EENS 111	Physical Geology
Tulane University	Prof. Stephen A. Nelson
Streams and Drainage Systems	

This page last updated on 02-Nov-2015

Streams

A ***stream*** is a body of water that carries rock particles and dissolved ions and flows down slope along a clearly defined path, called a ***channel***. Thus, streams may vary in width from a few centimeters to several tens of kilometers. Streams are important for several reasons:

- Streams carry most of the water that goes from the land to the sea, and thus are an important part of the water cycle.
- Streams carry billions of tons of sediment to lower elevations, and thus are one of the main transporting mediums in the production of sedimentary rocks.
- Streams carry dissolved ions, the products of chemical weathering, into the oceans and thus make the sea salty.
- Streams are a major part of the erosional process, working in conjunction with weathering and mass wasting. Much of the surface landscape is controlled by stream erosion, evident to anyone looking out of an airplane window.
- Streams are a major source of water, waste disposal, and transportation for the world's human population. Most population centers are located next to streams.
- When stream channels fill with water the excess flows onto the the land as a flood. Floods are a common natural disaster.

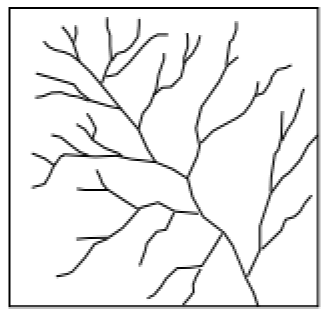
The objectives for this discussion are as follows:

1. How do drainage systems develop and what do they tell us about the geology of an area?
2. How do stream systems operate?
3. How do streams erode the landscape?
4. What kinds of depositional features result from streams?
5. How do drainage systems evolve?
6. What causes flooding and how can we reduce the damage from floods?

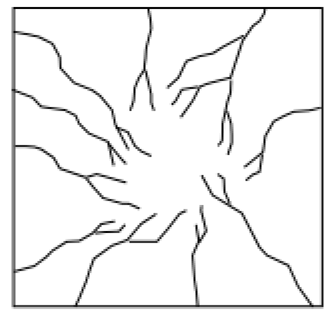
Drainage Systems

Development of Streams - Steamflow begins when water is added to the surface from rainfall, melting snow,and groundwater. Drainage systems develop in such a way as to efficiently move water off the land. Streamflow begins as moving sheetwash which is a thin surface layer of water. The water moves down the steepest slope and starts to erode the surface by creating small rill channels. As the rills coalesce, deepen, and downcut into channels larger channels form. Rapid erosion lengthens the channel upslope in a process called ***headward erosion***. Over time, nearby channels merge with smaller tributaries joining a larger trunk stream. (See figure 17.3 in your text). The linked channels become what is known as a ***drainage network***. With continued erosion of the channels, drainage networks change over time.

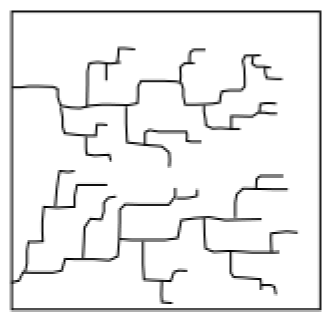
Drainage Patterns - Drainages tend to develop along zones where rock type and structure are most easily eroded. Thus various types of drainage patterns develop in a region and these drainage patterns reflect the structure of the rock.



Dendritic Drainage



Radial Drainage



Rectangular Drainage

- Dendritic drainage patterns are most common. They develop on a land surface where the underlying rock is of uniform resistance to erosion.
- Radial drainage patterns develop surrounding areas of high topography where elevation drops from a central high area to surrounding low areas.
- Rectangular drainage patterns develop where linear zones of weakness, such as joints or faults cause the streams to cut down along the weak areas in the rock.
- Trellis drainage patterns develop where registrant rocks break up the landscape (see figure 17.4 in your textbook).

Drainage Basins - Each stream in a drainage system drains a certain area, called a drainage basin (also called a catchment or a watershed). In a single drainage basin, all water falling in the basin drains into the same stream. A ***drainage divide*** separates each drainage basin from other drainage basins. Drainage basins can range in size from a few km^2, for small streams, to extremely large areas, such as the Mississippi River drainage basin which covers about 40% of the contiguous United States (see figure 17.5c in your text).

Continental Divides - Continents can be divided into large drainage basins that empty into different ocean basins. For example: North America can be divided into several basins west of the Rocky Mountains that empty into the Pacific Ocean. Streams in the northern part of North America empty into the Arctic Ocean, and streams East of the Rocky Mountains empty into the

Atlantic Ocean or Gulf of Mexico. Lines separating these major drainage basins are termed Continental Divides. Such divides usually run along high mountain crests that formed recently enough that they have not been eroded. Thus major continental divides and the drainage patterns in the major basins reflect the recent geologic history of the continents.

Permanent Streams - Streams that flow all year are called permanent streams. Their surface is at or below the water table. They occur in humid or temperate climates where there is sufficient rainfall and low evaporation rates. Water levels rise and fall with the seasons, depending on the discharge.

Ephemeral Streams - Streams that only occasionally have water flowing are called ephemeral streams or dry washes. They are above the water table and occur in dry climates with low amounts of rainfall and high evaporation rates. They flow mostly during rare flash floods.

Geometry and Dynamics of Stream Channels

Discharge

The stream channel is the conduit for water being carried by the stream. The stream can continually adjust its channel shape and path as the amount of water passing through the channel changes. The volume of water passing any point on a stream is called the ***discharge***. Discharge is measured in units of volume/time (m^3/sec or ft^3/sec).

$$Q = A \times V$$

Discharge (m^3/sec) = Cross-sectional Area [width x average depth] (m^2) x Average Velocity (m/sec).

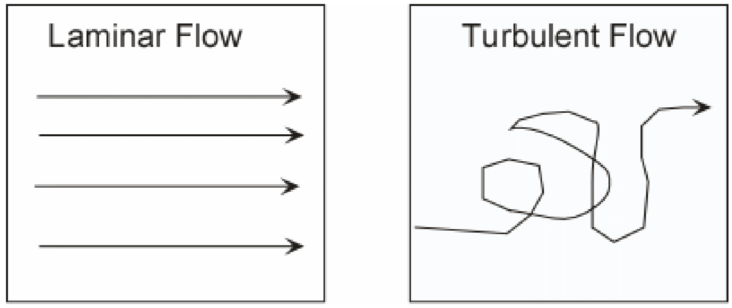
As the amount of water in a stream increases, the stream must adjust its velocity and cross sectional area in order to form a balance. ***Discharge increases as more water is added through rainfall, tributary streams, or from groundwater seeping into the stream***. As discharge increases, generally width, depth, and velocity of the stream also increase.

Velocity

A stream's velocity depends on position in the stream channel, irregularities in the stream channel caused by resistant rock, and stream gradient. Friction slows water along channel edges. Friction is greater in wider, shallower streams and less in narrower, deeper streams.

