Flow measurement and control

Water flow is measured to assess how much water is available for a supply and to check the quantity of water flowing through a system or treatment plant.

Flow control is essential in water treatment plants and for effective disinfection of distribution networks. Most water treatment processes require a controlled constant flow of water in order to operate effectively and efficiently.

Water source flow measurement

The measurement of water flow is important in selecting the best source for a drinking water supply. The source has to be able to provide sufficient water to serve the population, either on its own or in conjunction with other sources. The flow of water sources should be measured to assess the amount of water they may provide. Flow is usually measured in cubic metres per second or litres per second.

Different sources of water require different methods of flow measurement and can be divided as follows : surface water, springs and wells. In all cases, water flow measurement should be done when the flow is at its lowest, usually at the end of the dry season, to assess whether the source is able to provide sufficient water all year round.

Surface water sources

There are numerous ways to measure the flow of rivers and streams. Often all that is feasible is to make an initial assessment of flow as part of the selection of water sources. This means that only a limited number of flow measurements may be taken. There is a risk that a limited number of readings will not be representative of possible variation of the river flow. For this reason, it is important to interview members of the local community to try to find out if water flows and levels are often lower or higher than seen during measurement.

The two most common methods of flow measurement of surface water are : velocity-area method ; and overflow weir gauging.

Measuring velocity and cross-sectional area

In order to calculate the flow of rivers, the velocity and cross-sectional area need to be determined. As the depth of the river will vary, the best method is to divide the stream into sections of equal width, often 1 metre, and measure the depth of each section. The cross-sectional area can then be calculated for each section, and the sum of the areas of all the sections will be the cross-sectional area of the river.

The velocity is then measured using a current meter, which is shown in Figure 1. The current meter consists of a propeller which points upstream and is turned by the water flowing past. The propeller is connected to a counter which records the number of complete revolutions the propeller makes in a set time.

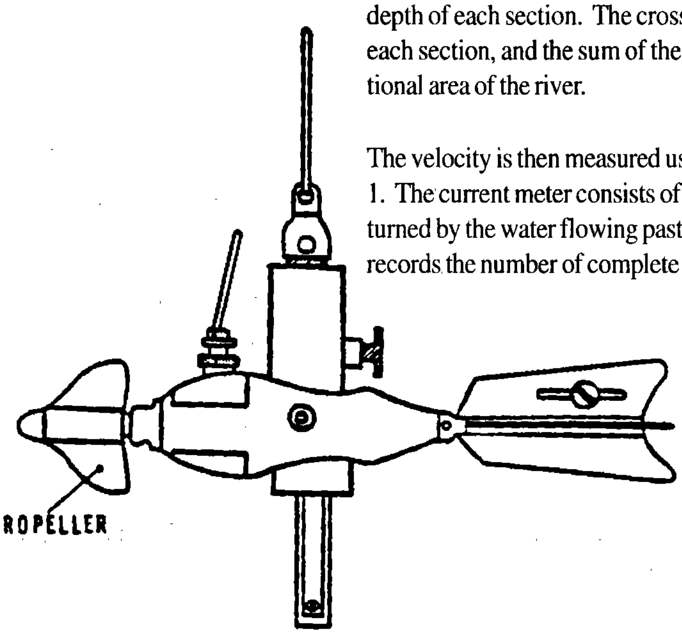
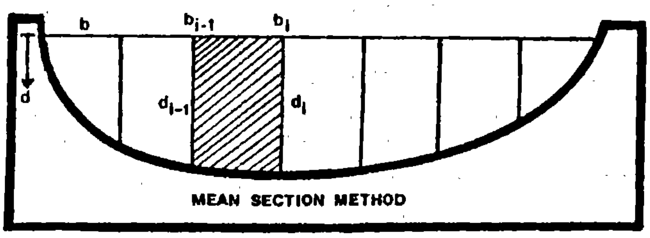


