Chapter 2
Types of Floods and Floodplains

Chapter Overview

There are several different types of floods. Most communities experience only a few of them. Floods are generally grouped into the following types;

- Riverine flooding
- Urban drainage
- Ground failures
- Fluctuating lake levels
- Coastal flooding and erosion

Within some of these groups there are several subtypes of floods.

Surface Water Runoff

When rainfall reaches the Earth's surface, water evaporates, infiltrates into the soil, or runs over the surface. The kinds of ground cover greatly influence the proportions of each of these actions. In various types of communities, and within communities, there are different cover types. For example, an urban area, like a city, might have these cover types:

- Open space (lawns, golf courses, parks) generally covered with grass
- Streets and roads
- Paved parking lots, shopping centers,
- Houses and residential areas
- Offices and business areas

If the rainfall intensity exceeds the evaporation rate and infiltration capacity of the soil, **surface runoff** occurs. It also occurs when rainfall falls on impervious surfaces, such as roadways and other paved areas. Water flows across the surface as either confined or unconfined flow. Unconfined flow moves in broad sheets of water often causing sheet erosion. It can also pick up and adsorb or carry contaminants from the surface. Water that flows along the surface may become trapped in depressions. Here water may either evaporate back into the air, infiltrate into the ground, or spill out of the depression as it fills. If local drainage conditions are inadequate to accommodate rainfall through a combination of evaporation, infiltration into the ground, and surface runoff, accumulation of water in certain areas may cause localized flooding problems.

Alternately, the sheet flow may reach a natural or constructed water conveyance system such as a swale, channel, or conduit. Water is conveyed to larger drainage systems such as creeks, streams and rivers. During winter and spring, accumulation of snow may increase water runoff generated by both precipitation and snowmelt.

Flooding problems resulting from runoff of surface water generally increase as areas become more urbanized. Greater population density generally increases the amount of impervious area, e.g., pavement and buildings. This reduction in the amount of natural ground that can absorb rainfall results in an increase in the amount of surface runoff generated. Uncontrolled, this runoff may be channeled to areas that cause flooding of structures and roadways. This may be especially true where the predevelopment land surface had a gently sloping surface with no defined channels. Such areas are subject to shallow sheet flooding during storms, but urbanization and other development speeds the accumulation of floodwater.

When surface water runoff introduced into streams and rivers exceeds the capacity of the natural or constructed channels to accommodate the flow, water overflows the stream banks, spilling out into adjacent low lying areas. **Riverine flooding** occurs as a consequence.

Riverine Flooding

The dynamics of riverine flooding vary with terrain. In relatively flat areas, land may stay covered with shallow, slow-moving floodwater for days or even weeks. In hilly and mountainous areas, floods may come minutes after a heavy rain. The short notice, large depths, and high velocities of flash floods make these types of floods particularly dangerous. Among the common types of riverine flooding are:

Overbank Flooding

Overbank flooding of rivers and streams – the increase in volume of water within a river channel and the overflow of water from the channel onto the adjacent floodplain – represents the classic flooding event that most people associate with the term "flood." In fact, this is also the most common type of flood event. Hundreds of riverine floods, great and small, occur annually in the United States.

Photograph of water everywhere—flooded subdivision.

Riverine floodplains range from narrow, confined channels (as in steep river valleys in hilly and mountainous areas) to wide, flat areas (as in much of the Midwest and in many coastal areas). In the steep narrow valleys, flooding usually occurs quickly and is of short duration, but is likely to be rapid and deep. In relatively flat floodplains, areas may remain inundated for days or even weeks, but floodwaters are typically slow-moving and shallow.

Photograph of mountainous floodplain.

Photograph of call to 911 to report flooding?

Along major rivers with very large drainage basins, the timing and elevations of flood peaks can be predicted far in advance and with considerable accuracy. In very small basins, flooding may be more difficult to predict to provide useful warning time. Generally, the smaller the drainage basin, the more difficult it is to forecast the flood.

Flooding in large rivers usually results from large-scale weather systems generating prolonged rainfall over wide areas. These same weather systems may cause flooding in hundreds of smaller basins that drain into the major river system. The streams and small rivers are also susceptible to flooding from more localized weather systems that cause intense rainfall over only a small area. In parts of the northern and western United States, annual spring floods result from spring snowmelt and the extent of flooding is dependent upon winter snowpack and spring weather patterns.

Several high-risk or unusual types of riverine flooding are described in the following sections. There is often no sharp distinction between flash floods, flooding due to structural failure or overtopping, flooding on alluvial fans, and the other types of high-risk flooding described. There is much overlap among these types of floods that tend to represent different characteristics of the entire range of riverine flooding. However, the following categories are widely recognized and helpful in considering not only the range of flood risk but also appropriate responses to the risk.

Photograph of flash flood devastating damage.

