4.0 Studying Streams - some fieldwork suggestions

4.1 Recording Stream Velocity

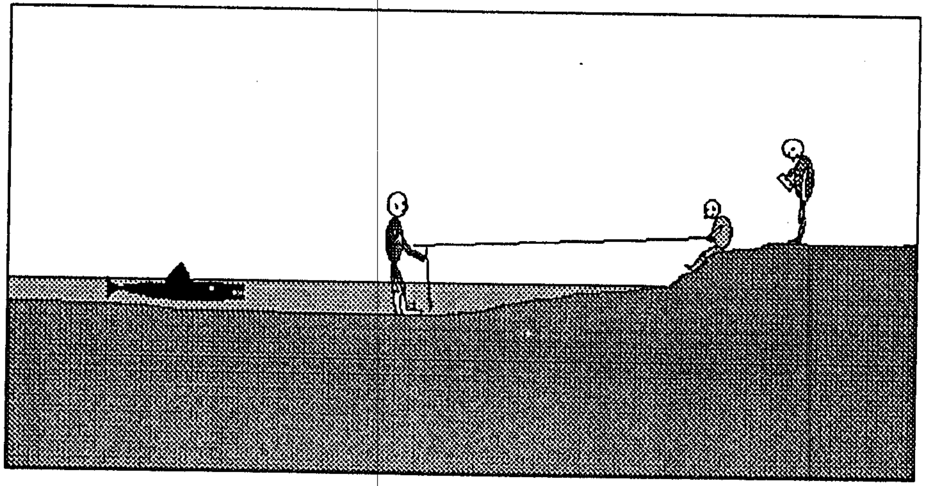
Equipment Needed:

MJP stream flowmeter
Stopwatch (if using Basic flowmeter)
Measuring tape
Ranging poles
Clipboard and pen
Data collection sheets

Working in groups of two or three, students make rapid progress provided they work efficiently, know their objectives and have thoroughly prepared the ground. For example, one student works in, or above, the stream with the meter while a second student uses a stopwatch to control the velocity recording time. A third member of the group records the data, such as notes on the site, distance from the bank from which the measurements are being taken, also the depth of reading, recording time, and finally of course, the number of counts per minute or velocity.

Measurements of the distance from the banks and the position of the meter in the stream are vital. For systematic collection of stream velocity data, the position of the meter readings should always be recorded with reference to one bank - DISTANCE OUT. For example, in larger channels this may be determined by attaching a tape to the waist or belt of the student working in the stream with the meter. By standing on the bank, and holding the tape out horizontally across the channel one person can determine the position of the meter from the bank.

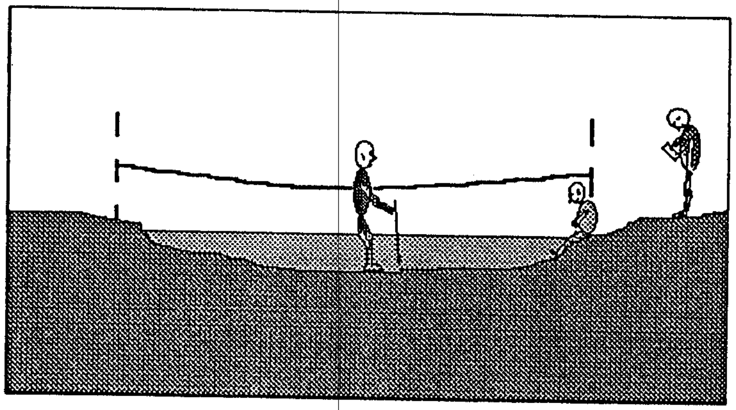
Figure 6 - Measuring "Distance Out" using tape attached to student's belt



In smaller channels it maybe more convenient to stretch the tape measure across the channel horizontally from bank to bank. The ends of the tape can be attached to ranging poles on the banks .

53

Figure 7 Measuring "Distance Out" using tape stretched between poles



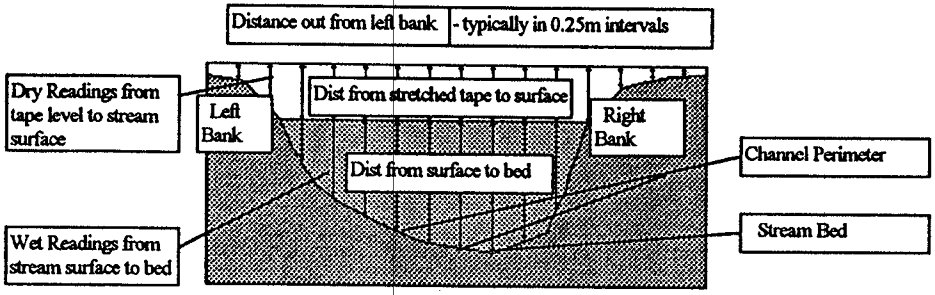
Depth of measurement (DISTANCE DOWN) can easily be measured if the flowmeter tubes are simply calibrated beforehand using tape or water-resistant paint or ink, or more accurately, by using a staff. In estimating water depth please note that each section of the flowmeter stem is 250 mm long. Total water depth from surface to bed (sometimes called the WET READING) can be measured with the impeller stick if less than 1m. It is useful to have an elastic band or some other device on the impeller stick which can be moved up and down the stem to the water level. This allows a reasonably accurate estimate of depth to be made visually. Alternatively, if calculating the position of 0.6 of the depth (see section 4.3) for mean water column velocity measurement, the band can be moved to the appropriate position along the stem.

4.2 Plotting the Channel Cross-Section

This is essential for meaningful stream velocity recording. A plan or "map" of the stream cross-section at each point where measurements are to be made forms the basis for recording observations.

One method of measuring and plotting the channel form is by stretching a tape measure across the channel as described above. Depths can then be measured vertically down from the tautly stretched tape to the stream surface (or channel perimeter) - see Figure 8. Measurements of channel widths and depths are then recorded using the data sheet provided. At regular intervals along the tape, two measurements should be noted. Firstly, the distance from the tape to the ground or water surface known as the DRY READING. Secondly, the WET READING should be recorded. This is the depth of the water at each point. This depth can be measured using the calibrated stem of the flowmeter, but more accurately by using a rule or staff. The greater the number of measurements taken at each cross-section, the more accurate the representation of the channel.

Figure 8 - Measuring & Plotting the Channel Cross-Section



4.3 Calculating Stream Discharge

In section 3.1 it was demonstrated (Figure 2) that :

DISCHARGE (Q) = Cross -Sectional Area x Flow Velocity

So, if the cross-sectional area of a channel was 1 m^2 and the rate of flow was measured at 1 m/s, then the Discharge Q would be 1m^3/s (1 cumec). If, after heavy rain the channel area increased to 2 m^2 and the flow velocity to 1.5 m/s then the Discharge (Q) would be 3 m^3/s or 3 cumec. Discharge is a very important variable. Unfortunately, it is not always easy to measure.

