EXERCISE 10

River Floods

"We are presently in a period of marked global increases in damage to life and property from floods and from other naturally catastrophic phenomena. The problem may be partly exacerbated by anthropogenic climatic change ("global warming"), but it is certainly tied to the human propensity to build in hazard-prone areas."

—Baker, 1994

"The reason they call them floodplains is that it is plain that they flood."

—Gore, 1995

INTRODUCTION

Tens of billions of dollars have been spent by the federal government, mainly since the 1930s, on flood control projects such as dams, levees, and channel improvements. Nevertheless, damages from flooding have continued to rise in the United States.

A flood occurs when bodies of water flow over land that is not usually submerged. Although we commonly think of floods as being caused by a river that overflows its banks during periods of excess precipitation or snowmelt, floods can also be caused by dam failures, high tides along seashores, high water levels in lakes, or high groundwater.

River floods occur when the water height (known as *stage,* and recorded as number of feet above a local base height) passes an arbitrary level. This level usually is the bank-full stage, or when a river is completely filling its channel. When a stream channel can no longer hold the increased water (its *discharge,* or total amount of water flowing past a site) and overflows its banks, then the river is said to be in flood. Water then flows on valley floors or floodplain adjacent to the normal river channel. Of course, higher discharges mean higher stages or levels of water within and outside a river channel.

Floods are a natural characteristic of rivers. They occur in response to the interaction of hydrologic, meteorologic, and topographic factors. Human actions also impact floods, for example building dams or levees, channelizing rivers, developing urban, suburban, or agricultural areas, and deforestation.

River floods are not the only types of floods. The term flood also is associated with the inundation of lake and marine coasts and alluvial fans. Even relatively flat and poorly drained upland regions are subject to flooding. In the latter case, water that would normally infiltrate to become groundwater or be carried away in poorly defined channels, sewers, or ditches remains on the land during excessive rainfall. When this water enters basements or garages, or otherwise makes life uncomfortable for the inhabitants of the area, the term flood is applied even though the area is not a floodplain, a coastal region, or an alluvial fan.

This exercise is designed to acquaint you with the nature of river floods, the problems that are created by flooding, and potential solutions. Part A analyzes flood losses in the United States, introduces the concepts of flood frequencies or recurrence intervals, magnitudes, and the variations of discharge with drainage basin area, which we consider here as intensity.

Parts B and C provide specific cases of floods. You will apply concepts and, using information from other sources, explore several solutions to flooding including those in the broad categories of (1) land use regulation and (2) engineering projects on rivers and watersheds.

Part D explores the identification of flood plains on topographic maps and the nature and use of Flood Insurance Rate Maps (FIRMs).

PART A. FLOOD FREQUENCY AND MAJOR FLOODS

Flood Discharge

The *discharge* of a stream is the volume of flow that passes a specific location in a given period of time. Discharge rates are usually expressed in cubic feet/second (cfs) or cubic meters/second (m^3/s). If the area of the wetted channel cross section (the measured width of the channel at a site multiplied by the depth of the water) and the velocity of the stream are known, then the discharge can be determined by the following formula:

$$Q = A \times V$$

where Q is the discharge, in cfs or m^3/s, A is the cross-sectional area of the stream in square feet or square meters, and V is the velocity, in ft/s or m/s.

Flood Frequency

Where flood records are available, computations of flood frequency are based on peak annual floods (the maximum discharge for the year at a specific station). Flood frequency is expressed as a recurrence interval (or return period), which is the average time interval (in years) between the occurrence of two similar floods, with the same water levels. The recurrence interval (T, in years) for a flood of a given discharge is determined by this formula:

$$T = (n + 1)/m$$

where n equals the number of years of record, and m is the rank or order of the annual flood discharges from the greatest (1), to the smallest for the number of years of record.

To understand better the impact and frequency of floods and to assist in flood prediction, one method is to plot flood data on a flood frequency graph with the discharge plotted on the vertical axis and recurrence interval on the horizontal axis. A straight "best-fit" line is drawn to join the points for each year. The average number of years that will elapse until a given magnitude flood occurs again can be estimated from this line. In other words, based on the line there is a certain probability that a flood of a given magnitude can be expected to occur x times within a fixed time interval. For example, if the recurrence interval for an annual maximum discharge of 500 cfs is found to be 4 years, then we would expect to see a discharge of 500 cfs or greater five times during a 20-year period (20 years divided by the 4-year recurrence interval).

The longer the number of years of flood records, the higher the probability is that very large floods with very large discharges have been recorded. Estimates of 100-year floods are better if they are based on 100 or more years of record. Where there are few years of flood data, such as in Table 10.1, reliable estimates of 100-year floods may be difficult.

The annual probability of exceedence, P, is the reciprocal of T. Written as a formula

$$P = 1/T$$

This is the probability or chance that in a single year the annual maximum flood will equal or exceed a given discharge. A flood having a recurrence interval of 10 years is one that has a 10 percent chance of recurring in any year; a 100-year flood has a 1 percent chance of recurring in any year.

The 100-year flood, as defined statistically, is a legal definition of areas that are likely to be flooded. If, in the United States, someone chooses to purchase a home in the 100-year floodplain, they must obtain flood insurance.

