

**Practical Manual**  
**On**  
**Soil and Water Conservation**  
**Engineering**

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**Ranchi**

# Preface

Out of the 173.5 m ha of the total degraded land of our country, nearly 95 m ha suffer from soil erosion, which constitutes 82.6 m ha erosion through water and 12.4 m ha erosion through wind. Annually 16.35 t soil/ha is lost through water erosion and in this process 5.4-8.4 t/ha nutrients are lost. The loss of valuable fertile soil and nutrients causes 5-50% decline in crop yield, siltation of water reservoirs and thus reducing their capacity and useful life, raising the beds of streams and rivers thus reducing their capacity and consequently spilling of the floodwater into the adjoining areas. So there is a need to understand the mechanisms involved in soil erosion and developing techniques to measure the loss of water through runoff and loss of soil through erosion. This will help to develop technologies to minimize these losses so that the soil health and productivity can be maintained for a long run.

The present practical manual on “Soil and water Conservation Engineering (13A.153)” is intended for use by post Graduate students of the Indian Agricultural Research Institute and other State Agricultural Universities. In this manual an attempt has been made to discuss complex experimental protocols in an easy and step-by-step manner, which will be very useful for the beginners. At the end of each chapter, exercises have been given with solved examples. The manual consists of twelve chapters viz., Computation of kinetic energy of falling rain drops, Estimation of runoff, Calculation of rainfall erosivity (R) factor from recording rain gauge, Determination of various Indices of soil erodibility (k), Measurement of land slope (s) by hand level and Abney level, Calculation of soil loss using universal soil loss equation (USLE) & MUSLE, Calculation of sediment discharge from different location of a river basin, Land capability classification, Prioritization of Watershed Using Remote Sensing and GIS and Delineation and Codification of Watersheds in India. In order to limit the volume of the manual, detailed theoretical aspects have been avoided and instead presented in a short and simple manner.

It is believed that the manual will prove useful for the student communities for whom it is intended. Authors look forward to receive suggestions for improvement of the manual.

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# 1. Study different types and forms of water erosion.

## What Is Erosion?

When you were a kid, did you ever play in the mud? There's no shame in it - personally, I don't judge. Maybe you made mud pies, working hard to get the consistency just right. What happened when you put too much water in the mix? The whole thing got really runny and ended up falling apart, right? More likely, what did your mom say when she saw you making mud pies in her flowerbed? Chances are she wasn't so happy. Of course, the thought of having a child rolling around her precious begonias was only half of the risk. If you spilled too much water, chances are her topsoil would become victim to erosion. Soil erosion is the process by which the topsoil is removed.

## Types of Erosion

So erosion removes topsoil, but how? While there are many types of erosion, all have the same basic process - the removal of topsoil by wind or water.

Wind erosion: - happens when wind gusts blow away unsecured soil.

Bank erosion: - happens when bodies of water sap away the topsoil near its shores.

Sheet erosion:- affects a whole area, when water or the wind act like a broom to clear out the topsoil.

Rill and gully erosion:- happen when impromptu streams form for water to carry away topsoil. The only different is the size - a rill may only be a few inches wide, but a gully could be meters across.



Wind Erosion



Wind Erosion



Rill Erosion:-



Gully Erosion:-



Gully Erosion:-

## 2. Exercises on computation of rainfall erosivity index

### Introduction

Among the various parameters that affect erosion of soil, precipitation plays a vital role. More the amount of rainfall more is the amount of soil detached from the earth surface and carried away by the runoff. Erosivity has been defined as the potential ability of rain to cause erosion. It is a function of the physical characteristics of rainfall (Hudson, 1971). Rainfall erosion - the interaction between rain and soil have been responsible for creating gullies and rendering millions of hectares of productive land into unproductive wastelands. Ravines are glaring examples of such type of erosion. As rainfall is the chief source for the supply of energy to make soil particles detached and transport, it is important to study behaviour of rainfall and its erosivity with regards to its distribution during the year. This chapter discusses spatio-temporal variation in rainfall erosivity in the Upper Bhama basin.

### Concept of rainfall erosivity:-

Soil erosion occurs when raindrops act upon the soil particles. Amount of erosion thus depends upon the combination of the power of rain to cause erosion and the ability of soil to withstand it. Potential ability of rain to cause erosion is known as erosivity (R - factor) which is a function of the physical characteristics of rainfall. Raindrops while falling acquire kinetic energy and on impact, the kinetic energy is used up in detaching the soil particles. Energy is required to break the soil aggregates, splashing them and subsequently carrying them with runoff. Surface runoff as it flows down the slope, gains kinetic energy, which is responsible for the scouring action on the land surfaces. Several researchers have worked on the rainfall erosivity and methods of computation of erosivity.

### Estimation of Erosivity from Rainfall Data:-

The rainfall erosivity is related to the kinetic energy of rainfall. The following two methods are widely used for computing the erosivity of rainfall.

1.  $EI_{30}$  Index method and
2.  $KE > 25$  Index method.