Figure 9a Semi-Circular Channel

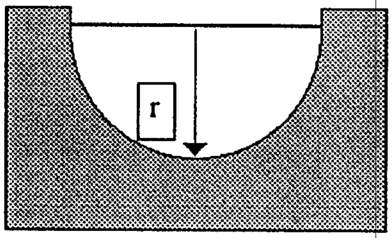
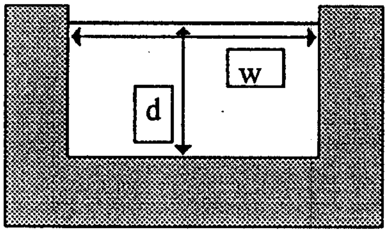


Figure 9b Rectangular Channel



Calculating discharge in the case of either the semi-circular channel (Figure 9a) or the rectangular channel (Figure 9b) is relatively simple.
In the semi-circular channel, if we take :

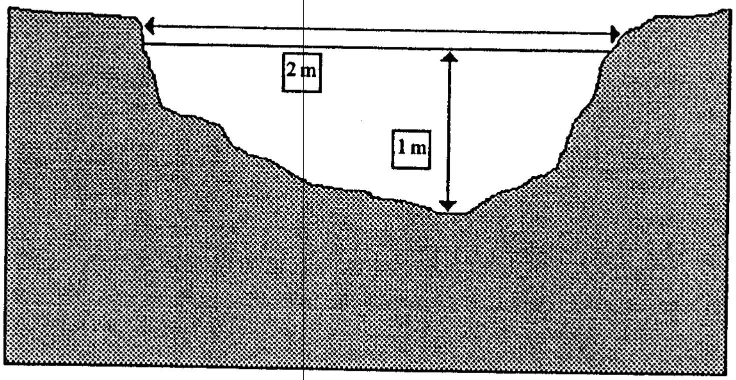
Radius of Channel (r) = 1 m
Cross-sectional area (Δ) = $\pi r^2 \div 2$
= 1.57 m^2
Mean Velocity (V) = 1 m/s
Discharge (Q) = Δ x V
= 1.57 m^3/s

Similarly, in the rectangular channel, if the :

Depth (d) = 1 m
Width (w) = 1.5 m
Cross-sectional area (Δ) = 1.5 m^2
Mean Velocity (V) = 1 m/s
Discharge (Q) = Δ x V
= 1.5 m^3/s

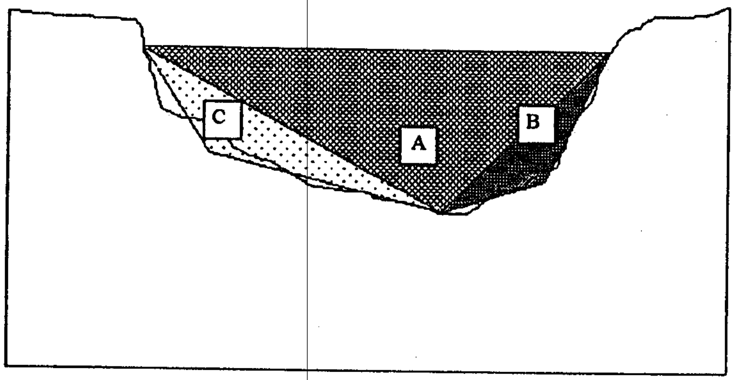
In a real-life situation, however, the channel geometry will be far from regular.

Figure 10a Irregular Stream Channel Cross-Section



In these cases, the calculation of the cross-sectional area is more complex as the following example shows :

Figure 10b Calculating the Cross-Sectional Area of an Irregular Channel



In this example, the channel area beneath the water line has been divided into three triangular shapes. The largest triangle is whole, while the other two approximate the geometry of the area which they respectively cover by a judicious mix of inclusion and exclusion. By finding the area of each triangle by the formula :

Area of Triangle = (Length of Base) x (Half the Height)

it is possible to calculate the cross-sectional area of the channel by summing the areas of the triangles (the values used are notional, for illustration only) :

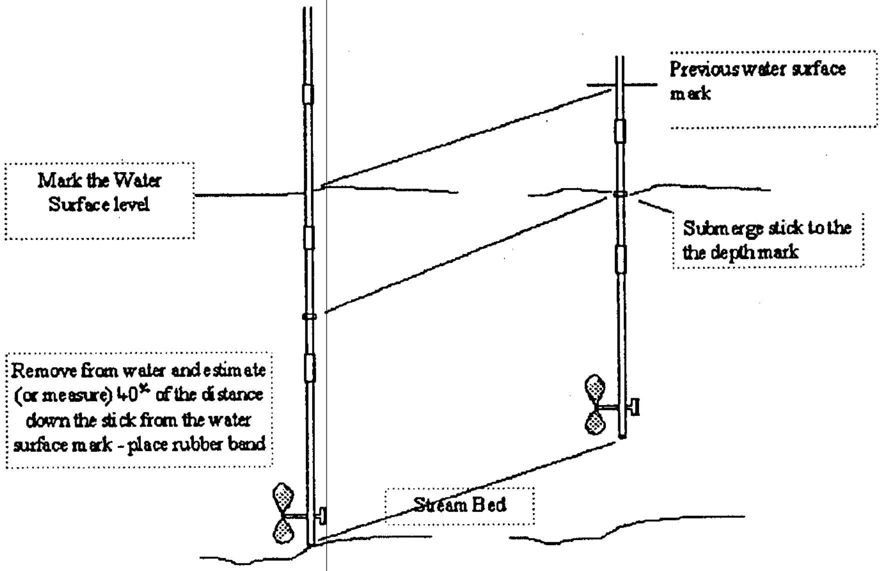
Area of triangle A = 1.00 m^2
Area of triangle B = 0.15 m^2
Area of triangle C = 0.30 m^2
Total Channel Area = 1.45 m^2

Unfortunately, there remains the problem of measuring the flow velocity in the channel. Because of friction with the bed and banks (the WETTED PERIMETER) and because of internal turbulence, stream velocity varies from point to point. Large numbers of observations under controlled conditions suggest that in water depths of less than 0.6 m, a reliable average velocity can be recorded at a point which is ***0.6 of the depth of the water below the surface***. At this depth the faster surface flow is averaged out against the slower bed flow and this figure is an acceptable EMPIRICAL GUIDELINE (i.e. one derived from observation and experiment under a variety of circumstances).

A quick way of finding 0.6 of the depth requires a special piece of equipment - a rubber band! Follow this simple procedure :

Step 1	rest impeller base on stream bed
Step 2	mark the water surface level with finger and thumb
Step 3	remove stick from the water keeping water surface mark
Step 4	visually estimate (or measure) 0.4 of the distance down the stick between the water surface mark and the base
Step 5	place a mark (e.g. rubber band) at this point
Step 6	submerge the impeller stick to this point on the stem
Step 7	the impeller will be approximately at the 0.6 of the depth from the surface down

Figure 11 Finding 0.6 of the depth

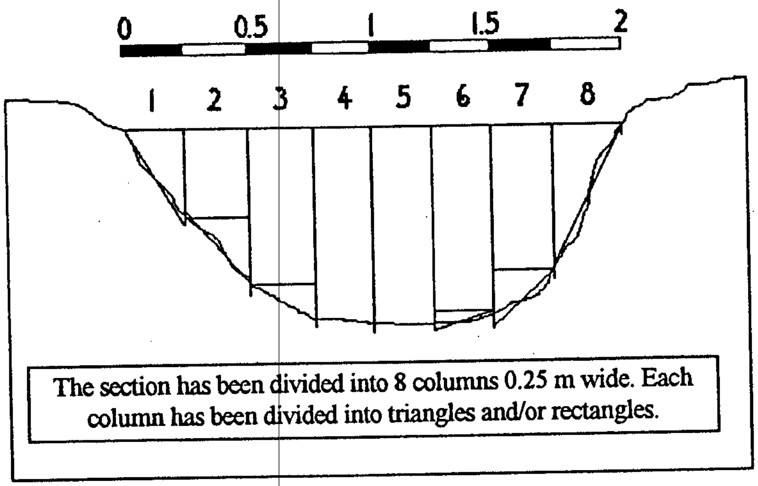


But the problems aren't over yet! In the semi-circular and rectangular channel sections shown in Figures 9a and 9b, an impeller placed in the centre of the channel at 0.6 of the depth, would give a reasonable average flow velocity. In the real-life section shown in Figure 10b, the channel geometry is much less regular. Where should the mean velocity be measured? The most likely choice would probably be in the vicinity of the label letter "A".