Figure 1. A current meter

Average velocity in a river occurs at 0.6 of the total depth ; however in order to make a reasonably accurate estimate, the average velocity is found by taking two readings in each section, one at 0.8 and one at 0.2 of the depth. These are averaged to give the average velocity for each section. The area of each section is calculated and the flow for each section calculated. The flows in each section are then summed to give the overall discharge for the stream. Figure 2 illustrates this method.

$$Q = \frac{(v_{i-1} + v_i)}{2} . \frac{(d_{i-1} + d_i)}{2} . (b_i - b_{i-1})$$



where Q = discharge
v = velocity
d = depth
b = distance of measuring point (i) from a bank datum

Shaw E. M. 1988, Hydrology In Practice, VNR International

Figure 2. Velocity-area method[1]

[1] Shaw, E. M. *Hydrology in Practice*, Nostrand Rheinhold (UK). Hong Kong, 1989

Gauging weirs

The most accurate way to estimate surface water flow is by using a gauging weir. These are structures which are placed across the stream to raise the water level and control the flow. Weirs can be permanent or movable structures which have an opening cut into the crest. Permanent weirs are more likely to be found where the stream or river is a source for a large water supply, or where hydrological measurements are regularly made. Movable or thin plate weirs can be very useful for programmes where many water supplies from small surface water sources are planned.

The water from the stream flows through the opening and must fall freely on to the stream bed below (see Figure 3).

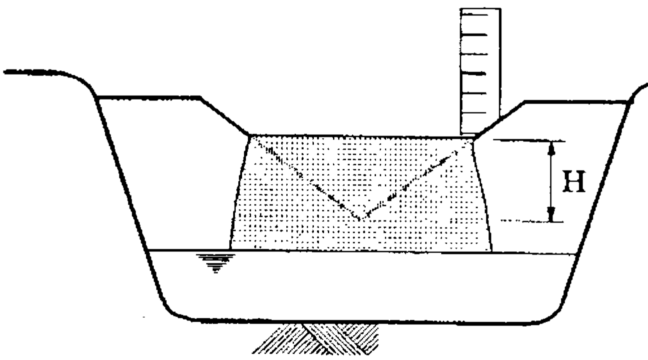


Figure 3. Weir

The flow of water in the channel can be determined by measuring the depth of water flowing over the weir. This is taken from the apex of the weir notch to the water surface and is called the " head ". The surface of the water below the weir must be at least 0.25 m below the crest to ensure that there is a clear overfall. The depth of water flowing over the weir should be measured some distance upstream of the weir, usually equal to 4 times the head.

For each type of weir there is a standard calculation which is used to relate depth of flow over the weir to discharge. These calculations can be found in standard texts on hydrology and hydraulics. The tables below give some examples of typical head-flow values for 90° and half 90° V-notch weirs.

Head-flow values for a 90° V-noch weir

Head of water (mm)	Flow of water (l/sec)
50	0.8
60	1.2
70	1.9
80	2.6
90	3.4
100	4.5
110	5.6
120	7.0
130	8.6
140	10.3

Head-flow values for half 90° V-noch weir

Head of water (mm)	Flow of water (l/sec)
50	0.34
60	0.53
70	0.77
80	1.07
90	1.44
100	1.86
110	2.36
120	2.92
130	3.56
140	4.28

Flumes can also be used to measure the flow of small streams. These are structures placed across the stream which instead of reducing the depth of the stream, as a weir does, reduce its width. The discharge is calculated from the head of water flowing through the flume. For each type of flume, there is a standard equation to calculate discharge. These equations can be found in standard texts on hydrology.

In large water supplies, where one or more rivers supply a town, it will be worthwhile to install permanent flow measurement stations. Once these are established, it is possible to prepare graphs so that only depth need be measured in order to find the flow.

Springs

The flow of water from a spring is usually termed the yield. The yield is determined by the amount of water which percolates into the aquifer, and how much water is stored in the aquifer. The yield may vary with the season, depending on the type of spring.

Gravity springs occur where groundwater emerges on the surface because an impermeable layer prevents it from seeping downwards, or the water table is at the same height as the land. The yield of gravity springs is likely to vary with the season. Measurements of yield should therefore always be done when the flow is least, usually at the start of the wet season. As springs rely on rainwater percolating through the ground to the aquifer, there will be a time lag between the onset of the wet season and an increase in the yield of gravity springs.

