27. Discharge measurements and estimates

Introduction

Community water-supply schemes are generally designed for water consumption in the approximate range of 15 to 60 litres per person per day. Allowance has also to be made for water use by livestock, for future growth in population and demand, and for losses of water by leakage etc. from the system.

It is important to check that the discharge of the source is enough, throughout the year, to meet the community's requirements. This requires measuring or estimating the dry season flow, when least water will be available.

If a small reservoir is to be built, more detailed flow data are needed:

- Year round flows, to size the storage
- Flood flows, to design the spillway

Useful conversion factors

One litre per second   = 1 l/s   One cubic metre = 1000 litres

                                     = 86 400 litres per day   One Imp gallon = 4.546 litres

   One US gallon = 3.785 litres

Ways to measure the flows of springs and small streams

Bucket and stopwatch

In this method, all the flow from a spring or small stream is collected in a container whose volume is known (e.g. a bucket, jerrycan, 200-litre drum) and the time to fill the container is measured. The filling time should be more than five seconds, to give reasonable accuracy.

Discharge or yield (l/s) = volume (litres)/time (seconds)

An oil drum below a bamboo spout
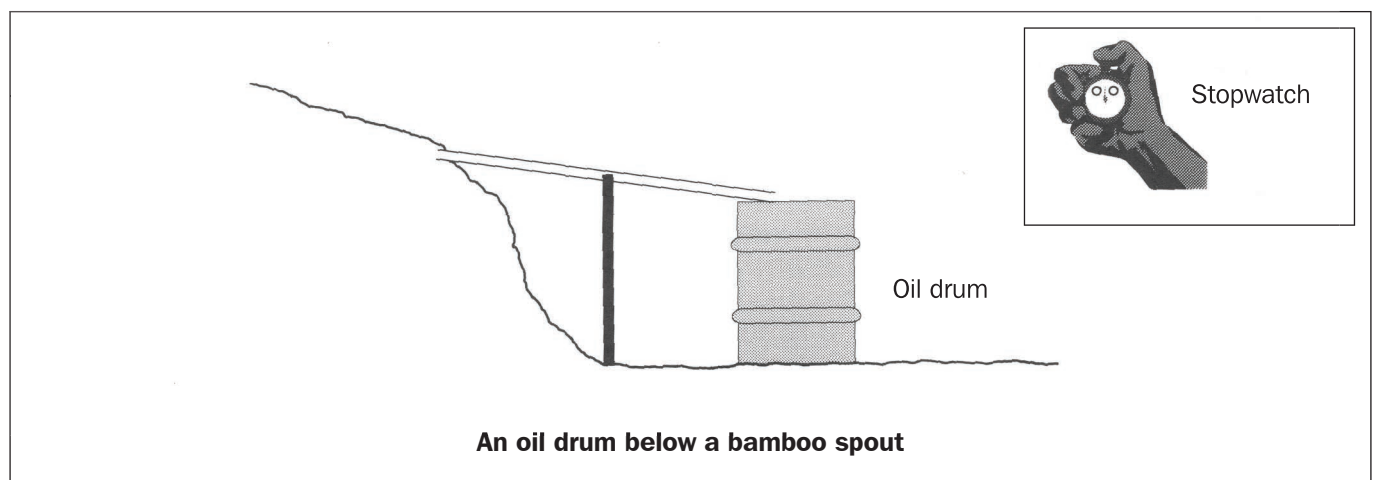
DISCHARGE MEASUREMENTS AND ESTIMATES

Float, stopwatch and tape

Floats are a simple way of measuring the velocity of a stream, but they are not very accurate. The surface velocity is obtained by measuring the time (t secs) for a float to travel a measured distance (L metres). It is best to choose a straight, uniform river section about 30m long, and to time the float over a number of repeated t runs. A piece of fruit makes a good float, as it is less affected by wind than a wooden stick. A factor of about 0.85 should be used to convert surface velocity to average velocity.

