Geopacks

A MAP MARKETING COMPANY

ZMFP51
Stream Flowmeter

OPERATION MANUAL

River Lyd at Brat Tor, Dartmoor.

Geopacks Standard Flowmeter

Be Aware – Be Safe

Fieldwork Safety when working in streams or rivers

There are a number of things to consider when carrying out work in streams or rivers.

1. CHECK THE WEATHER FORECAST before you go out on fieldwork. In heavy rain rivers can rise quickly and what was a gentle trickle can become a torrent in a short space of time. Fast moving water which is higher than knee-deep can easily take you off your feet, especially if working on an uneven, or rocky river bed.

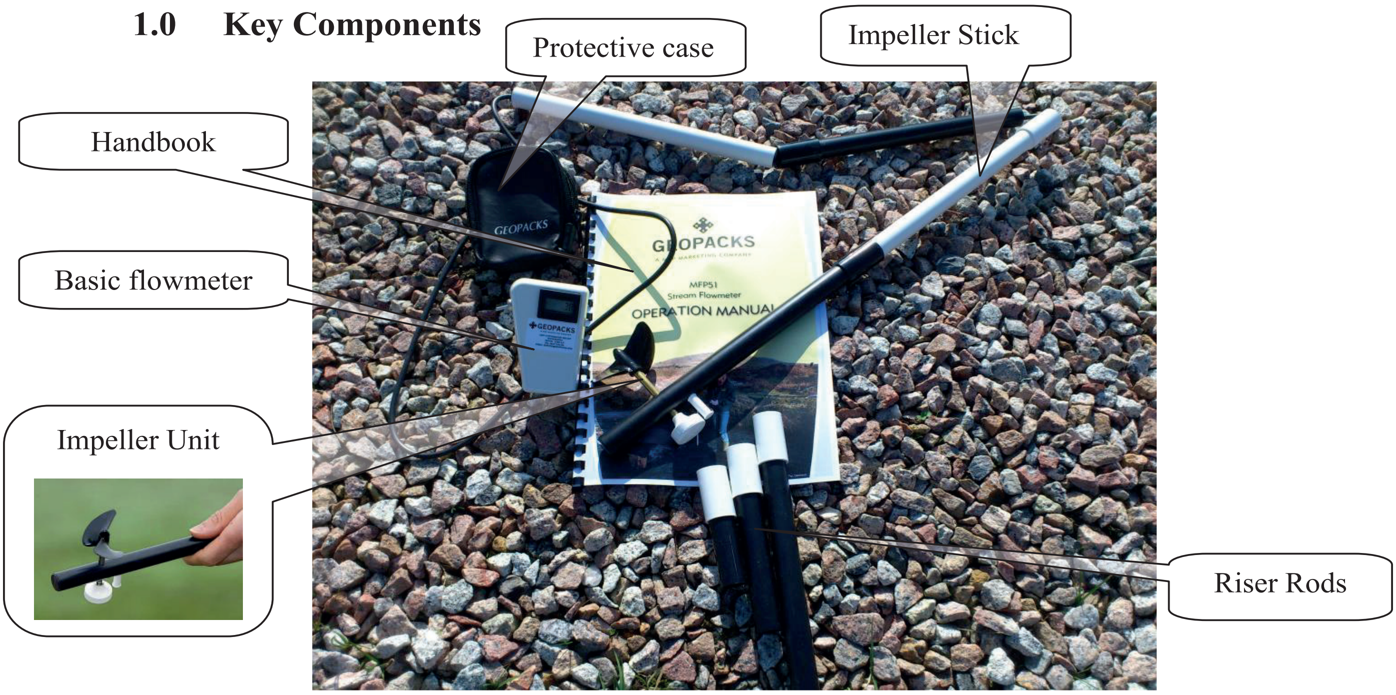
2. WEAR THE RIGHT CLOTHING for the day. If you get wet (see 4 below too) then you will get cold. Cold is unpleasant and uncomfortable at best and a life threatening at worst (hypothermia). Always make sure you take enough clothing even in summer. You'll be surprised how quickly you can get cold if you are wet, even on a summers day.

3. NEVER WORK ALONE and always let someone else know WHERE you are working and your EXPECTED TIME OF RETURN.

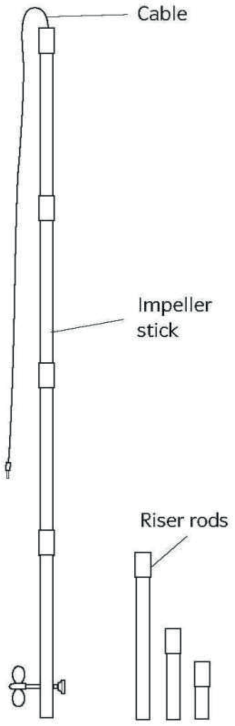
4. Moving water is powerful, and the banks of rivers may be undercut. CHECK THE STABILITY OF THE BANKS before you start working on the channel so you don't fall in before you've even started!

5. River beds can be very rough, or have a bed-load of boulders which can easily move underfoot. CHECK THE CHANNEL IS SAFE before stepping in to it. I remember nearly taking my eye out when I walked into the branch of a tree. Water can appear deceptively shallow at times. Check how deep it is before stepping into the channel.