Thus, if the flow velocity (V) at this point was recorded as being 1 m/s and with a cross-sectional area of 1.45 m^2 then the DISCHARGE (Q) would be 1.45 m^3/ s

To do the job properly however, it would be necessary to make a series of average flow velocity measurements, and this would require the channel cross-section to be subdivided into a series of columns like those shown in Figure 12.

Figure 12 Constructing Water Columns in a Stream Cross-Section



The section has been divided into 8 columns 0.25 m wide. Each column has been divided into triangles and/or rectangles.

Figure 12 shows a stream cross-section which is 2 m wide. The section has been subdivided into columns (WATER COLUMNS) 0.25 m wide. According to the geometry of the channel, each column consists of a triangle and/or a rectangle. The area of each column has been calculated using the techniques described earlier and using the scale provided on the diagram. At an appropriate point within each column, the flow velocity would be measured with an impeller. A set of hypothetical velocities and the area measurements are displayed in Table 1, along with the calculations necessary to determine DISCHARGE (Q).

Table 1 Table of Measurements and Calculations for the Cross-Section

	Col.1	Col.2	Col.3	Col.4	Col.5	Col.6	Col.7	Col.8	Cols 1 -8	
Area 1	0.00	0.07	0.12	0.22	0.23	0.19	0.13	0.00	0.96	
Area 2	0.07	0.06	0.03	0.00	0.00	0.02	0.02	0.11	0.31	
Area 1+2	0.07	0.13	0.15	0.22	0.23	0.21	0.15	0.11	**1.27**	Cross-Section area (m^2)
V	0.05	0.60	0.90	1.10	1.00	0.50	0.40	0.10	**0.58**	Mean Velocity (m/s)
Q	0.00	0.08	0.14	0.24	0.23	0.10	0.06	0.01	**0.86**	Discharge (m^3/s)

In the Table, Area 1 refers to rectangles and Area 2 to triangles

From the table :

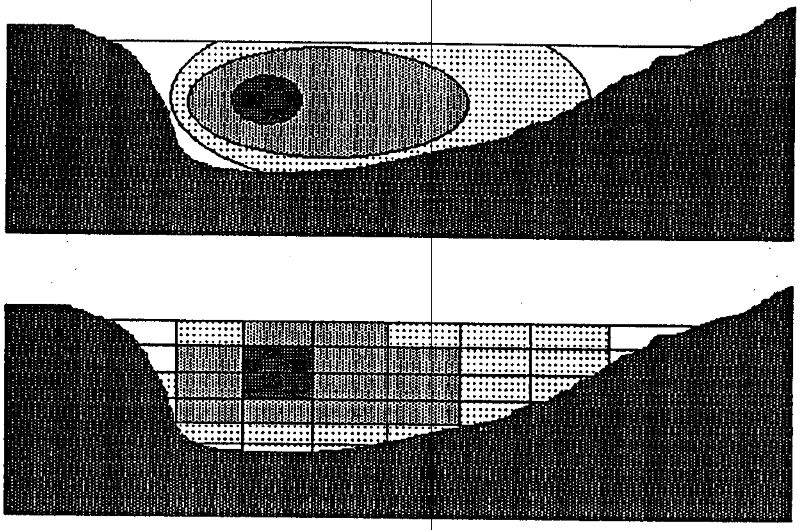
the total cross-sectional area has been calculated as	1.27 m^2
the mean flow velocity through the section is	0.58 m/s
the total Discharge (Q) through the section is	0.86 m^3/s

These procedures ensure that the best possible results are obtained from fieldwork. Once the hard work of surveying the channel section has been done, the profile can be used repeatedly under varying circumstances (e.g. before and after heavy rain) though adjustments for changes in depth and in-channel geometry due to erosion and deposition must be made. The exact position of the cross-section(s) must be fixed by inserting discrete stakes into the river banks.

4.4 Plotting Flow Patterns within a Stream

Using the cross-section channel profile(s) constructed for Discharge measurements (or survey some new sections), it is possible to collect data to illustrate the internal flow characteristics of channelled flow. There are a number of techniques, most common being the construction of ISOVELS or CHOROPLETHS. Isovels are lines joining points of equal velocity and Choropleths involve shaded areas of like and unlike velocity.

Figure 13 Showing internal flow patterns - Isovels (above) & Choropleths

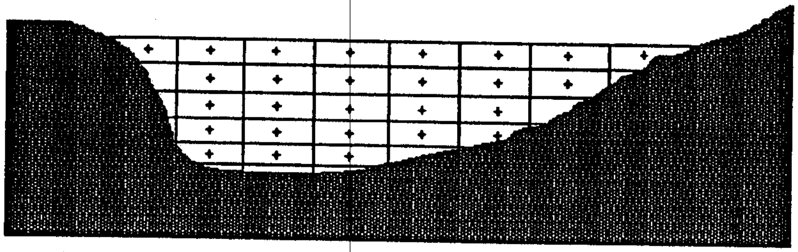


Key : dark shades = high velocity; light shades = low velocity

The isovels and choropleths represent lines and areas of equal velocity respectively. The highest velocity occurs usually in the centre of the channel near to the surface, while it is often lower nearer the bed and banks (Figure 13). However, the pattern displayed by the isovels and choropleths also reflects the shape of the channel i.e. its width, depth and symmetry (Figure 13). The spacing of the isovels and choropleths represents the velocity gradient.

Both methods can be effective in showing internal flow patterns. The degree of refinement depends on the number of readings which are taken - the more the better. Three values must be collected at each point - distance out from one or other bank; depth; and velocity at that point. The stream cross-section must be surveyed as meticulously as for the calculation of Discharge and readings collected systematically in a transect across the stream channel. Instead of taking just one velocity reading 0.6 of the depth, a number of readings are taken at regular points within the water column.

Figure 14 Data Collection Grid for Isovel and Choropleth Construction



In Figure 14, the "+" signs indicate the midpoints of each "cell" in the grid. Typically a grid would consist of cells 0.25 m wide and 0.125 m deep. The size is determined by the size and scale of the channel and degree of accuracy required.

Table 2 Stream Velocity Data collected in Cells

			Stream	Velocity	in m/s			
Depth	**Col.1**	**Col.2**	**Col.3**	**Col.4**	**Col.5**	**Col.6**	**Col.7**	**Col.8**
to 0.125	0.00	0.06	0.12	0.11	0.07	0.05	0.05	0.00
to 0.25	0.00	0.09	0.17	0.10	0.10	0.05	0.06	
to 0.375	0.05	0.11	0.16	0.10	0.10	0.10	0.04	
to 0.5	0.00	0.09	0.12	0.09	0.08	0.04		
to 0.625		0.06	0.07	0.06	0.06			
		Cells are 0.25 wide and .125m deep						

The data shown in this grid are ideally suited to constructing choropleths. For a representative and refined Isovel construction, at least twice as many velocity readings would be required (typically in a grid with 0.1 by 0.1 m cells).