Flash Floods

"Flash flood**"** is a term widely used by flood experts and the general population. The National Weather Service defines a flash flood as "*A rapid and extreme flow of high water into a normally dry area, or a rapid rise in a stream or creek above a predetermined flood level, beginning within six hours of the causative event (e.g., intense rainfall, dam failure, ice jam). However, the* *actual time threshold may vary in different parts of the country. Ongoing flooding can intensify to flash flooding in cases where intense rainfall results in a rapid surge of rising flood waters.*"[1] Flash floods are also characterized by a rapid rise in water, high velocities, and large amounts of debris. Major factors in flash flooding are the intensity and duration of rainfall and the steepness of watershed and stream gradients. Flash flooding occurs in all 50 states, most commonly in steeply sloping valleys in mountainous areas, but can also occur along small waterways in urban environments. Dam failure, release of ice jams, and collapse of debris dams also can cause flash floods.

Photograph of flash flood.

The damages caused by flash floods can be more severe than ordinary riverine floods because of the speed with which flooding occurs (possibly hindering evacuation or protection of property), the high velocity of water, and the debris load. Channel velocities of 9 feet per second, typically realized in flash floods, can move a 90 pound rock and major flash floods like the one that occurred in the Big Thompson Canyon in Colorado in 1976 (see below), where velocities exceeded 30 feet per second, moved boulders weighing 250 tons.[2] The density of water enables it to pack a destructive punch. **Water moving at 10 miles per hour exerts the same pressure on a structure as wind gusts at 270 miles per hour.**[3]

[1] National Weather Service Manual 10-950, April 26, 2006

[2] FEMA/EMI, Floodplain Management Course, Session 6

[3] "Floods can cause damage to structure," USA`Today, September 9, 2005, page 3B

Photograph of highway washout.

Sudden destruction of structures and washout of access roads may result in loss of life. A high percentage of flood-related deaths result from motorists underestimating the depth and velocity of flood waters and attempting to cross swollen streams.

The National Weather Service (NWS) has identified 2,000 communities across the country with potential flash-flood problems. More than 800 of these localities nationwide have adopted flash flood warning, evacuation planning, or other mitigation efforts to deal with flash flooding. Table 2-1 lists some of the recent flash flood disasters.

A flash flood occurred in September 1992, near Cherokee, North Carolina. Light rainfall in the immediate area provided no indication of what was to suddenly occur. Runoff from a storm in the adjacent Great Smoky Mountain National Park roared down Raven Fork. Several thousand inhabitants in campgrounds along the stream were evacuated just before the flood arrived.

Miraculously, no lives were lost. The crest of the flood was measured at *ten feet* above the calculated 1-percent-chance flood for this area.

Table 2-1. Recent Flash Flood Disasters	
1972	**Buffalo Creek, West Virginia: 118 dead** • *Washout of coal refuse embankment* • 546 houses destroyed, 538 houses damaged
1972	**Rapid City, South Dakota: 236 dead** • *Heavy rain, dam failure* • $100 million in property damage
1976	**Big Thompson Canyon, Colorado: 145 dead** • *Heavy rains* •
1977	**Johnstown, Pennsylvania: 77 dead** • *Heavy rain, dam failure* • $200 million in property damage
1990	**Shady Side, Ohio: 25 dead**

Dam and Levee Failure

Some of the most significant losses due to the failure of flood control structures can be attributed to the construction of inadequate dams and levees or to a flood that exceeds the design protection level. Many private or locally built levees and dams may provide only limited flood protection or are sometimes poorly designed and maintained. Many were built with no design standards. Levee overtopping or failure typically occurs from floods beyond their capacity to handle, often with spectacular and tragic results.

Dam failure can often be traced either to a poor decision made during design and construction or to inadequate maintenance or operational mismanagement. Failure may also result from natural hazards, such as earthquakes, or from flow volumes that exceed capacity (Figure 2-1). Damage from dam failure is especially severe because of the high velocity of floodwater. Breaching often occurs within hours after the first visible signs of dam failure, leaving little or no time for evacuation.

Photograph of outwash from the Lawn Lake Dam (Colorado) failure some 8 miles upstream. (Note person in photograph.)

