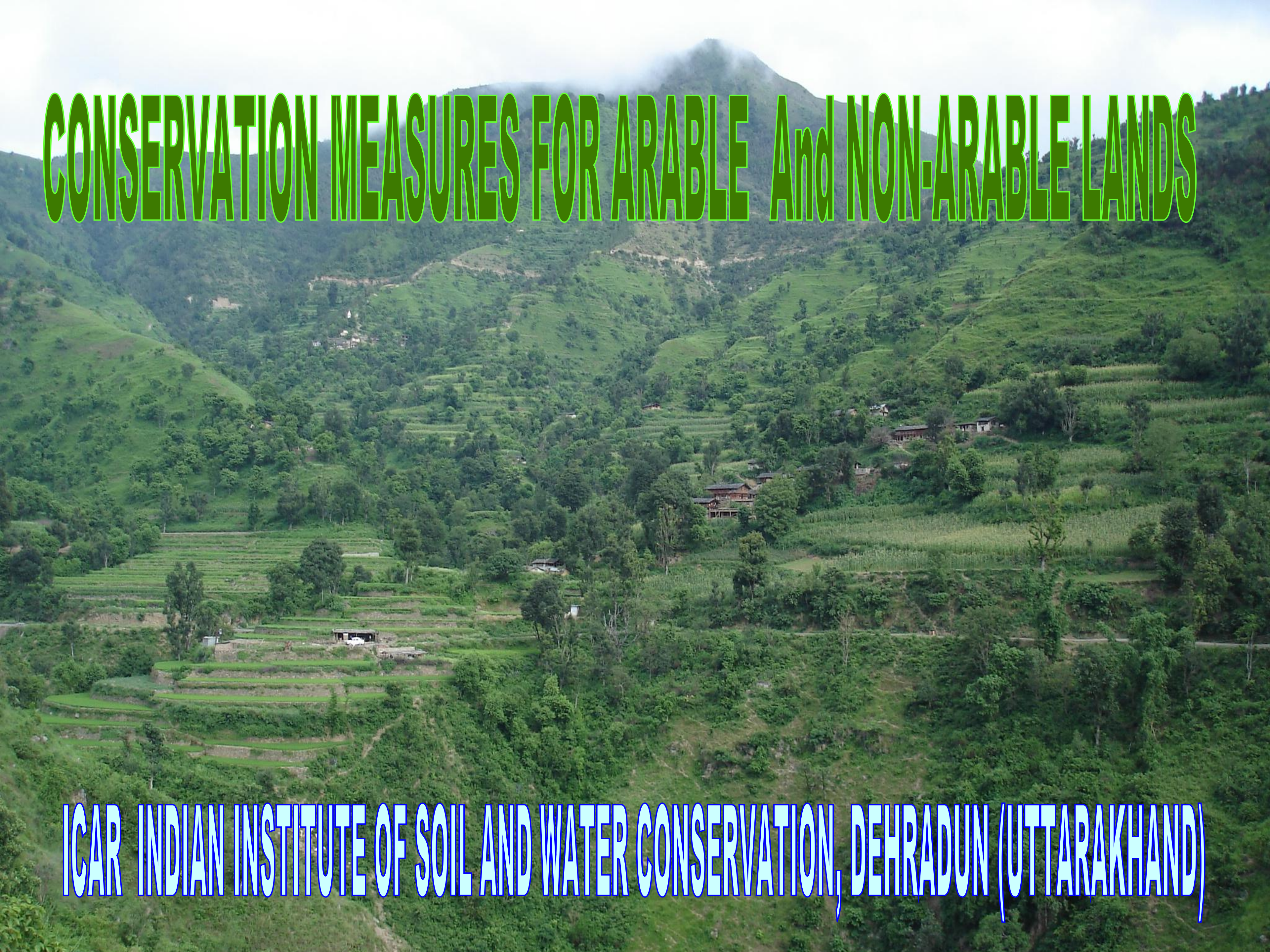

CONSERVATION MEASURES FOR ARABLE And NON-ARABLE LANDS
ICAR INDIAN INSTITUTE OF SOIL AND WATER CONSERVATION, DEHRADUN (UTTARAKHAND)

STRUCTURES SUITABLE IN ARABLE and NON ARABLE LANDS

Measures	Most suitable in: Plain land and mild slope	Most suitable in: Hilly land
A. Suitable for arable land		
A.1. Mechanical or Engineering		
1. Bunding		
a. Narrow based terracing		
a1 Contour bunding		
a2 Graded bunding(uniformly and	√	
varible graded)	√	
b. Broad based terracing		
b1 Level or absorptiive type	√	
b2 Graded or disposal or channel type	√	

(2) Trenching		
a. Contour trenching		
a1 Continuous	√	√
a2 Staggered	√	√
b. Graded trenching	√	√
(3) Terracing (Bench)		
a. Level		√
b. Inward sloping		√
c. Outward sloping		√
d. Puertorican type		√
(4) Stonewall		
a. Contour	√	√
b. Graded	√	√

(5) Zing terracing	√	√
(6) Conservation bench terracing	√	√
(7) Land levelling/grading	√	√
(8) Silt detention tank	√	√
(9) Water ways or disposal drain	√	√
(10) Revetment		√
A.2.1. Agronomical Practices		
(1) Contour cultivation	√	√
(2) Strip croppig (contour, field, wind permanent or buffer)	√	√
(3) Inter or mixed cropping	√	√
(4) Green manuring	√	√
(5) Crop Rotation	√	√
(6) Use of crop residue	√	√
(7) Mulching	√	√
(8) Relay cropping	√	√
(9) Seasonal crop cover	√	√
(10) Improved crop management practices	√	√

A.2.2. Vegetative measures		
(1) Grassed contour barrier	√	
(2) Grassed waterway or grassed disposal drain	√	√
(3) Agroforestry	√	√
(4) Agri- Pasture	√	√
(5) Agri-Horticulture	√	√
B. Suitable for non-arable land		
B.1 Mechanical or Engineering		
(1) Trenching		
a. Contour trenching	√	√
a1 Continuous	√	√
a2 Staggered		
b Graded trenching	√	√
(2) Stonewall		
a. Contour	√	√
b. Graded	√	√
(3) Silt detention tank	√	√
(4) Diversion drain	√	√
(5) Toe wall/Toe drain	√	√

(6)	Interceptor drain	√	√
(7)	Channelisation of flow or stream training	√	√
(8)	Waterways	√	√
(9)	Retaining wall		√
(10)	Revetment		√
(11)	Wattling		√
(12)	Check dam		√
(13)	Drop structure		√
(14)	Drop inlet structure		√
(15)	Chute structure		√
B.2	**Biological measures**		
(1)	Afforestation/reforestation	√	√
(2)	Social forestry	√	√
(3)	Silvipasture	√	√
(4)	Pasture development	√	√
(5)	Leguminous Pasture plant	√	√
(6)	Farm and range plant	√	√
(7)	Meadow grasses	√	√
(8)	Check dam		√
(9)	Stream training	√	√
(10)	Wattling	√	√
(11)	Mulching	√	√

EFFECT OF SOIL AND WATER CONSERVATION WORKS

- Increase in yield (crop)
- Changes in cropping sequence/rotation/intensity
- Increase in ground water table
- Increase in no. of wells in the vicinity
- Changes in flora and fauna
- Changes in micro organisms
- Prolonged life of water harvesting structure at down stream
- Increase in discharge in the stream
- Increase in flow days in the stream
- Improved socio-economic condition of the inhabitant
- Reduction in peak flow
- Reduction in silt loss

DESIGN CRITERIA OF S&WC STRUCTURE

- It should serve the purpose for which it is made
- Should be as per the need of the people as they visualise
- Should not have any adverse effect over the environment
- Should not significantly change/modify the natural system
- Easy to be understood by field executer
- Should be flexible
- Cost involved should be minimum
- Should be requiring less maintenance
- Should last for its designed life
- Should utilize the local material and the labour to the extent possible

STRATEGIES FOR ARABLE LANDS

- Agronomic Measures

  (Contour farming, manipulation of crop canopy, intercropping, mixed cropping, strip cropping conservation tillage, mulching and alley cropping etc.)

- Land Configuration Measures

  (Contour bunding, graded bunding, terracing, conservation bench terracing, waterways etc.)