Artesian springs occur where groundwater emerges at the surface after confinement between two impervious layers of rock. Artesian springs tend to have a constant yield, as the aquifer is confined under pressure and so produces a constant amount of water.

To measure the yield of a spring, an overflow gauging weir may be used as described above. If this method is used, then care must be taken to ensure that the level of water behind the weir does not rise above the level of the eye of the spring.

An alternative method is to divert the spring flow into a container of known volume. The time taken for the container to fill is measured and the yield in litres per second easily calculated. This method is illustrated in Figure 4.

It is a good idea to take several measurements of the yield and average the results. The main problem in spring yield measurement is to ensure all the flow of the spring is collected. The best way is to build a small earth dam around the spring to create a pool. A length of pipe is laid through the dam and leads to the container. Whilst the pool is filling, no water should run into the container but should be diverted. Once the pool has reached a level when it is no longer filling up, the water should be allowed to run into the container and the yield measured. When the pool has reached a steady level, the water flowing out of the pipe is equal to the water flowing into the pool from the spring.

If it is not possible to trap all the spring water, the yield can still be estimated. As long as the part of the yield measured exceeds the requirement, then the source can be used.

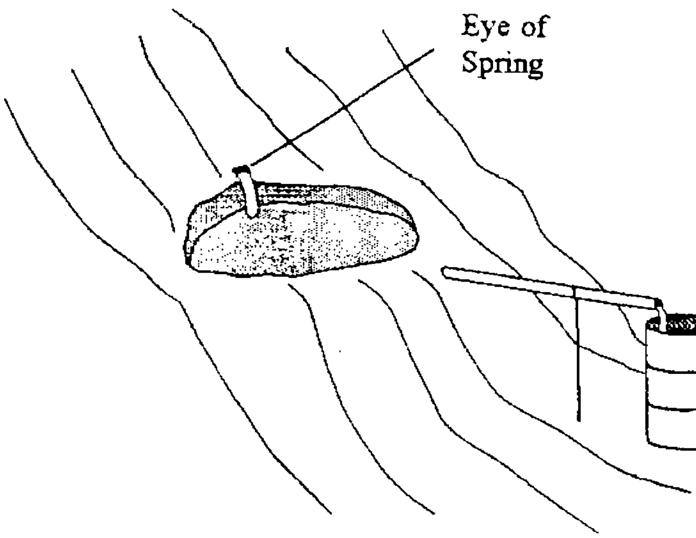


Figure 4. Measuring the yield of a spring

Wells and boreholes

The amount of water that comes from a well or borehole is termed its yield. The measurement of the yield of a groundwater source is important to assess the viability of the source and the depth of well required. Measurements of yield should be taken when the water table is at its lowest level. Usually this is at the start of the wet season, as there is a time lag between the onset of the rains and water table rising. Artesian wells, like artesian springs, will maintain a steady level all year.

The accuracy and the detail of the measurements of groundwater yield required will vary with the type of well to be sunk.

Where wells or boreholes are to be sunk for small isolated communities, there need only be basic tests. An initial pilot borehole should be sunk to determine the depth of the water table. A test of the yield of the aquifer can also be made at this stage but may not give accurate results.

If a handpump or other manual means of raising water is to be used, then a quick pump test is all that is required once the well is completed. All the water in the well, or as much as possible, should be pumped out. The rise of the water back into the well, to the point where it regains its former level, is timed. The yield can then be roughly calculated from the diameter of the well, the height of the water column and the time taken for the water to rise. This can be compared with the requirements of the community and a decision made on whether the well needs any deepening.

Where a large number of boreholes are to be sunk in an area, all equipped with pumps, a full pumping test should be undertaken. This is particularly important where electric or other motor pumps are to be used.