Surface velocity (m/s) = L/t

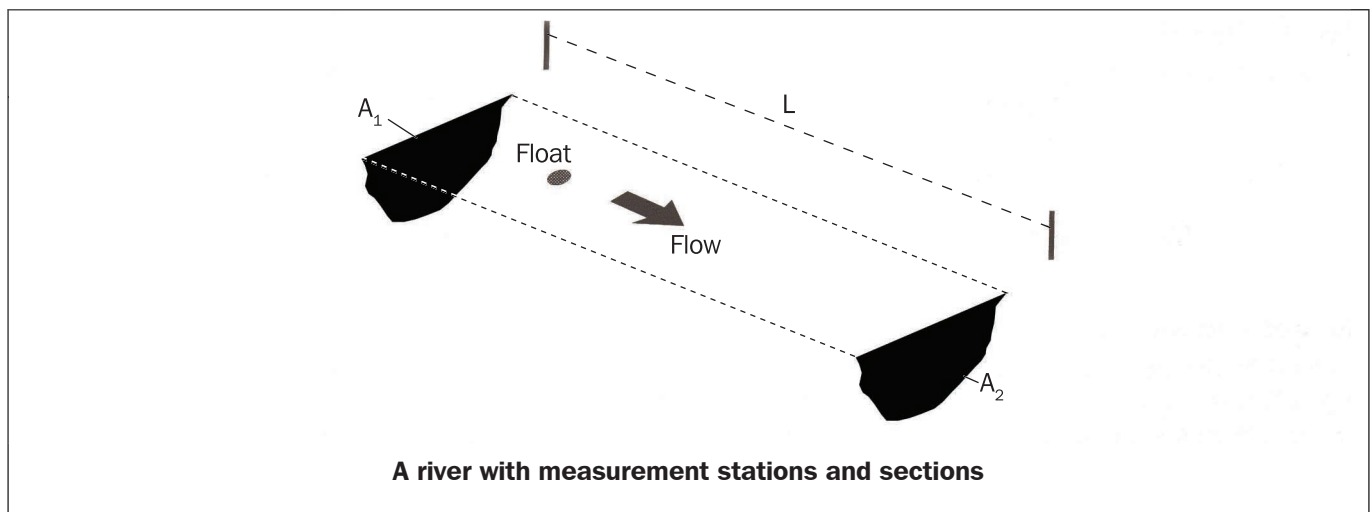Average velocity (m/s) = 0.85 x L/t

The cross section of the stream should be measured up carefully in a number of places along the test distance, and the average cross-sectional area calculated (A sq m).

Discharge (cubic metres per second)

    = average velocity x cross sectional area of stream

    = 0.85 x (L/t) x A

Discharge (L/s) = 1000 x 0.85 x (L/t) x A:

