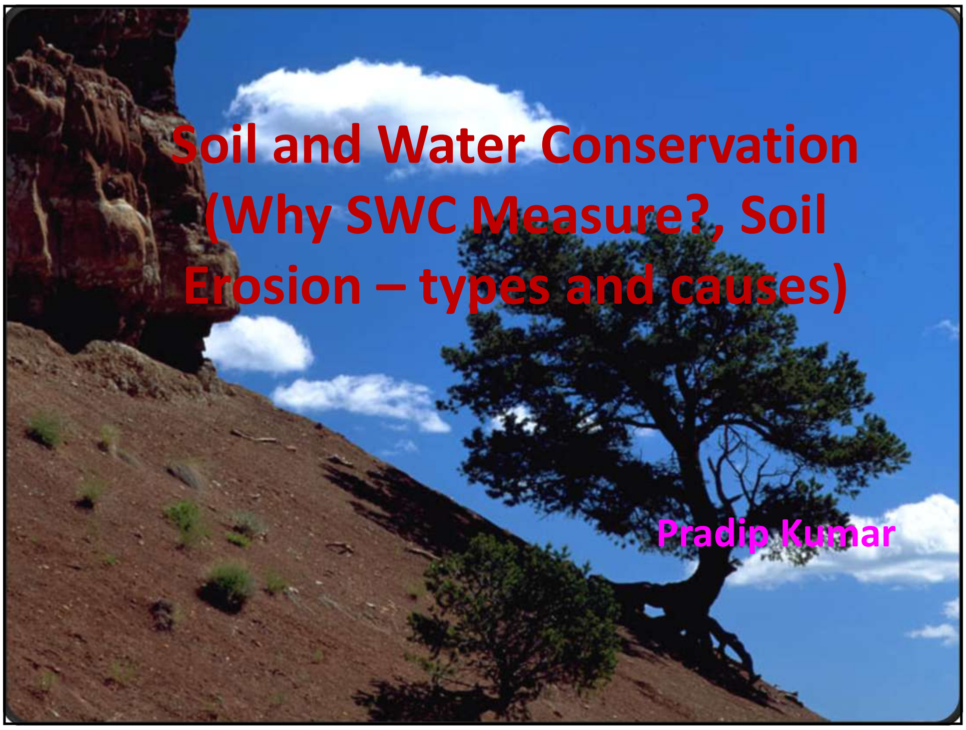

WHY SOIL AND WATER CONSERVATION MEASURES?

- *Soil and water are the most important natural resources on which survival of humans depend*

EXTENT OF SOIL DEGRADATION IN INDIA

Degradation type	Area affected (M ha)
Water erosion	148.9
Wind erosion	13.5
Chemical deterioration	13.8
Physical deterioration	11.6
Total affected area	187.7

Source : Sehgal and Abrol (1994)

- ***SWC measures are required to reduce the extent of soil degradation***

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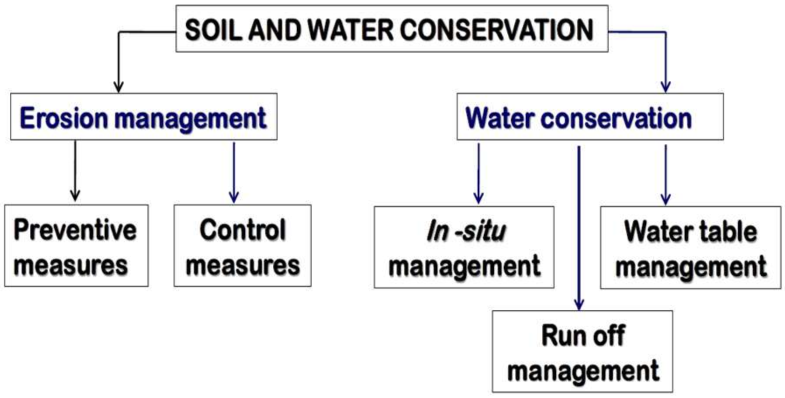
WHY SOIL AND WATER CONSERVATION MEASURES?



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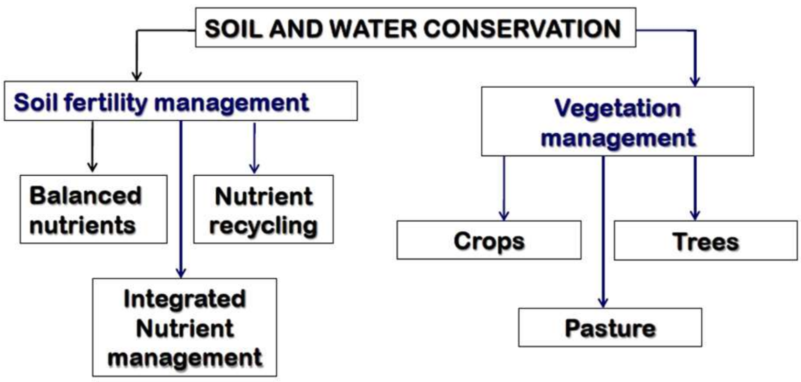
WHY SOIL AND WATER CONSERVATION MEASURES?



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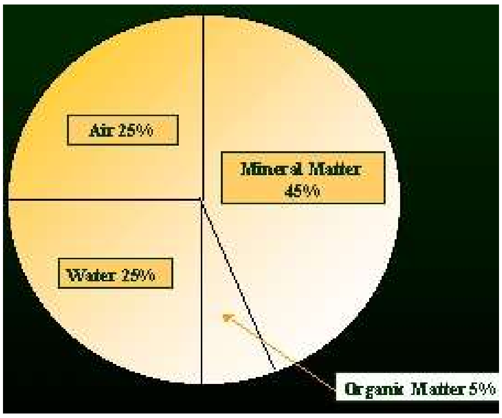
What is soil?

- According to the Natural Resource Conservation Service "soil refers to the loose surface of the earth as distinguished from rock".
  - Soil is composed of organic matter, mineral and nutrients
  - An average soil sample is 45% mineral, 25% water, 25% air and 5% organic matter
  - Soil texture comes from different size mineral particles such as sand, silt and clay



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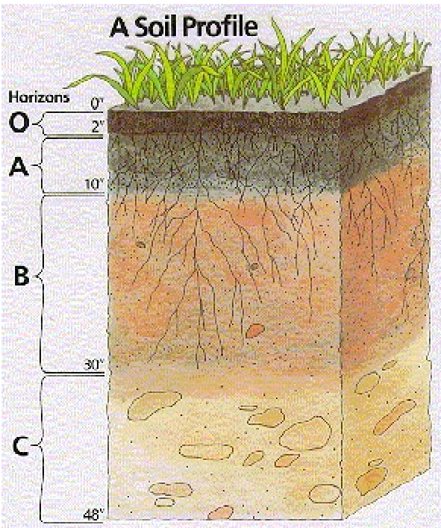
Soil Horizons

- O Horizon—organic layer
- A Horizon—topsoil
- B Horizon—subsoil
- C Horizon—substratum
- R Horizon—bedrock



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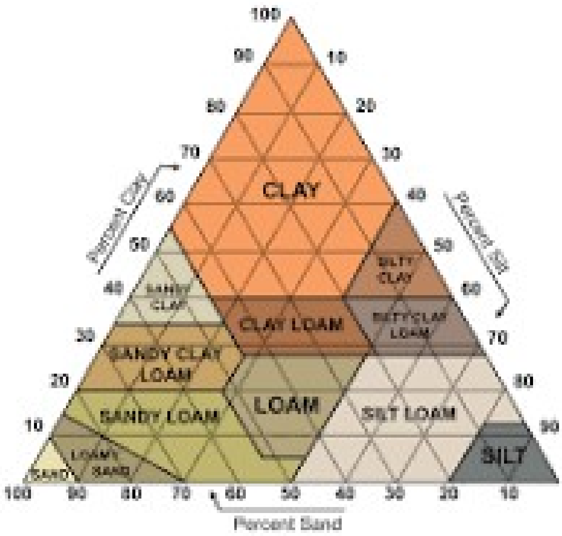
SOIL TEXTURAL TRIANGLE



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Soil Conservation and Water Conservation

- Soil conservation means reducing the amount of soil erosion and maintaining soil fertility. It relies on increasing the amount of water seeping into the soil, reducing the speed.
- Soil conservation is closely related to water conservation.
- Water conservation relies on trapping as much of this water as possible and storing it on the surface (in tanks or reservoirs) or allowing it to sink into the soil in order to raise the water-table and increase the soil-moisture level.

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Erosion scenario

- Soil erosion happens when particles of soil become loose and are carried away by water or the wind : " Detachment and transportation of soil particles from one place to other place by action of water or wind"
- From rivers and reservoirs, it is estimated that about 5,334 M tonnes of soil are getting eroded annually in the country at the rate of 16.34 t/ha/yr
- Of this, about 29% is lost permanently into the sea, 10% gets deposited in the reservoirs and the remaining 61% is dislocated from one place to another causing land degradation problems.
- The storage capacity of major reservoirs is getting lost by 1 to 2 percent every year due to high siltation rates

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EROSION HAZARDS IN MOUNTAINOUS AREAS

- **More than 50% of rainfall is lost as runoff, carrying with it about 20 t/ha of soil loss on erosion-prone steep slope in western Himalayan region**
- **Annual loss of 18 M t of soil due to shifting cultivation in the NEH region**
- Grain yield of maize reduced by 76 kg/ha due to one inch of soil loss at Dehradun, and by 506 kg/ha due to 6 cm of top soil removal in Shiwaliks
- **The loss in crop productivity cannot be compensated by additional chemical fertilization and repeated organic manuring is essential to restore productivity**

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Land Problems to be addressed

Agents of Soil Erosion

- **Water**

Water is most common agent of soil erosion. Rainfall and surface runoff can wash away topsoil, which can lead to the formation of rills and gullies over time.

- **Wind**

Second agent for soil erosion is wind. Wind can pick up soil and blow it away, especially in arid and semi-arid regions.

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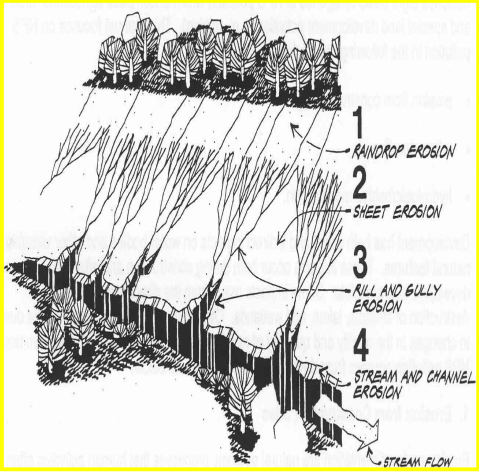
TYPES OF SOIL EROSION

1. Raindrop erosion
2. Sheet erosion
3. Rill erosion
4. Gully erosion (Stage: Formation, Development, Healing, Stablization)
5. Stream bank and bed erosion
6. Wind erosion



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Raindrop / Splash erosion

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Sheet erosion

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Rill erosion

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Gully erosion

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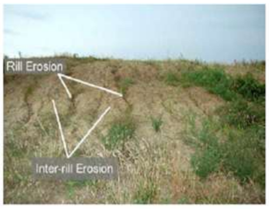
FORMS OF WATER EROSION

Splash Erosion

Sheet Erosion



Rill Erosion

Gully Erosion

Ravines

Landslides

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The four important factors which influence the soil erosion

- **Rainfall** (intensity, duration, distribution, frequency)
- **Topography** (slope, shape)
- **Nature of soil and sub-soil, and**
- **Vegetative cover and agricultural practices**

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Erosion impacts

- Loss of productive topsoil.
- deterioration of farmlands
- deterioration of forests
- occurrence of floods and droughts
- siltation of rivers and water reservoirs

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Visible Impacts of soil erosion: Drainage Problems

Ravine Formation


Flood Havoc
Draught Havoc


Thanks
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IMAGE BANK

PARTICIPATORY WATERSHED DEVELOPMENT: (OVERVIEW AND CONCEPT & PRINCIPLES)

Pradip Kumar

16-09-2025

GLOBAL ALARMING ISSUES IN TODAY'S CONTEXT

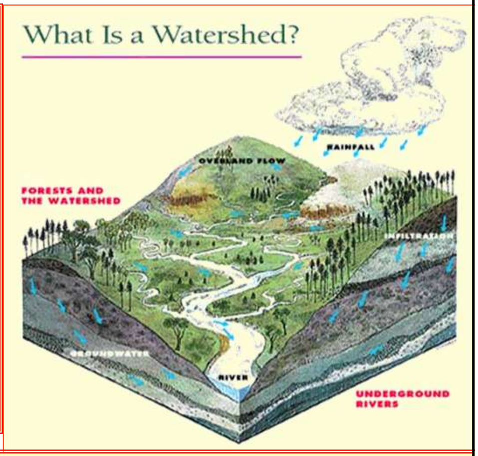
- Heavy demographic pressure.
- Unscientific mining
- Land use systems/degradation.
- Biotic and abiotic stresses
- On-site and off-site effects
- Shrinking of glaciers
- Increase in CO_2 by 0.4% annually
- Rise in temperature
- Change in climate
- Depletion of water resources
- Lowering of water table
- Rise in sea level
- Decrease in reserve fossil fuel
- Ignorance of proper SWC measures
- Non-judicious use of manures and fertilizers
- Discharge of effluents
- Faulty irrigation and management practices
- Over exploitation of resources

Degradation

Shrinking of glaciers

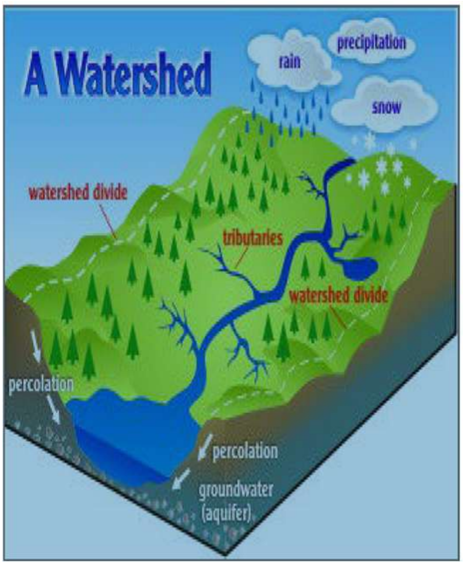
WSM

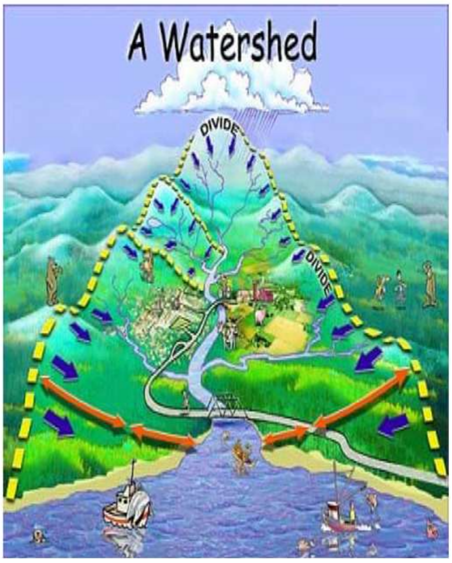
- **Watershed – area which sheds water to a given point.**
- **Watershed management is a well accepted tool and sound strategy for sustainability .**
- **Soil and water conservation including micro-scale water resource development are an integral component of any WSD programme supported by a number of other protection, production and livelihood support interventions.**



- **Water is the most critical input and acts as a catalyst to bring in ecological, social and economical revolution. Ancient civilizations flourished along the water courses and near water bodies and perished on drying up the water resources.**

How a Watershed Look Like?





