

## Chapter Three

### Sediment load sampler

#### 3.1 Introduction

Knowledge of sediment transport in a river is essential in all studies where morphological problems exist. It is therefore necessary to study the characteristics of the sediments, as well as their modes of transport and to link the sediment transport to the hydraulic parameters of the river under consideration.

Sediment transport can be classified in two different ways

- based on the origin of the material, 'bed material transport' and 'wash load' can be distinguished;
- based on the mechanism of transport, distinction can be made between 'bed load' and 'suspended load'

As far as measuring procedures are concerned it is essential to distinguish between bed load and suspended load. Each of these modes of transport requires its own procedure. On the other hand, for morphological phenomena, the distinction between bed material transport and wash load is more relevant. Knowledge of the bed material transport is needed for description and prediction of erosion and sedimentation; in places where the flow velocity decreases to such an extent that the fine particles are able to settle, for instance upstream of dams, in estuaries and in river ports, knowledge of the wash load is important.

The bed material transport can be obtained by adding bed load and that part of the suspended load which does not belong to the wash load. To determine the latter part analytical methods are applied using the particle-size distribution of the bed material, for which purpose sampling and analysis are necessary. Two principal methods exist to gain insight into the processes of sediment transport by actual measurement. These make use of:

- (i) Mechanical sampling: for which the instruments can be classified as *bed load samplers* and *suspended load samplers*.
- (ii) Tracers methods

One should realize that such methods, which are used to justify the use of a particular sediment transport formula, are laborious and time-consuming since a great number of measurements are needed under a variety of conditions to compensate for their restricted accuracy. Obviously, however, for rivers under continuous survey, one of these two methods should be applied.

It still remains to be said that if the investigation and projects are of small scale in character and the opportunity to take sufficient measurements is restricted, an *alternative* method can be

applied: the application of a specific transport formula based on a comparative study with similar rivers which have been under study for a long time. In such cases, however, whether valuable information could be obtained by additional measurements should be considered.

### **Sampling site**

The selected sites should be well-distributed over the project area and be representative for the (mean annual) prevailing hydraulic and morphologic conditions. Some general requirements are:

- Located in a straight reach
- Located in a stable cross-section
- Located normal to the flow direction
- Sufficiently deep with respect to the dimensions of the sampling equipment
- Accessible and clear of natural and/or artificial obstacles
- Well defined geometrical dimensions

### **Sample size**

#### ***Number of measurements for bed load transport***

Typical bed load transport sampling problems related to the variability of the physical processes involved are:

- Sampling duration of individual measurements
- Number of samples at each location
- Number of sampling locations along the bed form length
- Number of locations over the width of the cross-section

#### ***Number of measurements for bed load transport***

For wash load the sediment discharge can simply be obtained by multiplication of the flow discharge and the concentration. Since the concentration is approximately constant over the cross-section, the number of samples can be limited to a few samples.

For suspended sediment the cross-section is divided in to several subsections. The sediment discharge passing through each subsection is determined by measuring (point or depth-integrated measurements) along one vertical within each subsection. The accuracy depends on:

- The number of points over the depth
- The number of verticals over the bed-form length in each subsection
- The number of verticals over the width (cross-section)