MJP Geopacks publishes a computer software package called "Channel Analysis for WINDOWS™" which not only plots choropleths from fieldwork data but also draws channel cross-sections and calculates discharge among a wide range of other functions. For details see Appendix VI.

5.0 Using Anemometers

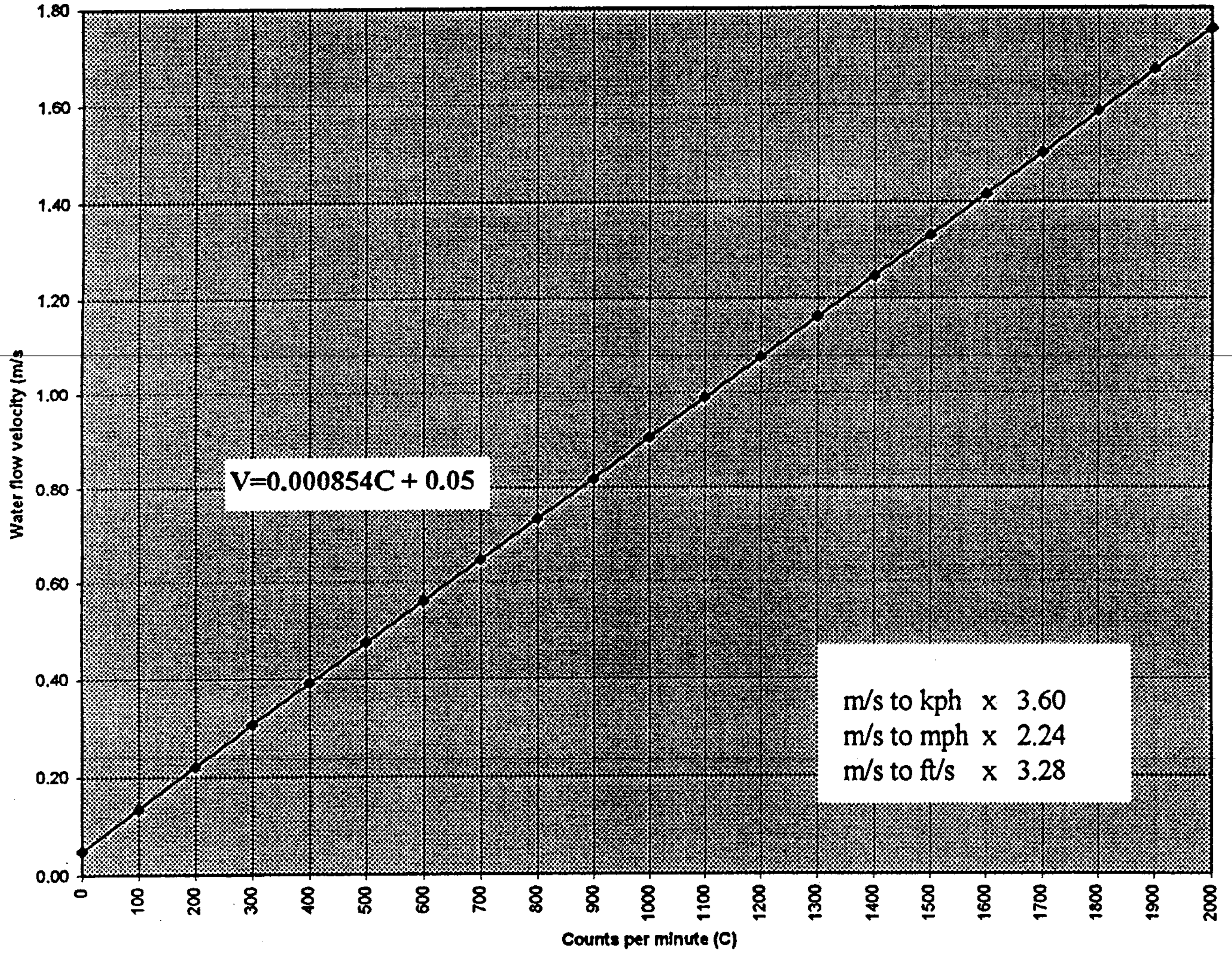
The anemometer can be used in a number of ways to monitor variations in wind speed. Here are some suggestions :

5.1 Measuring Variations in Wind Speed

Anemometers can be used to measure wind speed at various positions around buildings (e.g. the school), over a transect, above different types of terrain and ground cover and at various points under variable meteorological conditions. Ideally, a number of anemometers should be employed for simultaneous measurements in different positions. Wind direction using a vane and compass should be recorded alongside wind speed.

The following data show considerable variation in wind speed and direction at eight sites round the buildings of a school in West Cornwall. The observations were all taken during

Water Velocity Calibration Chart



#	Out		Minute (C)	(v)	#	Out	Depth	Counts/ Minute (C)	Velocity (v)
1					51				
2					52				
3					53				
4					54				
5					55				
6					56				
7					57				
8					58				
9					59				
10					60				
11					61				
12					62				
13					63				
14					64				
15					65				
16					66				
17					67				
18					68				
19					69				
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39					89				
40					90				
41					91				
42					92				
43					93				
44					94				
45					95				
46					96				
47					97				
48					98				
49					99				
50					100				

V.1 For use with the MJP Flowmeter for Stream Velocity
(users may copy this sheet)

Figure 8 - Measuring & Plotting the Channel Cross-Section

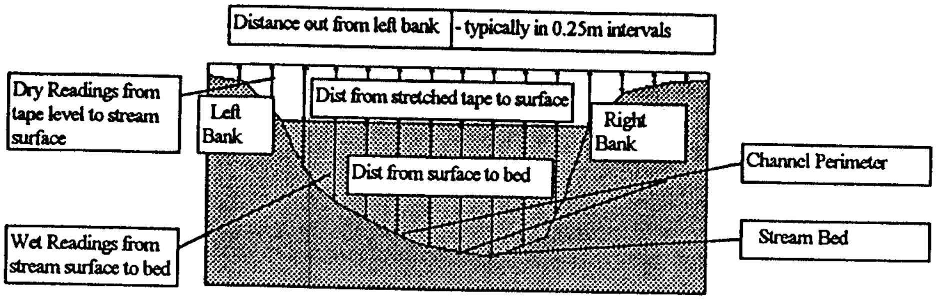

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Figure 9a Semi-Circular Channel

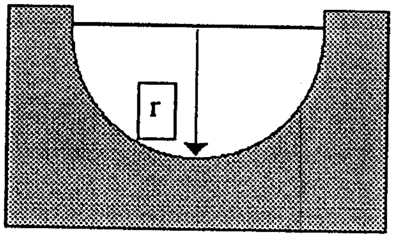
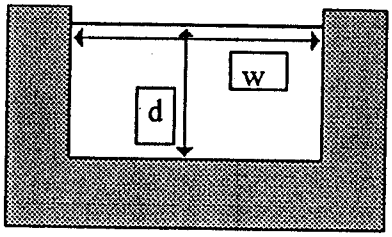


