

Name: \_\_\_\_\_

## Lab 13: Fluvial Processes and Landforms

Geomorphology is the study of Earth's surface and of the processes acting to shape it. Streams, for example, are significant continental land-shaping agents. The action of running water effectively both erodes rock and moves and deposits sediment. Streams therefore create a wide variety of fluvial (stream-related) landforms associated with the erosion, transport, and deposition of sediments. Streams are also important from a human standpoint: they form major transportation and shipping corridors, they provide irrigation and drinking water, they act as wastewater disposal systems, they provide hydroelectricity, and finally, stream flooding is one of the most expensive and most dangerous of natural hazards.

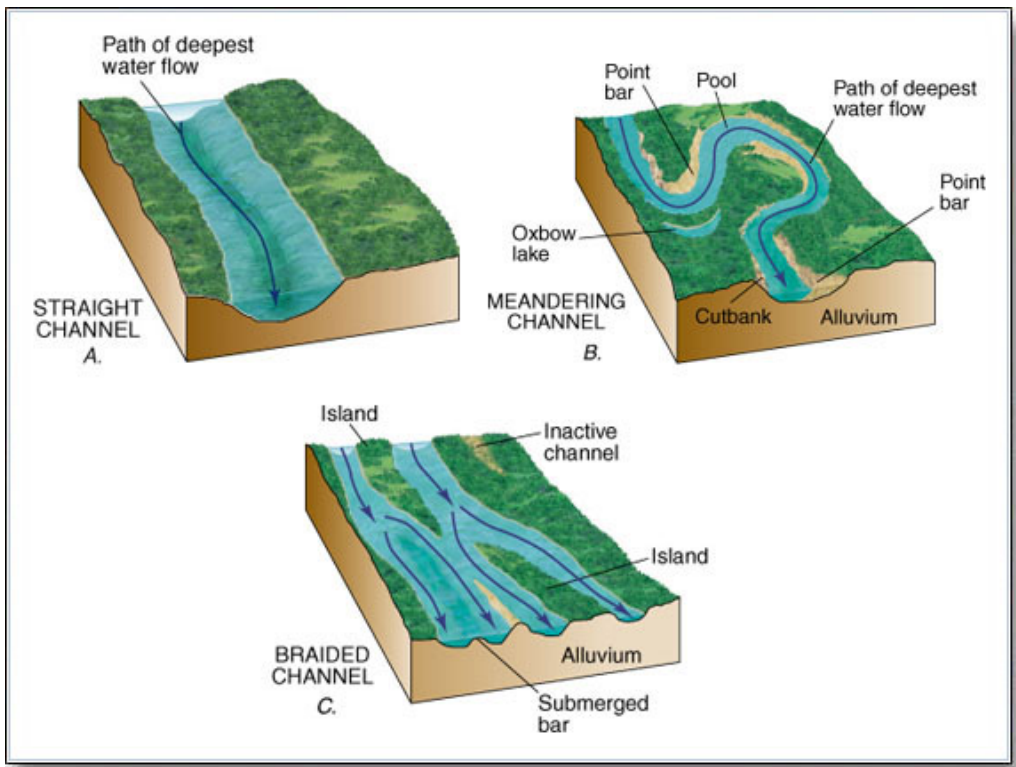
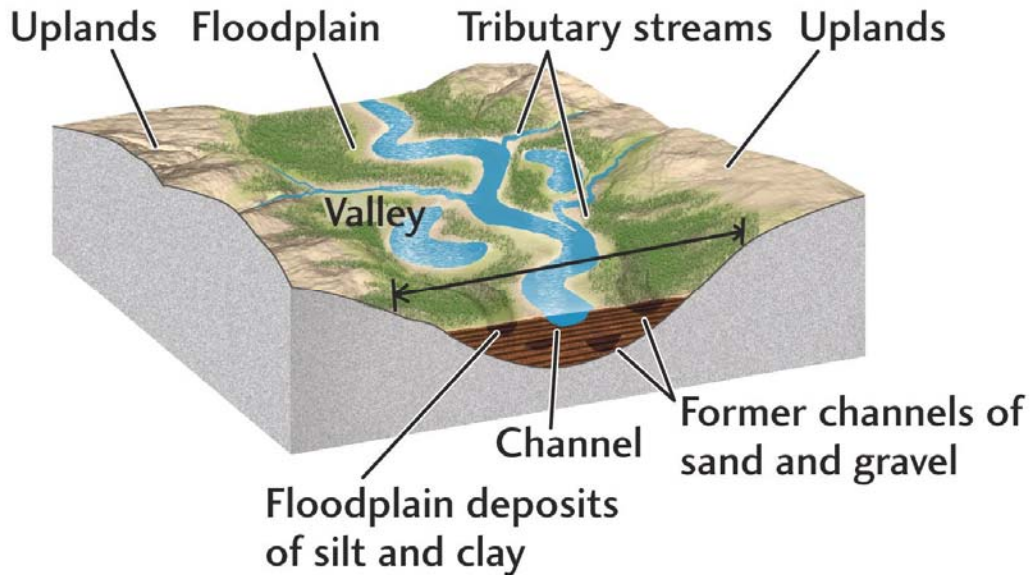
Streams sculpt the land surface through the processes of erosion and deposition.