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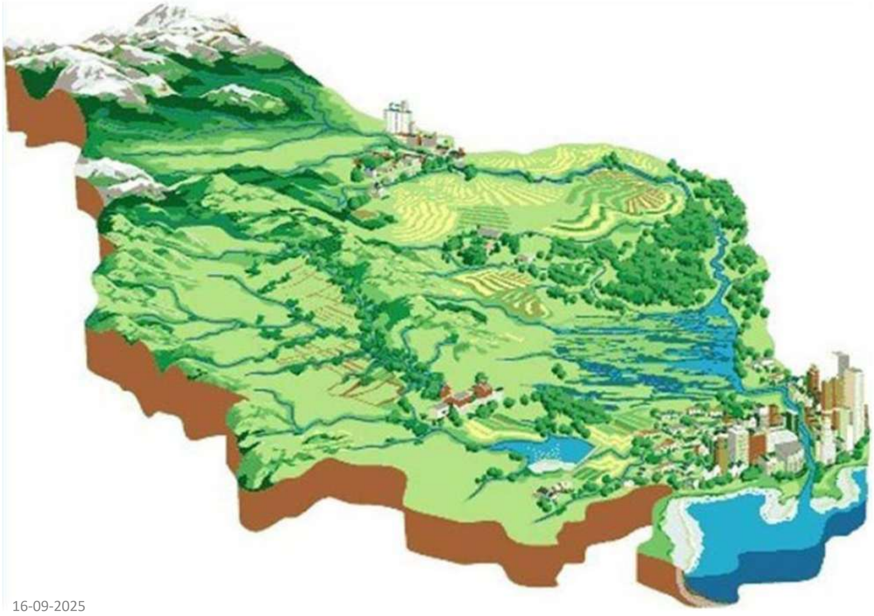
How a Watershed Look Like?



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- **Proper planning, development, management and optimal utilization of water resources are of paramount importance for socio-ecological development.**
- **Drainage lines, like veins and arteries in human body, play an important role in a watershed since through them water, if in excess, could be drained or if needed, could be stored.**
- **Sustainable production depends considerably upon proper development, conservation, management and use of water resources at watershed level involving the local community.**
- **Hence, a proper understanding of the basic principles, approach and application of participatory watershed management is essential for resource conservation and sustainable production.**

Watershed delineations on all India Basis

Category of hydrological units	Number	Area (ha)
Region	6	250 lakh – 10 crore
Basin	35	30 – 250 lakh
Catchment	112	10 – 30 lakh
Sub-catchment	500	2 – 10 lakh
Watershed	3,237	0.5 – 2 lakh
Sub-watershed	12,000	10,000 – 50,000
Milli-Watershed	72,000	1,000 – 10,000
Micro-watershed	4,00,000	500 -1000
Source: Bali, 1979		

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Objectives of Watershed Management

- **Effectively conserve soil, rainwater and vegetation & harvest the surplus water in addition to ground water recharge**
- **Promote sustainable farming and stabilize crop yields by adopting suitable cropping and crop management systems**
- **Cover the non-arable area effectively through afforestation, horticulture and pasture development based on land capability**
- **Enhance the income of the individuals by adopting alternative enterprises**
- **Restore the ecological balance**

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Components of Watershed Management

- Treatment of arable and non-arable land for effective in situ and ex situ moisture conservation
- Implementation of programmes like afforestation, horticulture, agro-forestry, pasture production in stored water/moisture
- Identification of a sound crop production systems and its implementation through the involvement of developmental and input agencies
- Developing suitable infrastructural facilities and people's organizations to maintain the developed services

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Principles of Watershed Management

- Utilizing the land according to its capability
- Conserving as much rain water as possible at the place where it falls
- Draining out excess water with a safe velocity and diverting it to storage ponds for future use
- Avoiding gully formation & checking at suitable intervals to control soil erosion & recharge ground water
- Increasing cropping intensity & land equivalent ratio through intercropping and sequence cropping

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Objectives of Watershed Management

- Safe utilization of marginal lands through alternative land use systems
- Ensuring the sustainability of the ecosystem benefiting the man-animal-plant-land-water complex in the watershed
- Maximizing the combined income from the interrelated and dynamic crop-livestock components over the years
- Stabilizing total income and cutting down risks during aberrant weather situations
- Improving infrastructural facilities with regard to storage, transportation and marketing

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WHY WATERSHED MANAGEMENT ?

- More logical unit of developing of natural resources than the administrative boundaries as flowing water rather follows physical laws and create inter-relationship between upstream and downstream.
- Water is one of the most important natural resource in our eco-system and is the basis of all life-forms i.e. plant, animal and man, hence needs to be conserved efficiently within a watershed
- The piecemeal approaches such as contour bunding or terracing on individual holdings or a group of farms only marginally benefit as they are done ignoring to what happens to other areas which influence the hydrological characteristics
- Such sporadic actions generally fail to attract farmers. Thus, for maximizing the advantages, all developmental activities should be undertaken in a comprehensive way on watershed basis.
- Watershed development is an integrated program and demands a team-work of all the development agencies

- **Watershed Management (WSM) has, therefore, emerged as a new paradigm for planning, development and management of land, water and biomass resources with a focus on social and institutional aspects apart from bio-physical aspects following a participatory "bottom-up" approach.**

- **Watershed development reverses land degradation and promotes more favourable ecological condition leading to healthy environment**

- **Hence, WSM becomes increasingly important as a way to improve livelihood of people while conserving and regenerating natural resources.**

- **The role and importance of community participation in ensuring the success and sustainability of WSM is now widely accepted.**

WATERSHED APPROACH/CONCEPT

- **Watershed, a hydrological unit of an area draining to a common outlet point, is recognized as an ideal unit for planning and development of land, water and vegetation resources.**

- **It is an integrated approach to harmonize use of natural resources like land, water, vegetation, livestock, fisheries and human resources.**

- **Integrated watershed management covering the area from the highest point (ridge line) to the outlet is, therefore, the process of formulating, implementing and managing a course of actions involving natural and human resources in a watershed, taking into account of all the factors operating within the watershed**

- **Watershed also allows accurate measurements and monitoring of components of water balance in hydrologic cycle, sediment, energy, heat, carbon and nutrients balances in an ecosystem.**

- **The monitoring at the level of watersheds or sub-watersheds in a basin will help in analyzing impacts of current and future activities and accordingly plan area specific management options or alternatives based on the priorities as per the intended project objectives.**

WATERSHED APPROACH/CONCEPT

- Watershed Management is the integration of technologies within the natural boundary for optimum development of land, water, plant resources to meet basic needs of people and animals in a sustainable manner

Socio-Technical views on Watershed Development

- Community's unit of understanding is the revenue village boundary and not hydrologically defined watersheds.
- Selection and prioritization of villages can be facilitated with the village community on the basis of microwatershed maps and site inspection.
- Any small area can be treated keeping in view the basic principles of delaying the discharge, conserving soil and optimally utilizing land (Ridge to Valley approach and Contour line treatments)

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Strategy for Watershed Development:

(Package Approach based on Principles of Watershed Management)

- Village/Ward/Panchayat institution development and strengthening
- Participatory planning, implementation and management of natural resource development activities at village/ward level
- Development of technical support structures and local expertise at village level
- Linkage to livelihood Programmes
- Participatory impact monitoring

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Participatory Planning at Village Level

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COMMUNITY ORGANIZATION AND PEOPLE INSTITUTIONS

- **Participatory approach is more pertinent in the planning and development of watershed management programmes, because it is basically the peoples' programme and the government agency should participate as a facilitator.**

- **This is so because it not only requires the resources to be developed or managed properly but equitably distributed among the stakeholders or beneficiaries. It also requires that along with the Private Property Resources (PPR), the Common Property Resources (CPR) are developed, managed and maintained efficiently.**

- **For this, it is imperative that every stakeholder in the watershed accepts and implements the recommended management plan and is very much involved in the planning, implementation and maintenance processes.**

- **Before commencing the developmental activities of the programme, sufficient attention should be paid towards generating awareness among the community members regarding the strategy, approach and benefits of Watershed Development".**

- **For this purpose, repeated meetings in large or small groups may be arranged. It would be useful if traditional street plays, folk songs, etc., are adopted to communicate the spirit of the watershed programme during large group meetings.**

- **If required, handouts on watershed development concepts, approach in local language may also be distributed to local willing persons. This whole process may involve the following steps:**

- **Meetings with the Watershed Community : Conduct regular meetings with farmers in villages to clearly explain the purpose of the programme, get their feed backs, develop contacts, gather ITK, and win their confidence and support.**

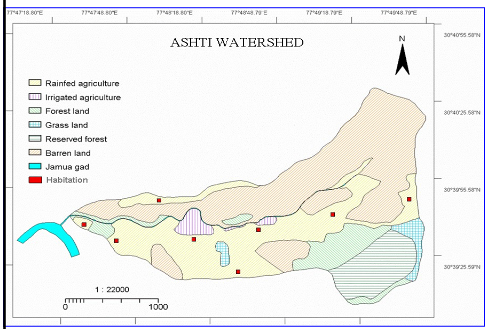
- **Problems Appraisal and Plan Formulation : Conduct PRA or RRA exercises to gather information, diagnose problems, needs and priorities to arrive at a common outline of Detailed Project Report (DPR).**

- **Formation of local Peoples' Institution : Local level peoples' institutions such as Watershed Association, Watershed Committee, SHGs and UGs are formed, by-laws framed and society is registered for day to day operations, management and distribution of benefits.**

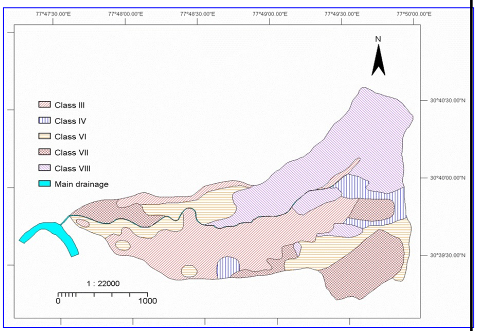
- **Create working capital through revenue generation : Peoples' contribution etc., for repair and maintenance of the assets. Community Based Organisations take a lead in operationalisation and implementation taking support from the local departments/institutions/Organizations. This will create a self sustaining local institution to take over the activities after withdrawal of the project**

PREPARATION FOR WATERSHED DEVELOPMENT PLAN (DPR)

- Based on the present land use, LCC map, problems, needs and priorities ascertained through PRA, watershed treatment/development plan is prepared for arable and non-arable lands including drainage lines and infrastructural development. Components of a typical plan may include the following:



Present Land use map of a watershed



Map of Land Capability Classification

LAND CAPABILITY CLASSIFICATION

LCC	Characteristics
	Land Suitable for Cultivation
I	Very good cultivable, deep, nearly level productive land with almost no limitation or very slight hazard. Soils in this class are suited for a variety of crops, including wheat, barely, cotton, maize, tomato and bean. Need no special practices for cultivation
II	Good cultivable land on almost level plain or on gentle slopes, moderate depth, subject to occasional overland flow, may require drainage, moderate risk of damage when cultivated, use crop rotations, water control system or special tillage practices to control erosion
III	Soils are of moderate fertility on moderate steep slopes subject to more sever erosion and severe risk of damage but can be used for crops provided adequate plant cover is maintained, hay or other sod crops should be grown instead of row crops.
IV	These are good soils on steep slopes, subject to severe erosion, with severe risk of damage but may be cultivated occasionally if handled with great care, keep in hay or pasture but a grain crop may be grown once in 5 or 6 years.
	Land unsuitable for cultivation but suitable for permanent vegetation
V	Land is too wet or stony which make it unsuitable for cultivation of crops, subject to only slight erosion if properly managed, should be used for pasture or forestry but grazing should be regulated to prevent cover from being destroyed.
VI	These are shallow soils on steep slopes, used for grazing and forestry; grazing should be regulated to preserve plant cover; if the plant cover is destroyed, use should be restricted until cover is re-established.
VII	These are steep, rough, eroded lands with shallow soils, also includes droughtly and swampy land, severe risk of damage even when used for pasture or forestry, strict grazing or forest management must be applied
VIII	Very rough land, not suitable even for woodland or grazing, reserve for wild life, recreation or wasteland consideration.

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Watershed Management – Land Capability Class

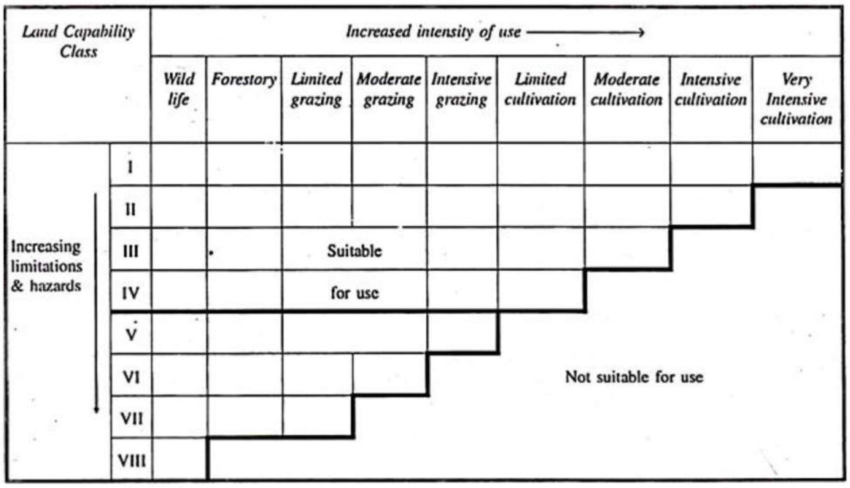

Fig. 22.3. Chart showing the limitations of different LUCCs and their intensity of use.

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- **Protection and conservation measures** : Based on experience of concluded watershed projects it is suggested that a blend of structural and vegetative measures is a better option. This will include all the measures/structures including *insitu* soil and moisture conservation measures like bunding, leveling, terracing and vegetative barriers, water harvesting structures such as ponds, nalla bunds, small dams, percolation ponds etc., drainage line treatments with engineering structures and vegetation for checking land degradation and conserving water; and repair, restoration/strengthening of existing common structures for sustained benefits from previous investments made, if any.