Where electric or other motor pumps are used, the " ideal yield " of the borehole (where output meets requirements and pumping costs are minimized) should be found. This allows the correct pump to be selected for the borehole and the required pumping rate to be determined. Pumping tests also help to determine the aquifer's characteristics and how the exploitation of the aquifer at one location will affect it at other points. This helps to site boreholes so that they do not interfere with the water available to other boreholes, and to ensure that there is no excessive lowering of the water table.

The interpretation of pumping test results, the calculation of aquifer properties and the effects of adjacent boreholes on well yield is beyond the scope of this Fact Sheet. Standard texts on hydrology and hydrogeology should be consulted, and expert advice sought for further information.

Measurement and control of water flow in water treatment

Water flow must be controlled continuously and accurately during treatment. This is important because, in most treatment processes, if the flow of water is not constant (within set limits), the treatment may be inefficient and the water supplied of poor quality. Flow measurements give an indication of the efficiency of a process and indicate if filter beds need cleaning. The measurement of flows through a treatment plant must be done regularly. Further information on water treatment processes is given in Fact Sheets 2.10 to 2.14.

Methods of flow control

Various methods of water flow control can be used. Valves can be set to allow specific flows of water through a treatment plant, either at the inlet or the outlet. If a regulating valve is fitted, it will require regular (possibly daily) adjustment to ensure that a constant flow is maintained. A globe valve is often used, as it is a variable rate valve, although sometimes a gate valve may be used. With this method, the flow from the outlet must be recorded regularly in order to assess when the regulatory valve needs to be opened. A V-notch weir or a flume can be used for this, or if the flow is large enough, a flow meter.

Float controlled valves can also be used to regulate flow. These are valves which close when the water reaches the required level in an inlet tank.

The need for constant adjustment is a major drawback with the use of valves, as an operator is required for the plant. Automatic devices are generally preferred. Although float controlled valves can be used they are not always reliable and are prone to breakdown. Where the influent water is turbid or contains corrosive chemicals, valves may become worn and no longer ensure a constant flow.

The most common automatic flow control method is the use of flumes and weirs. These are the same devices that are used to measure the flow of surface water, although they may be smaller. The flow is controlled by the amount of water allowed to pass over the weir or through the flume. In small community water supplies, V-notch weirs are the most common form encountered as they are the most accurate at low flows. The flow of water over the weir can be calculated from the height of the water above the weir crest, or the head, by using calculations given in standard texts on hydrology or hydraulics. The tables above give values for flow in relation to depth.

When a V-notch weir is used to control the flow, a spillway is constructed as well. The spillway acts as a flow control when the influent flow rate exceeds the rate required, by allowing the excess water to flow over it. Figure 5 shows a typical example of V-notch weir with a spillway used in a slow sand filter.

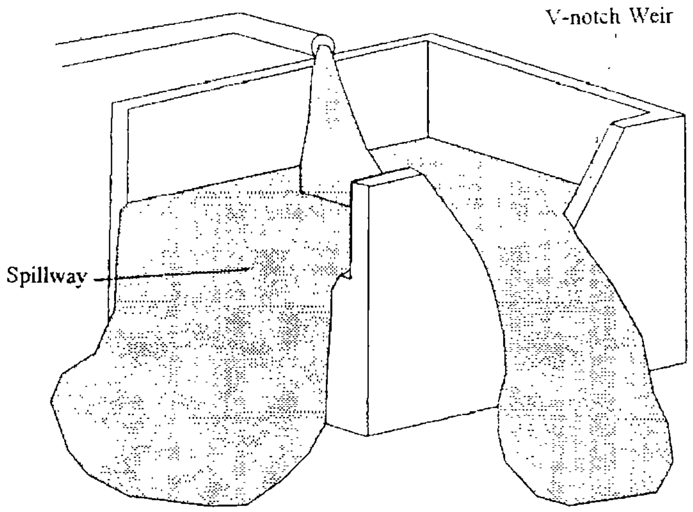


Figure 5. V-notch weir and spillway

Where the water supply is regularly disinfected, flow measurement and control are needed for many types of disinfectant dosing. Disinfection is covered in detail in Fact Sheets 2.16 to 2.28, which include information concerning dosing equipment and requirements.