams," in which dislodged river ice accumulates at constrictions or river bends, forcing ponding upstream and rapid release of water when the ice dams breach. Such was the case in April 1952 on the Missouri River, North Dakota, where an eroding ice dam resulted in flow increasing from about 2,100 m^3/s to more than 14,000 m^3/s in less than 24 hours.

Ice jams, like this one on the Yukon River, Alaska, can cause severe flooding when impounded water overflows the stream channel upstream and when breakup of the jam suddenly releases water downstream. (Photograph courtesy of the Alaska Department of Military and Veterans Affairs)

Extreme ice-jam floods are most common in high-latitude, north-flowing continental river systems like the Lena River and adjacent large river systems of northern Eurasia, and the MacKenzie River of North America. Large poleward-flowing rivers are especially susceptible to large breakup floods because headwater areas may melt before downstream areas, increasing the potential for large blockages.

Large Meteorological Floods

In the tabulation of Quaternary floods with peak discharges greater than 100,000 m^3/s, only four floods primarily due to rainfall or snowmelt make the list (table 1)—the floods of 1953, 1963, and 1976 on the Amazon River at Obidos, Brazil, and the 1870 flood of 110,000 m^3/s on the Yangtze River, China. The Amazon River, draining by far the world's largest basin, with an area 7 million km^2 (square kilometers), including a vast portion of the equatorial South American Cordillera, can generate tremendous floods by virtue of its immense size and tropical location. The Yangtze (Chang Jiang) River of China is also a large basin that receives substantial tropical moisture.

The paucity of meteorological floods in this list of largest Quaternary floods does not indicate lesser significance of meteorologic floods. Indeed, meteorologic floods are by far the most common of the types of floods in the human experience, affecting parts of the globe every year. Such floods can bring good, such as the fertile soils formerly brought to the Nile Delta by annual flooding. However, large floods are mostly known for their catastrophic loss of life and property, such as the floods on the Mississippi River in 1927, when several hundred casualties resulted, the Columbia River in 1948, when the town of Vanport was destroyed, and the Yangtze River in 1931, when nearly 4 million people died from flooding and ensuing famine.

The town of Vanport, Oregon, was destroyed in May 1948 when the Columbia River flooded due to rapid melting of large snowpacks in the Columbia and Snake River Basins. (Photograph from Oregon Historical Society [negative OrHi: 68809], used by permission)

Records of the largest historic floods from the Earth's largest drainage basins (figs. 5 and 6, table 2) show that, in general, larger basins produce larger floods. Variation within this general observation owes partly to a pronounced geographic pattern of larger unit discharges (defined as peak discharge per unit basin area) in the tropics, primarily between latitudes 10° S and 30° N (fig. 7). The largest floods in large basins within the tropics are primarily derived from rainfall within areas affected by tropical cyclones or strong monsoonal airflow, such as the Brahmaputra, Ganges, Yangtze, Mekong, Huangue River Basins, or eastward-draining continental basins, such as the Amazon and Orinoco River Basins, which intercept easterly flows of tropical moisture. The distribution of relatively large floods is skewed northward of the Equator by the preponderance of land in the northern hemisphere, promoting northward migration of monsoonal moisture flow driven by orographic lifting over large mountain belts, such as the Himalaya in south-central Asia.

Several large basins in the tropics do not produce relatively large peak discharges. These include the Congo, Niger, Chari, and Sao Francisco River Basins, which drain large areas of low relief or are isolated from zones of major precipitation. Likewise, many of the horse-latitude (20°–40° N) and midcontinental drainage basins outside areas of seasonal tropical moisture influxes do not produce large flows compared with more tropical basins. Examples include the Murray and Darling River Basins in Australia, the Nile River and Zambezi River Basins in Africa, and the Colorado and Mississippi River Basins of North America.

Northward of 40° N, snowmelt and ice jams are important contributors to peak discharges from large basins, forming a group of rivers with flood discharges greater than the apparent latitudinal limits of flood flows derived primarily from rainfall (fig. 7). Exceptional discharges on the Lena, Yenisey, and Yukon Rivers were augmented by ice jams, but relatively large flows on rivers such as the Columbia and Dnieper Rivers indicate the importance of melting snow to peak flows, especially in midlatitude basins with substantial relief. With the present configuration of continents, there are no southern hemisphere river basins greater than 500,000 km^2 with peak discharges substantially affected by snowmelt.

