

Integrated Watershed Management

Chapter 1 : Watershed Management – Problems and Prospects

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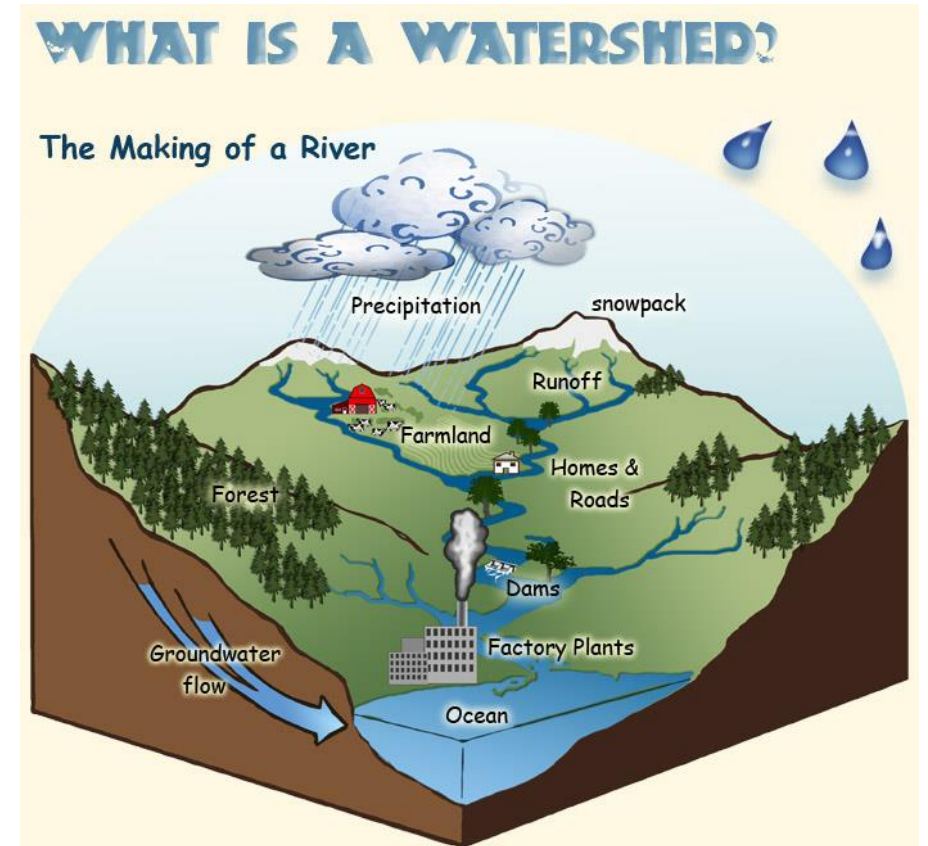
A Watershed



(Source: <http://www.recycleworks.org/kids/watershed.html>)

1.1 Definition of watershed

In American English, the word 'watershed' is used as a synonym for 'catchment' or 'basin' wherein rainwater or storm water gets collected from an area enclosed by a ridge line. This water eventually flows through the various drainage channels which merge with one another to form one or rarely more than one outfall(s) of a stream. **Thus, 'watershed' is defined as an area enclosed within a watershed line. In this course, the word 'watershed' is used for a small basin or a small catchment representing a hydrological unit which drains all its rainwater into a stream.** Therefore, it is independent in terms of its water in general and surface water in particular.



To distinguish a watershed -which generally implies a small catchment or a basin,

- **Bali (1980)** suggested an upper area limit of 2,000 km² for a watershed.
- This classification is an extension of the classification suggested by **Rao (1975)** for large river basins -with an area greater than 20,000 km², medium river basins –with an area between 2,000 and 20,000 km² and small river basins commonly referred to as watersheds.

All India Soil and Land Use Survey (AISLUS)

All India Soil and Land Use Survey (AISLUS) in **1990** classified watershed into 5 categories

based on their **areas**

macro-watersheds

500 and 2,000 km²

sub-watersheds

100 and 500 km²

milli-watersheds

10 and 100 km²

mini-watersheds

1 and 10 km²

micro-watersheds

area less than 1 km²

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- A watershed is a physical entity consisting of the natural elements in it such as plants of various sizes and types which grow over various types of soil or rock layers.
 - Additionally, watershed also comprises of all the artificial elements such as roads, bridges, tunnels, buildings, and burrow holes etc. which are mostly introduced in it by human beings .

1.2 Scope of Watershed Management

- ❖ As we have already seen in the previous section, watersheds represent small basins.
- ❖ By delineating the ridgelines in a medium or a large river basin, the entire basin can be subdivided into a number of watersheds
- ❖ Because of their compact size, it is always easier to manage watersheds rather than a river basin.
- ❖ In a well-managed watershed, all the natural resources such as soil, water, vegetation, etc. are conserved.

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- Vegetation or plants play a vital role in conserving the natural resources of a watershed such as soil and water.
 - The underground components of the plants such as **roots spread within the soil and thereby stabilize and reinforce the soil**. This generally leads to **soil conservation**.

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- ❖ The terrestrial components of plants such as stems, branches and leaves prevent the soil below it from getting directly exposed to sunlight as well as to the impact of raindrops.
 - ❖ Thus, a significant part of the momentum and energy in rainwater is absorbed. On one hand this process creates water bodies like the groundwater reservoirs and rivers.
 - ❖ On the other hand, this process also substantially **reduces the soil erosion** and the surface flow velocity of storm water.

A watershed containing large amounts of vegetation is considered as a healthy watershed. It is also called a well-managed or a 'green watershed'. It has no or very limited soil erosion and also it has large reserves of groundwater as well as surface water. In general, it has most of its natural resources conserved.

End noted on **Scope of Watershed Management**

- Thus, the scope of watershed management involves all the actions and programs aimed at achieving an overall balance between utilization and conservation of natural resources in a watershed.
- It represents a sustainable approach for resource conservation through watershed management. In the next section, the Indian and global perspective to watershed management is discussed.

1.3 Watershed Management: Indian and Global Perspective

- ❖ India has the second highest population of over 1.2 billion among all the nations [i.e., 17.1% of the world population], a seventh highest land area of 3.29 million km² among all the nations [i.e., 2.4% of the world area] and an annual river flow of 1869 km³ out of an annual rainfall of about 4000 km³ [i.e., 4% of the world water].
- ❖ The rainfall distribution is highly uneven spatially with the highest annual rainfall of 11,690 mm in the north-eastern state of Meghalaya and the least annual rainfall of 150 mm in the western part of the north-western state of Rajasthan.

The number of rainy days [i.e., number of days with a minimum recorded daily rainfall of 2.5 mm] varies from 5 to 150. The rainfall distribution is also very uneven temporally with about **75% of the annual rainfall occurring only in the four monsoon months of June to September.** The average annual rainfall is 1160 mm which is slightly higher than the global average of 1110 mm. In the year 2010, the annual per capita water availability was estimated at 1588 m³, which is considered as water stressed [i.e., between 1,000 and 1,700 m³] as per the international norms. The annual potential evapotranspiration (PET) varies from 1,500 to 3,500 mm.

Although India has a well-developed precipitation pattern in the form of monsoons and an equally well developed drainage network consisting of 14 large river basins, 44 medium river basins and hundreds of small river basins, there is a huge stress on water and land resources due to continuous overexploitation.

This has led to many adverse hydro-meteorological impacts like large scale soil erosion, excessive lowering of water table, extensive river/ground water pollution due to municipal/industrial wastewaters, widespread loss of forests/ grass lands/ crop lands/ wetlands/ water bodies, silting of existing water bodies, frequent occurrence of floods/ droughts, alarming reduction in Himalayan glaciers etc.

All these phenomena have generally made the Indian perspective in watershed management very vulnerable to climatic and anthropogenic factors. Thus, achieving sustainable water resources development and integrated watershed management are two major challenges in the Indian context.

In spite of this alarming scenario, there are hundreds of best management practices (BMPs) –adopted both in the government sector and the non-government sector over the entire length and breadth of India, which have been the bright spots in water and land resources management. These BMPs employ technologies which are either traditional or modern or a combination of both. Some of these BMPs - which were effectively implemented in different parts of India, are as follows:

Watershed Management Programmes in India

- The actual timeline of watershed management programmes in India starts from the 1950s during the First Five Year Plan, with the establishment of a number of Soil Conservation Research Demonstration and Training Centres (SCRDTCs) by the Ministry of Agriculture (MoA) of the Government of India (GoI).
- In 1956, 42 small [i.e., less than 1 km²] experimental watersheds were established for monitoring the impact of land use changes and conservation measures on surface hydrology, soil loss reduction and biomass productivity improvement.

In 1961-'62, the MoA, Gol sponsored a scheme for soil conservation in the catchments of River Valley Projects (RVPs) for preventing siltation in major reservoirs.