1.0 Key Components



1.1 Impeller Stick



The impeller stick is used for measuring water velocity and consists of:

- An IMPELLER and coupled SENSOR in which a switch opens and closes as the impeller is rotated by the flow of water
- Four 250 mm long tube sections which slot together to make a 1m stick
- Three “riser rods” which when slotted singly or in combination, allow the impeller to be elevated above the stream bed at fixed heights – 250mm, 125 mm and 75 mm or combinations of these up to a maximum of 450mm.
- A 1m long cable which connects to a flowmeter

1.2 Basic Flowmeter

The basic Flowmeter is an electronic device that counts signals (pulses) from the impeller stick proportional to velocity. The total number of counts per unit of time (normally one minute) can be converted into a velocity value by referring to calibration charts or using a formula. The unit has the following features:

- An LCD (liquid crystal display) counter;
- A locking socket for the jack plug connection
- A three way switch on which the switch positions are:
  - **NEUTRAL** – centre switch position
  - **START** – flick the switch DOWN
  - **STOP** – flick back to centre
  - **RESET** (to zero) – UP to the top position
  - **NEUTRAL** – Centre position again

The act of inserting the jack plug from the impeller stick turns the meter ON. Having inserted the jack the value in the LCD should read 0. If greater than 0, move the switch to the UP position and rotate the impeller fractionally to close the relay to reset at 0 then move the switch to the NEUTRAL position

2.0 Operating Instructions

2.1 Impeller Stick with the Basic Flowmeter

Slot the rods of the IMPELLER unit together and point the impeller up into the flow of moving water at the required depth (Figure 1a).
Use one or more of the three “riser” rods to elevate the impeller off the stream bed if necessary (figure 1b).

Figure 1a Impeller Stick in the flow

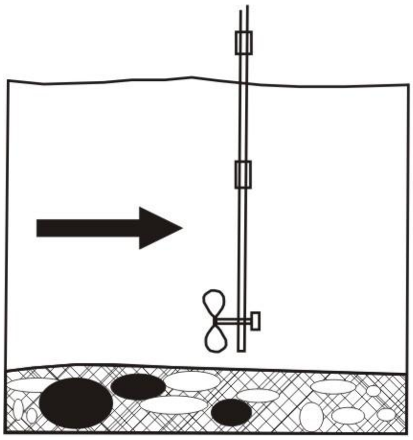
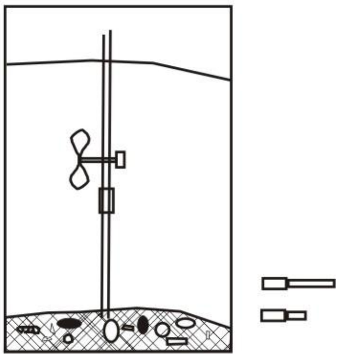


Figure 1b Using Riser Rods



When the impeller is turning at the correct depth (which will depend on the purpose of your measurements), flick the switch down to the start position and hold for 60 seconds (best to have a time keeper at hand!). Stop the count (CENTRE position) at the correct time and note the count value.

Determine the flow speed via the graph provided (see section 5.1, page 16 and Appendix II). Alternatively, the flow speed (V), in m/s is given by the following formula in which C is the number per minute:

$$\textbf{Water Velocity (V) m/s} = (0.000854C) + 0.05$$

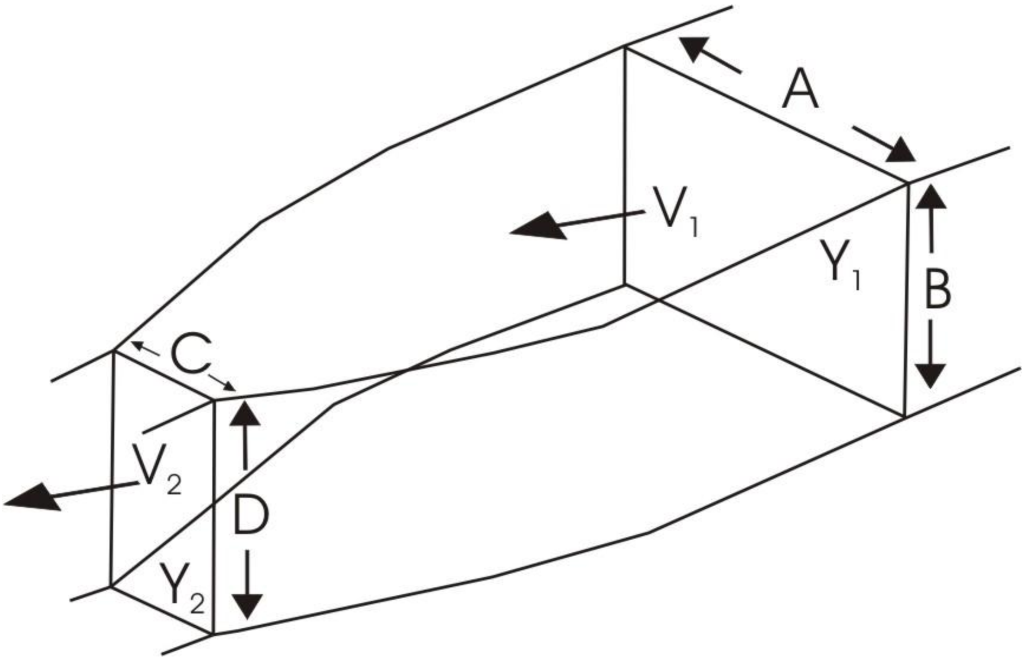
Zero the counter – UPPER switch position (turn impeller slightly, if necessary, to close the impeller relay) and return to CENTRE switch position ready for further measurements.

3.0 Stream Flow Velocity

3.1 Theoretical Background

A moving fluid exhibits certain important features. The flow velocity of a fluid depends upon the cross-sectional area of the flow, the roughness of the surfaces it is passing over (friction) and upon the quantity of fluid, which passes through that area in unit time. This is known as the DISCHARGE and illustrates the 'Principle of the Continuity of MASS'.