Figure 9b Rectangular Channel



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Mean Velocity (V) = 1 m/s
Discharge (Q) = $\Delta \times V$
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Similarly, in the rectangular channel, if the :

Depth (d) = 1 m
Width (w) = 1.5 m
Cross-sectional area (Δ) = $1.5 m^2$
Mean Velocity (V) = 1 m/s
Discharge (Q) = $\Delta \times V$
= $1.5 m^3/s$

FLOOD FREQUENCY ANALYSIS

HOW-TO: Steps in plotting a Gumbel flood-frequency curve:

1. Count or calculate the length of record (n, in years).
2. Determine the rank (r) for each flood of record. Rank in order from greatest flood (r = 1) to least flood (r = n).
3. Determine the recurrence interval for all floods with the equation (n + 1)/r.
4. Select a vertical axis for plotting discharge on the Gumbel curve. This takes experience and intuition, as the vertical axis must allow for the greatest flood of record AND 200 YEAR RECURRENCE FLOODS, which are usually greater than any flood of record. As a general rule, a vertical axis in which the greatest flood of record is 1/2 to 2/3 of the maximum value on the vertical axis will be adequate.
5. Plot the individual flood events on the curve.
6. Fit the curve with a straight line, or 2 or 3 straight line segments. Line segments should be defined by more than 2 data.

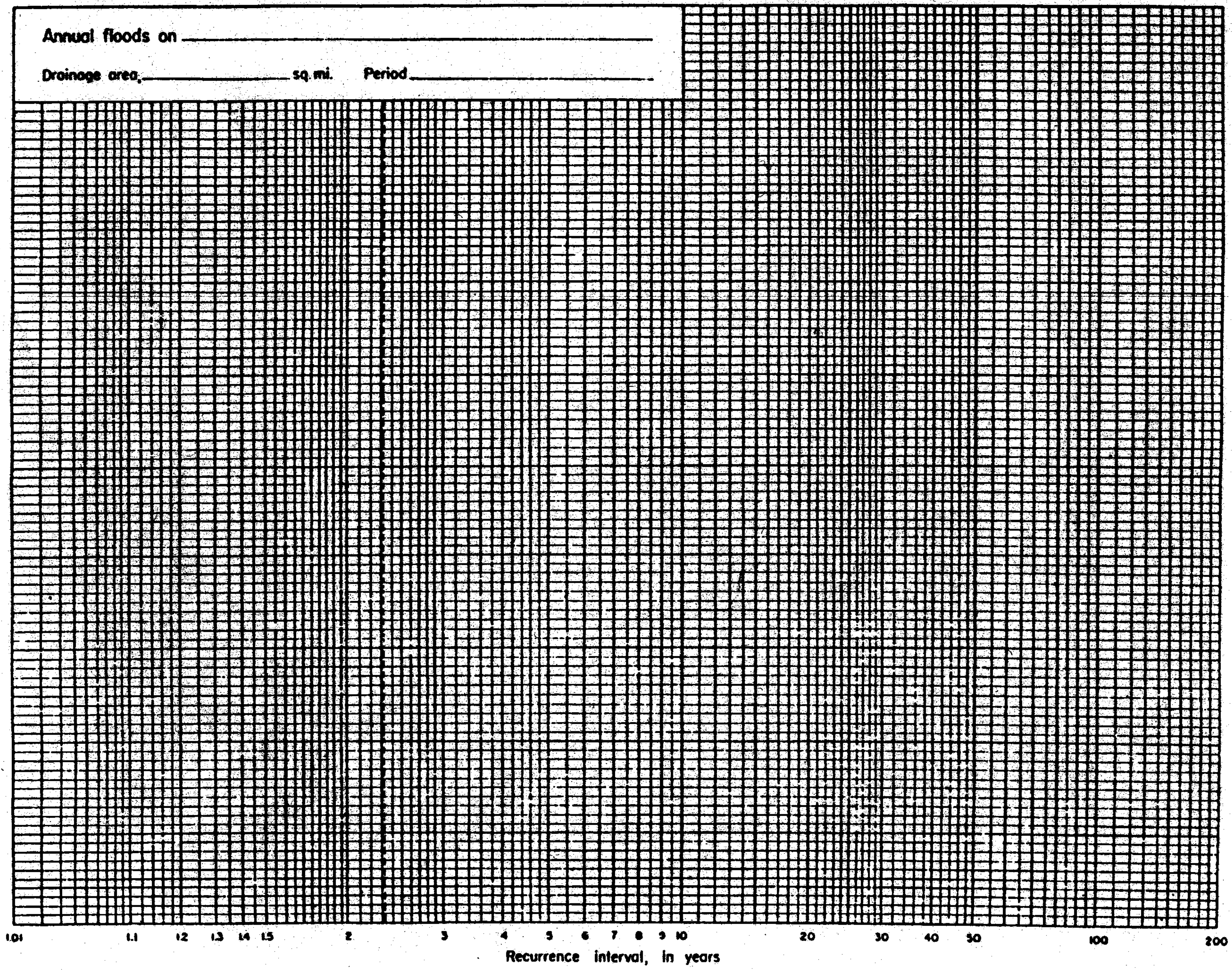
Recurrence Interval and Gumbel Plots

The recurrence interval of a given flood discharge is commonly calculated from a set of historical data. The annual peak discharges for the Luckiamute gaging station are listed in Table 4. The "annual peak discharge" represents the maximum discharge recorded at the station for a given water year. Recurrence interval of annual peak discharge represents an estimation, based on the historical record, of the probability of a given flood discharge occurring over a given time period. For example, the "100 yr flood" is a flood-discharge magnitude that has a probability of occurring once every 100 yrs. Generally, the lower the magnitude of event, the statistically more frequent the chance of occurring, and vice-versa. Once the recurrence intervals for given discharges are calculated, the relations may be visually plotted on a Gumbel-type graph. This is more-or-less a semi-log graph relation (see the attached Gumbel graph paper).