Geomorphologists often make a distinction between **alluvial** streams (a stream that flows in a channel formed in and by sediment transported by that stream under its current flow pattern) and **non-alluvial** streams (those bounded by concrete or bedrock). Alluvial streams can adjust their shape to fit changing flow conditions because they are capable of moving the material that forms their boundaries; they also typically flow in a large floodplain valley. Non-alluvial streams include steep mountain streams, artificial canals, and canyons.

### General Stream Terminology

- **channel:** The trench in which the water flows. An active channel has water flowing in it. An abandoned channel formerly had water flowing in it, but now does not. An ephemeral channel has water flowing only during part of the year. On USGS topo maps, active channels are marked with blue lines, whereas ephemeral channels are dashed blue lines.
  - **Meandering channel:** gentle gradients, carries fine-grained sediments
  - **Braided channel:** variable discharge, and easily eroded banks
- **alluvium:** Sediment moved and deposited by a stream.
- **bed:** The bottom of the channel. The bed can be made of bedrock, alluvium, or a mix of both.
- **slope (or gradient):** The drop in elevation per unit horizontal distance. Both the slope of the water surface and the slope of the channel are of interest.
- **thalweg:** The fastest part of the water flow. The thalweg typically goes around the outside of meanders and bends.
- **discharge:** The volume of water moving per unit time past a given point.
- **sediment flux:** The volume (or mass) of sediment transported per unit time.
- **drainage area/drainage basin/watershed:** The land surface that contributes water to a stream.
- **tributary:** A smaller stream that feeds into a larger one.
- **base level:** The lowest elevation of a drainage. Ultimately, the global base level to which all streams are adjusted is sea level.
- **incision:** Erosion of the channel bed, causing it to cut down.

**Alluvial Landforms**



**Sediment Transport**

Streams are conveyor belts that erode and move sediment from the continents to the oceans. Nearly all the materials that end up in marine sedimentary rocks (clasts for clastic rocks and dissolved ions for chemical sediments) were brought to the oceans by streams. Streams can move sediment in three forms:

**Dissolved load:** Water-soluble ions, products of chemical weathering. Depending on the solubility of the bedrock, there may be more or less dissolved load in a stream. For example, areas with abundant limestone typically have high amounts of dissolved load.

**Suspended load:** Clay to very fine sand-sized particles can be suspended in the flow of water and therefore will move as fast as the flow. Suspended loads increase after big rainstorms, when silt is washed off hillslopes into the channel and the discharge is high. Muddy and turbid water has abundant suspended sediment. The amount of sediment that can be suspended is a function of velocity: faster water can lift more and larger sediment. By volume, ~90% of the clastic sediment in a stream is in suspension. Floodplains consist of fine sand, silt and clay that settles out of suspension once a stream tops its banks, spreads across its plain, and slows.

**Bed load:** Clasts that are too big to be suspended can still be rolled, pushed, and bounced along the streambed. In general, more and larger clasts are moved with faster water and steeper gradients. In some streams, particularly with coarse (gravel to cobble-sized clasts) beds, the bed load only moves during floods. The clasts move much slower than the water itself, and typically only ~10% of the total volume of clastic sediment is moved as bed load.

Alluvial streams adjust their slope and channel shape to move the available sediment with the available discharge. In other words, a stream will tend to develop the exact gradient and discharge necessary to move the sediment supplied to it by the hillslopes. If sediment supply increases suddenly, sediment will build up in the channel, and eventually the channel steepens so that the water can once again move the new, higher amount of sediment. The channel may also steepen its slope by cutting off looping meanders. Similarly, if sediment supply is reduced in a channel, the channel might erode and incise because sediment is not being replaced. Eventually only the largest, heaviest clasts will remain, causing the bed to coarsen. The channel might also respond to a decrease in sediment by decreasing the slope through meander growth. Changes to sediment supply or discharge can cause significant changes to the shape, slope, and sediment size of the channel.