Water harvesting structures

Drainage line treatment

PRODUCTION MEASURES

- These include the activities that are required to make the efficient use of conserved soil and water resources in producing user products such as food, fodder, fuel, fruit, fibre, milk etc., on sustained basis.
- These may include improved crop cultivation and management practices, afforestation, alternate land use systems, cultivation/raising of industrial, medicinal and aromatic grasses and plants for providing alternate livelihood support system, development of livestock, dairying, poultry, sericulture, fisheries and other essential income supporting activities.
- Common approach guidelines for Watershed Development Projects, GOI, have very clearly indicated that out of 73.0 % budget allocated for development component, 50, 13 and 10 % are meant for watershed development works, production systems, micro enterprises and livelihood activities respectively.

Convergence Approach

WSM is a single window, integrated area development programme. Integrated watershed management cannot perhaps be achieved just by following integration of resources using multidisciplinary approach with the funding or support provided alone under any watershed programme.

Social Acceptance & Approval of Plan by Society

The Detailed Project Report (DPR) for watershed development so formulated is summarized and presented in a general body meeting to invite discussions, suggestions and modifications, if any to seek social acceptance and approval of plan by the Society.

CAPACITY BUILDING

- **Training and capacity building in the concept of multi-disciplinary integrated participatory watershed management is most important both for the field level project staff/officers and functionaries of people's institutions i.e., watershed community which generally remains neglected.**
- **Apart from enhancing technical skills of project staff, this would also provide an opportunity to community members to develop their capacity to implement works as per DPR and to sustain the programme as future custodians after project's withdrawal.**
- **GOI has earmarked 5% of the total budget allocation for building capacity of watershed community and functionaries.**

- **This may also involve harmonized use of resources available from other on going/existing sectoral and development schemes in the area/district. Such resources can be dovetailed with the watershed programmes that will not only help in useful convergence of various schemes and programmes for overall development of the area but also in effective monitoring.**
- **Some of these sectors may include education, health, sanitation, drinking water; roads etc., and most of these can also be dovetailed with the entry point activities.**
- **The DPR should elaborate the gap to be filled through other schemes following convergence approach**

Phases and Duration of Watesrhed Prog

Phase	Name	Duration	
I	Preparatory Phase	upto 1	Year
II	Works Phase	2 to 3	Years
III	Consolidation and Withdrawal Phase	upto 1	Year

PREPARATORY PHASE

Institution and Capacity Building

- Short term training program
- SHGs of women formed.
- Meeting organized to apprise watershed villagers about project activities, development strategies, modus operandi and contribution.

Entry Point Activities

- Construction of village paths, bouries etc..

WORKS PHASE: Protection, conservation and production activities

CONSOLIDATION PHASE Prog sustainability – institution and WDF

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HEAD-WISE DISTRIBUTION OF WATERSHED BUDGET

Major Head	Sub Heads	Percentage of Budget
Administrative	Management Cost	10
	Monitoring & Evaluation	2
Preparatory Phase	Entry Point Activity	2
	DPR Preparation	1
	Institution &Capacity Building	3
Works Phase	Natural Resource Management	47
	Production System	15
	Natural Resource Management &Governance	2
	Livelihood Activities for the asset less persons Micro Enterprises &Business Development	15
Consolidation & Withdrawal Phase		3
	Total	100

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SUSTENANCE AND FOLLOW UP

- **An institutional arrangement preferably with active involvement of local community should be formed and entrusted with this responsibility.**
- **Participatory watershed resource management is a good example in this endeavour. Village Resource Management Societies (VRMS) or Watershed Committees (WC) may generate revenue, manage the resources and look after repair and maintenance of these structures.**
- **The government agencies should provide necessary technical guidance/supervision whenever required.**

General guideline for some Watershed interventions

Slope	Treatment	Remarks
A.	**Ridge Area**	
>25%	Plantation of grasses, shrubs and trees	Native species to the area
	Contour bunding with boulders	Where boulders are available (without disturbing boulders embedded in the ground)
10-25%	Contour trenching	
<10%	Earthen contour bunding	
B.	**Drainage Line**	
>20%	Brushwood checks	Where thinning operation yields adequate raw material
5-20%	Loose boulders checks	If boulders are freely available
	Boulders-cum-earthen checks	If boulders are not freely available
>5%	Earthen dams	Which serves as percolation tank
	Sand-filled bags structures	Where sand is locally available
	Gabion structure	Where velocity and volume of run-off too high
Eroded sides	Nala training : deepening, raising sides	Stream overflow and erode field alongside
	Gabion or sand filled bags	
GW well on side	Underground dykes	where impermeable strata overlain by permeable layer

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Major Milestones of WDD IN INDIA at a Glance

- 1974 – Drought Prone Area Programme launched by Ministry of Rural Development GoI
- 1978 – Desert Development Programme launched by MoRD
- 1985 - Establishment of National Wasteland Development Board under Ministry of Environment and Forest , GoI
- 1989 – Integrated wasteland Development Project launched by MoRD
- 1990 – National watershed Development programme for rainfed areas launched by ministry of Agriculture, GoI
- 1993 – Employment Assurance Scheme launched by MoRD
- 1995 – Watershed Development in shifting Cultivation Areas launched by MoA
- 2003 – Hariyali Guidelines by MoRD
- 2005 – Mahatma Gandhi National Rural Employment Guarantee Act implemented by MoRD
- 2006 – Establishment of National Rainfed Areas under the Planning Commission, GoI
- 2008 – Common guidelines for watershed Development Projects by NRAA
- 2009- Launch of Integrated Watershed Management Programme
- 2021- Guidelines for New Generation Watershed Development Project (WDC-PMKSY 2.0)

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MAP READING, DELINEATION AND CHARACTERISATION OF WATERSHEDS

Pradip Kumar

16-09-2025

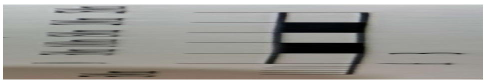
MAP READING

Map reading is the first important step for obtaining information relevant to watershed planning and management. The following steps are involved in map reading.

1. Orientation of the map
2. Legend and symbol
3. Scale of the map
4. Horizontal and vertical distances and angles
5. Identification of natural and man-made ground features
6. Delineation of watershed boundaries.

What is Map?

- Map is representation of earth or its parts on paper or plane surface and drawn to a scale.
- For a representation to qualify as a map , it must have three attributes .
  - *Direction: guide to hold map – top portion directed at North*
  - *Legend: gives description of sign and symbols on map*
  - *Scale (in word, graphical scale, representative fraction-RF)*
    - *Scale in word: 1:4000 (1 cm on map is equal to 4000 cms or 40 m on ground*
    - *Graphical scale: Straight line divided into number of equal parts and each part represents an actual distance on the ground.*



    - *Representative Fraction (RF) = Distance on Map / Distance on Ground*
- Types of Map: Sketch, Cadastral, Thematic, Satellite, Topographical

Exercise:

Que.1: Derive RF of cadastral map with a scale 16 inches = 1 mile?.

Que.2: An original map of scale 1:10000 was enlarged by 25%. What is the new scale of map?

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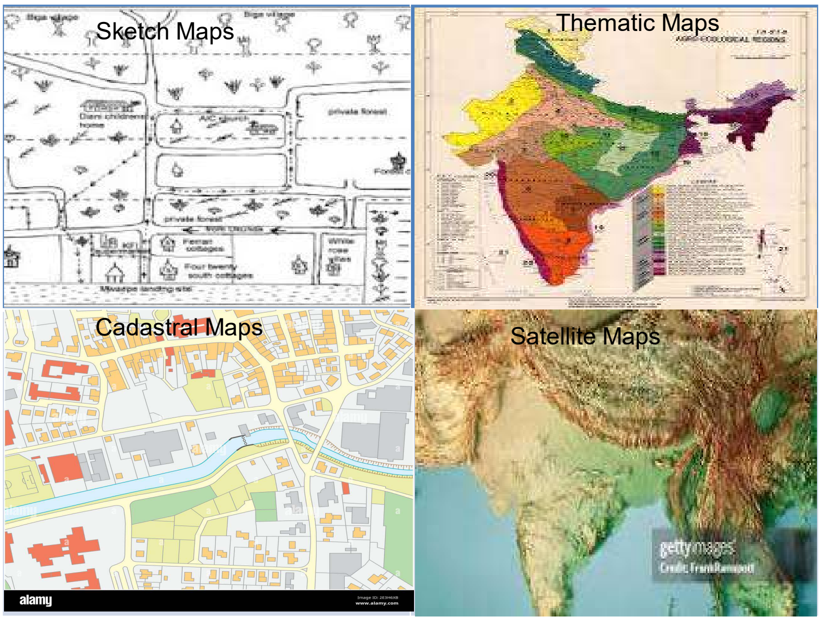

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Topographical Maps

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Topographical Maps or Toposheets

- Provide information about lay of land.
- Special feature- along with direction, scale and legend it provide information about relief of land using contour lines.
- Provide detailed information on contour lines, drainage, water harvesting structures, land use, villages and urban settlements, roads, railway lines electricity and telephone lines etc.
- Vertical interval in a toposheet remains constant.
- Elevation and area of any spot can be found using topographical map.
- Toposheets are made on the basis of latitudes and longitudes.
- Toposheets are available by Survey of India mainly on 3 scales: 1:1000000, 1:250000, and 1:50000. For special areas toposheets on scale 1:25000

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Characteristics of Different Scales SOI Toposheet

Number of map (example)	Name	Number of Divisions	Scale in Degrees	Scale in Inches	Scale in Centimeters	Contour interval in ft.
53	Million Sheet	136	4° latitude × 4° longitude	1 in = 16 mile	1cm = 10 km	500
53 C	Degree or Quarter	16 (A to P)	1° latitude × 1° longitude	1 in = 4 mile	1cm = 2.5 km	250
53 C/NE	Half Inch	4 (NE, SE, NW, SW)	30’× 30’	1 in = 2 mile	1cm = 1.25 km	100
53 C/8	Inch	16 (1 to	15’ × 15’	1 in =	1cm = 0.5	50

- Numbering of sheets in India is based on the number system of maps of India and these series bears the numbers like1,2,3,4…upto136 consisting of the segments that cover only land area.
- These136 such sheets cover India and adjacent countries and these numbers are known as index number of the area.
- For example, sheet number73 is consider for Jharkhand area.

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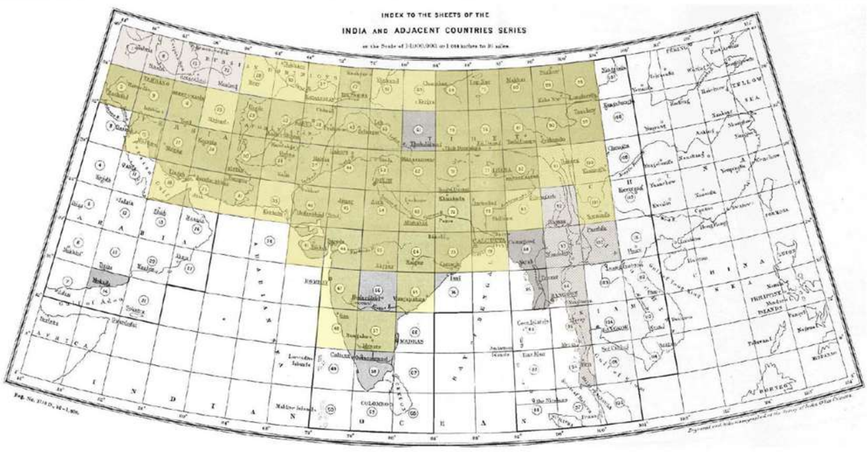
Toposheet Grid



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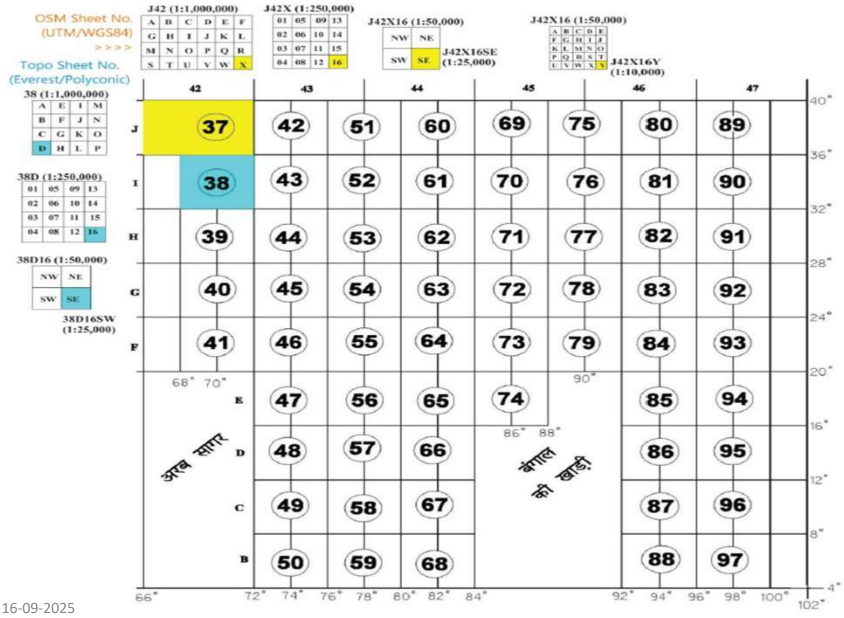
Index for Conversion of Toposheet number to OSM sheet number



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Topo Sheet Grid

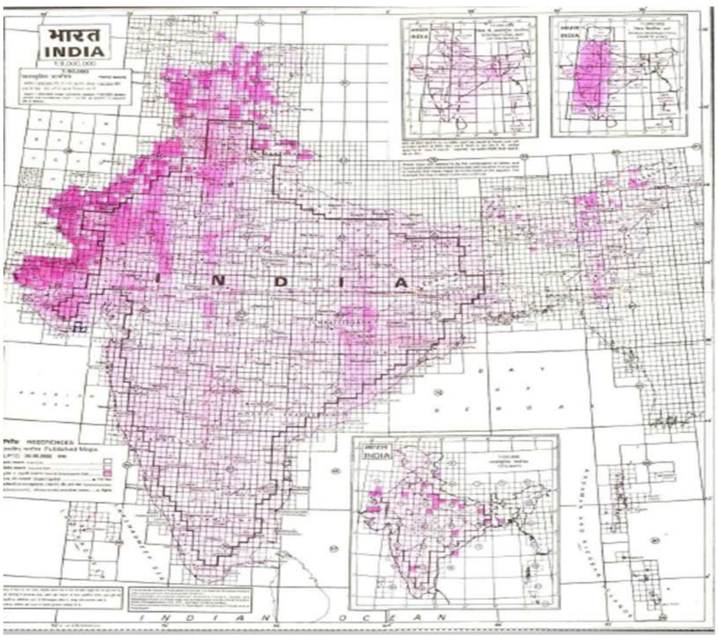

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Table 1. Kinds of maps used in watershed planning

	Maps:	Scale	Source	Use
Primary	Topomap	1:50000	Survey of India, Dehradun.	General physical features – Gullies, Ravines and Ponds etc.
	Cadastral Map	1:5000	Gram Panchayat, Collectorate	Land ownership and land use
	Soil Map	1:2,50,000	National Bureau of Land Use Survey and Planning, Nagpur.	Land capability classification and Management.
Secondary	i) Drainage and contour maps a) For large watershed b) For small watershed	1:50,000 1:5000	Toposheets Magnification of topomap or GIS base map of given area	Determination of physiographic characteristics
	ii) Rainfall map	1:50,000/ 1:5000	Prepared by analysing rainfall data	Determination of Hydrologic Characteristics
	iii) Land use capability Map	1:50,000/ 1:5000	Field Survey	Soil erodibility and erosion risks
	iv) Present land use map	1:50,000/ 1:5000	Field Survey	Identification of extent and kind of land uses

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INTERPRETATION OF MAPS

1. On steep slope the contour lines are spaced closely together, while on gentle slope they are spaced apart. Close spacing of contour lines indicate the steepness of hill.
2. A uniform slope is indicated when contour lines are uniformly spaced, while a plane surface (such as embankment of a pond) is indicated when they are straight and parallel.
3. As contour lines represent level lines, they are perpendicular to the lines of the steepest slope.
4. Contour lines cannot merge or cross one another on the map, except in the case of a overhanging cliff. A vertical cliff is indicated when several contours coincide, the horizontal equivalent being zero.
5. Contour lines cannot end anywhere, but close on themselves either within or outside the limits of the map.
6. A series of close contour lines on a map indicate a depression or a summit, depending on whether the successive inside contours have loser or higher values inside. Fig. 2 (a) and (b) represent a typical hill and valley respectively.
7. Contour lines cross ridge lines or valley lines at right angles. A ridge line is shown when the higher values are inside the loop or bend in the contour, while in the case of a valley line, the lower values are inside the loop as shown in Fig 2 (c) and (d). The same contour appears on either side of a ridge or valley.