Figure 2: River Cross-sections and Flow Velocity



In the river channel depicted in Figure 2 the volume of water, which passes through section Y_1 in a second, is the DISCHARGE (Q) and will be given by:

$$Q = a \,.\, b.\, V_1$$

and similarly at section Y_2

$$Q = c \,.\, d.\, V_2$$

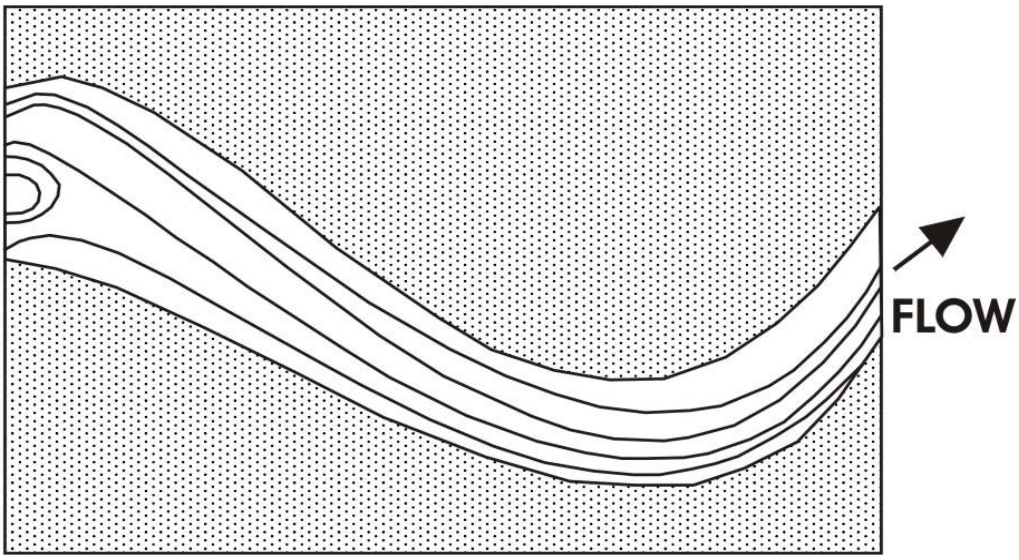
In these equations, a and c are the widths and b and d are the depths of the channel at the two sections, and V_1 and V_2 are the flow velocities. Since the same DISCHARGE (Q) passes through both of the sections then flow velocity relates to the difference between a . b and c . d (the cross-sectional area) ; i.e. if the channel becomes either narrower or shallower then the flow velocity increases and vice versa.

This principle explains many of the variations in the river channel morphology and in flow velocity. It is therefore important that this principle be understood by anyone undertaking serious fieldwork measurements in rivers. This could be demonstrated by measuring channel cross-sectional area discharge at a number of different sections along a short stretch of river.

3.2 Describing Flows

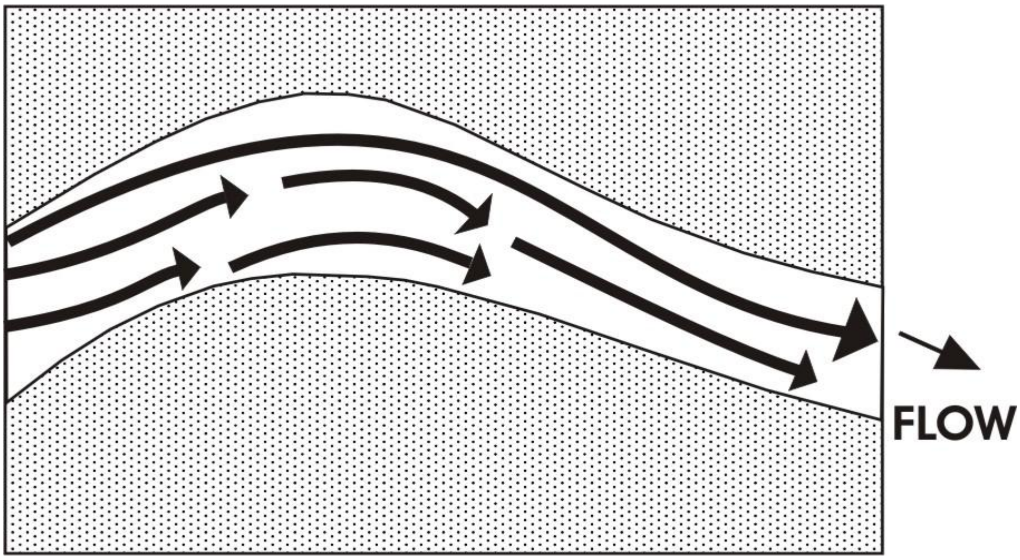
To understand the flow characteristics within streams of moving water it is sometimes helpful to consider the flow in the form of STREAM LINES or VECTOR LINES.
Figure 3 shows how Stream Lines depict possible paths of a single fluid particle.

Figure 3 Stream Lines in a flow around a meander



Vector Lines represent both the flow direction and velocity. The longer and broader the line the greater the flow velocity. Vector lines convey useful information about the stream flow characteristics.