In 1974, all the SCRDTs were reorganized under the Central Soil and Water Conservation Research and Training Institute (CSWCRTI), Dehradun.

A real breakthrough was achieved by CSWCRTI when watershed technologies were demonstrated under natural field settings using community driven approaches through four model Operational Research Projects (ORPs) in different regions of the country. The world famous **Sukhomajri** model in **Haryana** was also one of them. The Ministry of Rural Development (MoRD), Gol launched major nationwide watershed development programs like the Drought Prone Area Programme (DPAP) in 1973-'74 and Desert Development Programme (DDP) in 1977-'78. The MoA, Gol launched watershed programs in 10 catchments under the Flood Prone Rivers (FRP) Project.

During 1983, encouraged by the success in the earlier four model ORPs, CSWCRTI, Dehradun developed **47 model watersheds** in the country in association with the Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad.

The Planning Commission, Gol also started adopting integrated watershed approach in **1987-88** for its Western Ghats Development Programme (WGDP) and Hill Area Development Programme (HADP) covering **16,000 km²** area in Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu.

In **1989-90**, the Ministry of environment and Forests (MoEF) initiated National Afforestation and Eco-development Projects (NAEP) scheme following integrated watershed approach.

In the 1990s, many watershed development programs externally funded by the World Bank, European Economic Council (EEC), Danish International Development Agency (DANIDA), some Indo-German, Indo-Swiss and Japanese organizations were undertaken in various parts of India.

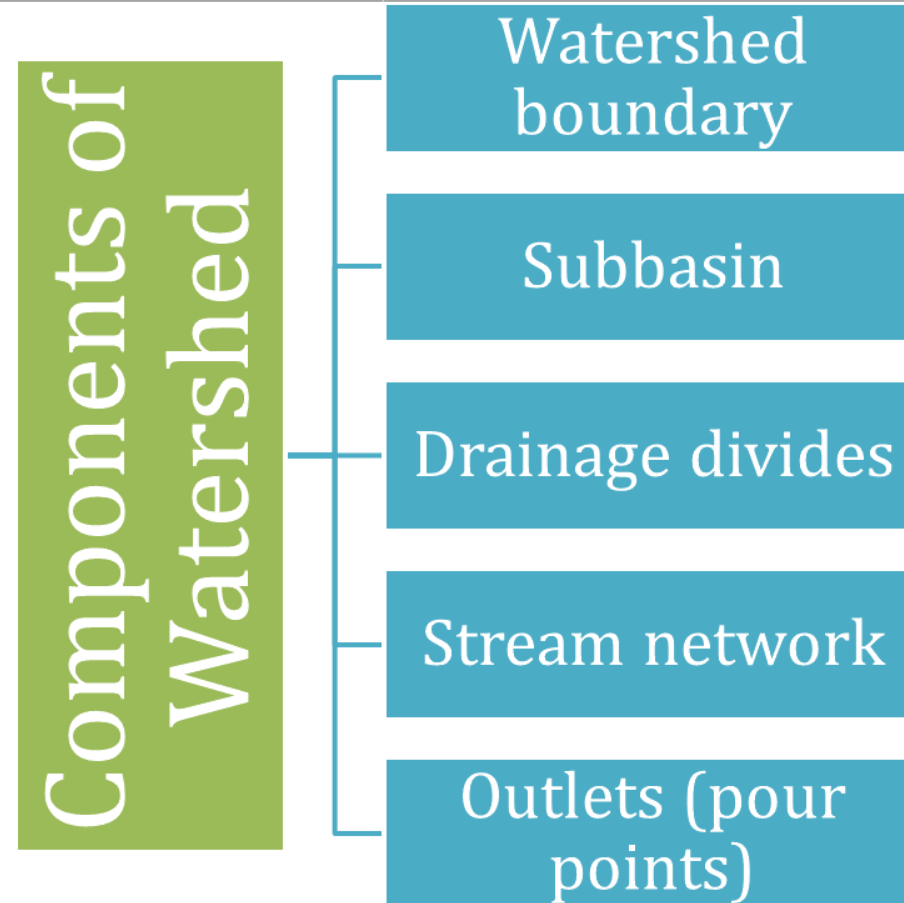
Around the same time, MoA initiated a massive project on National Watershed Development Programme for Rainfed areas (NWDPR) in 1991. In 1995, MoRD launched another big project called Integrated Wastelands Development Project (IWDP) with well formulated guidelines.

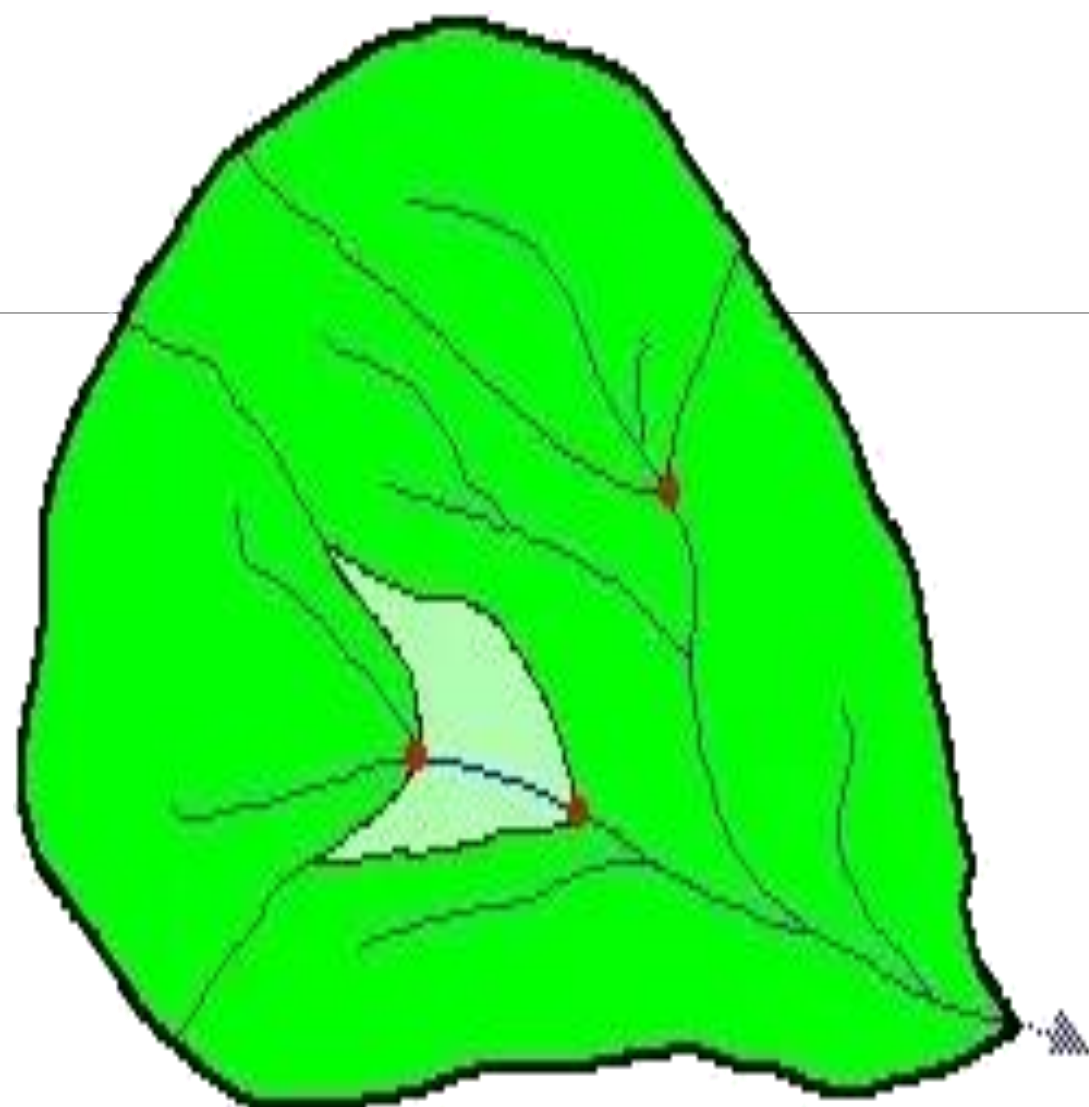
In 2001, the Planning Commission, Gol drew up an ambitious plan of treating 88.5 Mha of degraded/ rainfed lands in India, by the end of the 13th Five Year Plan in 2022 involving a huge financial investment of Rs. 72,750 crores. To strengthen the participating institutes, MoRD revised the watershed development guidelines as 'Haryali' [i.e., greenery] guidelines in 2003.