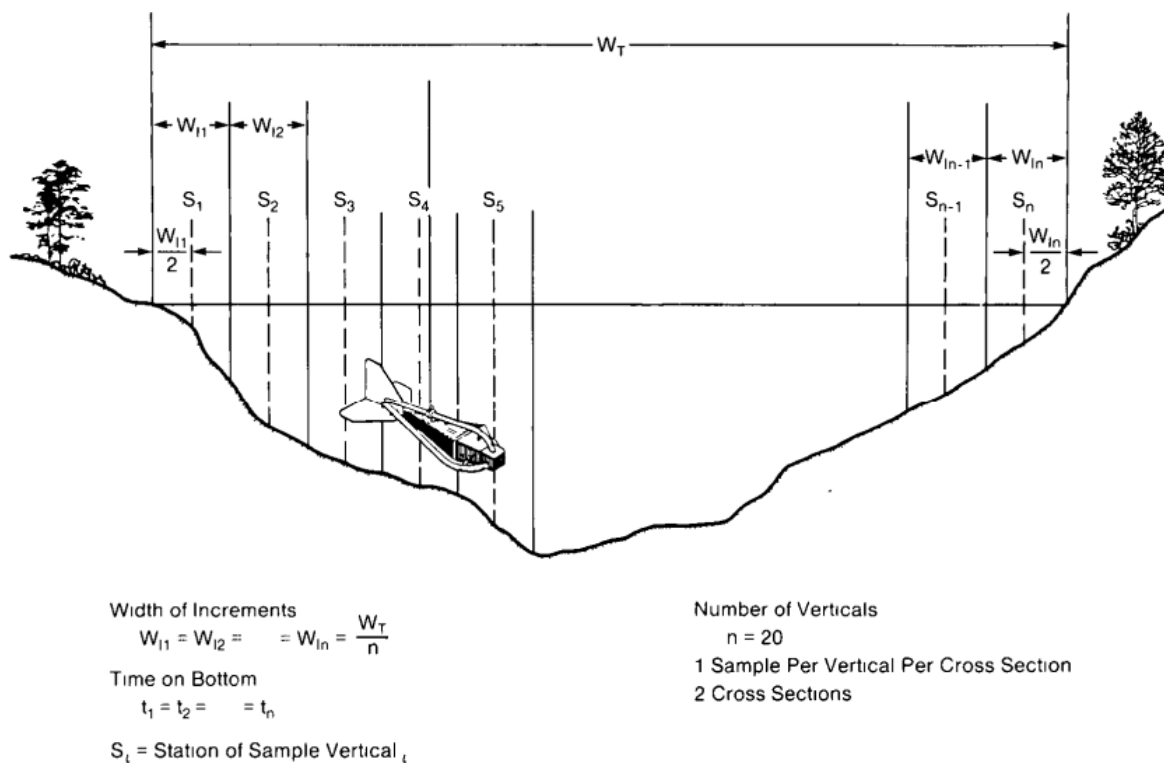
- The number of verticals over time (flood period, ebb period)

### 3.2 Bed load sampler

The most widely used method for the measurement of bed-load is the direct method by means of mechanical trap-type samplers. The USGS suggests 40 samples for each cross-section. The width of sampling stations in this case could be  $3m < W < 15m$ . The sampling time could also be between  $5sec < t < hours \rightarrow$  generally 60 sec.

