DESIGN OF CHANNEL ON REGIME CONCEPT

Dr. ShriRam Chaurasia

Necessary Condition for Design of Irrigation Channels: *Uniform and Steady Flow*

Steady and Uniform flow is said to prevail when the discharge at the sections in a particular length of channel under consideration is same and the depth of flow does not change.

Chezy Equation

$$U = C\sqrt{RS}$$

where,

U = mean velocity of flow in m/s.

C = a coefficient (called Chezy's C) value depends upon the shape and surface of the channel.

R = hydraulic mean depth in m.

S = slope of channel.

A number of statistical analysis has been made from time to time by various authors to determine the value of Chezy's C out of which the values expressed by Ganguillet and Kutter and later Manning have found acceptance and are generally used.

According to Kutter's Formula,

$$U = \left(\frac{23+\frac{1}{n}+\frac{0.00155}{S}}{1+\left(\frac{23+0.00155}{S}\right)}\right)\sqrt{RS}$$

Although, Kuttt's Equation is quite cumbersome, but satisfactorily results have been obtained by its use.

According to Manning, $C = R^{1/6}/n$ (In metric units)

Substituting in place of C in Chezy's equation we get:

$$U = \frac{1}{n}R^{2/3}S^{1/2}$$

where n = a roughness coefficient.

The value of n varies according to physical roughness of the sides and bottom of the channel and influenced by such factors as (i) Channel Curvature, (ii) Changes in size and shape of cross-section, (iii) Obstructions such as debris roots, structure, (iv) Vegetation etc.

Values of n recommended by I.S.I. for excavated channels are given below:

Values of n for excavated open channels		
(a)	Earth, straight and uniform	Value of n
(i)	Clean, straight	0.016 to 0.020
(ii)	Clean, after weathering	0.018 to 0.025
(iii)	With short grass, few weeds	0.022 to 0.033
(b)	Rock cuts	
(i)	Smooth and uniform	0.025 to 0.040
(ii)	Tagged and irregular	0.035 to 0.050

The value of n to be adopted in design depends upon the channel condition expected in the future. The channel condition is primarily governed by the extent of weeds and silting or scouring problems and standard of maintenance.

Design of channel on the basis of maximum permissible velocity

With known value of n, slope and other channel dimensions, the mean velocity can be determined with the help of Manning's or Kutter's Formula. On the other hand, if the maximum permissible velocity is known, channels in erodible strata which do not present any silting problems are often designed on the principle of maximum mean velocity that will not cause erosion of the channel's body.

Channels in which silting problems are anticipated may be designed on the principle of minimum permissible velocity or the non-silting velocity. It is the minimum velocity that would not start sedimentation. This velocity is very uncertain and cannot be determined easily.

Irrigation channels in this country are often construction in alluvial soils without lining. These channels take their supplies from rivers which always carry sediment rolling on their bed or held in suspension.

If the velocity in a channel is very high, the water will erode its bed; if the velocity is very low, the sediment held in suspension will settle down. A channel should therefore, be designed for a velocity such that neither the bed is eroded nor silt is deposited but is transported to the fields. The alluvial channels designed on the principle of maximum and minimum permissible velocities have not always functioned satisfactorily.

The pioneer research work in the direction of obtaining a stable non silting and non-scouring channel was done by Kennedy in Punjab and later by Lacey in Uttar Pradesh. A lot of excellent research work has been done on the theories of silt transportation in recent years.

Recommended maximum permissible velocity

Type of Soil	Maximum permissible (velocity in m/sec)
Ordinary Soils	0.60 to 0.90
Very light loose and to average sandy soil	0.30 to 0.60
Sandy load, Black Cotton Soil and similar soil	0.60 to 0.90
Murum, Hard Soil etc.	0.90 to 1.10
Gravel	1.50
Rock (disintegrated)	1.50

Problem: Find out Normal Water Depth and Velocity in channel carrying a discharge of 10 cumecs and having bed width of 5m.

Solution: Assuming side slopes as 1:1

Area of channel A = (B + D) × D

Wetted Perimeter P = $2D\sqrt{2}$

where, B = bed width of the channel

and D = Water Depth

By Manning's Formula,

$$U = \frac{1}{n} R^{2/3} S^{1/2}$$

$$= \frac{1}{n} \times \left[\frac{(B+D)D}{(B+2D\sqrt{2})}\right]^{2/3} \times (0.0015)^{1/2}$$

$$= \frac{1}{1.7212} \times \left[\frac{(B+D)D}{(B+2D\sqrt{2})}\right]^{2/3}$$

Also, $Q = A \times U$

Substituting values,

$$Q = (B + D)D \times 1.7212 \left[\frac{(B+D)D}{(B+2D\sqrt{2})}\right]^{2/3}$$

$$Q = 1.7212 \left[\frac{((B+D)D)^{5/3}}{(B+2D\sqrt{2})^{2/3}}\right]$$

Solving by trial and error we get,

$Q = 10$, assuming $D = 1.09$, we have

$$Q = 1.7212 \left[\frac{\left((5 + 1.09)1.09\right)^{5/3}}{(5 + 2 \times 1.09\sqrt{2})^{2/3}}\right]$$

Substituting values of B and D in the eqn we get,

$$U = 1.7212 \left[\frac{(5+1.09)D}{(5+2\times1.09\sqrt{2})}\right]^{2/3} = 1.508 \text{ m/s}$$

Kennedy's Silt Theory

R.G. Kennedy based his theory on the charges and grade of silt present in the upper Bari Doab Canal and its distributaries. He deduced from the observations that, for non-silting and non-scouring channels in steady regime, there is always one velocity which is called the 'critical velocity', denoted by V_o, and that velocity is a function of the depth of water in the channel.

By plotting his observations of velocity and depth in the steady regime reaches, Kennedy obtained the equation.

$U_o = 0.546\ m\ D^{0.64}$ in metric units

where D = the depth of water in metre

and U_o = the velocity in m/s

This equation was applicable to the grade of silt available at upper Bari-Doab canal only. To take account of varying grades of silt, another factoer in the equation was introduced which is called the 'critical velocity ratio' C.V.R. and is denoted by m. The equation may thus be written as,

$U = 0.546\ m\ D^{0.64}$

where, $m = U/U_o$ = C.V.R.

The values of m for different types of silt are given below:

Type of Silt	Value of m
Light sandy silt in the rivers of Northern India	1.00
Somewhat coarser silt or debris of hard soils	1.10
Sandy, Loamy Silt	1.20
Rather coarser silt or debris of hard soils	1.30
Silt of River Indus in Sindh (Pakistan)	0.70

For channels carrying bed and suspended loads, it is recommended that the value of m be taken as 1.1 at the head and 0.85 towards the tail end.

Kennedy's Theory does not take width, shape of channel or slope into consideration. Before proceeding with the design it is necessary to assume trial values of these parametres. The velocity worked out should give the required discharge for the assumed section, and the same time satisfy the Kennedy's equation. The mean velocity of the channel should not be less than the critical velocity.

The following items must be known:

I. The design discharge of the channel, Q (cumec)
II. The slope, S
III. The Rugosity coefficient, n
IV. The critical velocity ratio, $m = U/U_o$

The equation to be used are:

I. $Q = AU$
II. Kutter's $U = \left(\frac{23+\frac{1}{n}+\frac{0.00155}{S}}{1+\left(\frac{23+0.00155}{S}\right)}\right)\sqrt{RS}$
III. Kennedy's, $U = 0.546\ m\ D^{0.64}$

Procedure

a) Assume a trial value of D. Substitute in equation to determine U, the critical velocity required for this trial depth.

b) In equation (I), A = Q/U, 'A' can be written in terms of B and D (the bed width water depth of the channel) assuming side slopes of ½:1, of not otherwise specified. For the assumed value of D, work out the value of B. For the values of B and D, work out R (Hydraulic mean depth.)

c) Substitute the value of R in equation (II) to obtain the value of U which will be actual velocity for the assumed channel dimensions.

d) If the velocity worked out from equation (II) agrees with that obtained from equation (III), the assumed depth is correct, otherwise wrong. Repeat the calculation with changed value of D till the two values of velocities are almost the same.

Problem: Design an irrigation channel to carry 45 cumec at slope of 1/6000 with Kutter's n = 0.0225 and m = 0.95.

Assume depth = 2.25 m

Kennedy's U = 0.546 x 0.95 x $2.25^{0.64}$ = 0.87 m/s

A = Q/U = 45/0.87 = 51.80 sq. metre

For the purpose of discharging capacity are considered as ½:1.

Hence A = BD + D^2 = 51.80 sq. m.

Substituting,

$2.25 B + 2.25^2/2 = 51.80$

$B = 21.90$

P = B + 2.24 D = 21.90 + 5.04 = 26.94 m

R = A/P = 51.80/26.94 = 1.92 m

Chezy's C according to Kutter's equation

$$= \left(\frac{23 + \frac{1}{0.0225} + \frac{0.00155}{1/6000}}{1 + \left(\frac{23 + 0.00155}{1/6000} \right) \frac{0.0225}{\sqrt{1.92}}} \right)$$

Actual velocity of flow = $C\sqrt{RS}$

$$U = 50.381\sqrt{1.92 \times 1/6000} = 0.90 \text{ m/s}$$

The actual velocity of flow comes out to be nearly the same as the critical velocity of 0.87 m/s. Hence, the assumed channel dimensions are in order.

Bed width = 21.90 m; Depth = 2.25 m.

Lacey's Theory

Gerald Lacey (1930) said, "A channel flowing in unlimited incoherent alluvium of the same grade as the material transported, if continued uninterrupted (i.e. the condition of discharge and silt remaining constant)" would attain of final regime conditions.

Lacey followed Lindley's hypothesis:

"dimensions and slope of a channel to carry a given discharge and silt load in easily erodable soil are uniquily determined by nature".

According to Lacey:

"Silt is kept in suspension by the vertical component of eddies generated at all points of forces normal to the wetted perimeter".

Regime Channel

"A channel is said to in regime, if there is neither silting nor scouring".

According to Lacey there may be three regime conditions:

(i) True regime;

(ii) Initial regime; and

(iii) Final regime.

When a balance silting and scouring and a dynamic equilibrium in the forces generating and maintaining the channel cross-section and gradient has been obtained, is said to have attained the true regime conditions.

(1) True regime

A channel shall be in 'true regime' if the following conditions are satisfied:

(i) Discharge is constant;

(ii) Flow is uniform;

(iii) Silt charge is constant; i.e. the amount of silt is constant;

(iv) Silt grade is constant; i.e., the type and size of silt is always the same; and

(v) Channel is flowing through a material which can be scoured as easily as it can be deposited (such soil is known as *incoherent alluvium*), and is of the same grade as is transported.

But in practice, all these conditions can never be satisfied. *And, therefore, artificial channels can never be in 'true regime'; they can either be in initial regime or final regime.*

Note:

1. There is only one section of the channel and only one slope at which the channel carrying a given discharge will carry a particular grade of silt.
2. If a channel is designed with a section too small for a given discharge and its slope is kept steeper than required, scour will occur till final regime is obtained.
3. If a channel is designed with a section too large for a given discharge and its slope is kept flatter than required, silting will occur till final regime is obtained.

(ii) Initial regime

- bed slope of a channel varies
- cross-section or wetted perimeter remains unaffected

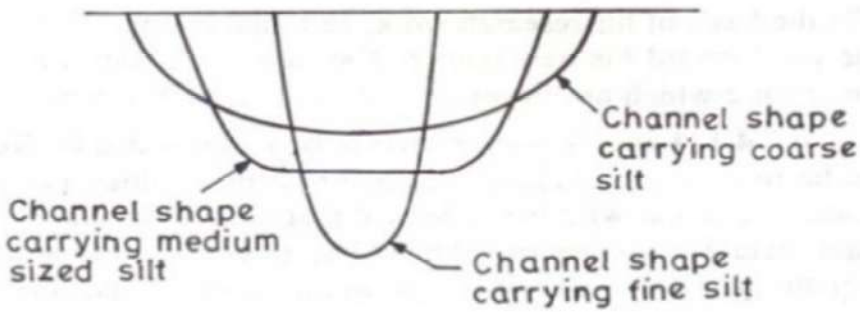
(iii) Final regime

- all the variables such as perimeter, depth, slope, etc. are equally free to vary and achieve permanent stability, called *Final Regime*.

In such a channel,

The coarser the silt, the flatter is the semi-ellipse.

The finer the silt, the more nearly the section attains a semi-circle.



Lacey's Regime Equations

Lacey originally gave two equations by plotting the actual observations. In metric units, these are,

$$U = \sqrt{2/5} \times \sqrt{f\,R} \qquad (i)$$

$$Af^2 = 140U^5 \qquad (ii)$$

where, U is velocity, f is the silt factor, R the hydraulic mean radius and A is the area of cross-section.

Perimeter Discharge (P-Q) Relation:

By combining these two equations as below, Lacey got an important relation $P = 4.75\sqrt{Q}$, in which P is the wetted perimeter and Q is the discharge. Raining both the sides of the eqn. (i) to the fourth power we get,

$$U^4 = {}^4/_{25}\, f^2R^2$$

Dividing equation (ii) by this result we get,

$$140U = 25/4 \times (A/R)$$

Multiplying both sides by A, we get

$$140\ UA = 25/4\ (A^2/R^2)$$

$$140\ Q = 25/4\ (P^2)$$

$$140\ U_A = 25/4\ (A^2/R^2)$$

$$P = 4.75\sqrt{Q} \qquad \text{(iii)}$$

V-Q-f relation: Multiplying both sides of equation (ii) by U, we get;

$$AUf^2 = 140U^6$$

$$Qf^2 = 140U^6$$

$$U = \left(\frac{Qf^2}{140}\right)^{\frac{1}{6}}$$

Regime flow equation: Lacey also obtained by plotting a large number of data, the relation,

$$U = 10.8\, R^{2/3} S^{1/3} \qquad \text{(iv)}$$

Cubing the equation both sides,

$$U^3 = 1260\, R^2 S$$

$$U^2 = 1260\, (R/U) RS$$

$$U = 35.5\sqrt{(R/U)}\sqrt{RS}$$

Regime, scour depth relations: As already derived,

$$\frac{25}{4}\left(\frac{A^2}{R^2}\right) = 140\, UA$$

Putting , $A = PR$, we have

$$P = R\,U$$

Substituting the value of P as 22.5 RV in the eqn. (iii) we have,

$$22.5\ R\ U = 4.75\sqrt{Q}$$

Hence, $$R\ U = q = \left(\frac{4.75}{22.5}\right)\sqrt{Q}$$

where 'q' is the discharge intensity per meter width

$$q = 0.21\sqrt{Q} \qquad (v)$$

Using eqn. (i)

$$R\sqrt{2/5}\sqrt{fR} = 0.21\sqrt{Q}$$

$$R = 0.47\ (Q/f)^{1/3} \qquad (vi)$$

From eqn. (v)

$$Q = (q/0.21)^2$$

Substituting in eqn. (vi) we get,

$$R = \{0.47/(0.21)^{2/3}\} \times (q^2/f)^{1/3}$$

$$R = 1.35\ (q^2/f)^{1/3}$$

Regime slope equations (S-q and S-Q relations):

Cubing eqn. (iv) and transposing

$$S = \frac{V^3}{1260R^2} = (U^2/R)^{\frac{5}{3}} \times 1260 \left(\frac{R}{U}\right)^{\frac{1}{3}}$$

From equation (i), $\frac{U^2}{R}$ = 2/5f. Substituting 2/5f for $\frac{U^2}{R}$ and q for RV, we have,

$$S = \left(\frac{2f}{5}\right)^{\frac{5}{3}} \frac{1}{1260q^{\frac{1}{3}}}$$

$$S = \frac{0.000178}{q^{\frac{1}{3}}} \times f^{\frac{5}{3}}$$

The equation represents the regime slope in terms of discharge per unit width. The slope can also be expresses in terms of total discharge.

$$S = \frac{0.000178}{q^{\frac{1}{3}}} \times f^{\frac{5}{3}} = \frac{0.000178}{(0.21)^{1/3}}\left(\frac{f^{5/3}}{Q^{1/6}}\right)$$

$$S = \frac{f^{5/3}}{3340Q^{1/6}}$$

Silt factor, grain size relation (f-$\mathbf{M_r}$ −Relation)

According to Lacey, the silt factor 'f' is dependent on the average size of the boundary material M_r in the channel and are related as given below

$$f = 1.76\sqrt{M_r}$$

Mr is the average size in mm and its value for different materials is given below:

Lacey's Silt factor for different materials		
Type of material	Size of grain in mm	Silt factor "f"
Silt		
Very Fine	0.052	0.40
Fine	0.081	0.50
Fine	0.120	0.60
Medium	0.158	0.70
Standard	0.323	1.00
Sand		
Medium	0.505	1.25
Coarse	0.725	1.50
Bajri and Sand		
Fine	0.888	1.75
Medium	1.290	2.00
Coarse	2.422	2.75
Gravel		
Medium	7.280	4.75
Heavy	26.100	9.00
Boulders		
Small	50.100	12.00
Medium	72.500	15.00
Large	183.800	24.00

Lacey's Equations:

Fundamental Equations:

$$V = \sqrt{\frac{2}{5} fR} \text{ or } f = \frac{5}{2}\frac{V^2}{R}$$

$$Af^2 = 140V^5$$

$$V = 10.8R^{2/3}S^{1/2}$$

where $f = 1.76\sqrt{D_{50}}$,

D_{50} is average grain/particle size in mm

Derived Equations:

$$P = 4.75\sqrt{Q}$$

$$V = \left[\frac{Qf^2}{140}\right]^{1/6}$$

$$S = \frac{f^{3/2}}{4980R^{1/2}}$$

$$S = \frac{f^{5/3}}{3340Q^{1/6}}$$

$$V = \frac{1}{N_a} R^{3/4} S^{1/2}$$

(Lacey's Non-regime flow equation)

The equations for determination of Velocity, Slope, etc are function of the silt factor, whereas silt factor is function of sediment size.

For upper Indus basin, f = 0.8 to 1.3

For Sindh plain, f = 0.7 to 0.8

$$\text{Lacey's Normal Regime Scour Depth} = 0.473\left(\frac{Q}{f}\right)^{1/3}$$

The above scour depth will be applicable if river width follows the relationship $P = 4.75\sqrt{Q}$

For other values of active river width,

$$\text{Lacey's Normal Scour Depth} = 1.35\left(\frac{q}{f}\right)^{1/3}, \quad q = \frac{Q}{L}$$

where

q = discharge intensity, and

L = actual river width at the given site

Lacey's Channel Design Procedure

(1) Calculate the velocity from equation

$$V = \left[\frac{Qf^2}{140}\right]^{1/6} \text{ m/sec.}$$

where Q is in cumecs :
V is in m/s ; and
f is the silt factor, given by

$$f = 1.76 \cdot \sqrt{d_{mm}}$$

where d_{mm} = Average particle size in mm

(2) Work out the hydraulic mean depth (R) from the equation

$$R = \frac{5}{2}\left(\frac{V^2}{f}\right)$$

where V is in m/sec ;
R is in m.

$$D = \frac{P - \sqrt{P^2 - 6.944A}}{3.742}$$

$$B = P - \sqrt{5}D$$

(3) Compute area of channel section $A = \frac{Q}{V}$

(4) Compute wetted perimeter, $P = 4.75\sqrt{Q}$

(5) Knowing these values, the channel section is known ; and finally the bed slope S is determined by the equation

$$S = \left[\frac{f^{5/3}}{3340\, Q^{1/6}}\right]$$

Problem: Design a regime channel for a discharge of 40 cumec with silt factor = 0.9 by Lacey's theory

Solution: Q = 40 cumec and f = 0.9

$$V = \left(\frac{Qf^2}{140}\right)^{1/6} = 0.783 \text{ m/s}$$

$$R = 2.5\frac{V^2}{f} = \frac{(2.50 \times 0.783^2)}{0.9} = 1.70 \text{ m}$$

$$P = 4.75\sqrt{Q} = 4.75\sqrt{40} = 30 \text{ m}$$

$$P = B + \sqrt{5}D = 30.0 \qquad \text{(i)}$$

$$A = BD + \frac{D^2}{2} = Q/V = 40/0.783 \qquad \text{(ii)}$$

Solving equations (i) and (ii), we get,

B = 26.7 m

D = 1.925 m

$$S = \frac{f^{5/3}}{3340Q^{1/6}} = \frac{0.9^{5/3}}{3340 \times 40^{1/6}} = 1/6670 = 15\text{cm/km}$$


THANK YOU

LECTURE ON IRRIGATION ENGINEERING

By-
Prof. ShriRam

What is Irrigation

- **Irrigation** is the artificial application of water to the soil through various systems of tubes, pumps, and sprays.
- **Irrigation** is usually used in areas where rainfall is irregular or dry times or drought is expected. There are many types of **irrigation** systems, in which water is supplied to the entire field uniformly.
- **Irrigation** is the process of applying controlled amounts of water to plants at needed intervals.
- **Irrigation** is important to a country like **India** because rainfall here is seasonal in nature. It is limited to four months of a year. It is also important because some crops require more water than what it is provided by the rainfall, therefore we have to depend on **irrigation**.

- **Objective of irrigation engineer?**

- To make water available to the cultivator with respect to location, time and quantity as per crop requirement.
- He has essentially to be associated with investigation, planning, design, construction, operation and maintenance of dams and their appurtenant works; canal system and hydraulic structures.

- Irrigation engineering is thus multi-disciplinary science encompassing hydrology, agriculture, geology, climatology, river engineering, agronomy, forestry, social science, hydraulics, river soil mechanics, snow hydrology and groundwater hydrology.

Need for Irrigation

1. ***Deficient Rainfall-*** When rainfall is less than 100cm, irrigation water is required

Rainfall (cm)	Irrigation Requirement
100	Rainfall needs to be supplemented by irrigation
100-50	Rainfall is insufficient. Irrigation is essential
50-25	Irrigation is essentially required
Less than 25	No crop can be grown without irrigation

2. ***Non-uniformity of rainfall-*** Where rainfall is sufficient but is not uniform.
3. ***Augmentation of crop yields-*** New high yielding varieties of crops have higher water requirement for giving higher yields. Sugarcane and Rice have higher requirement of water.
4. ***Exacting water requirement-*** The high yielding variety crops have more exacting requirement of water.
5. ***Cash crops cultivation-*** Cash crops require higher and assured supply of water with frequent waterings for maturity.
6. ***Assured water supply-*** For successful farming, availability of water in needed quantum and at right times is very essential
7. ***Orchards and gardens-*** Fruit trees grown in orchards and gardens have higher requirement of water.

Advantages and Disadvantages of Irrigation

Advantages

Direct Benefit

- Increase in food output
- Cultivation of cash crops
- It can increase value of land
- Protection from famine-irrigation
- Prevention of damage through floods
- Domestic water supply to towns and villages
- Hydel power generation at dam site
- Rise in subsoil water level in dry areas
- Means of communication
- Revenue from recreation facilities etc.

Indirect Benefit

- Increase in gross domestic product
- Increase in revenue from sales tax
- Increase in employment
- Improvement in groundwater storage
- Increased revenue to govt.
- Increase in value of land property
- General development of country
- Farm laborers are benefited
- Creation of more jobs and income
- Rise to whole array of agro-based industries.

Disadvantages

- Climate becomes damp and cold, causing malarial diseases
- Over-irrigation coupled with poor drainage in an areas where water-table is high leads to waterlogging of the area; and cause efflorescence.
- Low land revenue in certain cases where irrigation is extended as a protective measures.
- Excessive seepage from unlined canals leads to waterlogging of lands adjacent to canals.

Classification of irrigation

1. Classification Based on Source of water

i. Direct irrigation Project: Water is directly diverted from the river into canal by the construction of a diversion weir or barrage across the river

ii. Indirect Irrigation Project: Water stored in a reservoir with the construction dam across the river to provide dependable supply onto the offtaking canals.

2. Classification Based on Purpose served

i. Single Purpose Irrigation Project

ii. Multipurpose Irrigation Project

3. Classification Based on Administrative Convenience

Irrigation Projects are divided into the following three categories viz., Major, Medium and Minor Projects. The criteria of classification is as under:

- ✓ Projects having CCA more than 10,000 ha. are classified as **Major Project**
- ✓ Projects having CCA more than 2,000 ha. to 10000 ha. are classified as **Medium Projects**
- ✓ Projects having CCA less than 2,000 ha. are classified as **Minor Projects**

4. Classification Based on Financial Return

i. Productive Irrigation Projects: Benefit cost ratio in respect of which is **not less than 1.5**

ii. Unproductive Irrigation Projects: Benefit cost ratio in respect of which is **less than 1.5**

iii. Protective Irrigation Projects: Unproductive but taken up as for protection against famine

5. Classification Based on Physical Criterion

River Behaviour and River Management

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River ?

What is the importance of Study of River Behaviour and its Management???

Importance of Study of River Behaviour and Management...

Importance of Study of River Behaviour and Management...

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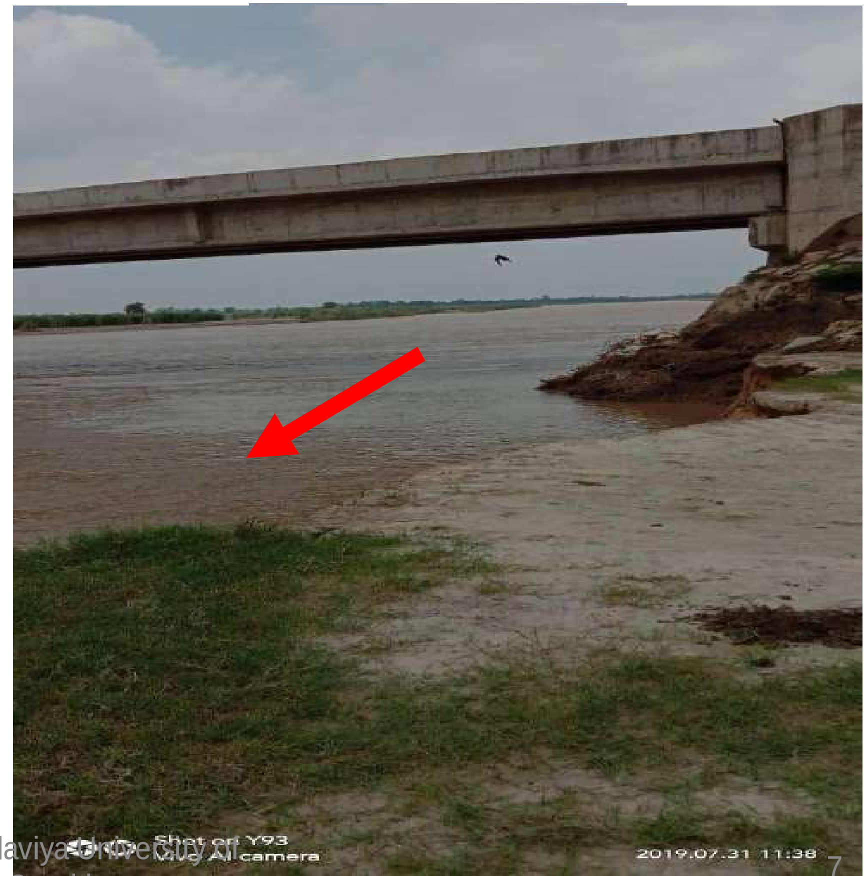
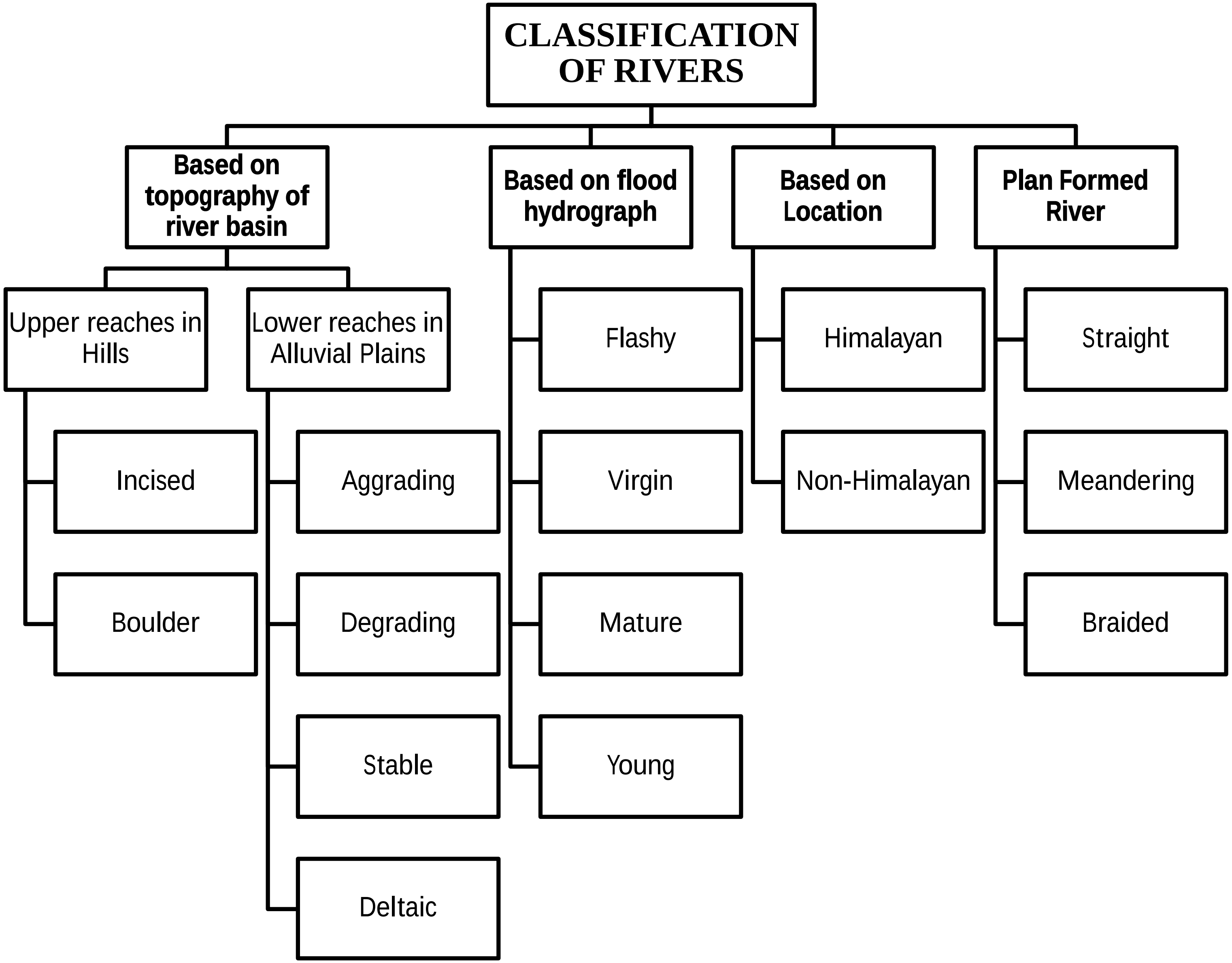
Importance of Study of River Behaviour and Management...