#### 1. $EI_{30}$ Index Method:-

This method was introduced by Wischmeier (1965). It is based on the fact that the product of kinetic energy of the storm and the 30-minute maximum rainfall intensity gives the best estimation of soil loss. The greatest average intensity experienced in any 30 minute period during the storm is computed from recording rain gauge charts by locating the maximum amount of rain which falls in 30 minute period and later converting the same to intensity in mm/hour. This measure of erosivity is referred to as the  $EI_{30}$  index and can be computed for individual storms, and the storm values can be added over periods of time to give weekly, monthly or yearly values of erosivity.

The rainfall erosivity factor  $EI_{30}$  value is computed as follows:

$$EI_{30} = KE \times I_{30} \quad EI_{30} = KE \times I_{30} \quad (17.5)$$

where  $KE$  is rainfall kinetic energy and  $I_{30}$  is the maximum rainfall intensity for a 30-minute period. Kinetic energy for the storm is computed from Eqn. 17.1.

**Limitation:-**

The EI<sub>30</sub> index method was developed under American condition and is not found suitable for tropical and sub-tropical zones for estimating the erosivity.

**2. KE > 25 Index Method:-**

This is an alternate method introduced by Hudson for computing the rainfall erosivity of tropical storms. This method is based on the concept that erosion takes place only at threshold value of rainfall intensity. From experiments, it was obtained that the rainfall intensities less than 25 mm/h are not able to yield the soil erosion in significant amount. Thus, this method takes care of only those rainfall intensities, which are greater than 25 mm/h. That is why the name is K.E. > 25 Index method. It is used in the same manner as the EI<sub>30</sub> index and the calculation procedure is also similar.

**Calculation Procedure:-**

The estimation procedure is same for both the methods. However, K.E. > 25 method is more advantageous, because it sorts out many data less than 25 mm/h, hence uses less rainfall data. For both the methods, it is important to have data on rainfall amount and its intensity. The procedure involves the multiplication of rainfall amounts in each class of intensity to the computed kinetic energy values and then all these values are added together to get the total kinetic energy of the storm. The K.E. so obtained, is again multiplied by the maximum 30-minute rainfall intensity to determine the rainfall erosivity value.

**Soil Erodibility:-**

Soil erodibility is an estimate of the ability of soils to resist erosion based on the physical characteristics of each soil. Generally, soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion. Sand, sandy loam and loam textured soils tend to be less erodible than silt, very fine sand, and certain clay textured soils (Fig. 17.2). On the basis of erodibility, a soil can be compared quantitatively with the other soils for a given rainfall condition. Bouyoucos (1935) suggested that the soil erodibility depends on mechanical composition of soil, such as sand, silt, and clay, presented by the ratio as:

$$\text{Erodibility, } E = \frac{\% \text{ sand} + \% \text{ silt}}{\% \text{ clay}} \quad (17.6)$$

The range of particle diameter of clay, sand and silt is:

Clay = < 0.002 mm

Silt = 0.002 – 0.006 mm

Sand = 0.06 - 2.0 mm.

**Erodibility Determination**

Erodibility is defined as the resistance of the soil to both detachment and transport. It varies with soil texture, aggregate stability, shear strength, infiltration capacity and organic and chemical content. Erodibility of a soil is designated by the soil erodibility factor *K*. There are several approaches to determine *K* and the three major ones are discussed as given below.

Explain detail about:-

1. Use of *in situ* erosion plots
2. Measuring  $K$  under a simulated rainstorm
3. Predicting  $K$  using regression equations describing the relationship between  $K$  and soil physical and chemical properties.

### 3. Computation of soil Erodibility index in soil loss estimation.

#### Theory

The rainfall erosivity factor ‘R’ is the sum of individual rainstorm erosivity value,  $EI_{30}$ , over a time period, usually a year (USDA). Here ‘E’ is the total kinetic energy of a rainstorm and I is the maximum 30 minute intensity of rainstorm. Storms with rain amount less than 13 mm and separated from other rain period by more than 6 h are not included in the computation unless 6 mm of rainfall occurs in 15 min. Mathematically, R is the annual cumulative erosivity and is given by the expression

$$R = \sum_{j=1}^n (EI_{30}) \quad \dots(1)$$

where, n = number of storm in a year. Kinetic energy of the storm is computed by the following equation

$$E = \int_0^T e * i dt \quad \dots(2)$$

where e is the rainfall energy per unit of rainfall and ‘i’ is the intensity of rainfall for the differential time dt. ‘T’ is the duration of rainfall of the storm. The above equation can also be rewritten as

$$E = \sum_{k=1}^p (e_k \Delta v_k) \quad \dots(3)$$

where  $e_k$  is the rainfall energy per unit of rainfall and  $v_k$  is the depth of rainfall for the  $k^{\text{th}}$  increment of the storm divided into ‘p’ parts such that each part has constant rainfall intensity  $i_k$ . This  $i_k$  is defined as

$$i_k = \frac{\Delta v_k}{\Delta t_k} \quad \dots(4)$$

where,  $\Delta t_k$  is the duration of increment over which the intensity is considered to be constant.