Floods, Landscapes, and Hazards

One observation evident from consideration of the world's largest floods is that the incidence of floods caused by different processes changes through time.

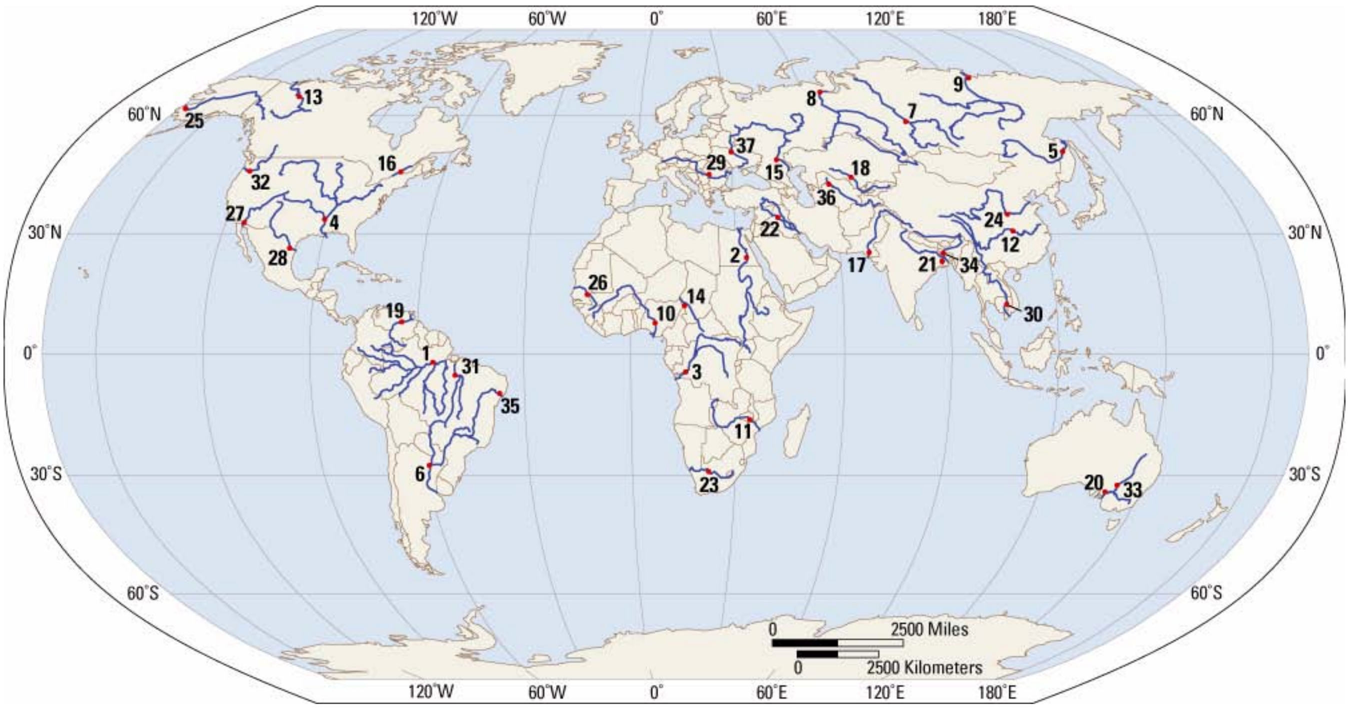


Figure 5. This map shows rivers with drainage basins larger than 500,000 square kilometers. Map numbers are keyed to table 2.