The GoI established the National Rainfed Area Authority (NRAA) under the Planning Commission in 2006. MoA also started the projects on Reclamation of Alkali soils (RAS), Watershed Development Project for Shifting Cultivation Areas (WDPSCA), Indo-German Bilateral Project (IGBP) and World Bank assisted Sodic Land Reclamation Project (SLRP). MoRD has initiated watershed projects under Mahatma Gandhi National Rural employment Guarantee Act (MGNREGA), Investment Promotional Scheme (IPS) and Technology Development Extension and Training (TDET), Wastelands Development Task Force (WDTF).

Till March 2005, an area of 28.53 Mha was treated at an investment of Rs. 1,457 crores by MoA, MoRD, MoEF, out of a total degraded land of 146.82 Mha –as per the estimates of the National Bureau of Soil Survey & Land Use Planning (NBSS&LUP), Nagpur. From 2008, the new watershed projects are being implemented as per the latest common guidelines for watershed development projects, developed by the NRAA.

Components of Watershed





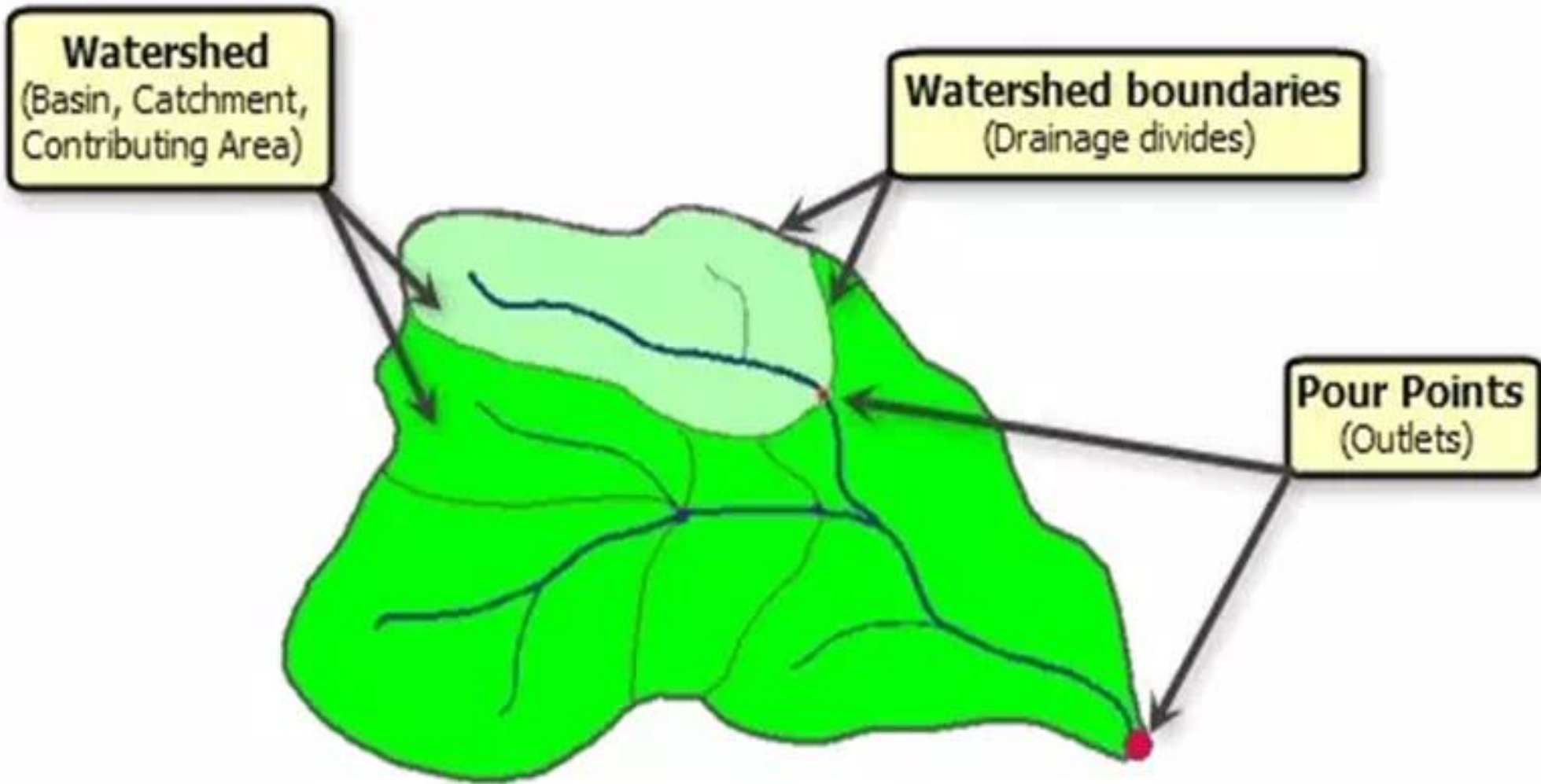
-  Watershed boundary
-  Subbasin
-  Drainage divides
-  Stream network
-  Outlets (pour points)

Sub basin

Large watershed and can also contain smaller watersheds, called sub basins.

Drainage Divide

The Boundaries between watersheds are termed drainage divide.

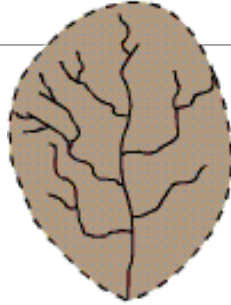


Picture showing components of a drainage basin

Outlets

The outlet or Pour point is the point on the surface at which water flows out of an area. It is the **lowest point** in the along the boundary of an watershed.