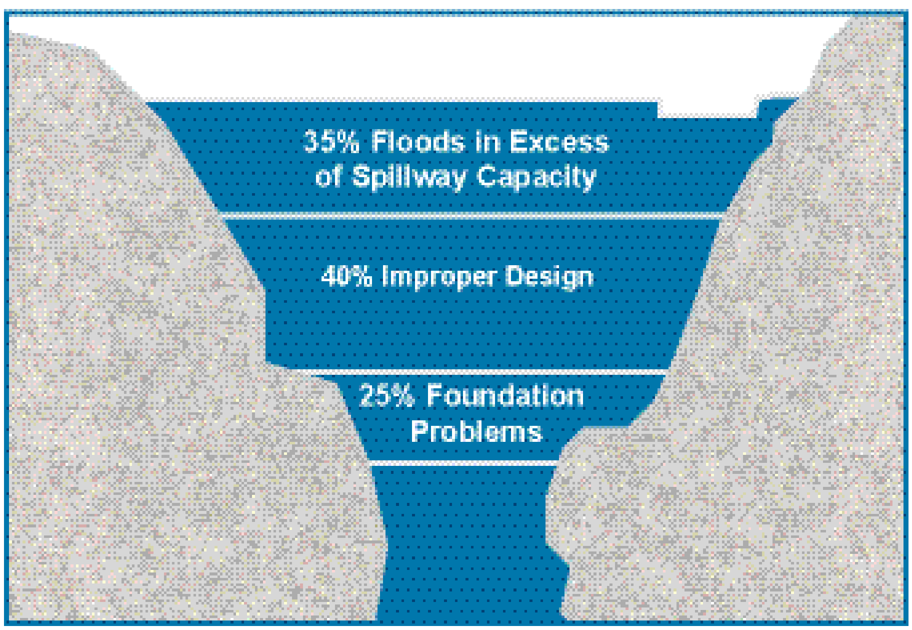

Figure 2-1. Causes of Dam Failure[4]

Alluvial Fans

Alluvial fans, which occur mainly in dry mountainous regions, are deposits of rock and soil that have eroded from mountainsides and accumulated on valley floors in a fan-shaped pattern. The

[4] "Carrying Out Floodplain Management in Your Locality."

deposits are narrow and steep at the head of the fan, broadening as they spread out onto the valley floor.

Fans provide attractive development sites due to their commanding views, but harbor severe flood hazards along with unique behavior. Channels along fans are not well defined and flow paths are unpredictable. As rain runs off steep valley walls, it gains velocity, carrying large boulders and other debris. When the debris fills the runoff channels of the fan, floodwaters spill out, spreading laterally and cutting new channels. The process is then repeated, resulting in shifting channels and combined erosion and flooding problems over a large area.

Photograph of "double jeopardy." The Colorado River is in the foreground; and an alluvial fan is in the background.

Like flash floods, flooding on alluvial fans can cause greater damage than typical riverine flooding due to the high velocity of water flow, the amount of debris carried, and the broad area affected by floodwaters. Floodwaters move at high velocities (15 to 30 feet per second are common) due to steep slopes and lack of vegetation. At these velocities, water has tremendous erosive force and damage potential. In addition, floodwaters in alluvial fans contain large amounts of sediment and debris, including boulders and trees. Since floodwaters are not confined to a single channel, but travel through numerous meandering channels, developments over a broad area can be threatened. During peak flow events, it is possible for water to reach any part of the fan.

Alluvial fans are common in a number of western states and in Kentucky, Tennessee, and West Virginia. Spring City, Tennessee, lies near the base of a fan.

Figure 2-2 illustrates factors affecting flood hazards on alluvial fans.

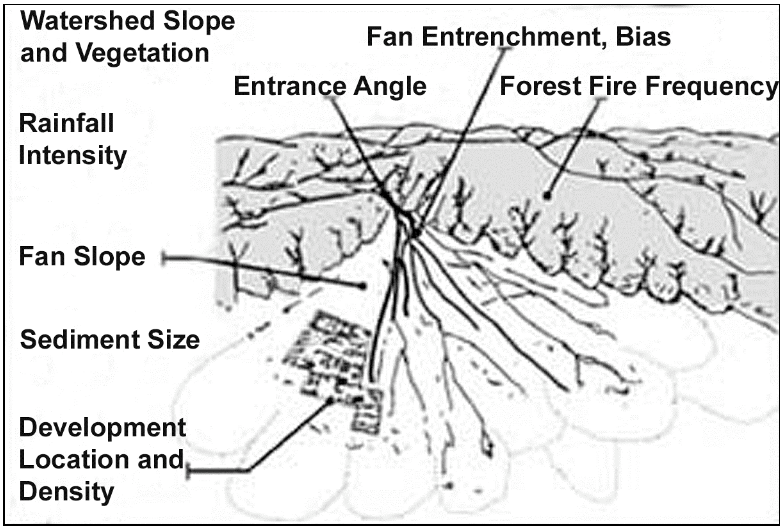

Figure 2-2. Factors affecting flood hazards on alluvial fans.[5]

Ice Jam Flooding
Flooding caused by ice jams is similar to flash flooding – the formation of a jam results in a rapid rise of water both at the point of the jam and upstream. Failure of the jam results in sudden flooding downstream. This type of flooding is a problem in some 35 states.

The formation of ice jams depends on both the weather and the physical conditions in the river channel. Flooding due to ice jams (or other ice conditions) can occur at different times and in different ways. Figure 2-3 illustrates areas where ice jams are most likely to occur.