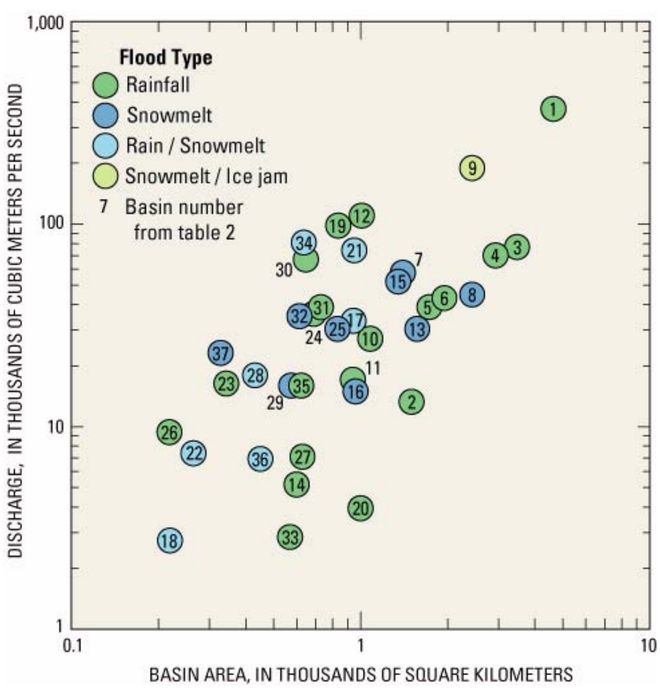


Figure 6. In general, larger river basins produce larger floods, but larger unit discharges in the moist tropics can result in floods of disproportionately large size. Numbers refer to basin numbers in figure 5 and table 2.

Most of the largest documented floods in the past 100,000 years resulted from the failures of natural dams, but conditions that caused some of the largest of these natural dams, such as the large ice-dam failures at the margins of continental ice sheets, are now absent. Consequently, earth history contains "flood epochs"—times when climate and topography combine to produce higher-than-typical frequencies of large floods. To produce floods with discharges greater than about 1 million m^3/s, times of advanced continental ice sheets and rapidly changing global water balances are required. In many locations, these outsized floods from previous flood epochs were dominant forces in establishing regional drainage networks and landscape patterns that persisted into times of fewer extreme floods.

Other geologically controlled cataclysmic floods are probably more evenly distributed in time, at least at time scales of hundreds to thousands of years. Consequently, the future likelihood and magnitude of such events can be more directly guided by analysis of past events. Within active volcanic provinces, the likelihood of large volcanic eruptions and the consequent flood-generation processes probably does not change significantly over hundreds or even thousands of years. Similarly, the frequency of large valley-blocking landslides probably remains relatively constant over such time scales.

Table 2. Largest meteorologic floods from river basins larger than about 500,000 square kilometers.

[Data from Rodier and Roche (1984) except as noted. River and station locations shown on figure 5. Station area: $10^3 km^2$, thousand square kilometers. Station latitude and longitude: N, north; S, south; E, east; W, west. Peak discharge: m^3/s, cubic meters per second]