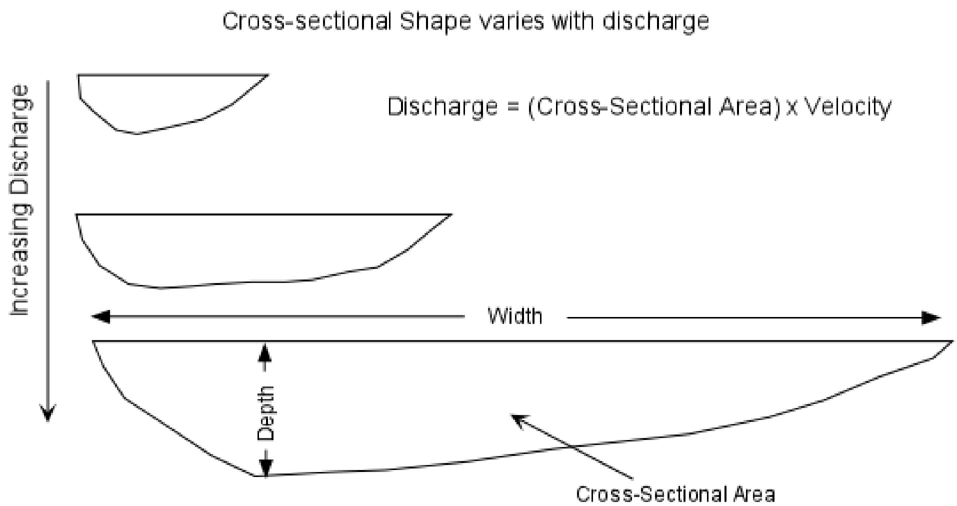
In straight channels, highest velocity is in the center. In curved channels,The maximum velocity traces the outside curve where the channel is preferentially scoured and deepened. On the inside of the curve were the velocity is lower, deposition of sediment occurs. The deepest part of the channel is called the thalweg, which meanders with the curve the of the stream. Flow around curves follows a spiral path.

Stream flow can be either laminar, in which all water molecules travel along similar parallel paths, or turbulent, in which individual particles take irregular paths. Stream flow is characteristically turbulent. This is chaotic and erratic, with abundant mixing, swirling eddies, and sometimes high velocity. Turbulence is caused by flow obstructions and shear in the water. Turbulent eddies scour the channel bed, and can keep sediment in suspension longer than laminar flow and thus aids in erosion of the stream bottom.



Cross Sectional Shape

Cross-sectional shape varies with position in the stream, and discharge**.** The deepest part of channel occurs where the stream velocity is the highest. Both width and depth increase downstream because discharge increases downstream. As discharge increases the cross sectional shape will change, with the stream becoming deeper and wider.



Erosion by Streams

Streams erode because they have the ability to pick up rock fragments and transport them to a new location. The size of the fragments that can be transported depends on the velocity of the stream and whether the flow is laminar or turbulent. Turbulent flow can keep fragments in suspension longer than laminar flow.

Streams can also erode by undercutting their banks resulting in mass-wasting processes like slumps or slides. When the undercut material falls into the stream, the fragments can be transported away by the stream.

Streams can cut deeper into their channels if the region is uplifted or if there is a local change in base level. As they cut deeper into their channels the stream removes the material that once made up the channel bottom and sides.

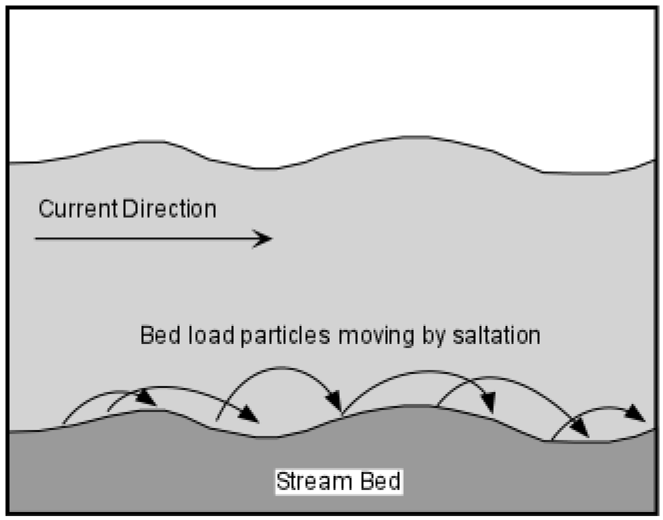
Although slow, as rocks move along the stream bottom and collide with one another, abrasion of the rocks occurs, making smaller fragments that can then be transported by the stream.

Finally, because some rocks and minerals are easily dissolved in water, dissolution also occurs, resulting in dissolved ions being transported by the stream.

Sediment Transport and Deposition

The rock particles and dissolved ions carried by the stream are the called the stream's ***load.*** Stream load is divided into three categories.

- ***Suspended Load*** - particles that are carried along with the water in the main part of the streams. The size of these particles depends on their density and the velocity of the stream. Higher velocity currents in the stream can carry larger and denser particles.
- ***Bed Load*** - coarser and denser particles that remain on the bed of the stream most of the time but move by a process of saltation (jumping) as a result of collisions between particles, and turbulent eddies. Note that sediment can move between bed load and suspended load as the velocity of the stream changes.



- ***Dissolved Load*** - ions that have been introduced into the water by chemical weathering of rocks. This load is invisible because the ions are dissolved in the water. The dissolved load consists mainly of HCO_3^{-2} (bicarbonate ions), Ca^{+2}, SO_4^{-2}, Cl^-, Na^{+2}, Mg^{+2}, and K^+. These ions are eventually carried to the oceans and give the oceans their salty character. Streams that have a deep underground source generally have higher dissolved load than those whose source is on the Earth's surface.

The maximum size of particles that can be carried as suspended load by the stream is called ***stream competence***. The maximum load carried by the stream is called ***stream capacity***. Both competence and capacity increase with increasing discharge. At high discharge boulder and cobble size material can move with the stream and are therefore transported. At low discharge the larger fragments become stranded and only the smaller, sand, silt, and clay sized fragments move.

When flow velocity decreases the competence is reduced and sediment drops out. Sediment grain sizes are sorted by the water. Sands are removed from gravels; muds from both. Gravels settle in channels. Sands drop out in near channel environments. Silts and clays drape floodplains away from channels.

Changes Downstream

As one moves along a stream in the downstream direction:

- Discharge increases, as noted above, because water is added to the stream from tributary streams and groundwater.
- As discharge increases, the width, depth, and average velocity of the stream increase.
- The gradient of the stream, however, will decrease.