Figure 4 Vector Lines in a flow around meander

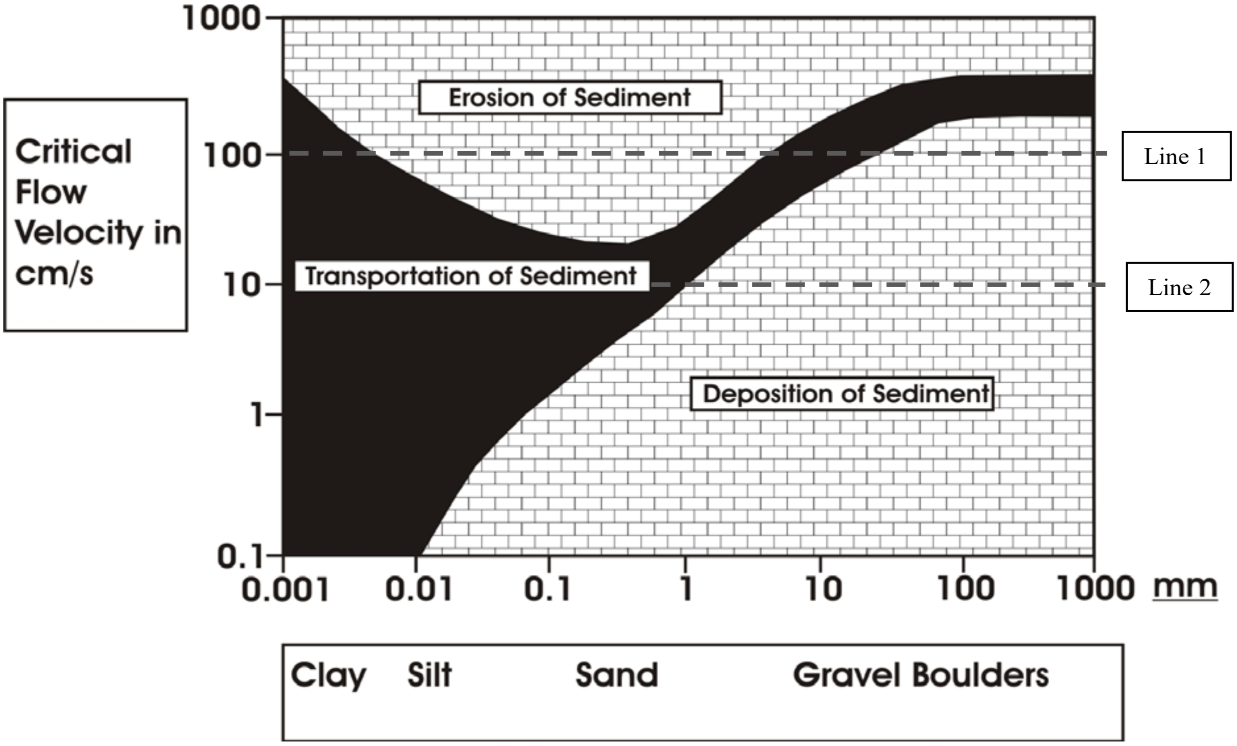


In this diagram the short thin arrows represent the slower areas of the stream and the long, thick lines the regions of faster flow.

3.3 Sediment Transport

The amount of sediment and maximum particle size that can be transported by moving water is related to the flow velocity. Therefore, measurements of velocity obtained using the flowmeter can be used to determine the maximum size of sediment particles, which may be transported by the flow (Figure 5).

Figure 5 Erosion Velocities for Water



The chart, which is referred to as the "Hjulstrom Curve", has been derived from a mass of accumulated observed data and shows that for a given flow velocity there are a range of behavioural possibilities for sediment particles lying on the bed, or entrained within the flow, of a stream. For example, at a measured flow velocity of 100 cm/s (1 m/s) silt and sand (though not compacted clay) will be eroded from the stream bed and transported downstream (see Line 1). At the same velocity, all sediment particles finer than 1mm, which were already in motion, will continue in motion. Where the stream velocity falls below 10 cm/s (0.1 m/s), due to, say, a widening of the channel, sediment particles greater than 1mm diameter will be deposited (see Line 2).

Thus, a stream flowmeter can be a valuable observation tool when used in sediment transportation studies. Observed flow velocities can be traced on the graph and the corresponding maximum particle size which can be transported at the velocity (the competence of the river) can be determined.

4.0 Studying Streams – Some fieldwork suggestions

4.1 Recording Stream Velocity

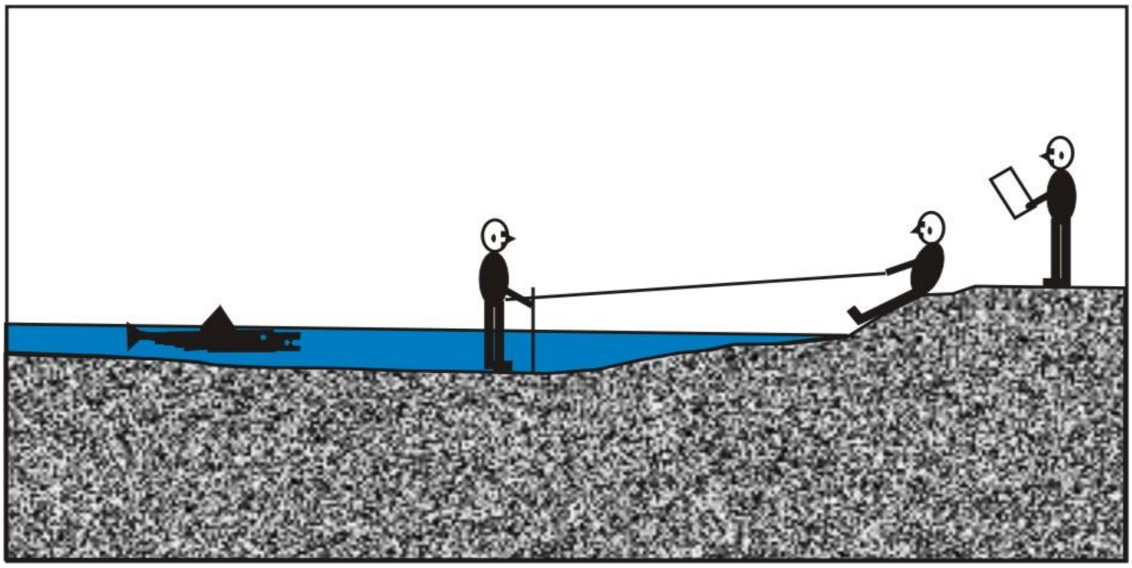
Equipment Needed:

- Geopacks stream flowmeter
- Measuring tape
- Ranging pole
- Stopwatch
- 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 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, where stretching a tape across is impractical, 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 the bank to bank. The ends of the tape can be attached to ranging poles on the bank or secured with heavy stones at each end.