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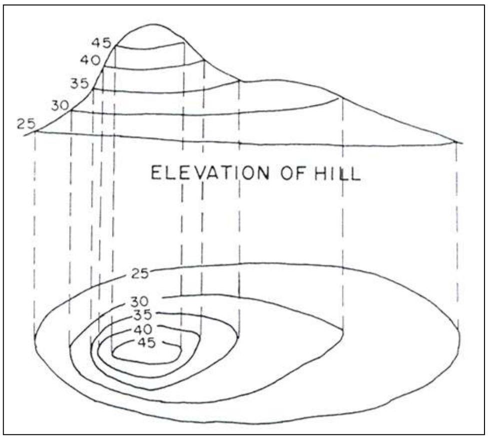
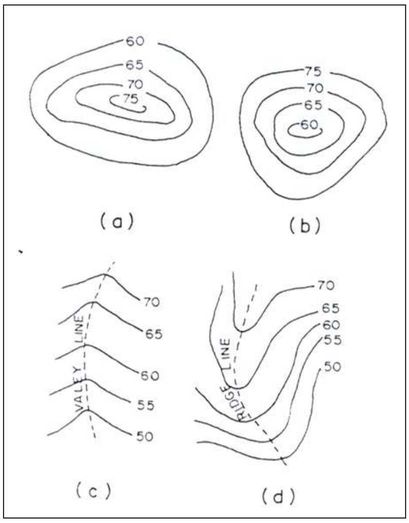


Elevation and plan of a hill



Characteristics of contour lines (a) Hill (b) valley (c) Valley line (d) Ridge line

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USES OF CONTOUR MAP

1. By inspection of a contour maps, information regarding the character of the tract of the region is obtained; whether it is flat, undulating or mountainous, etc.
2. Contour maps are very useful for planning soil conservation works. The most economical and suitable site for engineering structures, such as check dams, ponds, bunds etc. can be selected.
3. Watershed areas measured from maps are used in estimating runoff to be handled by gully control structures, waterway and pond spillways.
4. Area and slope measurement from contour maps can be used in preparation of land capability map of the watershed.
5. Preliminary selection of the most economical or suitable alignment for irrigation, channels, diversions, drainage ditches, roads etc. can be made.
6. Contour map may be used for computing the capacity of a reservoir and volume of earthwork involved.

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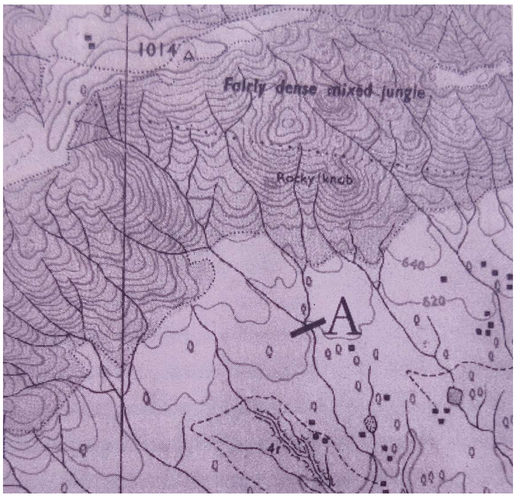
DEMARCATION OF WATERSHED

Step1: Identify the point with respect to which watershed is to be marked (The Exit Point - A).



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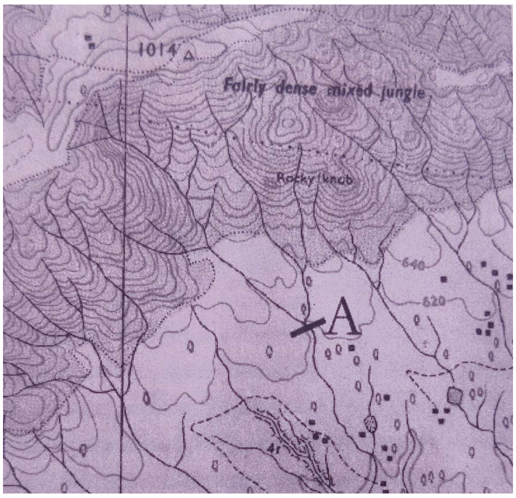
DEMARCATION OF WATERSHED

Step1: Identify the point with respect to which watershed is to be marked (The Exit Point - A).



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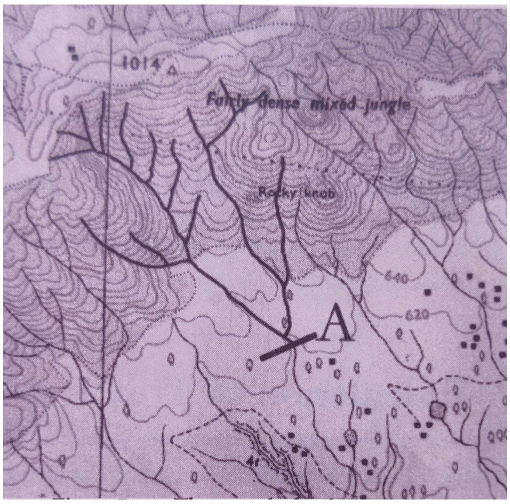
DEMARCATION OF WATERSHED

Step2: **Mark out the drainage lines of various orders, which drain into this common point - A.**



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DEMARCATION OF WATERSHED

Stage3: **Beginning from the exit point, draw a line around the drainage systems, which drain to point- A.**

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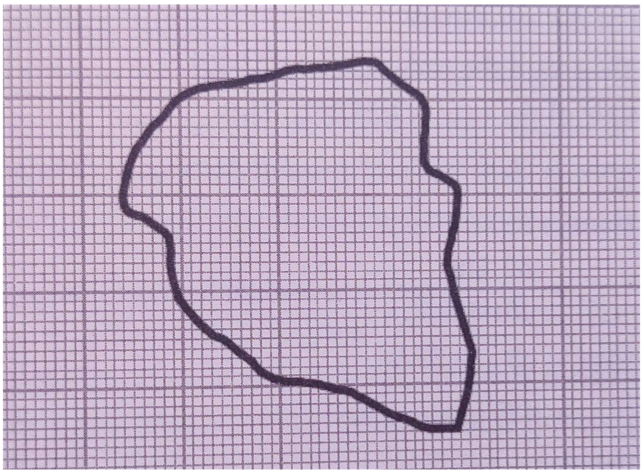
COMPUTATION OF WATERSHED AREA

We can not use a pre-determined formula for calculating area since the shape of waters.hed is irregular. However, area can be calculated quickly and easily using a translucent graph paper.



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Graphical Method Steps for Calculation of Watershed Area

First Step: Trace the boundary of demarcated watershed on transparent graph paper

Second Step: Count the number of whole 1 cm x 1 cm squares in the graph paper falling within watershed boundary.

Third Step: In the leftover partial 1 cm x 1 cm squares, count the number of whole 1 mm x 1 mm squares.

Fourth Step: Find out total number of 1 cm x 1 cm squares in the watershed boundary-

Total no. of 1cmx1cm squares = No. of complete 1cmx1cm squares + (No. of 1mmx1mm squares / 100)

Fifth Step: Area represented by one square centimeter in a map is obtained from the scale of map. Knowing this we can calculate the total area of watershed

Que.1: A watershed has been marked on a map with a scale of 1:25000. The area of the watershed in the map comes to 68 square centimeters.

- What is the area of the watershed?
- What would be area if the scale was 1:100000?

Ans: (425 ha, and 6800 ha)

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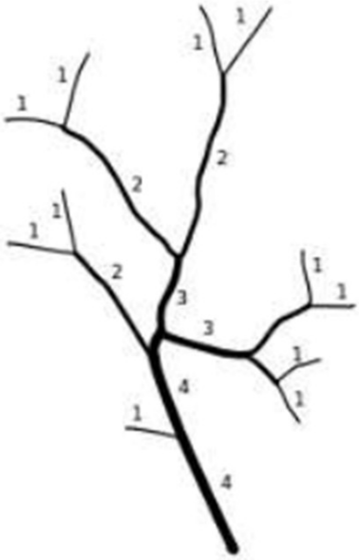
HOW TO ASSIGN STREAM ORDER



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CHARACTERISATION OF WATERSHED

1. **Catchment area and its perimeter.**
2. **Stream order, stream length and bifurcation ratio: The stream order is generally determined by the Horton's method. Order 1 is assigned to small, unbranched tributaries, order 2 to those streams which have first order only, order 3 to stream with second and lower orders etc.**
3. **Drainage density: It is defined as the length of stream per unit area. This parameter reflects upon the number of hydrological characteristics of a watershed.**
4. **Compactness coefficient: It is described as a ratio of the perimeter of watershed to the circumference of the circle of area equal to watershed area.**

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5. **Elongation ratio: It is the ratio of the diameter of a circle of an area same as basin area to the maximum length of basin.**
6. **Circulatory ratio: It is the ratio of basin area to the area of a circle of same perimeter as that of basin.**
7. **Relief ratio and relative relief : The relief ratio is the ratio of the maximum basin relief to the longitudinal distance along the largest dimension of the catchment parallel to the main drainage line. Maximum basin relief is the difference between the highest and lowest alleviation of main stream. Thus, relief ratio measures overall steepness of basin. The relative relief is the ratio of maximum relief to the basin parameter.**
8. **Average slope: The Average slope of a catchment is computed as S=MN/100A , where M is the total length of contours within the watershed, N is the contour interval and A is the area of watershed. Slope at any point of the Watershed can be directly determined from the contours drawn on the map.**

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Exercise: Overall Slope Calculation of Watershed

- Que.1: In a toposheet of scale 1:50000, Point A is on the ridge line and has a value of 320m above MSL, and Point B is located near exit point of watershed has a value of 240m above MSL. The Map distance from A to B is 6cm. What is overall slope of watershed.

  Ans: 2.7%

- Que.2: On a1:250000 toposheet, point A is at an elevation of 800 m, Point B is at 400 m and Point C is at 300 m, The map distances are 5 cm from A to B and 6 cm from B to C. What is the overall slope of the watershed.

  Ans. 1.9%

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THANKS

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RAINFALL MONITORING, RUNOFF ANALYSIS AND ESTIMATION OF WATER YIELD

Pradip Kumar

16-09-2025

Measurement of Precipitation

The amount of precipitation is measured using a raingauge (also called pluviometer, ombrometer, hyetometer etc).

Raingauges may be broadly classified into 2 categories viz.

1. Non-recording raingauges and

2. Recording raingauges

Non-recording Raingauges

Symon's gauge.
Circular collecting area of 12.7 cm diameter connected to a funnel. The rim of the collector is set in a horizontal plane at a height of 30.5cm above the GL.

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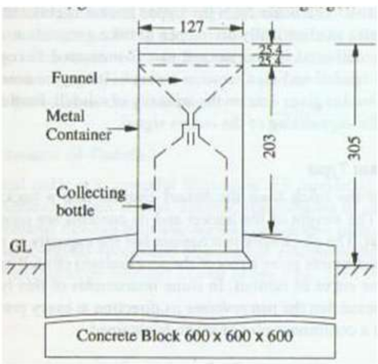
Non recoding Rain Gauges are manufactured as per IS:5225 :1969. Rain Gauge is manufactured from non corrosive fiber glass reinforced plastic container. It consists of collector assembled with brass Ring. Funnel, Locking Rings and Base. The Rain Gauge is supplied with 2 liter bottle and a measuring cylinder. Rain Gauges are available in 100 and 200 sq. cms collection area.



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Recently IMD has started adopting fibreglass reinforced polyester raingauges.

The collector is in two sizes – having 100 and 200 sq.m area. For details see IS:5225 and IS:4986.

When snow is expected, the funnel and the receiving bottle are removed and snow is collected in the outer metal container. It is then melted and the depth of resulting water is measured.