Flooding during fall freeze-up can result from the formation of frazil ice, which forms when temperatures drop but a swift current prevents the formation of a solid ice cover. The frazil ice floats downstream until it reaches a slower moving, frozen area and attaches itself to the underside of the ice cover (at times accumulating to form a hanging dam) or to the stream bed, forming anchor ice.

Ice-related flooding also occurs during mid-winter periods of very low temperature when water in the stream channel freezes completely solid, forming anchor ice. Additional water coming down the stream freezes on top of the solid ice until the channel is blocked and the stream flows overland, flooding and freezing on adjacent lands. Solid ice formed in this way frequently blocks culverts.

The classic ice jam occurs at spring breakup due to a combination of ice conditions. Generally, rising water levels in the river or stream resulting from snowmelt or rainfall break the existing

[5] Ibid.

ice cover into large, floating ice masses that lodge at bridges or other constrictions and create ice dams. Rapid flooding may occur, first upstream, then downstream as the mass of ice and water finally breaks free. Huge ice masses moving downstream can shear off trees and destroy buildings above the level of the floodwaters. Floating ice masses and their associated damages also occur in lakes.

Photograph of ice jam flooding.

As with other types of unique flood situations, damages from ice jam flooding usually exceed those of clear water flooding. Flood elevations are usually higher than predicted for free flow conditions, and water levels upstream and downstream increase rapidly.

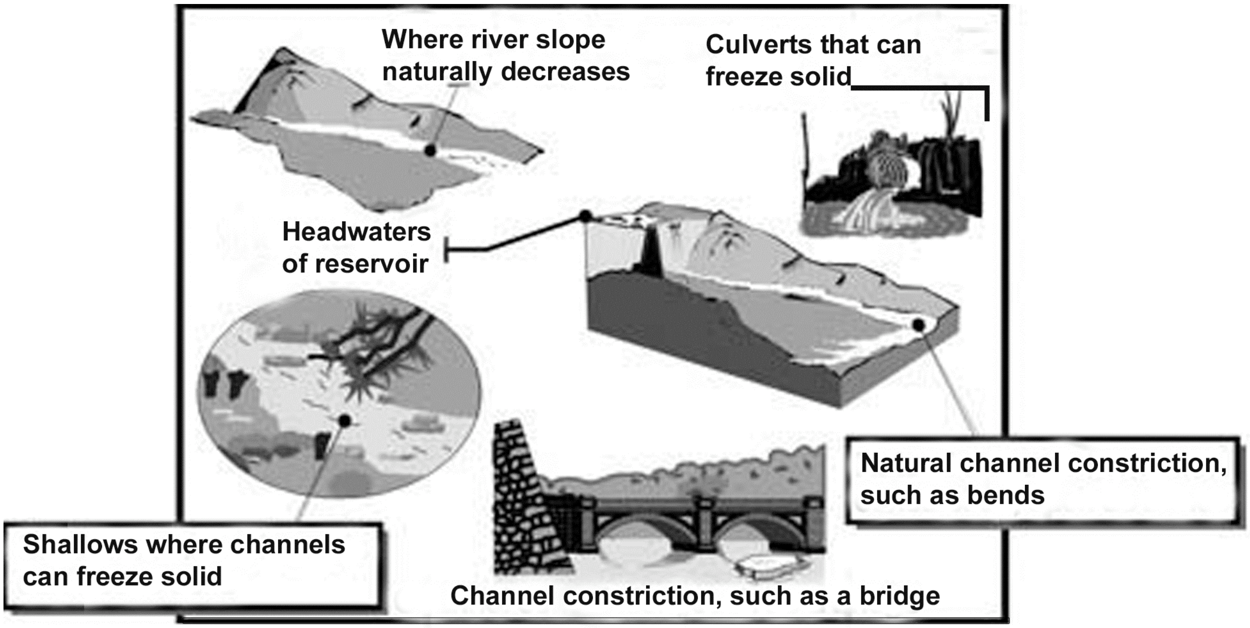

Figure 2-3. Likely ice jam areas.[6]

Moveable Bed Streams
Movement of streambeds is most common where steep slopes and the lack of vegetation result in a lot of erosion. During a flood, a new channel may be created by erosion or an existing channel may fill in with sediment. Moveable bed streams are most common in mountainous areas.

Urban Drainage

In an undeveloped area, the water runoff system is provided by nature. Some of the water remains where it falls, and evaporates; some is absorbed into the ground near the surface, and feeds trees and plants; some percolates deeply into the ground, and replenishes the groundwater supply. The remainder gradually or quickly collects into rivulets, accumulating both in quantity and speed as it hurries down the watershed through drainageways and streams to its ultimate destination – the river and then the sea, to begin the cycle again. (See Figure 1-1.)

Even where urbanization has not occurred, nature's inability to accommodate severe storms without significant damage is quite apparent. The natural drainage systems in an undeveloped area are not static in design, but are constantly changing. Streams change course, banks erode, vegetation and soil permeability change with seasons, water bodies fill with sediment and disappear. The stripping of vegetation and ground cover by fire may change an entire system, forcing new natural accommodations throughout the system.