Erosivity ( $EI_{30}$ ) index can be quantified using rain gauge data. The rainfall hyetograph is divided into successive increments of uniform intensity. Clock time and cumulative rain depth (mm) are read from the chart at each point where slope of the pen line changes

and are shown as first two columns in Table 6. Clock times (col.1) from successive rows are subtracted to obtain time intervals (min) given in col.3 and cumulative rainfall depths (col.2) are subtracted to obtain incremental rainfall depth (mm) as tabulated in col.4. Intensity (col.5) in mm h<sup>-1</sup> can be tabulated by dividing col.4 by col.3 and multiplying by 60. Unit energy for each increment shown in column 6 is obtained by substituting intensity for the increment (col.5) into Eq. 1. Rainfall energy for an increment (col.7) is the product of unit energy for that increment and depth of rainfall for the increment (col.4). Total energy of storm is the sum of energies for each increment given in col.7.

$$\text{Maximum 30 minute intensity } I_{30} = (14*77 + 9*40 + 7*26) / 30 = 54 \text{ mm h}^{-1} \quad \dots(5)$$

$$\text{Or alternatively, } I_{30} = (18 + 6 + 3) / 30 = 0.9 \text{ cm/min} = 54 \text{ mm h}^{-1} \quad \dots(6)$$

**Table 6: Example showing computation of energy of a rainstorm in SI units (Foster et al., 1981)**

Chart reading		Storm increments			Kinetic energy (E)	
Time (h) (1)	Depth (mm) (2)	Duration (min) (3)	Depth (mm) (4)	Intensity (mm h <sup>-1</sup> ) (5)	Per unit rainfall (MJ ha <sup>-1</sup> mm <sup>-1</sup> ) (6)	For storm increment (MJ ha <sup>-1</sup> ) (7)
4:00	0					
4:20	1	20	1	3	0.161	0.16
4:27	3	7	2	17	0.226	0.45
4:36	9	9	6	40	0.259	1.55
4:50	27	14	18	77	0.283	5.09
4:57	30	7	3	26	0.243	0.73
5:05	32	8	2	15	0.222	0.44
5:15	32	10	0	0	0	0
5:30	33	15	1	4	0.219	0.22
<b>Total</b>		<b>90</b>	<b>33</b>			<b>8.64*</b>

\* Total kinetic energy of a rain storm

Therefore,  $EI_{30}$  for this storm is  $8.64 \times 54 = 464 \text{ MJ-mm ha}^{-1} \text{h}^{-1}$

## References

1. USDA Agricultural hand book -703.
2. Foster, G.R., McCool, D.K., Renard, K.G. and Moldenhauer, W.C. 1981. Conversion of USLE into SI units. The Journal of Soil and Water Conservation, 36, 355-359.

## 4. Determination of length of slope (LS) and cropping practice (CP) factors for soil loss estimation by USLE and MUSLE.

### Calculation of Soil Loss Using Universal Soil Loss Equation (USLE)

#### Universal Soil Loss Equation (USLE)

USLE is an erosion model developed by Wischmeier and Smith (1965, 1978) to predict the longtime average soil losses from a specified land in a specified cropping and management system. The beauty of the USLE is to isolate each variable responsible for erosion and reduce its affects to a number so that when the numbers of different variables are multiplied together, the answer yields the amount of soil loss. The equation predicts only the losses from sheet and rill erosion under specified conditions. With appropriate selection of numerical values for various soil erosion variables, the equation will compute the average soil loss for a cropping system, for a particular crop year in a rotation, or a particular crop stage period within a crop year. It computes the soil loss for a given site as a product of six major factors, whose most likely values at a particular location can be expressed numerically (Wischmeier and Smith, 1978).

The soil loss equation is given as follows:

$$A = R \times K \times L \times S \times C \times P \quad \dots(1)$$

Where

- A is computed soil loss per unit area, expressed in the units selected for K and for the period selected for R. In practice, these are usually so selected that they compute A in metric tonnes per ha per year, but other units can be selected.
  - R is rainfall erosivity factor, which is the rainfall erosion index units for a particular location.
  - K is the soil erodability factor, which is the soil loss rate per erosion index unit for a specified soil as measured on unit plot which is defined as 21.13 m (72.6ft) length and 1.83m (6 ft) width of uniform 9 per cent slope continuously in clean-tilled fallow.
  - L is slope length factor, which is the ratio of soil loss from the field slope length to that from a 21.13 m (72.6ft) length under identical conditions.
  - S is the slope steepness factor, which is the ratio of soil loss from the field slope gradient to that from a 9 per cent slope under otherwise identical conditions.
  - C is the cover and management factor, which is the ratio of soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow.
  - P is the support practice factor, which is the ratio of soil loss with a support practice like contouring, strip cropping, or terracing to that with straight-row farming up and down the slope.
- The USLE groups the numerous inter-related physical and management parameters that influence erosion rate under six major factors whose site specific values can be expressed numerically.