- Vegetative Barriers

- Alternative Land Use/ Agro-forestry Systems

- Water Harvesting and Recycling Techniques

AGRONOMIC MEASURES

- Contour farming
- Manipulation of crop canopy (advance seeding, row spacing / orientation)
- Crop diversification (intercropping, strip cropping, cropping systems, alley cropping etc.)
- Conservation tillage
- In situ grown perennial/annual live mulches

WATERSHED MANAGEMENT TECHNOLOGIES FOR ARABLE LANDS

AGRONOMIC MEASURES

- Contour Farming
- Inter-cropping
- Mixed Cropping
- Tillage Practices
- Mulching
- Crop Canopy Manipulation

Contour Farming

Organic mulching for resource conservation

Intercropping (Maize +

Contour bunding

Bench terracing on hill slope

MECHANICAL MEASURES

- Contour Bunding
- Graded Bunding
- Bench Terracing
- Puertorican Type Terracing
- Conservation Bench Terracing
- Graded Trenches
- Conservation Ditching
- Grassed Waterways

LAND CONFIGURATION MEASURES

- Contour bunding (0.5 - 6% slope, <800 mm rainfall)
- Graded bunding (up to 8% slope, >800 mm rainfall)
- Bench terracing (most effective on steep slopes)
- Conservation bench terraces

RUNOFF (MM), SOIL LOSS (t/ha), AND MAIZE AND WHEAT YIELDS (kg/ha) ON DIFFERENT SLOPES TREATED WITH LAND SHAPING MEASURES IN DOON VALLEY

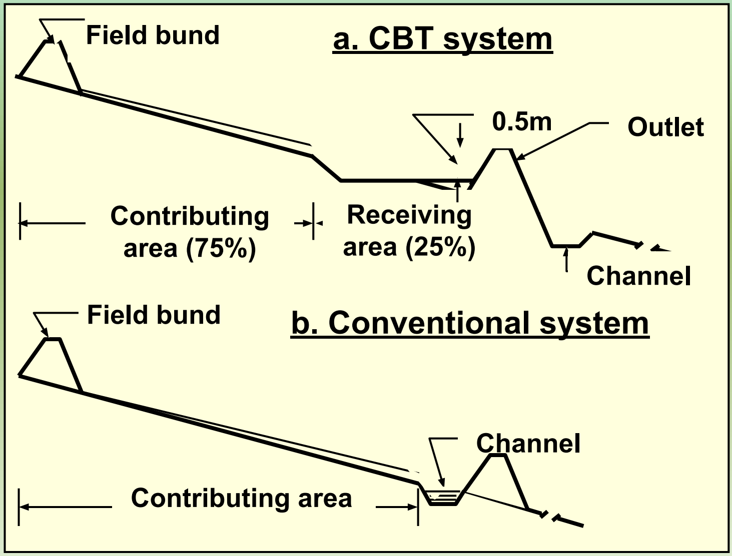
Land shaping measures	2% slope		4% slope		8% slope	
	Run-off	Soil loss	Run-off	Soil loss	Run-off	Soil loss
Contour cultivation	63.9	16.18	144.3	25.75	327.2	54.67
Graded bunding	27.8	4.28	67.9	7.24	156.1	19.40
Contour bunding	15.8	2.87	39.8	4.56	89.6	10.02
Bench terracing	9.3	1.53	16.2	2.15	27.2	3.01
	Maize	Wheat	Maize	Wheat	Maize	Wheat
Contour cultivation	2185	2165	2218	2070	1758	1750
Graded bunding	2007	2060	1936	2010	1576	1875
Contour bunding	1850	2350	1781	2335	1361	2085
Bench terracing	1528	2680	1594	2590	1432	2315

- Bench Terracing conserved runoff and soil by 92.2% and 95.8%, respectively over cultivated fallow followed by contour bunding, graded bunding and contour farming on 4-8% sloping lands of Doon valley.

CONSERVATION BENCH TERRACE SYSTEM – A VIABLE ALTERNATIVE TO CONVENTIONAL SYSTEM IN SUB-HUMID

Mean Runoff, Soil & Nutrient Losses and Crop Yields from CBT

System	Runoff (% of rainfall)	Soil loss (t/ha)	Nutrient loss (Rs./ha)	Crop yields (kg/ha)	
				Maize	Wheat
Conventional	36.3	10.1	254	1768	2069
CBT	7.4	1.2	6	2112*	2006

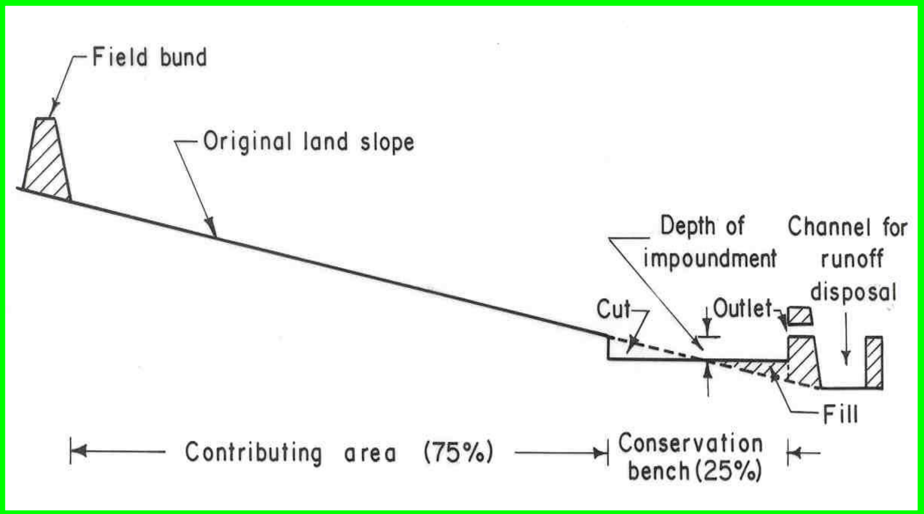


- Reduced runoff and soil loss by 80% and 90%, respectively over the conventional system.
- Technology is 19.5% more productive in terms of maize-equivalent yields and 71.7% more remunerative over the conventional system due to better in-situ rainwater conservation in sub-humid region of outer Himalayas.
- B:C ratio of system = 1.2:1.
- The ratio of conservational and CBT systems should be 50 : 50 or 25 : 75 to harvest sufficient runoff for recycling purposes.

upto 6% slopes in sub-humid climates of UK, J&K,HP and NEH states.

- The technology has been demonstrated in 5 villages covering 30 farmers in an area of 15 ha.

- **Conservation Bench Terrace system was effective in reducing runoff and soil loss by over 80% and 90%, respectively and was 19% more remunerative in terms of maize-equivalent yields as compared to conventional system of maize- wheat rotation on sloping borders.**



3:1 CONSERVATION BENCH TERRACE SYSTEM

CONSERVATION BENCH TERRACE WITH PADDY IN LAVELLED AND MAIZE IN THE SLOPING AREA, DEHRADUN (UTTARANCHAL).

MEAN RUNOFF, SOIL AND NUTRIENT LOSSES AND CROP YIELDS FROM CONVENTIONAL AND CBT SYSTEMS

System	Runoff (% of rainfall)	Soil loss (t/ha)	Nutrient loss (Rs./ha)	Crop yields (kg/ha)	
				Maize	Wheat
Conventional	36.3	10.1	254	1768	2069
CBT	7.4	1.2	6	2112*	2006

* Maize equivalent yield of rice crop in CBT system is included

ECONOMIC ANALYSIS OF DIFFERENT SYSTEMS WITH NUTRIENT LOSSES (25-YEAR PROJECT LIFE AND 10% DISCOUNT RATE)

Evaluation parameter	Maize-wheat (Rainfed)	Conventional system	CBT System
NPV (Rs./ha)	15.421	16.714	26,486.00
BCR	1.22:1	1.13:1	1.20:1
PBP (Years)	2	12	10
IRR (%)	NA	15.4	17.0

MEASURES FOR ARABLE LANDS

Contour bunding

- Land slope – upto 6%
- Low rainfall areas (< 800 mm annual)

Design

- Spacing of bunds
- Cross-section

Ramser's Formula

$$VI = 0.3 (S/a + b)$$

VI = Vertical interval between two bunds (m)
S = Land slope (%)
a, b = Constant
For good infiltration soils, a= 3; b = 2
For low infiltration soils, a = 4 ; b=2

SPACING OF CONTOUR BUNDS

Land slope	VI (m)	HI (m)
0 – 1	1.05	105
1 – 1.5	1.20	98
1.5 – 2	1.35	75
2 – 3	1.50	60
3 – 4	1.65	52

Example: Find horizontal spacing of bunds on a land having 3% slope and situated in a medium rainfall zone. Calculate also the length of bunds per ha.

Solutions:

VI = 0.3 (S/3 + 2) = 0.3 (3/3 + 2) = 0.9 m

$$\text{Horizontal spacing} = 0.9 \times \frac{100}{3} = 30\ \text{m}$$

$$\text{Length of bund/ha} = \frac{10{,}000}{30} = 333\ \text{m}$$

Cross – Section of bund

- Height
- Top width
- Side slope
- Bottom width

Usual Practice

Depth of impounding = 0.30 m
Depth of flow over crest = 0.30 m
Free board = 0.20 m
Total = 0.80 m

Size of bund

$$\text{Cross section area} = \frac{\text{Bottom width (B)} + \text{Top width (T)}}{2} \times \text{Height (D)}$$

Varies from 0.50-1.0 sq m in different regions

Bunding intensity

Bund length (m/ha) = 100 S/VI

S = Land slope (%)

VI = Vertical interval (m)

Earth work

Volume of earth work (m^3ha) = c/s area of bund (m^2) x bunding intensity (m)

Area lost due to bunding

$$\text{Area lost (m2/ha)} = \frac{100\ S}{VI} \times B$$

Permissible deviation on alignment

- < 15 cm from contour while cutting across a narrow ridge
- < 30 cm while crossing a gully or depression.

Bench terracing

- Widely practiced measure on hill slopes for crop production on sustainable basis.
- Transferring original steep land into a series of level or nearly level strips or steps across the slope supported by risers.
- Recommended upto 33% land slope (USDA).
- Due to topographical and socio-economic condition of hilly regions in India, recommended upto 50% land slope. (70% of bench terraces constructed between 50-70% land slope in mid-Himalaya).