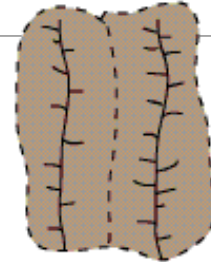
Drainage Patterns/Networks



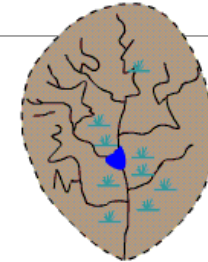
Dendritic



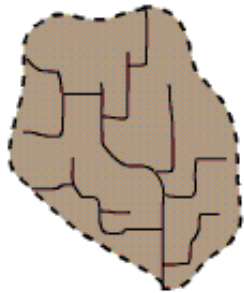
Parallel



Trellis



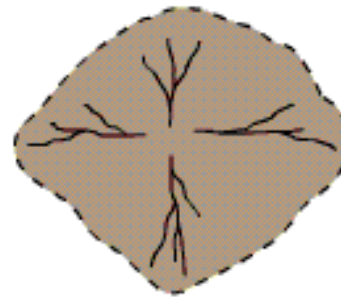
Deranged



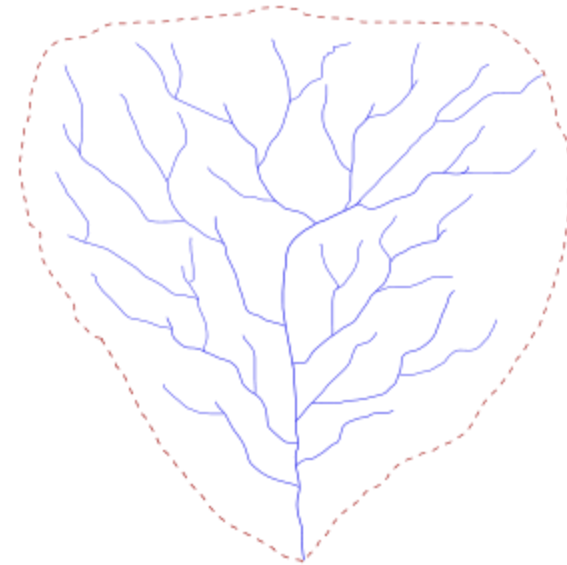
Rectangular



Radial

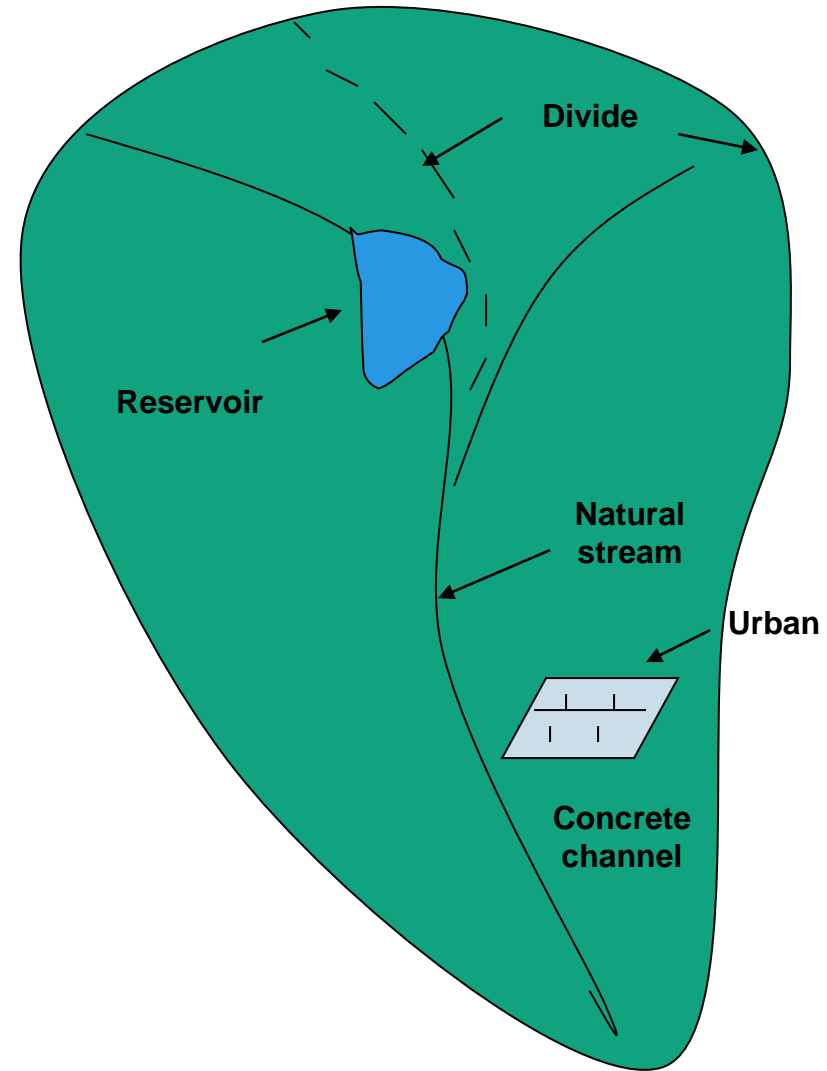


Centripetal



Watershed Characteristics

- ❖ Size
- ❖ Slope
- ❖ Shape
- ❖ Soil type
- ❖ Storage capacity
- ❖ Land use / cover



Basin size

Delineate watershed according to the height of land that separates water draining to the point of interest from water that drains to adjacent basins

Watershed area (km², ha)

- **smaller watersheds tend to have a more peaked hydrograph, more intermittent water supply**
- **larger watersheds have flatter hydrographs because larger channel network can store more water**

Watershed Land Slope

The slope of the sides of a watershed govern how fast water will drain to the channel

- steep slopes - peaked hydrograph
- gentle slopes - flat hydrograph

slope is vertical over horizontal distance, derived from topographic maps

An objective repeatable formula for land slope:

$$S = \frac{(L)(CI)}{A}$$

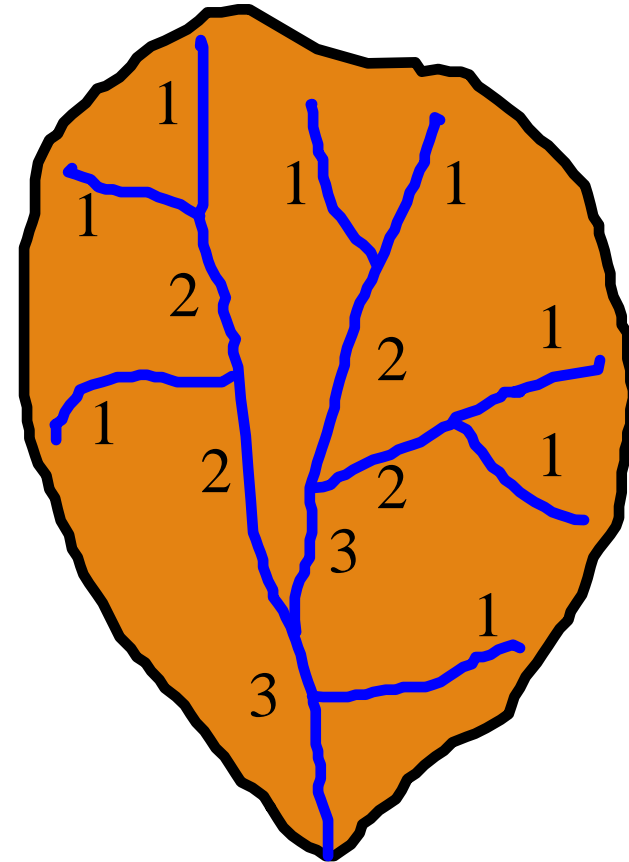
where L is the total length of contours, CI is the contour interval and A is the watershed area.

Strahler's Order of Streams

A headwater stream with no tributaries is a first order stream

When two first order streams join they form a second order stream

Two second order streams form a third order stream etc.



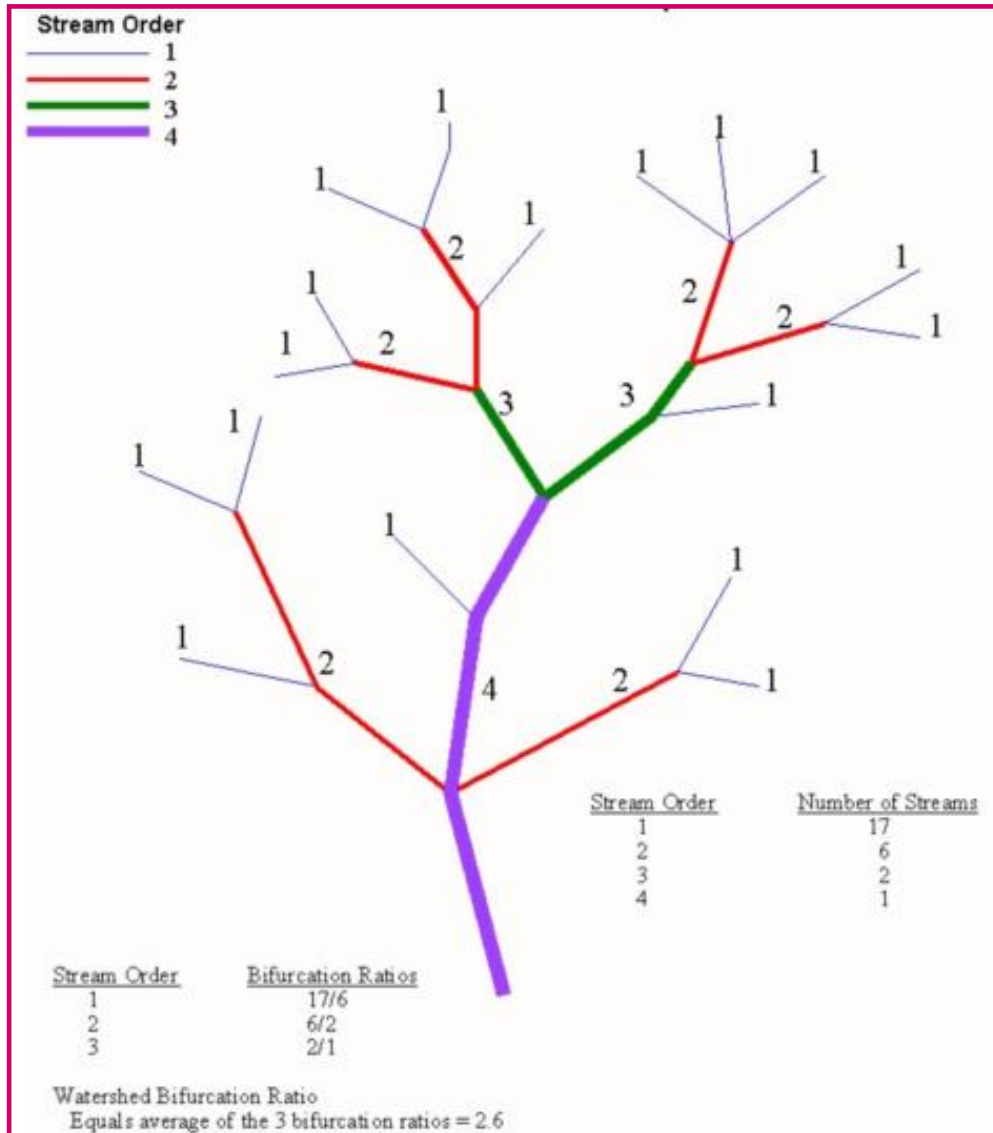
Bifurcation Ratio (R_B)

The ratio of the number of stream segments of a given order, N_n , to the number of segments of the next highest order, N_{n+1} , is called the bifurcation ratio, R_B :

$$R_B = \frac{N_n}{N_{n+1}}$$

**Bifurcation-splitting of a main body into two parts

Bifurcation Ratio - Example



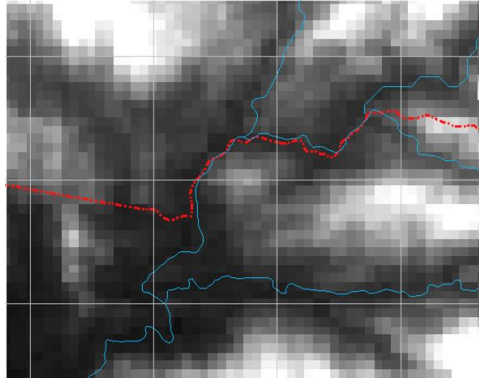
$$R_B = \frac{N_n}{N_{n+1}}$$

Stream order	No. of stream order	Bifurcation ratio
1	17	17/6
2	6	6/2
3	2	2/1
4	1	-