It is extremely important to note that the correct type of measuring jar appropriate to the type of rain gauge funnel in use should be used for measuring the amount of rainfall

Rainfall below 0.1 mm is marked as ‘trace’

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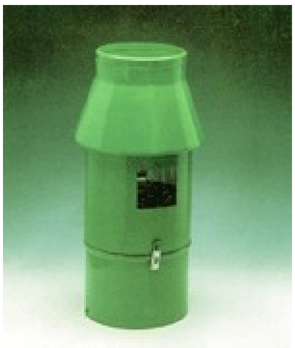
RECORDING TYPE RAINGAUGE

CONFORMS TO IS 5235-1969
NATURAL SIPHON TYPE FOR 10 MM RAINFALL COMPLETE WITH GUNMETAL RIM. BASE AND COLLECTOR OF FIBRE GLASS, ONE PEN, QUARTZ CLOCK WITH A SET OF CHARTS,



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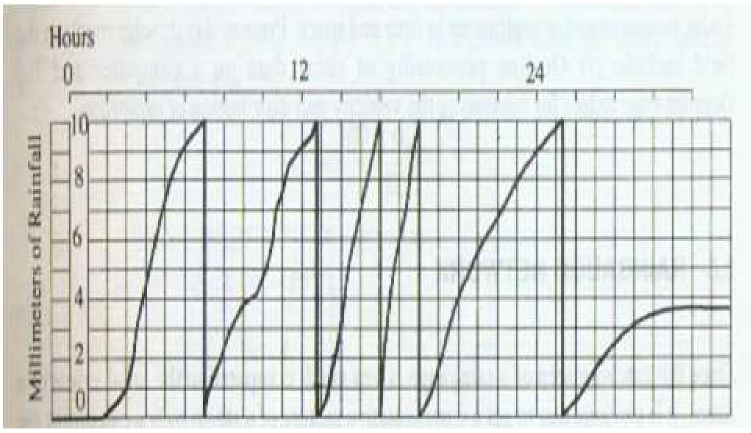
Rainfall Chart



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Digital Raingauge

Tipping Bucket Mechanism
0.2 mm and 0.5 mm least count
Data Logger – 1 month to 1 year recording

Radar Measurements

The hydrological range of radar is about 200km.
Heavy rains – 10 cm radar
Light rains and snow – 5cm radar
Doppler type radars are used for measuring the velocity and distribution of raindrops.

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Computation of Average Rainfall over a Basin

1. Arithmetic Average Method

   Pav = P1+P2+P3....+Pn/ N

2. Thiessen Polygon Method

   Pav = P1xA1+P2xA2+P3xA3...+PnxAn / A1+A2+A3...+An

3. Isohyetal Method:

   An isohyetal is a line joining places where the rainfall amounts are equal on a rainfall map of a basin

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Analysis of rainfall and runoff - *pre-requisite*

•Design and planning of soil and water conservation

• Rainfall, estimation of runoff, floods, drought and water yield

Important parameter of Rainfall

•Intensity of rainfall, millimeters per hour (mm/h)

•Very intense storms are not necessarily more frequent though these storms cause most erosion damage and floods.

•The design criteria, therefore, accounts for such infrequent, high intensity storms.

•Depth of rainfall expected to occur during selected period of time

The concept of time is a statistical term called 'the return period', that gives an estimate of the probable high intensity storm which can occur in an area within a specified time.

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Return period

The return period, sometimes called recurrence interval, is defined as the period of time within which the depth of rainfall for a given duration is expected to be equalled or exceeded atleast once. The probability of occurrence of an event and return period are related as

$$T = 100/p$$

where, T is the return period, and **p** is the probability of occurrence of an event.

Design return period for various types of structures

Type of structure	Return period, years
Storage and diversion dams having permanent spillways	50-100
Earthfill dams-storage having natural spillway	25-50
Stock water dams	25
Small masonry gully control structures	10-15
Terrace outlets and vegetated waterways	10
Field diversions	15

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Prediction of Design Peak Run-off

1. Dicken's Formula-Method
2. Rational Method
3. Hydrologic soil cover complex number
4. Table Method

Assumption:

- *Rainfall occurs at uniform intensity for a duration equal to time of concentration*
- *Rainfall occurs with a uniform intensity over entire watershed*

•Runoff depends upon bio-physical characteristics of the catchment

•Runoff estimation includes volume and peak rate of flow volume.

• For designing spillways and outlets or waterways, peak rate of runoff is required

• Assessing the storage in earthen dam, tanks and ponds etc. the estimates of runoff volumes are required.

• In drainage line treatment, the flow velocity is required for determining scour pattern in the river bed and along the banks.

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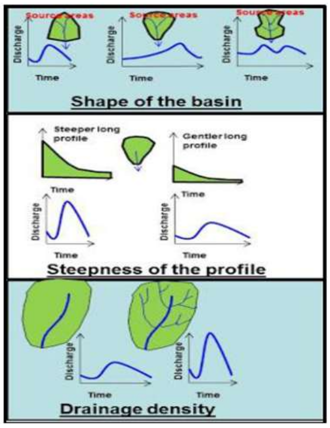
Peak Discharge

Peak Discharge : It is the highest concentration of discharge of a stream or a river from its basin or catchment area that occurs. It usually occurs during the monsoon, once in a year.

The peak discharge of a stream may vary from year to year and is a function of

- **Shape of the basin**
- **Drainage Density**
- **Rainfall Intensity**
- **Soil Texture**
- **Vegetation**
- **Slope** and
- **Geology**



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Peak Discharge / Runoff Estimation

1. Dicken's formula:

It was formerly adopted only in Northern India but now it can be used in most of the states in India after proper modification of the constant.

$$Q = KA^{3/4}$$

Where Q is discharge in m^3/sec.

A is area of catchment in km^2.

K is Dicken's constant.

According to the area of catchment (terrain, vegetation, etc) and amount of rainfall, the value of K for North and North East India is 11.37. In other parts it may be higher upto 22.04 in Western India.

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2. Rational Method

$$q_p = CiA/360$$

Where, q_p = peak discharge in m^3/s

C = Runoff coefficient

i = design intensity for a particular return period and duration equal to time of concentration, mm/h

A = area of the watershed, ha

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Runoff Coefficient, C

C is affected by many factors.

- cover condition
- design intensity
- For the parameterization of C, four hydrologic soil groups are defined
- The lumped value of C is tabulated for the soil group B
- For other soil groups the conversion factors are tabulated
- The conversion factors should be multiplied to the value of C for soil group B to get the C for other soil groups.

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Table 2 Hydrologic soil groups

Soil group	Description	Final infiltration rate, mm/h
A	Lowest runoff potential, deep sand with little silt and clay	8-12
B	Moderate low runoff potential, sandy soils less deep	4-8
C	Moderate high runoff potential, shallow soils, contains clay	1-4
D	Highest runoff potential, mostly clay and also shallow soils with impermeable sub-horizon	<1

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Landuse	Soil Group	Area	C
Agriculture	B	A1	C1
Forest	B	A2	C2
Scrub area	C	A3	C3

$$C = \frac{C1xA1+C2xA2+C3xA3}{A1+A2+A3}$$

Determine C for the watershed

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Values of Runoff coefficient 'C' in Rational method

Vegetative Cover	Soil Texture		
	Sandy loam	Clay and silt loam	Stiff clay
Cultivated Land			
0-5%	0.30	0.50	0.60
5-10	0.40	0.60	0.70
10-30	0.52	0.72	0.82
Pasture land			
0-5%	0.10	0.30	0.40
5-10	0.16	0.36	0.55
10-30	0.22	0.42	0.60
Forest			
0-5%	0.10	0.30	0.40
5-10	0.25	0.35	0.50
10-30	0.30	0.50	0.60

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Table 4 Hydrologic soil groups conversion factors

Cover	Conversion factor form group B		
	A	C	D
Row crop, poor practice	.89	1.09	1.12
Row crop, good practice	.86	1.09	1.14
Small grain, poor practice	.86	1.11	1.16
Small grain, good practice	.84	1.11	1.16
Good rotation	.81	1.13	1.18
Pasture, good	.64	1.21	1.31
Woodland, good	.45	1.27	1.40

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Design intensity

Peak rate of runoff is estimated for a particular design intensity.

- The return period for *i* should be the same for which the structure is to be designed.
- For this intensity-duration-frequency relationship for a particular place is used.
- The duration is taken as equal to the time of concentration (t_c).
- t_c depends upon watershed topography and is defined as the maximum time taken by the flow to reach the watershed outlet. Generally, it is calculated by using Kirpich formula

$$t_c = 0.0195 \times L^{0.77} S^{-0.385}$$

where, L is the maximum flow length, m

and S is the average gradient of channel, and is the ratio of difference in elevation of remotest point and outlet to L

$$S = \frac{\text{(elevation of remotest point - elev. of outlet)}}{L}$$

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Procedure for using Rational Formula

1. Determine the area under various land uses (A1, A2,....)
2. Determine the t_c
3. Determine the 1-h intensity for a given location from the maps (Fig. 1) or with following formula.

$$I_o = \frac{P}{2}(1+1/T)$$

where, P is the amount of rainfall from the most severest storm and T is its duration.

4. Convert 1-h intensity for design frequency for duration equal to time of concentration from Fig or with the following equation.

$$I_{tc} = \frac{2I_o}{t_c+1}$$

5. Determine the value of C from the table for each landuse cover and design intensity.
6. Compute weighted C

$$C = \frac{A_1C_1 + A_2C_2 + ... + A_nC_n}{A}$$

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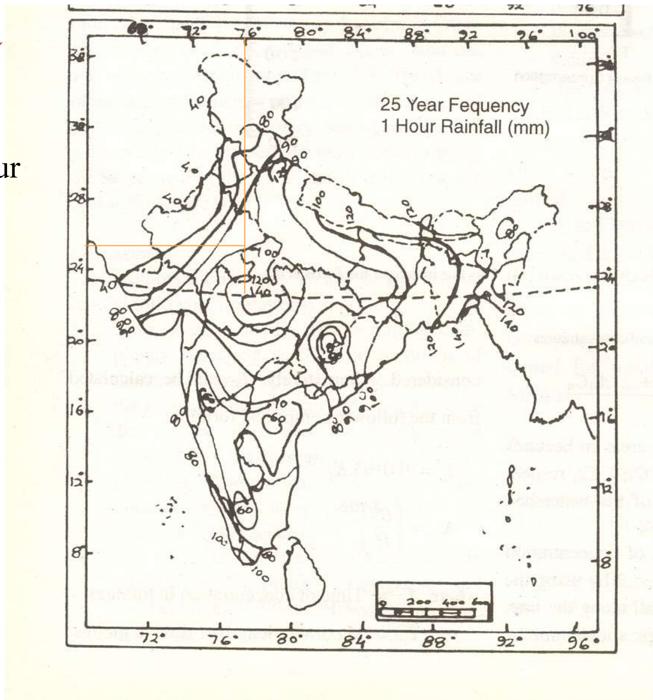
7. Compute the peak rate of runoff by using Rational formula.

DESIGN INTENSITY

Maximum One- hour Rainfall (I_0)



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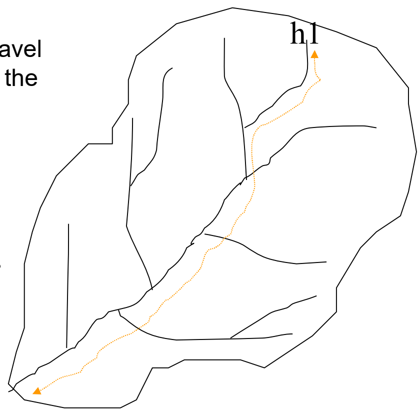
TIME OF CONCENTRATION

"Time taken by run-off water (flow) to travel from most distant point in watershed to the lowest point or outlet"

L = Max length of flow in m

S= (h1-h2) / L m/m

Tc = Time of concentration in minutes



Time of Concentration (Kirpich equation)

$t_c = 0.0195 \times L^{0.77} \times S^{-0.385}$

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TIME OF CONCENTRATION

Example

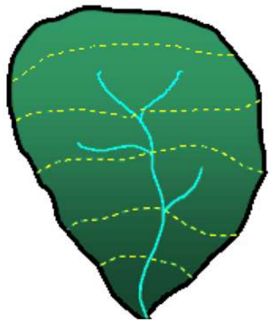
If the length of the longest drainage line is 500m and difference in elevation is 44m in a selected catchment of 20ha, then

$$\text{Slope } S = \frac{44}{500} = 0.088 \text{ and } L = 500\text{m}$$

$$Tc = \frac{0.0195\,L^{0.770}}{S^{0.385}} = \frac{0.0195\,(500)^{0.770}}{(0.088)^{0.385}}$$

$$= \frac{0.0195 \times 119.73}{0.39}$$

$$= \mathbf{6\ min}$$



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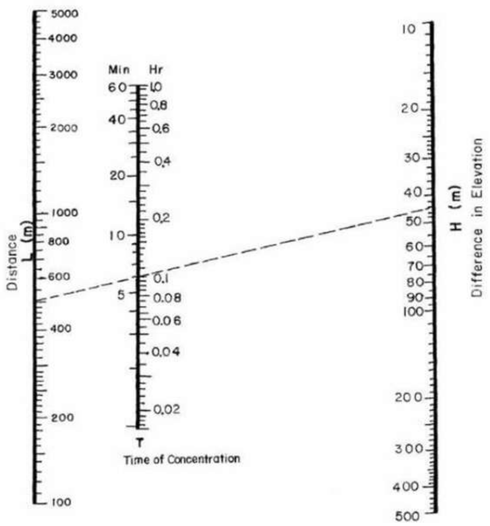
TIME OF CONCENTRATION – USING NOMOGRAPH

Example

This can also be calculated with the help of a **Nomograph.**

On the left is the length of the longest drainage line and on the right is the difference in elevation.

If we join the elevation difference i.e. 44 m with drainage length i.e. 500m it will cut the middle line of time of concentration at **6min**.



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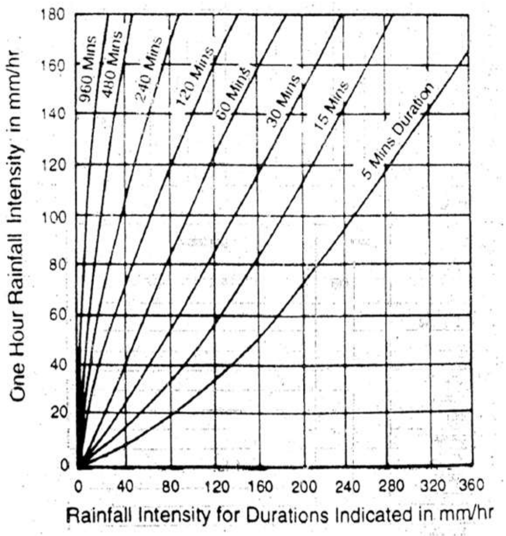
RAINFALL INTENSITY

In the graph on Y Axis is the one hour rainfall intensity. There are different graphs of Tc for different time.

Draw a horizontal line from Y axis to Tc of the area.