Bench terraces

Types

- Outward sloping
- Level or table top (paddy benches)
- Inward sloping

Outward sloping terraces

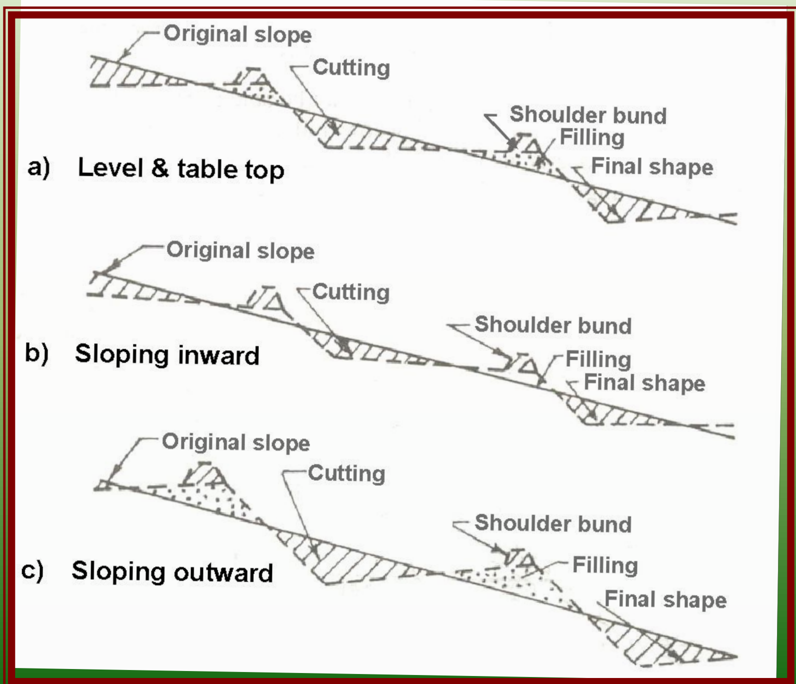
- Effective in low rainfall areas with permeable soils.

Level or table top

- Suitable for medium rainfall and highly permeable deep soils, paddy cultivation.

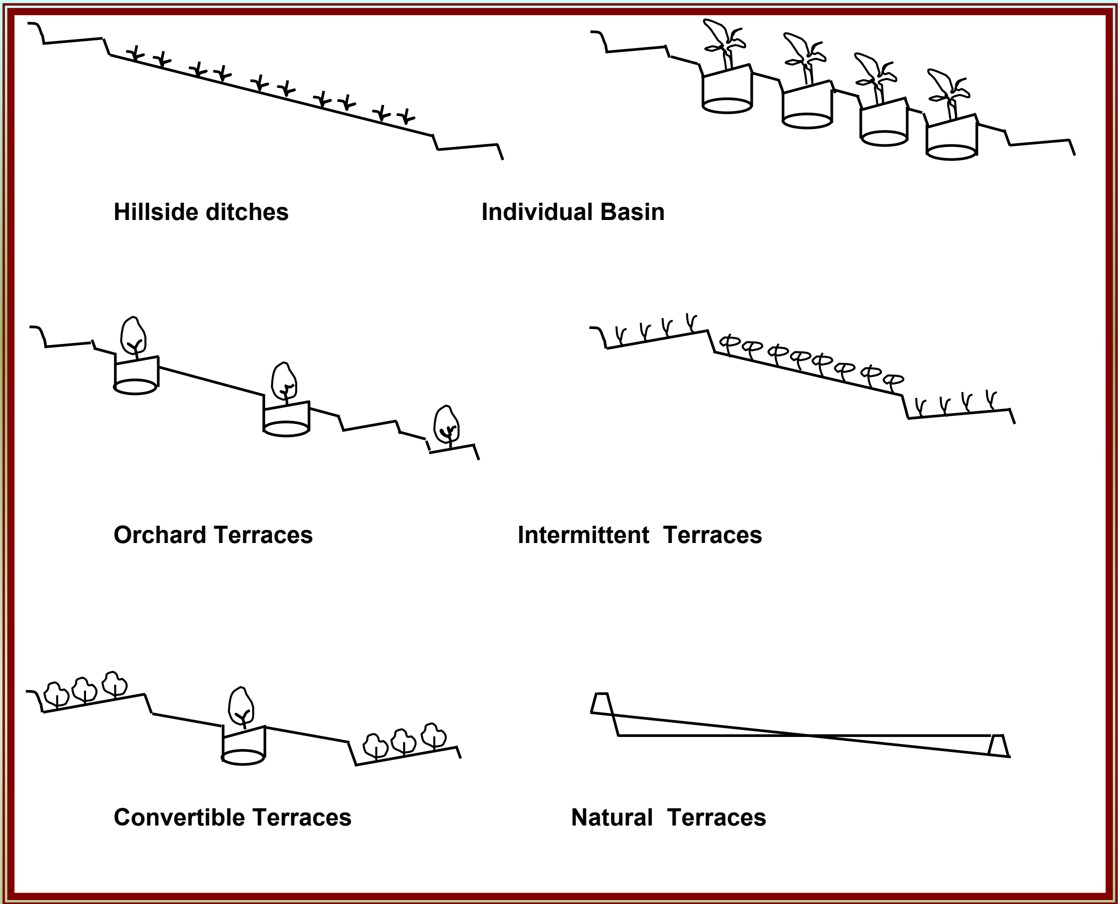
Inward sloping

- High rainfall areas and crops like potato which is susceptible to water logging.



Different types of bench terraces

Some typical terrace systems



Design of bench terraces

- Spacing
- Grade and length
- Cross-section

Terrace spacing

- Expressed by VI i.e elevation difference between two succeeding terraces.

How to compute VI ?

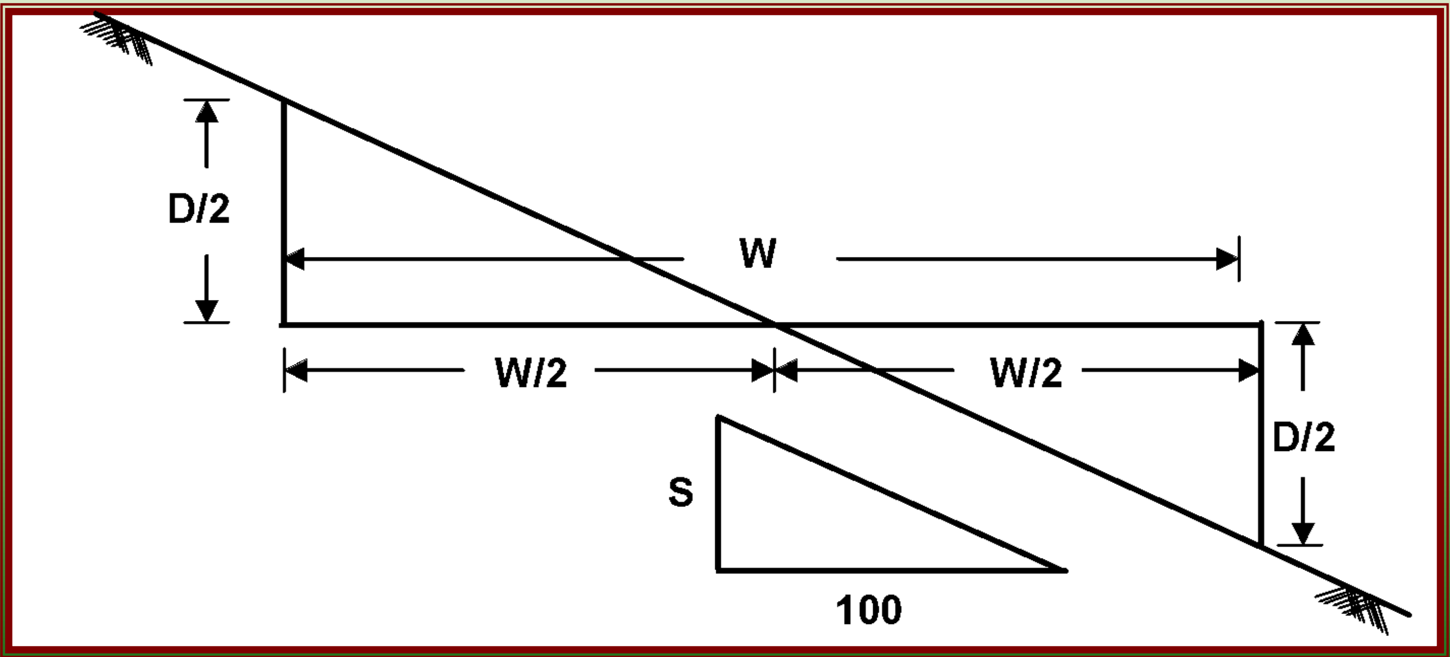
- Find maximum depth of productive soil (T).
- Find maximum admissible cut (d) for given land slope and crops. Cutting to enable construction of terraces of convenient width.