### **Applications of USLE**

The USLE can be used for the following purposes:

- Predict average annual soil loss from a field with a specified land use conditions
- Guide the selection of cropping and management system, and conservation practices for specific soils and slopes
- Predict the change in soil loss that would result from a change in cropping or conservation practices on a specified field
- Estimate soil losses from land use areas other than agricultural lands
- Provide soil loss estimates for conservationists to use for determining conservation needs
- Can be used as a first approximation for estimating the sediment yield of watersheds

### **Limitations of USLE**

USLE takes into account all the factors known to affect rainfall erosion and is widely employed around the world, still it has the following limitations:

- It is empirical
- It predicts average annual soil loss and when applied on a single storm basis and the results may be highly erroneous
- It doesn't predict gully erosion
- It does not predict sediment deposition and only predicts soil loss

### **Example**

In an area subjected to soil erosion, the following information is available: Rainfall erosivity index (R): 1200 MJ-mm/ha-h-y  
Soil erodability index (k): 0.20 t-ha-h/ha-MJ.mm  
Crop management factor (C): 0.60  
Conservation practice factor (P): 1.0  
Slope length factor (LS): 0.1

What will be estimated annual soil loss? Explain how this soil loss will decrease by adopting conservation practices.

### **Solution**

Using the USLE, the soil loss is obtained as  
 $A = 1200 \times 0.20 \times 0.60 \times 1.0 \times 0.1 = 14.4$  tonnes/hectare per year

To reduce the soil loss, if conservaton are introduced by contouring and factor P is now 0.6.

The soil loss is given by:

$$A = 14.4 \times 0.6 = 10.44 \text{ tonnes / hectare per year.}$$

Percentage reduction in soil loss after adoption of conservation practice factor is given by:

$$\% \text{ reduction in soil loss} = \{(14.4 - 10.44) / 14.4\} \times 100 = 27.5\%$$

### **Modified USLE:-**

Williams (1975) modified the USLE to estimate sediment yield for a single runoff event. On the basis of that runoff is a superior indicator of sediment yield than rainfall; i.e., no runoff yields no sediment, and there can be rainfall with little or no runoff-Williams (1975) replaced the R (rainfall erosivity) factor with a runoff factor. His analysis revealed that using the product of volume of runoff and peak discharge for an event yielded more accurate sediment yield predictions, especially for large events, than the USLE with the R factor. The Modified USLE, or MUSLE, is given by the following (Williams, 1975):

$$S = 11.8 (Q \times q_p \times A)^{0.56} \times K \times C \times P \times LS \times CFRG$$

Where,

S = Sediment yield for a single event in (Mg),

Q = Total event runoff volume ( $m^3$ ),

$q_p$  = Event peak discharge ( $m^3 s^{-1}$ ),

A = Area of the hydrologic response unit (HRU) (ha) and

K, LS, C, and P = USLE parameters and these are dimensionless.

CFRG = Coarse fragment factor, which is estimated as

$$CFRG = \exp(-0.053 \times \text{Rock})$$

Where, Rock is % rock in the uppermost soil layer.

The MUSLE approach has been used to estimate sediment yield at various sites. Some errors, however, have been associated with both USLE and runoff model estimates, resulting in under- and over-prediction of sediment yield from various rainfall events and site-specific characteristics, and have led to various proposals to increase accuracy after regression analysis. The complexity of watershed systems has forced modelers and users to develop modified, calibrated or revised versions of the MUSLE. Due to errors associated with the classic USLE, especially those relating to topographic factors in terms of limited availability of data on steep slope gradients; it is still unclear how the USLE can be applied to complex slopes beyond the range of the extended model. Application of the MUSLE has not been documented. The structure of the MUSLE model has inherited some limitations from classic USLE, especially those related to slope steepness (S factor).

### **References**

1. Murty, V.V.N. (2004) Land and water management engineering, Kalyani Publishers.
2. Singh, G., Babu, R. and Chandra, S. (1981) Soil loss prediction research in India., Bulletin No. T-12/D-9, CSWSRTI, Dehradun.

## 5. Exercises on soil loss estimation/measuring techniques.

### Universal Soil Loss Equation (USLE)

The USLE is an empirical soil model developed by Wischmeier and Smith, (1978). Originally, USLE was developed mainly for soil erosion estimation in croplands or gently sloping topography (Ganasri and Ramesh, 2016). The USLE quantifies soil erosion as the product of six factors representing rainfall and runoff erosivity (R), soil erodibility (K), slope length (L), slope steepness (S), cover and management practices (C), and supporting conservation practices (P) (Renard and Freimund, 1994). This empirical equation is based on the statistical analysis of more than 10,000 plot-years of data of sheet and rill erosion on plots and small watersheds (Roose, 1977).

**The equation is:**

$A = RKSLCP$  in which erosion

(A) is the estimated soil loss per unit area,

R is the rainfall-runoff erosivity  $\Sigma$  factor, K is the soil erodibility factor,

L is the slope length factor,

S is the slope steepness factor,

C is the cover management factor, and

P is the supporting practices factor (Wischmeier and Smith, 1978).

The model predicts rainfall based on rainfall erosivity (R factor) and soil erodibility (K factor). Bols (1978) proposed a formula for calculating the R factor in Indonesia in a model:

$$R = 2.5P^{2.100}(0.073P+0.73)$$

where P = Annual precipitation in millimetres and

R is in  $\text{MJmmha}^{-1}\text{hr}^{-1}\text{yr}^{-1}$

The soil erodibility index is calculated with the following equation (Roose, 1977):

$$K = \frac{A}{R \times SL \times 2.24}$$

Where A is the erosion in tons per hectare, R is the rainfall erosivity index, SL is the topographic factor, and 2.24 the coefficient necessary t

### References:-

1. Igwe, P.U. & et al 2017 International Journal of Advanced Engineering Research and Science (IJAERS) [Vol-4, Issue-12]

## **6. Study of Rain fall simulator for erosion assessment**

The extent to which the soil is sensitive to erosion is determined largely by the composition of the soil. Knowledge of the sensitivity to erosion is important for the development of a certain plot. The sensitivity to erosion is hard to measure. Absolute values can not be obtained. It is, however, possible to obtain a reasonable indication by means of a relative measurement. For such a measurement a rainfall simulator can be applied.