Basin number	River basin[a]	Country	Basin area (10^3 km^2)[b]	Station	Station area (10^3 km^2)	Station latitude (degrees)	Station longitude (degrees)	Peak discharge (m^3/s)	Date	Flood type
1	Amazon	Brazil	5,854	Obidos	4,640	1.9S	55.5W	370,000	June 1953	Rainfall
2	Nile	Egypt	3,826	Aswan	1,500	24.1N	32.9E	13,200	Sept. 25, 1878	Rainfall
3	Congo	Zaire	3,699	Brazzaville B.	3,475	4.3S	15.4E	76,900	Dec. 27, 1961	Rainfall
4	Mississippi[c]	USA	3,203	Arkansas City	2,928	33.6N	91.2W	70,000	May 1927	Rainfall
5	Amur	Russia	2,903	Komsomolsk	1,730	50.6N	138.1E	38,900	Sept. 20, 1959	Rainfall
6	Parana	Argentina	2,661	Corrientes	1,950	27.5S	58.9W	43,070	June 5, 1905	Rainfall
7	Yenisey	Russia	2,582	Yeniseysk	1,400	58.5N	92.1E	57,400	May 18, 1937	Snowmelt
8	Ob-Irtysh	Russia	2,570	Salekhard	2,430	66.6N	66.5E	44,800	Aug. 10, 1979	Snowmelt
9	Lena	Russia	2,418	Kasur	2,430	70.7N	127.7E	189,000	June 8, 1967	Snowmelt/Ice Jam
10	Niger	Niger	2,240	Lokoja	1,080	7.8N	6.8E	27,140	Feb. 1, 1970	Rainfall
11	Zambezi	Mozambique	1,989	Tete	940	16.2S	33.6E	17,000	May 11, 1905	Rainfall
12	Yangtze	China	1,794	Yichang	1,010	30.7N	111.2E	110,000	July 20, 1870	Rainfall
13	Mackenzie	Canada	1,713	Norman Wells	1,570	65.3N	126.9W	30,300	May 25, 1975	Snowmelt
14	Chari	Chad	1,572	N'Djamena	600	12.1N	15.0E	5,160	Nov. 9, 1961	Rainfall
15	Volga	Russia	1,463	Volgograd	1,350	48.5N	44.7E	51,900	May 27, 1926	Snowmelt
16	St. Lawrence	Canada	1,267	La Salle	960	45.4N	73.6W	14,870	May 13, 1943	Snowmelt
17	Indus	Pakistan	1,143	Kotri	945	25.3N	68.3E	33,280	1976	Rain/Snowmelt
18	Syr Darya	Kazakhstan	1,070	Tyumen'-Aryk	219	44.1N	67.0E	2,730	June 30, 1934	Rain/Snowmelt
19	Orinoco	Venezuela	1,039	Puente Angostura	836	8.1N	64.4W	98,120	Mar. 6, 1905	Rainfall
20	Murray	Australia	1,032	Morgan	1,000	34.0S	139.7E	3,940	Sept. 5, 1956	Rainfall
21	Ganges	Bangladesh	976	Hardings Bridge	950	23.1N	89.0E	74,060	Aug. 21, 1973	Rain/Snowmelt
22	Shatt al Arab	Iraq	967	Hit(Euphrates)	264	34.0N	42.8E	7,366	May 13, 1969	Rain/Snowmelt
23	Orange	South Africa	944	Buchuberg	343	29.0S	22.2E	16,230	1843	Rainfall
24	Huanghe	China	894	Shanxian	688	34.8N	111.2E	36,000	Jan. 17, 1905	Rainfall
25	Yukon	USA	852	Pilot Station	831	61.9N	162.9W	30,300	May 27, 1991	Snowmelt
26	Senegal	Senegal	847	Bakel	218	14.9N	12.5W	9,340	Sept. 15, 1906	Rainfall
27	Colorado[c]	USA	808	Yuma	629	32.7N	114.6W	7,080	Jan. 22, 1916	Rainfall
28	Rio Grande[c]	USA	805	Roma	431	26.4N	99.0W	17,850	1865	Rain/Snowmelt
29	Danube	Romania	788	Orsova	575	44.7N	22.4E	15,900	April 17, 1895	Snowmelt
30	Mekong	Vietnam	774	Kratie	646	12.5N	106.0E	66,700	Sept. 3, 1939	Rainfall
31	Tocantins	Brazil	769	Itupiranga	728	5.1S	49.4W	38,780	April 2, 1974	Rainfall
32	Columbia[c]	USA	724	The Dalles	614	45.6N	121.2W	35,100	June 6, 1894	Snowmelt
33	Darling	Australia	650	Menindee	570	32.4S	142.5E	2,840	June 1890	Rainfall
34	Brahmaputra[d]	Bangladesh	650	Bahadurabad	636	25.2N	89.7E	81,000	Aug. 6, 1974	Rain/Snowmelt
35	São Francisco	Brazil	615	Traipu	623	9.6S	37.0W	15,890	April 1, 1960	Rainfall
36	Amu Darya	Kazakhstan	612	Chatly	450	42.3N	59.7E	6,900	July 27, 1958	Rain/Snowmelt
37	Dnieper	Ukraine	509	Kiev	328	50.5N	30.5E	23,100	May 2, 1931	Snowmelt

[a]Basins larger than 500,000 square kilometers for which reliable data were not available include the Nelson River in North America; the Jubba, Irharhar, Araye, Tafassasset and Qattar Rivers in Africa; and the Kolyma and Tarim Rivers in Asia.

[b]Basin areas from Vörösmarty et al. (2000).

[c]Station and discharge data from U.S. Geological Survey National Water Information System (http://water.usgs.gov/nwis).

[d]Station area and drainage basin data from Global Runoff Data Centre in the Federal Institute of Hydrology, Germany (http://www.bafg.de/grdc.htm).