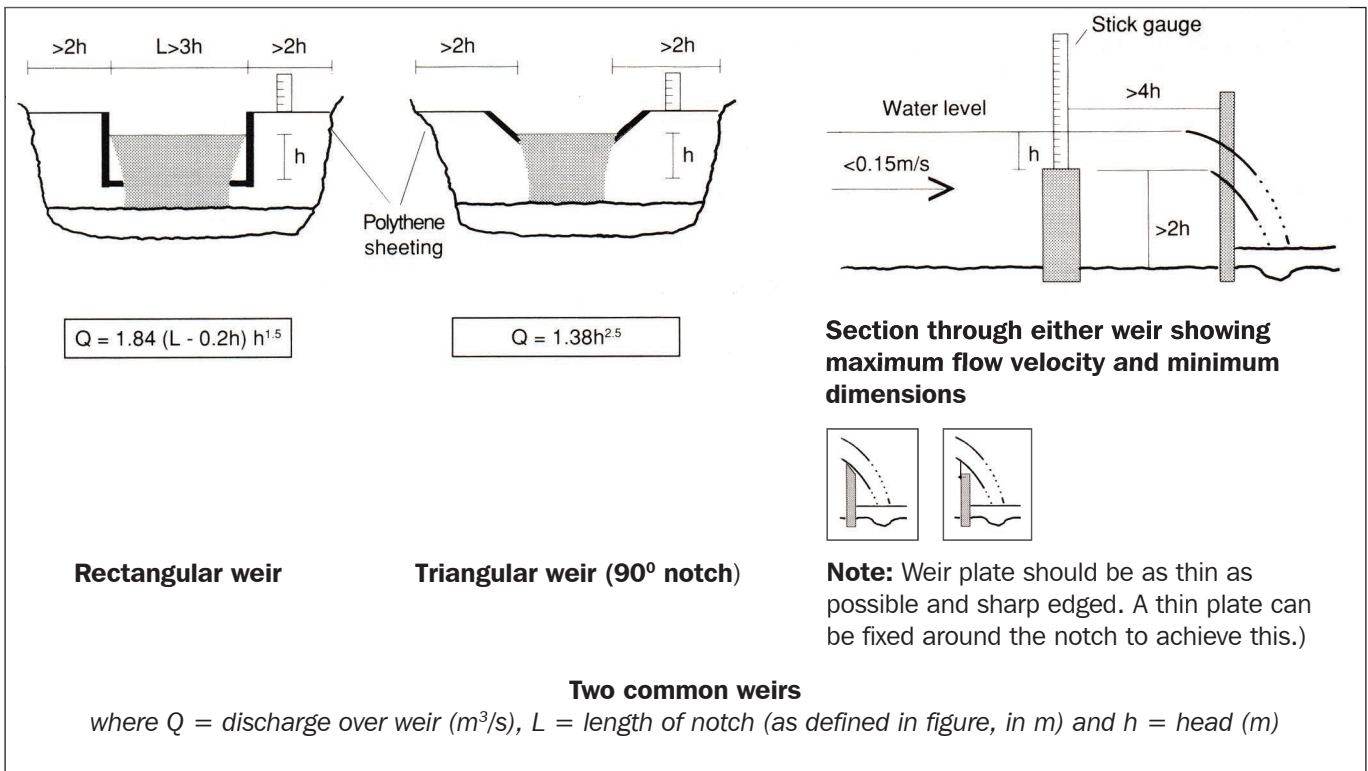**A river with measurement stations and sections**

Weir with stick gauge

Portable weirs made of steel plate can be used for measuring the flow of small streams or springs. They can give accurate measurements, if they are installed carefully. The weir should be set vertically, perpendicular to the stream, and with the crest horizontal. A free fall is required over the weir crest. Leaking must be prevented around the sides of the weir, possibly by using a polythene sheet.

A stick gauge, marked in centimetres, is set vertically at the side of the stream upstream of the weir. It is used to measure the head, h (m), which is the difference between the upstream water level and the crest of the weir. It is important to check that the gauge zero is truly at weir-crest height. This may be done using a spirit level and string line, or water-filled flexible plastic tubing.

There are different shapes of weir, each of which has a standard formula for calculation of discharge. Details for two common weir shapes are given opposite.

DISCHARGE MEASUREMENTS AND ESTIMATES

>2h	L>3h	>2h

h

>2h | >2h

h

Polythene
sheeting

$Q = 1.84 (L - 0.2h) h^{1.5}$

$Q = 1.38h^{2.5}$

Stick gauge

Water level

<0.15m/s →

h

>4h

>2h

Section through either weir showing maximum flow velocity and minimum dimensions

Rectangular weir

Triangular weir (90^0 notch)

Note: Weir plate should be as thin as possible and sharp edged. A thin plate can be fixed around the notch to achieve this.)

Two common weirs
where Q = discharge over weir (m^3/s), L = length of notch (as defined in figure, in m) and h = head (m)

## Estimating flows of small streams

Possible sources of information for estimating the range of flows are:
a) local knowledge
b) observation and survey
c) rainfall records
d) size of catchment area
e) spot measurement of discharge

It is important to take account of other users, both upstream and downstream.