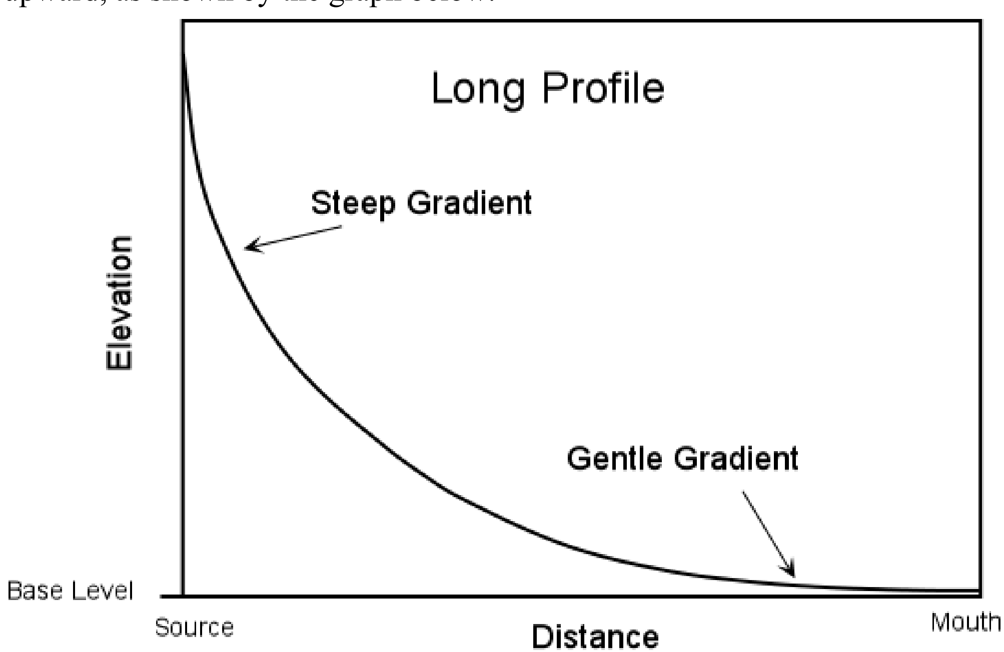
It may seem to be counter to your observations that velocity increases in the downstream direction, since when one observes a mountain stream near the headwaters where the gradient is high, it appears to have a higher velocity than a stream flowing along a gentle gradient. But, the water in the mountain stream is likely flowing in a turbulent manner, due to the large boulders and cobbles which make up the streambed. If the flow is turbulent, then it takes longer for the water to travel the same linear distance, and thus the average velocity is lower.

Also as one moves in the downstream direction,

- The size of particles that make up the bed load of the stream tends to decrease. Even though the velocity of the stream increases downstream, the bed load particle size decreases mainly because the larger particles are left in the bed load at higher elevations and abrasion of particles tends to reduce their size.
- The composition of the particles in the bed load tends to change along the stream as different bedrock is eroded and added to the stream's load.

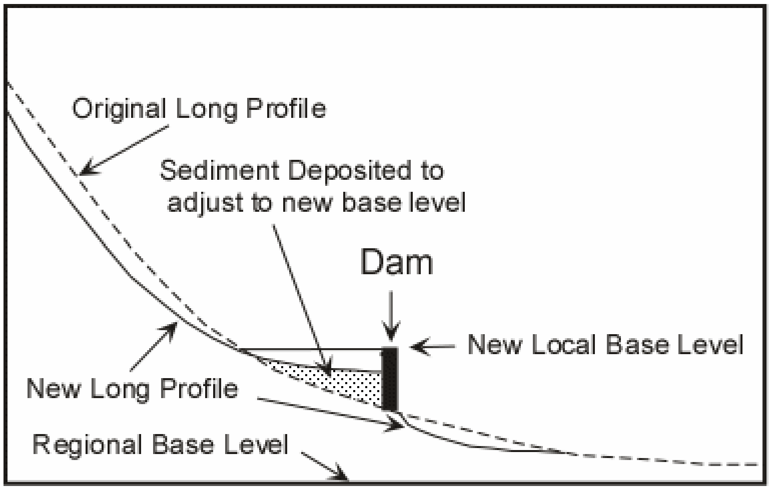
Long Profile

A plot of elevation versus distance. Usually shows a steep ***gradient*** or slope, near the source of the stream and a gentle gradient as the stream approaches its mouth. The long profile is concave upward, as shown by the graph below.



Base Level

Base level is defined as the limiting level below which a stream cannot erode its channel. For streams that empty into the oceans, base level is sea level. Local base levels can occur where the stream meets a resistant body of rock, where a natural or artificial dam impedes further channel erosion, or where the stream empties into a lake.



When a natural or artificial dam impedes stream flow, the stream adjusts to the new base level by adjusting its long profile. In the example here, the long profile above and below the dam are adjusted. Erosion takes place downstream from the dam (especially if it is a natural dam and water can flow over the top). Just upstream from the dam the velocity of the stream is lowered so that deposition of sediment occurs causing the gradient to become lower. The dam essentially become the new base level for the part of the stream upstream from the dam.

In general, if base level is lowered, the stream cuts downward into its channel and erosion is accelerated. If base level is raised, the stream deposits sediment and readjusts its profile to the new base level.

Valleys and Canyons

Land far above base level is subject to downcutting by the stream. Rapid downcutting creates an eroded trough which can become either a valley or canyon. A valley has gently sloping sidewalls that show a V-shape in cross-section. A Canyon has steep sidewalls that form cliffs. Whether or valley or canyon is formed depends on the rater of erosion and strength of the rocks. In general, slow downcutting and weak, easily erodable rocks results in valleys and rapid downcutting in stronger rocks results in canyons.

Because geologic processes stack strong and weak rocks, such stratigraphic variation often yields a stair step profile of the canyon walls, as seen in the Grand Canyon. Strong rocks yield vertical cliffs, whereas weak rocks produce more gently sloped canyon walls.

Active downcutting flushes sediment out of channels. Only after the sediment is flushed our can further downcutting occur. Valleys store sediment when base level is raised.

Rapids

Rapids are turbulent water with a rough surface. Rapids occur where the stream gradient suddenly increases, where the stream flows over large clasts in the bed of the stream, or where there is an abrupt narrowing of the channel. Sudden change in gradient may occur where an active fault crosses the stream channel. Large clasts may be transported into the stream by a tributary stream resulting in rapids where the two streams join. Abrupt narrowing of the stream may occur if the stream encounters strong rock that is not easily subject to erosion.

Waterfalls

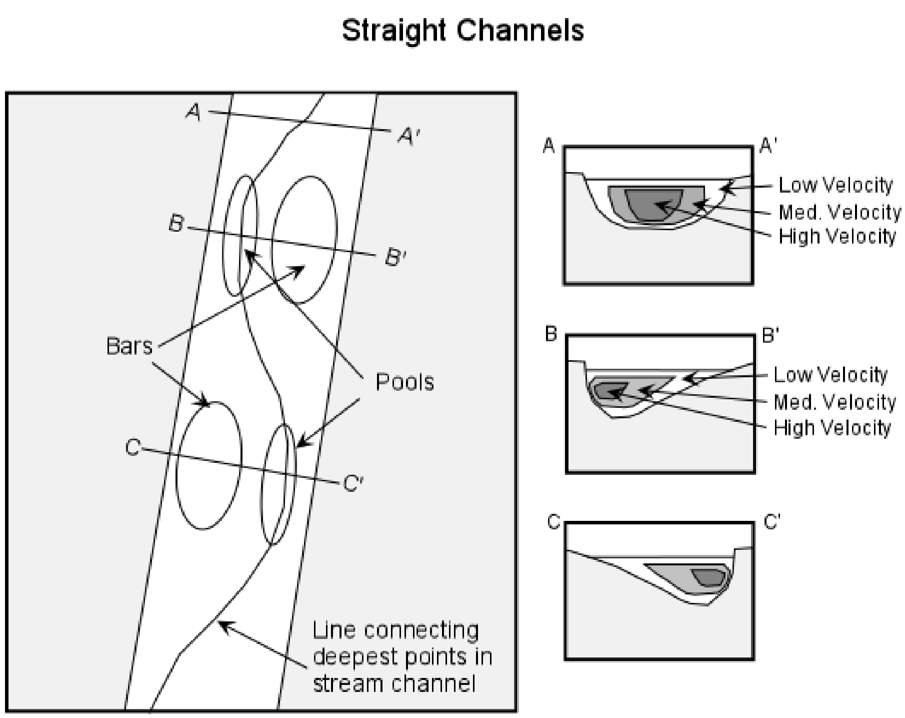
Waterfalls are temporary base levels caused by strong erosion resistant rocks. Upon reaching the strong rock, the stream then cascades or free falls down the steep slope to form a waterfalls. Because the rate of flow increases on this rapid change in gradient, erosion occurs at the base of the waterfall where a plunge pool forms. This can initiate rapid erosion at the base, resulting in undercutting of the cliff that caused the waterfall. When undercutting occurs, the cliff becomes subject to rockfalls or slides. This results in the waterfall retreating upstream and the stream eventually eroding through the cliff to remove the waterfall.