### **Benefits Rainfall simulator:-**

- Supplies rain storm for comparative research
- Small weight; no trucks needed
- Calibrated glass nozzles will last forever

### **The simulator:-**

The simulator allows erosion to take place on a small section of the plot. With the apparatus rainfall is simulated on a slanting surface. Through small capillaries in the plate under the water filled cylinder, the drops fall down on the slanting surface. Once fallen to the surface of the soil, the droplet loosens soil particles. These particles jump up and fall down again, slightly lower, on the slope. At the bottom of the slope, water and soil particles are collected in a reservoir.

Through research in the laboratory of the soil particles collected, an indication can be derived concerning the composition and the sensitivity to erosion of the soil under research. By comparing the measuring results to other measuring results, the researcher may set up a scale for sensitivity to erosion of the researched soil. To be able to obtain reliable results it is important to keep the factors influencing the process (such as for instance the temperature of the water) as constant as possible. It is also recommended to gather information concerning the history of the use of the soil. This may then be taken into account when translating the measuring results.



**This simulator uses a frame with nozzles (top) to apply water at various rates and a frame on the ground to catch sediments.**



**Rain fall simulator: - Field measurement**

## 7. Estimation of sediment rate using Coshocton wheel sampler and multi-slot devisor.

### Important terms used in sediment discharge studies

*Sediment* is solid material that originates mostly from disintegrated rocks and is transported by, suspended in, or deposited from water. It includes chemical and biochemical precipitates and decomposed organic material such as humus. The quantity, characteristics, and cause of the occurrence of sediment in streams are influenced by environmental factors. Some major factors are degree of slope, length of slope, soil characteristics, land usage, and quantity and intensity of precipitation. Sediments are commonly subdivided into three major groups—mechanical, chemical, and organic.

*Mechanical sediments* are derived from the erosion of earlier formed rocks on the earth's surface or in the oceans. These are then carried by streams, winds, or glaciers to the site where they are deposited. Streams deposit sediment in floodplains or carry these particles to the ocean, where they may be deposited as a delta. Ocean sediments, especially in the form of turbidites, are usually deposited at the foot of continental slopes. Glaciers carry sediment frozen within the mass of the ice and are capable of carrying even huge boulders.

*Chemical sediments* are formed by chemical reactions in seawater that result in the precipitation of minute mineral crystals, which settle to the floor of the sea and ultimately form a more or less chemically pure layer of sediment. For example, evaporation in shallow basins results in a sequence of evaporite sediments, which include gypsum and rock salt.

### Sediment Yield in a Basin

Water erosion is the most important type of erosion caused due to impact of rain drops and due to the flow of runoff. Its further importance under a monsoon climate, as occurs over India, is due to the sharp showers and copious runoff that follows the rainfall. In the entire process of erosion and transport; soil erosion, soil loss and sediment yield in a basin are three different but closely related concepts. Sediment yield is defined as the total sediment outflow from a watershed or drainage basin, measurable at a cross-section of reference in a specified period of time (Piest and Miller, 1975). In the comprehensive planning of a medium or small watershed, if the gross erosion and sediment delivery ratio are known, the sediment yield can be predicted.

Sediment observations are important baseline information for the optimal use of the water resources, for the protection against harmful impacts of the sediment as well as for the protection of the water and the environment. For that reason various types of sediment data are needed.

### Table 19.2. An overview of necessary sediment observations

Torrents	Rivers	Reservoirs and lakes
<ul style="list-style-type: none"> <li>• Bed load</li> <li>• Bed load potential</li> <li>• Transport capacity (maximum bed load discharge)</li> <li>• Bed load discharge during floods</li> <li>• Bed load discharge graph</li> <li>• Grain size distribution during flood events</li> <li>• Bed load discharge of floods of different size (recurrence intervals)</li> <li>• Suspended sediment</li> <li>• Suspended sediment concentration</li> <li>• Relation between water discharge and suspended sediment concentration</li> <li>• Suspended sediment discharge</li> <li>• Sediment features</li> <li>• Grain size distribution</li> <li>• Grain shape and petrography</li> <li>• Bulk density of accumulations</li> </ul>	<ul style="list-style-type: none"> <li>• Bed load</li> <li>• Bed load potential</li> <li>• Transport capacity (maximum bed load discharge)</li> <li>• Bed load discharge during floods</li> <li>• Bed load discharge graph</li> <li>• Grain size distribution at flood events</li> <li>• Bed load discharge of floods of different size (recurrence intervals)</li> <li>• Suspended sediment</li> <li>• Suspended sediment concentration</li> <li>• Relation between water discharge and suspended sediment concentration</li> <li>• Suspended sediment discharge</li> <li>• Sediment features</li> <li>• Grain size distribution (as function of place, time and water discharge) of moving and laying bed load and suspended sediment</li> <li>• Grain shape and petrography</li> <li>• Specific weight</li> <li>• Transported wood volume per flood event</li> </ul>	<ul style="list-style-type: none"> <li>• Sediment in-and output</li> <li>• Sediment load (to be determined in in-and outflowing rivers)</li> <li>• Bed load</li> <li>• Delta survey</li> <li>• Suspended sediments</li> <li>• Suspended sediment concentration (as function of time and space)</li> <li>• Turbidity profiles</li> <li>• Composition of suspended sediments (grain size distribution, organic/inorganic, chemical/mineralogical, clastic)</li> <li>• Features of adsorption</li> <li>• Sedimentation rate</li> <li>• Volume change by redeposition and diagenesis of sediments</li> <li>• Grain shape and petrography</li> <li>• Composition of suspended sediments (grain size distribution, organic/inorganic, chemical/mineralogical, clastic)</li> <li>• Transported wood volume per time</li> </ul>