Compute width of terrace (W)

$$W = \frac{200\ d}{S}$$

Where, W and d are in (m) and S in (%)

Width and depth of cut relations



Determine VI

$$VI = \frac{W \times S}{100 - n\,S}$$

(n = batter of riser)

For n = 1:1

$$VI = \frac{W \times S}{100 - S}$$

Also, see that VI = 2 (T - 0.15)

T = Productive soil depth

Terrace grade and length

- Longitudinal grade of 1% for drainage
- For inward terrace grade of 2.5% is given with a toe drain
- Length of terrace limited to 100 m

Terraces cross-section

- Minimum bench width : 3-5 m
- Terrace riser height limited to: 1.5 – 2.0 m
- For earthen riser batter slope – 1:1
- For stone riser batter slope - 1:4

Earthwork

$$\text{Earth Work / ha} = \frac{100}{8}\ W \times S$$

or 12.5 W x S

Area available for cultivation (m^2) = 100 (100 – nS)

Area lost due to benching (m^2) = 100 n.s

Riser area to be sedded = $100\sqrt{1 + n^2}$

WATER RESOURCE DEVELOPMENT THROUGH PARTICIPATORY COMMUNITY ACTION

Source	Perennial flow from Oak forest		
Material	RCC		
Size of irrigation tank	10 m x 5 m x 1.6 m		
Capacity of tank	80 cu.m		
Particulars	Period		
	(Oct to Dec.)	(Jan to Mar.)	(Apr to Jun.)
Av. inflow l/sec	6	4	3
Av. Inflow m^3 /day	512	345	259
No. of tank filling possible per day	6	4	3
Area irrigable with 5 cm depth of water application	1.02 ha	0.69 ha	0.52 ha
Area irrigated at 20 daye irrigation interval	20.4 ha	13.5 ha	10.4 ha
Year of Construction	2003		
Cost	Rs. 1,70000/-		
Farmers contribution	Rs. 22800/-		
No. of beneficiaries	27 of Sainji watershed		
Crops grown	*Kharif* – Paddy, *Rabi* – Wheat, Onion Peas *Zaid* – Assorted vegetables		

Delegates of World Bank Team visiting RCC irrigation tank at Sainji

DETAILS OF INTERFLOW WATER HARVESTING STRUCTURE AT VILLAGE KALIMATI, BLOCK RAIPUR UNDER IVLP

Parameters	Specifications
Intervention	Participatory water resource generation through community action
Structure model	Dugout type, surface and sub-surface water harvesting
Size of the pond	21x8x2m
Storage capacity	260 cu.m.
Total cost of construction	Rs.1,29,212+68.715=1,97,927.00
A. Farmers' contribution	35%
B. Service providers' contribution	65%
C. Year of completion	1998(Still functional and mainatined by WUA)

Interflow water harvesting – a potential Water source

ENGINEERING MEASURES FOR ARABLE AND NON-ARABLE LANDS

Soil Conservation Measures

- Biological
- Engineering or Mechanical
- Bio-engineering measures

Engineering Measures; Series of mechanical barriers across the slope to reduce length and/or degree of slope to dissipate energy of flowing water.

- Increasing time of concentration of runoff, thereby allowing more absorption by soil.
- Intercropping long slope into short ones – to maintain water velocity less than critical.
- Moisture conservation
- Silt detention

Bio-engineering measures

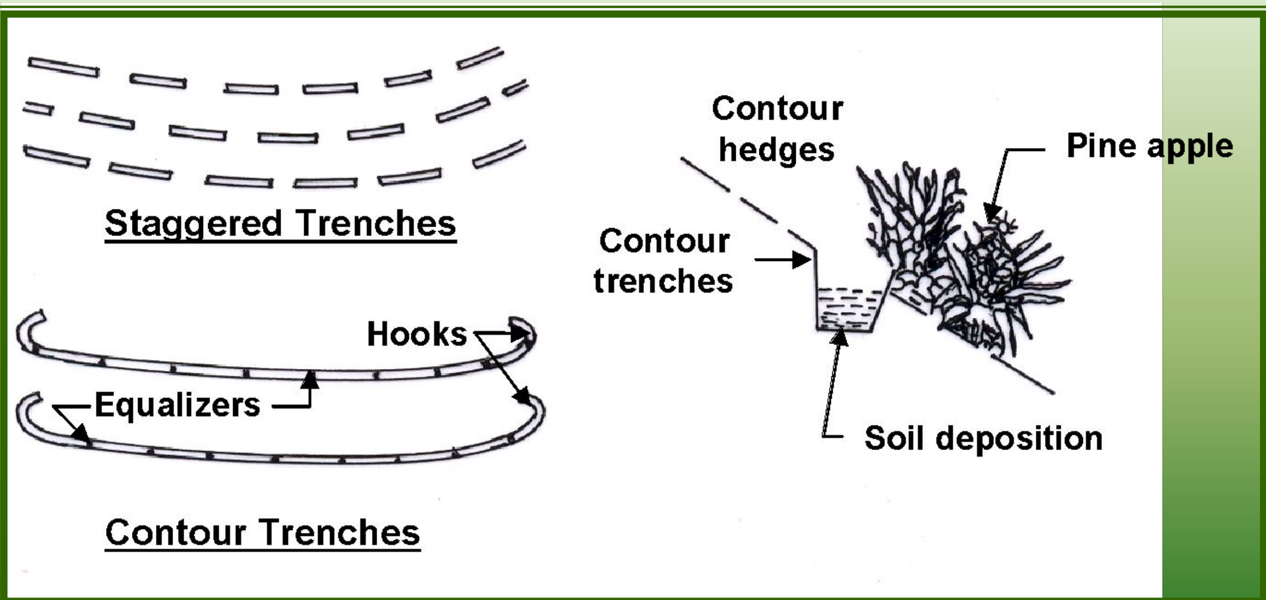
CONSERVATION MEASURES FOR NON-ARABLE LANDS

Diversion drains

- To divert runoff water away safely to protect the downstream area
- Aligned on non-erosive and non-silting grades.
- Preferable grade – 0.5%
- Narrow and deep cross-section preferred

Contour trenching

- Break velocity of runoff and store whole or part of runoff in trenches.
- Designed to store 60-90% of runoff from 6 hr storm of 4 years return period.
  - Continuous
  - Staggered



Contour and staggered trenches

Continuous trenches

- No break in length, can be 10-20 m long
- Cross-section 30 cm x 30 cm to 45 cm x 45 cm

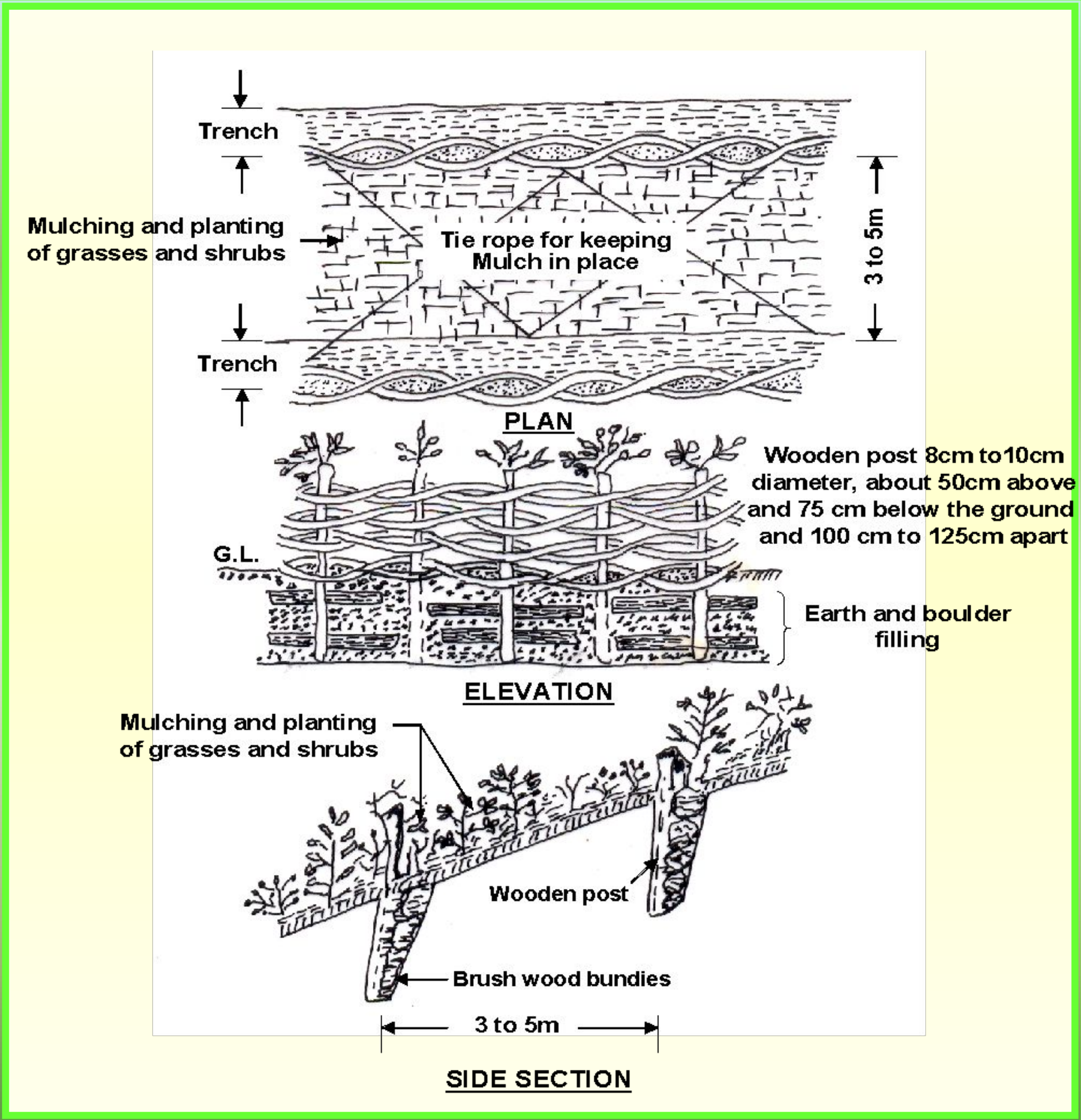
Staggered trenches

- Trench located directly one another in alternate rows in staggered fashion.
- May be made 2-3 m long and 3-5 m row spacing.