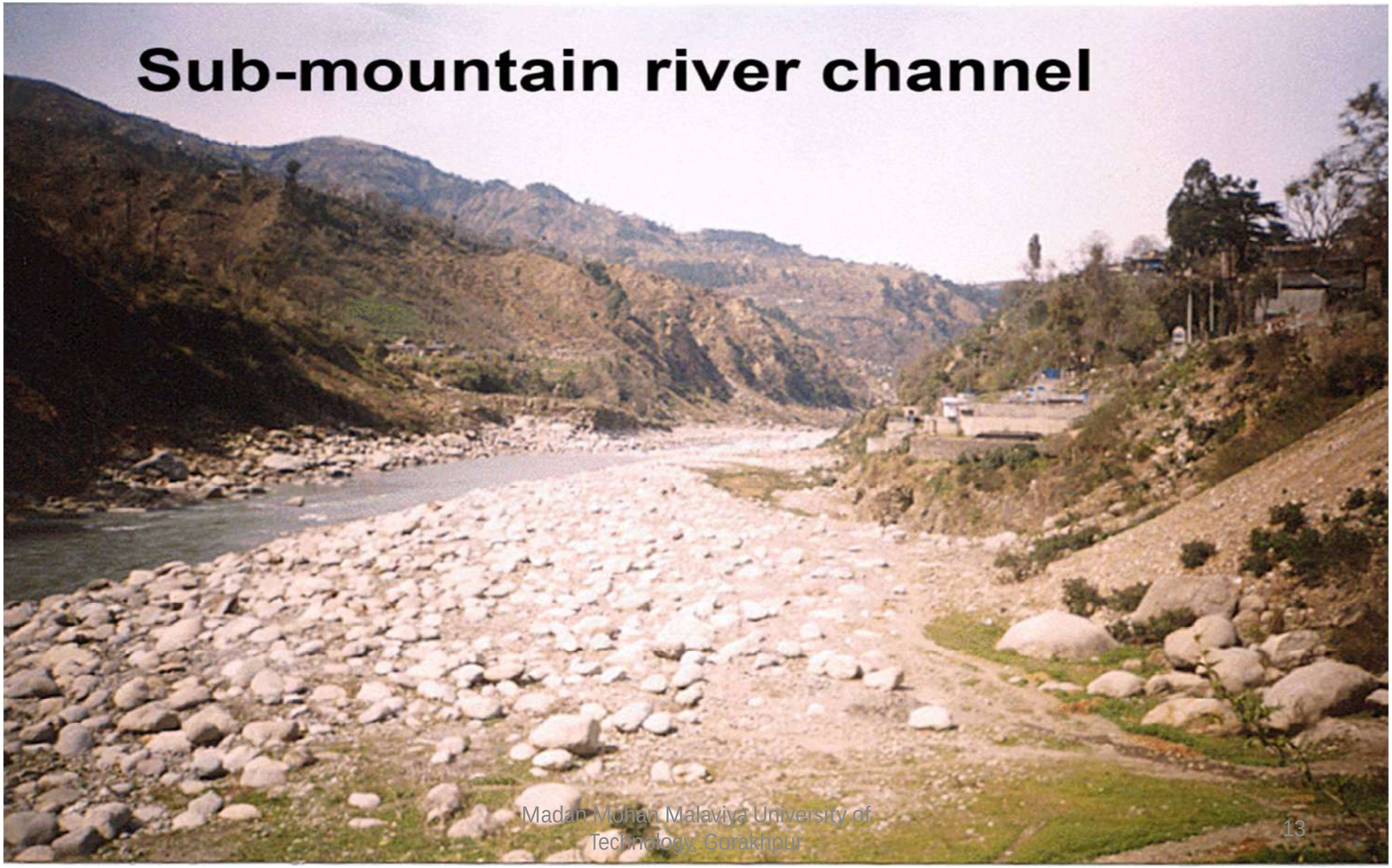
River Behaviour
and
River Management


CLASSIFICATION OF RIVERS
Based on topography of river basin
Upper reaches in Hills
Incised
Boulder
Lower reaches in Alluvial Plains
Aggrading
Degrading
Stable
Deltaic
Based on flood hydrograph
Flashy
Virgin
Mature
Young
Based on Location
Himalayan
Non-Himalayan
Plan Formed River
Straight
Meandering
Braided

Classification of Rivers

Based on topography of River Basin


River channel
in hills


Sub-mountain river channel

Rivers in Hills

(Rivers in Upper reaches of Hilly Areas)

Incised River

Boulder River

Incised River

- Formed by the process of degradation.
- Well defined narrow cross section cut through hill gorges.
- Rocky Bed.
- Clear Water mostly snow water.
- Swift Flow.
- Steep Bed Slope 1 in 100 to 1 in 500.
- Sediment transport is often dissimilar in character to that of the river bed.
- Rate of bed load cannot be determined, as it is a function of bed characteristics.
- Pattern of meanders is not regular due to varying resistance of bed and banks to erosion which vary along their lengths.

Boulder River

- Flows through sub-mountainous tract.
- Remains confined in the valley due to well defined cross-section.
- Steep Bed Slope 1 in 100 to 1 in 500.
- Velocities are high but lesser than in mountain range.
- Water is clear except rainy season.
- Larger deposits are accommodated by the river digging in deeper in valley.
- Boulders deposit themselves in the reach, and other finer materials are carried down to the plains.
- It flows through wide shallow bed and develops straight course.
- Bed material is pervious giving rise to a strong subsoil flow.

Rivers in Plains

(Alluvial River)

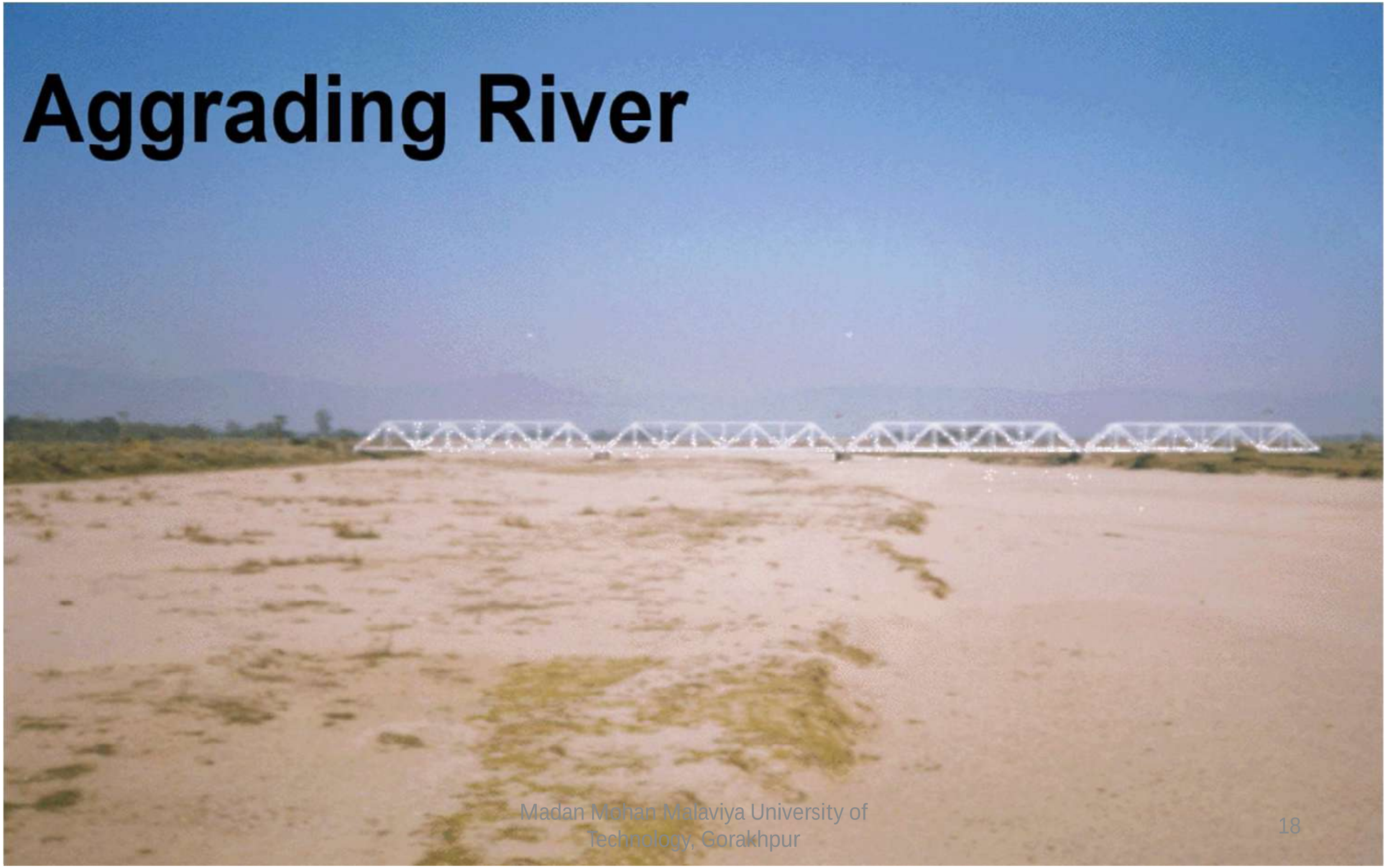
- River flows through deposits created by itself and is constantly building its flood plain by overflowing.
- Sediment transport except wash load is similar to that in its bed and banks.
- It follows a zigzag course i.e. it Meanders.
- Shape of cross-section and bed slope are determined by the relative sediment load and the erodibility of bed and banks.
- The river runs on relatively flat ground and finer materials settle down.
- Material is deposited by the river during the alternate processes of spreading and receding to form alluvial valleys which are now Indo-Gangetic Plains.
- In the deposits laid by the river itself, the river itself carves its own deep winter channel and a flood way or a khadir width.
- Meanders also travel down and during the course of adjustment form cutoffs as well.
- When in flood, river inundates large areas causing considerable damage.

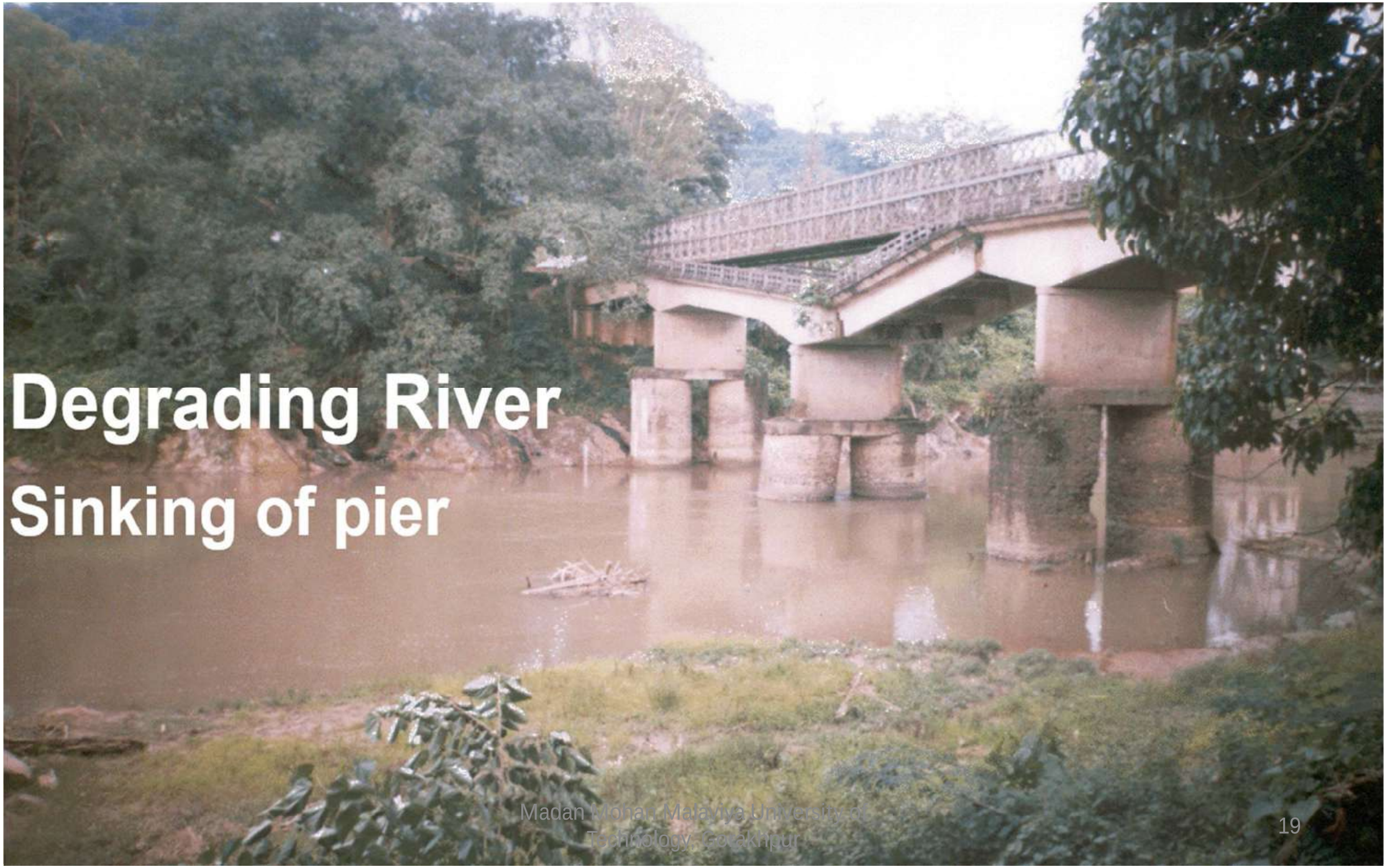
Aggrading River

- Aggrading River is in the process of increase or rise in specific levels of bed of a channel at any site.
- Chief reasons for aggradation are: heavy load carried by river, Obstruction by dam or a barrage across it, extension of the delta at the river mouth, sudden intrusion of sediment from a tributary.

Degrading River

- Degrading river get their bed scoured from year to year.
- It is either above a cutoff or below a dam or barrage.
- There is a sudden lowering of the water surface upstream of the cutoff which increases its slope of flow, and there is a sudden diminution of its sediment load.


Aggrading River


Degrading River
Sinking of pier

Lane’s Weight Balancing Theory

- The response of a stream to watershed changes has been expressed by hydraulic engineer E.W. Lane as a **Stream Balance Equation** (Lane, 1955).
- Lane concluded that a ***stream’s energy***, a function of *speed* and *volume of water*, must be in balance with the size and volume of sediment carried by the stream.
- In practical terms, this means that if either the volume of water (increased runoff) or velocity of water (steeper slope usually caused by channelization) increases, then the stream will need to carry more sediment to balance the increased energy.
- The usual source for the additional sediment is either from the stream bottom or the stream banks resulting in severe erosion.
- Conversely, if sediment load exceeds the available energy to transport it, then the stream aggrades, or fills in, causing loss of capacity and increased flooding.

Lane’s Weight Balancing Theory…

- Lane (1955) studied the changes in river morphology in response to verging and sediment discharge.
- These studies support the following general relationships:
  - The depth of flow $H \propto Q$ (Water Discharge).
  - Channel width (W) $\propto$ to both Q and Q_s.
  - Channel Shape: expressed as width to depth W/h ratio $\propto$ sediment discharge.
  - Channel slope (S) $\propto 1 / Q$
  - Channel slope (S) $\propto$ sediment discharge and grain size d_{50}.
  - Sinuosity $_{(s)} \propto$ valley slope.
  - Sinuosity $_{(s)} \propto 1 / Q_s$.
  - Transport of bed material $Q_s \propto$ Stream Power $\tau_o U$ and concentration of fine material C_F.
  - Transport of bed material $Q_s \propto 1 /$ fall diameter of the bed material d_{50}.

Lane's Weight Balancing Theory…

Simon (1975)

$$Q_S \sim [(\tau_o U) W C_F] / d_{50}$$

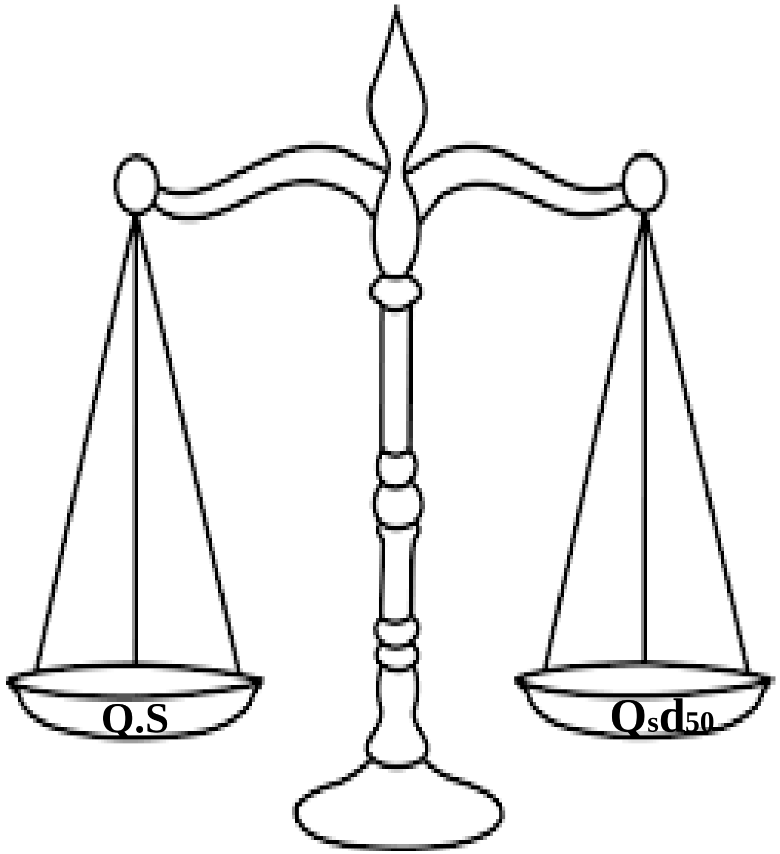
$$\tau_o = \gamma H S \text{ and } Q = AV = WHV$$

From continuity,

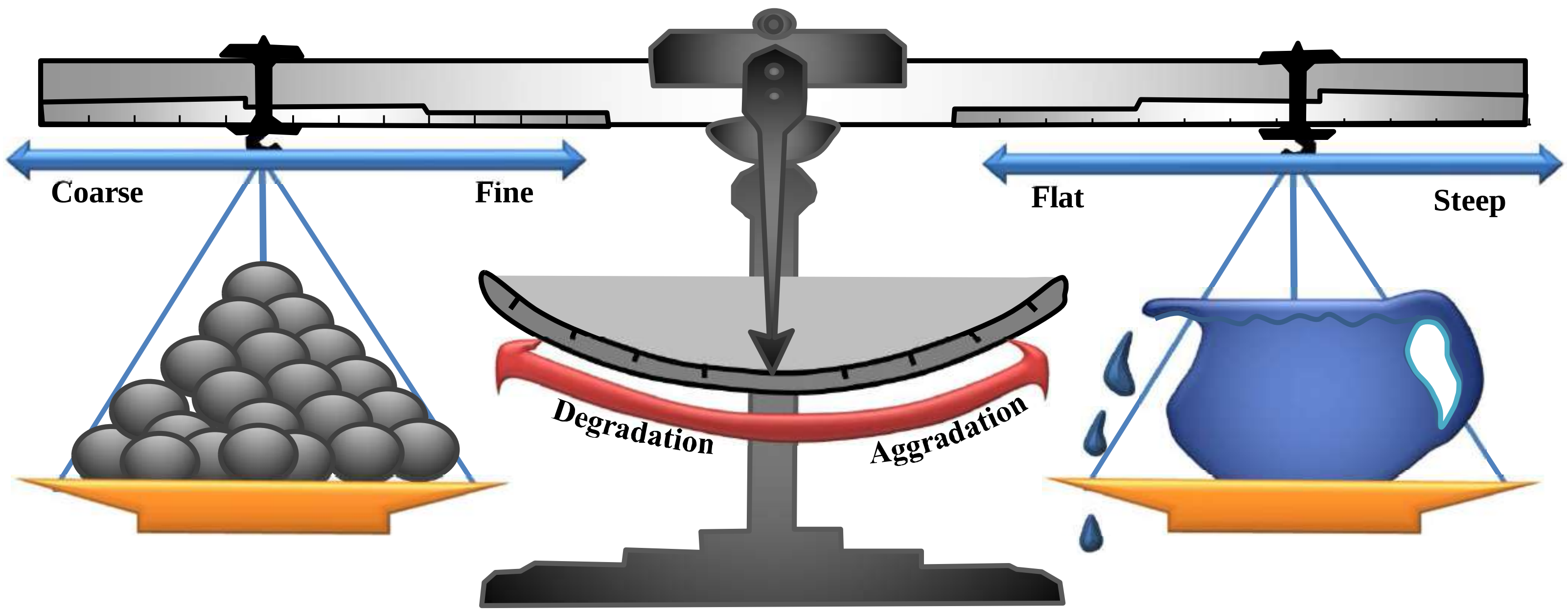
$$Q_s \sim \gamma HSWU / (d_{50}/C_F) = \gamma QS / (d_{50}/C_F)$$

If specific weight s is assumed constant and the concentration of fine material CF is incorporated in the fall dia, this relation can be expressed as

$$\mathbf{Q.S \sim Q_s d_{50}}$$



Lane's Weight Balancing Theory…



Q_sD_{50} Q_wS

Stream balance equation (Lane, 1955), where Qs is sediment discharge, D50 is median grainsize of bottom sediment, Qw is water discharge, and S is slope of stream

Stable River

- A river stream which as whole maintains its slopes , depths and channel dimensions without any noticeable raising or lowering of its bed from year to year. It may however migrate within its Khadir.

Deltaic River

- It is the reach of a river when it approaches the sea with very gentle slope(1 in 5000 to 1 in 10000) and velocity, drops down the sediment and divides into channels on either side of the deposits resulting in the formation of deltas.


Stable river

Classification of Rivers
Based on Flood Hydrograph

Flashy River

- A flashy river stream is one which has rise and fall of floods. The flow collects rapidly from the steep slopes of the catchment and flood peaks occur soon after rain. Flood hydrograph is very steep indicative of sudden flood

Virgin River

- Virgin river is one which dries up in arid zones before joining another river or sea. The flow in the river dries due to high percolation and evaporation losses after flowing a certain distance from the source. They are found in Kutch and Rajasthan.


Flashy Rivers in the hills

Virgin River

Mature River

- A river which flows through certain fixed limits is mature river. The limits are called Khadir.

Young River

- A river is young is young, in geological terms when it is actively eroding its channel.

Classification of Rivers Based on Location

Himalayan River

- They takeoff from Himalayas.
- Fed by melting of snow and rainfall.
- Perennial and carry fine silt and clay forming new lands by eroding some.
- Flood discharge is 50-100 times normal winter flow.
- Due to considerable variation in normal and flood discharges the rivers maintain a deep winter channel and a wider Khadir width for the passage of floods.
- They carry heavy sediment loads because of soft, friable Himalayan Rock.
- Seismic disturbances loosen the friable rock leading to landslips and consequently increased sediment load.
- Rivers of Chenab basin, All Rives of North India like Ganga, and Brahmaputra, Beas, Sutlej, Kosi etc.

Boulder River

- They are not snowfed.
- Receive supply from monsoon and by regeneration of water during dry periods.
- Non-perennial.
- They are more stable than Himalayan rivers because of flow through non-alluvial soils.
- They traverse Central and South India.
- They originate in Aravali, Vindhya, Satpura and Sahyadri ranges.
- Mahandi, Brahmani, Damodar, Suberuarekha, Vaitarui, Godavari, Krishna, Pennar and Cauvery to the west and Krishna, Godavari, and Mahanadi to east.

Major Rivers
INDIA
N
JAMMU & KASHMIR
Indus
Jhelum
Chenab
Ravi
Beas
HIMACHAL PRADESH
CHANDIGARH
PUNJAB
Satluj
PAKISTAN
CHINA (TIBET)
UTTARANCHAL
HARYANA
DELHI
Yamuna
Ganges
Gandak
NEPAL
Kosi
SIKKIM
BHUTAN
Siang
Lohit
ARUNACHAL PRADESH
Brahmaputra
ASSAM
NAGALAND
MEGHALAYA
MANIPUR
RAJASTHAN
Luni
Chambal
UTTAR PRADESH
BIHAR
GUJARAT
Saraswati
Narmada
MADHYA PRADESH
JHARKHAND
WEST BENGAL
TRIPURA
MIZORAM
Mahanadi
Tapi
CHHATTISGARH
ORISSA
MYANMAR
BANGLADESH
DIU
DAMAN
DADARA & NAGAR HAVELI
Godavari
MAHARASHTRA
Bhima
Krishna
ANDHRA PRADESH
YANAM (Pondicherry)
BAY OF BENGAL
ARABIAN SEA
GOA
KARNATAKA
Payaswani
Kaveri
LAKSHADWEEP
MAHE (Pondicherry)
PONDICHERRY (Puduchchery)
KARAIKAL (Pondicherry)
TAMILNADU
KERALA
ANDMAN & NICOBAR ISLANDS
State Boundary
Rivers
Map not to Scale
Copyright © 2006. Compare Infobase Pvt. Ltd.

Behaviour of Rivers

Behaviour of Rivers

- It is affected by silt-laden flow through the action of sediment deposition on river beds and raising them.
- This increases flood heights , causing inundation of areas and also huge sediment accumulation behind dams, thereby reducing their capacities, causing rivers to meander and to leave their original course often and flow along new courses.
- It results in the devastation of habitable an agricultural lands and silting up the irrigation and navigation canals, threatening safety of bridges and hydraulic structures.
- The beneficial aspect of the silt laden water passed down the canals is its manurial value.

Straight Reaches

- In a straight river reach, the river section is of trough shape with the high velocity flow in the mid section.
- Water Surface in the centre of the river is lower than that at the sides causing a transverse gradient from the sides towards the centre.
- Narrow deep rivers carrying moderate sediment cannot be straight but wide and shallow channels may carry heavy sediment load can be straight.

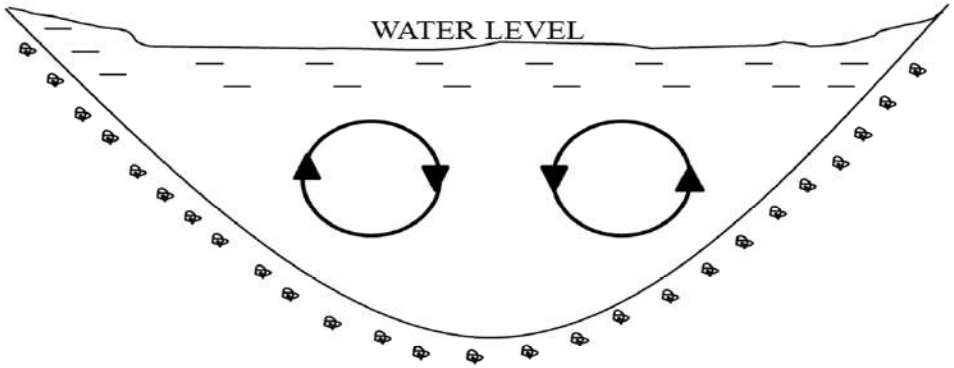


Fig: Transverse currents in a regular cross section and straight channel

Bends

- Alluvial rivers tend to develop bends which are characterized by scouring and erosion on the concave side and shoaling on the convex side.
- The flow is subjected to centrifugal forces and as a consequence, there is a transverse slope of water surface from the inner bank towards the outer bank. Thus at any level greater pressure is created near the outer bank than near the inner bank.
- Water in order to keep its own level, tends to flow from convex side, the places of higher free level, to concave side, the places of lower free level. However this moment is prevented along the water surface by centrifugal forces.
- At the bottom, the velocities are considerably slack than at the top, and enough centrifugal force is not available to counter the tendency of water move inwards. Hence, top water dives in at the concave (outer) bank and flows along the bottom carrying therewith sand and silt to the convex (inner) bank, where it is deposited.

- This rotary action brings about erosion of concave bank and deposition of sediment towards convex side where shoaling takes place. The action is further accentured on a bank slope, where the resistance of sediment particles to motion is reduced by sliding due to gravity.
- When once a bend is established, the flow tends to make its curvature larger.

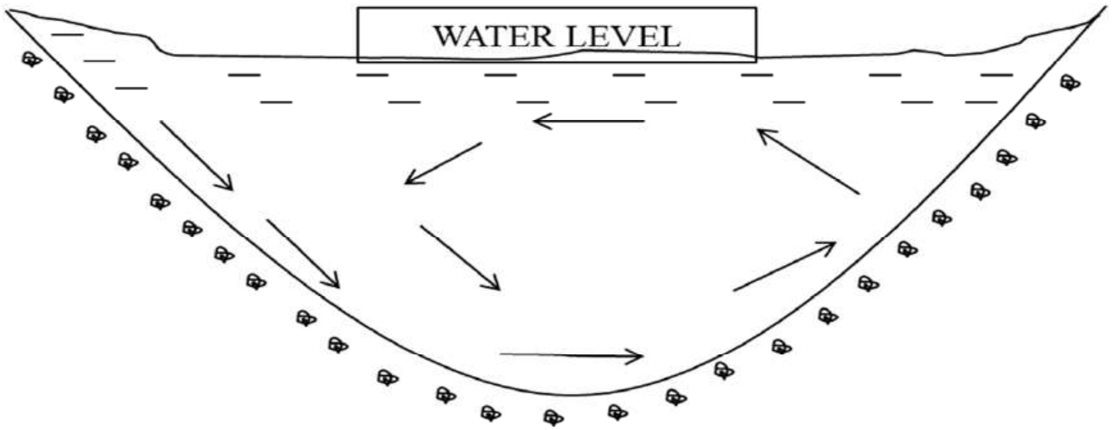


Fig: Helical movement of water on a curved channel

River Regime Theory

Earth’s Rotation Theory

- Earth moving round itself has a rotary motion.
- The flow in rivers running north or south does not acquire the same rotary motion as does the land and attack their west bank due to earth’s rotation bringing them against the current.
- This assumption is however not tenable and the theory is not in use.

Elli’s Tributary River Regime Theory

- A river bends to infalls of the tributaries owing to its bank being there blank and weak, the tributary forming a channel on that side.
- In order to control the river, some points should be fixed and neither any tributary enters it nor does any canal take off except at fixed points.
- No stream coming in on either side, straight well defined channel.
- Stream coming in on one side- a well defined channel on the other side only.
- Streams coming on both sides- an ill-defined channel and a shoal formation in midstream.

Molley’s River Regime Theory

- River bends alternatively from one bank to another.
- The characteristics of each bend are that there is deep water at the crest of bend and shallow crossings or bars are formed in the lengths where the river changes over from one side to the other due to the deposition of silt in the bed.
- The bars are formed by the action of the side channels. The side channels have offtakes and outfalls.
- The withdrawal of discharge into side channel at the offtakes brings about reduction in velocity in the main stream resulting in deposition of silt forming bars.
- Between main river and the side channel there are islands which are formed when flood recedes and river separates into main and side channels.

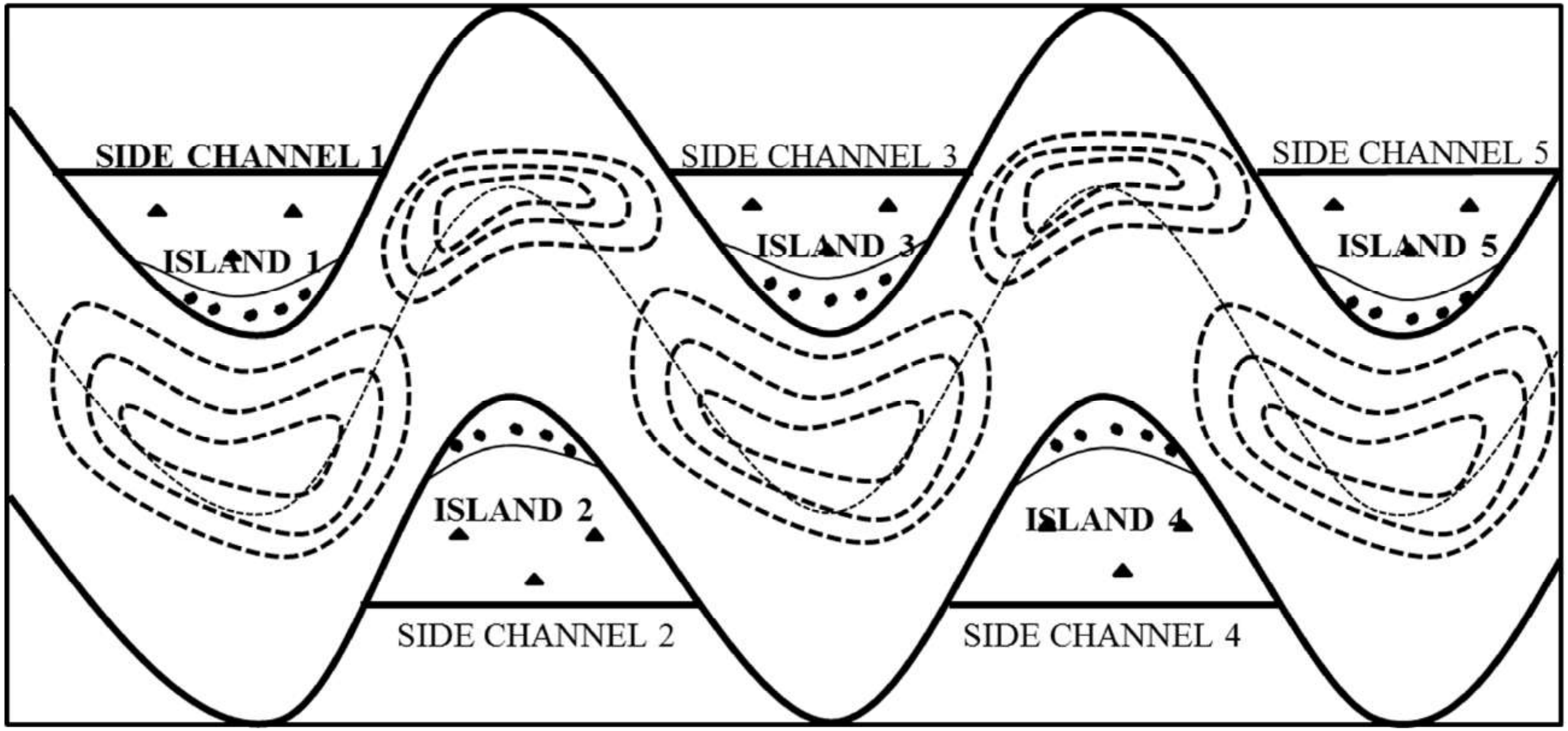


Fig: Plan of River

Oldham's River Regime Theory

- Every stream tends to be in an equilibrium condition in which the velocity is just sufficient to carry its solid burden. An excessive velocity shall scour the bed, thereby reducing gradient velocity and silt transporting power; while a lesser velocity shall entail the silt deposition, reduction in section and increased velocity required to transport silt.
- Every stream is alternatively collected into a single well-defined channel, called reach, or spread forming a fan. These fans can be seen when the river dries up in winter.
- The gradient of stream is not uniform. The bed is flatter in reaches and steeper in fans relative to the mean gradient. Fans are shallow and have reduced velocity.
- Both reach an fan work gradually upstream. Reach encroaches the upper fan by erosion and is encroached upon by the lower one by silting.