#### Sampling methods

##### Single equal-width-increment method (SEM)



**Figure 3.1:** Single equal-width-increment bed load sampling method

The computation of bed load transport could be

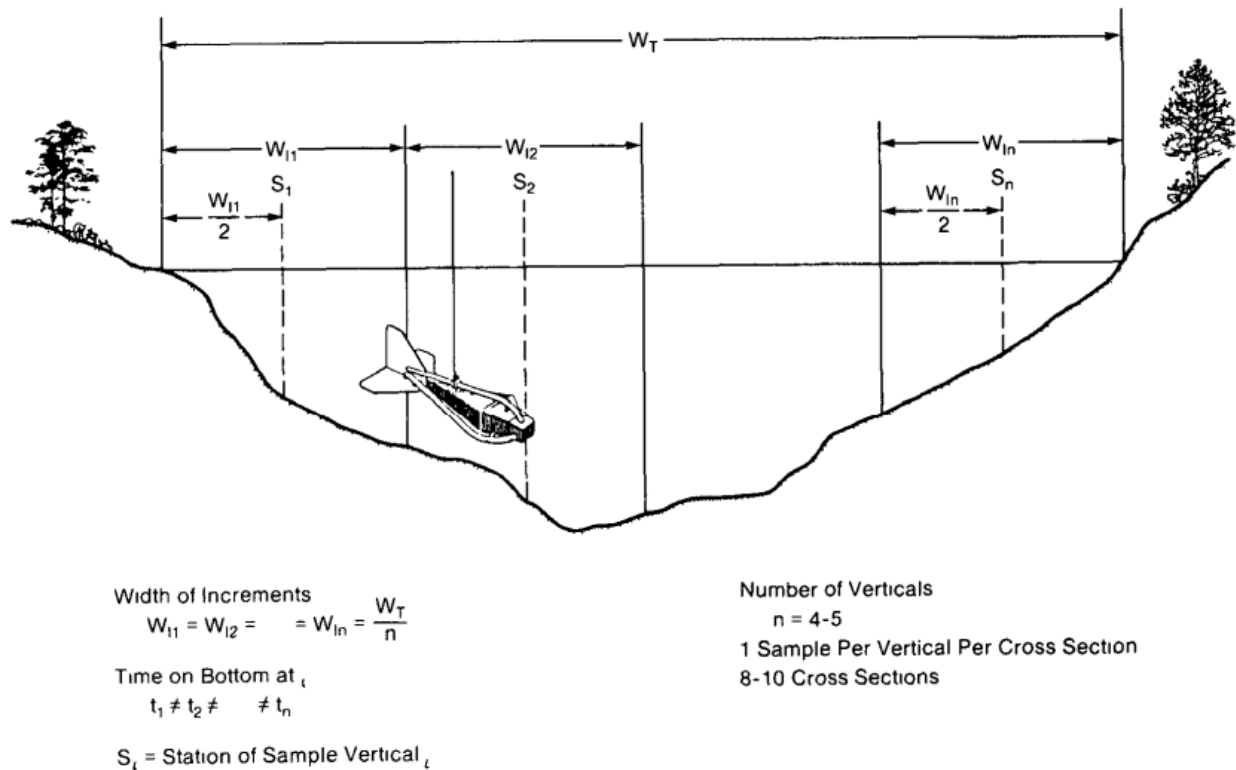
$$\frac{KM_i}{t_i}$$

Where:  $R_i$  = bed load transport rate as measured by bed load sampler, at vertical I, in tons per day per m

$M_i$  = mass of the sample collected at vertical I, in grams

$t_i$  = time the sampler was on the bottom at vertical I, in seconds

K = conversion factor from grams per m per sec to tons per m per day number of locations over the width of the cross-section (function of the sample nozzle).



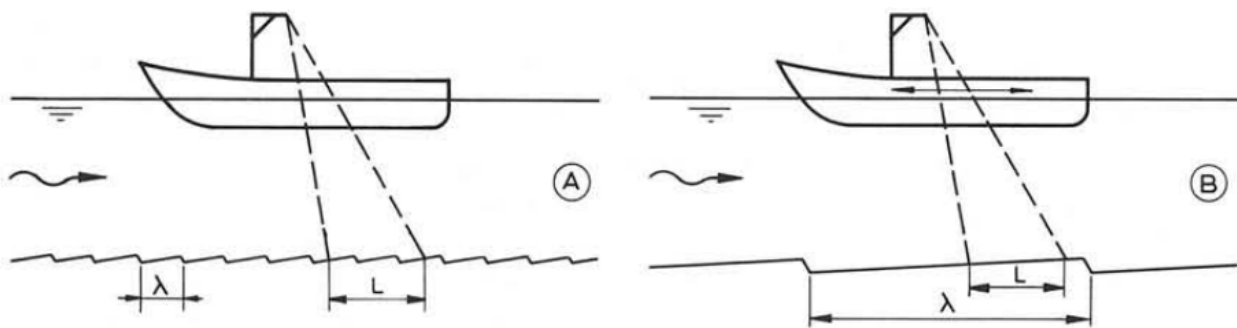
**Figure 3.2:** Multiple equal-width-increment bed load sampling method

Bed load can be measured by trapping the sediment moving along the bed in an instrument which is placed on the river bed for a fixed period of time. Either the volume or the mass of the material collected is measured. The transport can then be determined using a calibration curve. However, it is known from experience that the amount of sediment trapped in the sampler varies considerably. This is due to the stochastic nature of the transport phenomenon as well as to accidental circumstances related to the position of the sampler on the river bed. Many efforts have been made to improve instruments and methods in order to arrive at a more accurate estimation of the true bed load. At present, the devices used in practice are still based on the principle of trapping the bed load.

**Set up of instruments**

As has been stated before, the usual aim of measuring bed load is to select the most relevant bed load formula for the particular river. After selection, application of the formula enables estimation of the bed load for other hydraulic conditions in present or future situations. This is reflected in the two main requirements for the selection of the measurement site:

- (i) A stable river reach has to be selected in order to avoid non-steady bed conditions during the measurements, and
- (ii) Reliable measurements of the hydraulic conditions (depth, flow velocity, grain size and energy slope) have to be possible.