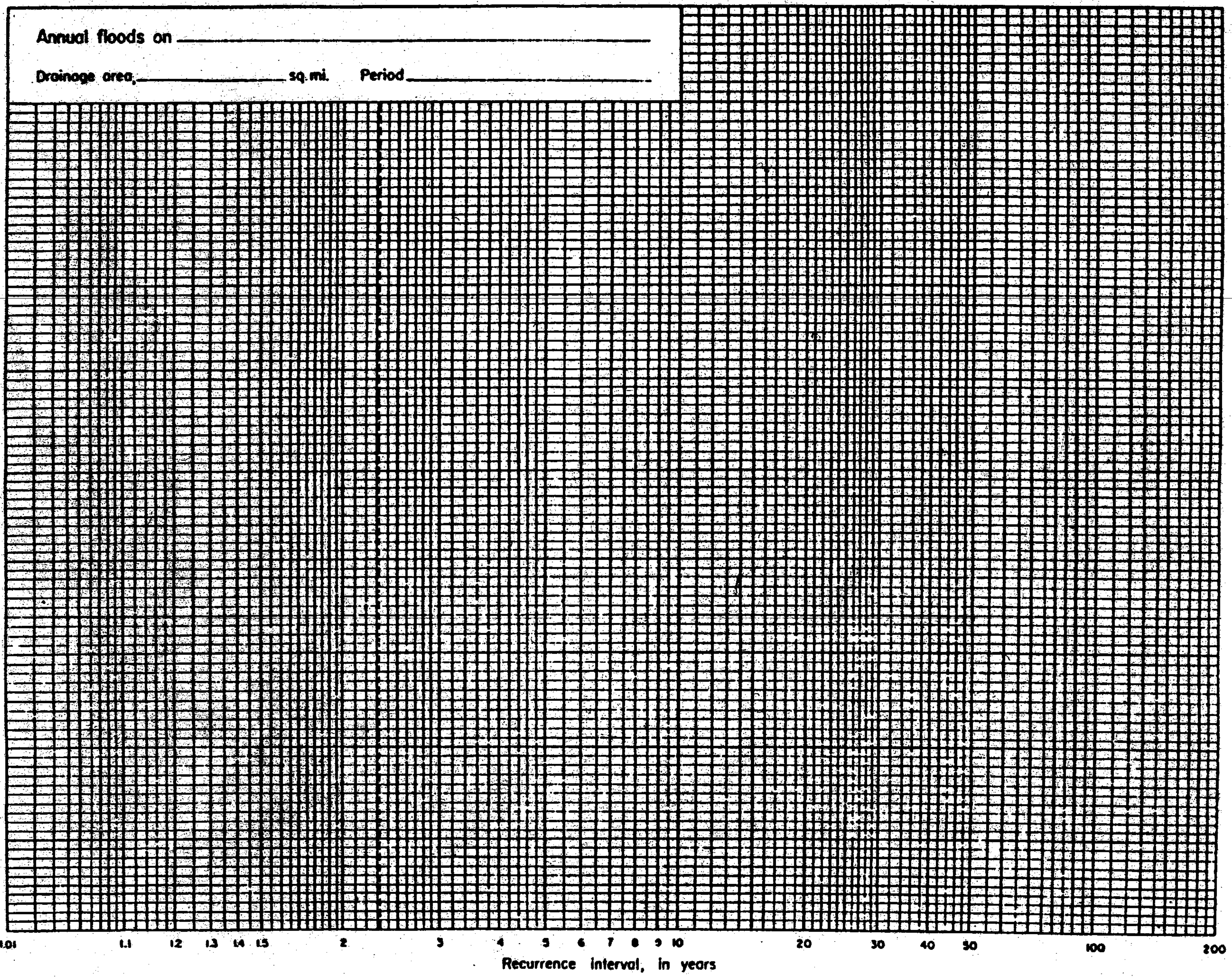
GUMBEL PLOT.

Annual floods on ____

Drainage area, ____ sq. mi. Period ____



GUMBEL PLOT.



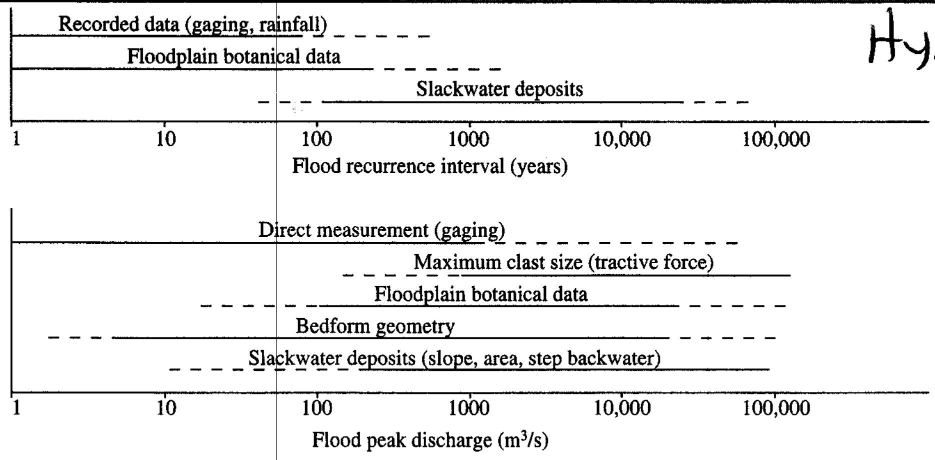
Annual floods on ____________________

Drainage area, ____________ sq.mi. Period ____________

PALEOFLOOD

Hydrology

TABLE 5.6 [illegible]



curves used in highway design. Successful techniques used in the Wyoming study included study of terraces, slackwater deposits, debris lines, dendrogeomorphology, and soils. Table 5.6 provides a summary of common paleoflood techniques and the range of applications.

A tremendous explosion in research related to paleohydrology has occurred since Schumm's (1965) seminal paper focusing attention on the prospects for Quaternary paleohydrologic studies (see, for example, entire books dealing with paleohydrologic studies such as Gregory 1983; Starkel et al. 1991). Paleohydraulic flood reconstructions have been used to gain perspective on the magnitude of some of the most catastrophic flows experienced in the Quaternary record such as the great Missoula floods responsible for carving the Channeled Scablands of eastern Washington (Baker 1973; Baker and Nummedal 1978; O'Connor and Baker 1992) and similar glacial lake-related floods in Siberia (Baker et al. 1993). Similar techniques have been used to detail the hydrology of Pleistocene lakes and breakout floods associated with the midcontinent portion of the Laurentide ice sheet (Kehew and Lord 1986; Lord and Kehew 1987).