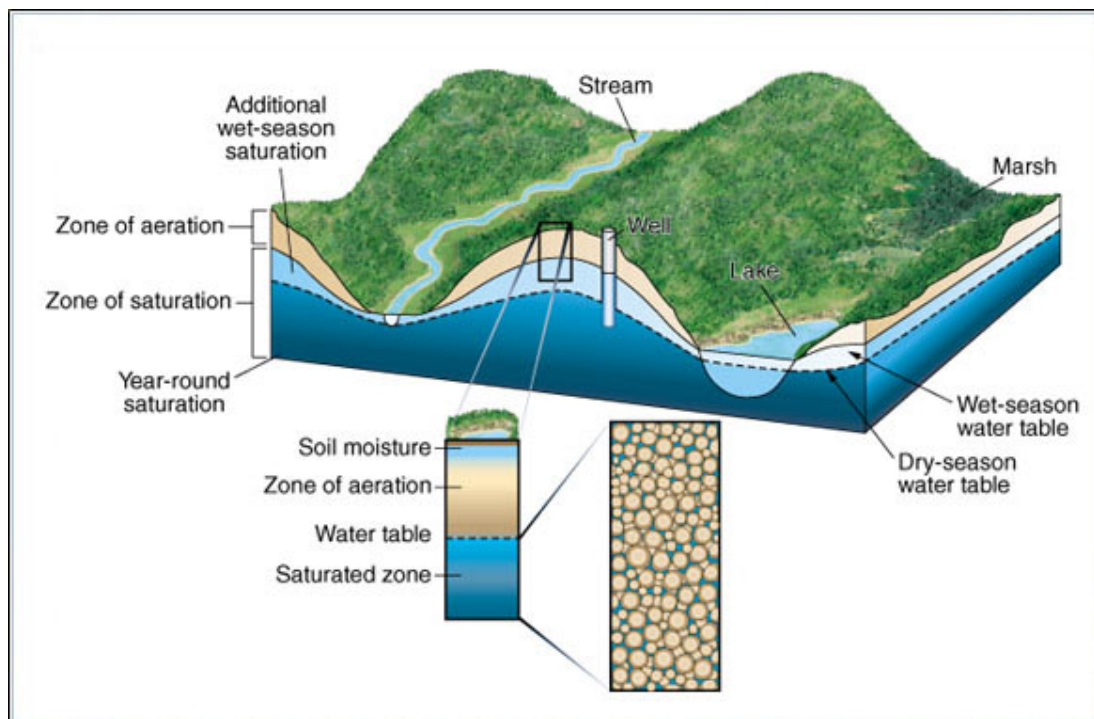
The delicate interplay between sediment supply, transport capacity, and discharge makes stream channels very sensitive to manipulation, such as via the construction of dams. Dams are built for a variety of purposes, including hydroelectric power, flood control, and water storage. One consequence of dam construction, however, is an increase in deposition above the dam (shallower gradient) and an increase of erosion below it (steeper gradient). Both will tend to undermine the long-term utility of the dam itself.

### **Groundwater**

Groundwater is defined as all the water in the ground occupying the pore spaces within bedrock and regolith. Although the volume of groundwater sounds small, it is 40 times larger than the volume of all the water in fresh-water lakes or flowing in streams. Most groundwater originates as rainfall. Rainwater that soaks into the ground and moves down to the saturated zone becomes part of the groundwater system and moves slowly toward the ocean, either directly through the ground or by flowing out onto the surface and joining streams.

A hole penetrating the ground ordinarily passes first through a layer of moist soil and then into a zone in which open spaces in regolith or bedrock are filled mainly with air. This is the *zone of aeration*. The hole then enters the *saturated zone*, a zone which all openings are filled with water. We call the upper surface of the saturated zone the *water table*. Normally, the water table slopes toward the nearest stream or lake. The water table fluctuates in level with seasonal changes in precipitation. Corresponding fluctuations are seen in the water level in wells that penetrate the water table. Lakes, marshes, and streams occur where the water table intersects the land surface.

Most of the groundwater within a few hundred meters of the surface is in motion. Unlike the swift flow of rivers, however, which is measurable in cubic meters per second ( $\text{m}^3/\text{s}$ ), groundwater moves so slowly that velocities are expressed in centimeters per day or meters per year. The reason for this contrast is simple. Whereas the water of a stream flows unimpeded through an open channel, groundwater must move through small, constricted passages. The flow of groundwater to a large degree depends on the nature of the rock or sediment through which the water moves.