(Source: [http://www.irtces.org/zt/11isrs/paper/Manfred Spreafico.pdf](http://www.irtces.org/zt/11isrs/paper/Manfred_Spreafico.pdf))

Sediment load may be classified as suspended load or bed load according to the mode of movement in the river. Suspended load is the sediment that moves in suspension in water under the influence of turbulence. Bed load is the part of sediment load that moves in almost continuous contact with the stream bed by saltation and traction. That is, by bouncing, sliding and rolling on or near the stream bed by the force of water. According to its origin, or source of supply, the total amount of sediment transported in rivers may be divided into two parts: wash load and bed material load. Wash load consists of fine particles, which refers generally to sediment size finer than 0.062 mm, and the amount depends mainly upon supply from the source area. The discharge of bed material is controlled by the transport capacity of the stream, which depends upon bed composition and the relevant hydraulic parameters. Wash load moves entirely in suspension, while the bed material load may move either as temporarily suspended load or as bed load. Suspended sediment load is easier to measure and is mostly used in estimating catchment soil loss, reservoir sedimentation, etc. Despite a large number of studies, the bed load movement mechanism is not well understood and is either neglected or some tentative value is assumed for estimating total sediment flow passed a section or from a watershed.

## 19.2 Sediment Sampler

Sediment samplers are used to collect sediment-laden water sample from a flowing water body (river, tributary, canal, etc.). The sample is subjected to laboratory analysis to determine mainly the sediment content and also the chemical, physical, toxicological and biological composition of sediment. Samplers are also used to collect scoops or cores of soil from a known silt deposition site (e.g., reservoir bottom, flood plain) to gather historical information. Choosing the most appropriate sampling device and technique depends on the:


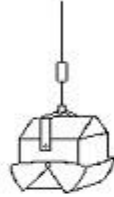

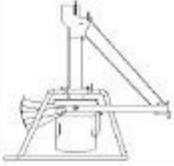
- 1) Purpose of sampling;
- 2) Location of sediment; and
- 3) Characteristics of sediment.

### Sample Types:

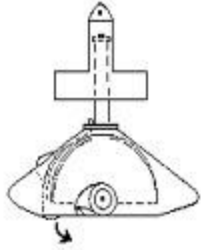


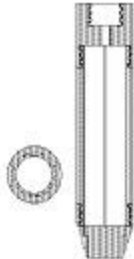
A description and rationale for the types of samples to be collected should be included in the plan. Different types of sampler are illustrated in Table 19.3 and Fig. 19.1.

- **Cores:** Vertical discrete grab samples. Most appropriate for historical contamination information or dredging decisions at heavily contaminated areas.
- **Cores:** Depth integrated composite samples. Most appropriate for reference and Section 404/401 issues.
- **Scoops and Dredges:** Surface (top two to four centimeters) sediment grab samples. Most appropriate for benthic, sediment oxygen demand (in-situ), recent ambient conditions and recent contaminant investigation.
- **Surface sediment composite samplers:** It may be used to reduce costs for specific conditions/situations such as some Section 404/401 issues or ambient or specific historical data. In general, however, discrete sampling is preferred if resources are available. An example of a discrete sample would be taking a section of one centimeter of sediment from a core sample that was originally one meter long.