Niagara Falls in upstate New York is a good example. Lake Erie drops 55 m flowing toward Lake Ontario. A dolostone caprock is resistant and the underlying shale erodes. Blocks of unsupported dolostone collapse and fall.
Niagara Falls continuously erodes south toward Lake Erie. In temporary diversion of the water that flows over the American Falls section revealed huge blocks of rock. The rate of southward retreat of Niagara Falls is presently 0.5 m/yr. Eventually the falls will reach Lake Erie, and when that happens Lake Erie will drain.

Channel Patterns

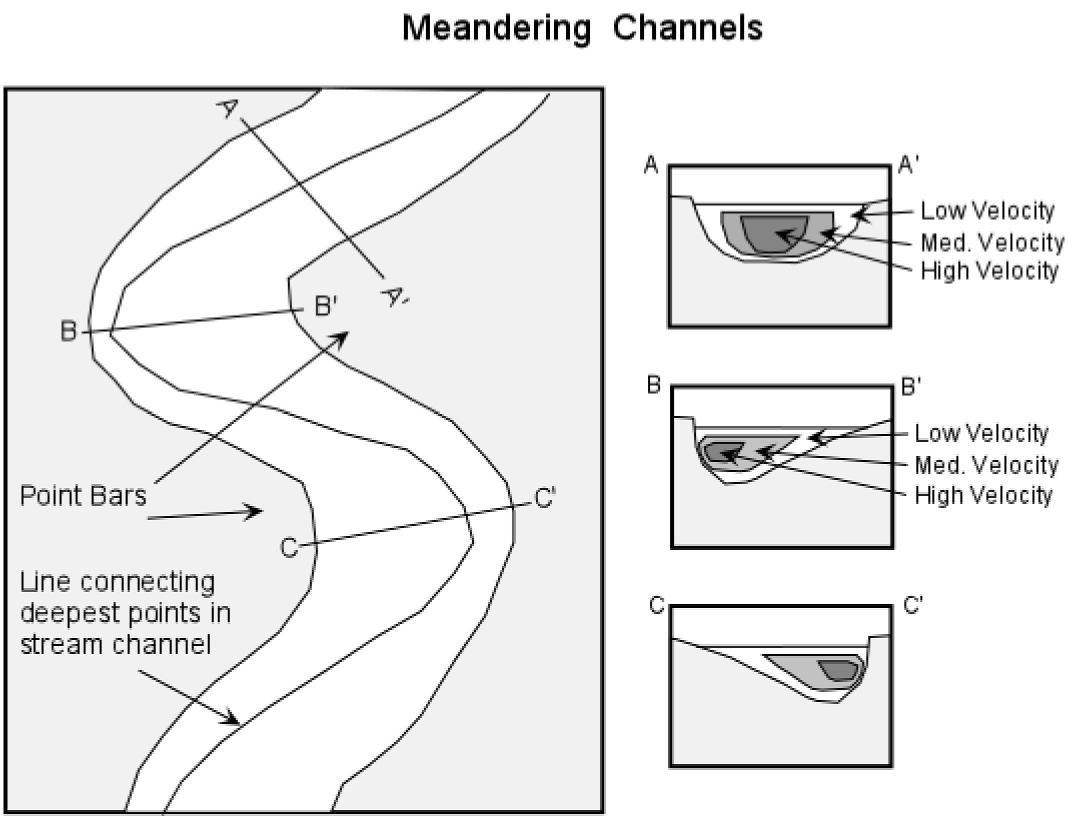
Straight Channels - Straight stream channels are rare. Where they do occur, the channel is usually controlled by a linear zone of weakness in the underlying rock, like a fault or joint system.

Even in straight channel segments water flows in a sinuous fashion, with the deepest part of the channel changing from near one bank to near the other. Velocity is highest in the zone overlying the deepest part of the stream. In these areas, sediment is transported readily resulting in ***pools***. Where the velocity of the stream is low, sediment is deposited to form ***bars***.

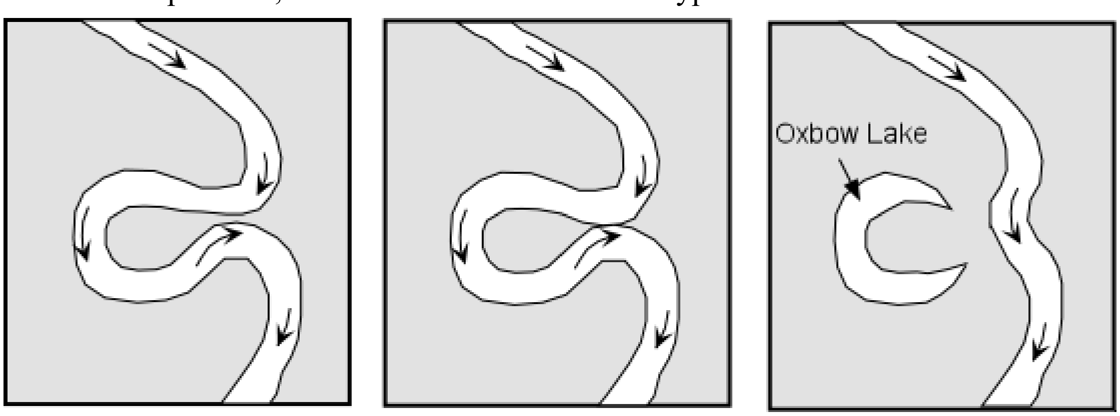


The bank closest to the zone of highest velocity is usually eroded and results in a ***cutbank***.

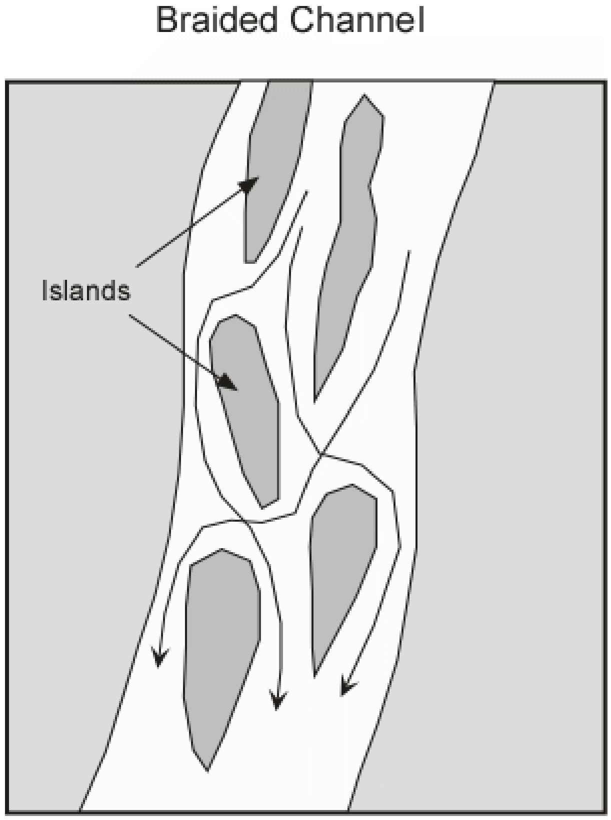
Meandering Channels - Because of the velocity structure of a stream, and especially in streams flowing over low gradients with easily eroded banks, straight channels will eventually erode into ***meandering channels***. Erosion will take place on the outer parts of the meander bends where the velocity of the stream is highest. Sediment deposition will occur along the inner meander bends where the velocity is low. Such deposition of sediment results in exposed bars, called ***point bars***. Because meandering streams are continually eroding on the outer meander bends and depositing sediment along the inner meander bends, meandering stream channels tend to migrate back and forth across their flood plain.