Watershed Delineation

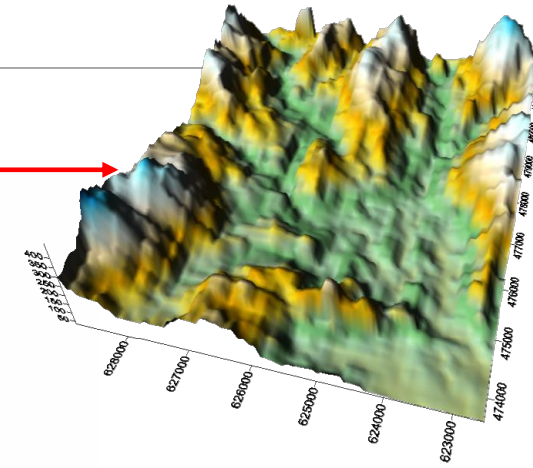
Catchment Surface

DEM Data



GIS

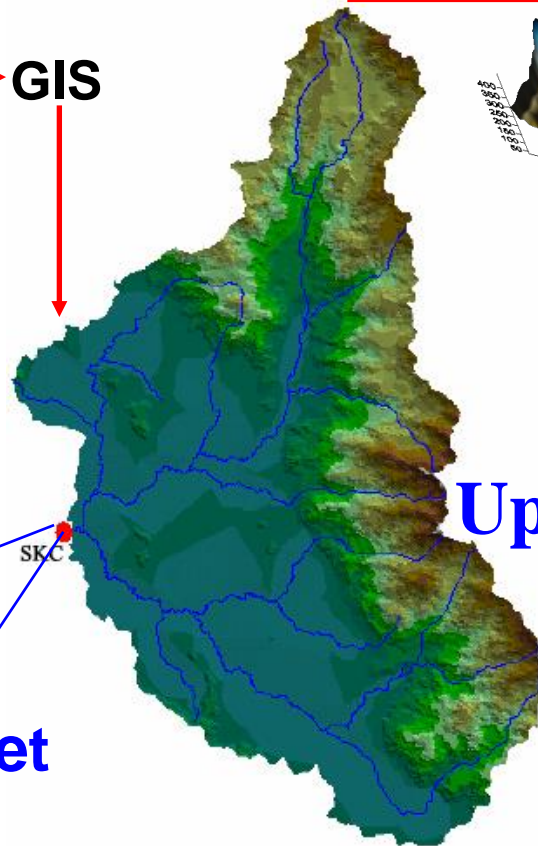
Upper Bernam Basin



SKC Bridge



Outlet



Upper Bernam River Basin

Familiarization with the watershed problems

❖ **Land degradation** in rain fed areas due to soil erosion from runoff is one of the major problems. In India it was estimated that the soil erosion in the 1990s was almost double that of soil erosion in the 1980s. Rainfall uncertainty and poor economic conditions act as a major constraint and thus prevents the farmers in rainfed areas from making investments. This leads to improper watershed management.

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- ❖ **Equitable benefit sharing of watershed management** within the farming communities as well as within the different locations of watershed is a huge problem.
 - ❖ Generally, women, marginal farmers and landless laborers gain very little or nothing at all from the watershed management activities.
 - ❖ Several case studies in water scarce states of Gujarat and Madhya Pradesh in India have showed that overdevelopment of water harvesting structures in the upstream portion of watersheds had significantly reduced the inflows into the downstream reservoirs.
 - ❖ On the other hand, it is also noticed that building of large reservoirs resulted in the submergence and hardship in the upstream parts and benefits for people in the downstream parts of the same watershed or a neighbouring watershed generally having an urban or an industrial area.

❖ **Acute shortage of water** in general and drinking water especially in summer has been observed in many watersheds with inadequate watershed management which may result in severe/ recurrent droughts. It may often result in limited and temporary food productivity gains.

❖ **Conflict among various government ministries** such as those related to agriculture [with emphasis on food production], rural development [with emphasis on employment generation & poverty alleviation], forests [with emphasis on maintaining biodiversity & wildlife], as well as conflict between government bureaucracy and elected representatives in their zeal to control funds, is a major problem in watershed management programs -which requires to be resolved on a priority basis.

❖ It is **hard to conduct meaningful impact assessment studies** on watershed management programs for lack of baseline data for monitoring and comparison of the current conditions. The whole exercise of watershed management is undertaken without properly estimating the water supply scenarios under drought/ normal/ surplus years as well as without proper demand management especially during drought years.

❖ Large areas inhabited with tribal population lack facilities to harvest water and to stabilize their food/ crop/ fodder production due to reduced forest yields, deterioration in land quality, lack of tribal agriculture policy and population pressure. This leads to a sustained misery, socio-political unrest and insurgency among the tribal population.

Objective of Watershed Management

- **The main goal of Watershed Management is to establish the sustainable management of natural resources to improve the quality of living for the population is to be accomplished by the following objectives:**
- To control damaging runoff and degradation and thereby conservation of soil and water. Improvement and restoration of soil quality and thus, raising productivity rates.
- To protect and enhance the water resource originating in the watershed. Supply and securing of clean and sufficient drinking water for the population .
- To increase infiltration of rainwater.
- To improve and increase the production of timbers, fodder and wild life resource

- To enhance the ground water recharge, wherever applicable.
- To manage the watershed for beneficial developmental activities like domestic water supply, irrigation, hydropower generation etc.
- To minimize the risks of floods, droughts and landslides.
- Rainwater harvesting and recharging
- Growing greenery – trees, crops and grasses

CODE OF WATERSHED

Ex. **1A2B3a1**

1A2B3a1 stands for a national code of a micro-watershed belongs to

Water Resource Region “1”,

Basin “1A”,

Catchment “1A2”,

Subcatchment “1A2B”,

Watershed “1A2B3”,

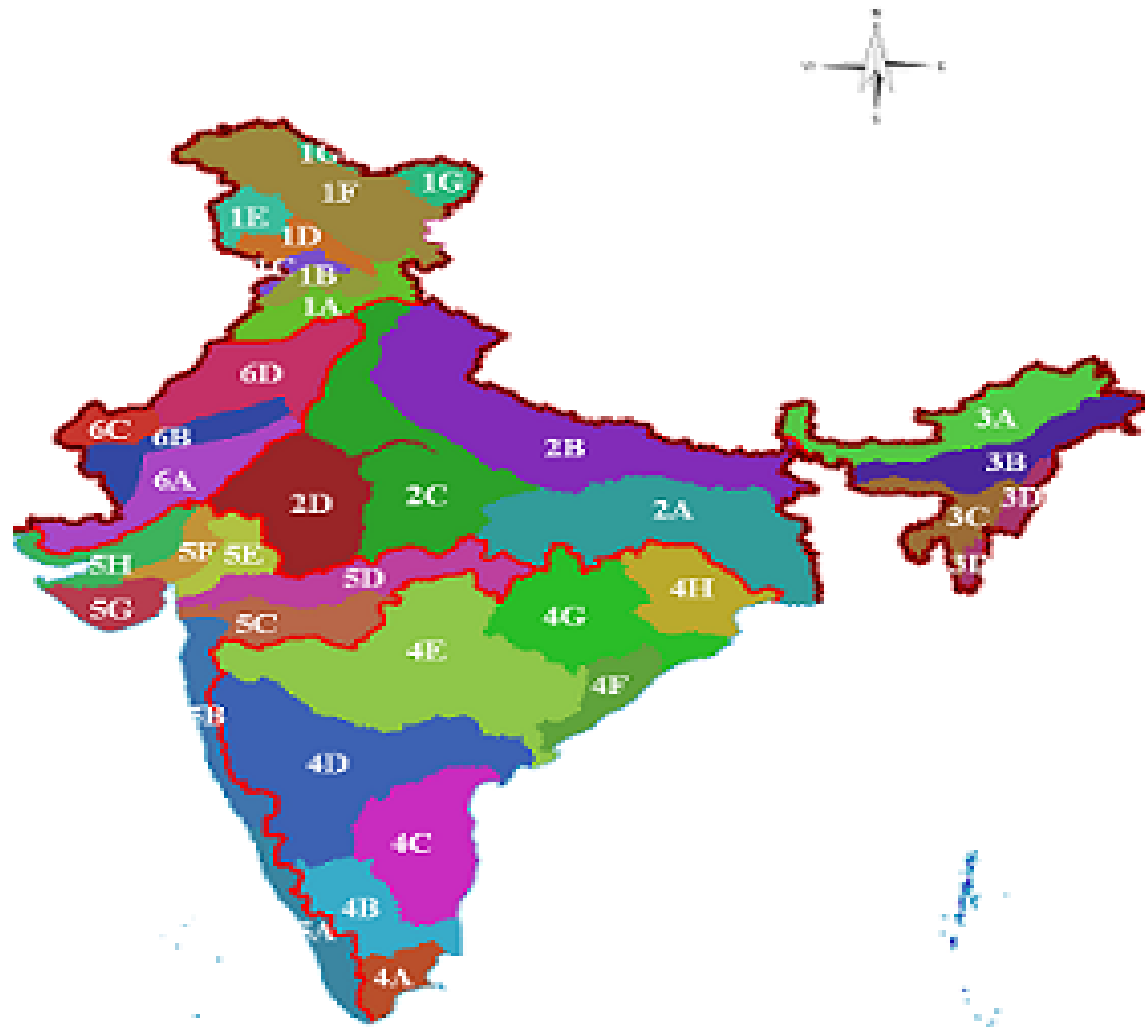
Subwatershed “1A2B3a” and

Microwatershed “1A2B3a1”