**Flooding**

The word “flood” most often is used for any stream discharge that overtops its banks, whether or not damage occurs. Sometimes the word “flood” means simply the highest stream discharge of the year, whether or not the bank is overtopped. While it is difficult to predict floods and the weather patterns that cause them, knowledge of the discharge history of particular streams and analysis of the statistical occurrence of large discharges is useful. Such analyses of flood frequency and magnitude help in the identification of flood-prone areas. One way of analyzing stream discharge records is to consider the largest discharges recorded each year for a particular time period. This type of analysis does not allow one to predict the largest flood expected in a given year, rather it lets one determine the probability of floods of particular sizes.

**Calculating Flood Probabilities**

**Step 1.** Obtain peak annual flood data (the highest discharge per year) for the stream of interest. The USGS ([www.usgs.gov](http://www.usgs.gov)) has annual discharge data for most major US streams.

**Step 2.** Rank floods in order from largest ( $R = 1$ ) to smallest ( $R = N$  for  $N$  years in record)

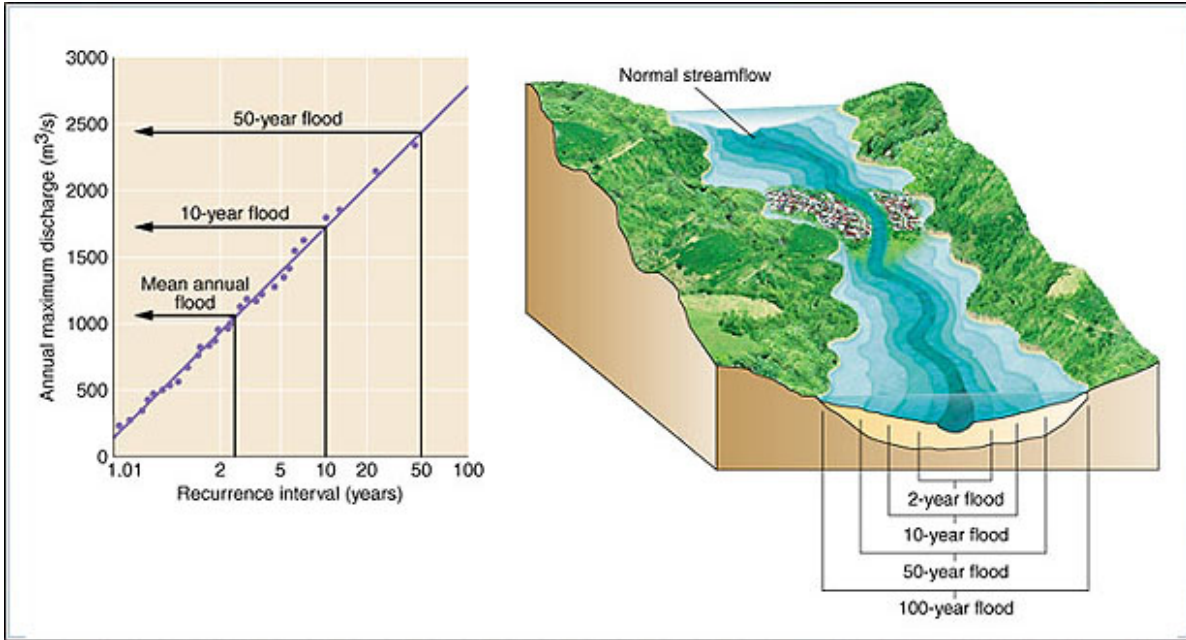
**Step 3.** Calculate, for each flood, the exceedance probability  $P$  (in percent):

$$P = \frac{100R}{N + 1}$$

Therefore  $P$  is the probability that a flood equaling or exceeding the size of that rank will occur in a given year. Return Period (Recurrence interval),  $T$ , is inversely proportional to exceedance probability:

$$T = \frac{100}{P}$$

The return period represents, on average, how many years likely pass between floods of a particular size (frequency). The phrase “100-year flood” is the term used for the discharge with a frequency of 100 years, or the size of flood with a 1% chance of being exceeded in a given year. A 100-year flood is **not** a flood that occurs precisely once every 100 years. Most discharge records only go back 50 years or so, so it is necessary to extrapolate discharge data to determine the frequency of very large floods. It is entirely possible to get two “100-year floods” in two consecutive years.