Urbanization has required **new** drainage systems because man was unwilling to suffer inconvenience caused by increased or previously un-experienced surface water runoff where it

[6] Ibid.

could be avoided. The basic philosophy of **urban drainage** has typically been to seek maximum convenience at an individual site by the most rapid possible elimination of excess surface water after a rainfall and the containment and disposal of that water as quickly as possible through a closed conveyance system. This has meant that no matter how large the rainfall or its duration, the drainage system is expected to remove runoff as quickly as possible. The cumulative effects of such an approach has been a major cause of increased frequency of downstream flooding, often accomplished by diminishing groundwater supplies, as direct results of urbanization; or have necessitated development of downstream measures to prevent flood damage

Controlling and regulating urban runoff is called "**stormwater management**." It is typically conducted on a street by street, even a building by building, basis.

Urban drainage (stormwater) management is comprised of both natural and man-made elements. The stormwater runoff system has two purposes: 1) the control of stormwater runoff to prevent or minimize damage to property and physical injury and loss of life which may occur during or after a very infrequent or unusual storm; and 2) the control of stormwater to eliminate or minimize inconvenience or disruption of activity as a result of runoff from more frequently occurring, less significant storms.

Photograph of stormwater management technique.

The straightening and lining of channels; the construction of streets, curbs, and stormwater inlets; sewers and other underground conduits; culverts; and other means of controlling runoff; result in improved "hydraulic efficiency" of the local drainage network. In other words, the time required for surface runoff to reach a stream channel is reduced. Unless the drainage network is specifically designed to counteract this increase in rate of runoff from the watershed, the result is likely to be an increase in flood peaks. Thus flooding will happen more quickly and usually to greater depths than before urban development occurred. Around 20-25 percent of all economic losses resulting from flooding occur in areas not designated as being in a "floodplain," but as a consequence of urban drainage.

Ground Failures

Flooding and flood-related erosion can result from several types of ground failures. Subsidence and liquefaction of soil may cause flooding of areas in the immediate vicinity of the ground failure, while mudflows and mudfloods may cause damages downstream or downslope of the location where the initial ground failure occurred.

Mudflood and Mudflows

Mudflow and mudfloods (also referred to as debris flow) are considered a subset of landslides and affect many of the nation's floodplains. Areas that have experienced the greatest landslide damage are the Appalachian region, the Rocky Mountain region, and the Pacific coast region.

The National Academy of Sciences (National Research Council, 1985) has defined mudflood and mudflow as follows:

- *Mudflood*: Refers to a flood in which the water carries heavy loads of sediment (as much as 50% by volume) including coarse debris. Mudfloods typically occur in drainage channels and on alluvial fans adjacent to mountainous areas, although they may occur on floodplains as well.
- *Mudflow*: Refers to a specific subset of landslides where the dominant transporting mechanism is that of a flow having sufficient viscosity to support large boulders within a matrix of smaller sized particles. Mudflows may be confined to drainage channels or may occur unconfined on hill slopes.

Mudflows and mudfloods are often the result of rain falling on terrain that has been denuded by forest fires and brush fires, and thus cannot retain runoff. In areas where ground cover has been removed, even small rains can cause mudflows and mudfloods. Steep lands with an identifiable subsoil layer of clay could break loose and start a mudflow when the clay layer becomes saturated. The most common mudlow resulting from slope failure in forested lands occurs about five to ten years after a major forest fire where established timber is killed. During the following years new growth is established. However, roots from the previous growth have deteriorated and the new roots are not strong enough to hold the soil from moving, thus starting a mudflow.

Both mudflows and mudfloods start with moving water or a stationary mass of saturated soil. Mudfloods usually originate as sheet flow or as water flowing in drainage channels, rivers or streams, and pick up sediment and debris as they flow. Mudflows often originate as a mixture of stationary soil and water. When the mixture gets wet enough, it begins to move as a mass, either as a result of gravity or when triggered by an earthquake or sudden flow of debris laden water. Mudflows may also begin as clear-water flows but incorporate sediments and other debris from the stream channel or banks and "bulk up" to flows much larger than the clear-water flow before eventually dropping the debris and attenuating. Mudflows may travel many miles from their source.

Mudflood resulting from eruption of Mt. St. Helens.

Mudflows and mudfloods may cause more severe damage than clear water flooding due to the force of the debris-filled water and the combination of debris and sediment. The force of the water often destroys pilings and other protective works, as well as structures in its path (or when structures remain intact, sediment must often be physically removed with shovels or hoses). Mud and debris may also fill drainage channels and sediment basins, causing floodwater to suddenly inundate areas outside of the floodplain.