<http://slusi.dacnet.nic.in/dwainew.html>

WATERSHED ATLAS OF INDIA

(ON 1:1 MILLION SCALE)



Basin Legend

- 1A- Sutlej
- 1B- Beas
- 1C- Ravi
- 1D- Chenab
- 1E- Jhelum
- 1F- Indus
- 1G- Ephemeral
- 2A- Lower Ganga
- 2B- Upper Ganga
- 2C- Upper Ganga
- 2D- Chambal
- 3A- Right Bank Brahmaputra upto Lohit confluence
- 3B- Left Bank of Brahmaputra
- 3C- Brahmaputra Tributaries Flowing into Bangladesh (Kali, Suma)
- 3D- Eastern Parts of Manipur & Mizoram Draining into Chindwin(Burma)
- 4A- Cape Comorin to Cauvery
- 4B- Cauvery
- 4C- Cauvery to Krishna
- 4D- Krishna
- 4E- Godavari
- 4F- Godavari to Mahanadi
- 4G- Mahanadi
- 4H- Mahanadi to Ganges Basin
- 4I- Andaman and Nicobar Islands
- 5A- Southern Western Ghats
- 5B- Northern Western Ghats
- 5C- Tapti
- 5D- Narmada
- 5E- Mahi
- 5F- Sabarmati
- 5G- Southern Kathiawar
- 5H- Gulf of Kutch
- 5I- Lakshadweep
- 6A- Great Rann of Kutch & Luni
- 6B- Ephemeral(Barmer to Jaisalmer, Nagaur, Sikar)
- 6C- Ephemeral(Jaisalmer, Nagaur, Sikar)
- 6D- Ghaghar and old Saraswati

Water Resource Regions (WRR) wise Distribution of Different Basins

Watershed Atlas of India

Water Resource Regions -6, Basins - 37

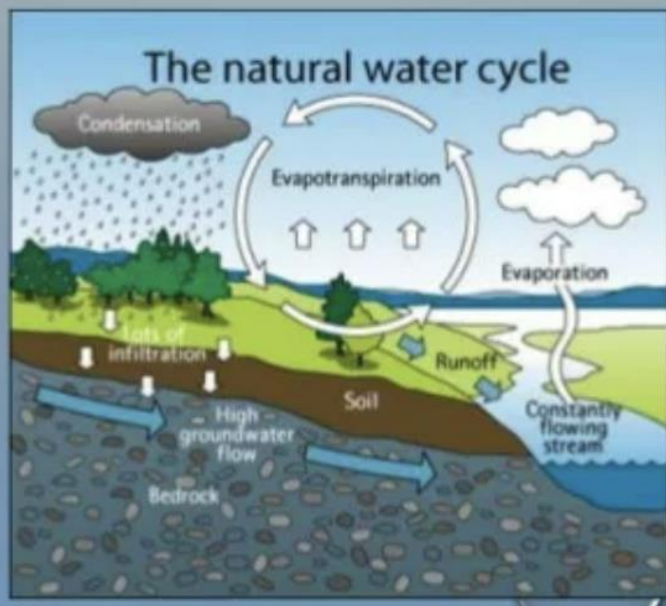
Catchments -117, Sub-Catchments-588

and Watersheds- 3851

Watersheds in India

S. No.	Hydrologic Units	Size Range (ha)	No. of Units
1	Water Resource Region	270,00,000-1130,00,000	6
2	Basins	30,00,000-300,00,000	34
3	Catchments	10,00,000-50,00,000	112
4	Sub-catchments	200,000-10,00,000	500
5	Watersheds	20,000-300,000	3237
6	Sub-watersheds	5,000-9,000	12000
7	Micro-watersheds	500-1,500	400000

STORMWATER IS RAINWATER AND MELTED SNOW THAT RUNS OFF STREETS, LAWNS AND OTHER SITES. WHEN STORMWATER IS ABSORBED INTO THE GROUND, IT IS FILTERED AND ULTIMATELY REPLENISHES AQUIFERS OR FLOWS INTO STREAMS AND RIVERS.



EFFECTS OF POOR STORMWATER MANAGEMENT

- DOWNSTREAM FLOODING
- STREAM BANK EROSION
- INCREASED TURBIDITY FROM EROSION
- HABITAT DESTRUCTION
- COMBINED SEWER OVERFLOWS
- INFRASTRUCTURE DAMAGE
- CONTAMINATED STREAMS, RIVERS, AND COASTAL WATER

STORMWATER IS ACTUALLY CONCERN FOR TWO MAIN ISSUES:

- a) RELATED TO THE VOLUME AND TIMING OF RUNOFF WATER (FLOOD CONTROL AND WATER SUPPLIES)
- b) RELATED TO POTENTIAL CONTAMINANTS THAT THE WATER IS CARRYING, I.E. WATER POLLUTION.

The background is a light blue gradient. There are several realistic-looking water droplets of various sizes scattered in the corners: top-left, top-right, and bottom-right. The text is centered in the middle of the page.

ADVANTAGES & DISADVANTAGES

ADVANTAGES

- ✓ PROVIDES PROPER DRAINAGE OF SURFACE RUN-OFF AND AVOIDS DAMAGES ON INFRASTRUCTURE SUCH AS PRIVATE PROPERTIES AND STREETS.
- ✓ PROVIDES POSSIBILITY TO RECHARGE GROUNDWATER AND RE-USE PRECIPITATION WATER AND SURFACE RUN-OFF AS IRRIGATION OR HOUSEHOLD WATER.
- ✓ MINIMIZING HEALTH RISKS.

- ✓ PROVIDES EFFECTIVE STORMWATER FLOOD CONTROL.
- ✓ CAN BE INTEGRATED INTO THE URBAN LANDSCAPE AND PROVIDE GREEN AND RECREATIONAL AREAS.
- ✓ REVENUE GENERATED BY A STORMWATER UTILITY CAN BE USED AS A NEW, DEDICATED SOURCE OF FUNDS TO SUPPLEMENT OR REPLACE THE COMMUNITY'S CURRENT STORMWATER MANAGEMENT FUNDING, ENABLING TAX-BASED FUNDING TO BE USED FOR OTHER COMMUNITY NEEDS.

DISADVANTAGES

- EXPERT PLANNING, IMPLEMENTATION, OPERATION AND MAINTENANCE REQUIRED FOR A STORMWATER MANAGEMENT.
- IT DEPENDS ON THE TECHNIQUE, A LOT OF OPERATION AND LABOUR REQUIRED.
- THERE IS RISK OF CLOGGING INFILTRATION SYSTEM CAUSED BY HIGH SEDIMENTATION RATES.
- TEMPORARY COVERING METHODS, SUCH AS PLASTIC SHEETING, CAN BECOME TORN OR RIPPED, EXPOSING THE CONTAMINANT TO PRECIPITATION AND/OR STORM WATER RUNOFF.

EXAMPLES OF SUSTAINABLE STORM WATER MANAGEMENT

1. INCORPORATES BOTH THE NATURAL ENVIRONMENT AND ENGINEERED SYSTEMS
2. PROMOTE SUSTAINABLE STORMWATER MANAGEMENT PRACTICE TO **REDUCE RUNOFF, IMPROVE WATER QUALITY AND ENCOURAGE INFILTRATION.**
3. GREEN ROOFS / RAIN GARDENS / POROUS PAVEMENT
4. GREEN INFRASTRUCTURE - AT THE SCALE OF A NEIGHBORHOOD OR SITE, GREEN INFRASTRUCTURE REFERS TO STORM WATER MANAGEMENT SYSTEMS THAT MIMIC NATURE BY SOAKING UP AND STORING WATER.