Figure 7 Measuring “Distance Out” using tape secured at each end

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 taping a meter ruler to them. 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.

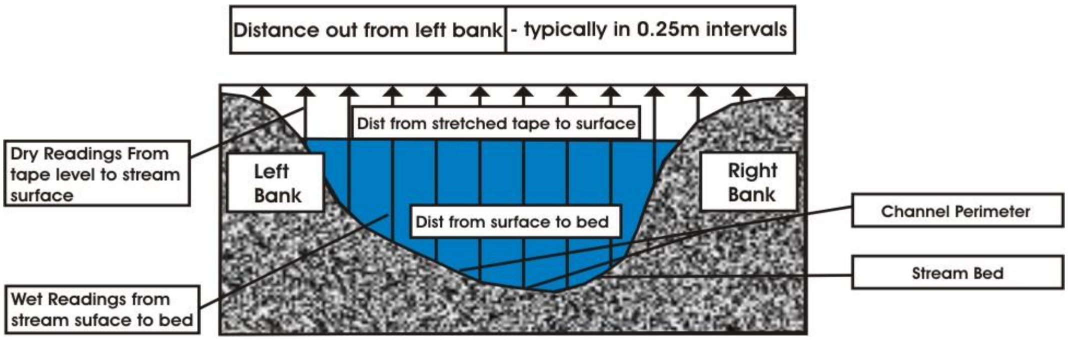
One method of measuring and plotting the channel form is by stretching a tape measure across the channel as described above. Depths can be measured vertically down from the tautly stretched tape to the stream bed.

Distance from Bank	Dry Reading	Wet Reading	Total
0m	0 cm	0cm	0cm
0.25m	14 cm	3cm	17cm
0.50m	14 cm	15cm	29cm
0.75m	14 cm	22cm	36cm
1.00m	14 cm	31cm	45cm
1.25m	14 cm	35cm	49cm
1.50m	14 cm	38cm	52cm
1.75m			

Measurements of channel widths and depths are then recorded using 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 meter rule. The greater the number of measurements taken at each cross-section, the more accurate the representation of the channel, however, the closer the readings are together the longer it will take.   In small channels, which are less than say 2 metres wide, a horizontal interval of 10cms would be workable. However, in a larger channel, maybe 5 or 6 metres across an interval of 20 or 25cms would give sufficient accuracy.

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 section 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 1 m^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 an important variable, unfortunately, it's not always easy to measure.

Figure 9a Semi-Circular Channel

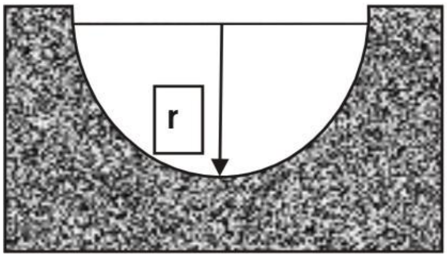
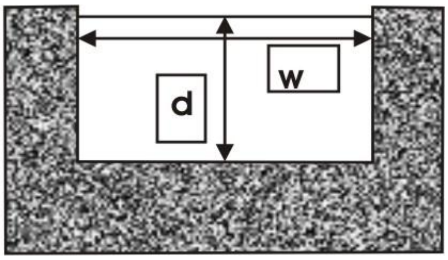


Figure 9b Rectangular Channel



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) = π^2) 2 = 1.57m^2
Mean Velocity (V) = 1 m/s
Discharge (Q) = Δ x V = 1.57 m^3/s

Similarly, in the rectangular channel, if the:

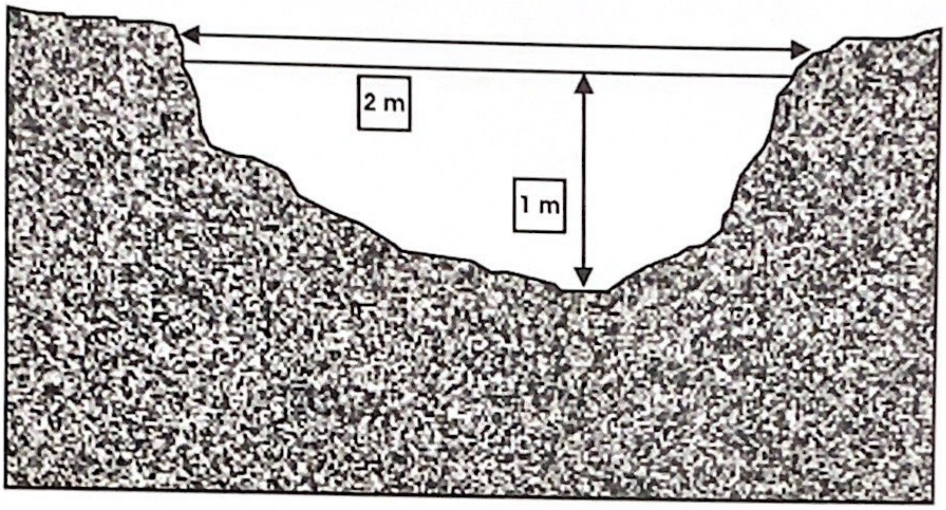
Depth (d) = 1 m
Width (w) = 1.5 m
Cross-sectional area (Δ) = 1.5m^2
Mean Velocity (V) = 1 m/s
Discharge (Q) = Δ x V = 1.57 m^3/s

In a real-life situation, however, the channel geometry will be far from regular. However, there is a "work around" which allows fairly accurate estimates to be made of these channel variables with a minimum of calculation. Try this…