Staggered contour trenching

Wattling

- Contour wattles provided at 3-5 m interval.
- Trenches 0.3 wide and 1 m deep dug up on contours and filled with brushwood bundles.
- Posts of self sprouting spp. planted at 1m interval e.g. *Salix, Vitex, Ficus, Erythrina* etc.



Wattling and mulching techniques for slope

Geotextiles

- Wooven nets of natural fibres of jute or coir used in soil conservation and slope stabilization.
- Help in initial germination of plants by holding them in place, conserving fine soil and moisture for its growth.
- Bio-degrade in 2 years period.

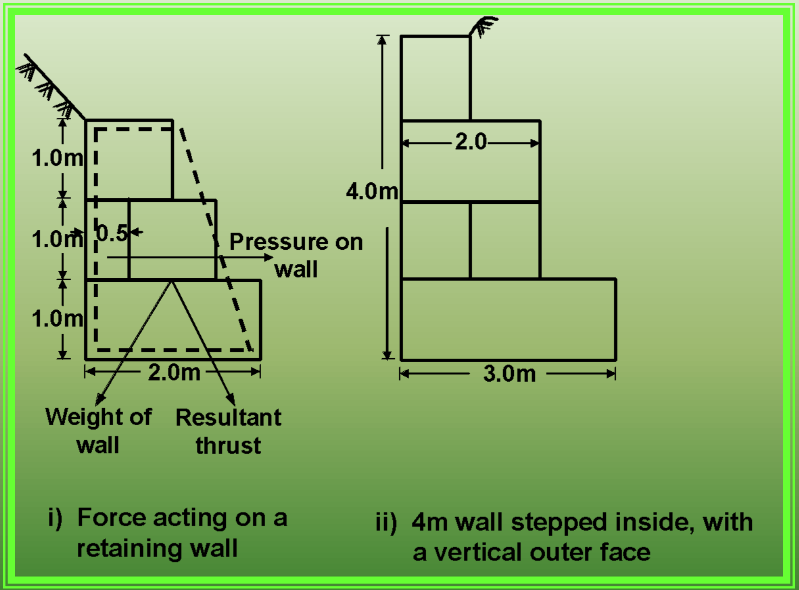
Retaining walls

- For stabilizing precipitation bill slopes and river banks.

Thumb rule

- Take base width as 2/3rd height of wall.
- Width reduced in steps to 1 m at top.

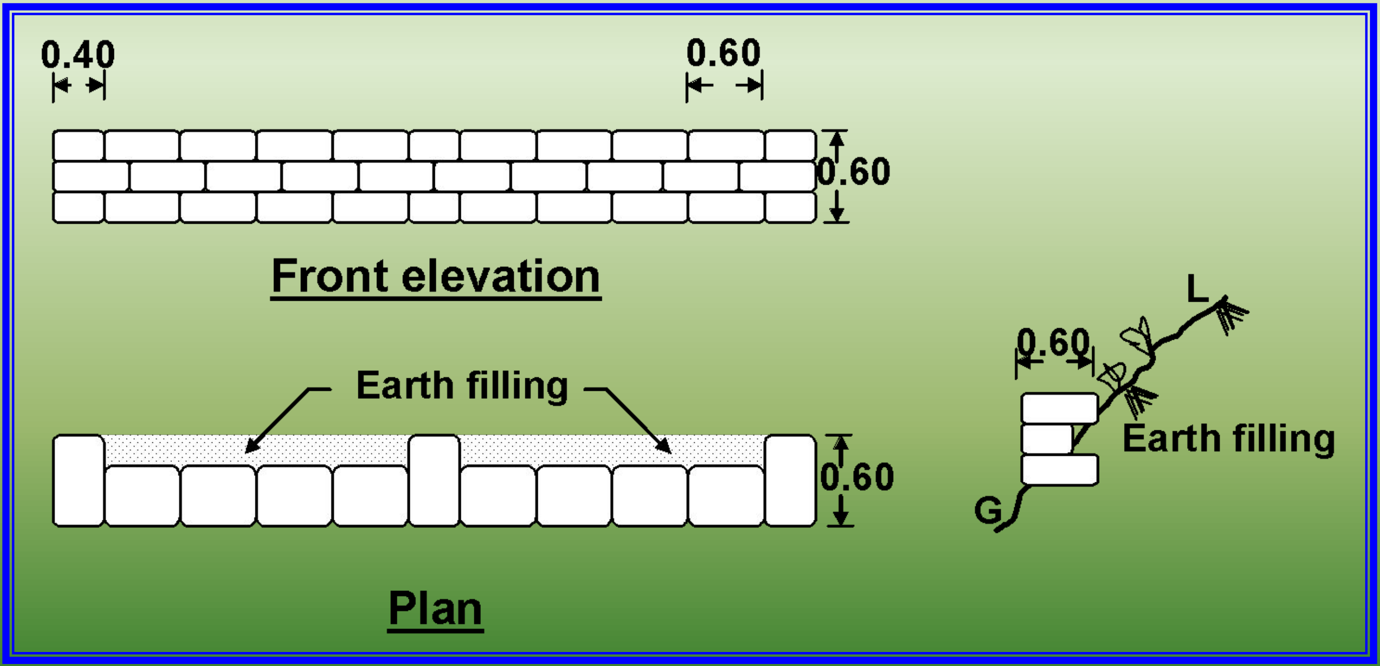
Geojute matting for slope stabilization



A typical gabion retaining wall

Katta-crate structures

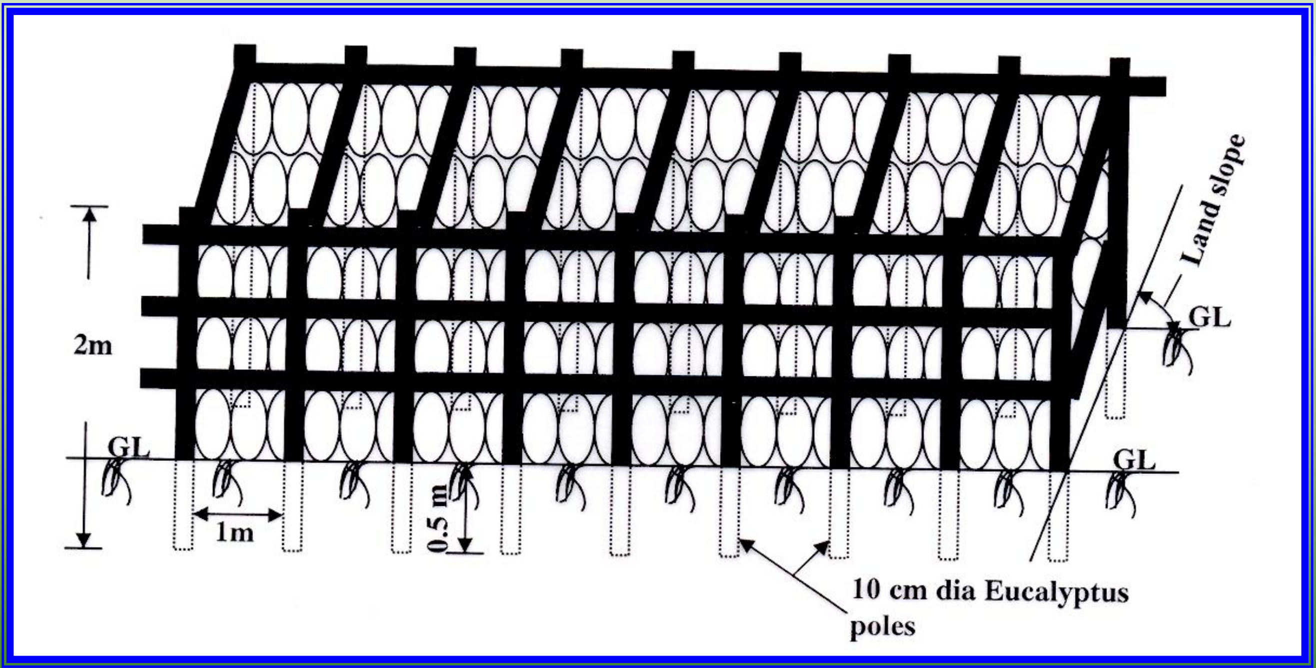
- Used for stabilization of minespoil area, where stones are not available nearby. Small quantity of cement mixed with locally available gravel (1:18 ratio) is filled in disposed synthetic cement bags.
- Filled bags laid across the slope in a rows over one another in 3 layers, making total height 0.6 m.



Katta-crate structure for slope stabilization

Crib structures

- Used for stabilizing steep slopes (>40 %).
- Poles of 2-3 m length and 8-12 cm dia driven to a depth of 50-75 cm and erected in two lines, 1 m apart line to line and pole to pole which are nailed together by providing horizontal braces of poles.
- Interspace planted with suitable soil conserving species.