**Figure 3.3:** influence of dominant dune length ( $\lambda$ ) on random measurements over length  $L$

Bed load transport  $S_b$  is measured in a number of verticals in a cross-section. In each of these verticals a good estimate of  $S_b$  is necessary. It should be recalled that  $S_b$  has a fluctuating magnitude; the 'periods' presenting these fluctuations are governed by the wave period of the bed form (ripples and dunes). Except in rare cases, where dune lengths are large in comparison with the depth of water, it is not possible to place the sampler with sufficient accuracy in a particular location on a sand dune. Therefore, random sampling has to be made.

Lowering the sampler from an anchored survey boat implies that measurements are carried out at random over a length  $L$  (see Fig. 3.3). This length  $L$  depends on depth, flow velocity and type of instrument and has to be relatively large in comparison with the dominant dune length  $\lambda$ . If the condition  $L \geq \lambda$  is fulfilled (case A), the sampler, lowered from a fixed survey boat, reaches the bed at a random position somewhere within the interval  $L$ . For  $L \approx \lambda$  or  $L < \lambda$  (case B), the survey boat has to take different positions along a line perpendicular to the cross-section, in order to achieve a random sampling.

Obviously, it is essential to know  $\lambda$  under the given circumstances. Therefore sounding along lines perpendicular to the cross-section is necessary before bed load measurements are taken with samplers.

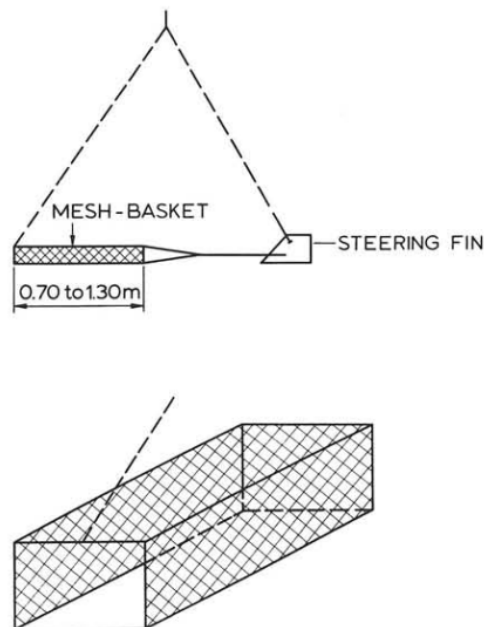
### Instruments

For trapping bed load there are three basic types of samplers: the basket- or box-type, the tray- or pan-type, and the slot-type.

### ***Basket- or box-type***

As shown in Fig. 3.4, instruments of this type consist of a basket or box, usually made of meshed material. The box is open at one end and in some cases also at the top. The bottom of the box is often flexible to enable it to conform to local irregularities of the river bed. A steering fin attached to the box assures positioning of the instrument in the direction of the flow. Most of these samplers have been developed in Europe (Switzerland, Austria, and Poland). Their sizes are adapted to the rates of bed load transport to be expected in the rivers for which they are designed.

The presence of the instrument in the stream causes increased resistance to flow which, compared to normal undisturbed conditions, results in a smaller flow velocity and a smaller rate of bed load transport in front of the open end. Thus only 40 to 60% of the material moving toward the instrument is actually caught in it.