**Table 19.3. Table of Sediment Sampling Equipment**

TYPE	MODEL	CURRENT	SUBSTRATE TYPE	REMARKS	ILLUSTRATION
GRAB	Spoon Scoop	Zero to Slight	All	<ul style="list-style-type: none"> <li>• Use only in relatively calm and shallow water.</li> <li>• Relatively little sample disturbance.</li> <li>• Simple and inexpensive</li> <li>• Fines may washout when retrieved through water column</li> </ul>	
GRAB	Eckman (Birge)	Zero to Very Slight	Clay and Silt	<ul style="list-style-type: none"> <li>• Use in relatively calm water.</li> <li>• Pebbles and branches may interfere with jaw closure</li> <li>• Excellent jaw shape and cut.</li> <li>• Relatively little sample disturbance.</li> <li>• Poor stability. Light weight allows for tendency to "swim" in a current. Sometimes causes miss triggers.</li> <li>• 0.02 m<sup>2</sup> sample area.</li> <li>• Weight with sample is 10 kg.</li> </ul>	
GRAB	Petite Ponar Peterson	Zero to Very Slight	Clay to fine gravel	<ul style="list-style-type: none"> <li>• Need relatively calm/sheltered waters.</li> <li>• Good stability.</li> <li>• Poor jaw shape and cut. Sample disturbance.</li> <li>• Less washout if extra weights are used.</li> <li>• More cumbersome than an Eckman; requires a winch.</li> <li>• 0.1 - 0.2 m<sup>2</sup> sample area.</li> <li>• Weight with sample is 30 - 50 kg.</li> </ul>	
CORE	Box	Zero to moderate	Clay to sand	<ul style="list-style-type: none"> <li>• Difficult to handle.</li> <li>• Large sample size.</li> <li>• Requires boat/barge with winch.</li> <li>• Rectangular shaped box.</li> </ul>	

(Source: <http://www.epa.ohio.gov/portals/35/guidance/sedman2012.pdf>)

TYPE	MODEL	CURRENT	SUBSTRATE TYPE	REMARKS	ILLUSTRATION
GRAB	Shipek	Zero to strong	Clay to gravel	<ul style="list-style-type: none"> <li>Requires boat/barge with winch (mini shipek can be used manually).</li> <li>One of the most reliable in terms of triggering, stability, washout, and leaching.</li> <li>Excellent jaw shape and cut. Extremely clean cutting action.</li> <li>0.04 m<sup>2</sup> sample area.</li> <li>Weight with sample is 60 - 70 kg (mini shipek weight with sample is 20 - 30 kg).</li> </ul>	
CORE	Manual	Zero to strong	Clay to sand. Inserts needed for sandy samples.	<ul style="list-style-type: none"> <li>Recommended for use in shallow water.</li> <li>Deployed by hand or by driver (hammer).</li> <li>Extension handles can be used for deeper waters.</li> </ul>	
CORE	Coring Tubes	Zero to moderate	Clay to sand. Inserts needed for sandy samples.	<ul style="list-style-type: none"> <li>Quick and easy.</li> <li>Relatively undisturbed sample.</li> <li>Small sample volume.</li> <li>Samples sometimes compressed.</li> </ul>	
CORE	Split Spoon	Zero to moderate	Clay to sand. Inserts needed for sandy samples.	<ul style="list-style-type: none"> <li>Recommended for use in shallow water.</li> <li>Deployed by hand or by driver (hammer).</li> <li>Vertical profile remains intact and is visible.</li> <li>Point design can reduce sample compaction.</li> <li>Stones can interfere with collection.</li> <li>Equipment is heavy.</li> </ul>	

(Source: <http://www.epa.ohio.gov/portals/35/guidance/sedman2012.pdf>)



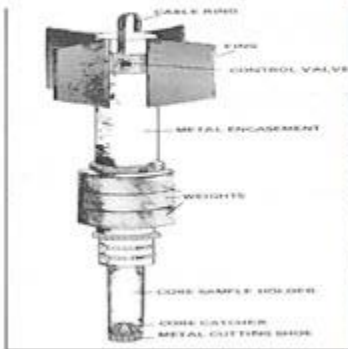
US DH-48



US DH-74



US DH-76



Gravity Corer



Ponar Sampler

Fig. 19.1. Silt sampler. (Image source: [http://www.glc.org/tributary/documents/sedimentcourse/buffalo/D104MonitoringForSed\\_Zajd.pdf](http://www.glc.org/tributary/documents/sedimentcourse/buffalo/D104MonitoringForSed_Zajd.pdf))



**Fig. 19.2 Coshocton wheel water sampler**  
(source: <http://ars.usda.gov/Research/docs.htm?docid=10027>)

### 19.3 Discharge Proportionate Samplers

Flow measurement data are required for information on the rates, volumes and frequencies of waste discharges to the wastewater system. The measured trade waste volume is used together with sample analysis results to calculate the masses of pollutants discharged. The flow data gathered is used to:

- Determine mass (trade wastewater) and volume (sewer usage) charges accurately
- Determine a discharge factor
- Provide the customer with discharge data, so that they can manage their trade wastewater discharge more effectively
- Enable flow proportional sampling of the trade wastewater
- Provide hydraulic data to assess the future capacity of the wastewater system.

Different types of instrument used for measurement of flow velocity are illustrated in Figs. 19.3 to 19.7. Instruments for measurement of discharge like weirs and flumes are illustrated in Fig. 19.8 to 19.12.