One of the most important uses of flood frequency analysis is to determine the risk a particular area has of being inundated. Floodplains are, by definition, landscapes that are regularly flooded. The very reasons floodplains are attractive places to farm or inhabit (flat, near a water source, and typically with fertile soil) are a direct result of this regular flooding.

Unfortunately, the floods that maintain the landscape can destroy farms and buildings. Engineers define the risk of floodplains by the probability that an area will be flooded. For example, a “100-year floodplain” is the area of a floodplain that will be inundated during a 100-year flood: A house in the 100-year floodplain has a 1% chance of flooding in any given year.

## Part I. Flood Frequency

The table on the next page shows the largest annual discharges on record for the Skykomish River at Gold Bar, Washington, from 1947 to 2003. Discharge data are in cfs, or cubic feet per second. The data are already ranked in order from largest to smallest.

1. Calculate the exceedance probability and return period for the five largest floods and enter these figures in the table. The rest have already been calculated.

2. What is the approximate return period of the average-sized peak annual discharge, 44,400 cfs?

**Peak annual floods on the Skykomish River, 1947-2003**

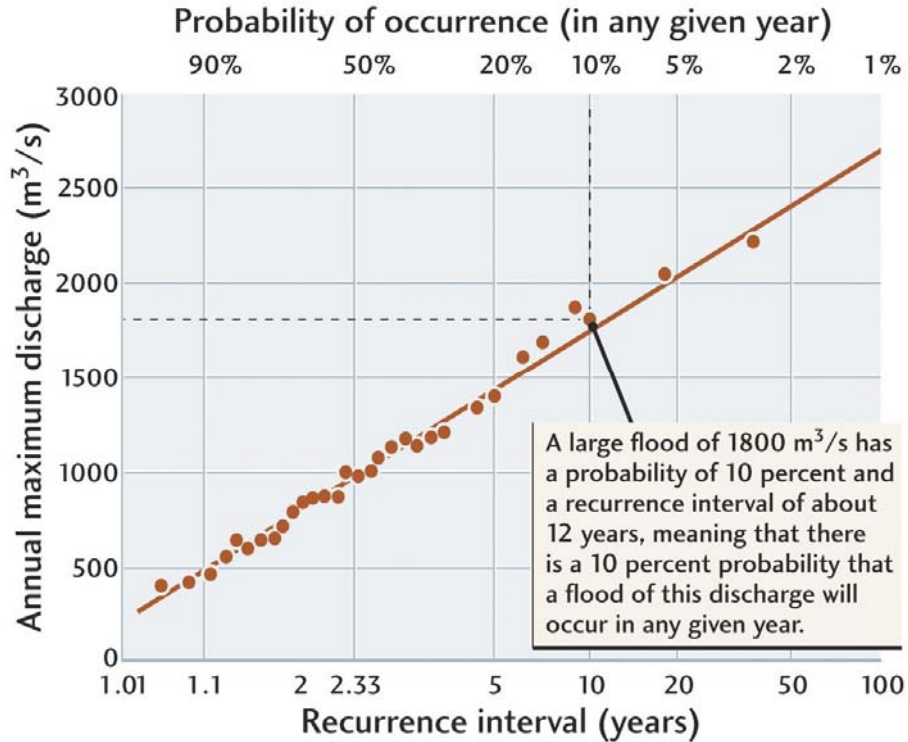
Rank	Year*	discharge (cfs)	probability (% exceedance)	return period (years)
1	1990	102000		
2	1980	90100		
3	1995	80400		
4	1959	78800		
5	1975	76600		
6	1986	76500	10.5	9.5
7	1962	72000	12.3	8.1
8	1951	65600	14.0	7.1
9	1998	63800	15.8	6.3
10	1977	62800	17.5	5.7
11	1956	59100	19.3	5.2
12	1982	58600	21.1	4.8
13	1949	56500	22.8	4.4
14	1988	56300	24.6	4.1
15	1989	56100	26.3	3.8
16	1979	52200	28.1	3.6
17	1997	50400	29.8	3.4
18	1968	49200	31.6	3.2
19	2003	48700	33.3	3.0
20	1986	47600	35.1	2.9
21	1955	46900	36.8	2.7
22	1974	46800	38.6	2.6
23	2002	46100	40.4	2.5
24	1947	45300	42.1	2.4
25	1997	44900	43.9	2.3
26	1995	44100	45.6	2.2
27	1999	42900	47.4	2.1
28	1974	42600	49.1	2.0
29	1958	42100	50.9	2.0