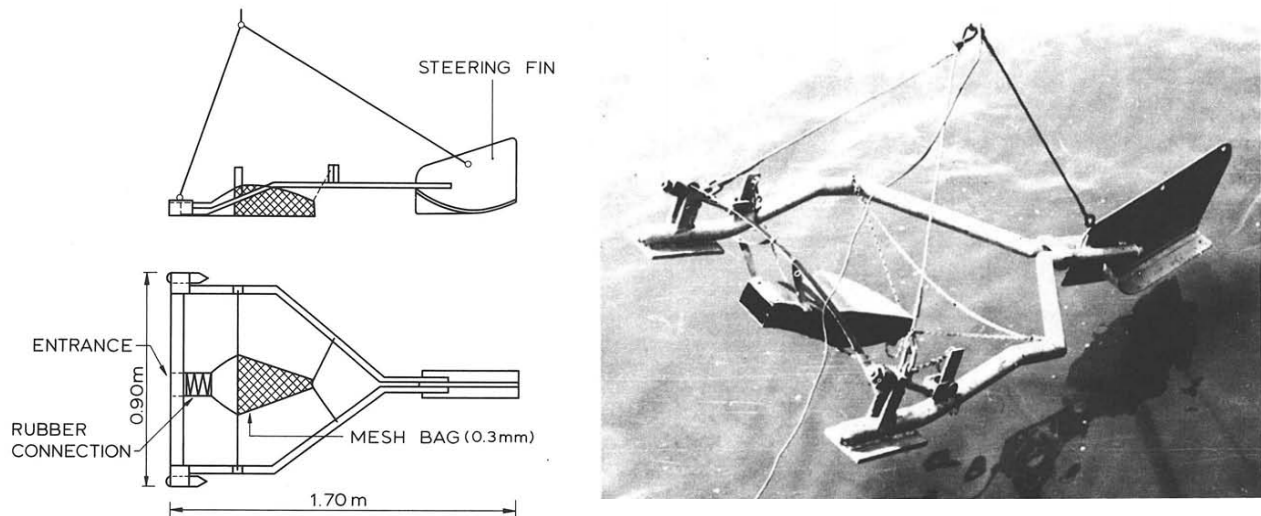


**Figure 3.4:** Basket or box type sampler

In order to convert the results of the measurements into the true transport under undisturbed conditions, the efficiencies of the various types of samplers have to be determined by calibration.

### **Arnhem sampler (BTMA)**

To overcome the objection of decreased velocity and bed load movement at the entrance, so-called *pressure-difference* instruments have been developed. They have a section which diverges in a downstream direction, causing a pressure drop at the exit of the instrument to compensate for the energy loss mentioned before. As an example, the Arnhem sampler (BTMA) which was developed in the Netherlands is shown in Fig. 3.5. Another example of the pressure difference type is the VUV sampler, initially designed by Karolyi (1947) and improved by Novak (1959).



**Figure 3.5:** Arnhem sampler

**Principle:** the total bed load particles that are too coarse to pass the mesh are caught. The BTMA catches material coarser than 300 $\mu\text{m}$  (theoretical value of the mesh).

**Assumptions:**

- the height of the sampler mouth corresponds with the thickness of the bed layer
- no suspended load is entering
- the 60-300  $\mu\text{m}$  fraction is negligible

**Advantage:** simple and sturdy

**Disadvantage:**

- A davit and winch are needed to handle it
- Flow velocity  $< 2.5\text{m/s}$

**Site selection:**

- Stable river reach to avoid unsteady bed conditions during measurements
- Reliable measurements of the hydraulic conditions (depth, flow velocity, grain size and energy slope)

**Procedure:**

- Bed load transport  $S_b$  is measured in a number of verticals in across-section. In each of them random sampling has to be performed over a length  $L$ . If  $L \leq \lambda$  the boat has to take different positions in order to achieve a random sampling.
- Sampling time is usually 2min
- The sample is measured volumetrically
- Generally 10 samples are taken and converted in  $m^3/day/m$  by means of calibration curve

**Elaboration:**

- Average the volume of the catches that have been performed
- The calibration curve is based on the following equation

$$T_i = \frac{\alpha V f}{b}$$

Where:

$T_i$  = bed load transport in a vertical ( $m^3/day/m$ )

$\alpha$  = trap efficiency factor ( $\alpha=2$ ) neglecting losses

$V$  = catch ( $cm^3/2min$ )

$b$  = width of the mouth of the instrument ( $b=0.085m$ )

$f$  = conversion factor from  $cm^3/2min$  to  $m^3/day$  ( $f=750 \cdot 10^{-6}$ )

the total bed load transport in the cross-section  $T$  becomes;

$$T = \sum T_i b_i$$

where  $T$  = total bed load transport in the cross – section ( $m^3/day$ )

$b_i$  = part of bottom width of the river, representative for the catch  $T_i$  (m)

Using pressure-difference instruments, one cause of error is presumed to be eliminated. Several other sources of error, however, are recognized and these cause deviations from the true load. For instance, the position of the instrument on the irregular bed deviates from the ideal conditions for which the apparatus is designed; the wire mesh may become filthy during the measurement; the sampler's efficiency is subject to changes related to the amount of sediment trapped, etc. Therefore calibration remains essential.