A logwood crib structure

Drainage Line Treatment

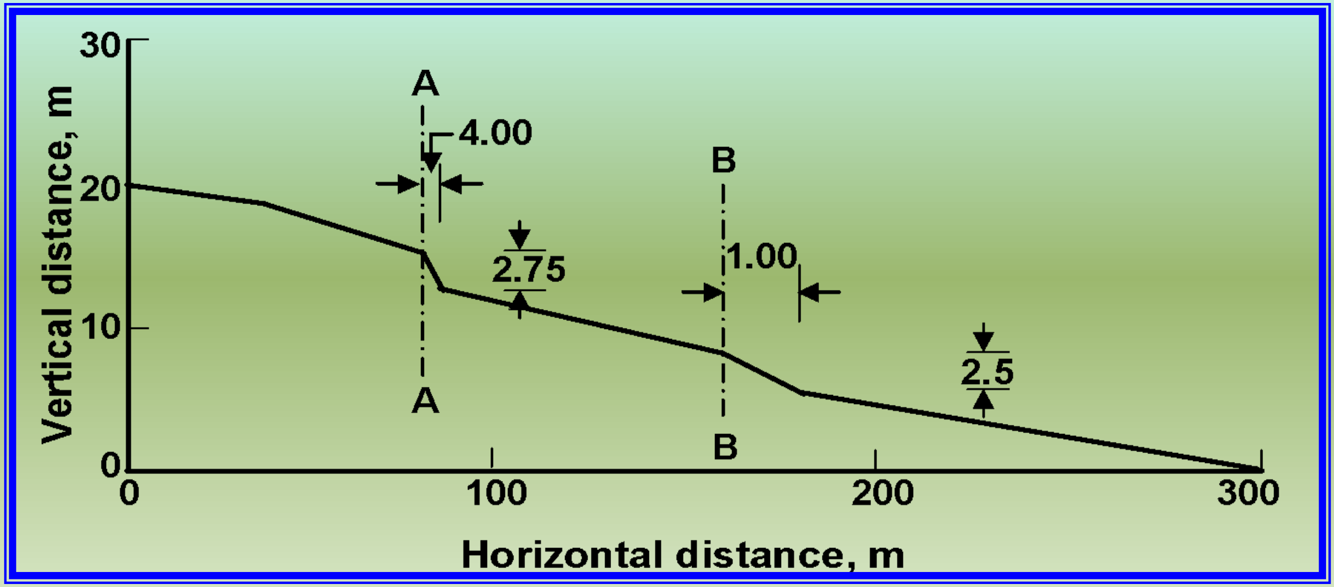
- Drainage lines are essential features of watershed which carry runoff and sediment flow.
- Different forms viz. nala, gully, stream, river, torrent.

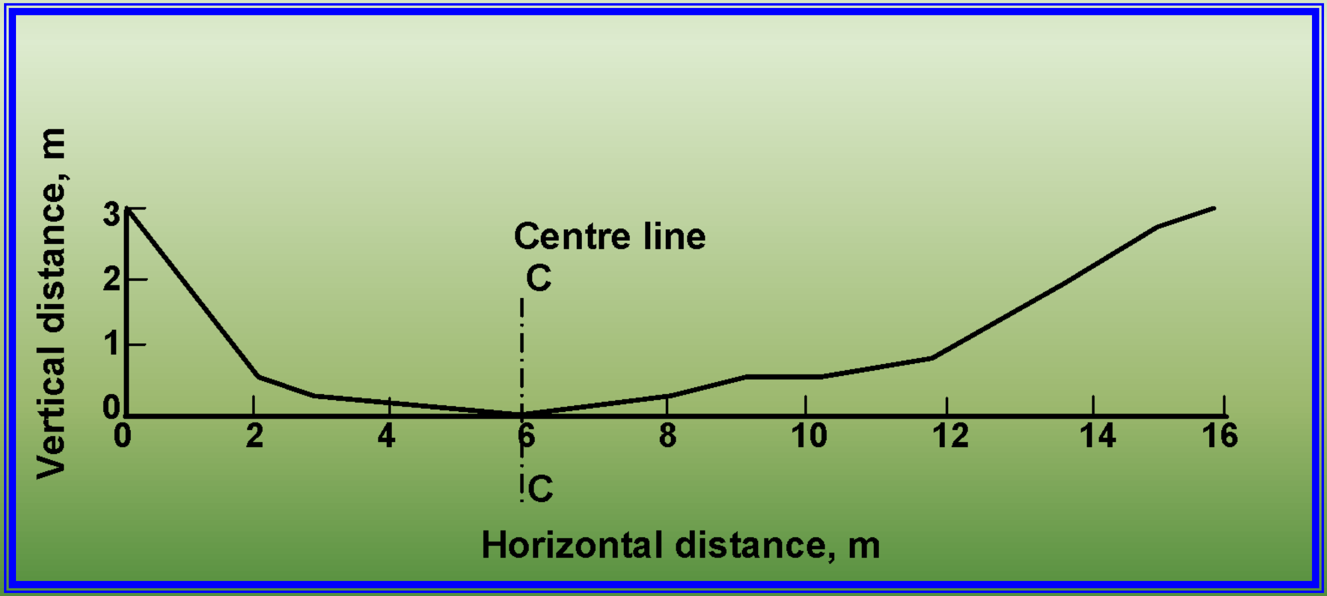
Objectives

- Check soil erosion
- Conserve moisture
- Groundwater recharge
- Store water, wherever feasible
- Flow guidance and bank protection

Survey and Planning

- L-Section
- X-Section





L-section and cross-section of a typical drainage line/gully

Check dams

- Series of check dams used to transform steep gradient to flat steps with low drops.

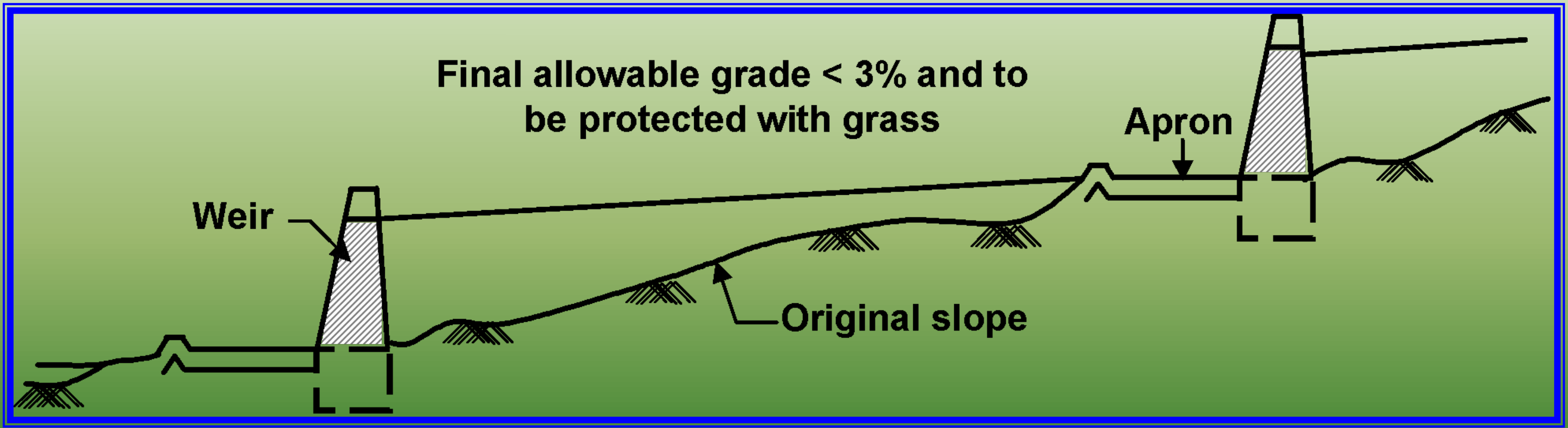
Spacing

- Top of downstream CD at a level (or permissible gradient) with bottom of one upstream of it.

$$L = \frac{100}{M - N} H$$

Where,

L = Horizontal distance between check dams
M = Original gully gradient
N = Proposed gully gradient after sediment deposition
H = Height of check dam



Spacing of check dams showing compensation gradient between the two structure in a typical gully

Types of Check Dams

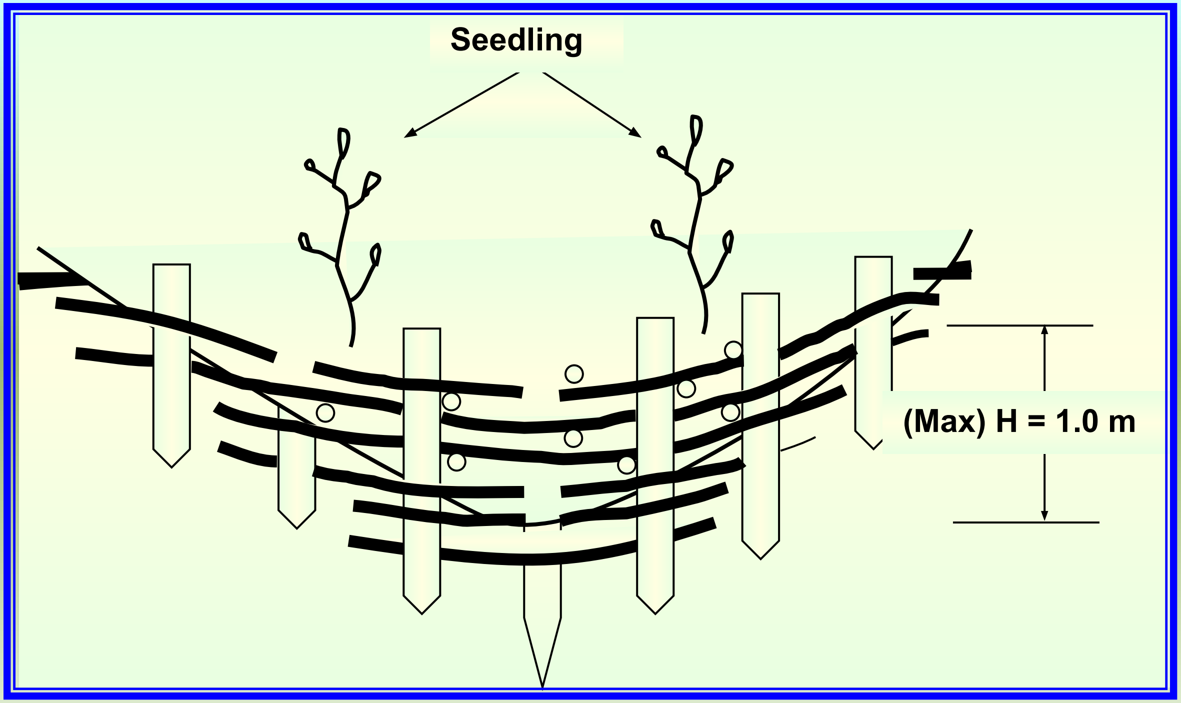
- Live check dam/vegetative barrier
- Temporary check dam
- Gabion checkdam