RAIN GARDENS

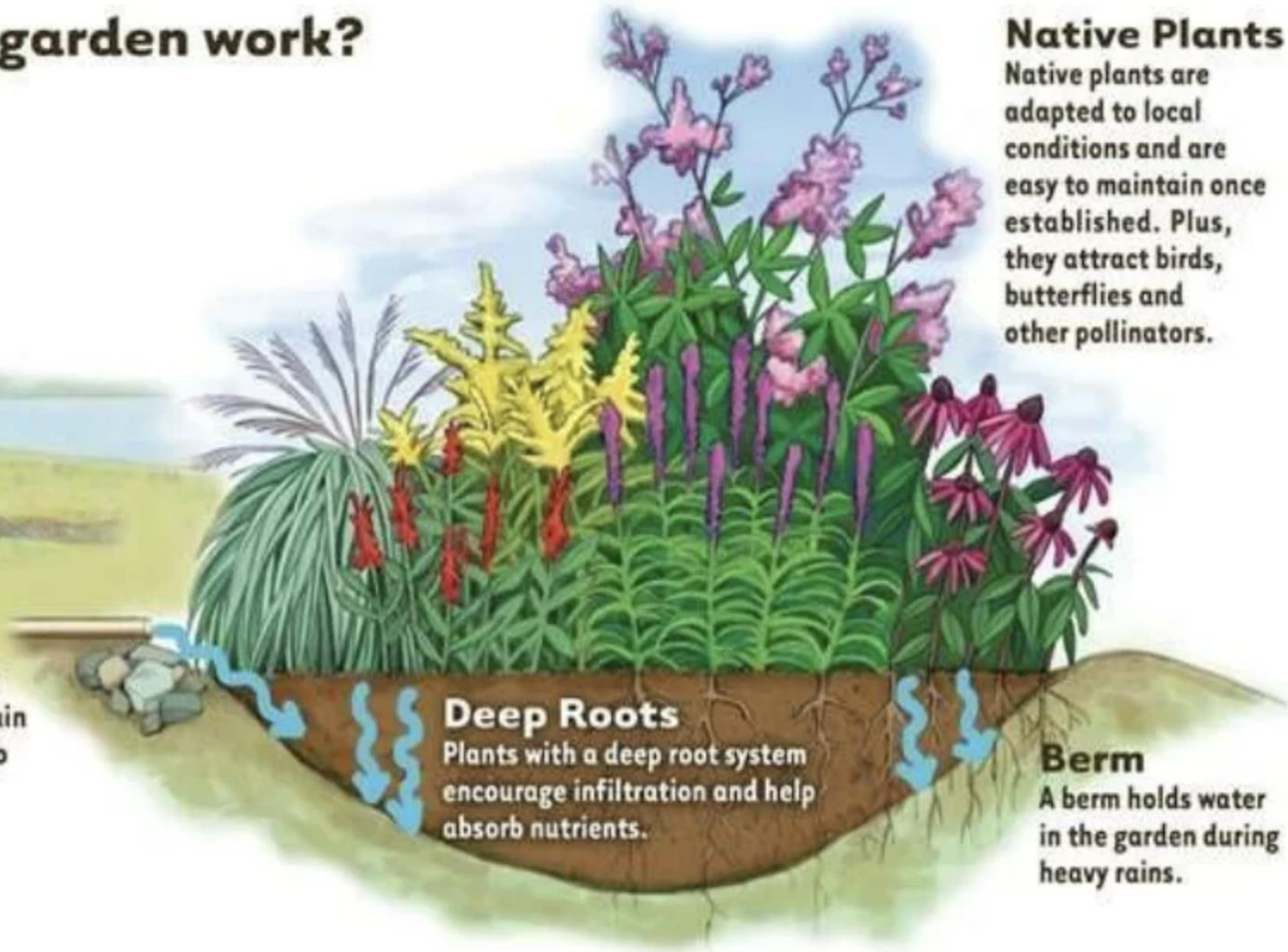
1. CONSTRUCTED DEPRESSION
2. MANAGE AND TREAT SMALL VOLUMES OF STORM WATER BY FILTERING RUNOFF THROUGH SOIL AND VEGETATION
3. HOLDS THE WATER FOR A SHORT PERIOD OF TIME AND ALLOWS IT TO NATURALLY INFILTRATE INTO THE GROUND

How does a rain garden work?



Gutters & Down Spouts

Assist with directing rain water from your roof to your rain garden.



Deep Roots

Plants with a deep root system encourage infiltration and help absorb nutrients.

Berm

A berm holds water in the garden during heavy rains.

Native Plants

Native plants are adapted to local conditions and are easy to maintain once established. Plus, they attract birds, butterflies and other pollinators.

rain and run-off

As rain falls on the roof, the gutters and downspouts collect the water and direct it toward the rain garden. Even a small roof can generate A LOT of run-off. A one-inch rain falling on the front roof area shown would amount to approximately 187 gallons of water! In addition to the roof run-off, the garden can be sized to collect water from nearby turf areas and any hard surfaces that drain to the garden. Most gardens are designed to accommodate up to a 1 1/2" inch rainstorm.



go to profile view

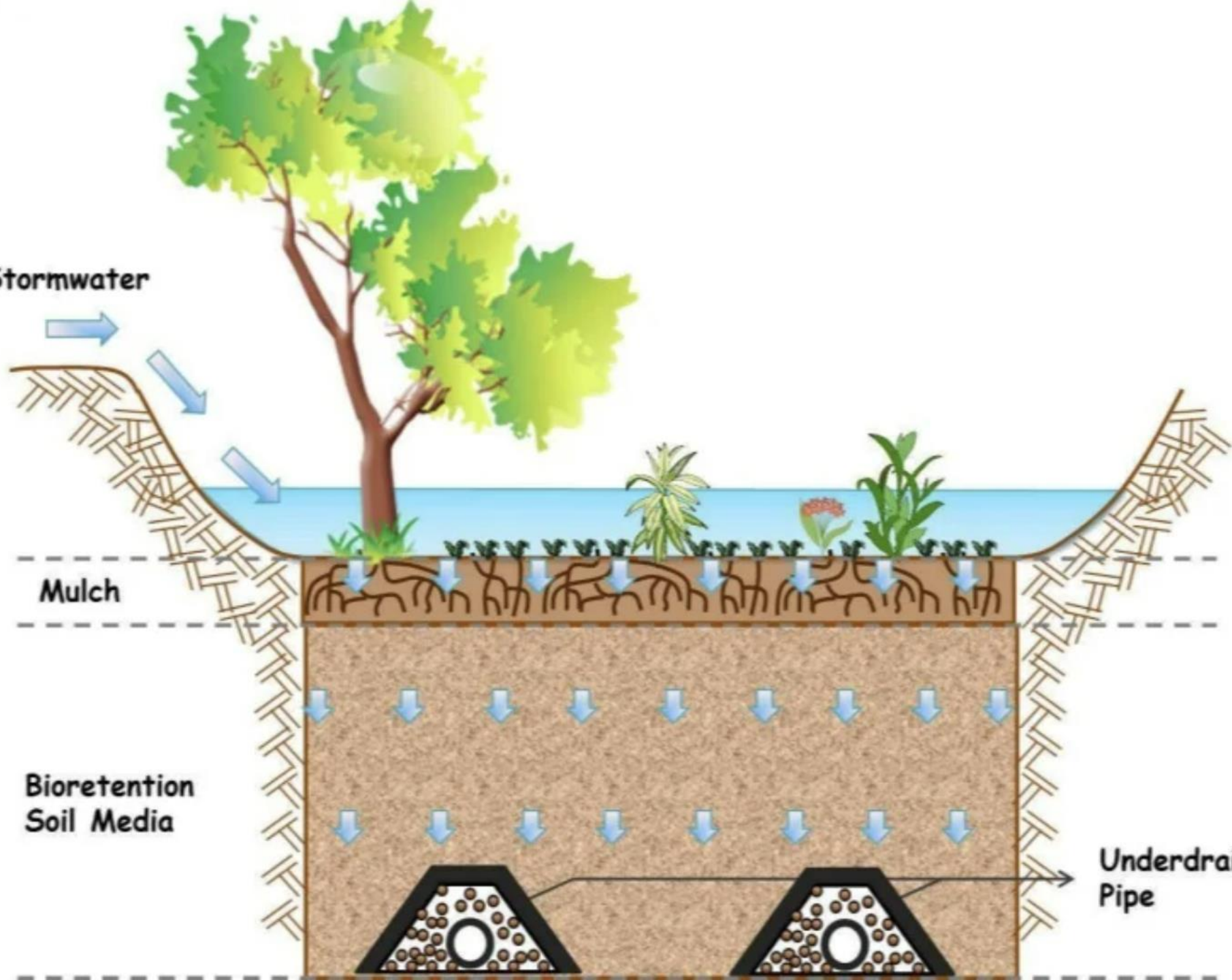
BIORETENTION AREAS

1. CONSTRUCTED DEPRESSION
2. LARGER THAN RAIN GARDENS AND DESIGNED WITH AN UNDERDRAIN TO CONNECT TO THE STORM DRAIN SYSTEM.