Although understanding of the causes of landslides and the development of improved methods for handling them has progressed, the problem continues to grow. In the last 30 years, the number of damaging landslides has increased, due largely to continuing urban expansion in areas of steeply sloping terrain and unstable slopes. This urban development alters hillslope configuration and upsets established equilibrium conditions, affecting the natural instability of many slopes and, in some cases, reactivating older landslides.

Subsidence

Subsidence is a type of ground failure that can lower the ground surface, causing or increasing flood damage in areas of high ground water, tides, storm surges or over bank stream flow. Subsidence occurs in nearly all the states. Ground failure due to subsidence can result in increased flood damages for two main reasons. If the land surface is lowered it may be more frequently or more deeply flooded. In addition, subsidence can block or otherwise alter drainage patterns leading to deeper or unexpected flooding.

Subsidence is the result of both natural processes and human activities. Natural causes include solution (karts topography), consolidation of subsurface materials (such as wetlands soils), and movements in the earth's crust. Human activities, which accelerate the natural processes leading to subsidence, include mining, inadequate compaction of fill material during construction, and withdrawal of oil or water from subsurface deposits. Baytown, Texas, near Houston, is a classic example of a local flood problem greatly aggravated by subsidence resulting from the latter situation.

Liquefaction

Although less common than subsidence, liquefaction is another type of ground failure that contributes to flood problems. Liquefaction can result in serious flooding of structures built on fill or saturated soils, as in portions of San Francisco and Anchorage.

Liquefaction is triggered by earthquakes and occurs when seismic shock waves pass through unconsolidated and saturated soil, allowing the soil grains to move freely and pack more closely together. A soil structure with water in the pore spaces is transformed to groups of grains in a fluid matrix, and the load of the overlying soil and buildings is transferred from the soil grains to the pore water. If the pressure on the water causes it to drain away, the overlying soils and structures will sink or tilt. If the water cannot drain away, the water pressure rises. When the water pressure equals the downward pressure of the overlying strata and structures, the saturated soil layer will become liquid and flow. On steep slopes (greater than 3%) where the saturated layer is at or near the surface, soil, vegetation and debris can flow rapidly downslope with the liquefied material. These flow failures can result in the movement of materials for miles. On gentle slopes (0.3 to 3%) where the saturated layer is below the surface, failures termed lateral speed occur, with huge blocks of soil moving 10 to 100 feet or more.

Fluctuating Lake Levels

Water levels in the nation's lakes can fluctuate of a short-term (e.g., seasonal) or long-term (e.g., yearly) basis. Periods of heavy rainfall, for example, can cause high water levels for short periods of time and annual snowmelt can result in higher water levels in the spring. Long-term lake level fluctuations are a less-recognized phenomenon that can cause high water and subsequent flooding problems lasting for years or even decades.

While all types of lakes may exhibit fluctuating water levels, they do not change dramatically in lakes where outlet streams provide a fairly regular balance of inflow and outflow. Some lakes, however, are completely landlocked or have outlets that are inadequate for maintaining a balance between inflow and outflow. These lakes, commonly known as “closed basin lakes,” are particularly susceptible to dramatic fluctuations in water levels – five to fifteen feet in some instances – over long periods of time. The Great Salt Lake in Utah, Devils Lake in North Dakota, and the Salton Sea in California are examples of landlocked lakes, and the Great Lakes are examples of lakes with inadequate outlets under extreme high water level conditions.

Long-term water level fluctuations are particularly pronounced on the Great Lakes and other lakes that were formed by glacial action. The significance of this problem is underscored by fact that most of the lakes in the United States are glacial lakes. In the states of Alaska, Maine, Michigan, Minnesota, New York, North Dakota, and Wisconsin alone, there are more than 100,000 inland lakes.

The “playa” or drainage lakes in the West and Southwest have no outlets or only limited outlets and are also subject to long-term fluctuations in water levels. Sinkhole lakes in Florida and throughout the Southeast also exhibit the characteristics of closed basin lakes. Flooding can be a problem on the shorelines of oxbow lakes, which are common in the floodplains of the Mississippi River, its tributaries and other southern rivers.

Flooding caused by fluctuating lake levels presents a different set of problems than riverine flooding. Riverine flooding is typically of short duration, lasting for a period of hours or days. While relatively short-duration flooding can also occur on lakes, flooding associated with closed-basin lakes or lakes with inadequate outlet channels may persist for years.

Coastal Flooding and Erosion

Coastal flooding and erosion are serious problems along much of the nation’s coasts, although the frequency and magnitude of flooding and the severity of the erosion vary considerably. They result from **storm surges** and **wave actions**.

Storm surge is the increase in water surface elevation above normal tide levels due primarily to low barometric pressure and the piling up of waters in coastal areas as a result of wind action over a long stretch of open water. The low pressure inside a storm or hurricane’s eye creates suction like a straw, creating a dome of water near the center of the storm. In the deep ocean, this dome of water sinks and harmlessly flows away. But as a storm nears land, strong winds in the storm push this dome of water toward the shore, the rising sea floor blocks the water’s escape and it comes ahore as deadly storm surge. (See Figure 2-4.) An intense hurricane can send a dome of water many miles wide and more than 25 feet deep barreling toward the shore as the storm hits land.