Measured
Width = as measured (in metres)
Wet Readings = as measured (use metres – convert from cms if necessary)
Velocity = as measured (metres per second)
Calculated
Mean Depth = the mean average of all wet readings taken (in metres)
Cross Sectional Area = Width * Mean Depth (metres^2)
Wetted Perimeter = Width + (2 * Mean Depth)
Hydraulic Radius = Cross Sectional Area / Wetted Perimeter (metres)
Discharge = Cross Sectional Area * Velocity (metres^3 per second)

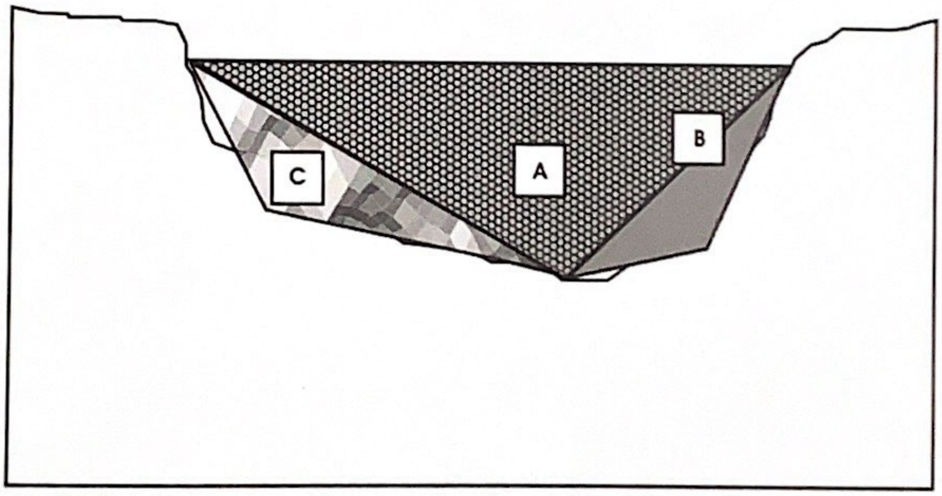
In a real-life situation, however, the channel geometry will be far from regular.

Figure10a 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 a 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):

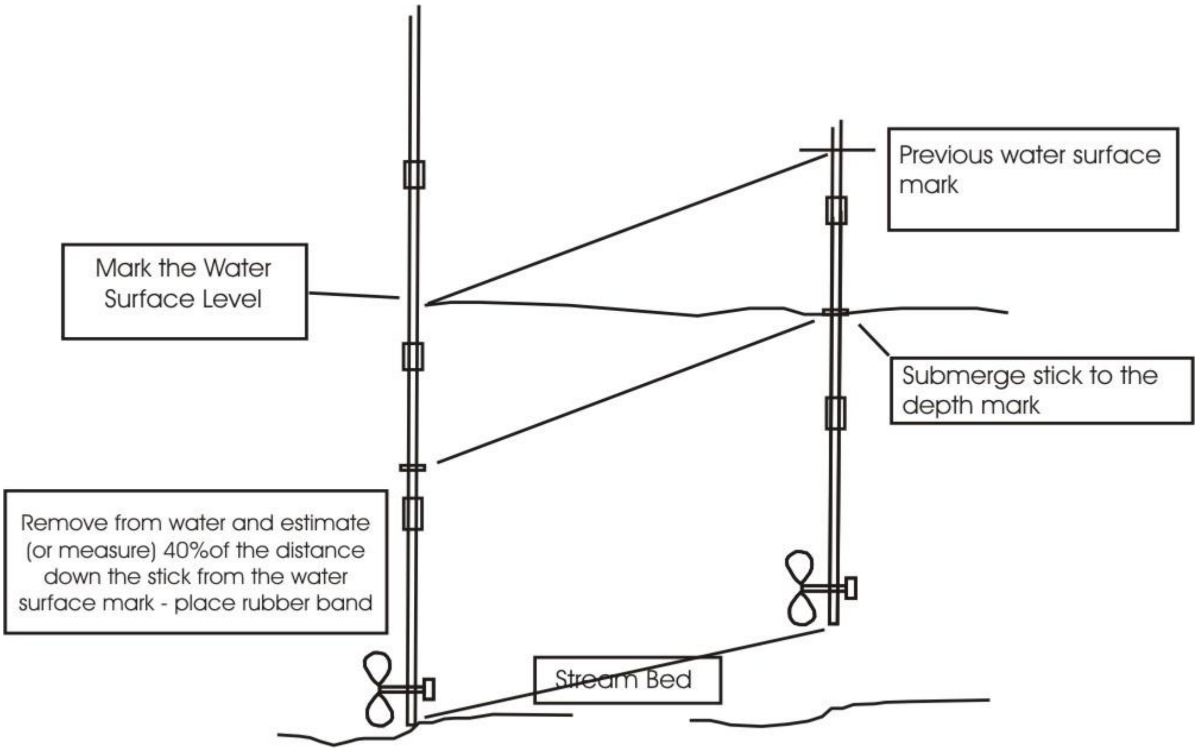
Area of triangle A = 1.00 m^2
Area of triangle B = 0.15 m^2
Area of triangle C = 0.30 m^2
Total Channel Area = 1.45 m^2

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 0.6m, 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	removestick 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 in Figure 12.