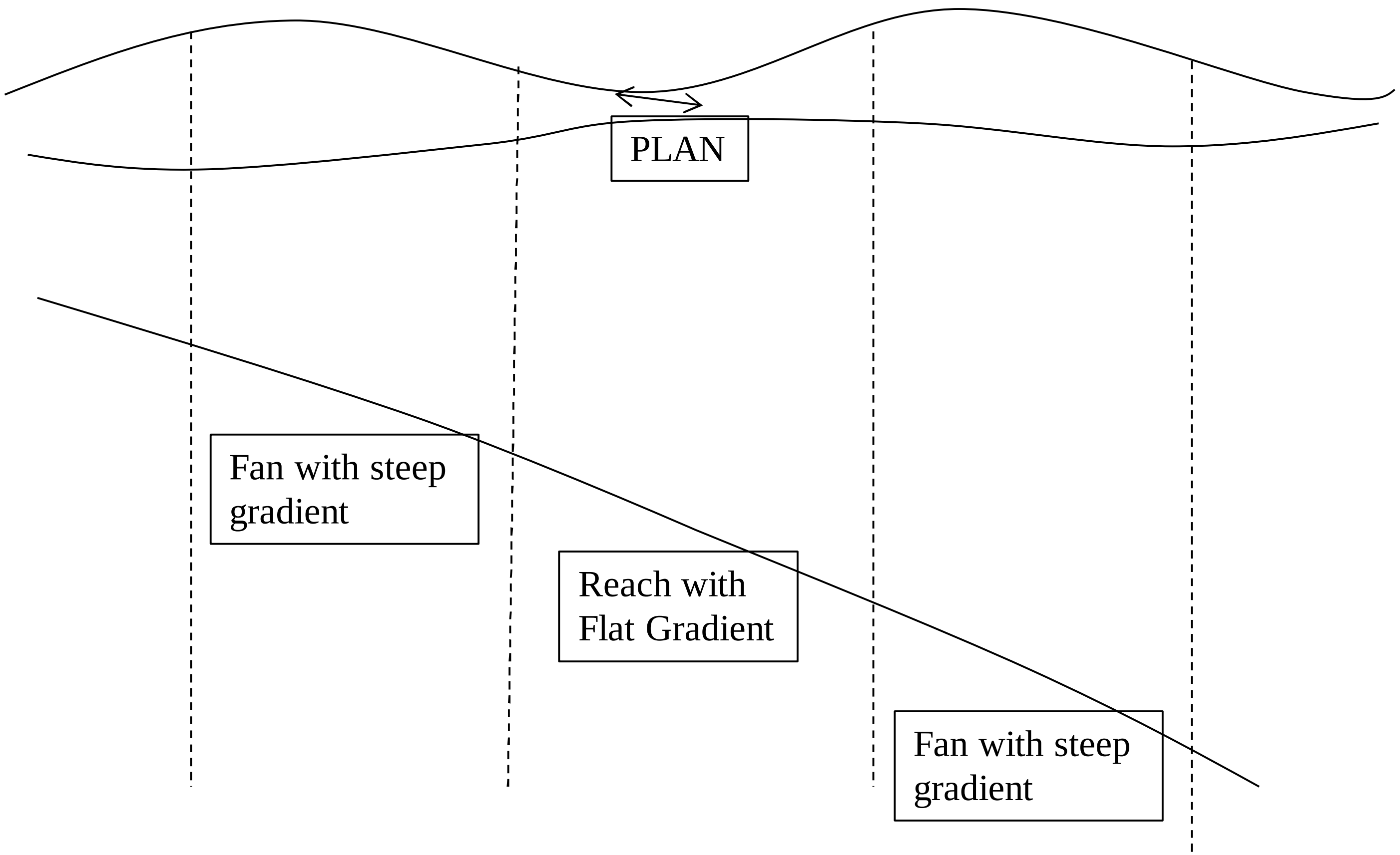
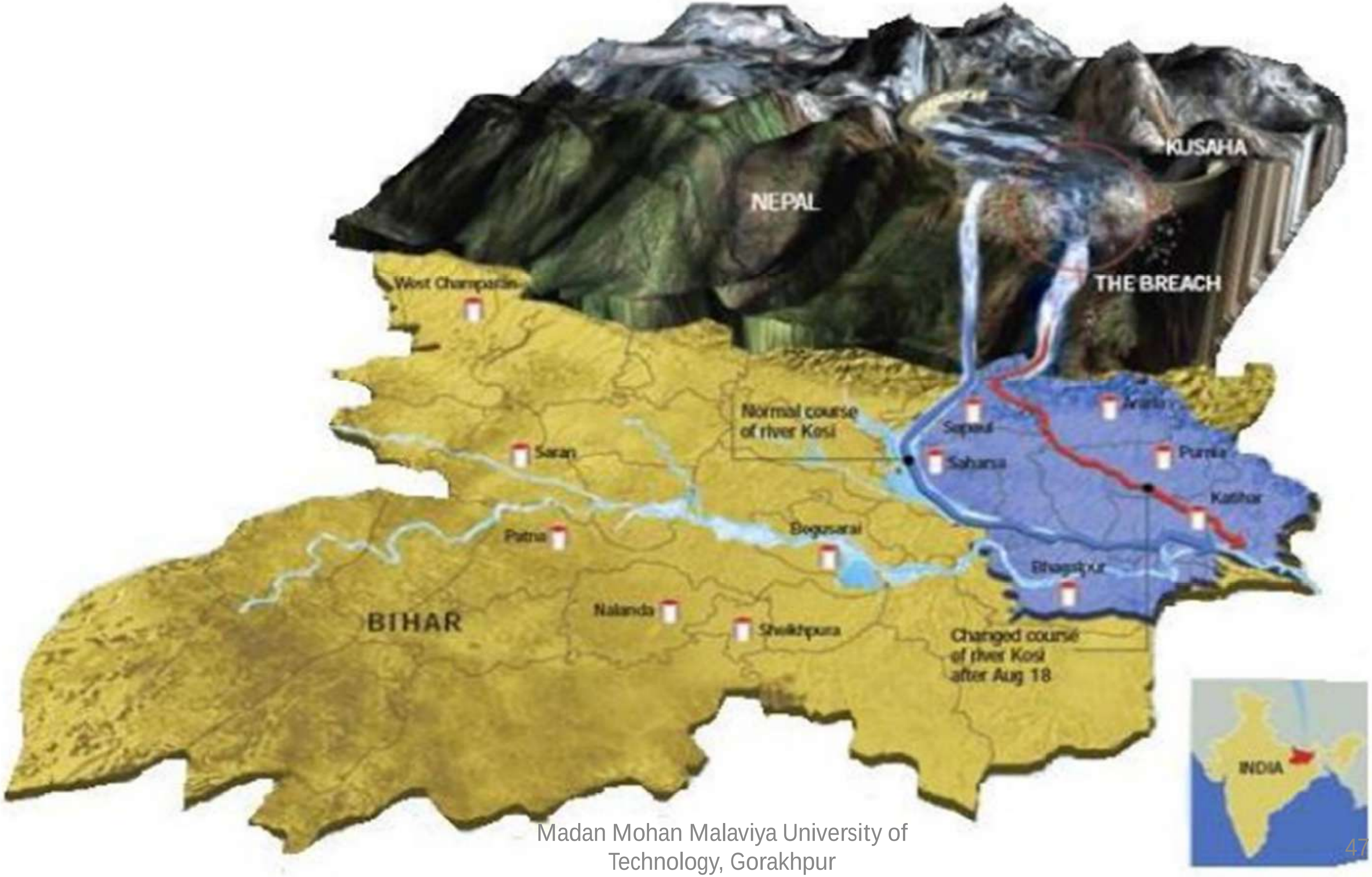
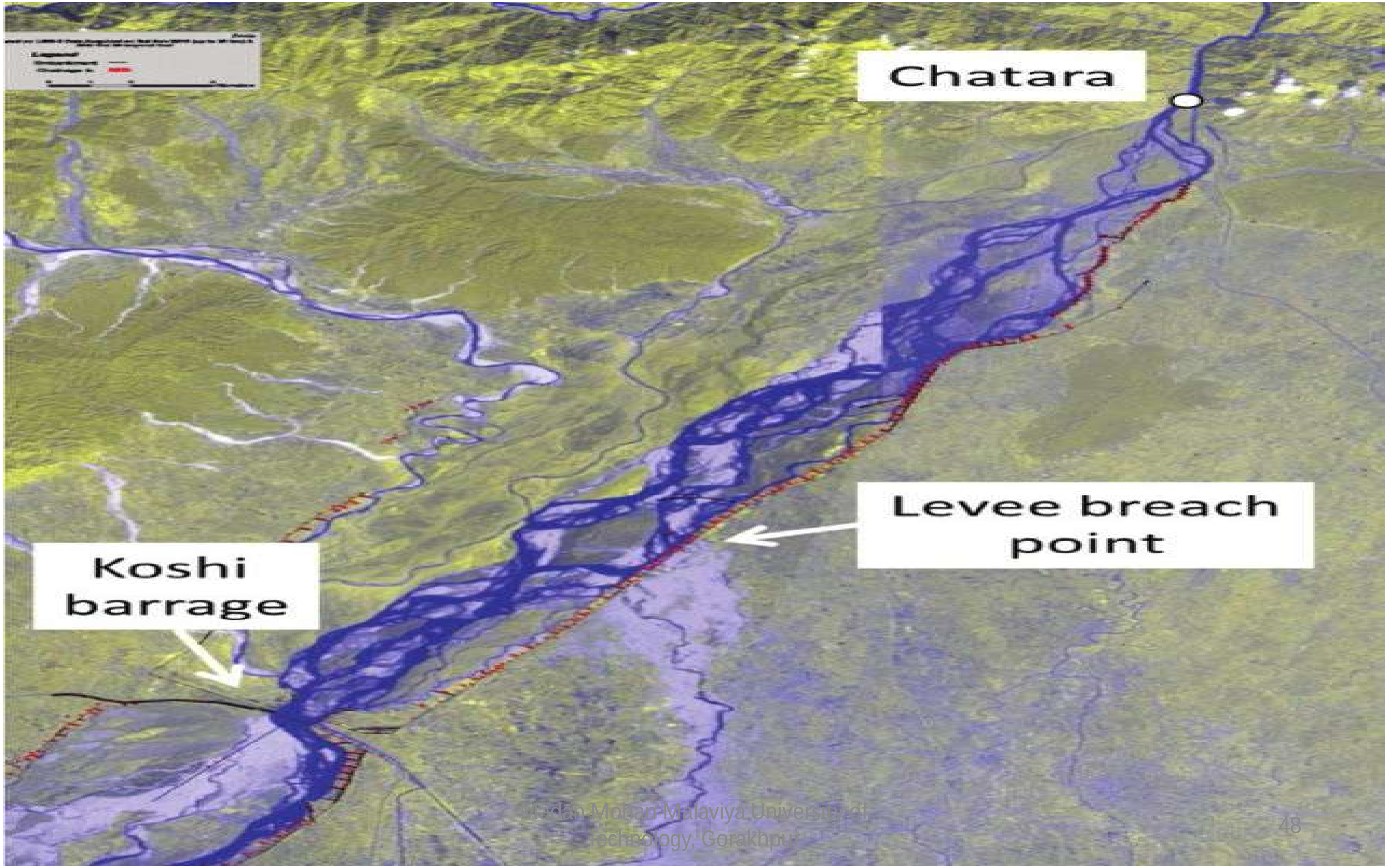
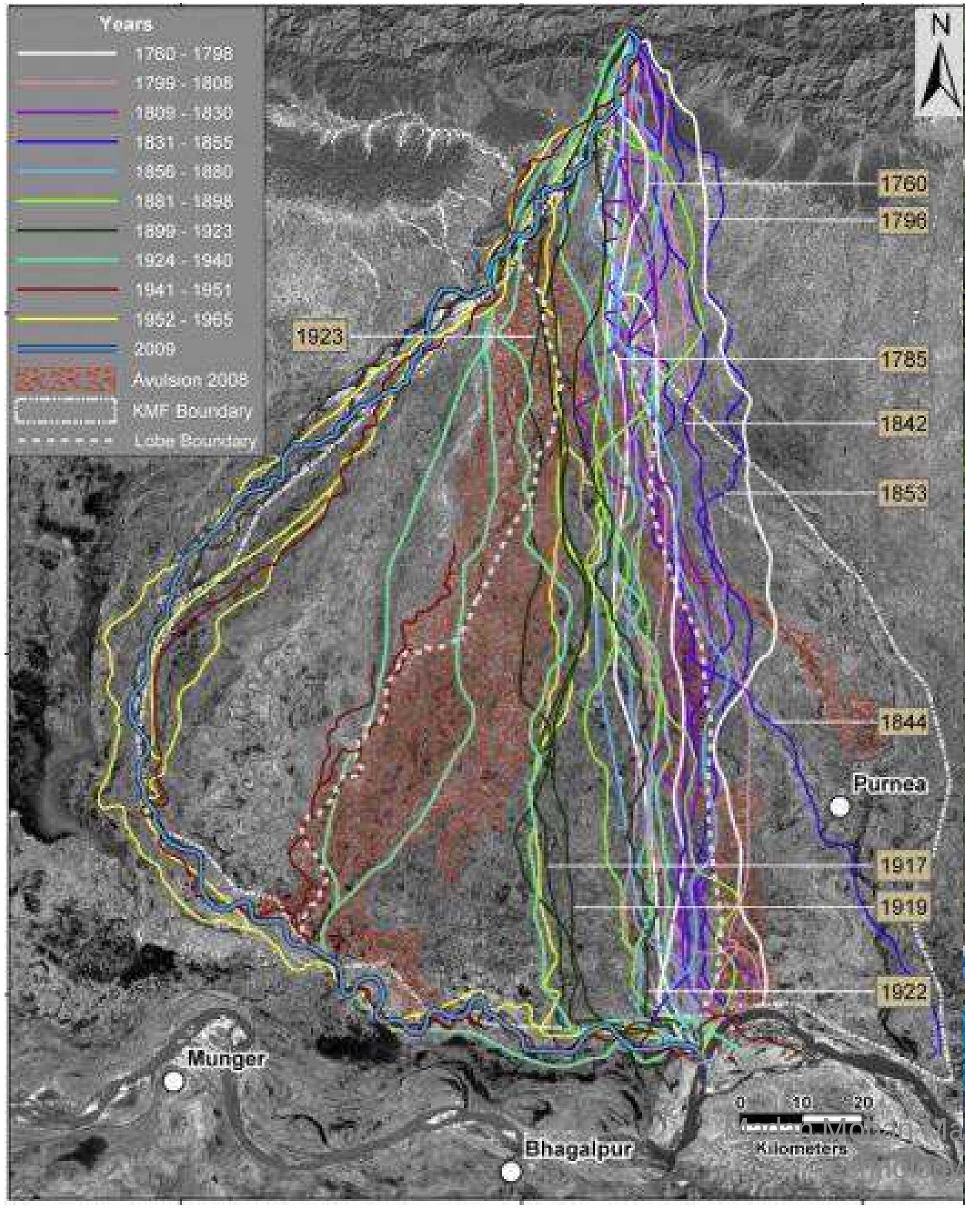


Fig: Oldham's River Regime Theory

Meandering


KUSAHA
NEPAL
THE BREACH
West Champaran
Normal course
of river Kosi
Supaul
Araria
Saran
Saharsa
Purnia
Katihar
Begusarai
Patna
Bhagalpur
Nalanda
BIHAR
Sheikhpura
Changed course
of river Kosi
after Aug 18
INDIA


Chatara
Levee breach point
Koshi barrage


Years
1760 - 1798
1799 - 1808
1809 - 1830
1831 - 1855
1856 - 1880
1881 - 1898
1899 - 1923
1924 - 1940
1941 - 1951
1952 - 1965
2009
Avulsion 2008
KMF Boundary
Lobe Boundary
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1760
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1919
1922
Purnea
Munger
Bhagalpur
0 10 20
Kilometers

Flood Management & River Training

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Civil Engineering Department

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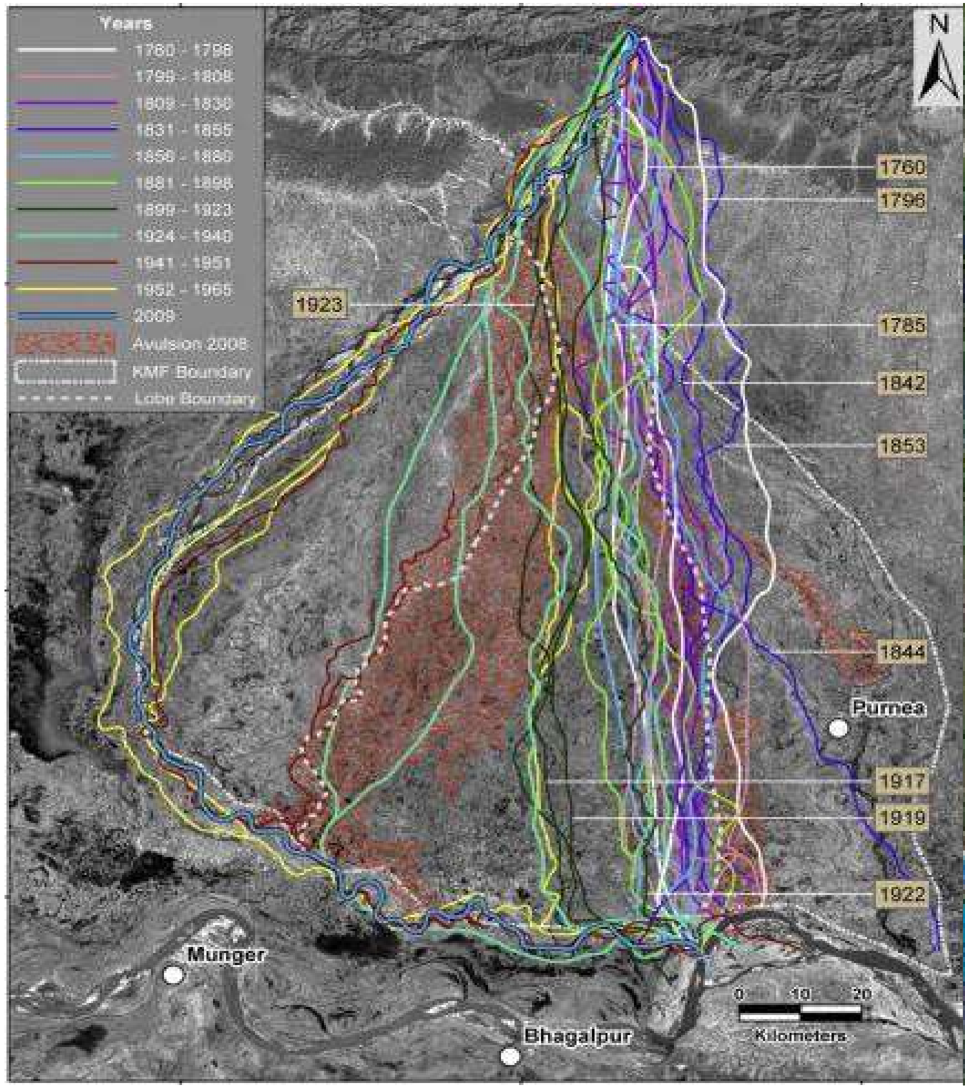
Kosi Mahasetu at Nirmali Bihar


Years
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Bhagalpur
0 10 20
Kilometers

Importance of River Training

Importance of River Training

Importance of River Training

Importance of River Training

River Training

What is River Training???

- River training refers to the structural measures which are taken to improve a river and its banks.
- Training works could be for various purposes such as flood control, navigation, guiding the flow or bank protection.
- The discussion will be confined to the training works related to hydraulic structures such as canal head works.
- These include guide banks, afflux bunds and spurs.

Why is it necessary to Train a River?

- Frequent changes in river course.
- Avulsion of one river into another.
- Heavy shoal formation - diversion of main current towards banks.
- Development of natural cut-off.
- Landslides in catchment - rise in silt load.
- Aggradation of river bed - high flood levels – Flooding
- Heavy erosion of banks by hill streams due to flash floods.
- River instability - change in bed slopes (seismic activity).
- Changes in river channels due to changes in rainfall pattern.
- Erratic behaviour of rivers in deltaic areas and of braided rivers.
- Navigational problems due to shoal formations.
- Formation of sand bars at river out-falls into sea.
- Changes in a river due to changes in its base level.

Objectives

- Ensure effective disposal of sediment load.
- Provide minimum water depth for navigation.
- To protect river by deflecting it away from attacked bank.
- Prevent river from changing its course.
- Avoid outflanking of structure.
- Prevent flooding by providing safe passage of flood water.


Physical Methods of River Training
◇MARGINAL EMBANKMENTS OR LEVEES
◇GUIDE BUNDS/GUIDE BANKS
◇SPURS/GROYNES
◇ARTIFICIAL CUT OFF
◇PITCHED OF BANKS AND PROVISION OF LAUNCHING APRONS
◇PITCHED ISLANDS
◇MISCELLANEOUS METHODS
Madan Mohan Malaviya University of Technology, Gorakhpur

Marginal Embankment

◇These are earthen embankments, also known as levees, which are constructed in the flood plains of a river and run parallel to the river bank along its length.

◇The aim of providing these embankments is to confine the river flood water within the cross section available between the embankments.

◇The flood water of a river is thus not allowed to spill over to the flood plains.

◇This kind of protection against flooding has been provided for most of the rivers of India that are flood prone with low banks and have extensive flood plains in the last century.

Marginal Embankment

Spacing of Embankment

" The spacing of embankments and their alignment need careful consideration with respect to their vulnerability to the river and the rise of high flood levels on account of reduction in flow area and also increase in peak discharge due to reduction in flood plain storage by construction of the embankment. Finalisation of the alignment and the spacing with due consideration to the above factors and at the same time optimizing the benefit from the proposed embankment would need considerable experience of the river behavior and studies of the effects of the embankments along different alignments. In view of the widely varying nature of the rivers, no general recommendation about spacing of embankment can substitute the need for the above studies. The following general guide lines about the minimum spacing etc. are however given, mainly with an idea to check the tendency of excessive encroachment of the natural flood plain of the river."

In case of embankments on both banks of the river, the spacing between the embankments should not be less than 3 times Lacey wetted perimeter for the design flood discharge. In case of embankment on only one bank the embankment should not be less than a distance equal to 1.5 times Lacey's wetted perimeter from the midstream of the river.

Marginal Embankment

Design High Flood Level

Subject to availability of observed hydrological data, the design H.F.L may be fixed on the basis of flood frequency analysis. Embankment schemes should be prepared for a flood of 25 years frequency in case of predominantly agricultural area and if the embankments concerned are to protect townships, industrial areas or other places of strategic and vital importance, the design H.F.L. shall generally correspond to 100 year return period.

In the case of embankments on both sides of the river, the design H.F.L. shall be determined keeping in view the anticipated rise in the H.F.L. on account of jacketing of the river.

N.B:- Design criteria circulated by GFCC/2/73/191-208 DATED 15.4.80 modified on the line of R.B.A. recommendations in respect of paras on Design High Flood Level and Treatment on top of embankments.

Marginal Embankment

Free –Board

As a guideline, minimum free board of 1.5 m over design HFL including the backwater effect, if any should be provided for the rivers carrying design discharge upto 3000 cumecs., for higher discharge or for aggrading flashy rivers a minimum free board of 1.8 meters over the design H.F.L. shall be provided. This should be checked also for ensuring a minimum of about 1.0 meter free board over the design H.F.L corresponding to 100 year return period.

Top Width

Generally the top width of the embankment should be of 5.0 m. The turning platforms 15 to 30 m long and 3 m wide with side slope of 1:3 shall be provided along the countryside of the embankment every kilometer.

Hydraulic Gradient

Hydraulic Gradient line should be determined on the basis of the analysis of the soils, which are to be used in the construction of embankments. However, the following guidelines are recommended.

Type of fill	Hydraulic Gradient
Clayey Soil	1 in 4
Clayey sand	1 in 5
Sandy Soil	1 in 6

Marginal Embankment

Side Slope

River side slope

The river side slope should be flatter than the under water angle of repose of the material used in the fill upto an embankments height of 4.5 meter slope should not be steeper than 1 in 2 and in case of higher embankments slope should not be steeper than 1:3 when the soil is good and to be used in the most favourable condition of saturation and draw down. In case, the higher embankments are protected by rip-rap, the river side slope of earthen embankments upto 6 meters high may be 1 in 2 or 1 in 2.5 depending upon the type of slope protection.

In embankments constructed of sandy materials, the riverside slope should be protected with cover of 0.6 m thick good soil.

It is usually preferable to have more or less free draining material on riverside to take care of sudden draw down. In case of high and important embankment stone rip-rap either dry dumped or hand placed and concrete pavements/concrete blocks with open joints are adopted to protect the embankments against draw down and/or erosive action of the river; in less important embankments where rip-rap is costly willow mattress can be used.

Marginal Embankment

Country side slope

A minimum cover of 0.6 m over the hydraulic gradient line should be provided. For embankment upto 4.5 m height, the country side slope should be 1 in 2 from the top of embankment upto the point where the cover over hydraulic gradient line is 0.6 m after which a berm of suitable width with the country side slope of 1:2 from the end of the berm upto the ground level should be provided. For the embankments above 4.5 m and below 6 m heights, the corresponding slope should be 1:3. Normally berms should be of 1.5 m width. For embankments above 6 m height detailed design may be furnished in the project estimate.

Slope Protection Works

Generally the side slopes and 0.6 m wide in top from the edges of the embankments should be turfed with grass sods. In embankments which are in imminent danger of erosion, necessity of protective measures such as slope protection by rip-rap and / or river training works should be examined separately following I.S. Code no.14262-1995.

Marginal Embankment

Treatment on Top of Embankment

An embankment should be provided with suitable soling over filter for proper drainage. For embankments protecting towns industrial area and places of strategic importance the necessity of providing all weather road surfaces of 3 to 3.5 m width should be examined to ensure maintenance works for reaches which are not easily accessible.

In order to provide communication from one side of embankment to other, ramps at suitable places should be provided as per requirement to obviate subsequent interference.

Land Acquisition

To ensure uniformity in respect of land acquisition for flood embankments, it is suggested that the provision for land acquisition should include at least 1.5 meters additional width beyond the toe of the embankments on the river side and width of 3 meters beyond the toe of embankment on the country side.

Marginal Embankment

Borrow Areas

Generally the borrow area will be on the river side of the embankments. However, in unavoidable circumstances, when the earth is to be borrowed from the country side the borrow pits shall not be closer than 10 m from the country side toe of the embankments. In certain cases when the depth of the borrow pit is limited to 0.3 meters the borrow pit may be closer to the embankment but in no case the distance between the toe of the embankment and the edge of the borrow pit shall be less than 5 meters. In order to obviate development of flow parallel to the embankment, 5 to 6 metre wide cross bars spaced at 50 to 60 meters center to center shall be left in the borrow pits.

Marginal Embankment

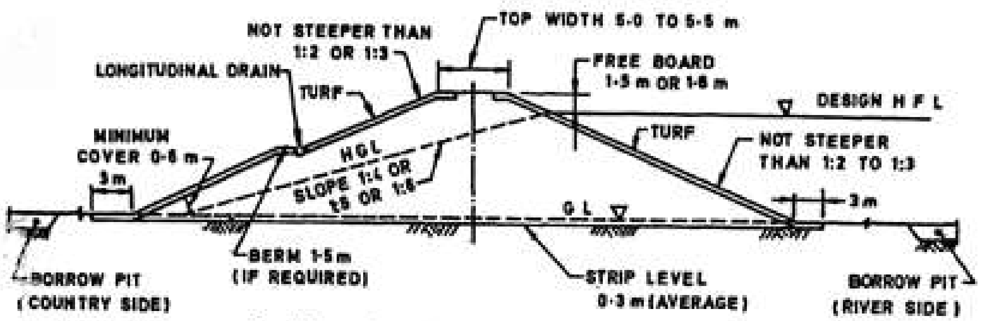


FIG. 1 TYPICAL CROSS-SECTION OF HOMOGENEOUS EMBANKMENT

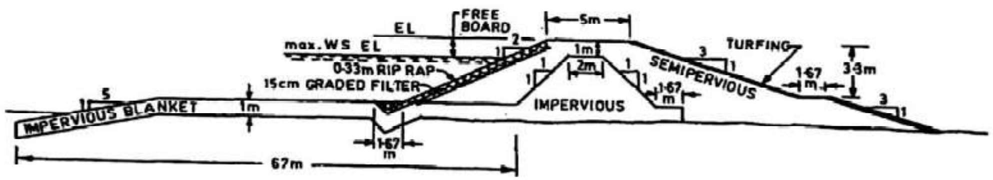


FIG. 2 TYPICAL CROSS-SECTION OF ZONED EMBANKMENTS

Marginal Embankment

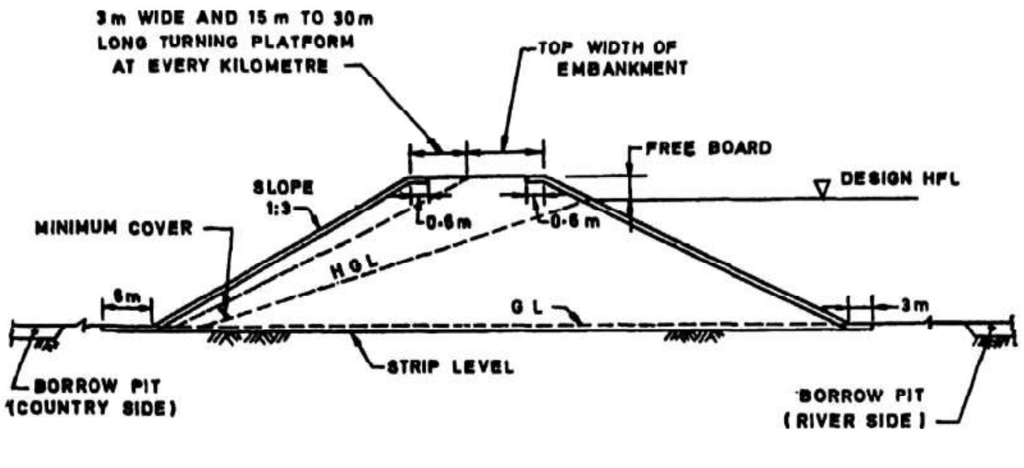
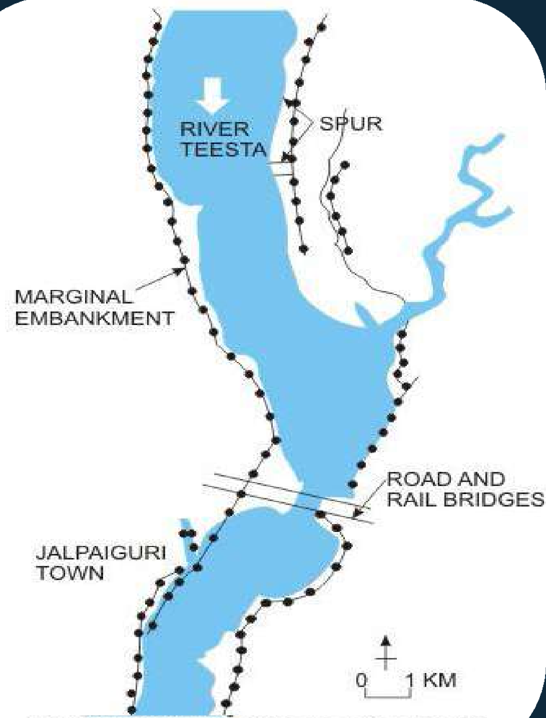


FIG. 3 TYPICAL CROSS-SECTION SHOWING TURNING PLATFORM

Marginal Embankment

A river in its original state during flood.