Rank	Year*	discharge (cfs)	probability (% exceedance)	return period (years)
30	1969	41900	52.6	1.9
31	1984	40800	54.4	1.8
32	1953	40600	56.1	1.8
33	1961	40400	57.9	1.7
34	1982	40400	59.6	1.7
35	1972	39700	61.4	1.6
36	1987	35500	63.2	1.6
37	1972	34700	64.9	1.5
38	1977	34700	66.7	1.5
39	1971	34100	68.4	1.5
40	1993	33700	70.2	1.4
41	1955	30600	71.9	1.4
42	1964	30400	73.7	1.4
43	1962	29600	75.4	1.3
44	1966	29000	77.2	1.3
45	1991	27800	78.9	1.3
46	1953	27500	80.7	1.2
47	1978	24700	82.5	1.2
48	1964	24400	84.2	1.2
49	1985	23800	86.0	1.2
50	1948	22300	87.7	1.1
51	1966	19100	89.5	1.1
52	2000	17600	91.2	1.1
53	1970	16900	93.0	1.1
54	1994	15700	94.7	1.1
55	1958	14100	96.5	1.0
56	1951	13300	98.2	1.0

3. If the largest flood on record was 200,000 cfs instead of 102,000 cfs, would that change its probability or return period? In other words, does the size of the flood (other than rank) factor into these probability calculations? What does this suggest about the usefulness of these calculations for estimating the probability of very large floods?



The graph below shows the Skykomish River data (1947 to 1978 only) on a flood frequency graph. Typical flood distributions plot as a straight line on this type of graph. Note that the two x-axes are logarithmic.



4. Using the graph above, what is the discharge of a 50-year flood? Note that discharge on the graph is in cubic meters per second, so convert this to cfs.
  
5. Plot the 1990 flood (from the previous table) on the graph above. Does it fall on the line? According to the best-fit line, what return period (recurrence interval) should this discharge have? Is the return period of the 1990 discharge better estimated from the table or from the graph? Explain.
  
6. Since the Skykomish had a very large flood in 1990, is it true that there will not be another flood of that size for at least 50-90 years? Why or why not?

## Part II. The Water Table

Surficial bodies of water (streams and lakes) provide a guide to the location of the water table in an area, since the boundaries of such features will be at the same elevation as the top of the zone of saturation in areas where the ground is permeable, which is usually the case. *Use the Lake Wales Quadrangle for the following:*

7. What are the elevations of the following lakes?  

Annie	Pierce	Starr	Effie	Belle
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  - a. What is the change in elevation across each lake? (Careful with this one.)
  - b. Which part of the map has lakes with the highest elevations?
  - c. Which part of the map has lakes with the lowest elevations?
  - d. In which direction is the groundwater generally flowing?
  
8. The water table roughly follows topography, but for short distances its position may be estimated by linear interpolation between two known points. With this in mind:
  - a. What is the elevation of Lake Starr?
  - b. What is the elevation of Lake Pierce?
  - c. What is the elevation of the "T" in Road 17A at section line 13/18?
  - d. Sketch a cross section between the two lakes. Label the elevations of the two lakes and the road intersection. Show and label the water table.
  
  - e. Suppose one wishes to build a housing development at the intersection, to be supplied by groundwater from a well. How far down must one drill to reach the water table? Is this an adequate depth for the well? Show your work and explain your reasoning.



*Use the Vicksburg Quadrangle for the following:*

12. A bayou is a swamp or marsh. Find the Wrong End Bayou and sketch its outline below.

13. What is the shape of this bayou? How does its width compare to that of the adjacent Mississippi River?

14. How did the Wrong End Bayou form? Give a brief explanation of the several (three to four) steps towards its present condition.

15. Find the Port of Vicksburg. This is an old meander bend of the Mississippi; it used to flow around this bend, but was then cut off. In what year did this occur?

16. Explain the position of the state line between Louisiana and Mississippi around such features as Paw Paw Island and Race Track Towhead.

17. On the figure below, label carefully with arrows and names ONE example of each of the following:

- A. stream channel
- B. meander bend
- C. active point bar (not vegetated)
- D. inactive point bar (vegetated)
- E. oxbow lake
- F. (likely) flood plain

Also show and label the most likely place for the next meander cutoff.



Part IV. Dams

18. What are 3 benefits of building a dam on a river?

19. How will a dam influence the sediment transport of a stream? Why do you think this is important environmentally? Economically? Explain.