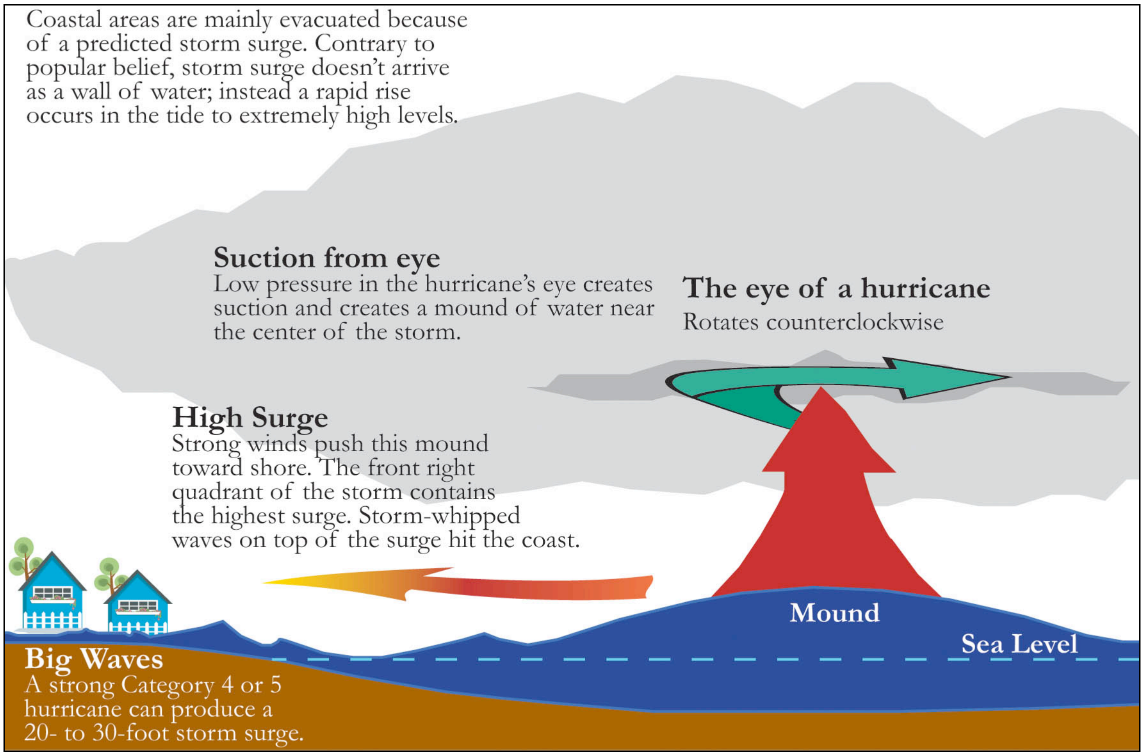

Figure 2-4. Graphical representation of storm surge.

Depending upon local topography, a storm surge may inundate only a small area (such as along sections of the Northeast and Northwest coasts) or may inundate coastal lands for a mile or more inland from the shoreline (as in many areas of the south Atlantic and Gulf coasts).

Storm surge is usually estimated by subtracting the regular/astrological tide level from the observed storm tide. Typical storm surge heights range from several feet to more than 25 feet. The exact height of the storm surge and which coastal areas will be flooded depends on many factors, including the strength, intensity and speed of the hurricane or storm; the direction it is moving relative to the shoreline; how rapidly the sea floor is sloping along the shore; the shape of the shoreline, and the astronomical tide. In general, storm surge is most damaging when it occurs along a shallow sloped shoreline, during high tide, in a highly populated and developed area with little or no natural buffers, such as barrier islands, coral reefs and coastal vegetation. Storm surge is also most damaging in the storm's right front quadrant because the storm, its winds and ocean waves are all moving in an onshore direction due to the counter-clockwise rotation of hurricanes in the Northern Hemisphere. In contrast, to the left of the eye, ocean waves and sea-level rise are moving toward the shore, but the winds are blowing in an offshore direction, thus counteracting or moderating some of the effects of the storm surge.

Storm surge causes sea levels to rise for a relatively short period of time (typically four to eight hours, though some areas may take much longer to recede to their pre-storm levels) – often resulting in extensive coastal flooding that can weaken or destroy coastal structures. By temporarily raising sea level, storm surge permits "dangerous and battering waves" and floating debris to access coastal areas and structures never conceived of nor built to withstand the punishing effects of ocean waves. It is these battering waves that cause most beach erosion and extensive damage to coastal structures such as buildings, roadways, bridges, marinas, piers, boardwalks, and sea walls.