If erosion on the outside meander bends continues to take place, eventually a meander bend can become cut off from the rest of the stream. When this occurs, the cutoff meander bend, because it is still a depression, will collect water and form a type of lake called an ***oxbow lake***.



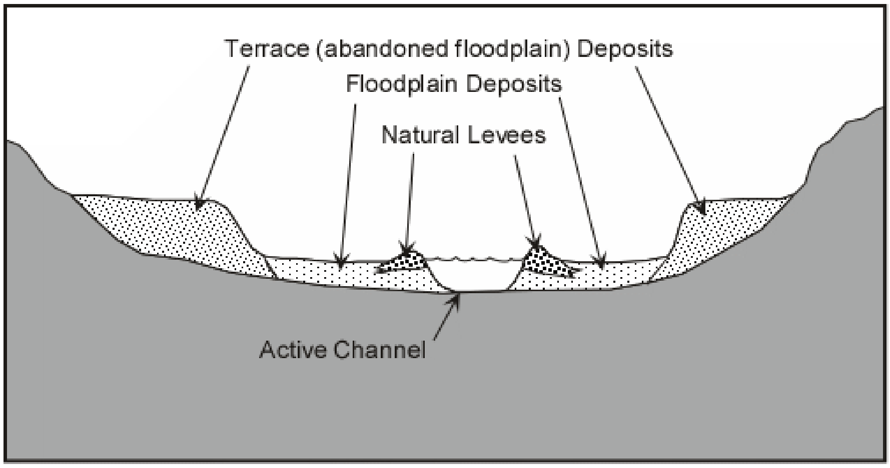
Braided Channels - In streams having highly variable discharge and easily eroded banks, sediment gets deposited to form bars and islands that are exposed during periods of low discharge. In such a stream the water flows in a braided pattern around the islands and bars, dividing and reuniting as it flows downstream. Such a channel is termed a ***braided channel***. During periods of high discharge, the entire stream channel may contain water and the islands are covered to become submerged bars. During such high discharge, some of the islands could erode, but the sediment would be re-deposited as the discharge decreases, forming new islands or submerged bars. Islands may become resistant to erosion if they become inhabited by vegetation



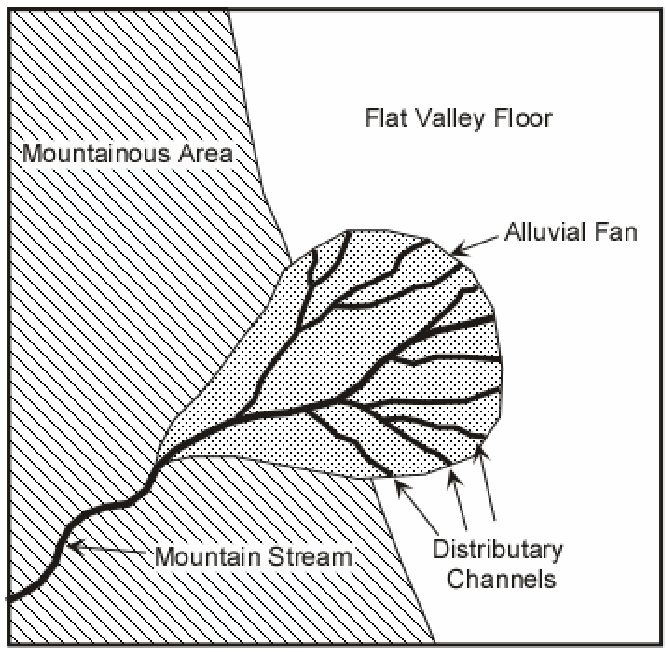
Stream Deposits

Sudden changes in velocity can result in deposition by streams. Within a stream we have seen that the velocity varies with position, and, if sediment gets moved to the lower velocity part of the stream the sediment will come out of suspension and be deposited. Other sudden changes in velocity that affect the whole stream can also occur. For example if the discharge is suddenly increased, as it might be during a flood, the stream will overtop its banks and flow onto the floodplain where the velocity will then suddenly decrease. This results in deposition of such features as levees and floodplains. If the gradient of the stream suddenly changes by emptying into a flat-floored basin, an ocean basin, or a lake, the velocity of the stream will suddenly decrease resulting in deposition of sediment that can no longer be transported. This can result in deposition of such features as alluvial fans and deltas.

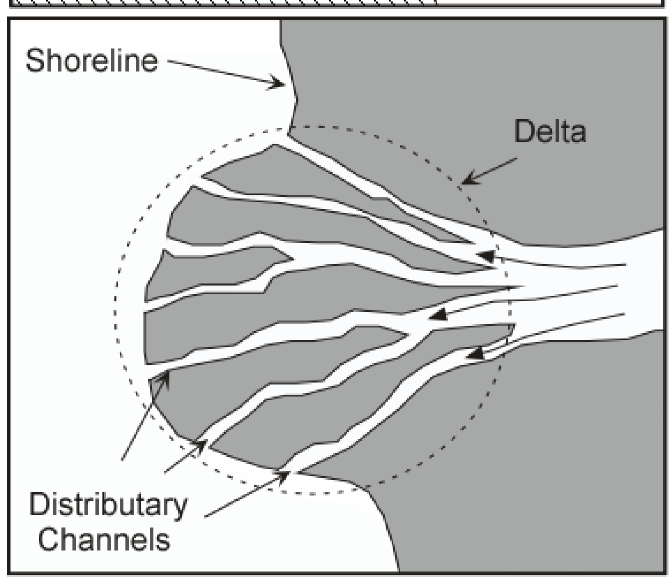
- ***Floodplains and Levees*** - As a stream overtops its banks during a flood, the velocity of the flood will first be high, but will suddenly decrease as the water flows out over the gentle gradient of the floodplain. Because of the sudden decrease in velocity, the coarser grained suspended sediment will be deposited along the riverbank, eventually building up a natural levee. Natural levees provide some protection from flooding because with each flood the levee is built higher and therefore discharge must be higher for the next flood to occur. (Note that the levees we see along the Mississippi River here in New Orleans are not natural levees, but man made levees, built to protect the floodplain from floods. Still, the natural levees do form the high ground as evidenced by the flooding that occurred as a result of levee breaches during Hurricane Katrina).