Then draw a vertical line from the point of intersection to get the **Rainfall intensity in mm/hr for the required Tc.** For the selected watershed it is about **260 mm/hr**



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ESTIMATION OF RUN-OFF COFICIENT

Assuming that the soil texture in the selected watershed is loamy and the land use is Agricultural land = 4ha (A_1) with 10%, pasture land = 6ha (A_2) with 20% slope and forest land = 10ha (A_3) with 30% slope, then

As per table C for Ag Land = 0.60 (C_1), for Pasture Land = 0.42 (C_2) and for Forest Land = 0.50 (C_3) then

average run-off Coefficient is given by:

$$\mathbf{C} = \frac{A_1 C_1 + A_2 C_2 + A_3 C_3}{A_1 + A_2 + A_3}$$

$$= \frac{4 \times 0.6 + 6 \times 0.42 + 10 \times 0.50}{4 + 6 + 10}$$

$$= \frac{2.4 + 2.52 + 5.0}{20}$$

$$= \mathbf{0.496}$$

S. No.	Type of Area	Value of C	
	Slope	Rolling 6-10%	Hilly 11-30%
1	Agricultural land		
	Sandy soil	0.40	0.52
	Loamy soil	0.60	0.72
	Clayey soil	0.70	0.72
2	Grassland		
	Sandy soil	0.16	0.22
	Loamy soil	0.36	0.42
	Clayey soil	0.55	0.60
3	Forest		
	Sandy soil	0.25	0.30
	Loamy soil	0.35	0.50
	Clayey soil	0.50	0.60

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ESTIMATION OF PEAK DISCHARGE BY RATIONAL METHOD

Now Peak Discharge Qp is given by

$$\mathbf{Qp} = \frac{\mathbf{CIA}}{\mathbf{360}}$$

For the selected watershed

C = 0.496

I = 260 mm/hr and

A = 20 ha then

$$\mathbf{Qp} = \frac{0.496 \times 260 \times 20}{360}$$

$$= \mathbf{7.16\ cumec}$$

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ESTIMATION OF SPILLWAY LENGTH

Suppose a water harvesting structure like a **check dam** is proposed at the outlet point of the catchment area. To make the dam **safe** it is important that the water should **not overtop** the dam. For this a spillway is constructed. These are usually **rectangular** in section. The discharge over the rectangular section is given by

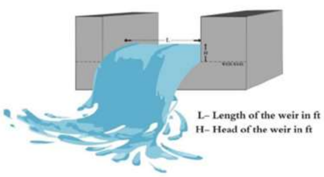
$$Q = 1.84\ L\ H^{3/2}$$

where,

Q= Discharge in m^3 /sec

L= Length of the weir (or channel width)in m

H= Head of water over of the weir in m



The height of spillway is usually not kept more than 0.75m. Therefore for the selected catchment length of the spillway

$$\mathbf{L} = \frac{Q}{1.84\ H^{3/2}} = \frac{7.16}{1.84 \times 0.75^{3/2}} = \frac{7.16}{1.95} = \mathbf{5.99\ m}$$

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ESTIMATION OF SPILLWAY CROSS-SECTION

A thumbs rule process to assess the cross-sectional area during peak discharge is as follows.

- Go to the approximate location of the drainage point where a structure will be constructed.
- Enquire with the villagers (preferably experienced elderly person) the maximum level of water in the drainage line in the last 20 years or so. He/she might say the water reached the toe of a tree on the left bank some 15 yrs back or the rock on the right bank was submerged.
- Take a rope and placing it horizontally, place two pegs on either side of the banks.
- Measure depth of the drain at regular interval
- Calculate the area of cross section as was discussed in discharge measurement session earlier.

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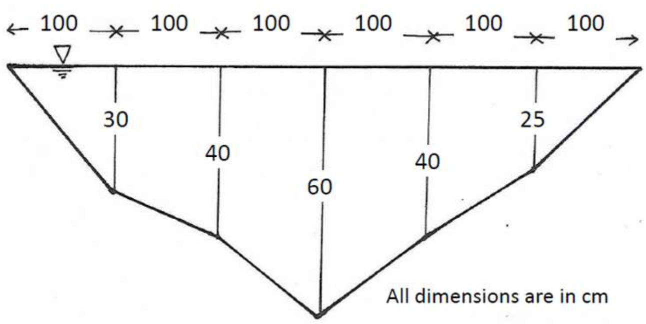
ESTIMATION OF SPILLWAY CROSS-SECTION Contd.

- Draw the section on a plain paper or graph paper
- Calculate the area of different sections



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ESTIMATION OF SPILLWAY CROSS-SECTION Contd.

The areas of different sections are:

Section 1: Triangle Area A1 = ½ 100 x 30 = 1500cm^2.

Section 2: Trapezoid Area A2 = ½ (30+40) x 100 = 3500cm^2

Section 3: Trapezoid Area A3 = ½ (40+60) x 100 = 5000cm^2

Section 4: Trapezoid Area A4 = ½ (60+40) x 100 = 5000cm^2

Section 5: Trapezoid Area A5 = ½ (40+25) x 100 = 3250cm^2

Section 6: Triangle Area A6 = ½ 25x100 = 1250cm^2.

Total cross sectional area

A = (A1+A2+A3+A4+A5+A6) = 19,500cm^2 = **1.95 m^2**

This is the cross sectional area for peak discharge. If the depth of spillway is fixed at 0.75 the length **(L)** of the spillway would be 1.95/0.75 = **2.6**m

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Example

Estimate the peak rate of runoff expected to occur once in 25 years from 50 ha watershed located at 76° long and 25° lat with sandy loam soil. The landuse is 20 ha of agricultural land, 15 ha of good grass land, and 15 ha of good forest land. The difference in elevation between highest point and outlet is 20m and maximum length of flow is 1200 m.

t_c = 22 min = 0.37 h

i_{1-h} = 100 mm/h for long 76 and lat° 25° from Fig

i_{tc} = 166 mm/h from Fig. 2

C = (20x.36+15x.17+15x.1)/50 = 0.22

q_p = CiA/360 = 0.22 x 166 x 50 = 5.07 m^3/s

Discussion:

Using North Zone equation for i, i_{tc} = 114.8 mm/h and q_p = 3.5 cumecs, therefore estimation of i_{tc} is important for the reasonable estimation by the Rational method.

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Table 1 : Intensity-Duration-Return period relationships of various rainfall zones of India

Zone	Equation	Zone	Equation
Northern	$I = \frac{4.4008\ T^{0.2239}}{(t+0.40)^{0.9323}}$	Western	$I = \frac{5.7557\ T^{0.2131}}{(t+0.60)^{0.9676}}$
Central	$I = \frac{7.1320\ T^{0.1993}}{(t+0.80)^{1.0237}}$	Southern	$I = \frac{8.0787\ T^{0.1838}}{(t+0.80)^{1.0771}}$
Eastern	$I = \frac{7.1320\ T^{0.1993}}{(t+0.80)^{1.0237}}$		

I = intensity (cm hr^{-1}); T = return period (year); and t = duration (hour).

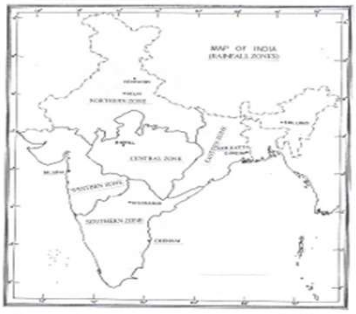

Fig.1 : Map showing the boundaries of different rainfall zones of India

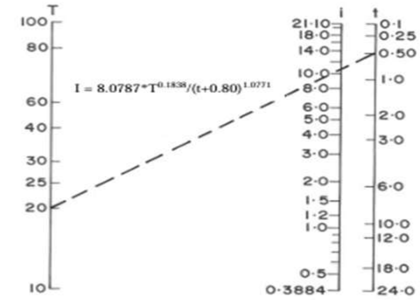

Fig.2 : Nomograph for solving intensity-duration-return period for recurrence interval – Southern rainfall zone,

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THANK YOU

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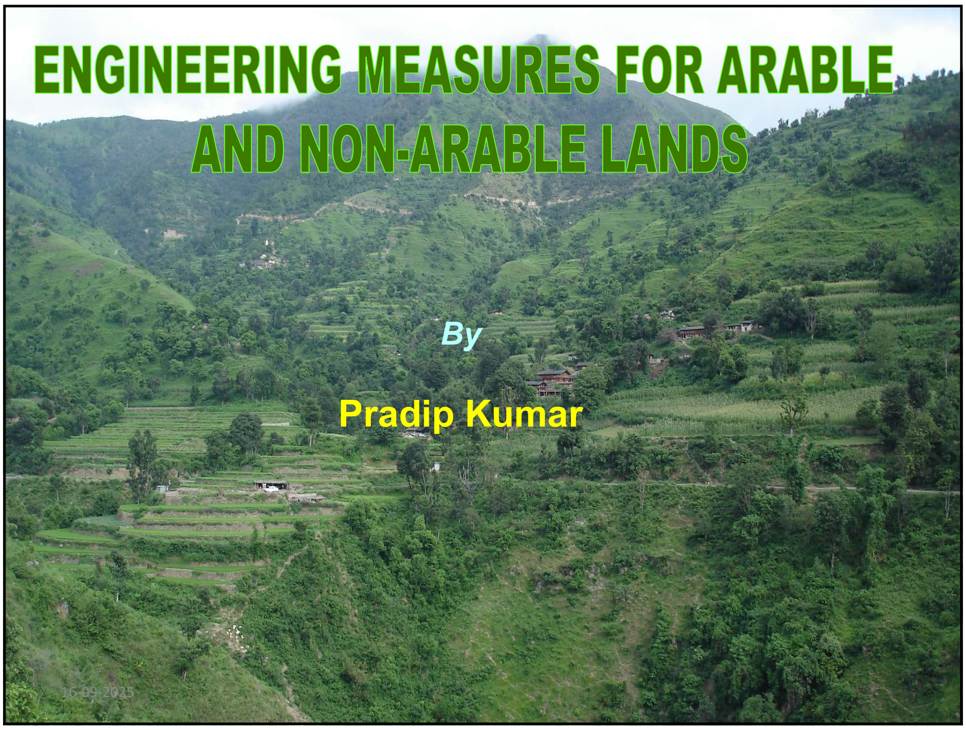

ENGINEERING MEASURES FOR ARABLE AND NON-ARABLE LANDS

Soil Conservation Measures

- Biological / Agronomical
- 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

ENGINEERING MEASURES FOR ARABLE LAND

- Land leveling and Shoulder bunding
- Graded border strips
- Bunding
  - Contour
  - Graded
- Terracing
  - Level
  - Outward sloping
  - Inward sloping
- Conservation Bench Terraces (CBT)

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ARABLE LAND MANAGEMENT Soil and Water Conservation Measures

Agronomical measures

Wind erosion control measures
- Vegetative cover
- Strip cropping
- Stubble mulching
- Tillage practices
- Wind breaks & shelter belts

Water erosion control measures
- Contour farming
- Ley farming
- Crop residue management
- Vegetative barriers/live bunds
- Ridges and furrows

•Agronomical measures are supported with mechanical /engg measures where land slope exceed permissible limits and run-off gains erosive velocity.

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Vegetative Barriers and its Role in SWC

- Vegatative barriers are closely spaced plantations, usually of a few rows of grasses or shrubs, grown along contours for erosion control and in-situ moisture conservation.
- Relatively cheaper, eco-friendly, provide reinforcement by roots and bind soil particles, and enrich soil through decomposed biomass.
- Increases efficiency of conventional bunding, if used in combination and also provide other product like fodder, fruit, green manure etc.
- Veg barrier break slope length, reduce run-off velocity and increase infiltration opportunity time.
- Reduce erosivity and transport capacity of run-off, cause deposition of erosion products, trap nutrients and induce terracing and stabilize cultivation on steeper slopes.

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Selection of Vegetative Barriers

- Arid and semi-arid region:

-Ability to survive moisture, nutrient and and fire stress

-withstand frequent grazing and to sprout new tillers quickly after first rain.

-Minimum loss of crop yield (not proliferate as weed, not compete with crop moisture, light and nutrient, not a host for pests & disease, require only a narrow width to be effective

- Flood plains:

- Deep root system to provide anchorage against turbulent flow.
- Resistance to water-logging and drought, recover growth subsequent to inundation with sediment.
- Yield economic return either thru production of seed or hay. mass.

- Mountain and hill slopes:

-Dense root system and good lateral root spreading around species

-Frost and cold resistance and

-Good seed production for dispersal.

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Vegetative barriers used in different places

Vegetative Drainage Line – Thick and deep rooted *Saccharum munja* in Punjab Shivaliks

Vegetative Drainage Line – Broom grass –*Thysanolaena maxima* in Punjab Shivaliks

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Vegetative barriers used in different places

Vegetative barriers on field boundary: barriers of *Saccharum munja* in Agra, U.P

Vegetative barriers on field boundary: Close view of *Saccharum munja barrier* in Agra, U.P.

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Vegetative barriers used in different places

Vegetative barrier on sloping land – *Panicum Maximum* on 4% sloping land in Dehradun, U K

Stabilization of Water Channel: barrier of *Panicum Maximum* on sandy nala bed in Punjab

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Vegetative barriers used in different places

Vegetative Protection of Field Bunds: live hedge of *Euphoria sp.* in aravali hills in Gujarat

Vegetative Protection of Field Bunds: planted slips of *Saccharum munja* in Punjab

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Vegetative barriers used in different places

Vegetative Drainage Line – Thick and deep rooted *Saccharum munja* in Punjab Shivaliks

Vegetative Drainage Line – Broom grass –*Thysanolaena maxima* in Punjab ShivaliksBroom

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ENGG 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

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

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

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Cross – Section of bund

- Height
- Top width
- Side slope
- Bottom width

Usual Practice

Depth of impounding = 0.30 m
Depth of flow over cost = 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

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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.

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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% lands lope in mid-Himalaya).

Bench terraces

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Types

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

Outward sloping terraces

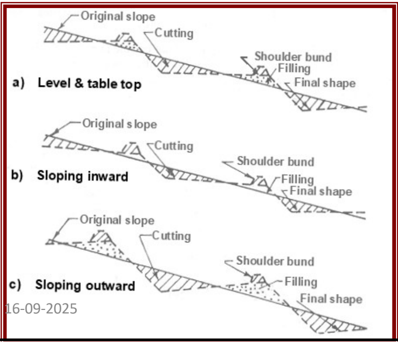
- Effective in low rainfall areas with permeable soils.

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.



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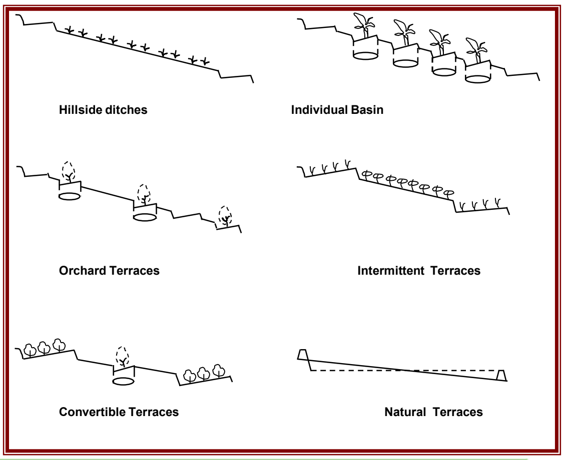
Different types of bench terraces

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.

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How to compute VI ?