A river embanked , during flood.



Marginal embankments along river Teesta.

Marginal Embankment

Salient features of BIS codes relevant to Planning, Design and construction of Flood Management and Anti-Erosion Works

Planning & Design of River Embankment (IS 12094-2000)

This standard covers planning and design of river embankments (levees) on dry land.
The salient features/main design aspects covered in this code are described in the following paragraphs:-

Spacing of embankment

3 times of Lacey wetted perimeters of embankment on both bank of river

Design High Flood Level

Protection of agriculture land-25 year flood frequency
Protection of township, Industrial area-100 year flood frequency

Free Board

1.5 meters over design HFL (for $Q<3000$ cumecs)
1.8 m over design HFL (for $Q \geq 3000$ cumecs)

Marginal Embankment

)   **Top width** - 5.0 meter

Hydraulic gradient

Clayey soil – 1 in 4
Clayey sand- 1 in 5
Sandy soil – 1 in 6

River side slope: 1:2 to 1:3
Country side slope: 1:2 to 1:3 and
0.6 m cover over H.G.L.

Planning & Design of Revetment (IS 14262:1995)

This standard lays down the guidelines for planning and design of revetment used for embankment and bank protection works in case of alluvial rivers and canals.

The salient features/main design aspects covered in the code are described in the following paragraphs:-

Data required

Design discharge corresponding to 50/100 year floods.

Marginal Embankment

(ii) Design velocity at Bank
(iii) Silt factor (f)
(iv) L.W.L.
(v) HFL- 25/100 years return period.
(vi) Design discharge intensity
(vii) Bank slope
(viii) Size of stone for pitching
(ix) Wt. Of stone/boulder in Kg.

$$W = (0.02323 \times Ss \times V^6) / [(K \times (Ss-1)^3]$$

Where $K = [1-(\sin^2\theta / \sin^2\phi)]^{1/2}$

Ss = Specific gravity of stone

ϕ = Angle of repose of material of protection works

θ = Angle of sloping bank

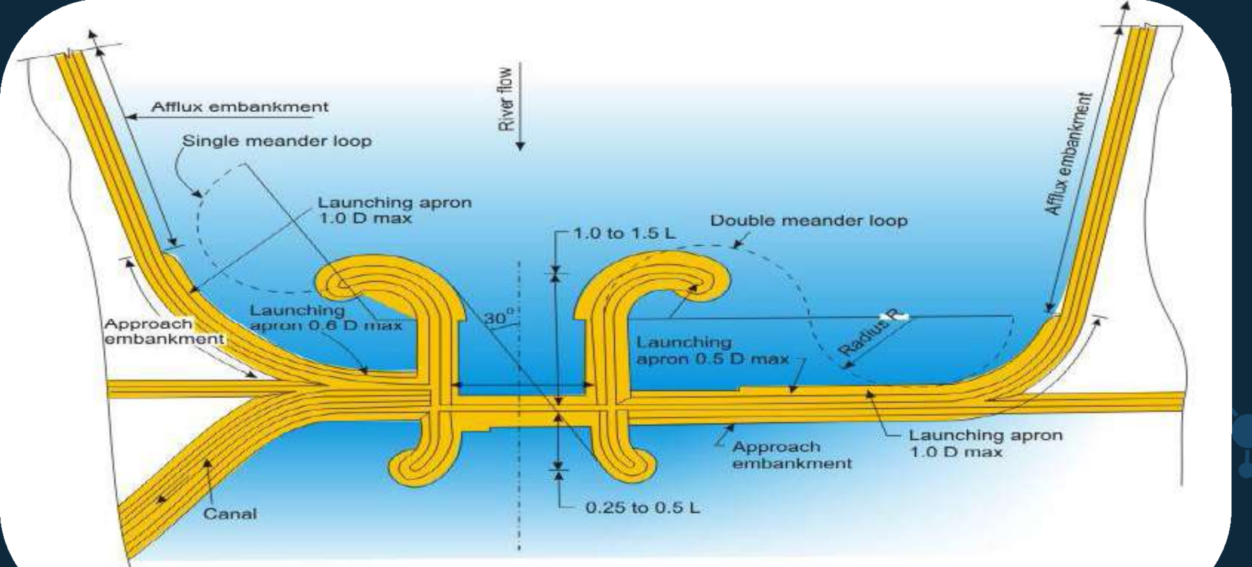
V = Velocity at bank

Thickness of protection layer

$$T = V^2 / [2g \times (Ss-1)]$$

Where V= Velocity in m/sec.
g = acceleration due to gravity in m/s
Ss= Specific gravity of stone

Guide Banks



Typical layout of river training work.

…Types of Guide Bunds/Guide Banks

Guide Banks
- Divergent
- Convergent
- Parallel

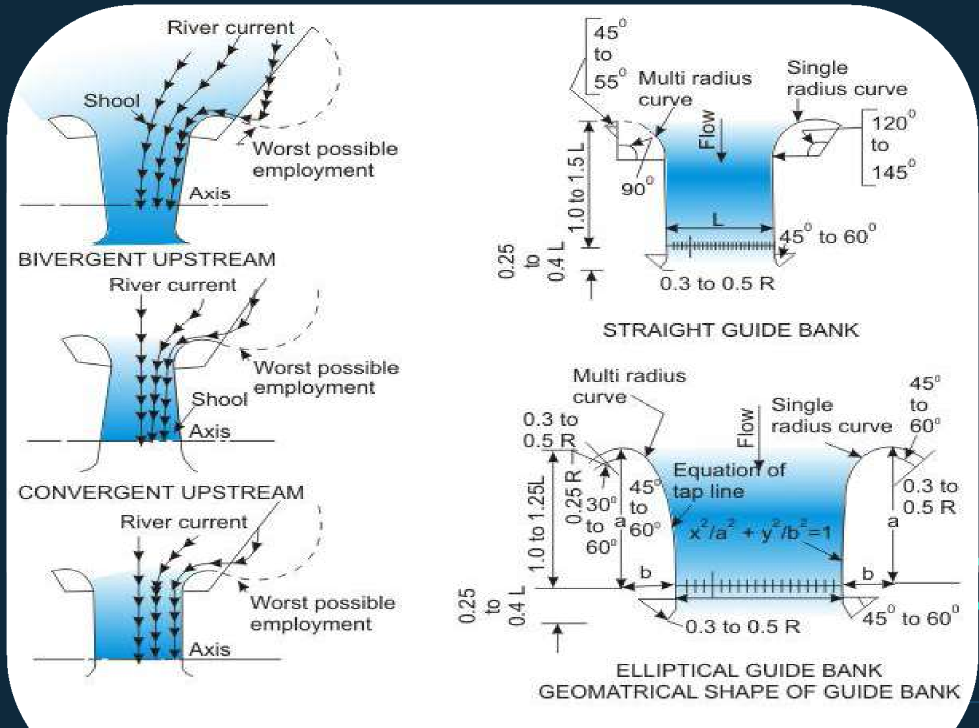


FIGURE 2. Types of guide banks and typical dimensions.

Planning & Design of Guide Bund/ Guide Bank(IS 10751-1994)

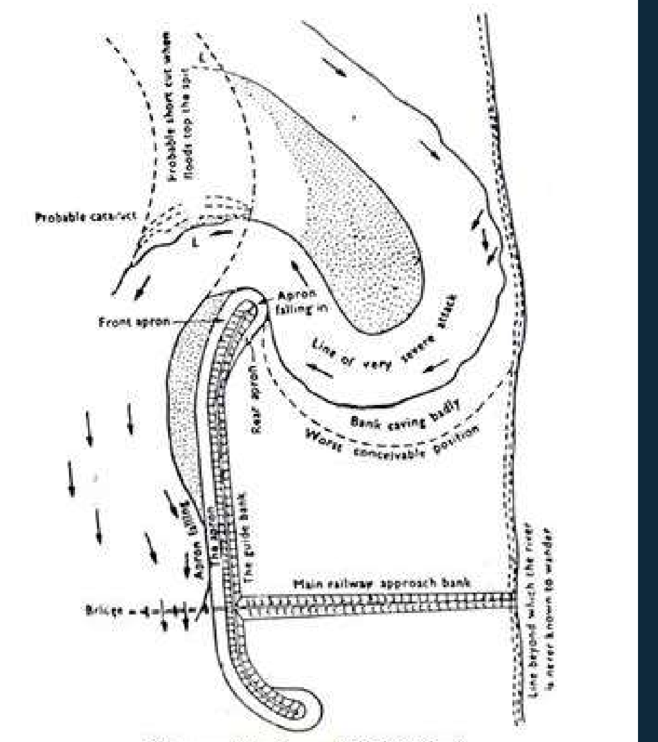
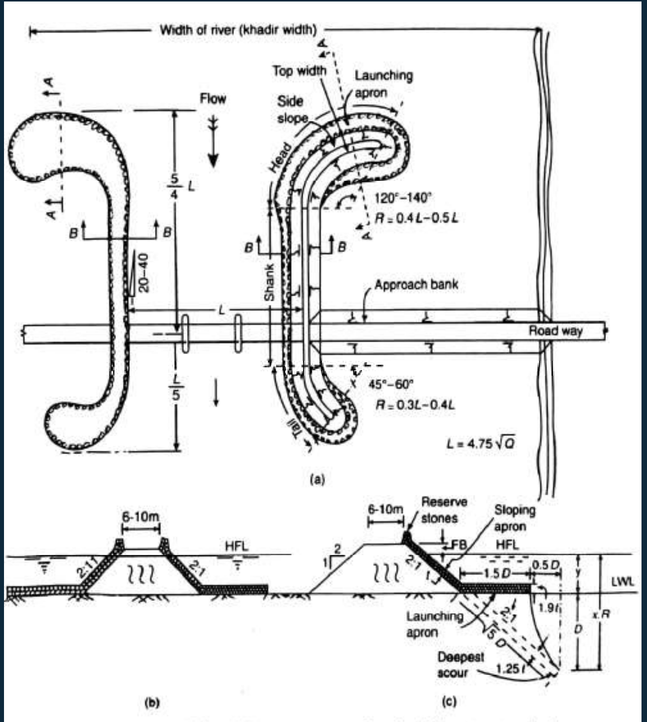


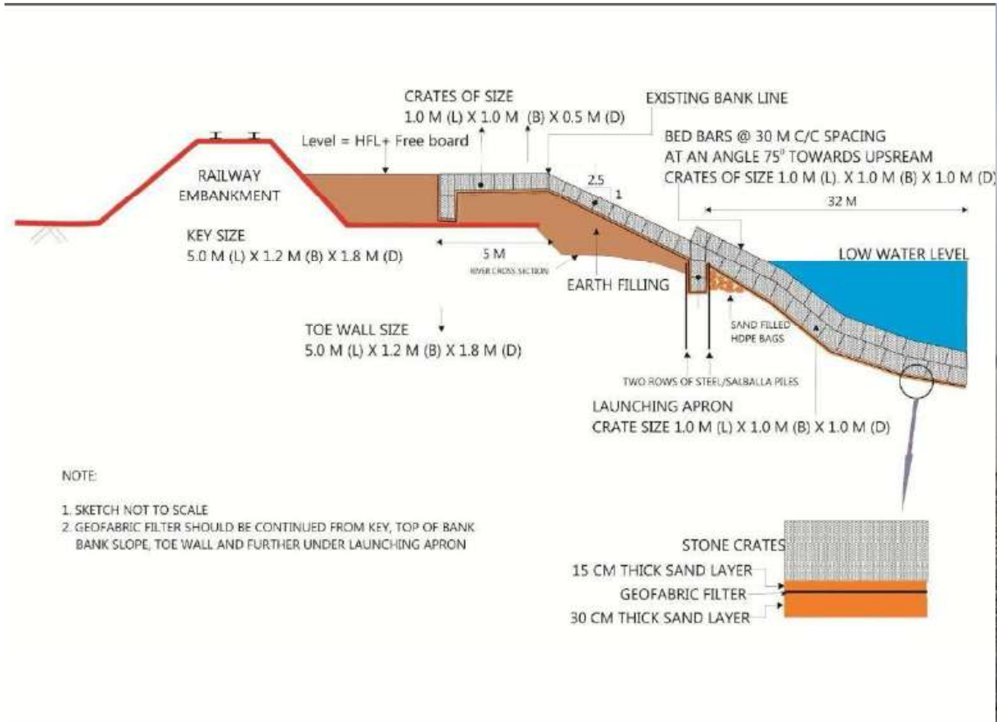
Figure: Attack on A Guide Bank

Planning & Design of Guide Bund/ Guide Bank (IS 10751-1994)



Guide bunds: (a) plan; (b) section BB at shank; (c) section AA, at head.

River Training Works



Dr. ShriRam
MMMUT, GKP

What is Training of River?

'**River training**' refers to the structural measures which are taken to improve a **river** and its banks.

River training is an important component in the prevention and mitigation of flash floods and general flood control, as well as in other activities such as ensuring safe passage of a flood under a bridge

Why is it necessary to Train a river?

Natural Problems

- Frequent changes in river course.
- Avulsion of one river into another.
- Heavy shoal formation - diversion of main current towards banks.
- Development of natural cut-off.
- Landslides in catchment - rise in silt load.
- Aggradation of river bed - high flood levels - Flooding
- Heavy erosion of banks by hill streams due to flash floods.
- River instability - change in bed slopes (seismic activity).
- Changes in river channels due to changes in rainfall pattern.
- Erratic behaviour of rivers in deltaic areas.
- Erratic behaviour of braided rivers.
- Navigational problems due to shoal formations.
- Formation of sand bars at river out-falls into sea.
- changes in a river due to changes in its base level.

Anthropogenic Problems

- Degradation of river bed downstream of a dam or a barrage.
- Effects of constriction of river width.
- Effects of flood embankment on the regime of rivers.
- Effects of extraction of sand and boulders.
- Effects of spurs and bed bars of different types on river behaviour.
- Effects of inter-basin transfers of water on the regime of rivers.
- Effects of river bed cultivation and construction by farmers.
- Effects of dredging/channelization of river bed.
- Effects of pucca bathing ghats in big cities and places of pilgrimage.
- Effects of heavy urbanization along the river banks.

DIFFICULTIES OF RIVER BEHAVIOUR

- Bank erosion, Channel Course Change.
- Flood Protection.
- Aggradation/ degradation of channel bed.
- River Flow extraction/diversion.
- Bridging the river channel.
- Maintaining Navigable Channel.

River behaviour during flood is affected

Objectives of River Training

- Safe and quick passage of high flood
- Efficient transport of sediment load
- Make river course stable and prevent bank erosion
- Provide sufficient draft for navigation
- Prevent outflanking of a structure by directing the flow in a defined stretch of the river

PROTECTION OF RIVER BANK

Rivers are dynamic and continuously change their position, shape, and other characteristics with variations in discharge and time.

Stable River has different definitions for differing people.

Navigation engineer	one that maintains adequate depths and alignment for safe navigation
flood control engineer	channel maintaining the ability to pass the design flood
local landowner	that does not erode the bankline
Geomorphologists and biologists	Erosion is simply part of the natural meandering process of stable rivers and would be perfectly acceptable in their definition of a stable river.

Stable River: Final definition

- River behaviour may be influenced by a number of factors.
- Schumm (1977) identified these as independent and dependent variables.
- Independent variables may be thought of as the basin inputs or constraints that cause a change in the channel morphology.
- Independent variables include: basin geology, hydrology (discharge of water and sediment), valley dimensions (slope, width, depth), vegetation (type and density), and climate. Dependent variables include: channel slope, depth, width, and planform.
- A channel that has adjusted its dependent variables to accommodate the basin inputs (independent variables) is said to be stable.
- An Unstable River causes erosion of bed and bank.

River Training Structures

River training structures can be classified into two main categories:

- Transversal protection structures and

  installed perpendicular to the watercourse: Check dams, Spurs, Sills, Screen, bandals, Porcupines, Bank protection as a bar.

- Longitudinal protection structures.

  installed on river banks parallel to the river course: Levees or earth fill embankments, Concrete embankments, Revetments and rock riprap, sheet piles, etc

- Other Protection Structures.
  Sandbagging, Channel lining, Bamboo piles

River Training Structures

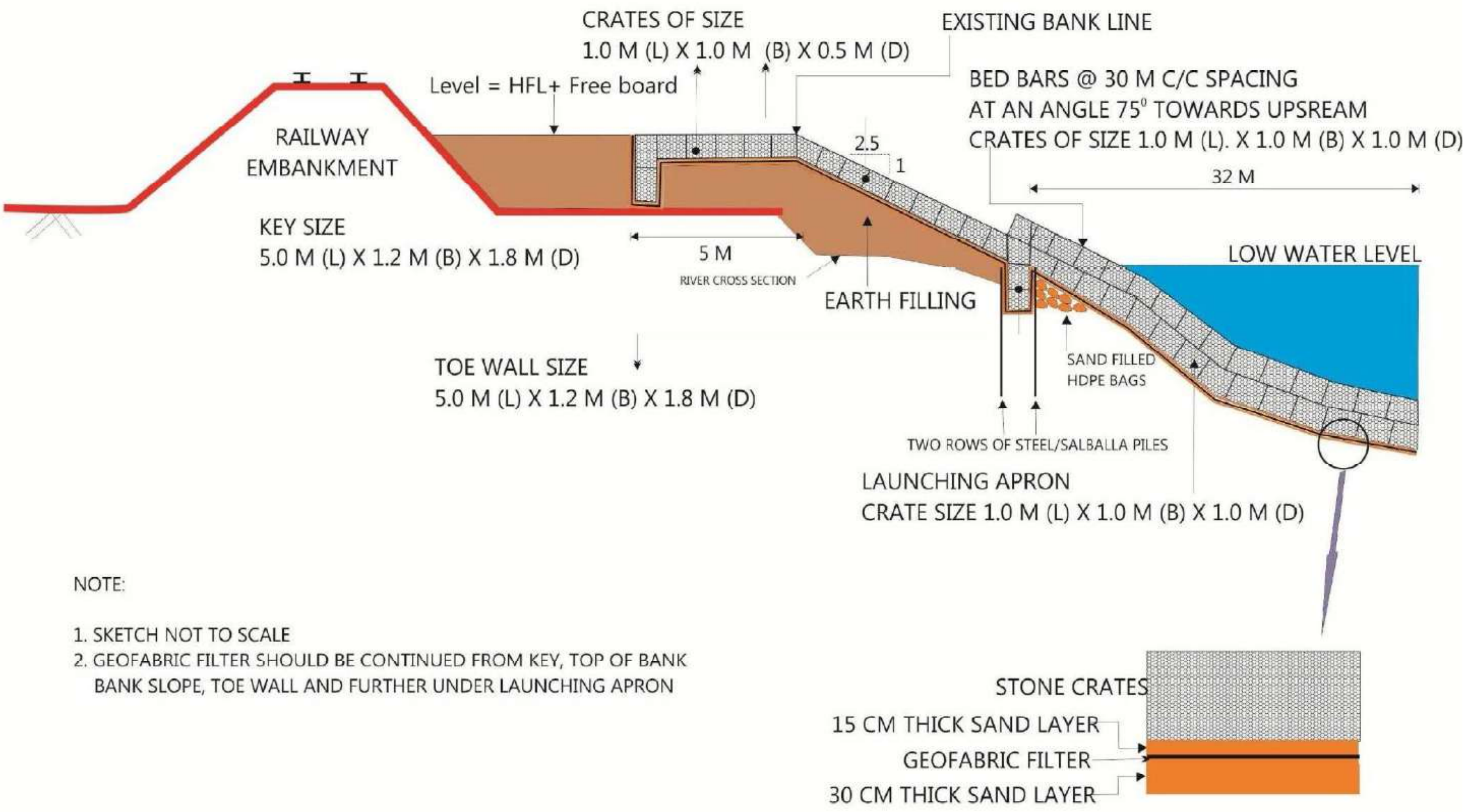
Classification based on action:

Direct protection works and indirect protection works.

Direct protection works are the one which are placed directly over the portion that needs to be protected such as, Riprap over the erosion prone bank.

Indirect protection works are the one which modify the flow conditions to protect the erosion prone bank such as, spurs, vanes etc.

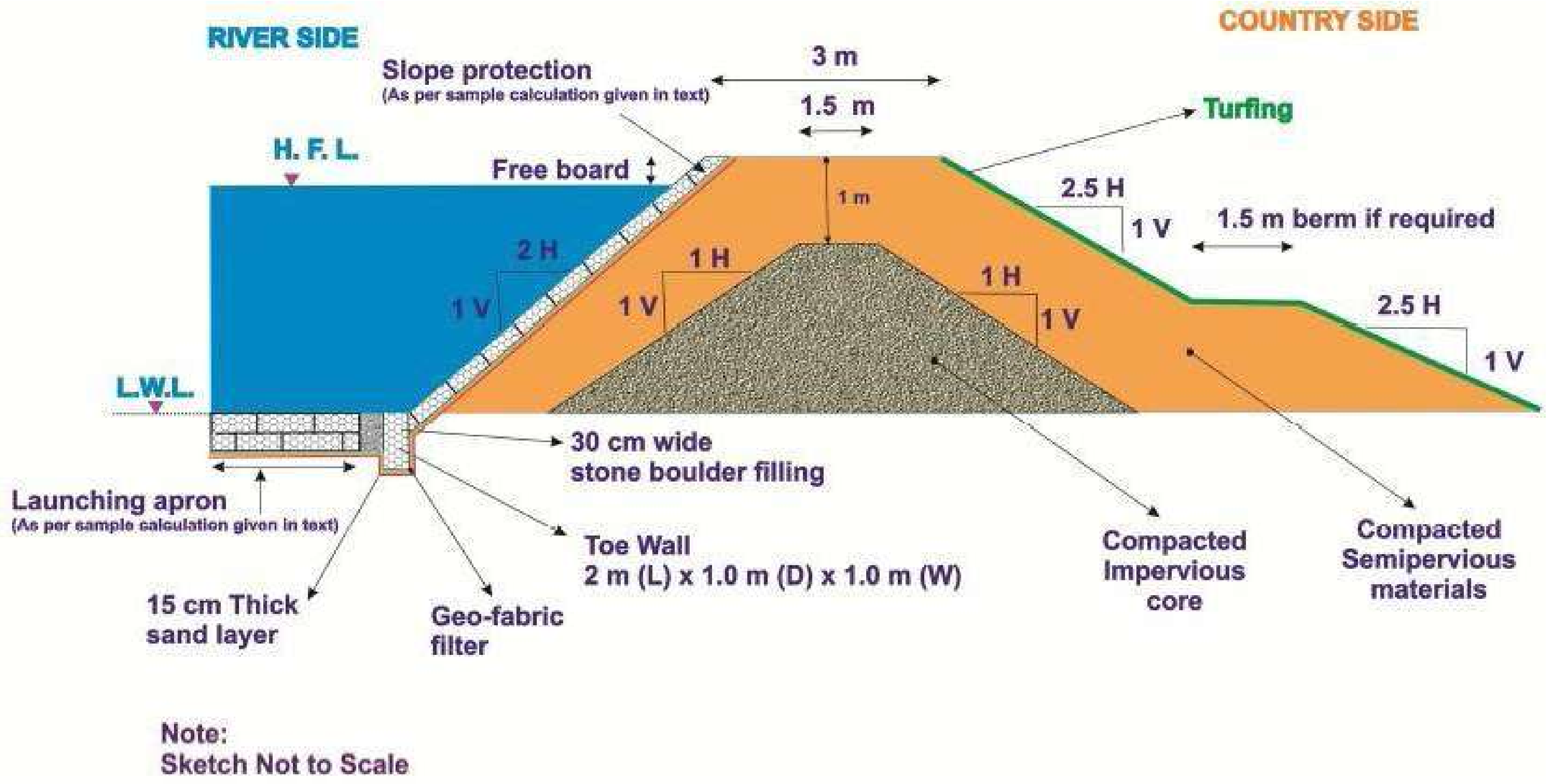
Sloping Bank Protection Work



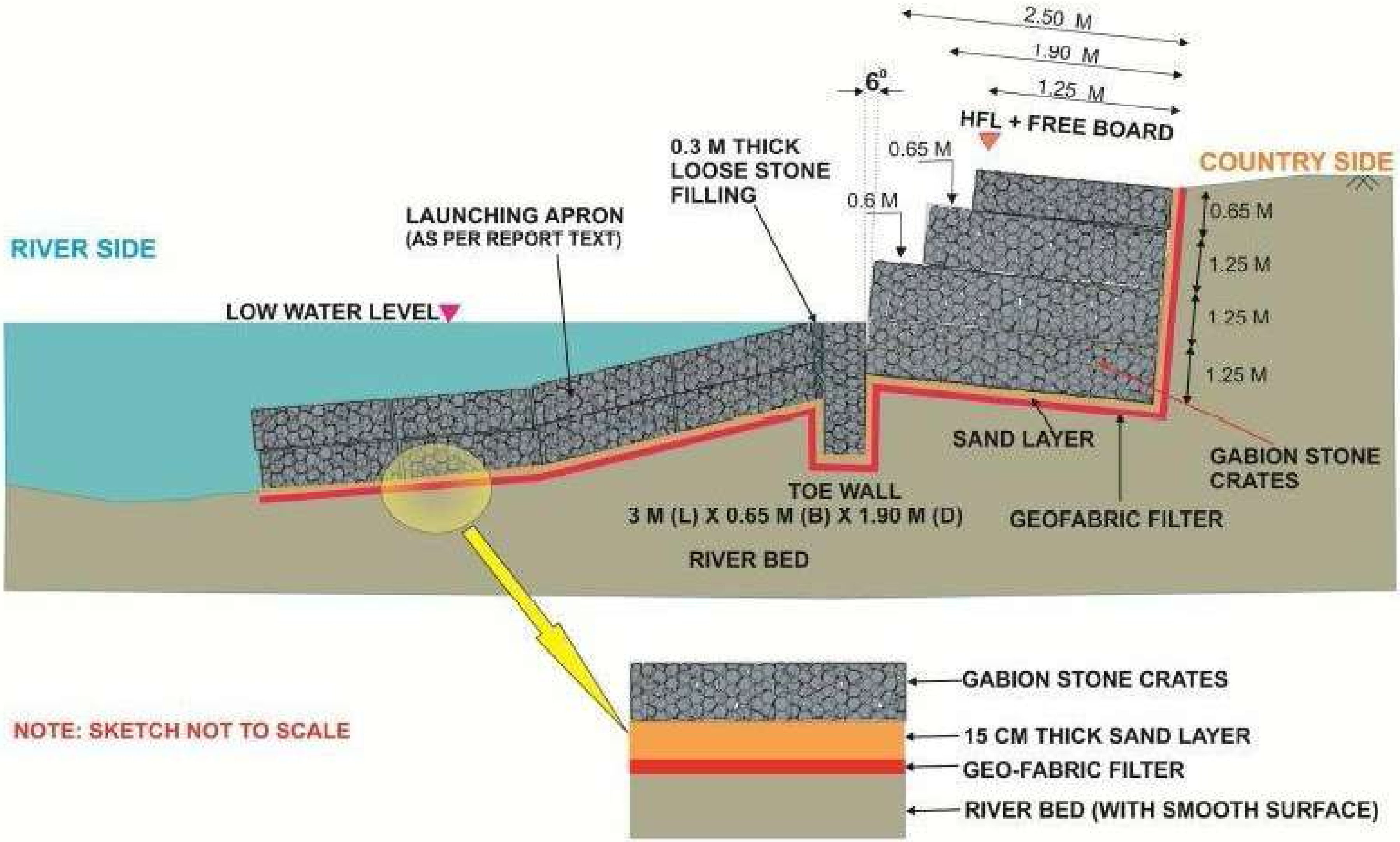
Bank protection works along with sleeper porcupines.

Eroded opposite bank after passage of single flood.
Bank safe after passage of 3 floods (2013)

Direct Bank Protection Work: Details

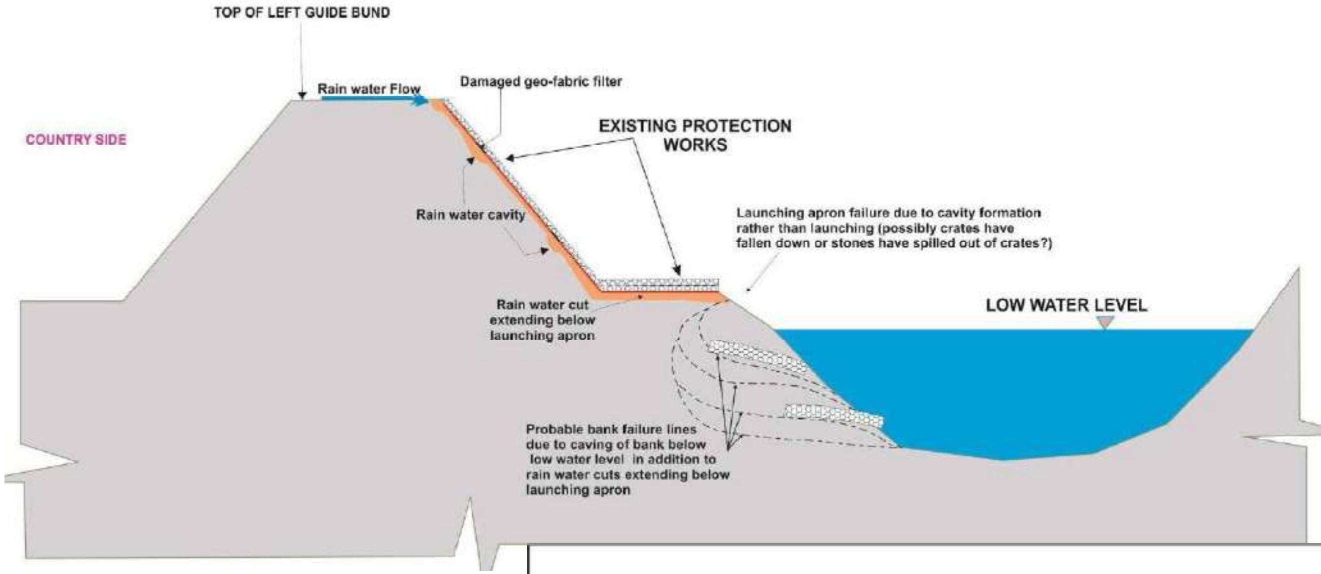


Direct Bank Protection Work: Vertical Gabionwall

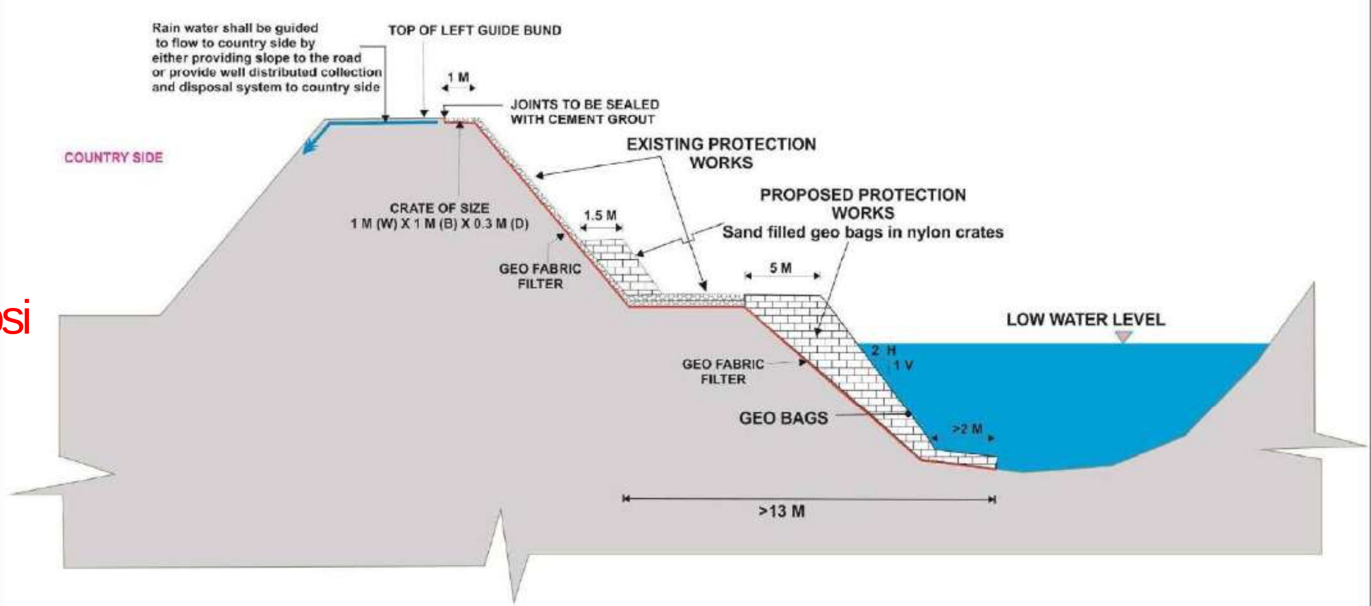


NOTE: SKETCH NOT TO SCALE

Failure Process of Direct Bank protection Work/ improvement

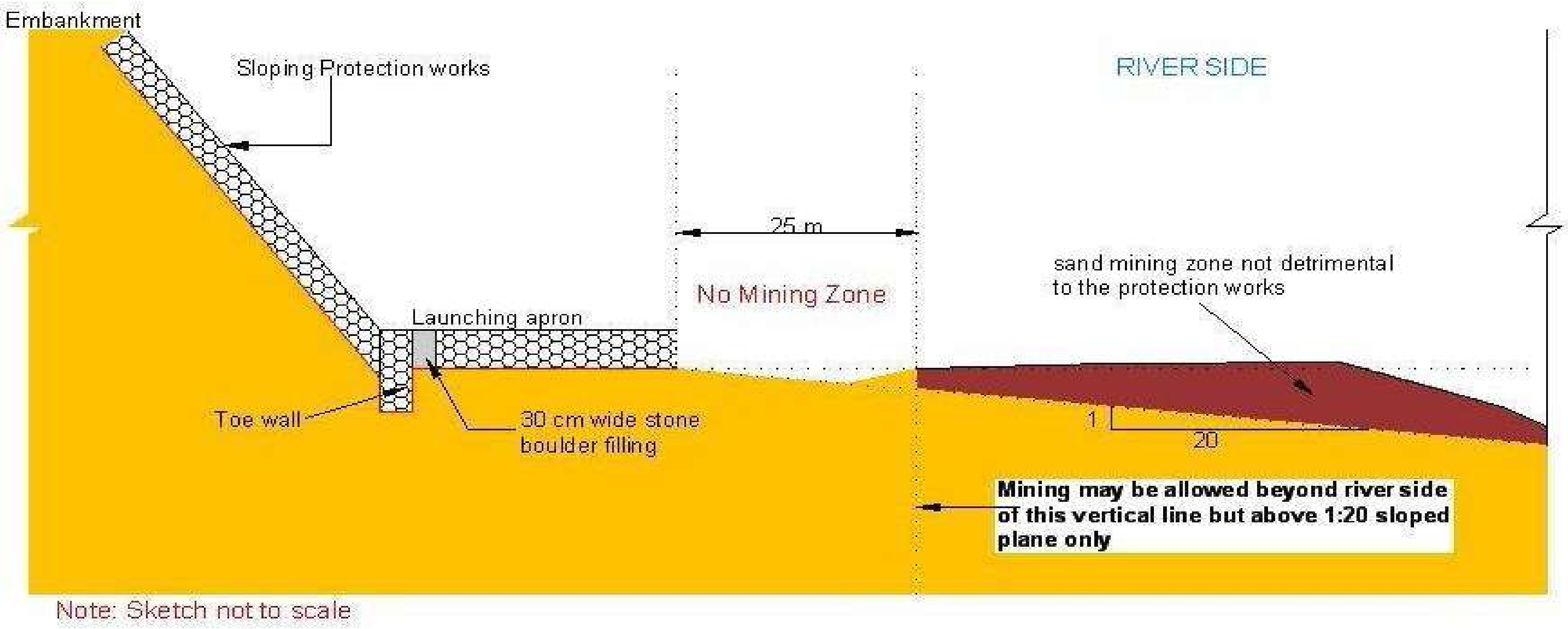


Eastern Guide bund of Kosi Mahasetu.