- ***Terraces*** - Terraces are exposed former floodplain deposits that result when the stream begins down cutting into its flood plain (this is usually caused by regional uplift or by lowering the regional base level, such as a drop in sea level).
- ***Alluvial Fans*** - When a steep mountain stream enters a flat valley, there is a sudden decrease in gradient and velocity. Sediment transported in the stream will suddenly become deposited along the valley walls in an alluvial fan. As the velocity of the mountain stream slows it becomes choked with sediment and breaks up into numerous distributary channels.



- ***Deltas*** - When a stream enters a standing body of water such as a lake or ocean, again there is a sudden decrease in velocity and the stream deposits its sediment in a deposit called a delta. Deltas build outward from the coastline, but will only survive if the ocean currents are not strong enough to remove the sediment.



As the velocity of a stream decreases on entering the delta, the stream becomes choked with sediment and conditions become favorable to those of a braided stream channel, but instead of braiding, the stream breaks into many smaller streams called distributary streams.

Over the last 1,000 years, most of the land that makes up southern Louisiana has been built by the Mississippi River depositing sediment to form delta lobes. These delta lobes have shifted back and forth through time as the River's course changed in response to changes in sea level and the River trying to maintain the shortest and steepest path to the Gulf of Mexico (see figure 17.25a)

Drainage Evolution

Landscapes on Earth's surface evolve over time with the main cause of change being streamflow and the resulting erosion and deposition. For example:
Uplift sets a new base level which causes streams to cut deeper, resulting in widening of valleys and erosion of hills. If these erosional processes were to continue, the landscape would be eroded to base level.

Stream Piracy

Stream piracy is where one stream erodes headward to capture the drainage of another stream. The stream with more vigorous erosion (steeper gradient), intercepts another stream and water from the captured stream no flows into the pirating stream (see figure 17.26 in your text).

Drainage Reversal

Drainage reversals can occur as a result of tectonic processes. For example, in the early Mesozoic when Africa and South America were part of the same continent, South America drained westward. Eventually Africa separated from South America to form the Atlantic Ocean on the eastern side of South America. On the west coast, subduction began and the resulting compression caused the uplift of the Andes mountains. As the uplift occurred, the drainage had to reverse to flow to the east into the Atlantic Ocean (see figure 17.27 in your text).

Superposed and Antecedent Streams

In looking at the landscape, it is often evident that streams sometimes cut through deformed terrain seemingly ignoring the geologic structures and hardness of the rock. If a stream initially develops on younger flat strata made of soft material and then cuts downward into the underlying deformed strata while maintaining the course developed in the younger strata, it is referred to as a ***superposed stream***, because the stream pattern was superposed on the underlying rocks. In such cases much of the original soft strata is removed. (see figure 17.29 in your text).

If tectonic uplift raises the ground beneath established streams and if erosion keeps pace with uplift, the stream will cut downward and maintain its original course. In such a case, the stream is called an ***antecedent stream,*** because the stream was present before the uplift occurred . (See figure 17.30 in your textbook).

Some antecedent streams have incised meanders. The meanders initially develop on a gentle gradient then uplift raises the landscape (dropping the base level) and the meanders cut downward into the uplifted landscape (see figure 17.28 in your text for an example).

Floods

Floods occur when the discharge of the stream becomes too high to be accommodated in the normal stream channel. When the discharge becomes too high, the stream widens its channel by overtopping its banks and flooding the low-lying areas surrounding the stream. The areas that become flooded are called ***floodplains***.

Floodwaters are devastating to people and property. During a flood discharge exceeds the storage volume of the stream channel. Velocity (thus, competence and capacity) increase and water leaves the channel and flows onto adjacent land. Water slows away from the thalweg, dropping sediment.

Causes of Flooding

1. Heavy rains dump large volumes of water on the landscape increasing the amount of water flowing into the stream.

2. If the soil has become saturated as a result of rain so that there is no room in the soil for water to infiltrate, the water instead will run into stream channels and increase the discharge.

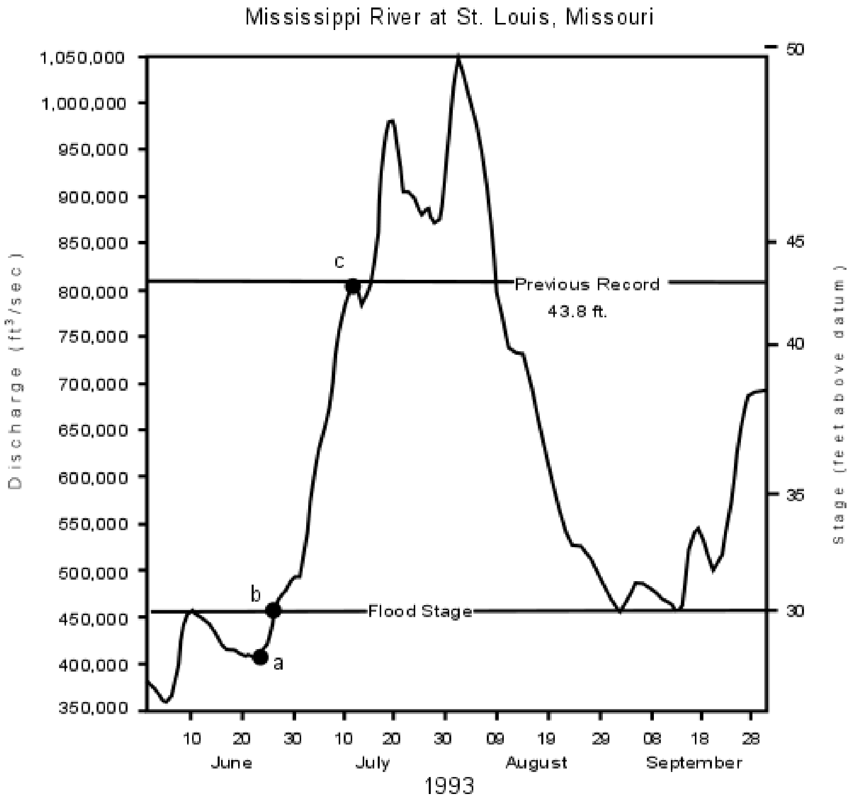
3. In the winter, if a sudden increase in temperature rapidly melts snow causing an influx of water into the drainage system.

4. When a natural or artificial dam breaks or levee breaks, releasing water into a channel with a sudden increase in discharge or releases water from the channel onto the surrounding floodplain.

Flood Stage

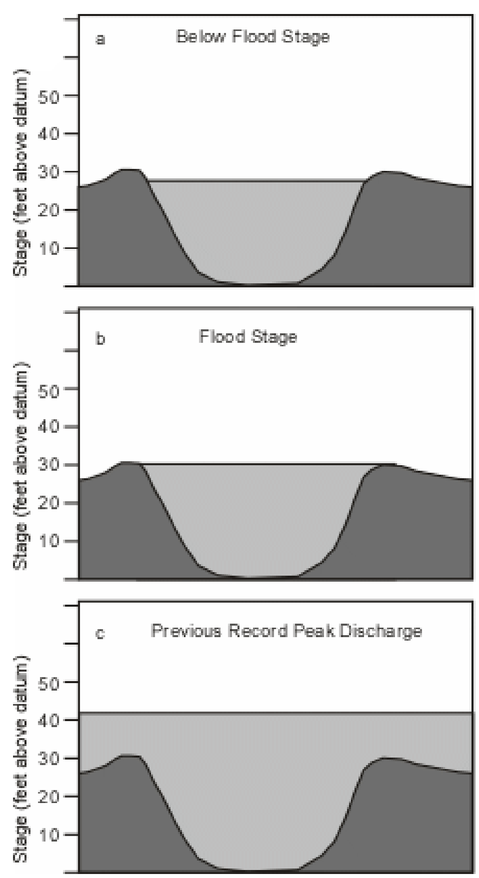
- The term ***stage*** refers to the height of a river (or any other body of water) above a locally defined elevation. This locally defined elevation is a reference level, often referred to as datum. For example, for the lower part of the Mississippi River, reference level or datum, is sea level (0 feet). Currently the Mississippi River is at a stage of about 12.5 feet, that is 12.5 feet above sea level. Other river systems have a reference level that is not sea level. Most rivers in the United States have gaging stations where measurements are continually made of the river's stage and discharge. These are plotted on a graph called a ***hydrograph***, which shows the stage or discharge of the river, as measured at the gaging station, versus time.