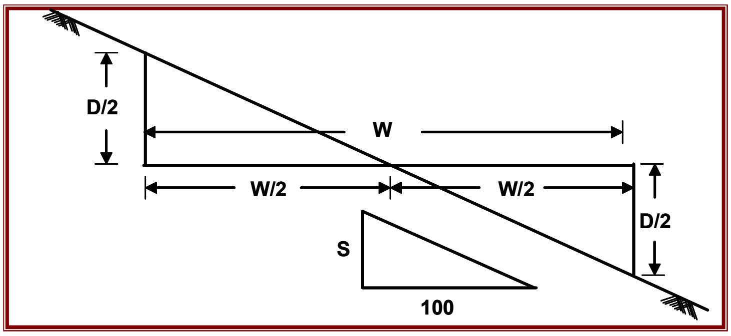
- Find maximum depth of productive soil (T).
- Find maximum admissible cut (d) for given land slope and crops. Cutting to enable construction of terraces of convenient width.

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



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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

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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 = $100\sqrt{1 + n^2}$

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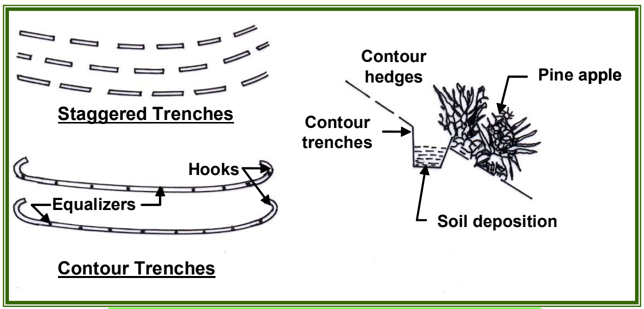
CONSERVATION MEASURES FOR NON-ARABLE LANDS

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

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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

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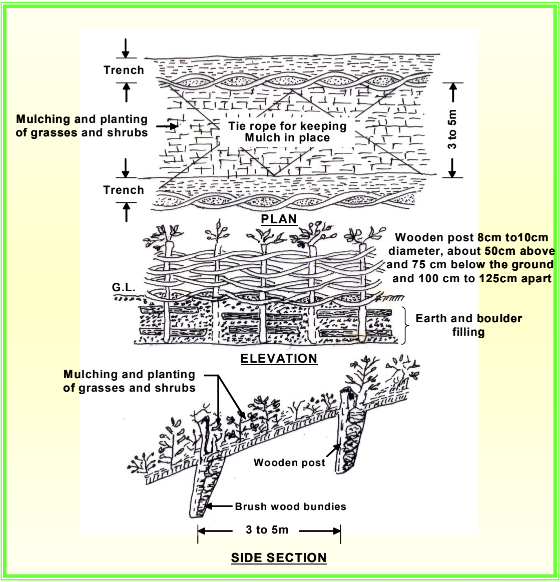
Wattling

- 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

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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.

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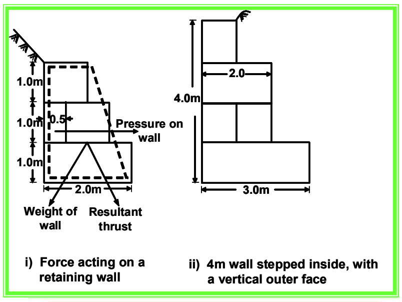
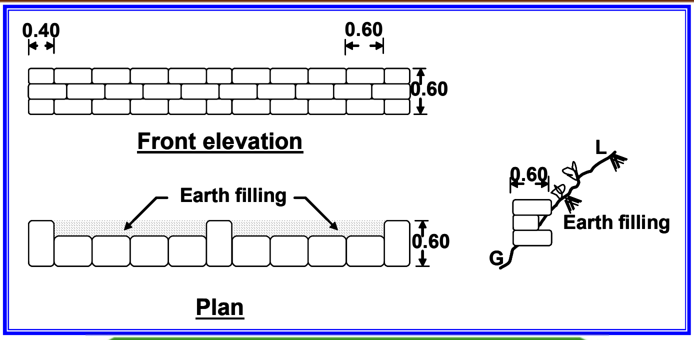
Geojute matting for slope stabilization



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.



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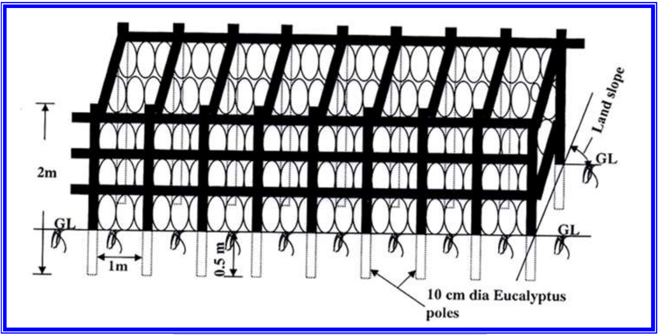
Katta-crate structure for slope stabilization

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.



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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

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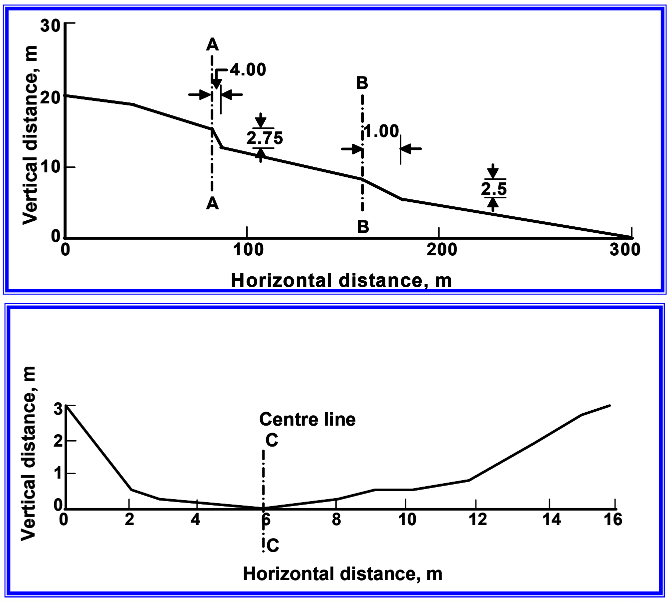

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L-section and cross-section of a typical drainage line/gully

Check dams

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

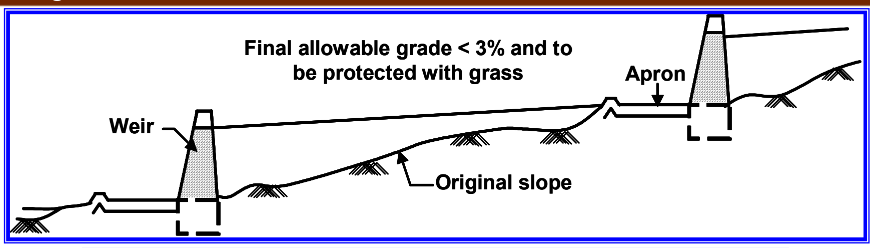
Spacing

- 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



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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

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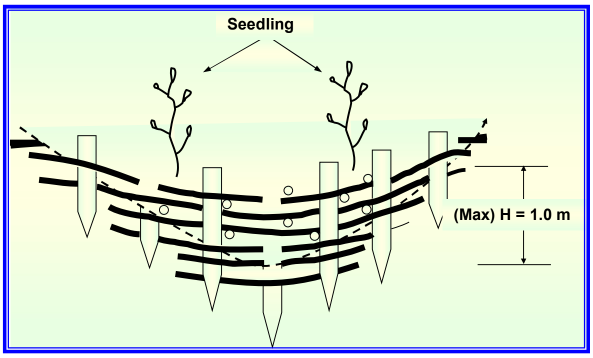


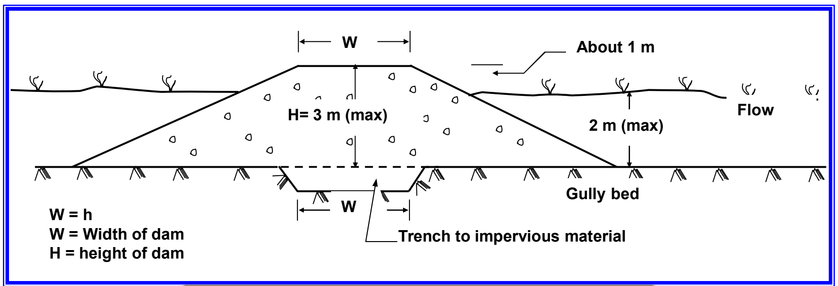
A brushwood check dam

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



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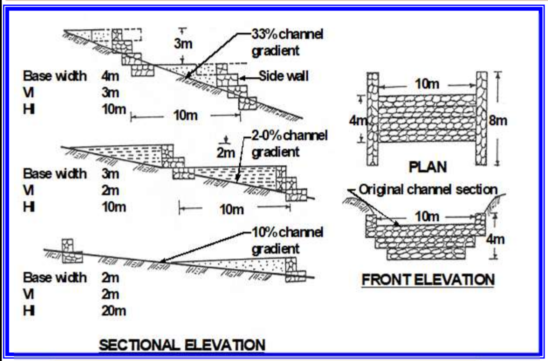
Cross-section of an earthen gully plug

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



A series of check dams for nala stabilization

Gabion check dams on different channel gradients

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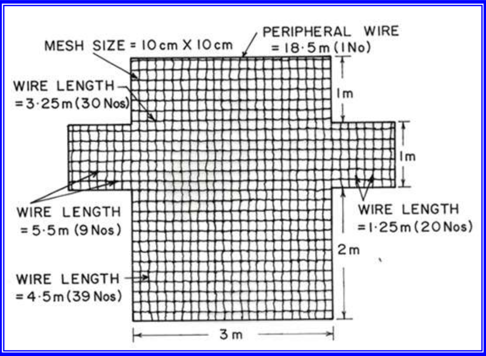
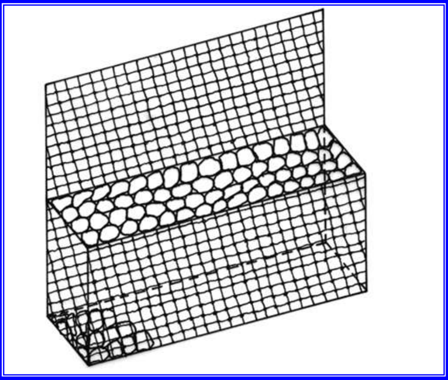
WIRE MESH FABRICATION



Details of a finished wire mesh



A rectangular gabion box

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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)

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B. Cost

Material Cost	Amount (Rs.)
1. Cost of G.I. wire 18 Kg (10 gauge) @ Rs.25/Kg	450.00
2. Cost of stones 3.75 cum @ Rs. 80 /cum including quarriyng , royalty etc.	298.00
Labour Wages	
3. Wire netter 1/2 No. @ Rs. 100/day	50.00
4. Mason (semi skilled) 1 No. @Rs. 70/day	70.00
5. Mazdoor 1No. @Rs. 60/day	60.00
Total	928.00 or say
(for 3 cm of gabion work)	930.00
Therefore, cost per cum of gabion is Rs. 310. The cost of gabion construction is almost 1/2 to 1/3rd of the cement masonry one.	

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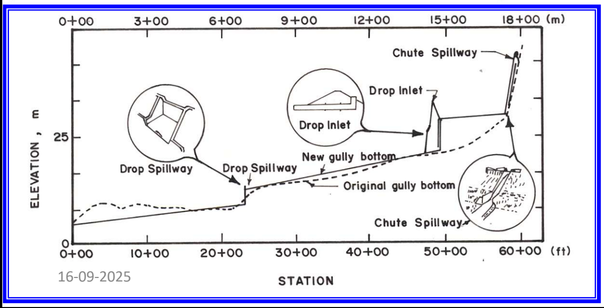
Permanent Gully Control Structure

- Drop spillway
- Chute spillway
- Drop inlet spillway

Drop Spillway

- Drop less than 3 m
- Hydrologic design
- $Q = \frac{CIA}{360}$
- Hydraulic design
- $Q = 7.11\ LH^{3/2}$

A drop spillway for gully stabilization and water storage



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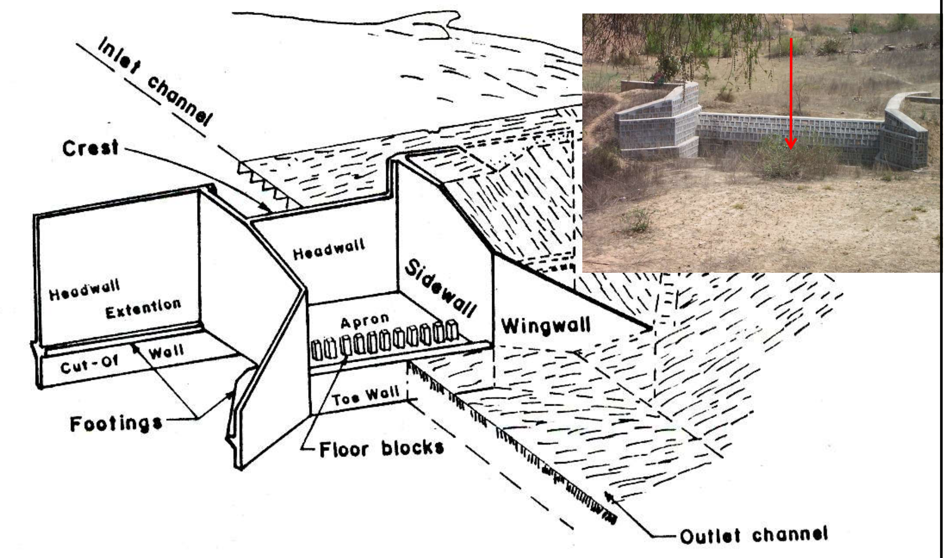
Profile of a gully showing application of different types of permanent structures

Drop structure



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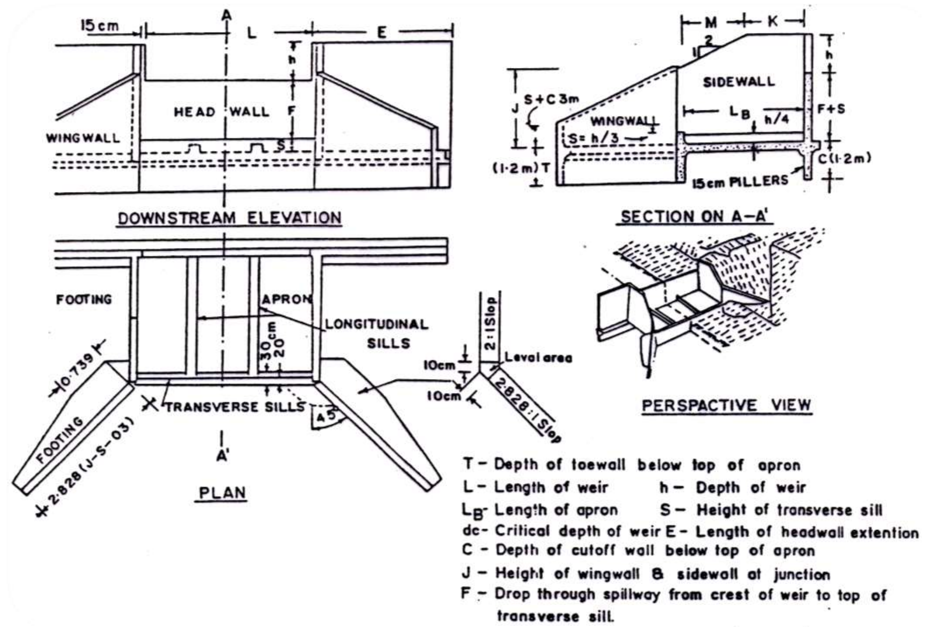