Figure 12 Constructing Water Columns in a Stream Cross-Section

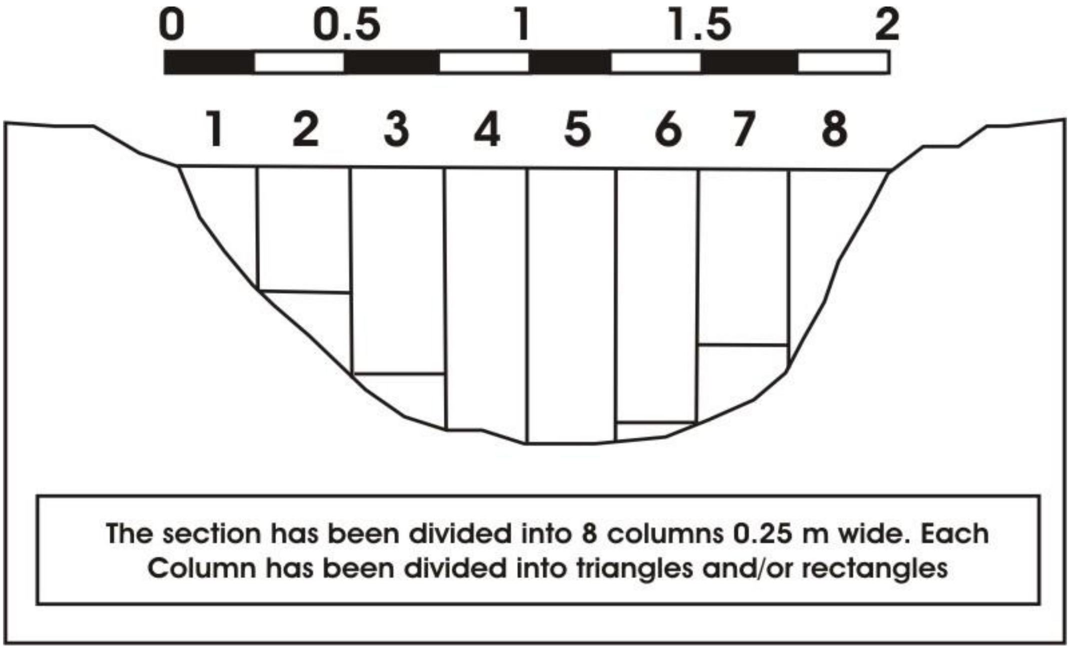


Figure 12 shows a stream cross-section which is 2 m wide. The section has been subdivided into columns (WATER COLUMNS) 0.25 m wide. According to the geometry of the channel, each column consists of a triangle and/or a rectangle. The area of each column has been calculated using the techniques described 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/S^3)

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

From the table:

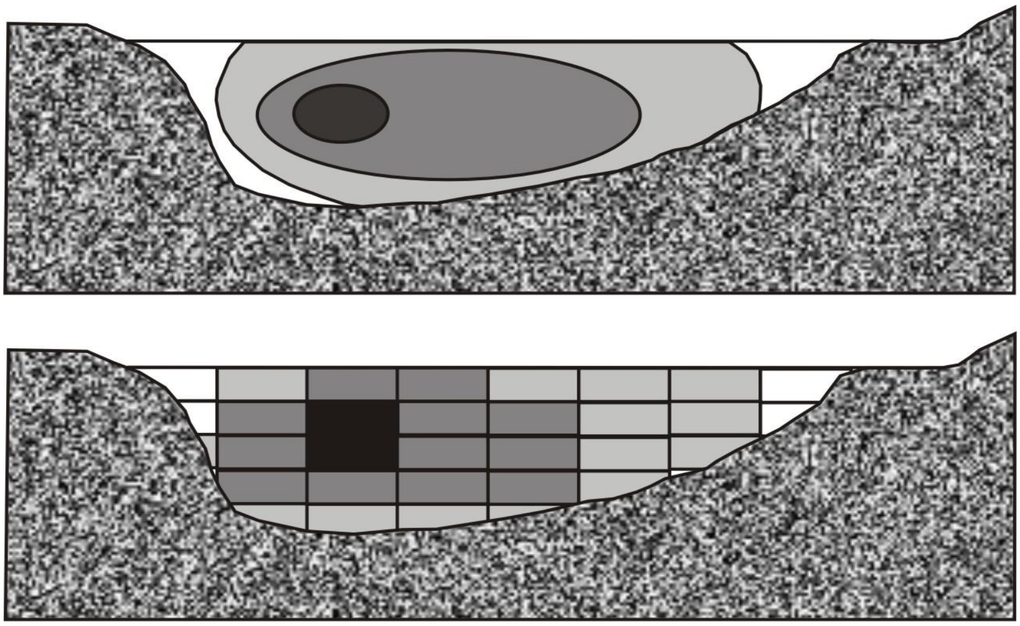
The total cross-sectional area has been calculated as	1.27 m^2
The mean flow velocity through the section is	0.58 m/s
The total discharge (Q) through the section is	0.86 m^3/s

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 (below)



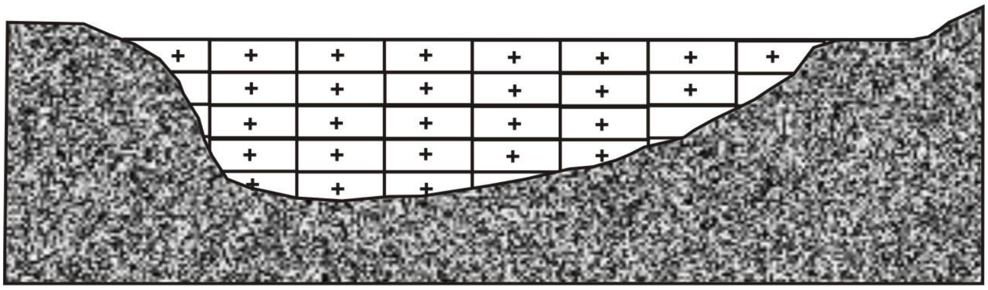
Key: dark shades = high velocity; light shades = low velocity

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 are 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 midpoint 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 1.25m 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).

Geopacks publishes a computer software package called "*River Channel Analysis*" 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 III.

5.0 Calibration

Before shipment the impeller unit has been carefully calibrated under laboratory conditions. The formulae and graphs from what we call the Calibration Data are essential for users of the Basic Flowmeter with impeller stick.