- When the discharge of a river increases, the channel may become completely full. Any discharge above this level will result in the river overflowing its banks and causing a flood. The stage at which the river will overflow its banks is called ***bankfull stage*** or ***flood stage.*** For example, the graph below is a hydrograph of the Mississippi River at St. Louis, Missouri during the time period of the 1993 flood. Discharge is plotted on the Y-axis, and dates are plotted on the x-axis. Note that stages corresponding to various discharges are shown on the left-hand y-axis, and that the spacing between equal units of stage are not equal along the y-axis.



- Note that for the 1993 Mississippi River Flood, the river reached flood stage of 30 feet above datum on about June 26 and peaked (or crested) at just under 50 feet above datum on August 1. The sudden drops seen in discharge around July 15 and July 20 corresponded to breaks in the levee system upstream from St. Louis that caused water to flow onto the floodplain upstream, thus reducing both the stage and discharge measured at St. Louis.

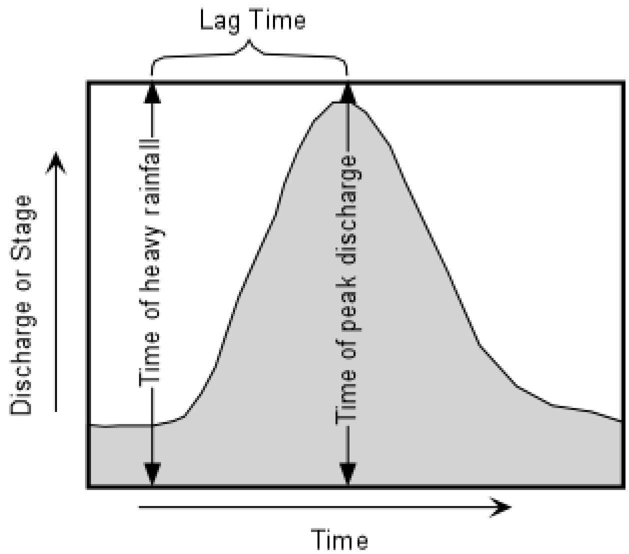
  To illustrate, for the Mississippi River flood at St. Louis, idealized cross sections of the River are shown below for points a, b, and c in the diagram above.



Lag Time

The time difference between when heavy precipitation occurs and when peak discharge occurs in the streams draining an area is called ***lag time.***

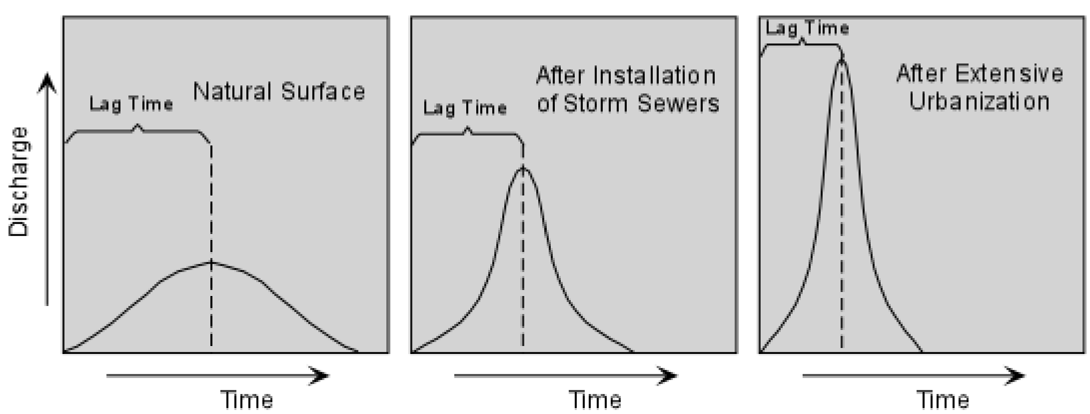
Lag time depends on such factors as the amount of time over which the rain falls and the amount of water that can infiltrate into the soil.



If the amount of rain is high over a short time period, lag time is short. If the amount of rain is high over a longer time period, lag time is longer. Lack of infiltration and interception reduce lag time

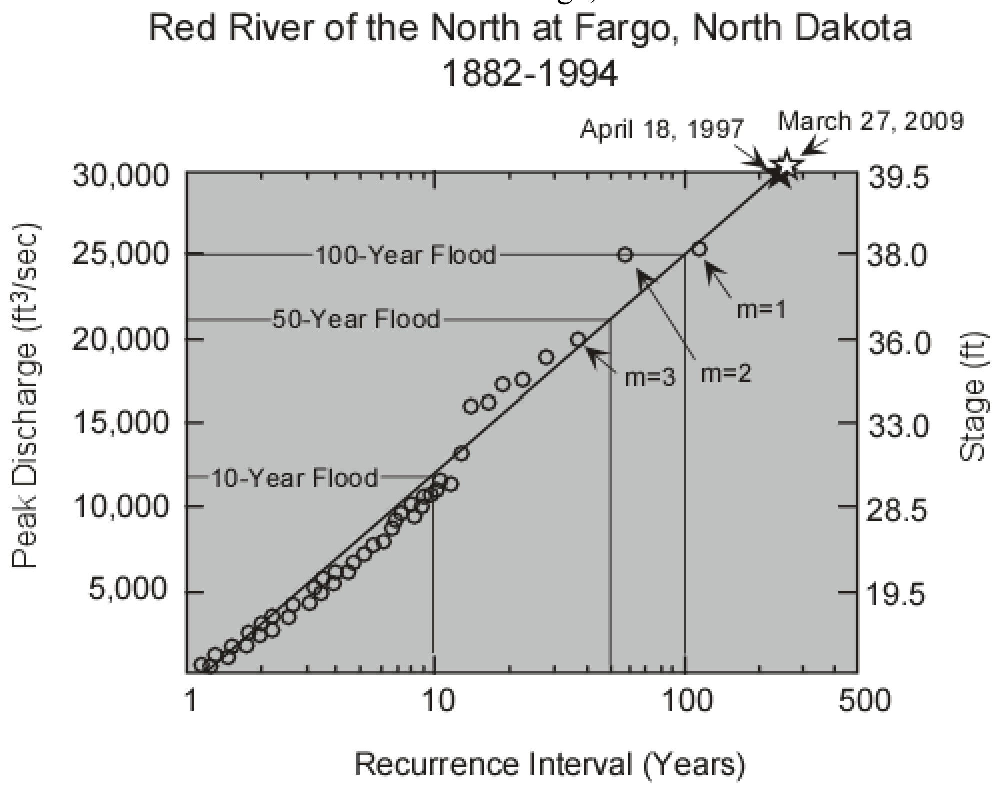
Flash floods occur when the rate of infiltration is low and heavy rains occur over a short period of time. Because they come with little warning, flash floods are the most dangerous to human lives. Such floods stem from unusually intense rainfall or dam failures, strike with little warning,an they are often deadly. (See the example of the Big Thompson Canyon flash flood in your text, p. 644).