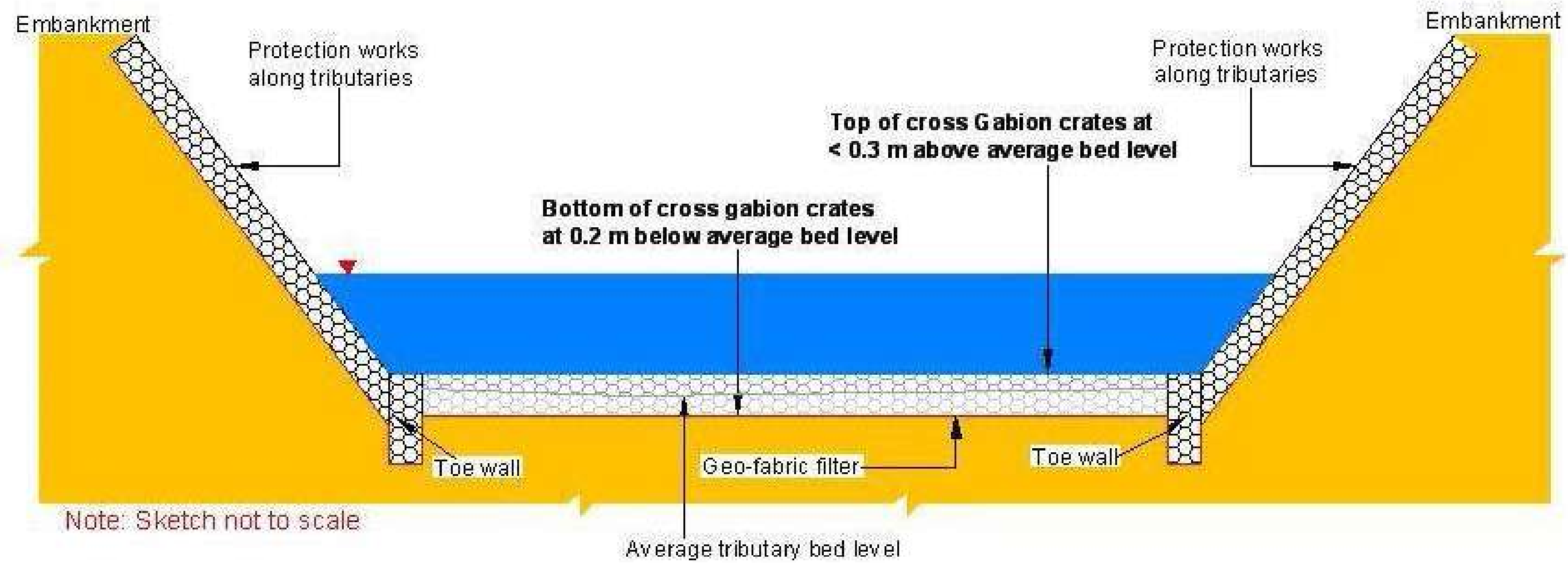


NOTE:
- Sketch not to scale
- In the absence of cross section (as executed) drawing, this sketch is prepared by assuming various dimensions wherever possible.
- Generally river front slope shall be 1H:2V.
- Embankment slope protection work above launching apron suggested here shall be up to a height till it covers the damaged portion and supports repaired/ old geofabric filter & the existing crates above properly.

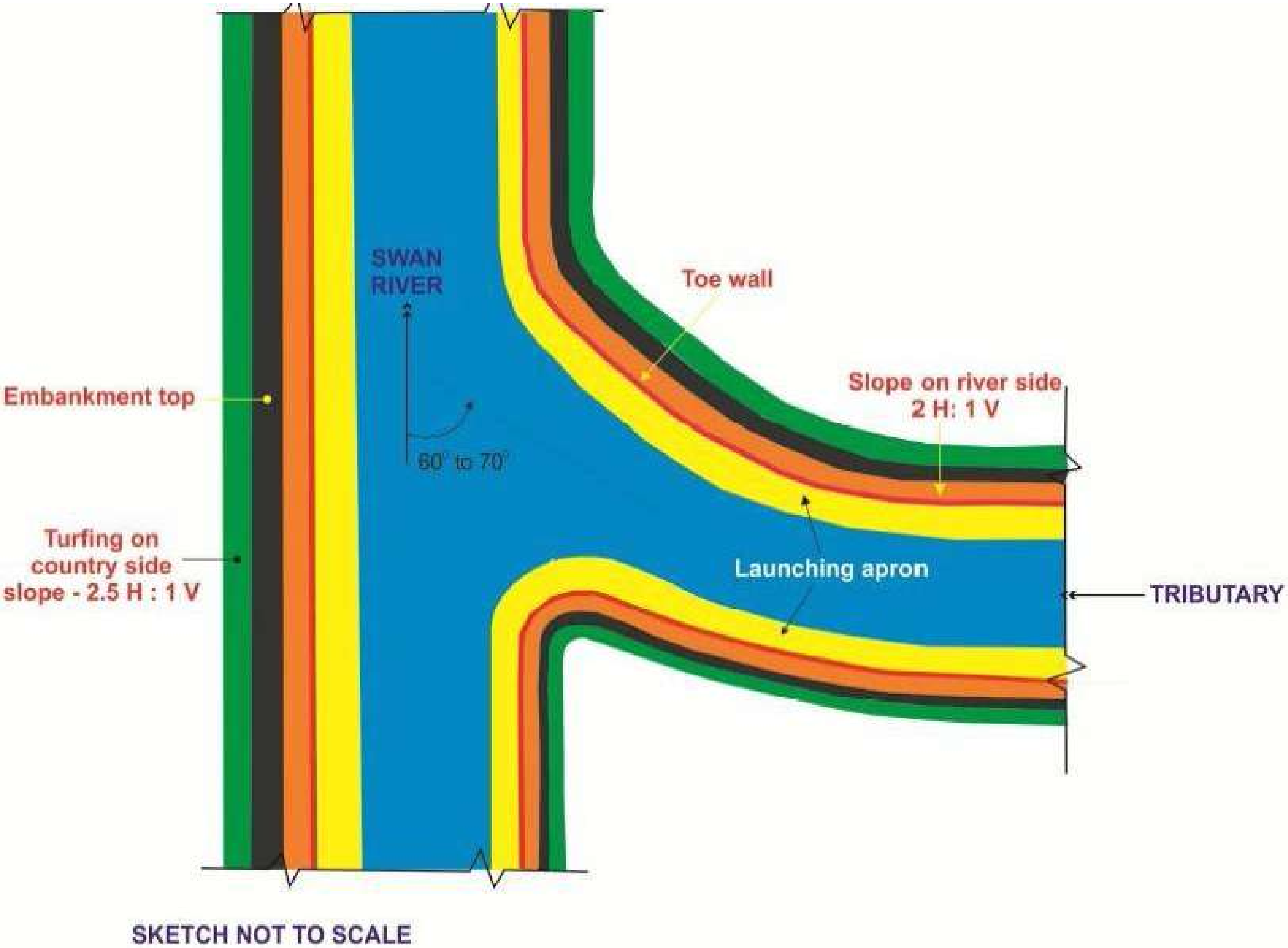
Mining of Sand Near Direct Bank Protection Work



Bridge vent blocked by sediments brought by tributary of river swan – Sediments obstruction by check dams in tributories



Tributary Confluence streamlining



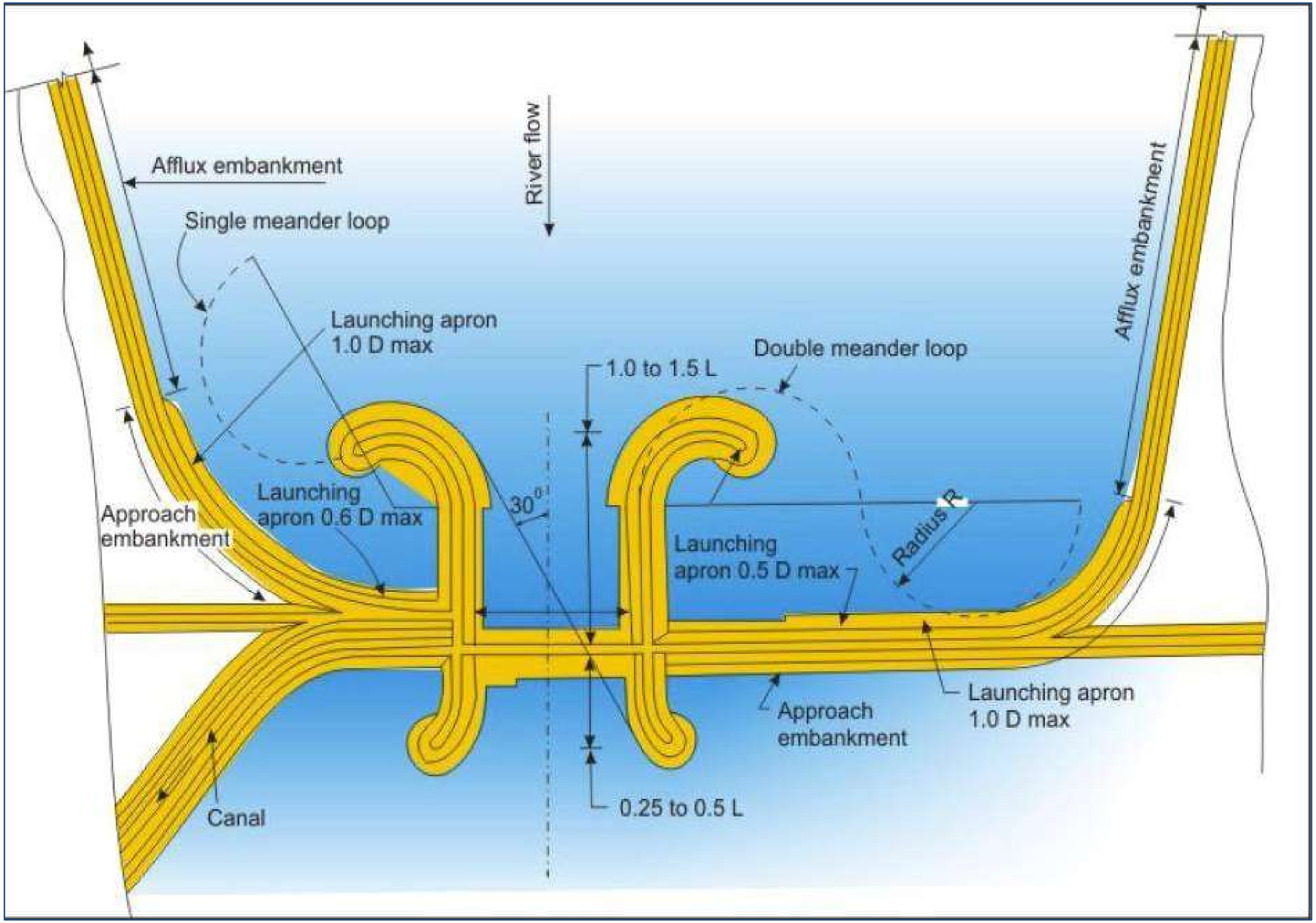
Discussion about Free board ???

(IS 10635: Freeboard requirements in embankment ...

2014 Jhelum flooding Kashmir

Chennai flooding of 2015

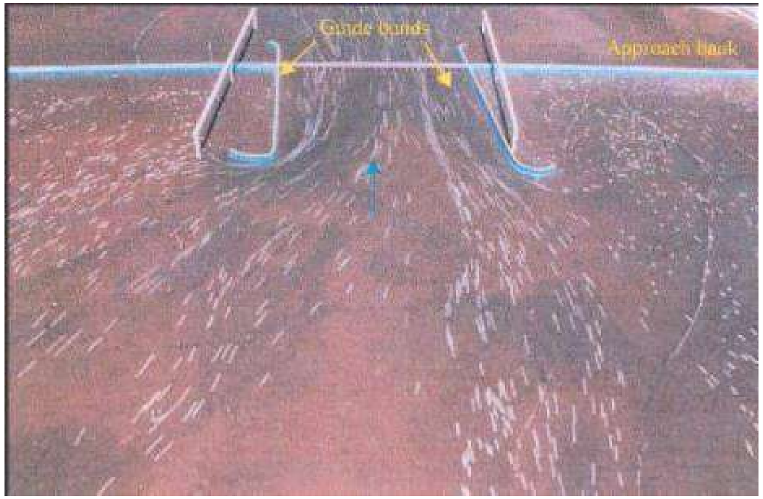
Typical layout of River Training Measures used in barrage/bridge



Kosi Mahasetu at Nirmali, Bihar

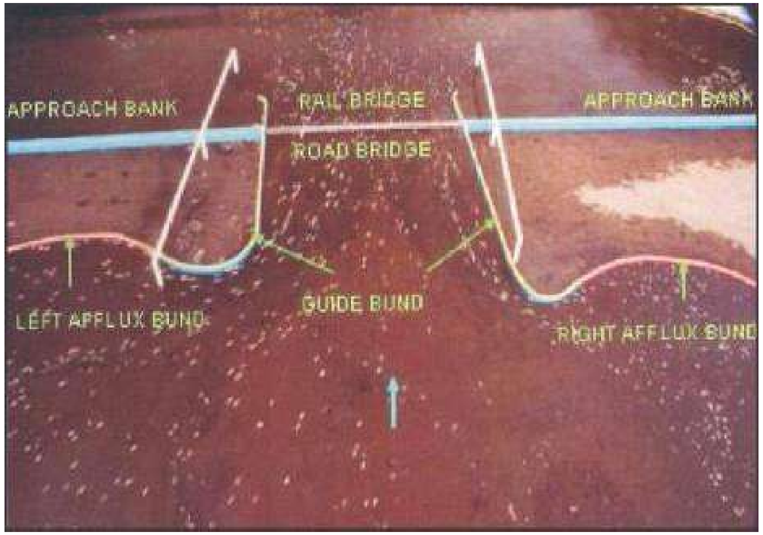
Road cum Rail Bridge – U/S and D/s Guide bunds, extended guide bunds or afflux bunds

Alignment, layout are best decided based on model studies.



Original Proposal – Stage I

Modified Proposal with Afflux bund – Stage II



Modified Proposal with Afflux bund and reduced waterway- Stage III

Embankment or levees or stop bunds or encasing

SPURS or DYKES or Thoker

(STRUCURES CONSTRUCTED TRANSVERSE TO FLOW)

GUIDELINES FOR SPURS

- 2 to 5 spurs are constructed in a battery.
- shouldn't be used in narrow channels.
- could be permeable (may be submerged) or impermeable (non submerged).
- **H**eight of spurs < the bank height (Kosi).
- Submerged spur height ~ 1/3 to ½ times the water depth.
- Flow constriction 20 % max or length of spur ~ 1/5 of river width and not less than 2-2.5 times scour depth on concave bank and 2.5 to 3 times on convex bank.
- Spacing – 4 to 5 times length
- Nose, u/s & d/s portion of shank needs protection
- Filter below launching apron essential.
- Model study to establish favorable flow conditions necessary.

Figure 2. Low cost bamboo stone spur

Figure 3. Low cost spur made of tree trunks and branches

Figure 4. Permeable & Impermeable spurs

Figure 5. Submerged and non-submerged spurs

Figure 6. Orientation of spurs

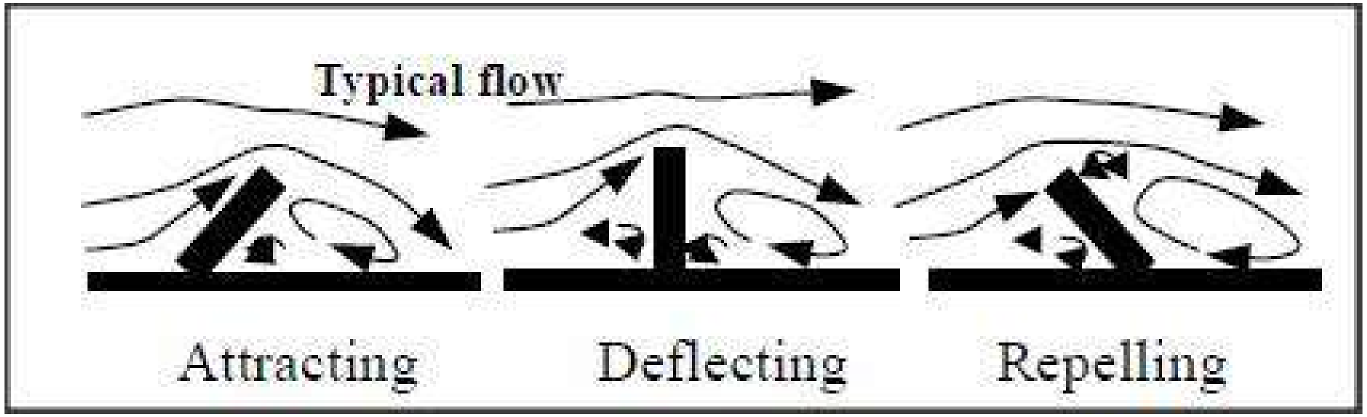
Figure 7. Shapes of spurs

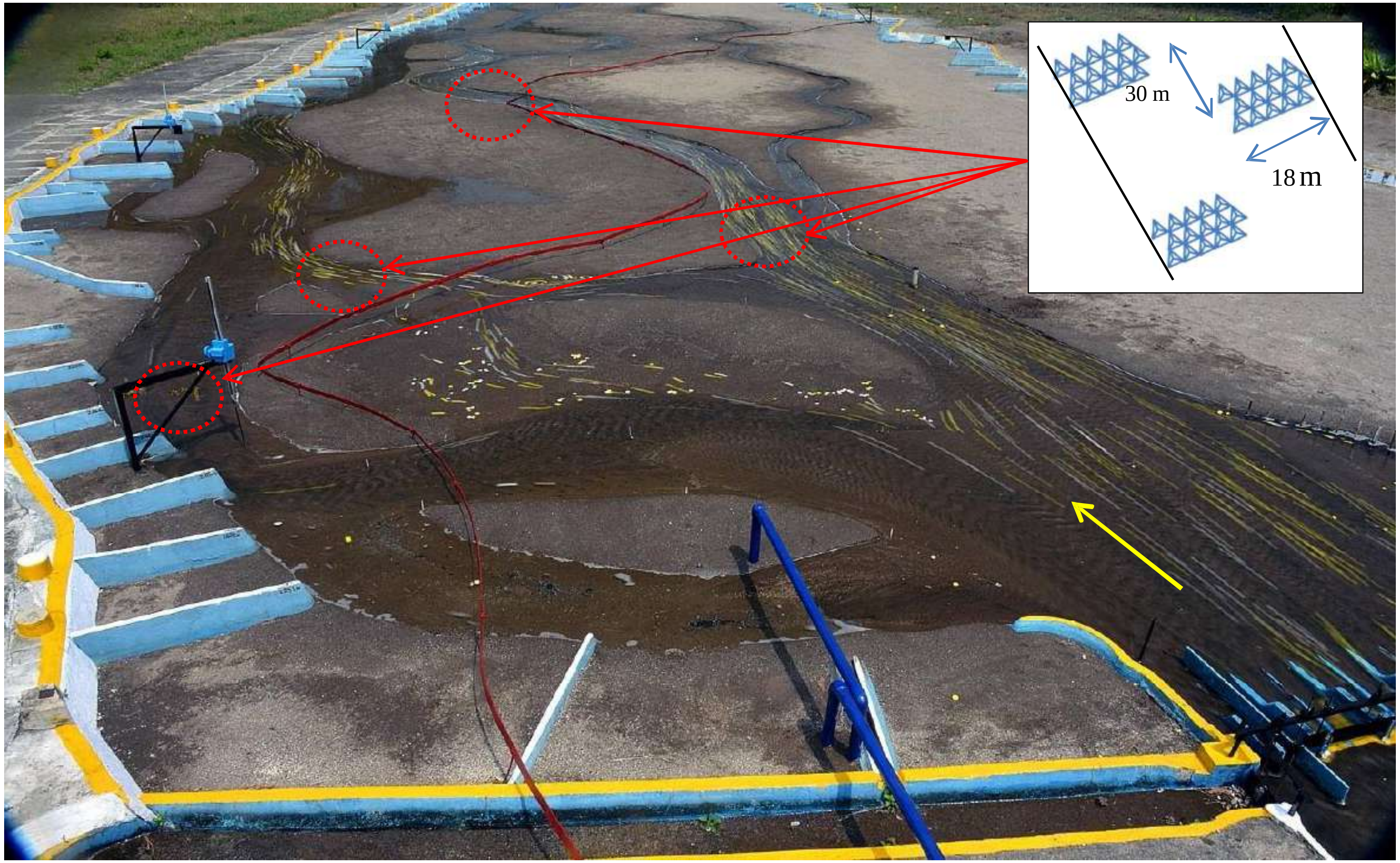
Types of Spurs

An Attracting spur points downstream and attracts the flow towards its head and thus to the bank.

A Deflecting Spur is normal to the flow and diverts the flow at its head

A Repelling spur inclines in upstream direction and diverts the flow away from itself.





Generalized flow pattern downstream of Kosi barrage for a discharge of 5,663 m³/s after placing porcupine screens along active channels.