Possible ways of estimating flows in the dry season are:
a) From spot measurements during the dry season. This is the best way.
b) From spot measurements at other times of year,
   either, reduced by suitable factors derived from experience on similar river basins
   or, plotted against time on a graph, and extrapolated to the dry season. Records from measurement on similar river basins can be used to derive a typical shape for the graph.
c) From any records of flows in a similar river basin nearby, with similar rainfall, by using the following method:

A_1

A_2

Q_1 (known) Q_2 (not known)
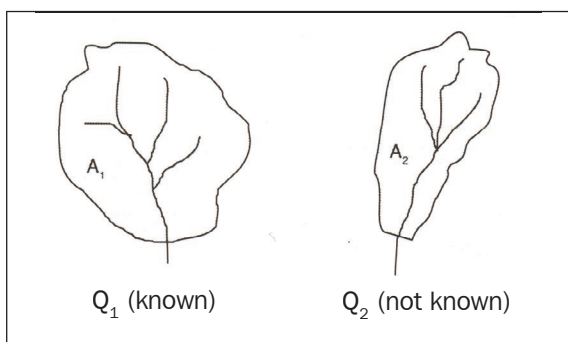
■ for the recorded basin, measure the catchment area A_1 which drains to the measurement station;

■ for the unrecorded basin measure the catchment area A_2 which drains to the point where the flow is to be estimated;

■ obtain the dry season flow Q_1 for the recorded basin;

■ the dry season flow Q_2 for the unrecorded basin can then be estimated as: $Q_2 = Q_1 \times A_2/A_1$.

d) From local reports (or records) of dry season depth, coupled with survey of the cross section and slope of the stream, and using the Manning equation:

$$Q = \frac{A\,R^{2/3}\,s^{1/2}}{n}$$

Q = discharge (m³/s)
A = area (m²)
R = A/P where P = wetted perimeter (m)
s = slope (m/m)
n = Mannings roughness coefficient

suitable values of n are:
straight river with earth bed: 0.02 - 0.025
straight river with stony bed: 0.03 - 0.04
winding river with earth bed: 0.03 - 0.05
winding river with stony bed: 0.04 - 0.08

Constant discharges from boreholes or pipes

These may be measured by one of the following methods:
1. Using a V-notch weir set in a steel tank or earth channel
2. Using a calibrated orifice plate and pressure gauge on an upstream tapping (the pressure difference across an orifice plate will depend on the flow rate)
3. Measuring the co-ordinates of the water trajectory from a horizontal pipe, as shown below.

$$Q = (CAx)\sqrt{\frac{g}{2y}}$$

where C is a coefficient
in range 1.0 to 1.1
for x >20, y>20
g = 9.81 m/s/s

x

100mm = y

Straight unobstructed length

1 metre minimum
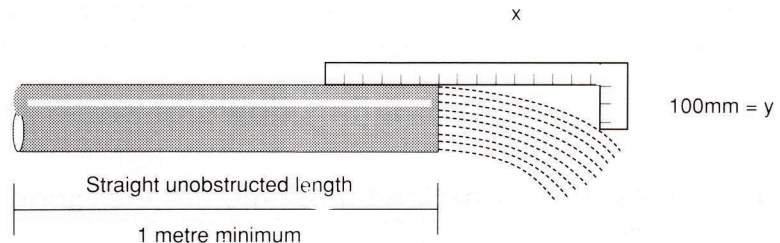
Measurement of flow from a horizontal pipe

Horizontal distance, x (mm) for fall in water trajectory y= 100mm. - See above figure	Nominal pipe diameter D (mm)				
	25	32	37	50	62
100	0.36	0.6	0.8	1.4	2.0
125	0.45	0.8	1.0	1.7	2.5
150	0.54	0.9	1.3	2.1	3.0
175	0.6	1.1	1.5	2.4	3.5
200	0.7	1.2	1.7	2.8	3.9
225	0.8	1.4	1.9	3.1	4.4
250	0.9	1.5	2.1	3.5	4.9
275	1.0	1.7	2.3	3.8	5.4
300	1.1	1.8	2.5	4.2	5.9
325	1.2	2.0	2.7	4.5	6.4
350	1.3	2.1	2.9	4.9	6.9
375	1.3	2.3	3.1	5.2	7.4
400	1.4	2.5	3.3	5.5	7.9

Water flow from horizontal pipes (litres/second) flowing completely full at the end

Further information:
Cairncross, S. and Feachem, R., Small water supplies, Ross Institute Bulletin No.10, 1978.
Herschy, R. W., Stream flow measurement, Eisevier, 1985.

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