> SOMEWHERE IN THE UNITED STATES, YEAR 2000 PLUS OR MINUS. Nature takes its inexorable toll. Thousand-year flood causes untold damage and staggering loss of life. Engineers and meteorologists believe that present storm and flood resulted from ··· conditions [that] ··· occur once in a millennium. Reservoirs, levees, and other control works which have proved effective for a century, and are still effective up to their design capacity, are unable to cope with enormous volumes of water. This catastrophe brings home the lesson that protection from floods is only a relative matter, and that eventually nature demands its toll from those who occupy flood plains. (Hoyt and Langbein, 1955)

QUESTIONS (10, PART A)

Flood Frequency in the Seattle/Tacoma area

Questions 1-11 investigate recurrence intervals, 100-year floods, and changing flood frequencies for two watersheds in the state of Washington. These data are slightly modified from U.S. Geological Survey information. Population in the Puget Sound area is growing rapidly, and humans have made many changes to rivers and drainages.

Pick **one** of the four data sets (Mercer Creek 1, Mercer Creek 2, Green River 1, or Green River 2) in Table 10.1. Be sure, if you are working in a laboratory or class, that one or more students select each of the four data sets. Each data set spans 11 years of record along Mercer Creek or the Green River. Use your chosen data set to estimate the likely discharge for a 100-year flood. Follow the steps below.

1. Rank the peak flood discharges for the data set you have chosen in order of magnitude, starting with 1 for the largest and ending with 11 for the smallest. Write these results in the "Rank" column.

TABLE 10.1 Flood Data for Mercer Creek and the Green River. Discharge Data in cfs.

Mercer Creek-Data Set 1				Mercer Creek-Data Set 2			
Year	Peak Flood Discharge	Rank (1 is greatest)	Recurrence interval	Year	Peak Flood Discharge	Rank (1 is greatest)	Recurrence interval
1957	180			1979	518		
1958	238			1980	414		
1959	220			1981	670		
1960	210			1982	612		
1961	192			1983	404		
1962	168			1984	353		
1963	150			1985	832		
1964	224			1986	504		
1965	193			1987	331		
1966	187			1988	228		
1967	254			1989	664		
Green River-Data Set 1				**Green River-Data Set 2**			
Year	Peak Flood Discharge	Rank (1 is greatest)	Recurrence interval	Year	Peak Flood Discharge	Rank (1 is greatest)	Recurrence interval
1941	9310			1976	4490		
1942	10900			1977	9920		
1943	12900			1978	6450		
1944	13600			1979	8730		
1945	12800			1980	5200		
1946	22000			1981	9300		
1947	9990			1982	10800		
1948	6420			1983	9140		
1949	9810			1984	10900		
1950	11800			1985	7030		
1951	18400			1986	11800		

2. Use the formula $T = (n+1)/m$ and determine the recurrence interval of each of the 11 floods. Write the results for each year in the "recurrence interval" column.

3. Determine an appropriate vertical scale for your discharge data. The vertical scale should be chosen such that the numbers you plot from the data above fill about one-half or slightly more of the length of the scale. Write the appropriate numbers for your discharge along the left edge of the scale.

4. Plot the discharge and recurrence interval for each of your 11 floods.

5. Draw a best-fit straight line, not a dot-to-dot curve, through the data points. Extend your line to the right side of the graph.

6. Based on your data, what is the predicted discharge for a 100-year flood?

7. Either find someone who has plotted the second set of data for your stream, or repeat steps 1 through 7 to determine the predicted discharge for a 100-year flood, using the second set of data for your stream. (You may plot the second set of data on Figure 10.1; note that depending on your choice of numbers for the first plot, you may need to have a second set of values on the vertical axis.) How does your prediction made in Question 6 compare with the answer from the other set of data for the river you plotted?

8. Suggest possible human activities in the watershed that could have caused the differences in predicted floods that result from the two sets of data.

9. When you have completed interpretation of the stream you selected, find students who have done the other stream. How do their data compare with yours? What human activities did they suggest for the changes in flood predictions they discovered?

10. Based on the flood predictions for all four data sets, what does the contrast in predicted flood discharges imply about the usefulness of the 100-year flood as a legal designation for these two streams?

11. What information do you need to know if you are about to buy a house that is located adjacent to, but just outside of, the 100-year floodplain?

Large Floods in the United States

Data in Table 10.2, partly from the U.S. Army Corps of Engineers, show the damages suffered and deaths due to flooding. The U.S. Army Corps of Engineers (2000) provides data on *damages avoided* by flood projects and by emergency activities of the Corps. For example, in 1999 flood projects reduced potential damages by $2.8 billion (75% by reservoirs and 25% by levees), while emergency activities of sandbagging and technical assistance saved $48 million in losses, a much smaller amount.

Do Questions 12–16, which refer to Table 10.2.

12. On Figure 10.2, place a point for each decade to show monetary flood loss (in billions of dollars) for each decade. What is the general trend in flood loss in the United States between 1900 and 2000 as determined from Table 10.2 and your graph?

13. Now place an open circle for each decade to show the U.S. population in millions of people at the end of each decade.