FLOOD PROTECTIVE MEASURES

Porcupines

Bamboo screen and permeablespur

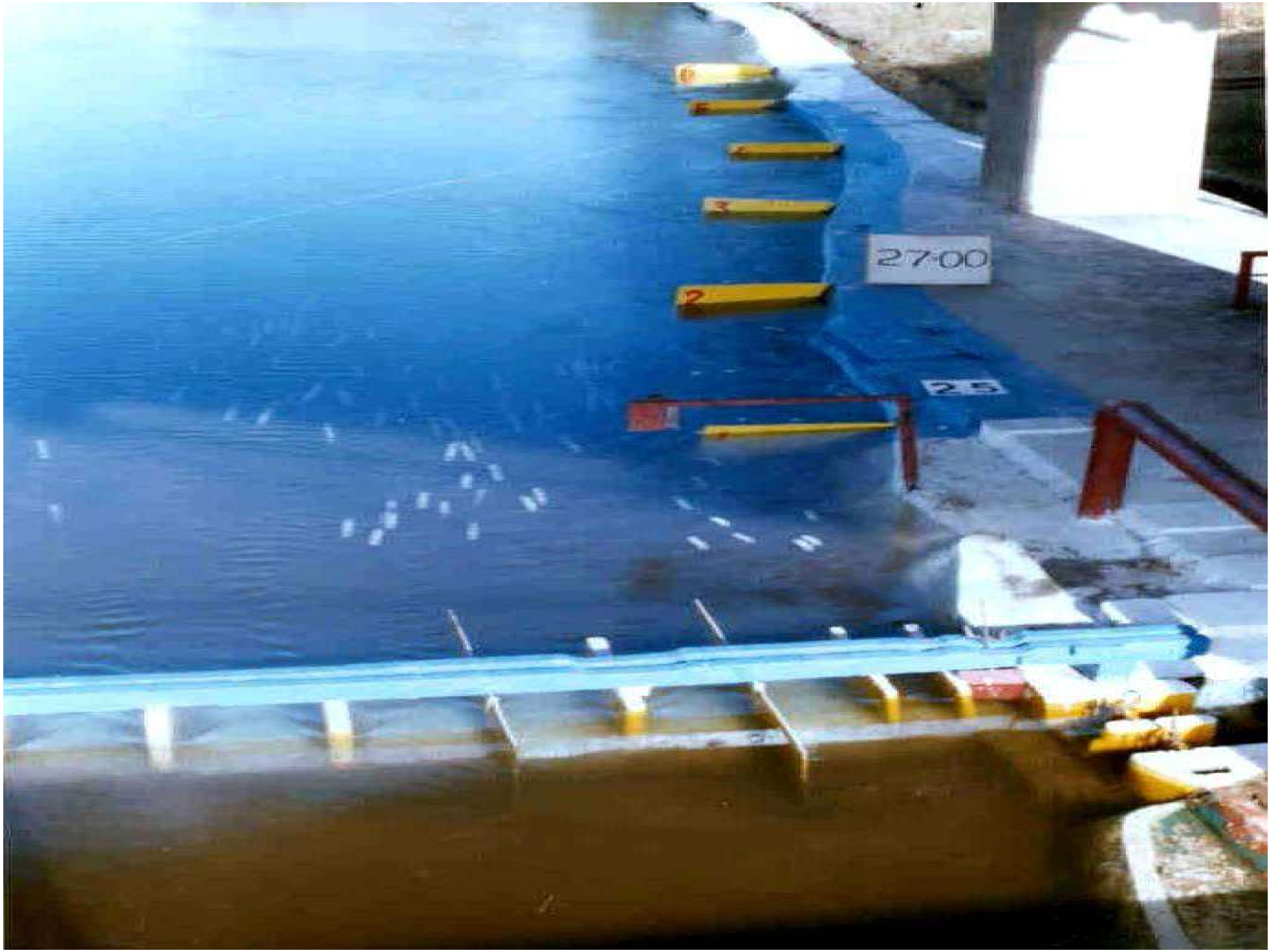

Studs

Flow diversion using studs immediately d/s of barrage

Kosi Barrage, Nepal

Impermeable spur

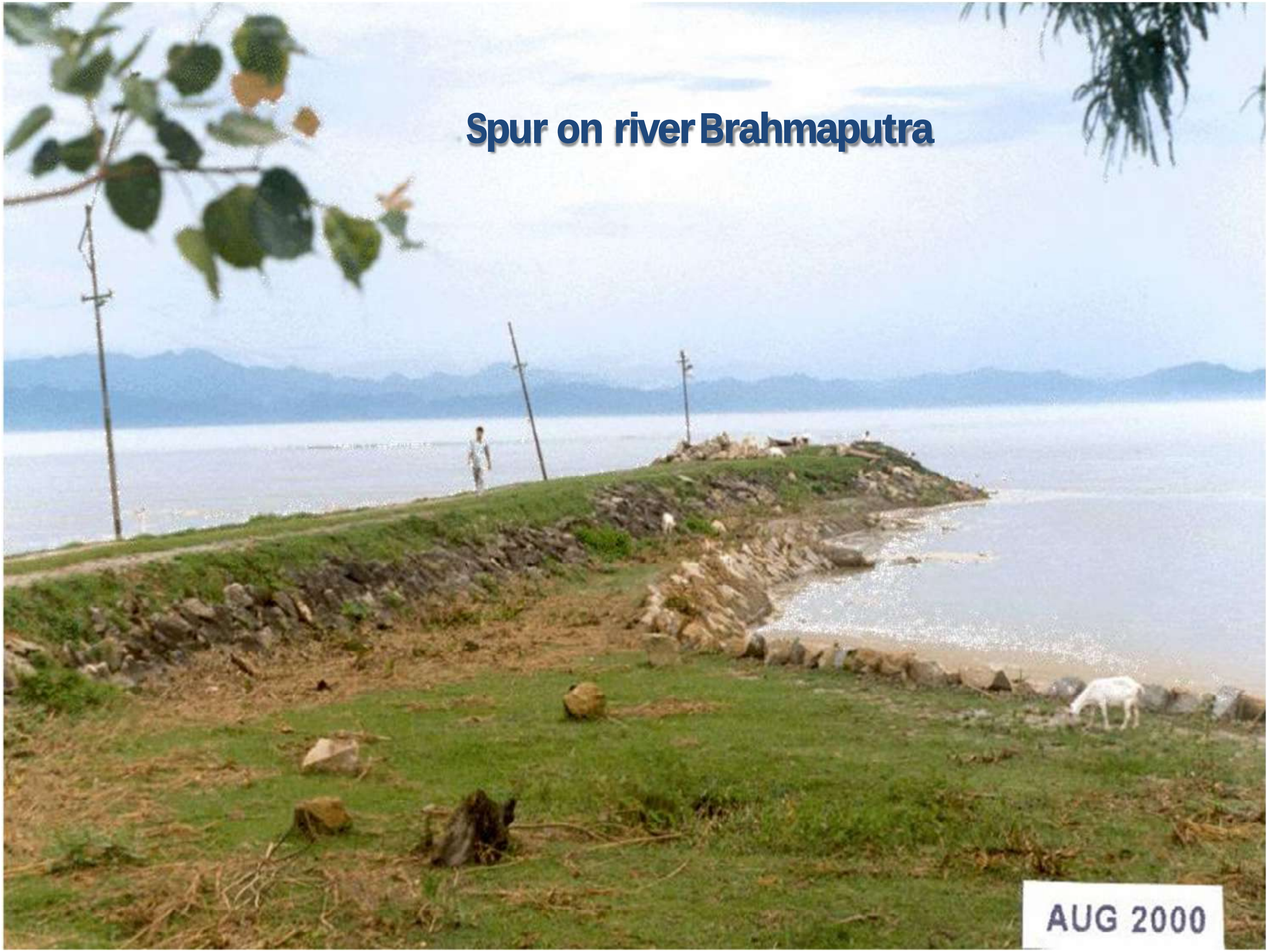
Model of River Ganga u/s of Farakka



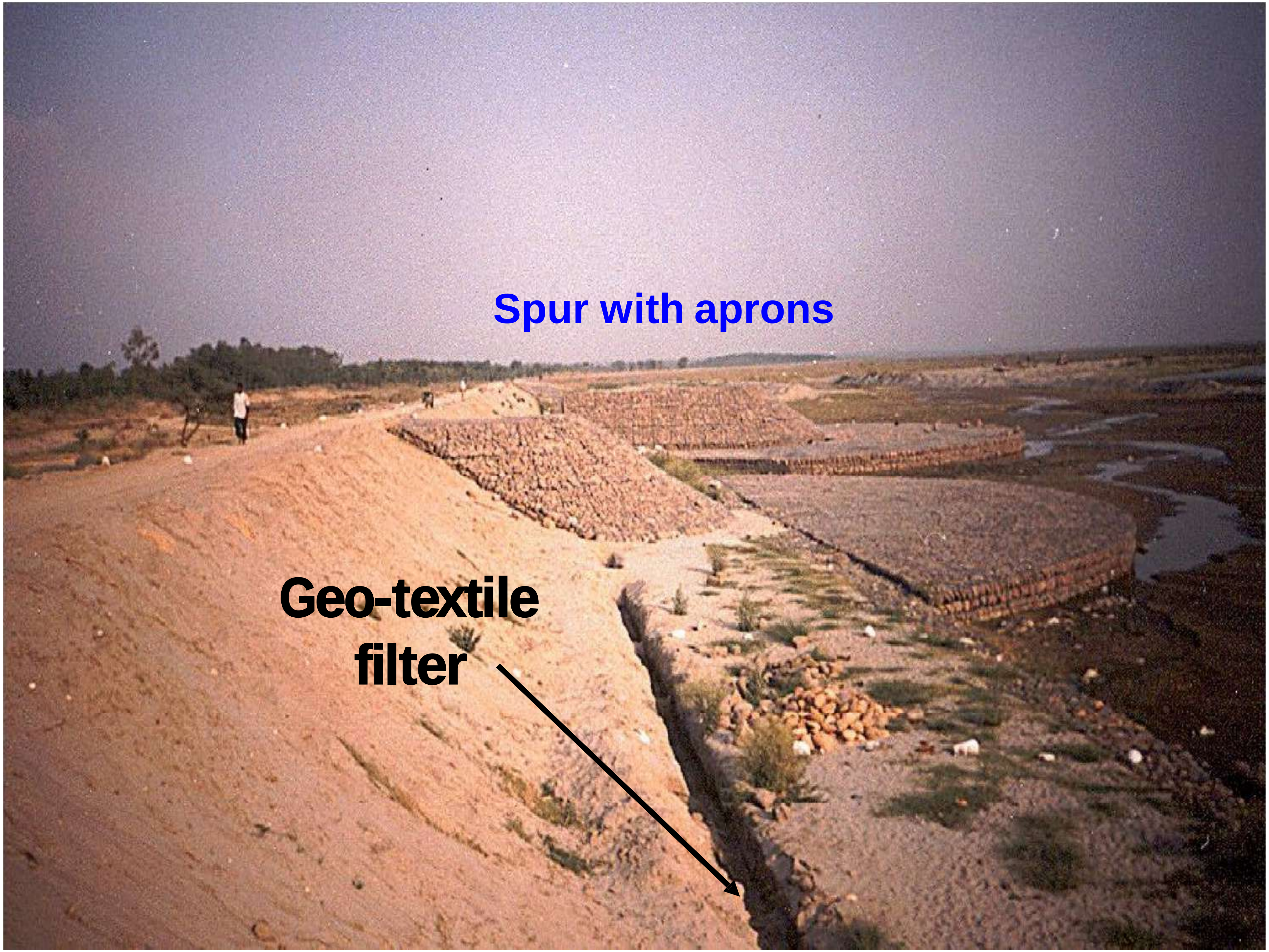

KOSI RIVER
Q - 4

Flume model for study of spur protection works

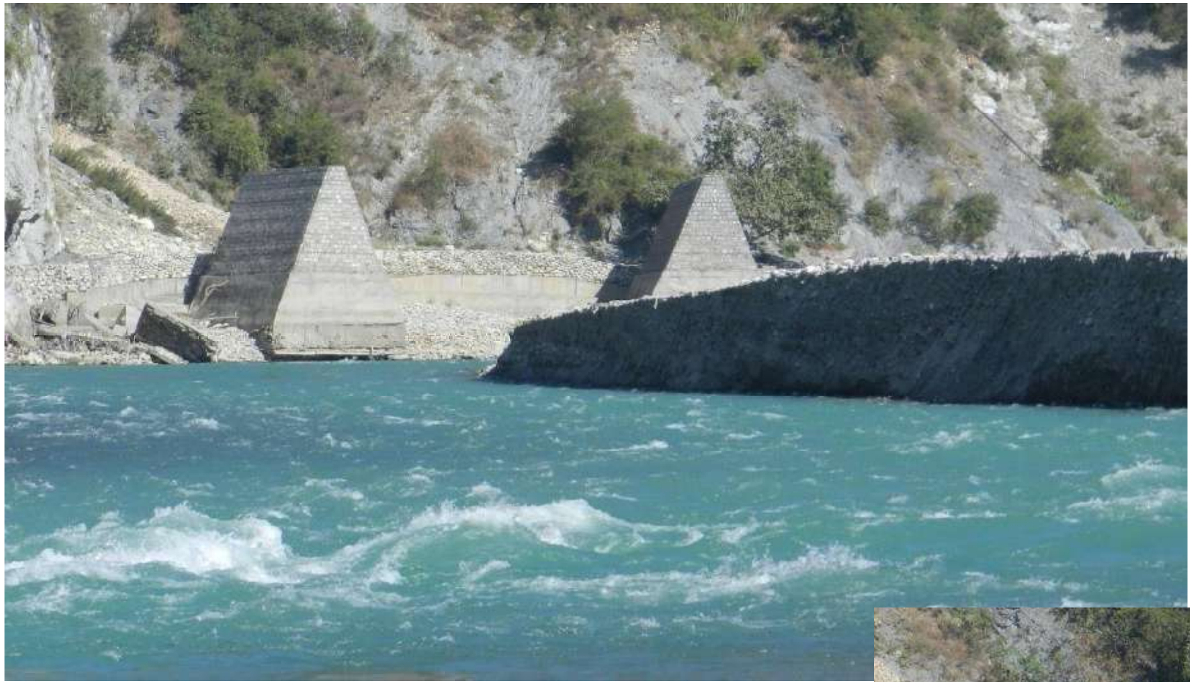
Typical photograph of dry model after running the model for a discharge of 5,663 m^3/s with porcupine units placed near the spur nose.


Spur on river Brahmaputra
AUG 2000

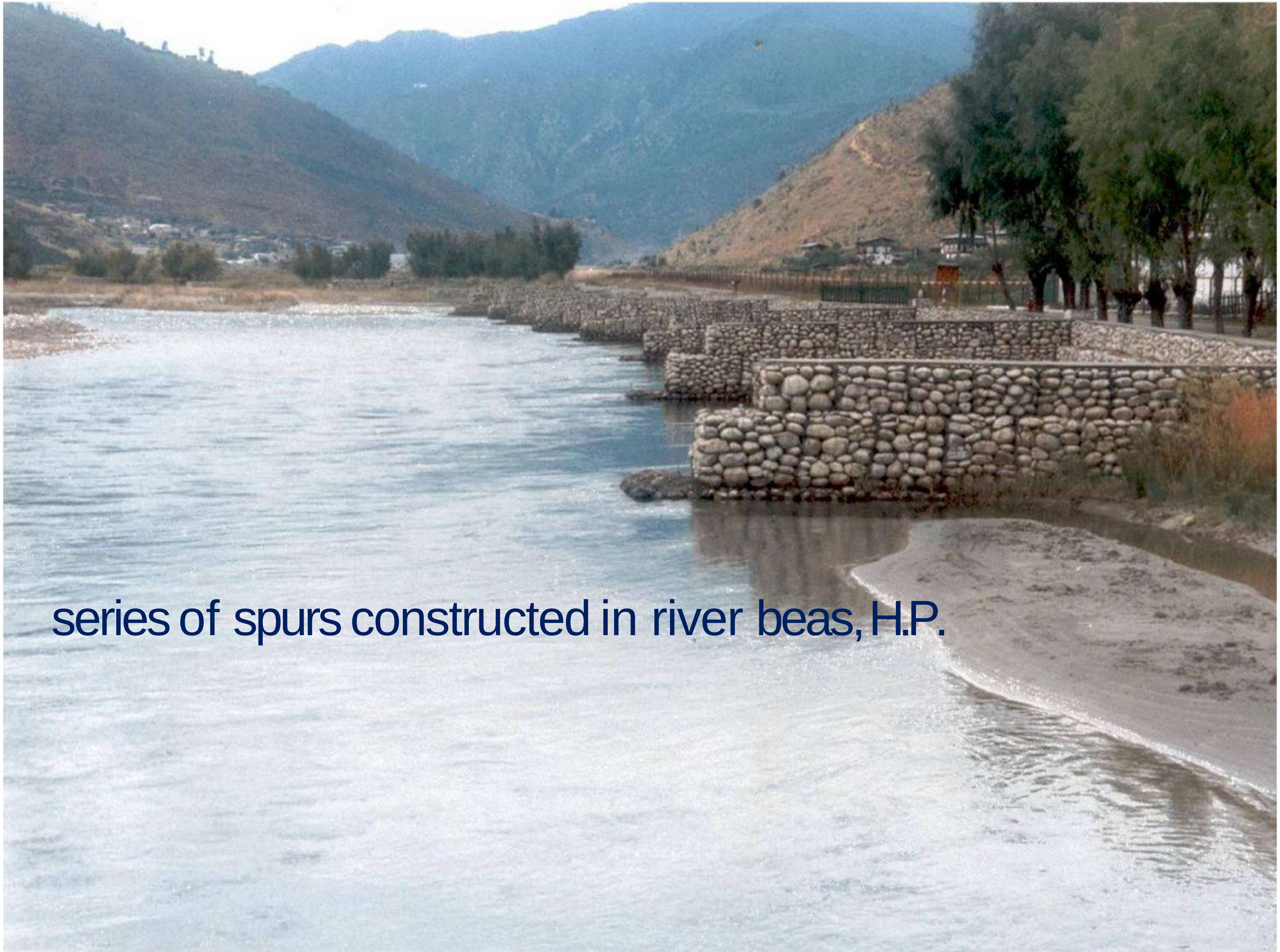
Spur with Stone core


Spur with aprons
Geo-textile filter

Spurs in River Alaknanda



How not to disturb River/ not to construct

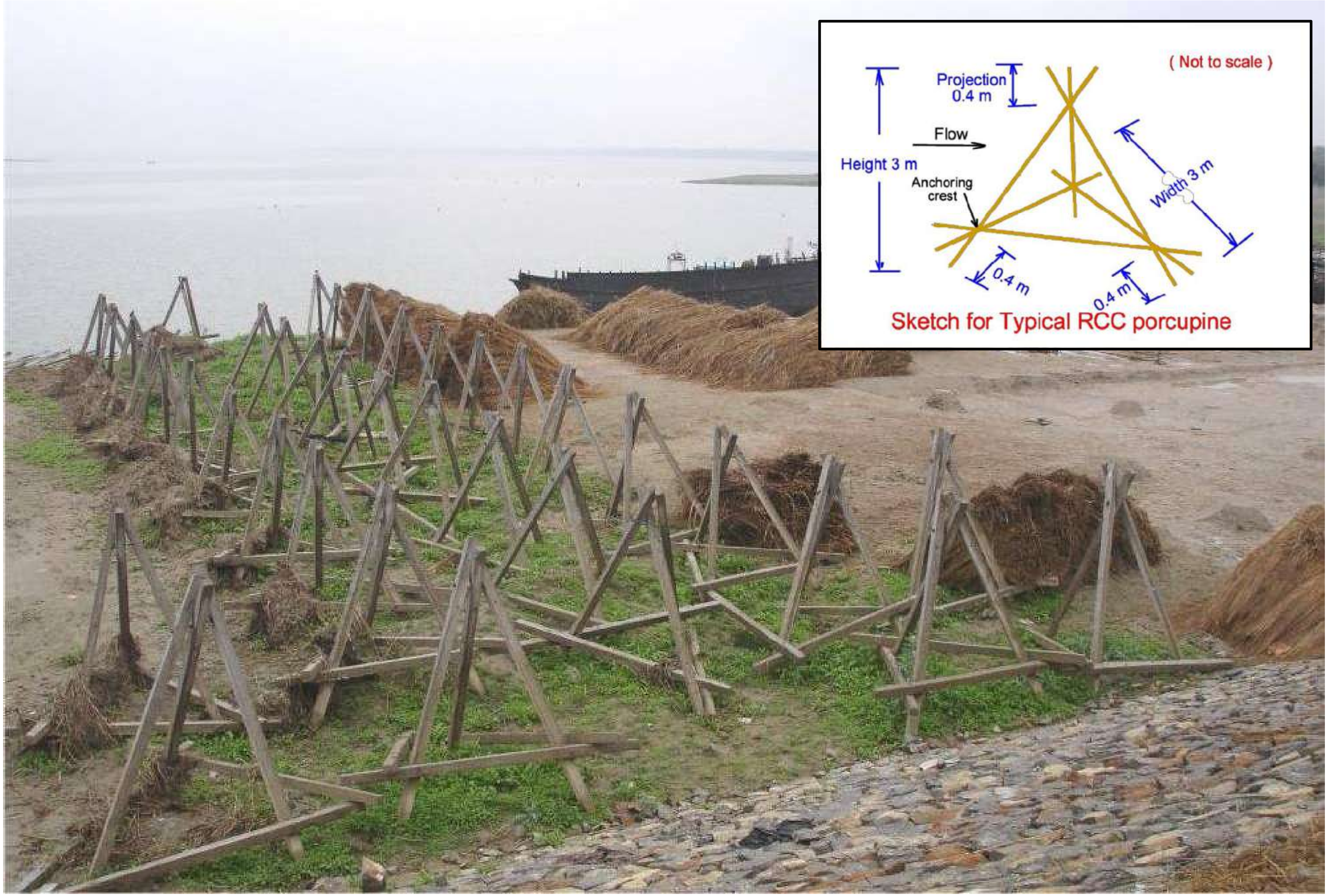


series of spurs constructed in river beas, H.P.


RCC Porcupines

- Bamboo Porcupines

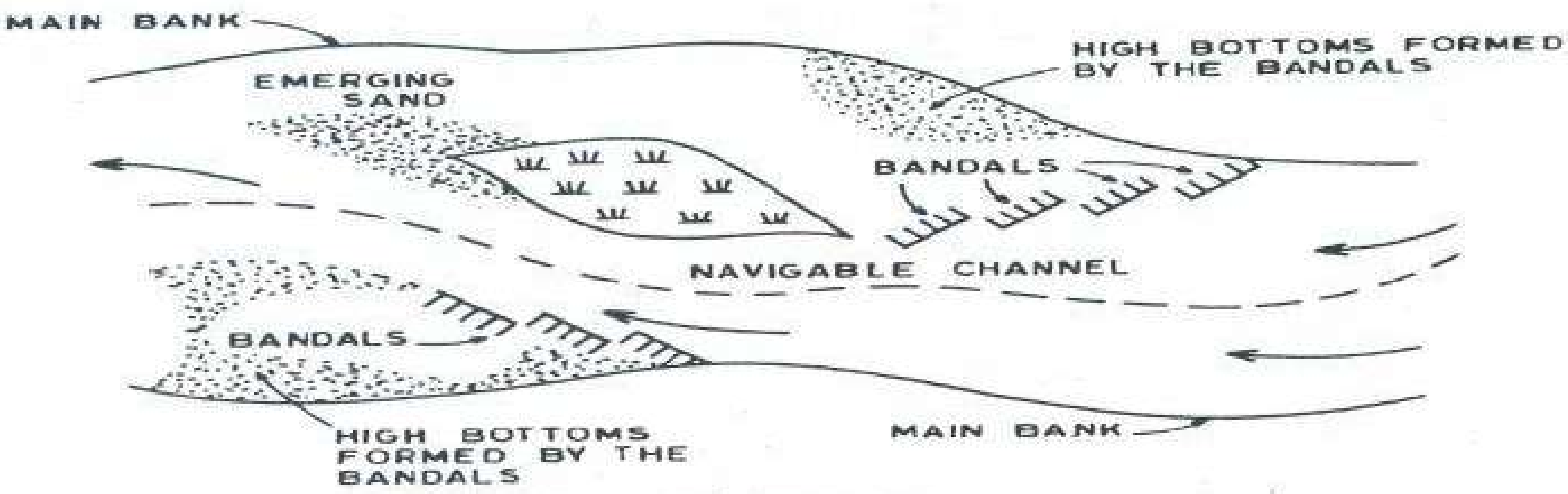
Porcupines in action during floods



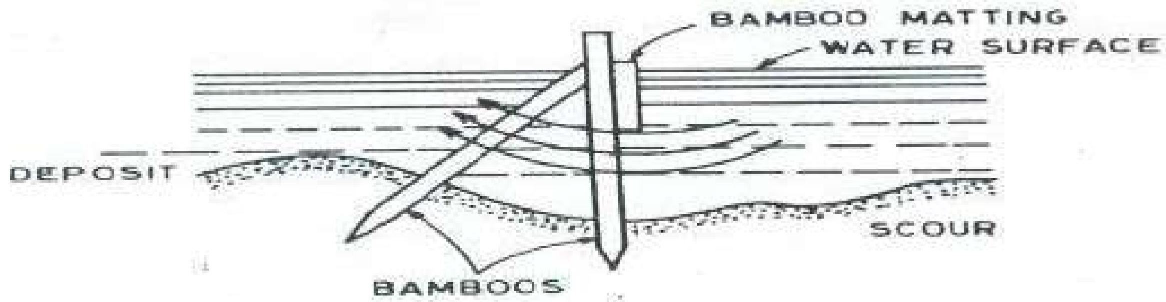
RCC Porcupine

Kahelgaon

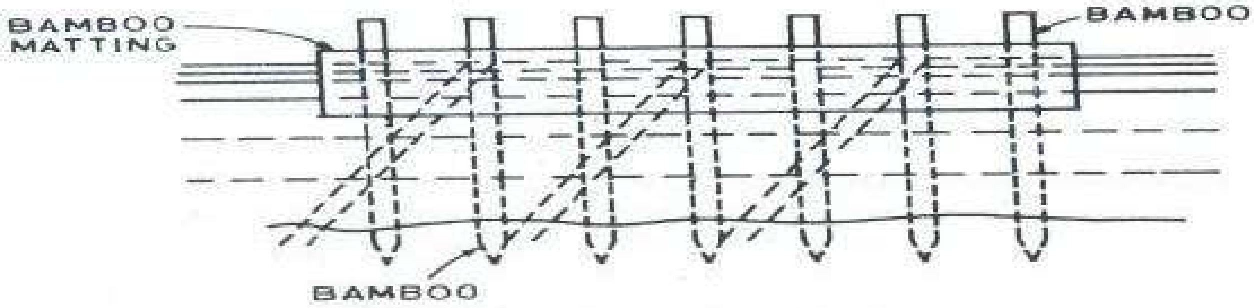
Dhyulian



LAYOUT PLAN OF BANDALS

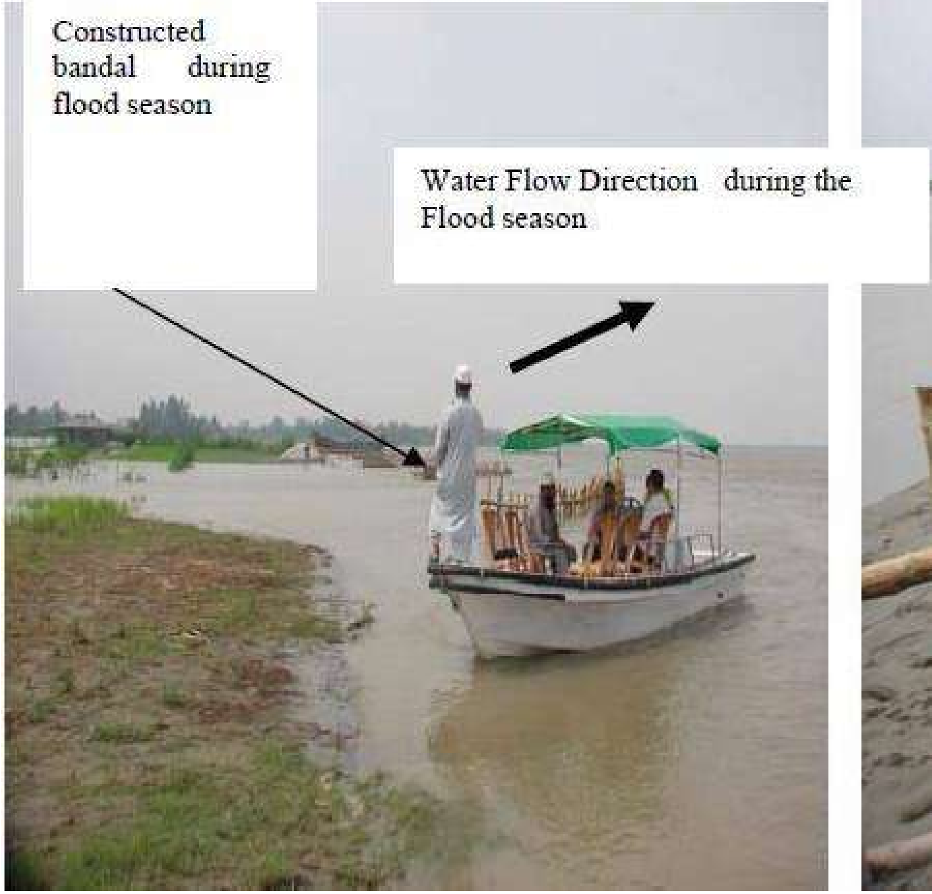


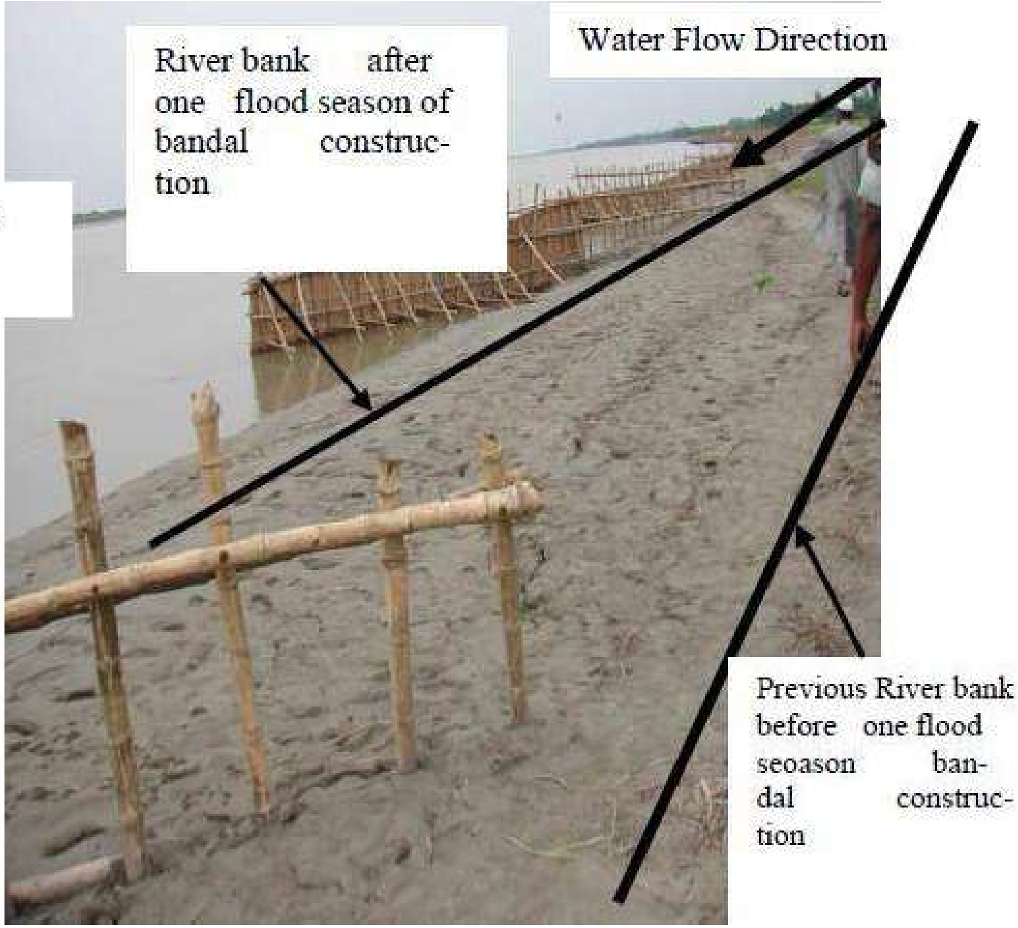
SIDE VIEW OF A BANDAL



ELEVATION OF A BANDAL

Working principles of bamboobandals





Stabilization of river bank with the bamboo bandalling

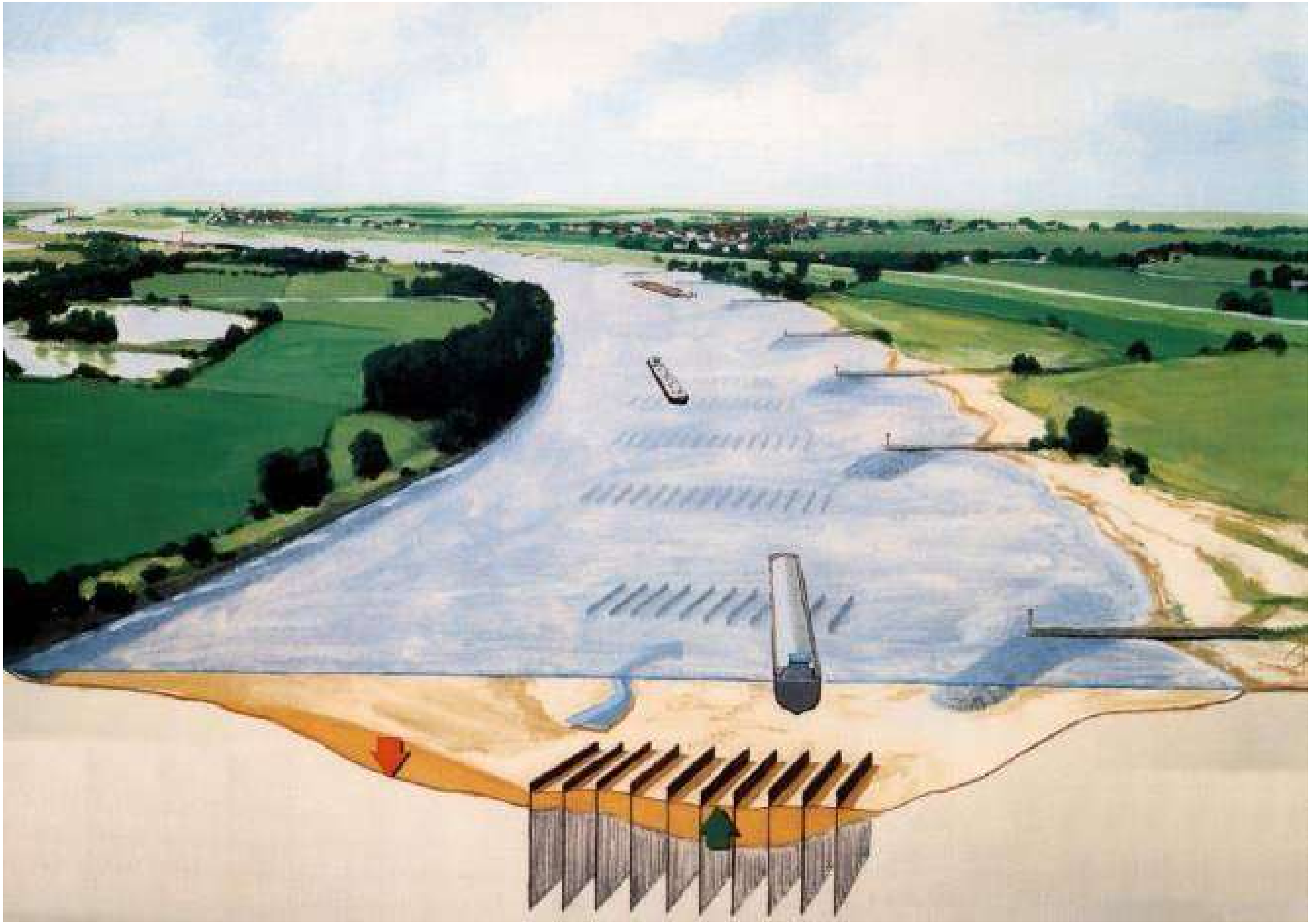
VANES

Structures designed to guide the flow away from an eroding bank line.

Can be constructed of rock or other erosion-resistant material

Top of vanes are below the design water surface elevation and would not connect to the high bank.

Bottom Vanes for navigability improvement



River Alaknanda (Steep slope) HNBG University campus (2013 Flood)

Photograph showing vertical profile of the affected site from river bed

Damaged approch road, falling retaining wall and water supply line as on 27-06-2013

Photo 2: Rock outcrop at upstream left bank of erosion site.

Sediment Threshold

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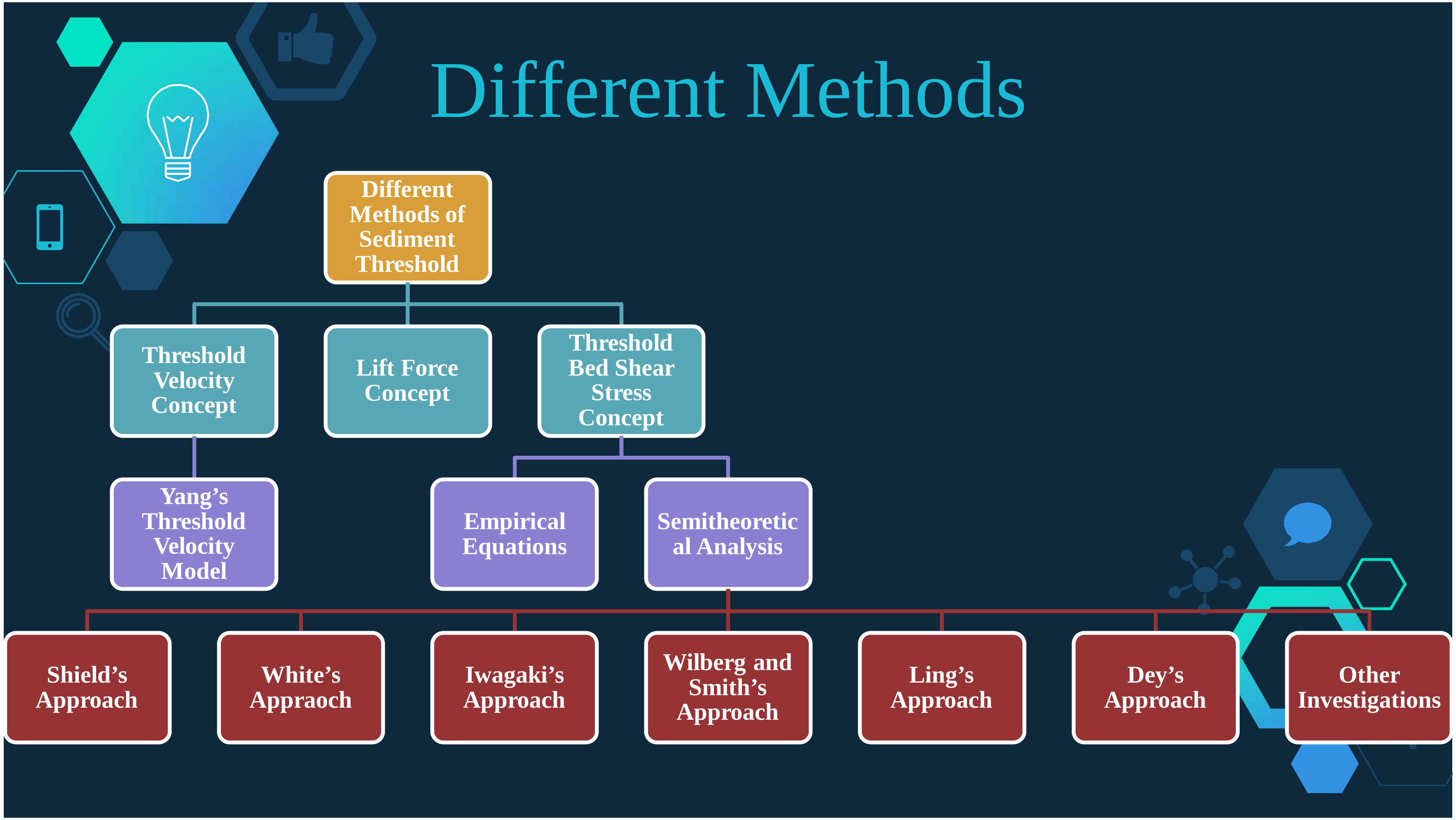
Definition of Sediment Threshold

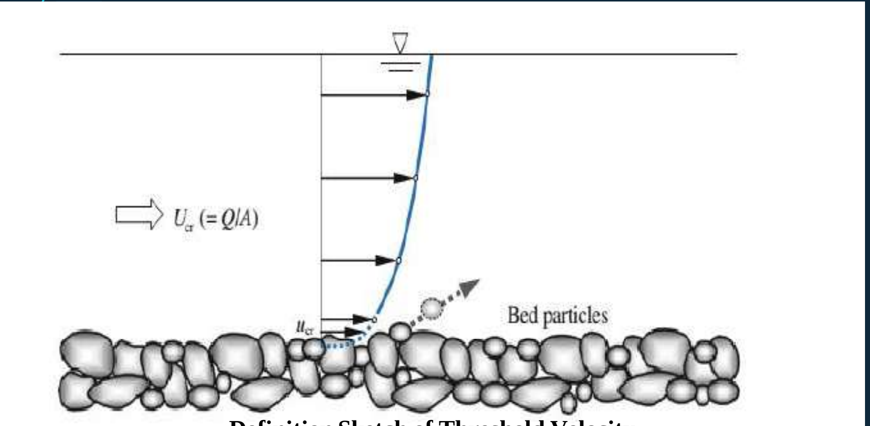
The condition that is just adequate to initiate sediment motion is termed threshold condition or critical condition of sediment entrainment. Importantly, the induced bed shear stress of the stream flow in excess of that of the stream flow at threshold condition governs the sediment entrainment mechanism.