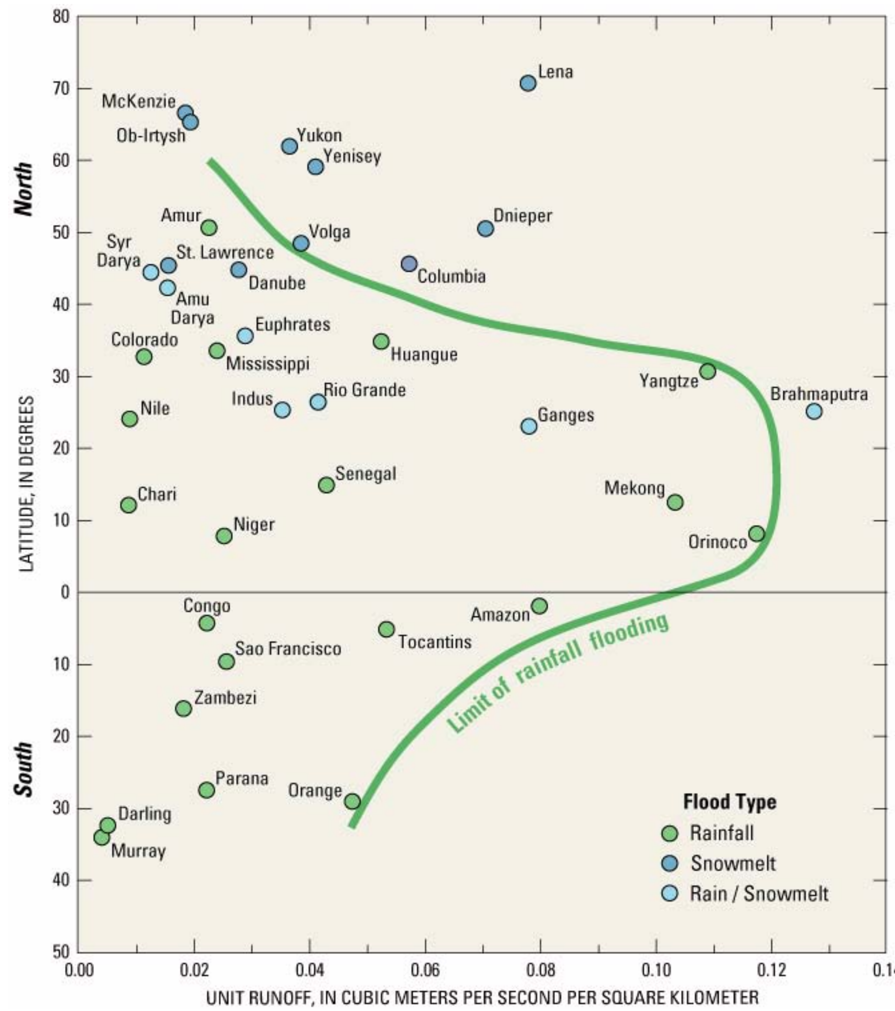


Figure 7. Nearly all of the largest floods caused by rainfall have occurred in basins south of latitude 40 degrees N. North of that, snowmelt- and ice-jam-related floods have predominated. Data from table 2.

Exceptionally large floods are not evenly distributed around the globe. The largest Quaternary floods from natural dam failures and closed basin spillovers have been in the mid-latitudes, where advancing ice sheets blocked large continental drainage systems and where closed basins in arid or semiarid regions filled and then spilled during wetter periods of earth history. The largest recorded meteorological floods have been in tropical regions, especially where monsoon moisture falling on large and high-relief drainage basins produces immense volumes of runoff.

This broad framework for the temporal and spatial distribution of floods is but a launching point for ongoing USGS flood research. Together with many cooperating State, local, and Federal agencies, academic institutions, and international partners, USGS studies focused on floods are taking many forms. These activities include developing new ways to measure and monitor floods and to map flood hazards, investigating the complex relations between floods and persistent climatic patterns such as the El Niño Southern Oscillation and the Pacific Decadal Oscillation, and understanding the role of flood processes in forming and maintaining landscapes and ecologic systems. All of these activities have the goal of providing high-quality scientific information that can be used to make informed decisions regarding the management of floods and their benefits and hazards throughout the world.

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For More Information:

USGS Flood Information
http://water.usgs.gov/osw/programs/floods.html

USGS Fact Sheet: Significant Floods in the United States During the 20th Century
http://ks.water.usgs.gov/Kansas/pubs/fact-sheets/fs.024-00.html

USGS Circular: Large Floods in the United States—Where They Happen and Why
http://pubs.water.usgs.gov/circ1245

USGS Water Watch
http://water.usgs.gov/waterwatch/

Dartmouth University Flood Observatory
http://www.dartmouth.edu/~floods/

EarthSat™ flood maps
http://www.earthsat.com/wx/flooding/

National Weather Service: Significant River Flood Outlook
http://www.hpc.ncep.noaa.gov/nationalfloodoutlook/

Federal Emergency Management Agency (FEMA) Flood Hazard Mapping
http://www.fema.gov/mit/tsd/fq_genhm.htm

Societal Aspects of Weather: Floods
http://sciencepolicy.colorado.edu/socasp/floods.html