In addition to storm surge, **wave action** is an important aspect of coastal storms. Breaking waves at the shoreline become very destructive, causing damages to natural and manmade structures by hydrodynamic pressure, battering solid objects and scouring sand from around foundations. Components of wave action include wave set-up and wave run-up. Wave set-up is the superelevation of the water surface over normal surge elevation and is caused by onshore mass transport of the water by wave action alone. Wave run-up is the action of a wave after it breaks and the water "runs up" the shoreline or other obstacle, flooding areas not reached by the storm surge itself. Where vertical obstructions such as seawalls are present, wave run-up is translated into upward movement of the water.

As waves move toward the shore, they encounter several obstacles. The first obstacle is the sloping bottom near the shoreline. When waves reach a water depth equal to about 1.3 times the wave height, the wave breaks. Breaking waves dissipate their energy by generating turbulance in the water and by transporting sediment lifted off the bottom and tossed around by the turbulent water. As the turbulent water travels forward, it expends most of its remaining energy as it rushed up the beach slope. The beach adjusts to changes in wave energy by changing its profile. Beach material is moved either seaward, creating an offshore berm, or landward, building up the beach. The beach is constantly adjusting to both wave energy and water level.

Offshore berms built up by the natural action of waves serve to protect the beach from most storm waves. When major storms generate larger waves, the berm may be eroded and berm material carried offshore. With the protective value of the berm removed, large waves can overtop the beach. In severe storms such as hurricanes 50- to 100-foot wide dunes may disappear in only a few hours. Although the dunes and beach may eventually recover to their previous conditions, the process may require many years.

While hurricanes are the most violent type of storm and receive the most attention, serious flooding and erosion problems are also caused by other coastal storms. In the Atlantic, extratropical storms that develop in mid-latitudes in the fall, winter and spring occur much more frequently than tropical hurricanes, and may be more than 1,000 miles in diameter, much larger than a tropical hurricane. Although maximum winds are of lower velocity than tropical hurricane winds (75 miles/hr. or greater), some wind gusts of hurricane velocity may occur with extratropical storms.

Extratropical storms that occur along the northern part of the east coast of the United States, accompanied by strong winds blowing from the northeast quadrant, are called northeasters. They may stall off the coast of the North Atlantic states and produce high tides that persist for several days.

Photograph showing damage as a consequence of a coastal storm.

Floodwater Damage to Structures

The extent of damage to structures that come in contact with floodwaters depends on the depth of the water in and around the structure, the length of time of inundation, the toxic extent of contaminants in floodwaters, and how rapidly the water is moving. Both static (little or no water movement) and dynamic (rapidly flowing water) forces are often at play.

In a static environment, water attacks and compromises the integrity of every part of a structure, particularly the wood foundation pilings, structural beams, carpets, wood floors, cabinetry, mechanical systems, utilities, and walls. Most damage to homes is sustained in the first four feet above the first floor. Within this space are located the above structural components and household furnishings. Floods that rise and recede quickly cause less damage than water that sits for long periods. In these types of floods, the carpets, floors and drywall can be replaced, other components dried out, and the remainder of the structure is likely sound.

Floodwaters that fill homes and other structures for weeks typically result in totally ruining interiors, i.e., replacing all of the components listed in the above paragraph. The economic decision is whether to demolish the structure and start over or repair what remains.

The dynamic forces of rapidly moving floodwater add to the above scenario. As stated earlier, water flowing around and within a structure can exert great pressure on structural surfaces (e.g., water flowing at 10 mph exerts the same pressure as wind gusts of 270 mph),[7] often causing further damage, even failure.

"Flood water" vs. "Storm water"

The floodplain management discipline is often faced with trying to distinguish between problems associated with floods and those with local drainage. The distinction may be necessary in order to determine program or agency responsibilities. To the layperson, the distinction may not be really important. Whether they have 2-3 feet of "storm water" or "flood water" in their residence or business may make little difference. They have still been flooded.

The following general distinctions can be made between the two:

- Flow directions in major streams
    - Flooding – water overflows the channel and moves away from the stream
    - Storm water – water runoff flows towards the channel or conveyance structure
- Size of drainage area
    - Flooding – the contributing drainage area is <u>greater</u> than one square mile
    - Storm water- the contributing drainage area is <u>less</u> than one square mile
- Nature of stream
    - Flooding – large natural channel, typically in a rural area
    - Storm water – small constructed or modified channel in urban area
- Stream flow
    - Flooding – continuous
    - Storm water – discontinuous

Funding for "flood problems" may be available from federal and state agencies. Storm water management and drainage is typically assumed to be a local responsibility.

[7] "USA Today," cited earlier.

Chapter Homework Assignment

1. What type of flood do you believe you will most frequently encounter in your professional practice and why?
2. Which type do you believe would be the most difficult for you to deal with and why?
3. Why is it necessary to distinguish between “floodwater” and “stormwater,” or is it really necessary?