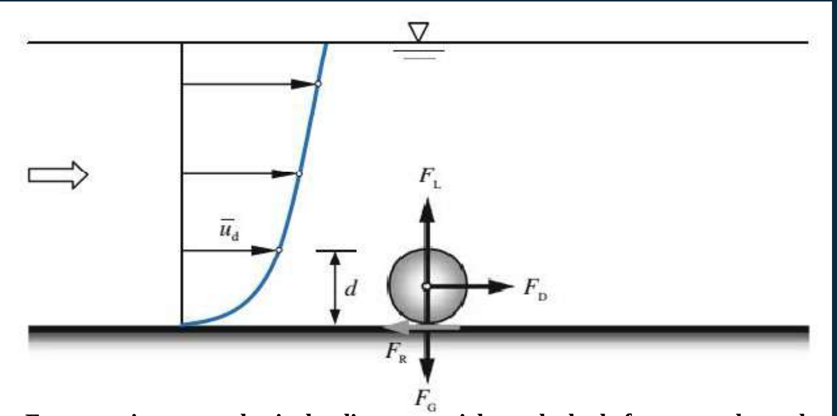
Different Methods
Different Methods of Sediment Threshold
Threshold Velocity Concept
Lift Force Concept
Threshold Bed Shear Stress Concept
Yang's Threshold Velocity Model
Empirical Equations
Semitheoretical Analysis
Shield's Approach
White's Appraoch
Iwagaki's Approach
Wilberg and Smith's Approach
Ling's Approach
Dey's Approach
Other Investigations

Threshold Velocity Concept

A threshold velocity or critical velocity is a near-bed velocity Ucr at the particle level or the average velocity Ucr, which is just adequate to start the sediment particle motion for a given size on the bed surface



Definition Sketch of Threshold Velocity



Forces acting on a spherical sediment particle on the bed of an open channel

$$U_{cr} = 1.07(\Delta g d)^{0.5} \log\left(8.8\frac{h}{d_{95}}\right)$$

$$U_{cr} = 1.41(\Delta g d)^{0.5} \left(\frac{h}{d}\right)^{1/6}$$

h is the flow depth, d is the representative sediment size, that is the median diameter, g is the acceleration due to gravity, D is the submerged relative density (=s - 1), s is the relative density of sediment (=ρs/q), ρs is the mass density of sediment, and q is the mass density of water. Subscript ''95'' denotes the percentage finer.

Lift Force Concept

Einstein (1950), Velikanov (1955), Yalin (1963), Gessler (1966), and Ling (1995) thought that the sediment is entrained solely by the lift force.

The lift force can primarily be induced for the following reasons:

◇Sediment particles on the bed surface experience maximum velocity gradient; thus, a lift acts on the particles due to considerable pressure difference.

◇sediment particles may experience lift due to the instantaneous vertical velocity fluctuations in the vicinity of the bed.

◇the slip-spinning motion of sediment particles may result in lift due to Magnus effect.

$$f_L = 0.5 C_L \rho \bar{u}_{0.35d}^2$$

CL is the lift coefficient assumed as 0.178 and u0:35d is the flow velocity at an elevation 0.35d from the theoretical bed.

Threshold Bed Shear Concept

◇The concept of threshold bed shear stress has been widely applied for the determination of inception of particle motion and seems to provide reasonable results.

◇The origin of this concept lies on the experimental (laboratory and field) or theoretical determination of so-called tractive force per unit area, that is the bed shear stress, given by $\rho gh\tan\Theta$.

◇This concept is based on the analysis of the hydrodynamic force caused by the flowing fluid and the stabilizing force due to submerged weight to formulate the threshold bed shear stress in non-dimensional form, termed threshold Shields parameter.

Empirical Equations

Attempts have been made to correlate the threshold bed shear stress Ʈoc with sediment properties obtained from the experimental and field measurements.

$$\tau_{0c} = 0.448 \rho g (\Delta S_p d^3)^{0.5}$$

is in kg m-2, Sp is the Corey shape factor varying from 1 for spherical to 4.4 for flat particles, and d is in m.

A simple equation of Ʈoc was given by Leliavsky (1966) as

$$\tau_{0c} = 166 d$$

Ʈoc is in g m-2 and d is in mm.

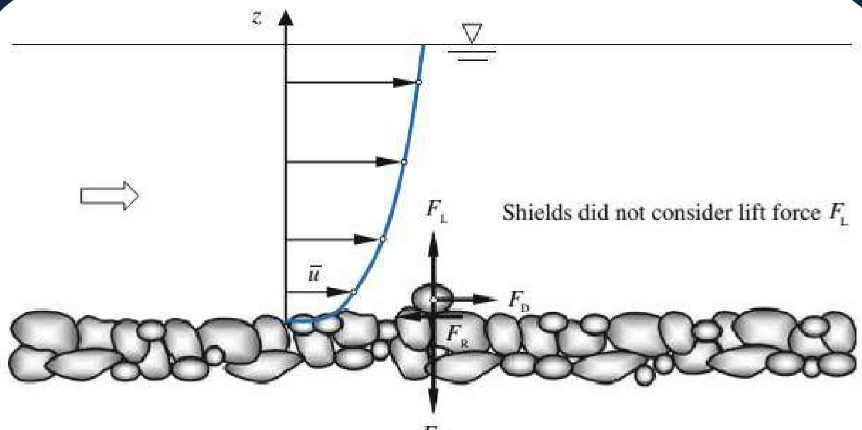
Semitheoretical Analyses

Shield's Approach

◇Shields (1936) was the pioneer in proposing a semi-theoretical method for the entrainment threshold of sediments.

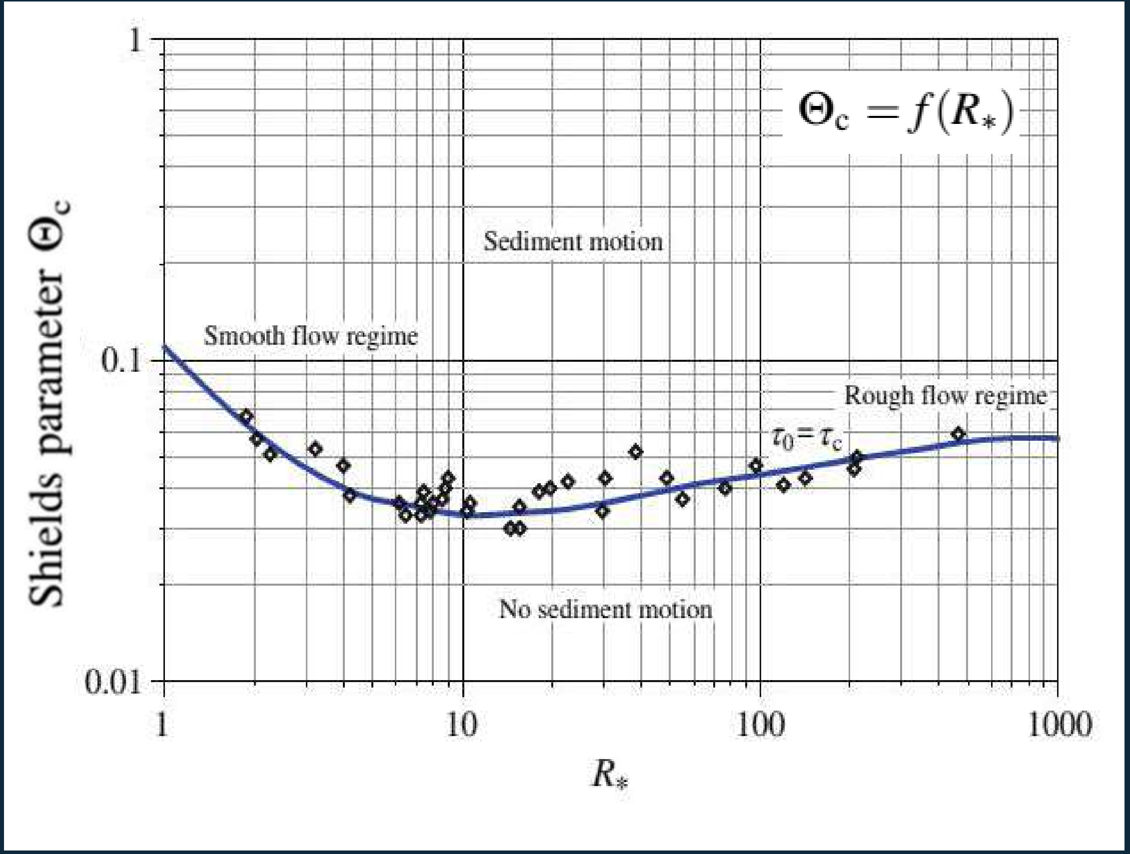
◇He considered that the particles do not move at very low velocity.

◇As the flow velocity increases to a certain value, the driving force on the sediment particles exceeds the tabilizing force, and the sediment particles start to move.



Schematic of a particle subjected to instantaneous hydrodynamic force

Shield’s Diagram



Existing Explicit Equations For Sediment Threshold

S.No.	Researchers	Equation
1.	Bonnefille(1963)	$\theta_{cr} = \begin{cases} 0.118d_*^{-0.468}; & d_* < 2.33 \\ 0.137d_*^{-0.648}; & 2.33 \le d_* < 9.15 \\ 0.063d_*^{-0.298}; & 9.15 \le d_* < 15.28 \\ 0.9d_*^{0.424}; & 15.285 \le d_* < 58.3 \end{cases}$
2.	Brownlie(1981)	$\theta_{cr} = 0.22\beta + 0.06 \times 10^{-7.7\beta}, \beta = \left[\frac{d_*}{\nu}\left((s-1)gd_*\right)^{0.5}\right]^{-0.60}$
3.	Chien and Wan(1983)	$\theta_{cr} = \begin{cases} 0.126d_*^{-0.44}; & d_* < 1.5 \\ 0.131d_*^{-0.55}; & 1.5 \le d_* < 10.0 \\ 0.0685d_*^{0.27}; & 10 \le d_* < 20 \\ 0.0173d_*^{0.19}; & 20 \le d_* < 40 \\ 0.0115d_*^{0.30}; & 40 \le d_* < 150 \\ 0.052; & d_* \ge 150 \end{cases}$
4.	van Rijn(1984)	$\theta_{cr} = \begin{cases} 0.24d_*^{-1.00}; & d_* < 4.0 \\ 0.14d_*^{-0.64}; & 4.0 \le d_* < 10.0 \\ 0.04d_*^{0.10}; & 10 \le d_* < 20 \\ 0.013d_*^{0.28}; & 20 \le d_* < 150 \\ 0.055; & d_* \ge 150 \end{cases}$
5.	Guo(1990)	$\theta_{cr} = 0.1R_*^{-0.667} + 0.054[1 - \exp(-0.1R_*^{0.52})];$ $where, R_* = \frac{d_s}{\nu}[0.1(s-1)gd_s]^{0.50}$
6.	Guo(1990)	$\theta_{cr} = 0.23d_*^{-1.0} + 0.054[1 - \exp(-0.0435d_*^{0.85})];$

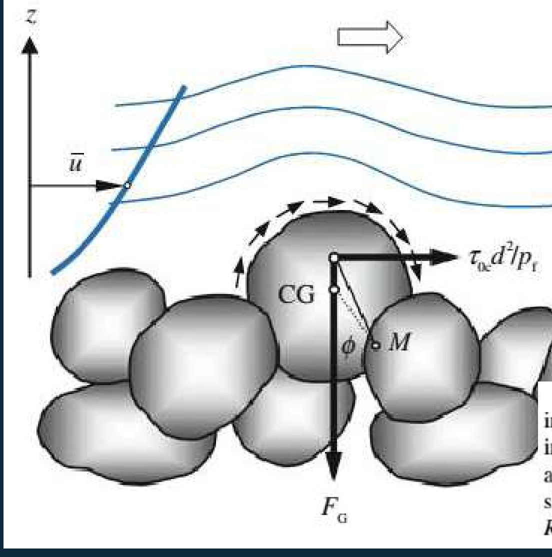
Existing Explicit Equations For Sediment Threshold

7.	Paphitis(2001)	$\theta_{cr} = \frac{0.273}{1+1.2d_*} + 0.046[1-0.576\exp(-0.02d_*)];$ $0.01 < Re_* < 10^4$
8.	Hager and Oliveto(2002)	$\theta_{cr} = \begin{cases} 0.12d_*^{-0.50}; & d_* < 10 \\ 0.026d_*^{0.167}; & 10 \le d_* < 150 \\ 0.06; & d_* \ge 150 \end{cases}$
9.	Shippard and Renna(2005)	$\theta_{cr} = \begin{cases} 0.25 + 0.1d_*^{0.50}; & 0.1 \le d_* < 3 \\ 0.023d_* - 0.000378d_* \ln d_* - 0.005 & ;3 \le d_* < 150 \\ 0.0575; & d_* \ge 150 \end{cases}$
10.	Cao et al. (2006)	$\theta_{cr} = \begin{cases} 0.1414R_d^{-0.2306}; & R_d \le 6.61 \\ \frac{[1+(0.0223R_d)^{2.8358}]^{0.3542}}{3.0946R_d^{0.6769}}; & 6.6 \le R_d < 282.84 \\ 0.045; & R_d \ge 282.84 \end{cases}$

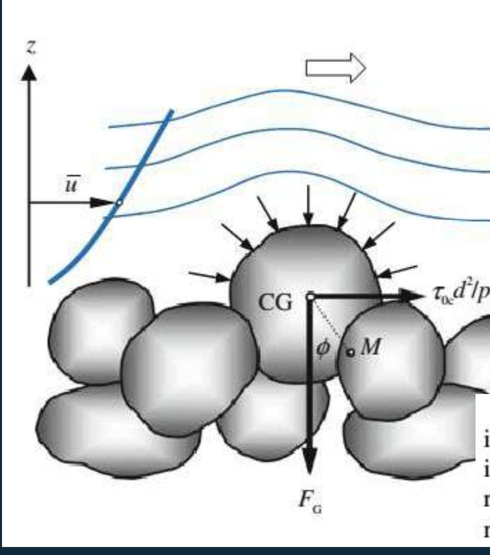
White’s Approach

◇White (1940) assumed that the lift force has negligible influence on threshold of particle motion compared to other forces, and hence, it was neglected in his analysis. At limiting equilibrium, the drag force (shear drag) is balanced by the frictional resistance.

◇White (1940) classified hydraulically transitional and rough flow regimes (R* C 3.5), and smooth flow regime (R*>=3.5) in analyzing threshold of particle motion.



Equilibrium of an individual sediment particle in hydraulically transitional and rough flow regimes for shear Reynolds numbers $R_* \geq 3.5$

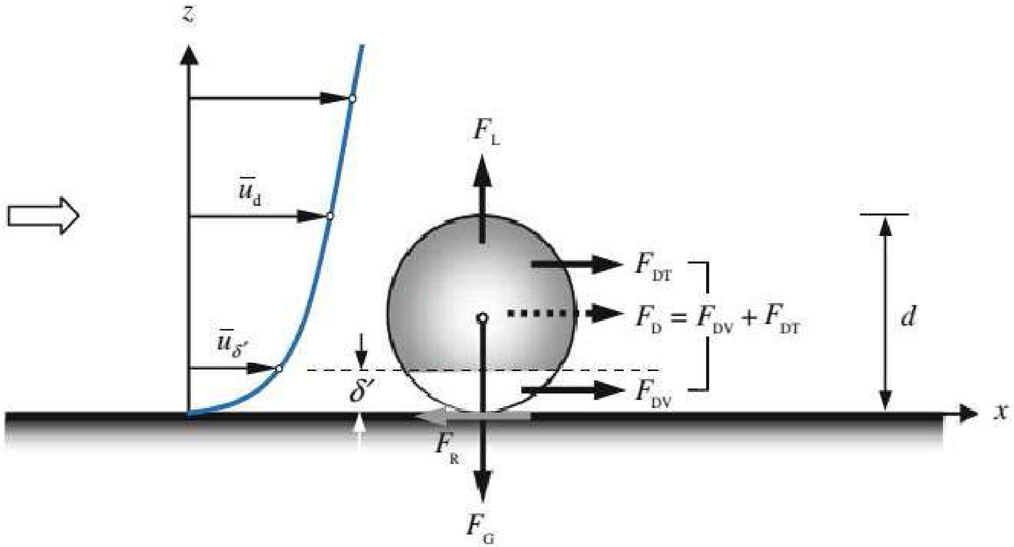


Equilibrium of an individual sediment particle in hydraulically smooth flow regime for shear Reynolds numbers $R_* < 3.5$

Iwagaki's Approach

◇Iwagaki (1956) analyzed the equilibrium of an isolated spherical particle having diameter d placed on a rough horizontal bed.

◇He considered the force balance within the flow region dividing into viscous sublayer and turbulent flow regions and obtained the conditions required for the beginning of sediment motion under a unidirectional stream flow.



Forces acting on an individual spherical particle resting on a horizontal bed, as considered by Iwagaki

Iwagaki's Empirical Curves Equation

$$\Theta_c(S_* \leq 2.14) = 0.14$$

$$\Theta_c(2.14 < S_* \leq 54.2) = 0.195 S_*^{-7/16}$$

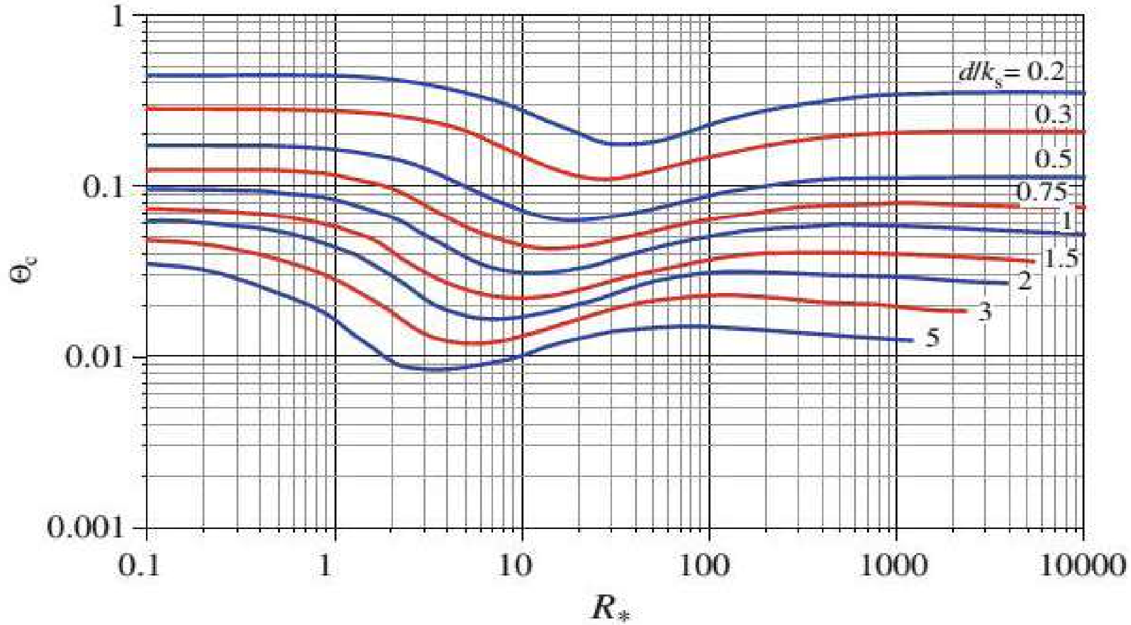
$$\Theta_c(54.2 < S_* \leq 162.7) = 0.034$$

$$\Theta_c(162.7 < S_* \leq 671) = 0.195 S_*^{3/11}$$

$$\Theta_c(S_* > 671) = 0.05$$

Wiberg's & Smith Approach

◇Wiberg and Smith (1987) analyzed the force system acting on a sediment particle for the limiting equilibrium of the particle resting over the bed formed by the sediment particles.

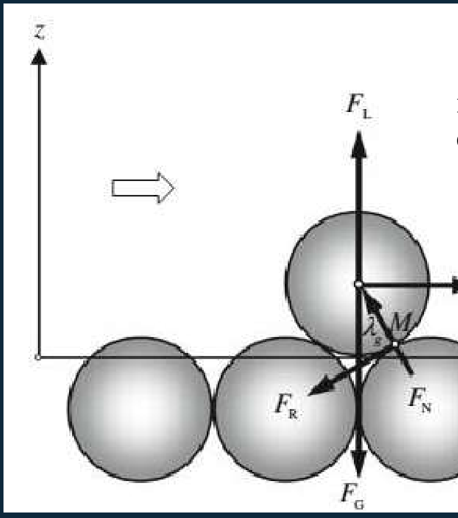


Threshold Shields parameter Ɵc as a function of shear Reynolds number R* for different ratios of particle size to bed roughness d/ks (Wiberg and Smith 1987)

Ling's Approach

◇Ling (1995) studied the threshold condition of a solitary sediment particle situated on the top of the spherical particles forming the bed.

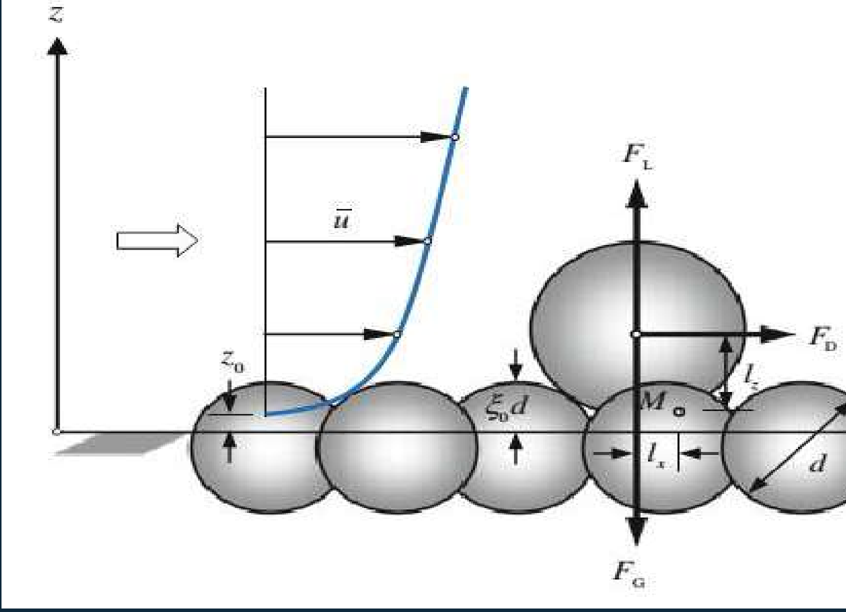
◇On the basis of mechanical and hydrodynamic considerations, two separate criteria for the threshold of sediment motion were derived. They are rolling threshold criterion and lifting threshold criterion.



Forces acting on a solitary spherical particle resting on bed particles, as considered by Ling (1995)

Dey's Approach

◇Dey (1999) considered a unidirectional steady-uniform flow over a sedimentary bed. The most stable three-dimensional configuration of a spherical solitary sediment particle of diameter D resting over three closely packed spherical particles of identical diameter d forming the sediment bed.



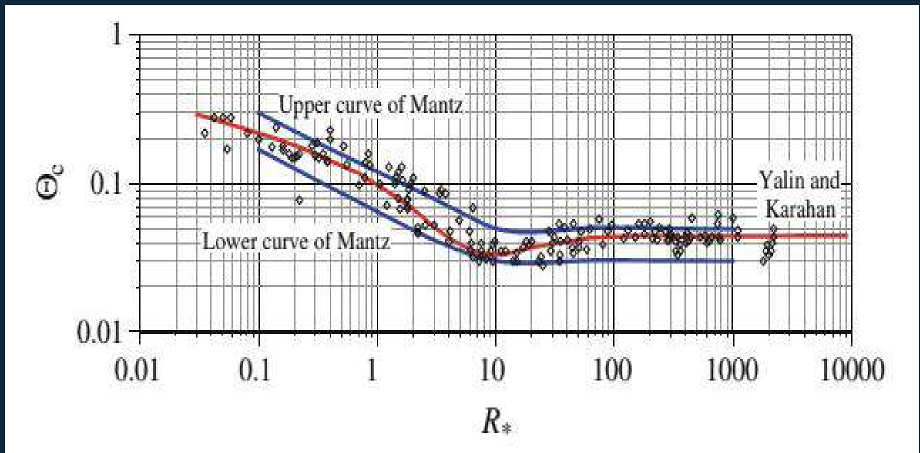
Diagrammatic presentation of forces acting on a spherical solitary particle, as considered by Dey (1999)

Other Investigations

◇Mantz (1977) proposed the extended Shields diagram to obtain the condition of maximum stability of sediment particles.

◇Yalin and Karahan (1979) presented a Ɵc(R*) curve, using a large number of data collected from literature.The Ɵc(R*) curve provides Ɵc(R*[70) = 0.045. Their curve is regarded as a superior curve to the Shields diagram.

◇Cao et al. (2006) derived a set of explicit equations for the curve of Yalin and Karahan (1979).



$$\Theta_c(S_* \le 6.61) = 0.1414 S_*^{-0.23}$$

$$\Theta_c(6.61 < S_* < 282.84) = \frac{\left[1 + (0.0223 S_*)^{2.84}\right]^{0.35}}{3.09 S_*^{0.68}}$$

$$\Theta_c(S_* \ge 282.84) = 0.045$$

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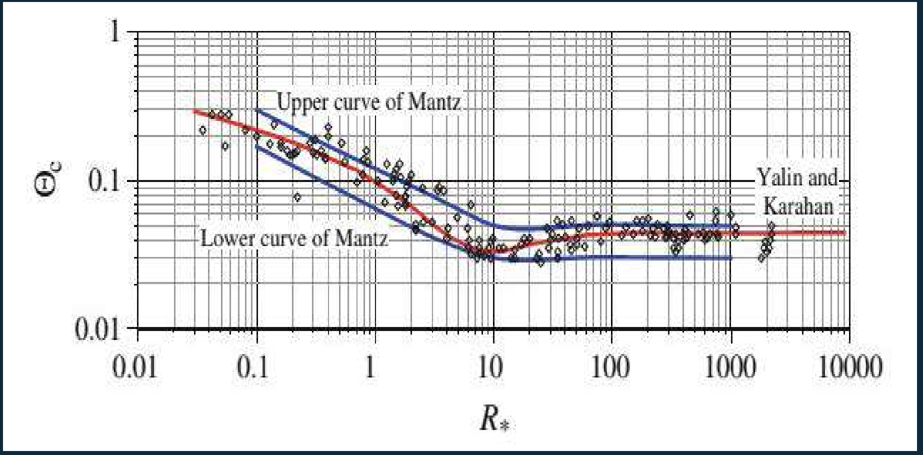

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Two-dimensional two-phase Motion

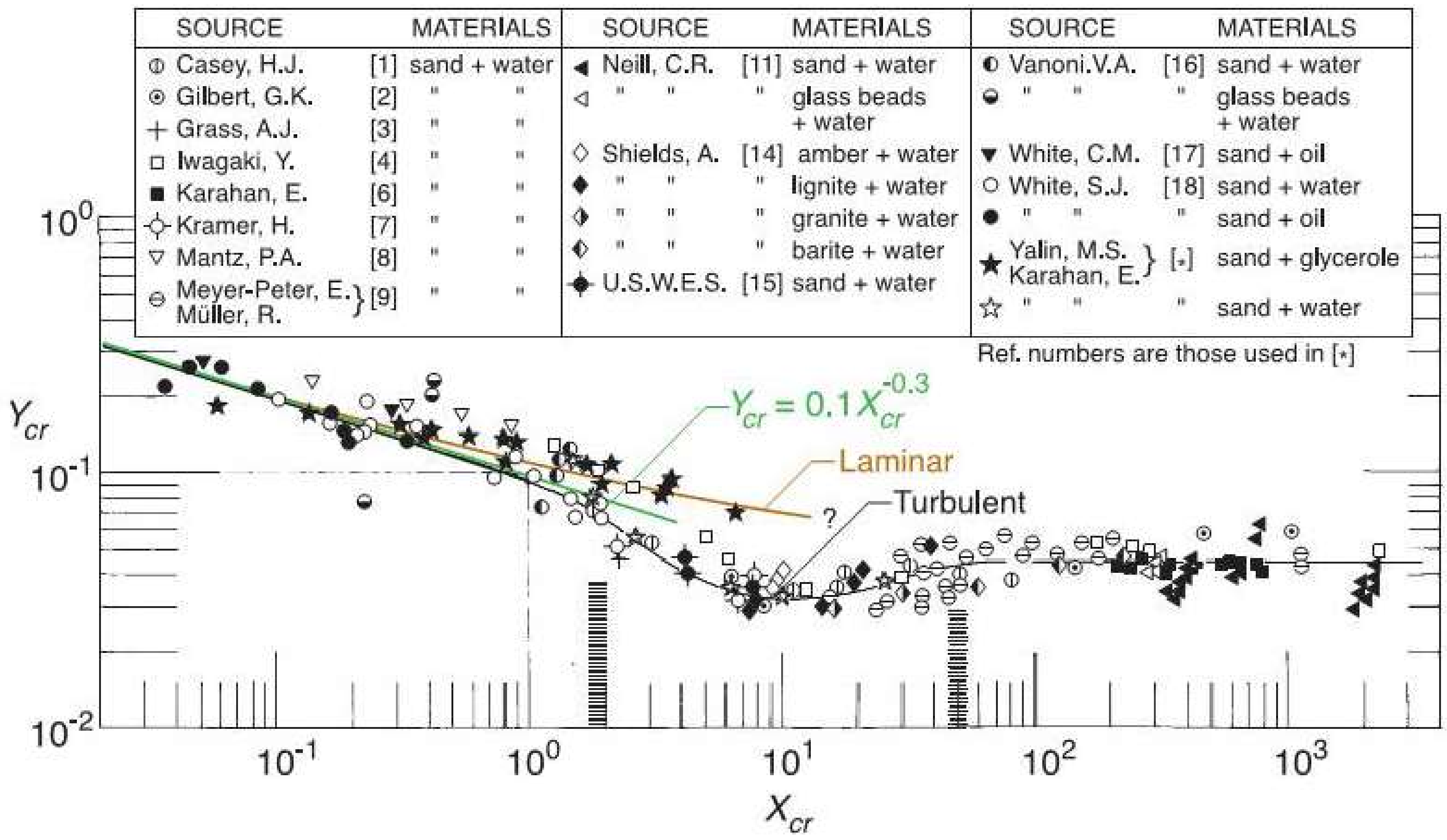
$$Y_{cr} = \Phi(X_{cr})$$

$$X_{cr} = \frac{\upsilon_{*cr} D}{\nu} \quad \text{and} \quad Y_{cr} = \frac{\rho \upsilon_{*cr}^2}{\gamma_s D} = \frac{(\tau_0)_{cr}}{\gamma_s D}$$

Consider the following combination of X and Y

$$\Xi^3 = \frac{X^2}{Y} = \frac{\gamma_s D^3}{\rho \nu^2}$$

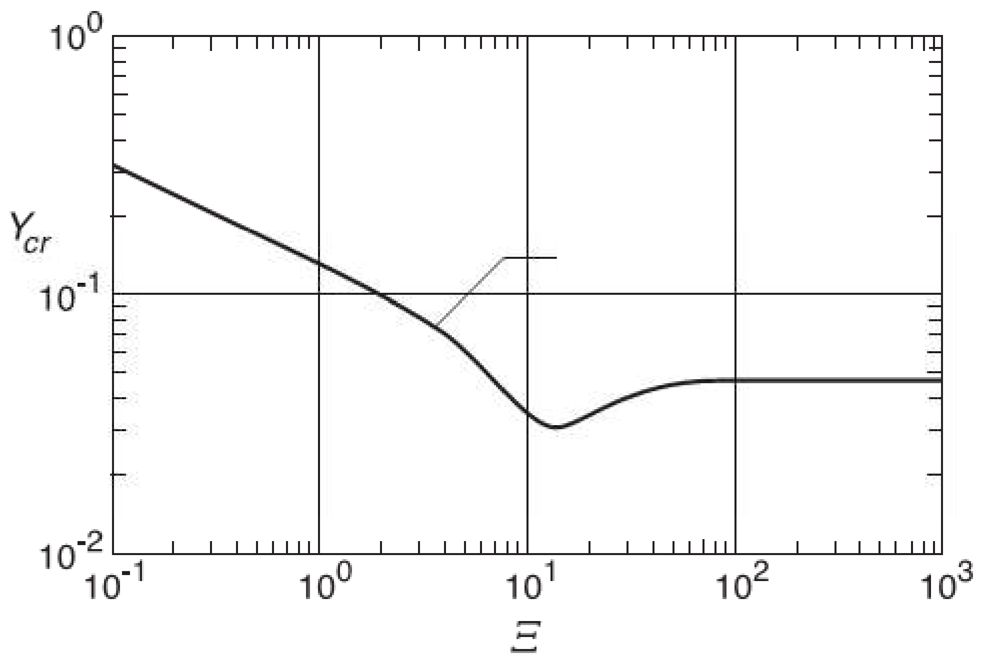
This combination reflects the influence of the solid (γ_s, D) and liquid (ρ, ν) phases involved and its value does not vary depending on the stage of the flow (for it does not



SOURCE MATERIALS
Casey, H.J. [1] sand + water
Gilbert, G.K. [2]
Grass, A.J. [3]
Iwagaki, Y. [4]
Karahan, E. [6]
Kramer, H. [7]
Mantz, P.A. [8]
Meyer-Peter, E. Müller, R. [9]
Neill, C.R. [11] sand + water
glass beads + water
Shields, A. [14] amber + water
lignite + water
granite + water
barite + water
U.S.W.E.S. [15] sand + water
Vanoni.V.A. [16] sand + water
glass beads + water
White, C.M. [17] sand + oil
White, S.J. [18] sand + water
sand + oil
Yalin, M.S. Karahan, E. [*] sand + glycerole
sand + water
Ref. numbers are those used in [*]
$Y_{cr} = 0.1X_{cr}^{-0.3}$
Laminar
Turbulent
?
Y_{cr}
X_{cr}
10^0
10^{-1}
10^{-2}
10^{-1}
10^0
10^1
10^2
10^3

The graph of the function *Ycr* =*Ψ*(*Ξ*) is shown in Figure. This function can be adequately represented, throughout the extent of *Ξ*-values in Figure, by the following comp-eq. (due to da Silva and Bolisetti 2000)

$$Y_{cr} = 0.13\, \Xi^{-0.392} e^{-0.015\Xi^2} + 0.045\left[1 - e^{-0.068\Xi}\right]$$



Modified sediment transport inception function (adapted from da Silva and Bolisetti 2000)

Development of New Equations

Shields (1936) who studied the initial motion of sediment in steady flow on a flat bed. Shields offered this relationship as

$$\theta_{cr} = \frac{\tau_{oc}}{(s-1)\rho g d} = f\left(\frac{u_{*c} d}{\nu}\right)$$

where, $\theta_{cr} =$ Shield's critical parameter; $\tau_{oc} =$ bottom shear stress; $\rho =$ density of the fluid; $s =$ specific gravity of sediment; $d =$ grain size of the sediment; $g =$ acceleation due to gravity; and $\theta_{cr} =$ the ratio of the shear atress acting on a unit area of the bed to the submerged weight of particles in that same area.