5.1 Pre –shipment Impeller Stick Calibration

The impeller sticks have been calibrated in a flume where flow velocities can be strictly controlled by combined variations in discharge, gradient and weir height adjustments. Flow rate was monitored by a miniature Nixon electronic flowmeter and an Ott flowmeter. The formula required to convert counts per minute (C) recorded by the Flowmeter to water velocity (V) in m/s is:

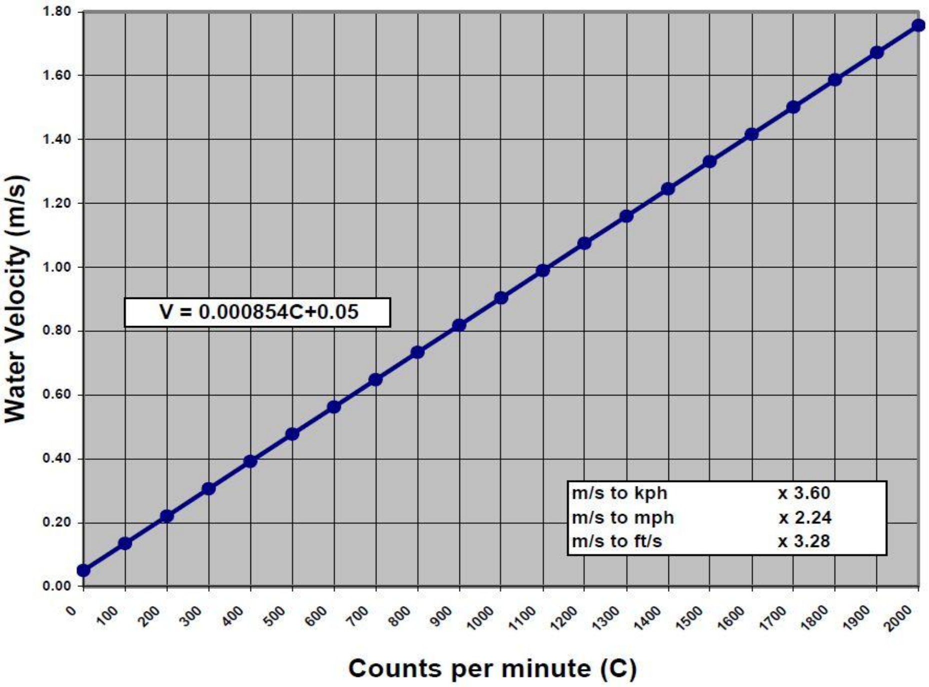
Water Velocity (V) m/s = (0.000854C) + 0.05

Alternative units can be calculated using the following conversion factors:

m/s to kph	**x**	**3.60**
m/s to mph	**x**	**2.24**
m/s to ft/s	**x**	**3.28**

Values in this manual are given in metres per second (m/s). The formula can be entered into a spreadsheet or other computer program and used to convert counts per minute into the desired unit of velocity. Alternatively, a Calibration Chart can be used which shows the relationship between revolutions of the impellor and calculated velocity displayed on the meter. The chart (Figure 15) is reproduced in laminated format with this manual for use in the field.

Figure 15 Calibration Chart showing the relationship between revolutions of the impellor and Water Velocity



Appendix I

CARE OF YOUR FLOWMETER

Check your equipment before you start work.

BEFORE leaving for fieldwork check your equipment as follows:

> Switch on the meter by plugging the impeller jack-plug into the socket turning the switch down and spinning the impeller.
>
> If nothing is displayed, check the batteries are correctly fitted. Batteries are accessed in the Basic flowmeter by undoing the small cross-headed screws on the back of the unit (try not to lose the screws!). Fit new batteries if necessary: always carry spare AAA for the Basic meter with an average life of several months.

Although your flowmeter has been designed for use by fieldwork parties under a wide range of conditions and is reasonably robust, it can be damaged by rough treatment or immersion in water. Should the meter be immersed in water, REMOVE the batteries IMMEDIATELY; the flow meter can be left open to dry in a warm room. Just remove the batteries, leave the battery panel off and leave it to dry slowly. In case of a serious dunking then, after removing the batteries, wipe dry with a towel and cover the meter entirely with dry rice and leave for 24 hours. The rice will absorb any moisture, discard the rice and replace the batteries.

Should the flowmeter (impeller stick and/or meter) be damaged or otherwise malfunction we can repair/replace damaged parts at a very reasonable cost and will also provide repairs under guarantee where appropriate.

Please telephone Geopacks on 0843 2160 456 and speak to customer services or email us on service@geopacks.com **before** returning the meter to the address below:

GEOPACKS
Unit 4A, Hatherleigh Industrial Estate
Holsworthy Road
Hatherleigh
Devon, EX20 3LP

We can also customise your Flowmeter for any special requirements.

After each field session we recommend that the flowstick and impeller are rinsed in clean water and allowed to dry before being stored back in the carry case. Also, the batteries should be removed if the equipment is not being used for any length of time.

YOUR FLOWMETER IS GUARANTEED AGAINST DEFECTS IN MATERIALS AND WORKMANSHIP FOR 12 MONTHS FROM THE DATE OF PURCHASE.

Appendix II

Calibration Charts

The large charts enclosed have been laminated for your convenience. Please make photocopies for your records in case the originals become mislaid or damaged in use.

Enclosed – water and wind speed calibration charts – 1 of each laminated

Appendix III

Data Collection Sheets

Insert units of measurement as appropriate (e.g. m and m/s)

V.1 For use with Geopacks Basic Flowmeter – stream velocity

Enclosed – 1 each of the above sheets, laminated

Geopacks
4A Hatherleigh Industrial Estate
Holsworthy Road Hatherleigh Devon EX20 3LP
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www.geopacks.com E-mail: service@geopacks.com