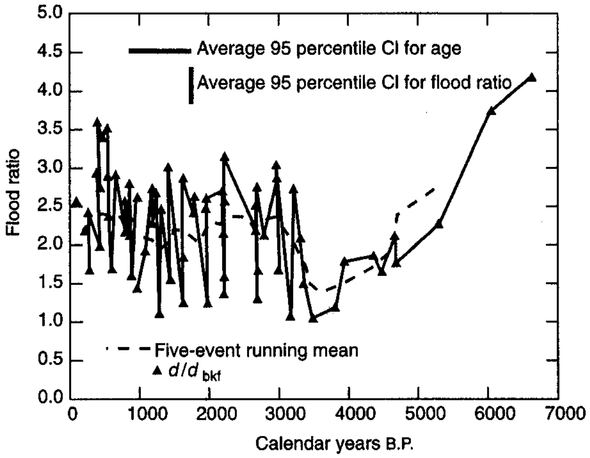
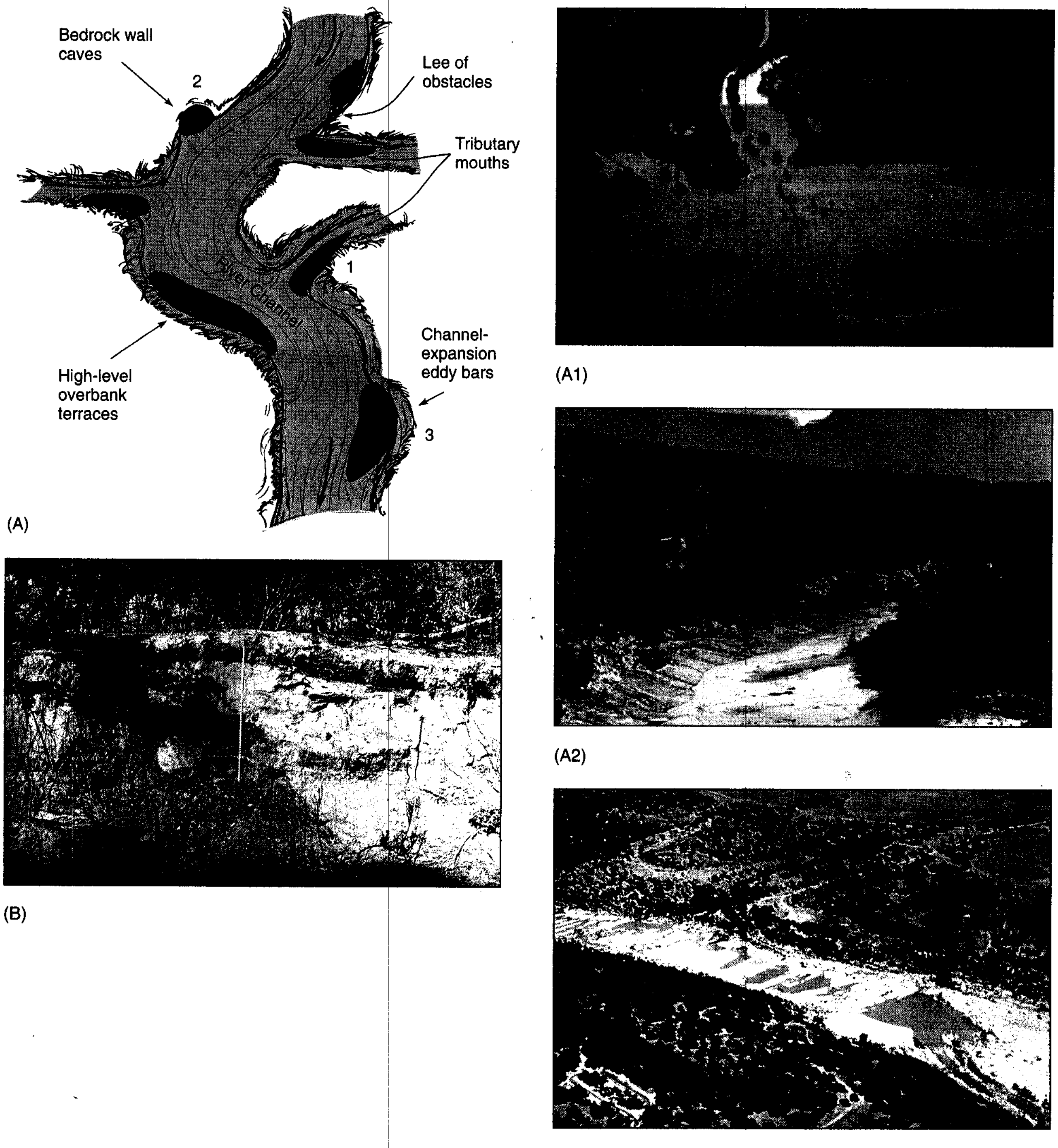


Figure 5.39
Holocene flood variations in the upper Mississippi River basin in response to small variations in climate.
(From Knox 1993)

Paleohydrological techniques also promise to play a major role in assessing the impact of human modifications on global climate, by facilitating the reconstruction of Holocene hydrologic regimes. Recent research has focused on fluvial responses to climatic change. This work is being done in arid bedrock channels (O'Connor et al. 1994) as well as in alluvial channels in semiarid regions (McQueen et al. 1993) and humid climates (Knox 1993; Patton 1988; Martin 1992). Paleoflood studies have been able to elucidate connections between climate and hydrology (Hirschboeck 1987) as well as the spatial variations in flooding between small basins (Martinez-Goytre et al. 1994). Ely (1997) found significant correlations in the frequency of Holocene paleofloods with climate fluctuations in the American southwest. Knox (1993; Knox and Kundzewicz 1997) presented a detailed reconstruction of paleofloods for the upper Mississippi River showing distinctive hydrologic variations during the Holocene. His data indicate that a drier and warmer climate prevailed from 5000 to 3300 B.P. Since then it has been cooler and wetter with more frequent large floods, perhaps similar to the devastating high water experienced in the summer of 1993 (fig. 5.39). Regional and even global correlations are now beginning to appear in paleoflood syntheses (Ely and Baker 1990; O'Connor et al. 1994; Smith 1992; Baker et al. 1995 Gregory et al. 1995; Kale et al. 1997) indicating that these methods may be able to function as useful tools for reconstructing hydroclimatic variations during the Holocene. The apparent correlation of regional paleoflood events with climatic variations should be anticipated because of the

75



(A)

(A1)

(A2)

(B)

(A3)

Figure 5.36

Slackwater deposits. (A) Location of common sites for slackwater sediment accumulation and preservation. Locations 1, 2, and 3 are illustrated by photos from the Pecos River in southwest Texas. (B) Stratigraphic package of over 2000 years slackwater sediment in a tributary mouth site along the Pecos River. Some of the flood units contain logs and other organic material useful in dating paleoflood events.

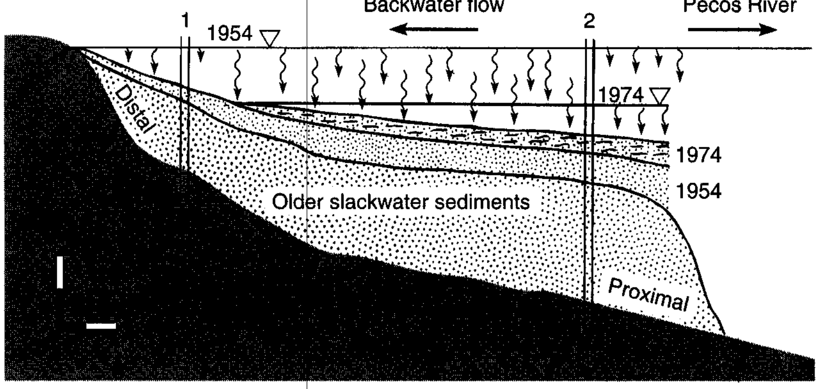


Figure 5.37
Schematic of on- and off-lap sequences and peak flood stage in a tributary valley for the 1954 and 1974 floods on the Pecos River, Texas. Sections in the proximal region (area 2) contain both floods, while distal regions (area 1) farther up the tributary record only the larger 1954 flood. Paleostage reconstructions are based on the elevation of the most distal sediments of each flood unit.
Kochel et al. 1982