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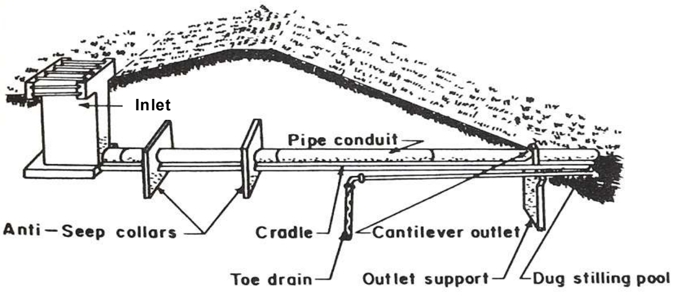
Drop Inlet Structure



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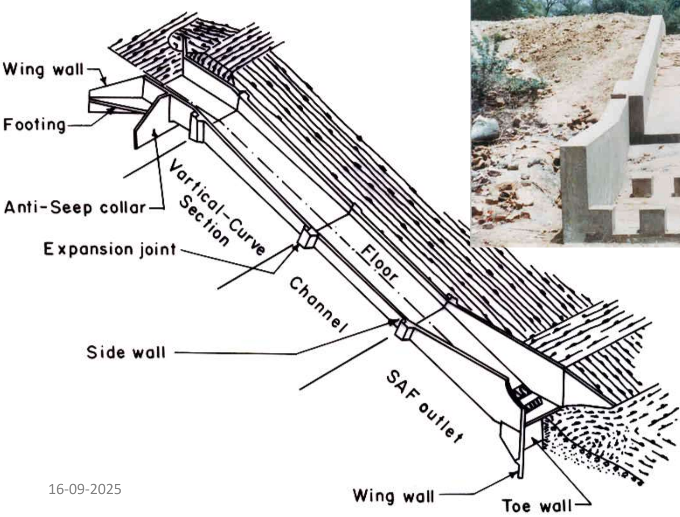
Chute Spillway



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TORRENT CONTROL MEASURES

Spurs: **Built out from the bank of a river to deflect the main river current away from eroding bank.**

Functions:

- **Protection of adjoining land and property**
- **Land reclamation**
- **Flow diversion**

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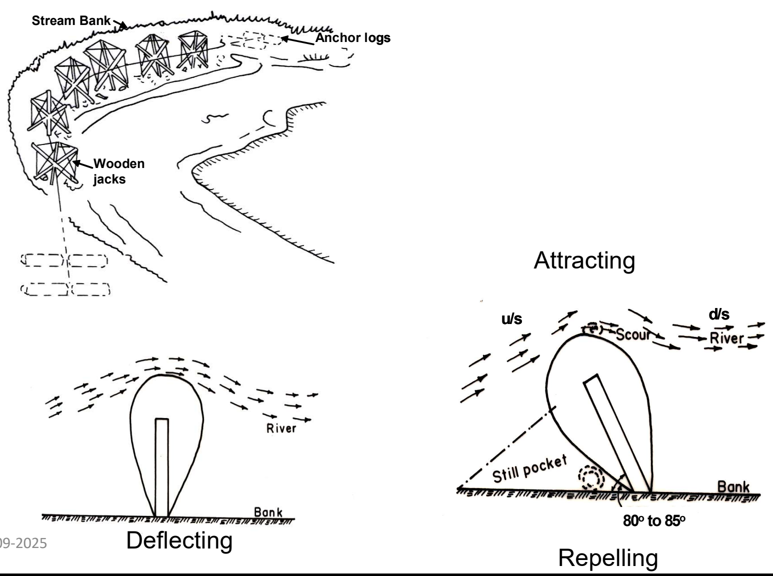
Spurs and Layout



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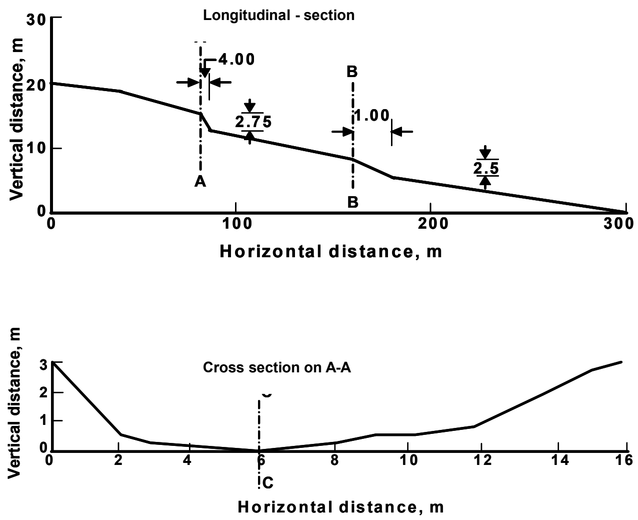

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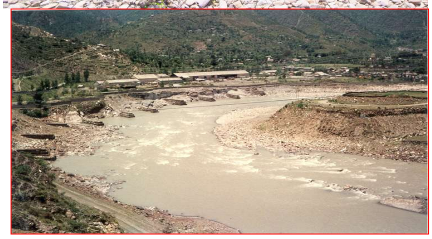
Torrent Control



Costing and Estimating of Soil and Water Conservation Engineering Measures

PRADIP KUMAR

Schedule of Rates

- Estimation of financial cost of works undertaken is usually done on the basis of a Schedule of Rate (SoR) prepared by concerned departments of each state government.
- SoR breaks up all work done to build any structure into a series of tasks and provides government approved rates for costing of each task. These are called task rates.
- Task rates include labour rates (based on minimum wages), rates for materials used, rates for transportation of materials, hiring charges of machines and vehicles, royalty payment for freely available natural resources and rates for maintenance of structure.
- SoR is used for preparing cost estimate of proposed work, and Valuation of work already completed.

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How do we use a SoR

- Step-1: Breakdown each work into its component tasks
  - Example- Construction of earthen contour bund can be broken down into various component tasks (Excavation of earth, construction of contour bund with excavated material and providing stone outlet which in turn involves collection of stones including transportation, construction of outlets with stone at appropriate place.
- Step-2: Calculate the physical quantities for each task (estimation)
  - Quantity estimation
- Step-3: Multiply these physical quantities by the task rates given in SoR (Costing)
  - SoR gives rates per unit of work done for each task – costing
  - Quantity estimation and costing are necessary at various stages- (1. for financial budgeting, while planning the construction; 2. for monitoring, while work is in progress; and 3. for valuation, after completion of construction
- Sum Up Costs of all Tasks

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What an SoR Contains

- In principle, the task rate is supposed to be arrived at by conducting a series of what are called "time and motion studied" that help estimate the amount of time involved in completing a task.
- The rate vary according to the nature of work, the material worked upong and the implements used.
- Rates for different work on the same strata are different. The rates for same activity in different strata are also different. These are extra rate for additional tasks like
  - picking up excavated material from a depth ("lift")
  - carrying excavated materials for disposal ("lead")
  - transportation of materials which are not locally available (also called "lead");
  - work under adverse circumstances like excavation in standing water ("wet excavation")
- SoR provides a higher rate for tasks which take more time.

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TYPES OF ESTIMATES

- Approximate or preliminary or rough estimate
- Detailed estimate
- Revised estimate
- Supplementary estimate

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Approximate Estimate

- **To decide the financial involvement and policy for administrative sanction by the competent authority.**
- **This estimate should show separately the cost of major components of work and cost of land, if any.**
- **A brief report explaining the necessity and urgency of work is also submitted along with the site plan.**
- **The estimate is prepared from the practical knowledge and cost of similar works undertaken in the near past.**

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Detailed Estimate

- **Accurate and based on the plan and sectional drawing/ details of the work.**
- **The quantities of items for each component of work are calculated from the dimensions taken from the drawing/ details while the total cost is worked out in the form known as abstract of cost.**
- **The rates of different items of work are taken as per schedule of rates available with the department. This schedule of rate is based on prevailing market rate of labour and material for finished item of work.**
- **It Consists of (i) working out the quantities of different items of work,**

  (ii) Abstracts of cost

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Detailed Estimate

Details of Measurement Form

Item No.	Description or particulars of item	No.	Length (unit)	Breadth (unit)	Height or Depth (unit)	Quantity (unit)

Abstract of Estimate Form

Item No.	Description or particulars of item	No.	Length (unit)	Breadth (unit)	Height or Depth (unit)	Quantity (unit)

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Detailed Estimate

- **Workable rates for different items of work are found by analyzing the market rates for a particular site by adding transportation cost, royalty, tools and plants (T&P), scaffoldings, contractor's profit etc.**
- **Contingencies (@ 3-5 %) is added towards unforeseen expenditure, changes in design and rates etc., which may occur during the execution of work.**
- **An expenditure towards work-charged establishment (@1.5-2%) may also be added, if required. The grand total thus obtained is the estimated cost of the work.**
- **Format may be utilized for preparation of estimated cost of work.**
  - Name of work
  - Location of the work
  - Cost estimate

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Sl. No	Description/ particular of item	Number	Measurement			Unit	Quantity	Unit rate (Rs.)	Total cost (Rs.)
			Length (Unit)	Width (Unit)	Height (Unit)				
1.									
2.									
3.									
4.									
5.									

Total ....
Contingencies@ 3% ....
Grant total ....

Prepared by ....
Checked by ....
Approved by ....

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Revised Estimate

This estimate is also a detailed estimate when the original sanctioned estimate is likely to exceed during the execution of work. The revised estimate is then prepared incorporating the component of work/rate which is responsible for the escalation of the cost. This is necessary for obtaining the revised sanction of the authority.

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Supplementary Estimate

- This is the first detailed estimate of the additional work in addition to the original one and is prepared when the additional work is required to supplement the original work as a result of further development during the execution of work.
- The abstract of cost should show the amount of original estimate and the total amount including the supplementary amount for which sanction is required.

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ANALYSIS OF RATE

- **Cost of material:** In analysis of rates the cost of material is taken at site including carriage, local taxes etc. The cost of material is calculated depending upon the quantities and their nature.
- **Cost of labour:** Labour required for each item depends on nature of work so the wages as per man hour required for particular item of work is taken into account while arriving the cost of work.
- **Tool and plants and sundries:** A lump sum amount is provided in analysis of rates for tools and plants (T&P) and other petty items (sundries) which cannot be accounted in detailed estimate. Normally 2 1/2 % to 3% of labour cost is considered both for T&P and sundry charges for these items in analysis of rates. A provision for water charge at rate of 1 1/2% of the total cost is also added where water is not available at site.
- **Carriage**: If the construction site is located in a remote place then proportionately the analysis of the carriage of material may also be added.

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Example: 1 Find out dry material required for 1 cu m. Cement concrete work with 1:4:8: ratio in foundation.

Solution:

Ratio: 1:4:8 (cement, sand, aggregate)

Sum = 1+4+8 = 13

Therefore, the following materials are required

$$\text{Cement} = \frac{1 \times 1.54 \times 28.8}{13} = 3.41 \text{ bags}$$ (one cubic mt. of cement includes 28.8 bag of 50 Kg each)

$$\text{Sand} = \frac{4 \times 1.54}{13} = 0.475 \text{ cu m}$$

$$\text{Aggregate (Brick ballast)} = \frac{8 \times 1.54}{13} = 0.95 \text{ cu m}$$

So material for 1 cu m cement concrete structure with 1:4:8 ratio requires dry materials of

Cement	**3.41 bags**
Sand	**0.575 cu m**
Brick ballast	**0.95 cu m**

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Example 2: Find out dry material required for 1 cu m brick masonry in cement sand mortar with 1:5 ratio.

Solution:

Ratio = 1:5 :: cement : sand

Sum = 1+5 = 6

Note: Total dry mortar for 1 cu m brick masonry is 0.30 cum

Therefore the following materials are required:

$$\text{Cement} = \frac{1 \times 0.30}{6} = 0.05 \text{ cu m} \times 28.8 \text{ (bag)} = 1.44 \text{ bags}$$

$$\text{Sand} = \frac{5 \times 0.30}{6} = 0.25 \text{ cu m}$$

No. of bricks required for 1 cu m brick masonry = 500 Nos. (20x10x10 cm size).

Material required for 1 cu m brick masonry in cement with 1:5 ratio

Cement	**1.44 bags**
Sand	**0.25 cu m**
Bricks	**500 Nos.**

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Example 3:Find out dry materials required for 10 sq m cement plaster with 1:4 ratio (1.25 cm thick).

Solution:

Quantity of wet mortar = Surface area x thickness
= 10 sq m x 1.25 cm
= 10 x 1.25/100 = 0.125 cu m.

Quantity of dry mortar = 0.125 x 1.2* = 0.15 cu m ; Ratio = 1:4 ; Sum = 1+ 4 = 5

Dry mortar for 10 sq m cement plaster with 1:4 ratio (1.25 cm thick) = 0.15 cum (calculated above).

Therefore, the following materials are required

$$\text{Cement} = \frac{1 \times 0.15}{5} = 0.03 \text{ cu m} \times 28.8 = 0.86 \text{ bags}$$

$$\text{Sand} = \frac{4 \times 0.15}{5} = 0.12 \text{ cu m}$$

Materials required for 10 sq m Cement plaster with 1:4 ratio (1.25 cu m thick)

Cement **0.86 bags**

Sand **0.12 cu m**

* 1.2 is the conversion factor to convert wet mortar into dry mortar because 0.25 cum wet mortar and 0.30 cu m dry mortar are required for 10 sq. m. Cement plaster. Therefore conversion factor is equal to 0.30 / 0.25 = 1.2

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Planting in blank areas (per ha)

Particulars	Unit	Quantity	Rate (Rs.)	Amount (Rs.)
Pit digging (0.45 m× 0.45 m × 0.45 m)	cum	18.23		
Cost of planting material	Nos.	200		
Cost of fertilizer/insecticide etc.		LS		
Transportation and planting	Nos.	200		
Maintenance		LS		
Total				

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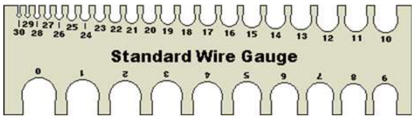

Diameter mm	Diameter Inches	Cross Sectional Area mm^2	SWG
4.06	0.160	12.95	8
3.66	0.144	10.52	9
3.25	0.128	8.296	10

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THANKS

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