**The Helley Smith Bed load sampler (BTMA)**

The Helley Smith bed load sampler is modified version of the BTMA sampler (Helley and Smith, 1971). It is advantageous that the Helley-Smith sampler has been extensively calibrated based on about 10,000 samples and it is simple to operate.



**Figure 3.6:** The Helley Smith Bed load sampler (BTMA)

### *Tray- or pan-type*

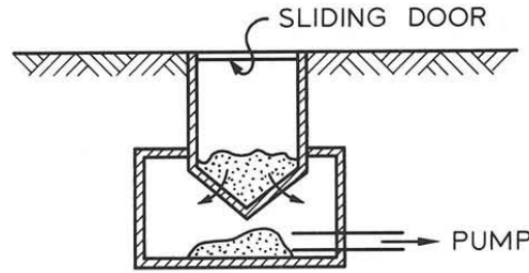
A sampler of this type is shown in Fig. 3.7a. It consists of a flat pan or tray-shaped device with baffles or slots to trap the moving material. The instrument causes obstruction to the flow and consequently decreases its efficiency. In order to trap a higher percentage of the true load the pressure-difference principle is applied in a modified design (*see* Fig. 3.7b). The entrance section diverges towards the rear, creating suction and consequently greater intake velocity. In both cases calibration is essential.



**Figure 3.7:** (a) Tray- or pan-type (b) Modified Tray- or pan-type

### *Slot-type*

Unlike the types already mentioned, instruments of the slot-type have to be placed *in* the bed, as shown in Fig. 3.8, allowing the moving material to drop into the slots. From the slots the sand is pumped to the bank at regular intervals and the amount of material collected in a given time is a measure of the rate of bed load transport. Obviously, special measures have to be taken to prevent the bed material moving whilst pumping is taking place. For that purpose, the slots are provided with a sliding door which can be opened and closed as desired. Application of this type is restricted and only possible in small streams with a stable bed.



**Figure 3.8:** Slot type sampler

### 3.3 Suspended load transport

#### *The measuring principles for suspended load transport*

The direct method is based on the direct measurement of the time-averaged sediment transport in a certain point (point-integrating) or over a certain depth range (depth-integrating). This latter procedure implies vertical movement at a uniform speed of the sampler over a certain depth range.

The indirect method is based on the simultaneous but separate measurement of the time averaged fluid velocity and the time averaged sediment concentration, which are multiplied to obtain the time-averaged sediment transport. This method implies two assumptions which introduce errors:

- The turbulent flux terms are zero and
- The fluid and sediment particle velocity are equal.

#### Suspended load transport measurement

##### ❖ Delft Bottle (DElftse Fles)

##### *Applicability:*

- From surface down to 0.5m above river bed when suspended on a wire
- From 0.5 to 0.05m above riverbed when fixed in a frame (sledge); in this case a bent nozzle is required
- The average grain size of the sediment must exceed 0.05mm(50 $\mu$ m)

##### *Principle:*

- The shape of the bottle –shaped sampler induces a low pressure at its rear end (water outlet) so that the sampling can be considered isokinetic. The material settles inside the

chamber and can be taken out and measured volumetrically once the DF is pulled out of water

- The DF loses part of the material
  - 100% of grains  $D < 50\mu\text{m}$
  - Partly for grains  $50 < D < 100\mu\text{m}$