Any time the surface materials of the Earth are covered with impermeable materials like concrete, asphalt, or buildings, the infiltration of water into the soil is prevented. Urbanization tends to reduce infiltration, and thus water must collect in storm sewers and eventually in the main drainage systems. Thus, extensive urbanization also decreases the lag time and increases the peak discharge even further. Urbanization can therefore lead to a higher incidence of flash floods.



Flooding Risk

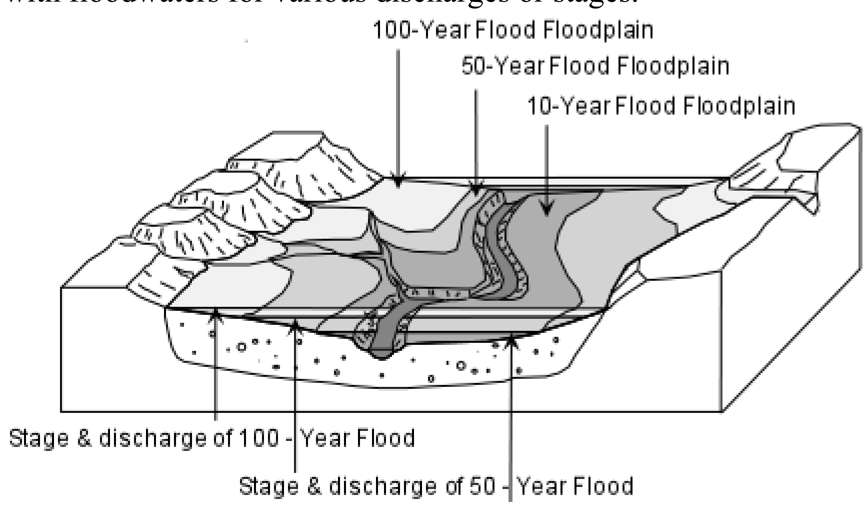
Discharge data collected over a long period of time on streams can be used to calculate flood probability. The data are plotted on a graph of Peak Discharge for each year versus recurrence interval. Note that the logarithm of the recurrence interval is used. As an example, such a graph is shown for the Red River of the North at Fargo, North Dakota below.



From such a graph one can determine the stage or discharge for different recurrence intervals. The 10 year flood is defined as the discharge that would have a 10% probability of occurring every year. Similarly, the 100 year flood is the discharge that has a 1% chance of occurring every year. Note that the 100 year flood does not necessarily occur only once every 100 years. For example, the graph for the Red River of the North, above, shows that 2 250 year floods occurred in an 8 year period.

Flood Hazard Mapping

Food hazard mapping is used to determine the areas susceptible to flooding when discharge of a stream exceeds the bank-full stage. Using historical data on river stages and discharge of previous floods, along with topographic data, maps can be constructed to show areas expected to be covered with floodwaters for various discharges or stages.



Flood Control

Response to flood hazards can be attempted in two main ways: An engineering approach, to control flooding, and a regulatory approach designed to decrease vulnerability to flooding.

- Engineering Approaches

    - Channel modifications - By creating new channels for a stream, the cross-sectional area can be enlarged, thus create a situation where a higher stage is necessary before flooding. Channelization also increases water velocity, and thus reduces drainage time.
    - Dams - Dams can be used to hold water back so that discharge downstream can be regulated at a desired rate. Human constructed dams have spillways that can be opened to reduce the level of water in the reservoir behind the dam. Thus, the water level can be lowered prior to a heavy rain, and more water can be trapped in the reservoir and released later at a controlled discharge.
    - Retention ponds - Retention ponds serve a similar purpose to dams. Water can be trapped in a retention pond and then released at a controlled discharge to prevent flooding downstream.
    - Levees, Dikes, and Floodwalls - These are structures built along side the channel to increase the stage at which the stream floods.
    - Floodways - Floodways are areas that can be built to provide an outlet to a stream and allow it flood into an area that has been designated as a floodway. Floodways are areas where no construction is allowed, and where the land is used for agricultural or recreational purposes when there is no threat of a flood, but which provide an outlet for flood waters during periods of high discharge. The Bonnet Carrie Spillway west of New Orleans is such a floodway. During low stages of the Mississippi River the land between the River and Lake Pontchartrain is used for recreational purposes - hunting, fishing, and dirt bike riding for example. During high stages of the River when there is a potential for the River to rise to flood stage in New Orleans, the spillway is opened so that water drains into Lake Pontchartrain. This lowers the level of water in the Mississippi and reduces the possibility of a levee break or water overtopping the levee.

- Regulatory Approaches

    With a better understanding of the behavior of streams, the probability of flooding, and areas likely to be flooded during high discharge, humans can undertake measures to reduce vulnerability to flooding. Among the regulatory measures are:

    - Floodplain zoning - Laws can be passed that restrict construction and habitation of floodplains. Instead floodplains can be zoned for agricultural use, recreation, or other uses wherein lives and property are not endangered **when** (note that I did not use the word if) flood waters re-occupy the floodplain.
    - Floodplain building codes - Structures that are allowed within the floodplain could be restricted those that can withstand the high velocity of flood waters and are high enough off the ground to reduce risk of contact with water.

- Floodplain buyout programs - In areas that have been recently flooded, it may be more cost effective for the government, which usually pays for flood damage either through subsidized flood insurance or direct disaster relief, to buy the rights to the land rather than pay the cost of reconstruction and then have to pay again the next time the river floods.

- Mortgage limitations - Lending institutions could refuse to give loans to buy or construct dwellings or businesses in flood prone areas.

Example of a Flood

During Hurricane Katrina in 2005, much of New Orleans flooded, mainly as a result of levee and floodwall failures that occurred on human made drainage and navigation canals. In lecture, this event will be discussed in some detail. For details on the geological aspects of the flood events see the following web page and its included links - www.tulane.edu/~sanelson/Katrina.

Examples of questions on this material that could be asked on an exam

1. Define the following: (a) ephemeral stream, (b) stream gradient, (c) stream discharge, (d) suspended load, (e) bed load (f) dissolved load (g) drainage basin, (h) drainage divide

2. What happens to a stream's discharge as one moves down stream? Explain why this occurs.

3. List and give a brief description of the various types of drainage net works..

4. What conditions are necessary for stream to be meandering stream and a braided stream?

5. How do streams erode?

6. Define the following: (a) alluvial fan, (b) delta, (c) floodplain, (d) point bar, (e) stream piracy, (f) floodstage, (g) hydrograph, (h) flash flood, (i) stream terrace.

7. What are the main causes of floods?

8. What is the probability that the 100 year flood will occur in any given year?

9. How does human development affect flood hazards?

10. What engineering approaches are available to reduce the risk of flooding?

11. Besides engineering solutions, what other steps can be taken to reduce vulnerability to flooding?

Return to EENS 1110 Page