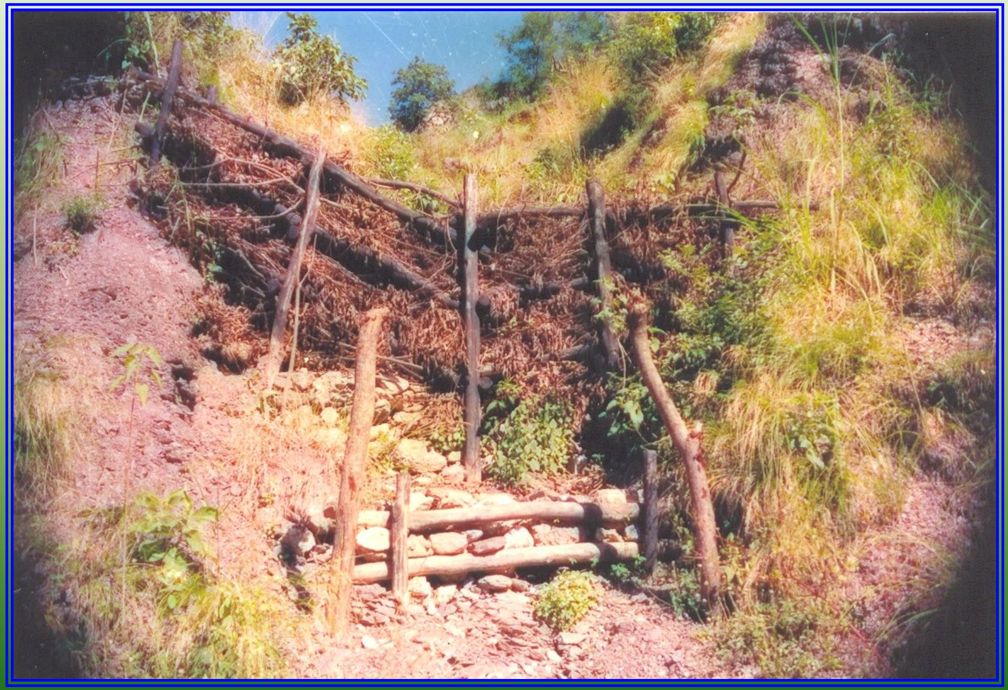
Live Check Dam

- Starting of gully head (Rills)
- Favourable climatic and soil condition
- Protection from grazing
- Rows of grasses/shrubs like *Agave, Vitex, Napier, Vetiver* planted

Temporary Check Dam

- Shallow and small gullies in upper reaches
- Runoff/debris load not high
- Construction material available locally





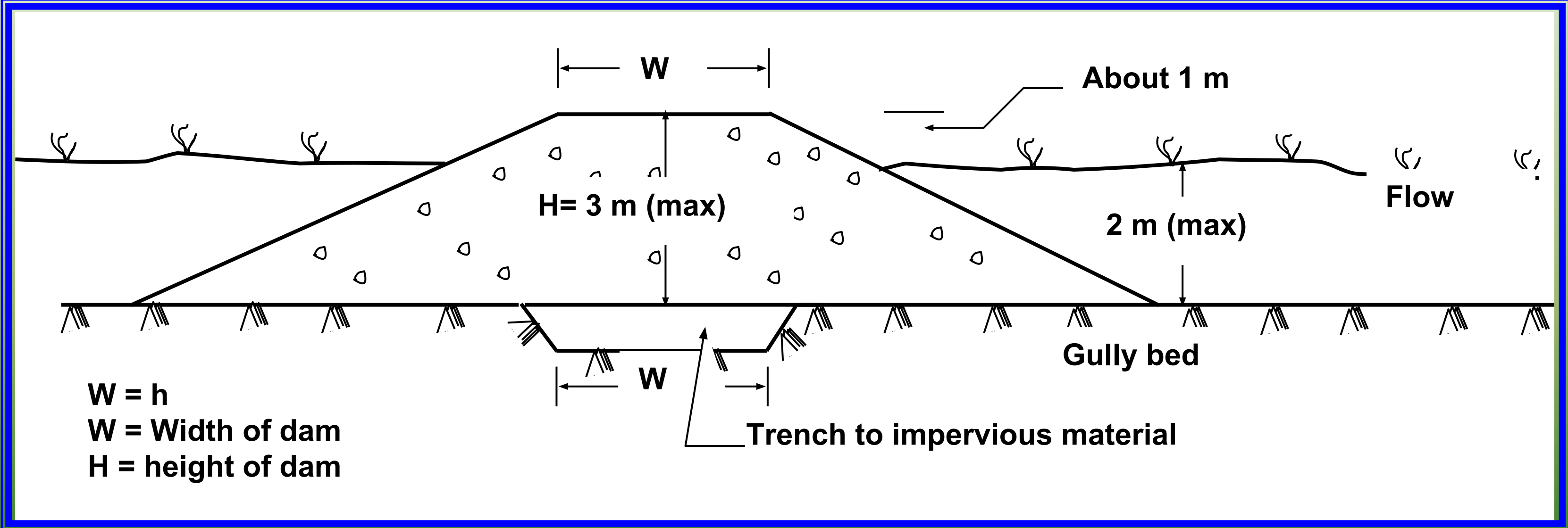
A brushwood check dam

Earthen gully plugs

- In upper catchment area having scope for water storage
- Suitable soil for embankment available
- Depth of gully less than 2 m
- Facility for side spillway

Gabion Check Dam

- Stone-wire-crate structure
- Flexible
- Porous
- Stable
- Economical

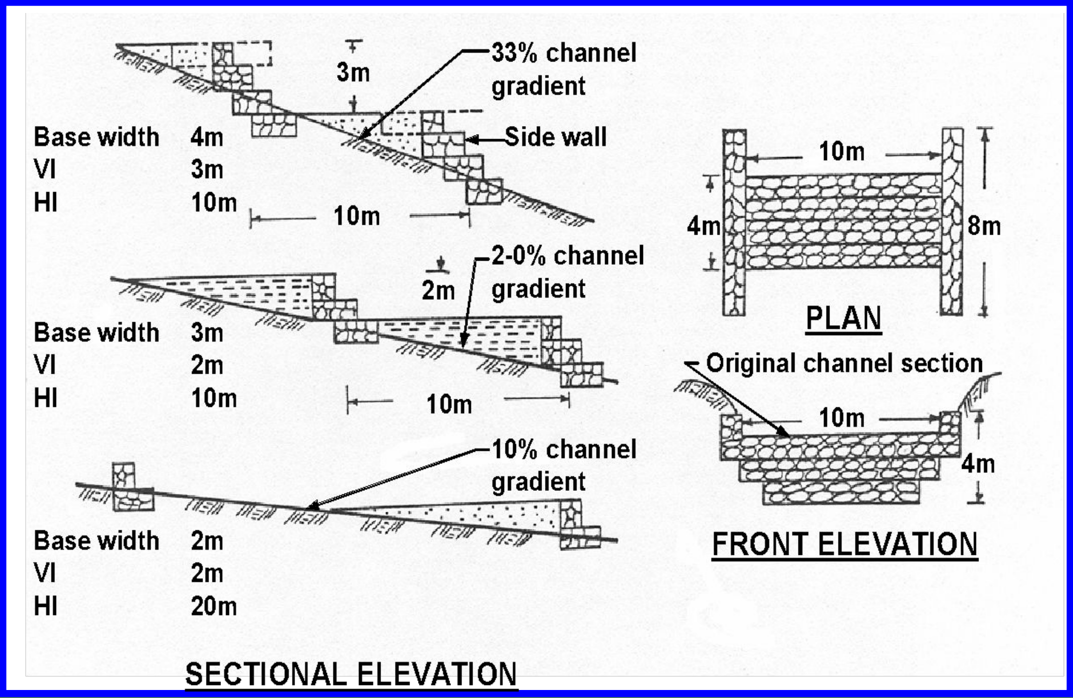


Cross-section of an earthen gully plug

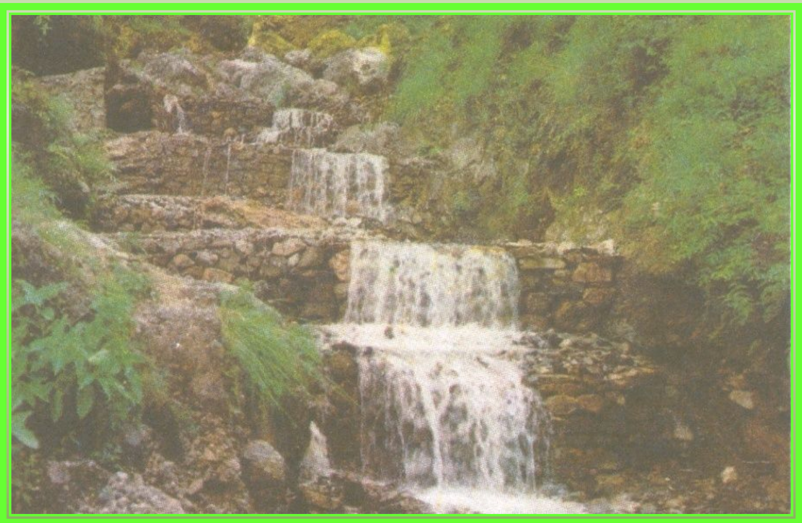
Gabion Check Dam

- Stone-wire-crate structure
- Flexible
- Porous
- Stable
- Economical

Wire size – 10 gauge (3.15 mm dia) (Hot dipped) zinc coated GI wire (IS:280-1978)
Mesh size – 15 cm x 15 cm