The two parameters in the Shield's diagram i.e. θ_{cr} and Re_*, both depend on the flow characteristics and the friction velocity, u_*, appears in both the axes and hence θ_{cr} in Eq. (9) is implicit, and τ_{oc} needs to be iterated. To overcome this weakness, new variable i.e. $s_* = d[(s-1)gd]^{1/2}/(4\nu)$ is introduced to rewrite Eq. (9) explicitly as $\theta_{cr} = F(s_*)$ because Re_* is also a function of s_* i.e.

$$\frac{u_* d}{\nu} = \left[\frac{\tau_{oc}}{(\rho_s - \rho_w) g d} \times \frac{g(\rho_s - \rho_w) d^3}{\rho \cdot \nu}\right]^{0.50}$$

From which we obtain $s_* = g_1(u_* d/\nu)$ *or* $(u_* d/\nu) = g_2(s_*)$. Thus, finally the modified Shields' criterion. $\theta_{cr} = G(s_*)$, may be approximated as, Madsen et al. (1976) converted the Shields diagram into the diagram showing the relation between the critical Shields' parameter, θ_{cr}, and the so-called sediment fluid parameter, s_*

Development of New Equations…

From which we obtain $s_* = g_1(u_* d/\nu)$ or $(u_* d/\nu) = g_2(s_*)$.

$$s_* = \frac{d[(s-1)gd]^{1/2}}{4\nu}$$

The Madsen et al. (1976) diagram is shown in Figure.2. Thus for this graphical presentation between θ_{cr} and s_* following equations are obtained.

$$\theta_{cr} = 0.101 s_*^{-2.857}; for\ s_* < 0.80$$

$$\theta_{cr} = 0.119 s_*^{-0.667} + 0.0551[1 - \exp(-0.0504 s_*^{0.664})]; for\ s_* < 300$$

$$\theta_{cr} = 0.0551; for\ s_* \geq 300$$

A correction to account for this has been made to give an improved threshold bed shear stress formula i.e.

$$\theta_{cr} = \frac{0.307}{1 + 3.03 s_*^{0.667}} + 0.055[1 - \exp(-0.0504 s_*^{0.667})];$$

an approximately constant value of $\theta_{cr} = 0.0551$ for larger grain size i.e. $s_* \geq 300$.

Development of New Equations…

This value of, θ_{cr} i.e. Eq.(14) does not take slope into effect.

Can be also used for computation of θ_{cr} at an angle of, β, in the longitudinal direction. i.e.

$$\theta_{cr,\beta} = cos\beta\left(1 - \frac{tan\beta}{tan\phi}\right)\theta_{cr}$$

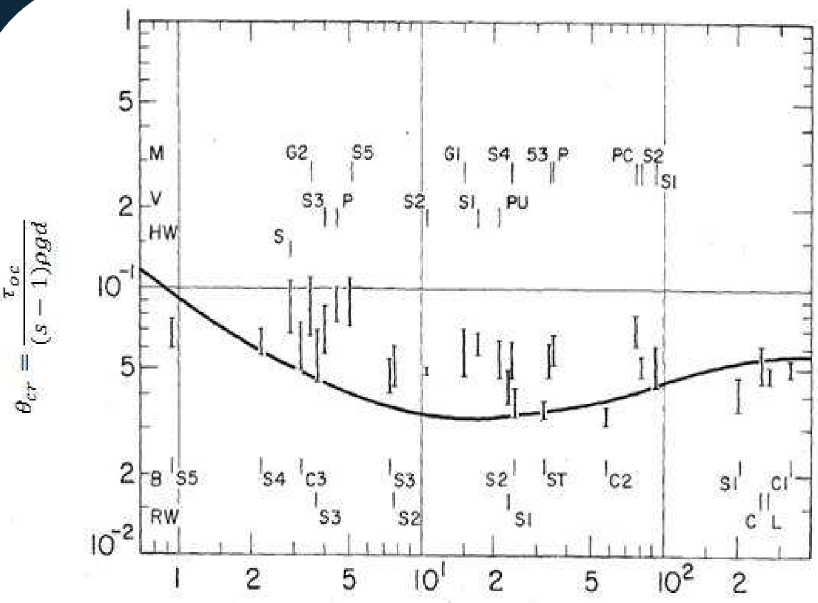
where, ϕ = angle of repose of soil; and β = slope of bed in longitudinal direction.

The kinematic viscosity coefficient for the above equations can be used as:

$$v = [1.14 - 0.0013(T - 15) + 0.000681(T - 15)^2] \times 10^{-6} m^2/s$$

where, T= temperature in°C.

Development of New Equations…



$$s_* = \frac{d[(s-1)gd]^{1/2}}{4\nu}$$

Madsen and Grant (1976) diagram

Thank You!

Water Requirement of Crops

By:- Prof. ShriRam
H.O.D., Civil Engineering Department
MMMUT, Gorakhpur

Content

Introduction

- The water need of a crop thus consists of transpiration plus evaporation. Therefore, the crop water need is also called **“Evapotranspiration".** The water need of a crop is usually expressed in mm/day, mm/month or mm/season.
- Water Requirement of Crop is defined as the depth of water needed to meet the water consumed through evapotranspiration by a disease-free crop, growing in

Cont…

large fields achieving full production potential under the given growing environment.

- A crop is a plant or plant product that can be grown and harvested for profit or subsistence. By use, crops fall into six categories: food crops, feed crops, fiber crops, oil crops, ornamental crops, and industrial crops. Food crops, such as fruit and vegetables, are harvested for human consumption.

Cont…

- **Rabi crops** are sown in winter from October to December and harvested in summer from April to June. Some of the important rabi crops are wheat, barley, peas, gram and mustard.
- **Kharif crops** are grown with the onset of monsoon

Cont…

- in different parts of the country and these are harvested in September-October.
- Important crops grown during this season are paddy, maize, jowar, bajra, tur (arhar), moong, urad, cotton, jute, groundnut and soyabean.

Cont…

- In between the rabi and the kharif seasons, there is a short season during the summer months known as the Zaid season. Some of the crops produced during 'Zaid' are watermelon, muskmelon, cucumber, vegetables and fodder crops.

Functions of Irrigation Water

- It acts as a solvent for the nutrients. Water forms the solution of the nutrients, and this solution is absorbed by the roots. Thus, water acts as the nutrient carrier.
- The irrigation water supplies moisture which is essential for the life of bacteria beneficial to the plant growth.
- Irrigation water supplies moisture which is essential for the chemical action within the plant leading to its growth.

Cont…

- Some salts present in soil react to produce nourishing food products only in the presence of water.
- Water cools the soil and the atmosphere, and thus makes more favorable environment for healthy plant growth.
- Irrigation water, with controlled supplies, washes out or dilutes salts in the soil.
- It reduces the hazard of soil piping.
- It softens the tillage pans.

Quality of Irrigation Water

- A good irrigation water is the one which performs the functions of irrigation without any side effects which related to the plant growth.
- Irrigation water may contain various types of salt such as sodium, calcium, magnesium and potassium etc. A high concentration of these salts may prove to be injurious to the crops.
- The salt content of irrigation water is usually expressed by one of the following ways:-

Cont…

a) Parts per million (ppm) or mg/l

b) Milli equivalents per litre (MEQ/L).

c) Electrical conductivity, expressed in EC $\times 10^6$.

- Salinity concentration of soil solution (C_s) can be determined by the given equation:-

$$C_s = \frac{C.Q}{Q - (C_u - P_{eff})}$$

where,

Cont…

C = Concentration of salt in irrigation water.

Q = Total Quantity of water applied to the soil.

C_u = Consumptive use of water

P_{eff} = Useful Rainfall

Classification of Irrigation water based on Salt Concentration

Types Of Water	Conductivity (micro-mhos/cm) at 25^{0C}	Suitable for Irrigation
Low Salinity Water (C_1)	100-250	Suitable for all types of crops and all kinds of soils. Permissible under normal irrigation practices except in soil of extremely low permeability.
Medium Salinity Water (C_2)	250-270	Can be used if a moderate amount of leaching occurs. Normal salt tolerant plants can be grown without much salinity control.
High Salinity Water (C_3)	750-2250	Unsuitable for soil with restricted drainage. Only high-salt tolerant plants can be grown.
Very High Salinity Water (C_4)	> 2250	Unsuitable for irrigation.

MADAN MOHAN MALAVIYA UNIVERSITY OF TECHNOLOGY, GORAKHPUR (U.P.)-273010

DEPARTMENT OF CIVIL ENGINEERING
COURSE- B.TECH
SUBJECT NAME- WATER RESOURCES ENGIEERING
SUBJECT CODE- BCE-14

FIRST ONLINE CLASS ON WATER RESOURCES ENGINEERING (BASICS AND DIFFERENT TOPICS IN THE SYLLABUS TO BE COVER)

– Prof. ShriRam

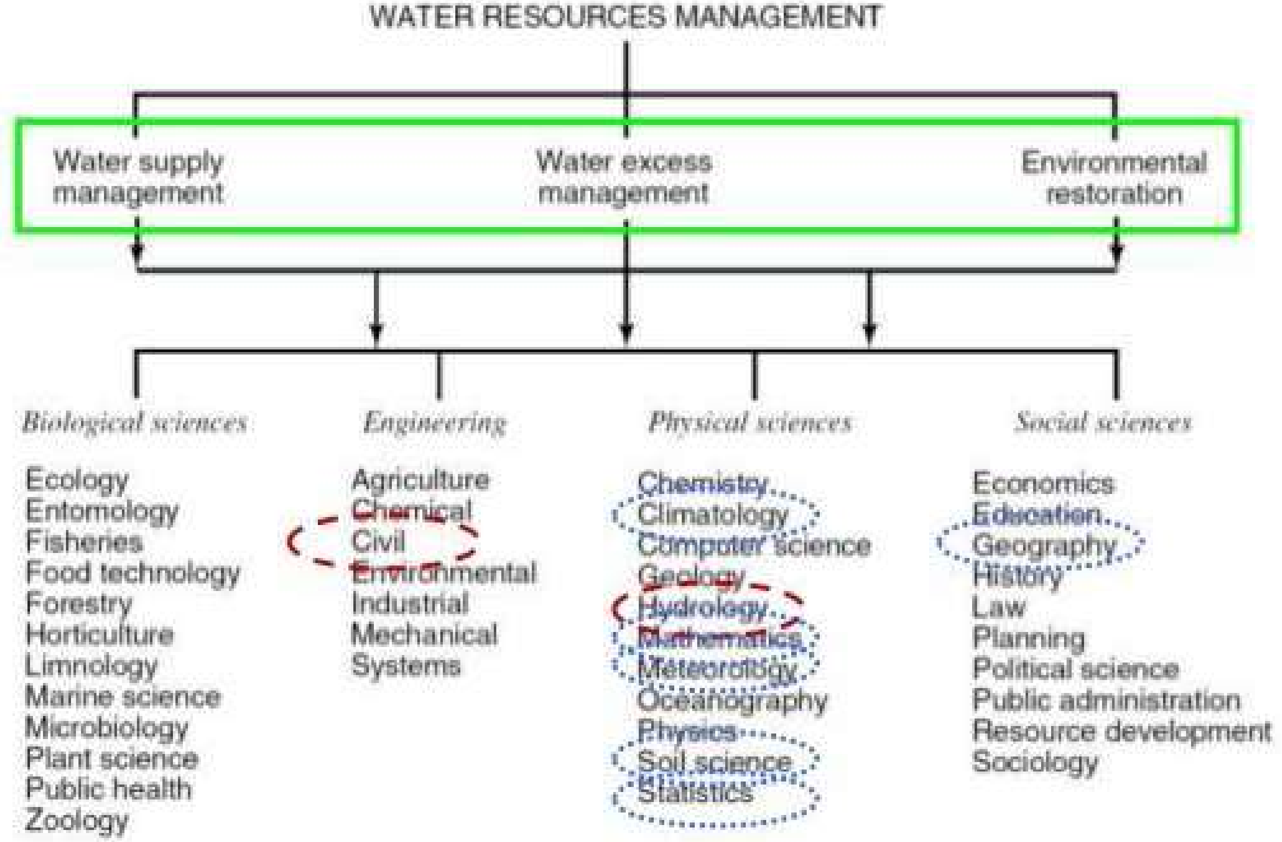
What do you mean by Water Resource Engineering?

- Water Resource Engineering is a specific kind of civil engineering that involves the design of new systems and equipment that help manage human water resources. Some of the areas Water Resource Engineers touch on are water treatment facilities, underground wells, and natural springs.
- Water resources engineering is the study and management of equipment, facilities and techniques that are used to manage and preserve life's most plentiful resource.
- In addition to assessing how and the best ways in which to control water as it pertains to water-related activities – such as irrigation, waste disposal and canal development – water resource engineers are also frequently involved in water management to ensure that it's safe to drink both for humans, plants and animal usage.
- Surface water makes up about 71% of the planet, which is the equivalent of roughly 326 million cubic miles. At the same time, though, just 3% of the Earth's water is fresh, according to the Bureau of Reclamation. And of this total, 2.5% of it is out of reach, contained in the soil, polar ice caps, the atmosphere and glaciers or too polluted to use safely.
- Water resource engineers may be tasked with the awesome responsibility of ensuring that the planning and management of available water supply are adequately leveraged and remain safe to use for as long as possible. They may also be involved in water treatment so that the quality of water is improved upon for various end uses, whether that's recreationally, commercially or industrially.

Why is water resources engineering important?

- Resources, by their very nature, are finite. There are only a small handful that are naturally renewable – such as wind, solar, hydro and biomass. While water may be renewable in terms of the many different ways it can be used and reused, it's not as abundant as it once was, which many earth scientists and climatologists point to as a function of climate change.
- Water resource engineers may be charged with developing new systems or processes for private or government entities that can preserve freshwater sources and find new ones. This may require the assistance of civil engineers involved as well, designing water purification methods through desalination or creating new equipment for contaminant transport when water is used for irrigation purposes.
- Understanding what works and what doesn't when it comes to water resource management is often a combined effort and may involve a number of different analyses, including hydrologic, which is the study of the water cycle and directions in which it flows, which may be influenced by weather and other environmental forces.

What is Water Resources Engr./Manag.?



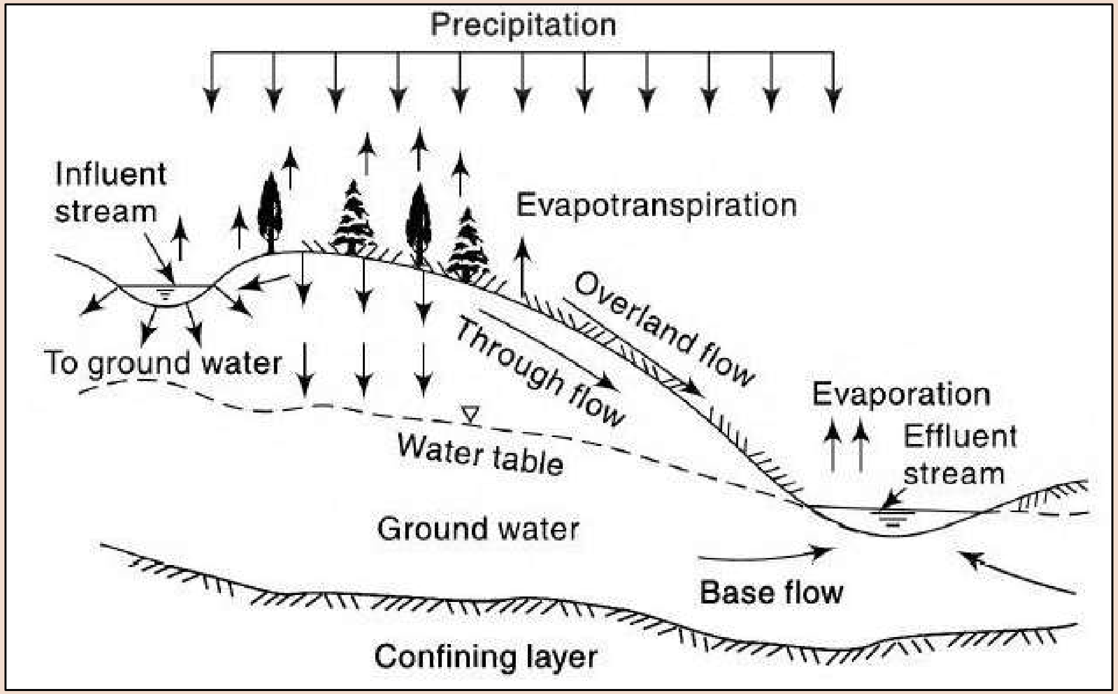

UNIT-1

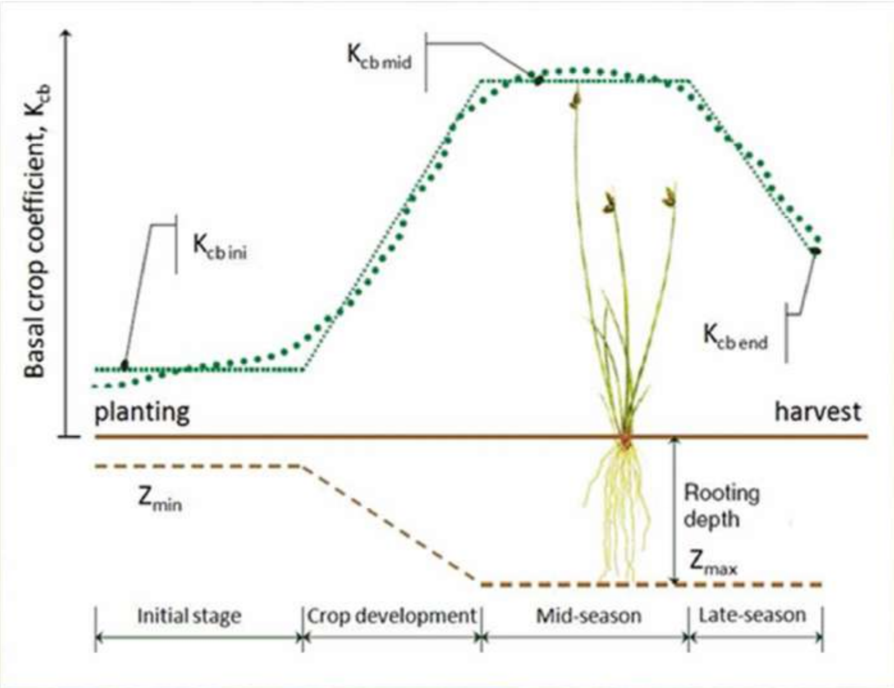
➢ Introduction

- **Irrigation-** The supply of water to land or crops to help growth, typically by means of channels.
- **Water resources of India-** Water resources come in many forms, but the three main categories are saltwater, groundwater and surface water.
- **Need of Irrigation in India-** Even in areas of high rainfall, irrigation is necessary to further increase the farm productivity. Indian rainfall is characterized by monsoon gaps. Consequently it may not rain for two or more weeks during the rainy season and the crops may be badly damaged in the absence of irrigation facilities.
- **Development of Irrigation in India-** Irrigation is important to a country like India because rainfall here is seasonal in nature. It is limited to four months of a year. It is also important because some crops require more water than what it is provided by the rainfall, therefore we have to depend on irrigation.
- **Impact of Irrigation on human environment-** The intensification of agriculture can lead to groundwater pollution related to the increased use of pesticides and fertilizers. Improved efficiency may significantly reduce return flows which are often utilized downstream by other irrigation schemes or wildlife habitats.
- **Irrigation systems-** Minor and Major irrigation projects
- **Command Area Development-** The command area, of a water source is the extent of area which can be reliably irrigated from that source. Reliable irrigation means that the availability of water is always larger than or equal to the irrigation need of a scheme.

➢ **Hydrology-** Hydrology is the study of the movement, distribution, and quality of water throughout the Earth, including the hydrologic cycle, water resources and environmental watershed sustainability. A practitioner of hydrology is a hydrologist, working within the fields of either earth or environmental science, physical geography, geology or civil and environmental engineering. Water covers 70% of the Earth's surface.

- **Hydrologic Cycle**
- **Rainfall-runoff process**
- **Factor affecting runoff**
- **Runoff hydrograph**
- **Runoff computations**
- **Flood discharge calculations for ungauged and gauged site**
- **Unit hydrograph method**
- **S-hydrograph**
- **Different methods of flood forecasting**

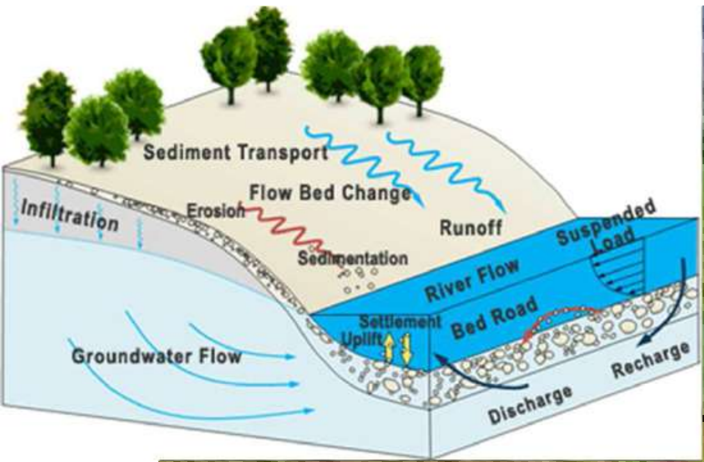




Crops	Duration (days)	Water requirement (cm)
Rice	100	95–100
Ragi	105	45–50
Pulses	70	20–25
Pulses (long duration)	150–250	30–50
Maize	100	40–45
Cotton	165	60–75
Groundnut	105	60–65
Sugarcane	300	225–250

Unit-2

- **Water Requirement of crop-** The water need of a crop thus consists of transpiration plus evaporation. Therefore, the crop water need is also called "evapotranspiration". The water need of a crop is usually expressed in mm/day, mm/month or mm/season. Suppose the water need of a certain crop in a very hot, dry climate is 10 mm/day.
- Crops and crop seasons in India
- Cropping pattern
- Quality of irrigation water
- Soil-water relationships- soil characteristics significant from irrigation considerations
- Root-zone soil water
- Infiltration
- Consumptive use
- Irrigation requirement
- Frequency of Irrigation
- Duty and Delta
- **Methods of applying water to the fields-** surface, sub-surface, sprinkler and trickle/drip irrigation types and its design and drawing.



Sediment Transport
Flow Bed Change
Infiltration
Erosion
Runoff
Suspended Load
Sedimentation
River Flow
Bed Road
Settlement
Uplift
Groundwater Flow
Recharge
Discharge

Unit- 3

- **Sedimentation Transportation-** Sediment transport is the movement of solid particles (sediment), typically due to a combination of gravity acting on the sediment, and/or the movement of the fluid in which the sediment is entrained.
  - Suspended, Bed load and Total Load and
  - its estimation by Einstein, VanRijn Rottner, Bagnold, Engelund and Hansen, Yang, Karim an Kennedy, Ackers and White method
- **Irrigation Channels-** An open canal, channel, or ditch, is an open waterway whose purpose is to carry water from one place to another. Channels and canals refer to main waterways supplying water to one or more farms. Field ditches have smaller dimensions and convey water from the farm entrance to the irrigated fields.
  - Sediment threshold and method calculation
  - Design of lined and unlined
- **Silt Theory-** Kennedy's, Lacey's
  - Tractive force Ackers and White and Engelund and Hansen method
  - Design procedure for irrigation channels
  - Longitudinal cross section
  - Schedule of area statistics and channel dimensions
  - Use of Garret's diagrams in channel design
  - Cross sections of an Irrigation channel
  - Computer programs for design of channels

- Lining of Irrigation canals: Advantages and types, factors for selection of a particular type, design of lined channels, cross section of lined channels, Economics of canal lining.

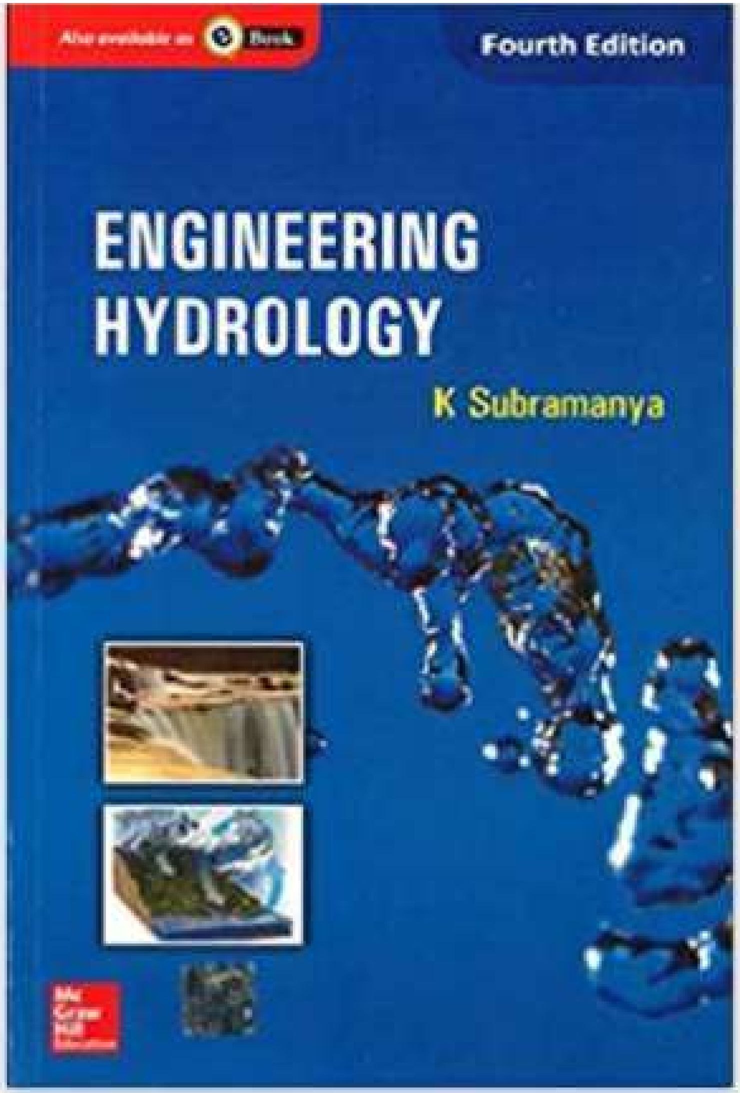
➢ **Water Logging-** Waterlogging occurs whenever the soil is so wet that there is insufficient oxygen in the pore space for plant roots to be able to adequately respire. Other gases detrimental to root growth, such as carbon dioxide and ethylene, also accumulate in the root zone and affect the plants.

- Definition
- Effects
- Cause and anti-water logging measures
- Drainage of water-logged land
- Types of drains open and closed
- Spacing of closed drains

Unit- 4


Marginal bund joined to high contours
Guide bank
River flow
Undersluice portion of weir (crest level lower than that of weir)
Canal head regulator with gated openings called head sluices
Divide wall
Normal weir portion or weir proper or main weir
Off taking canal
Weir divided into bays with piers
Fish ladder
Length divided into ways by piers. Each way is provided with a gate so as to act as an opening of controlled height

- **Irrigation Outlets:** Outlets are the openings constructed in the banks of distributaries and minors. Field channel takes off from this point and gets irrigation water through outlet. It is also called turnout or sluice in some parts of India.
  - Requirements
  - Types non-modular
  - Semi-module and
  - Rigid module
  - Selection Criteria
- **River Training-** River training' refers to the structural measures which are taken to improve a river and its banks. River training is an important component in the prevention and mitigation of flash floods and general flood control, as well as in other activities such as ensuring safe passage of a flood under a bridge.
  - Objective and need
  - Classification of rivers and River Training works
  - Lane Weight Balance Theory
  - Meandering, stages
  - Different methods of river training
  - Design and Drawing with field example problem as per IS code and IRC
  - Bank Protection
  - Methods for measurement of discharge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