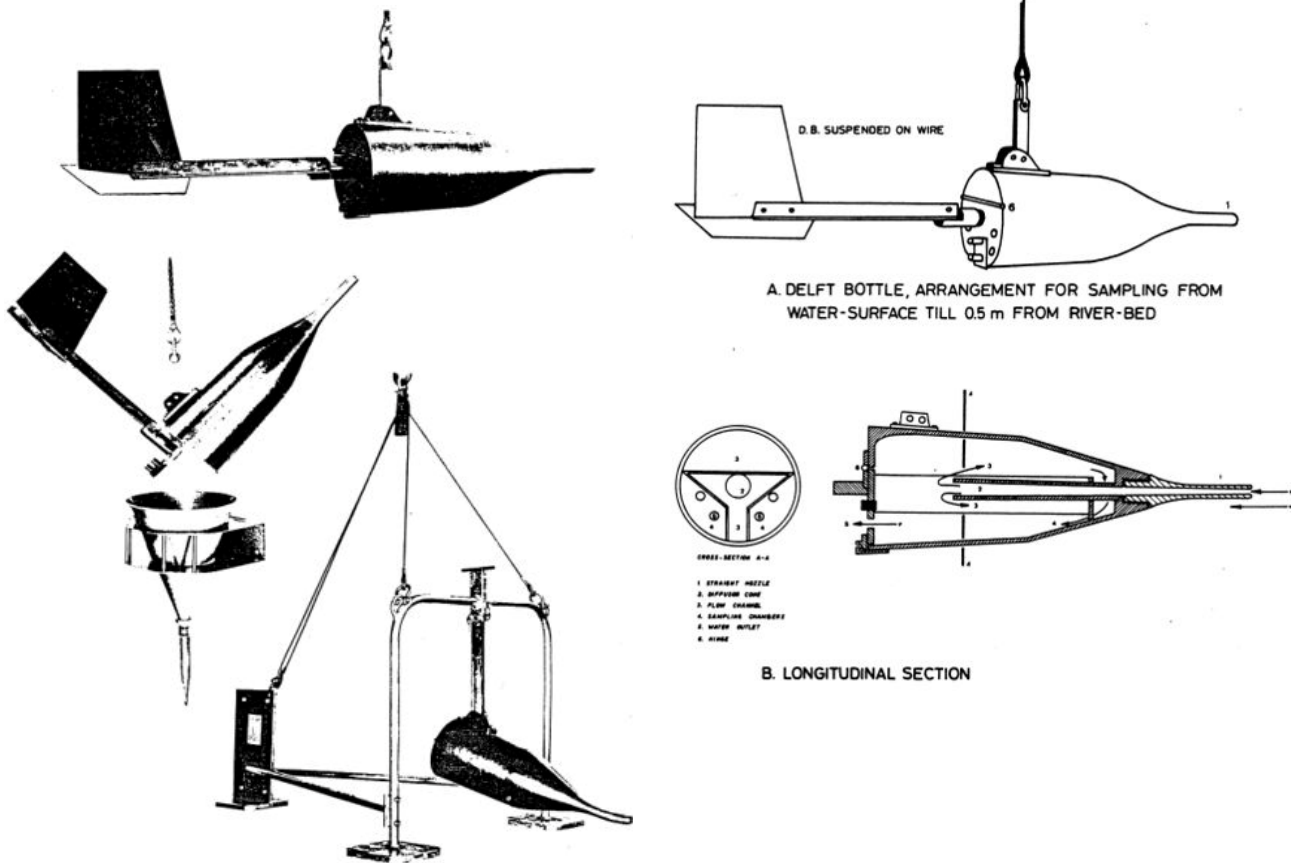
*Advantage:* simple and sturdy, a large volume of water is sampled

*Disadvantage:* a davit and winch are needed to handle it

Procedure:

- The depth of the instrument is determined by the quantity of paid-out cable and indicated on a counter clock. As long as the DF is fully submerged it is kept there for a while and the instrument will incline backwards due to the air content. The air will escape from the nozzle and a small opening at the top of the rear end.
- When filled with water it is quickly lowered to the required depth
- At this moment sampling time starts (3minutes)
- The hoisting time is recommended to be included in the sampling time
- The content of the bottle is emptied into the special DF glass and measured volumetrically
- Samples are taken every 1.5m in the vertical as well as five samples at every 10cm in the half meter above the riverbed





### ❖ Acoustic and Optical sampling methods

Measuring range:

- For an optical sampling resolution the wave length and particle size must be of the same order of magnitude
- Optical method is most suitable for silt particles ( $>50\mu\text{m}$ ). The upper concentration limit for optical samplers is about 25000.
- The acoustic method is most suitable for sand particles ( $>50\mu\text{m}$ ). The upper concentration limit is about 10000mg/l.

Advantages:

- The continuous measurement of suspended sediment concentration