14. a. For flood damage losses in the 20th century in Figure 10.2, describe and explain the trend.

b. What is the role, if any, of growth in population and rising flood losses in the 20th century?

c. What other factors contribute to increased losses?

15. Discuss the effectiveness of flood mitigation in the 20th century with your lab group. Are flood control systems effective?

16. According to the Corps of Engineers (2000), for the decade of the 1990s, the average damage loss per year was about $5 billion. For the same period the average value of flood damage reduction by projects per year is estimated at $20 billion. Using this information and that in the graphs you plotted discuss the statement "Flood-control dams and levees have been effective in reducing flood damage" and suggest additional measures for reducing flood damage.

The Discharge/Area Ratio

Questions 17 and 18 investigate ranges in flood discharge (Q) with drainage basin size (A) for several different sizes of rivers. This **flood intensity** comparison is based on data in Table 10.3, which will be plotted in Figure 10.3.

17. Use the flood records in Table 10.3 to calculate the discharge/area ratio for each river. Record your calculation in the column on the table. Plot the calculated ratio against drainage-basin area in Figure 10.3. Identify the six rivers that you are able to plot.

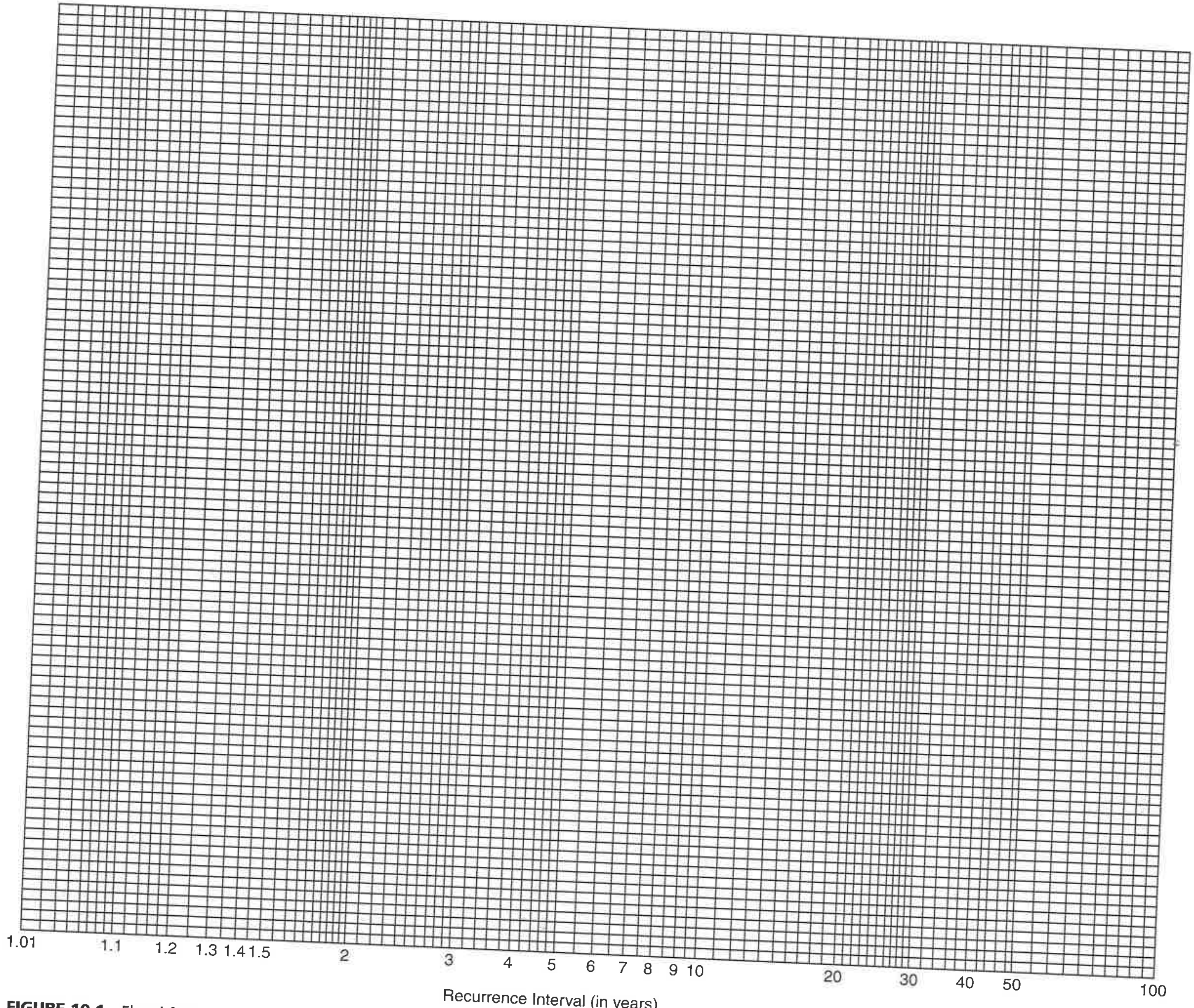

FIGURE 10.1 Flood frequency curve based on data from Table 10.1.