**Fig.19.3. Magnetic flow meter.**

(Source: [http://gallery.usgs.gov/images/07\\_20\\_2009/nsj7MYx43F\\_07\\_20\\_2009/large/000458-Current\\_Meter\\_\(4\).jpg](http://gallery.usgs.gov/images/07_20_2009/nsj7MYx43F_07_20_2009/large/000458-Current_Meter_(4).jpg))



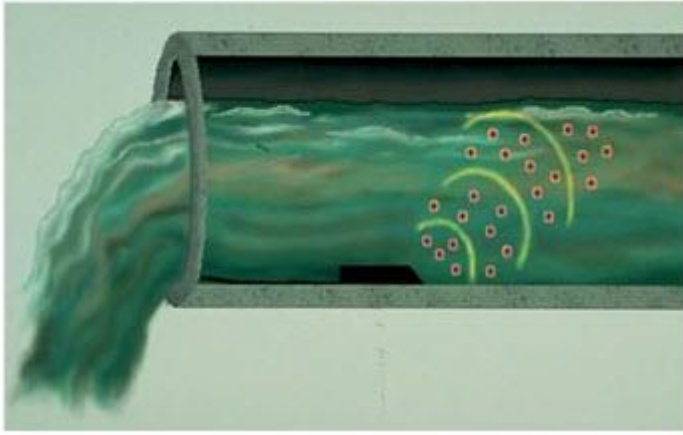
**Fig. 19.4. Current meter.**

(Source: [http://gallery.usgs.gov/images/07\\_20\\_2009/nsj7MYx43F\\_07\\_20\\_2009/large/000458-Current\\_Meter\\_\(4\).jpg](http://gallery.usgs.gov/images/07_20_2009/nsj7MYx43F_07_20_2009/large/000458-Current_Meter_(4).jpg))



**Fig. 19.5. Horizontal float type recorder.**

(Source: [http://ecx.imagesamazon.com/images/I/61srCwKjQvL\\_AA1500\\_.jpg](http://ecx.imagesamazon.com/images/I/61srCwKjQvL_AA1500_.jpg))



**Fig. 19.6. Area velocity continuous wave Doppler (CWD).**



**Fig. 19.7. Area velocity sensor mounting hardware.**



**Fig. 19.8. Parshall flume.**



Fig. 19.8. Repleg flume or long-throated flume. (Source: <http://inmtn.com/images/flumes/bench-b-ramp-flume.jpg>)



Fig. 19.9. Palmer Bowlus Flume.

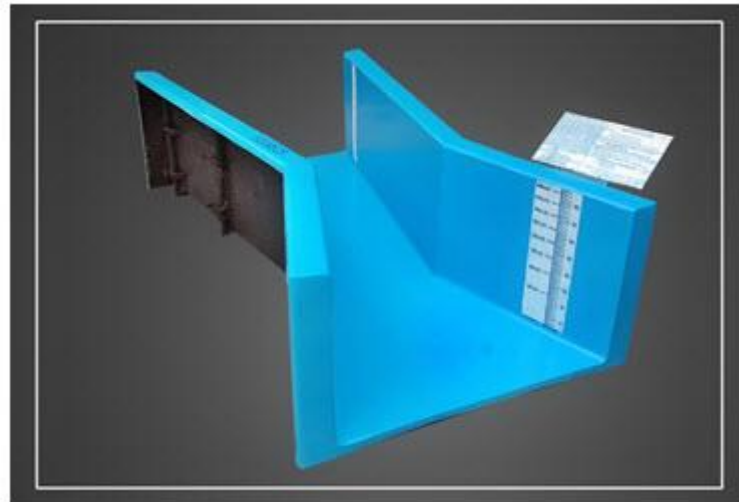


Fig. 19.10. Cut throat flume. (Source: <http://www.niplastindia.com/Ni-Plast/cut-throat-flume-gallery.aspx>)



**Fig. 19.11. V-Notch Weir.**



**Fig. 19.12. Flow Metering Insert (Weir).**

### **Water Level Measurement**

These instruments are used to measure the depth of water level from the ground surface. The instruments are illustrated in Figures 19.13 to 19.16.



**Fig. 19.13. Staff gauge.** (Source; <http://www.indiamart.com/sourcebusinesssyndicate/river-gauges.html>)



Fig. 19.14. US type A-71 water level recorder. (Source: <http://www.rickly.com/sm/Float-Type/WaterLevelRecorders.htm>)

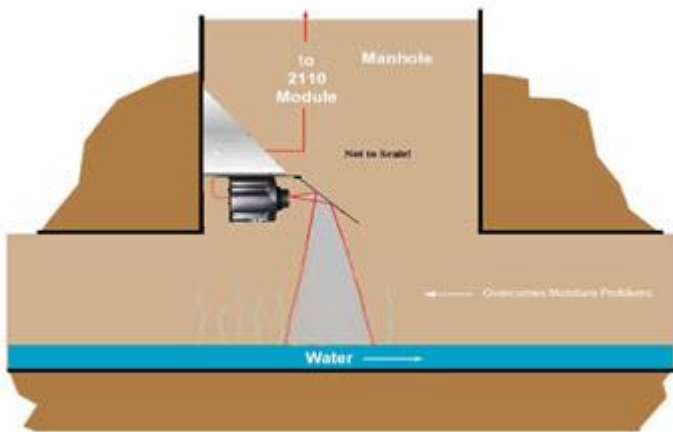


Fig. 19.15. Ultrasonic level measurement.



Fig. 19.16. Submerged probe / Pressure transducer. (Source: [http://www.mi-wea.org/docs/Hummel%20 %20IPP%20Flow%20Paced%20Strategies.pdf](http://www.mi-wea.org/docs/Hummel%20%20IPP%20Flow%20Paced%20Strategies.pdf))

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