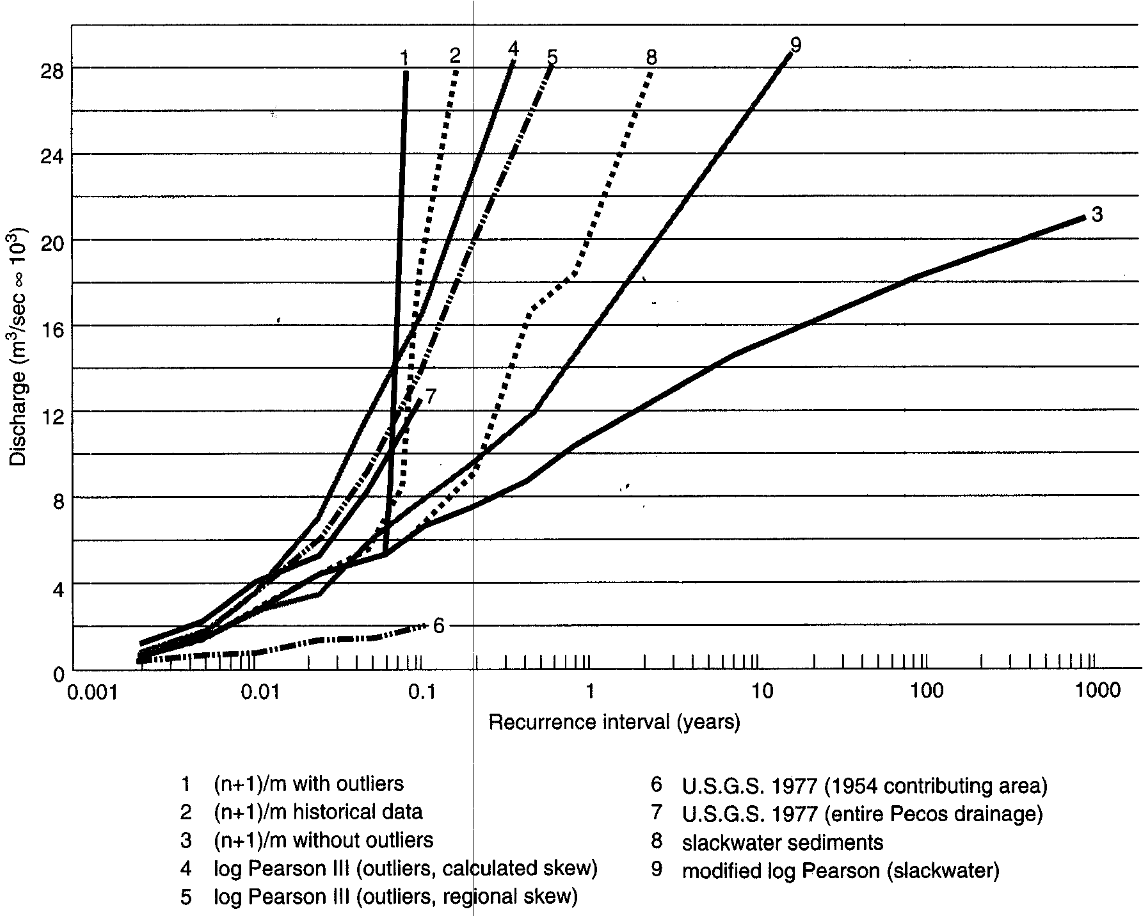


Figure 5.38
Range of potential flood frequency curves calculated using a variety of common standard techniques applied to the Pecos River flow data. Estimates of flood frequency for the 1954 flood outlier range from less than 100 years to more than 20 million years. Slackwater paleoflood deposits were used to provide a more realistic estimate based on physical flood evidence of around 2000 years.
Kochel and Baker 1982

PALEOFLOOD EVIDENCE

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FIGURE 5–10
Boulders moved by the 1976 Big Thompson River flood.

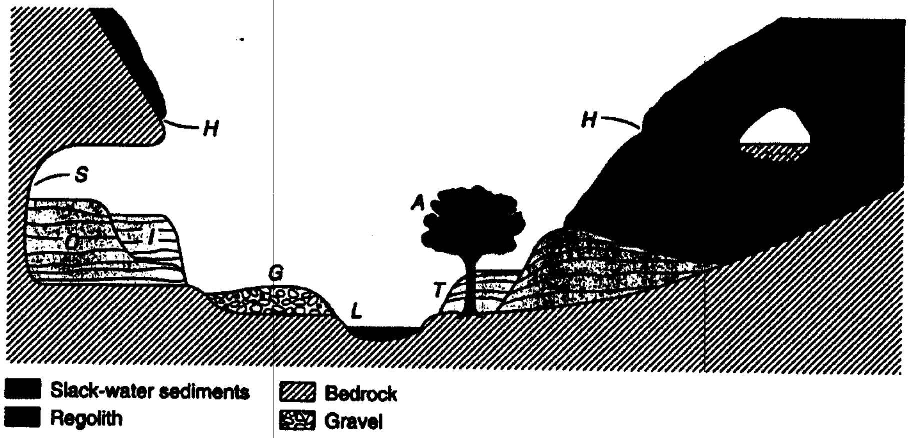

FIGURE 5–13
Idealized cross section of a bedrock canyon river. *A* is a tree with adventitious roots growing on flood deposits; *B* is high-level slack-water sediment in a cave on the canyon wall; *C* is a cave deposit of slack-water sediments; *G* is a gravel and boulder bar on the canyon floor; *H* is a high-water mark created by scour of soil on the canyon walls; *I* is inset slack-water sediments; *L* is the low-flow channel of active river; *M* is tributary-mouth, slack-water deposits; *S* is the silt line of a paleoflood preserved in a cave; and *T* is a slack-water terrace. (After Baker, 1987)

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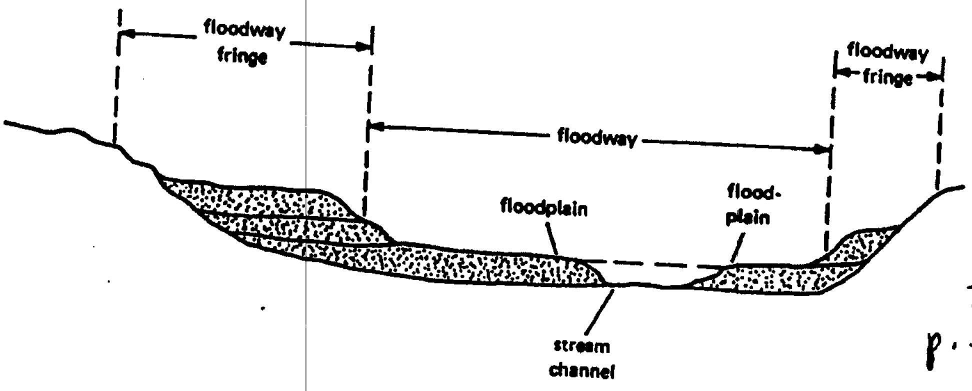

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Figure 11.1. View across a river. The floodway is the area along the river which is frequently flooded, an area over which the flood discharge moves with great velocity. The floodway fringe includes areas which are further from the actual channel and which are infrequently flooded by rare events. The floodway fringe is that area flooded by the "100-year" flood.

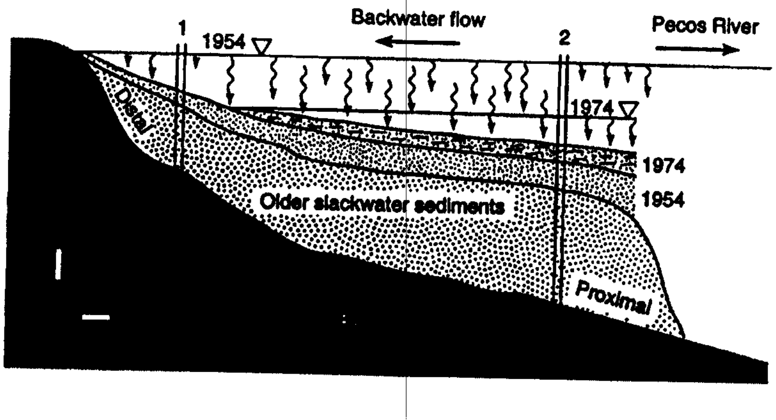

FIGURE 5.37

Schematic of on- and off-lap sequences and peak flood stage in a tributary valley for the 1954 and 1974 floods on the Pecos River, Texas. Sections in the proximal region (area 2) contain both floods, while distal regions (area 1) farther up the tributary record only the larger 1954 flood. Paleostage reconstructions are based on the elevation of the most distal sediments of each flood unit.

(Kochel et al. 1982)

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