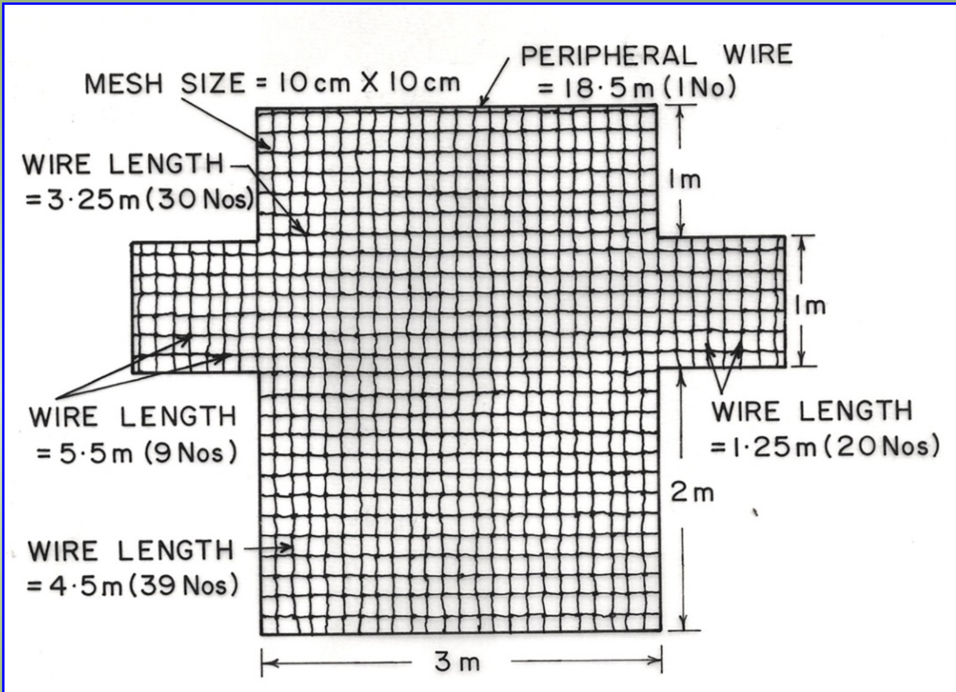


Gabion check dams on different channel gradients

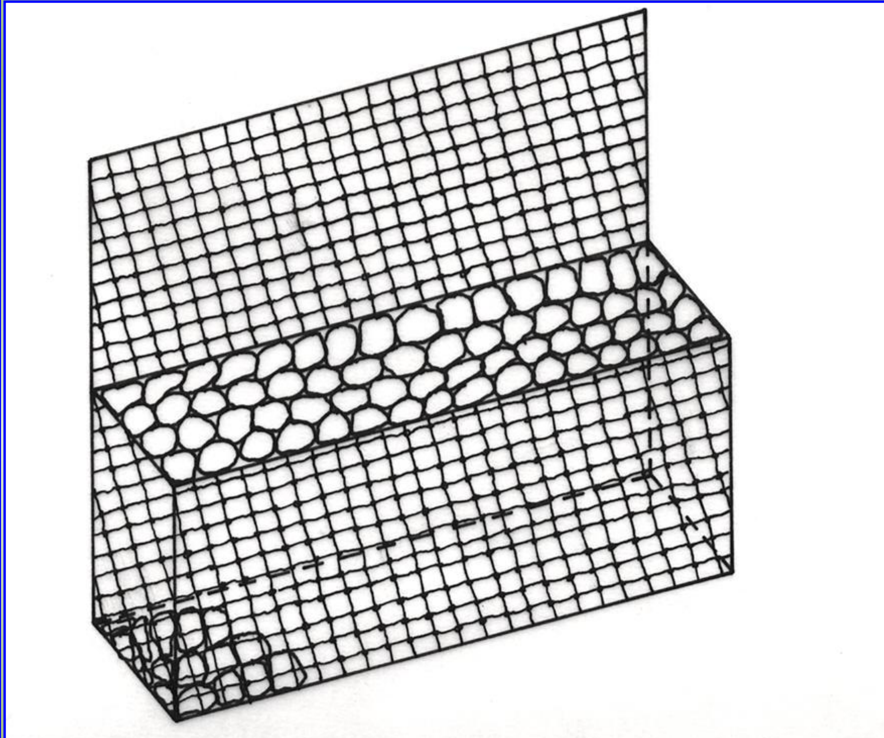


A series of check dams for nala stabilization

WIRE MESH FABRICATION



Details of a finished wire mesh



A rectangular gabion box

COST ESTIMATE

A. Material and labour requirement

Material particulars	Quantity
1. G.I. wire* 10 gauge, cages with 10 cm x 10cm opening of 3 m x 1m x1m size. Total surface area- 14 sq.m, weight of GI wire required @ 1.28 Kg/m^2 (including wastage)	17.92 kg say 18 Kg
2. Stone of size greater than 225 mm including wastage at site	3.75 cum
Labour	
1. Wire netter	1/2 No.
2. Semi - skilled worker (Mason)	1 No.
3. Mazdoor	1 No.

* Hot dipped zinc coated galvanized iron wire conforming to IS: 280-1978 (with amendments, if any)

B. Cost

Material Cost (Prevalent rates should be used)	Amount (Rs.)
1. Cost of G.I. wire 18 Kg (10 gauge) @ Rs.50/Kg	900.00
2. Cost of stones 3.75 cum @ Rs. 300 /cum including quarriyng , royalty etc.	1125.00
Labour Wages	
3. Wire netter 1/2 No. @ Rs. 400/day	200.00
4. Mason (semi skilled) 1 No. @Rs. 300/day	300.00
5. Mazdoor 1No. @Rs. 250/day	250.00
Total (for 3 cum of gabion work)	2275.00
Therefore, cost per cum of gabion is Rs. 925. The cost of gabion construction is almost 1/2 to 1/3rd of the cement masonry one.	

Permanent Gully Control Structure

- Drop spillway
- Chute spillway
- Drop inlet spillway

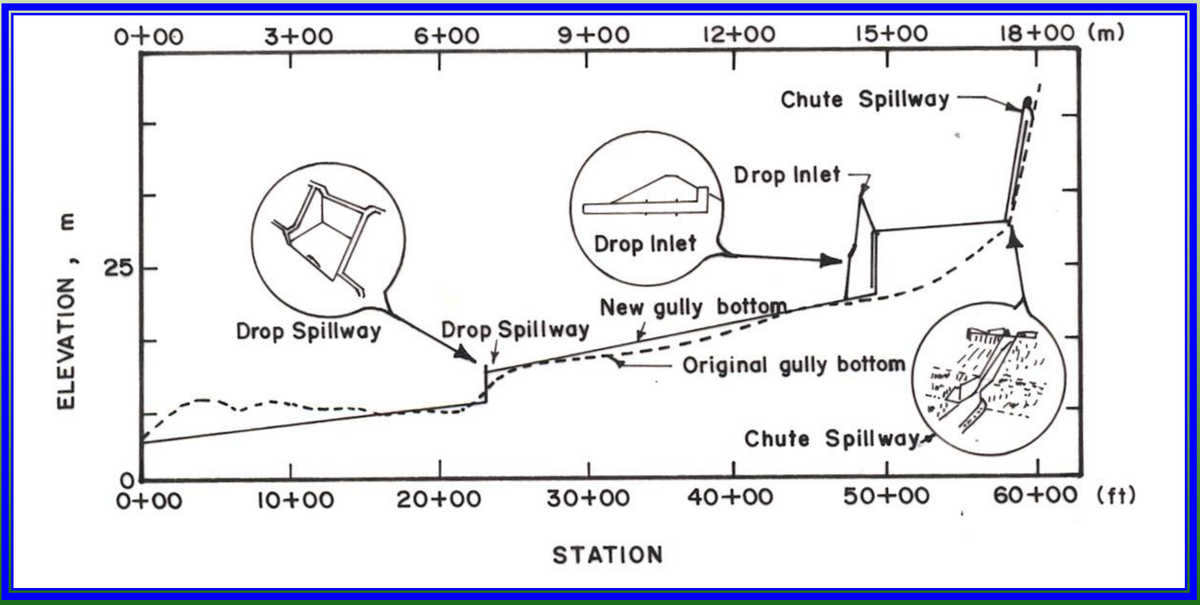
Drop Spillway

- Drop less than 3 m
- Hydrologic design

$$Q = \frac{CIA}{360}$$

- Hydraulic design
- $Q = 1.71\, LH^{3/2}$

A drop spillway for gully stabilization and water storage



Profile of a gully showing application of different types of permanent structures


THANKS