Press to exit full screen



Stormwater



Mulch

Bioretention
Soil Media

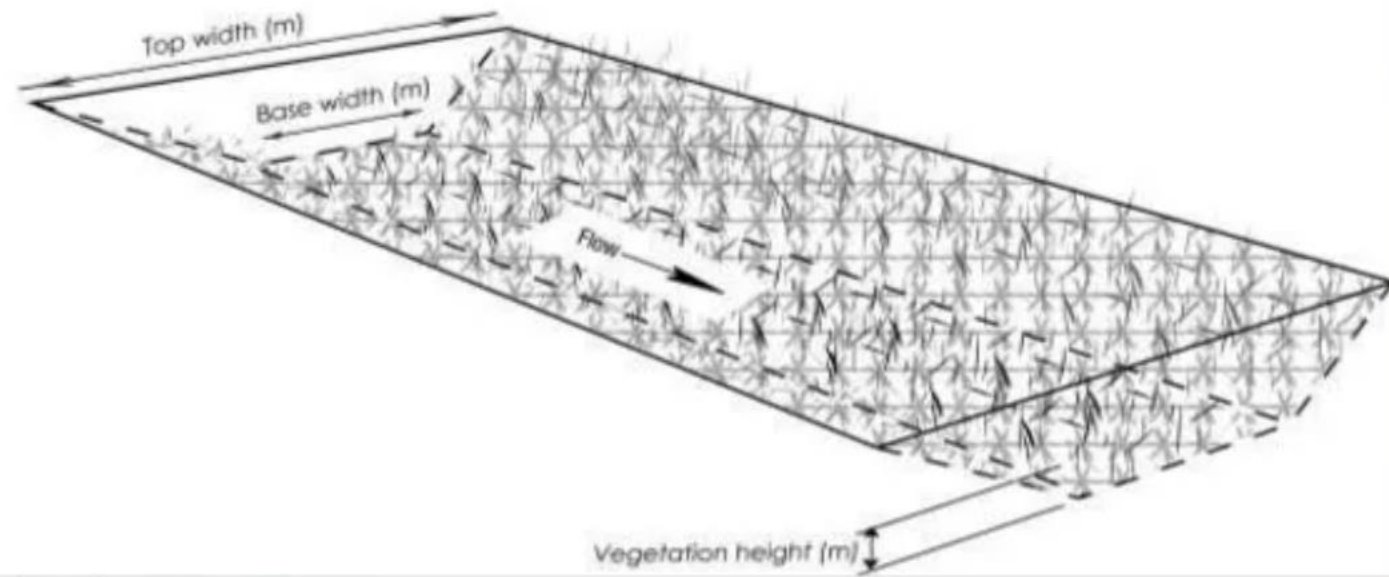
Underdrain
Pipe

VEGETATED SWALES

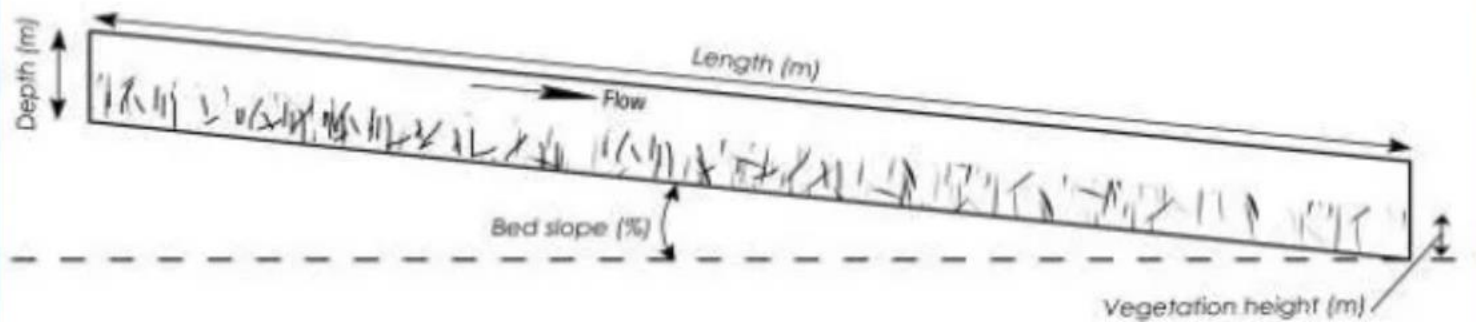
1. A NATURAL DRAINAGE PATHS OR VEGETATED CHANNELS
2. TRANSPORT WATER INSTEAD OF UNDERGROUND STORM SEWERS OR CONCRETE OPEN CHANNELS TO CONVEY STORMWATER RUNOFF.

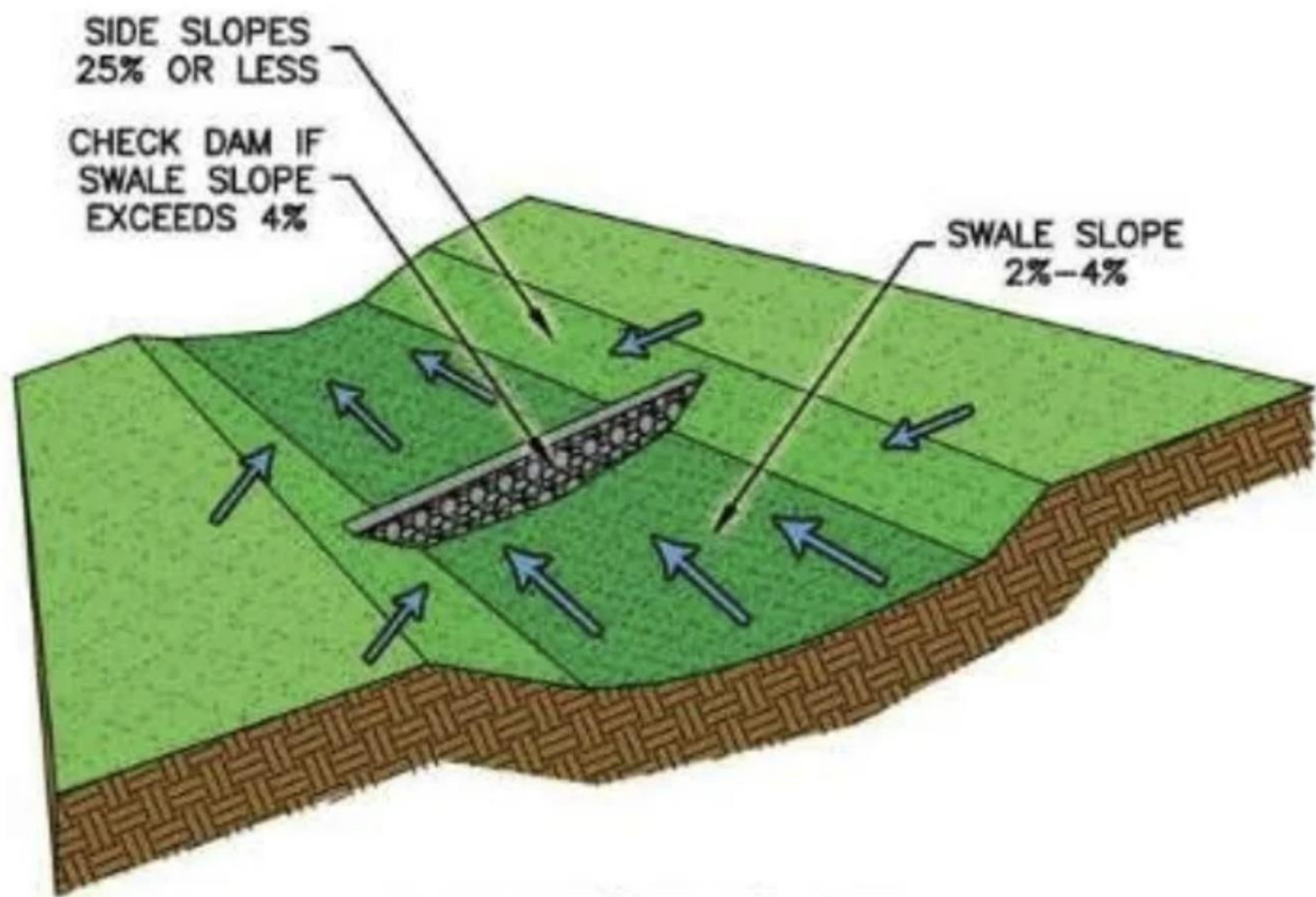
Swale

3D Perspective



Longitudinal Section



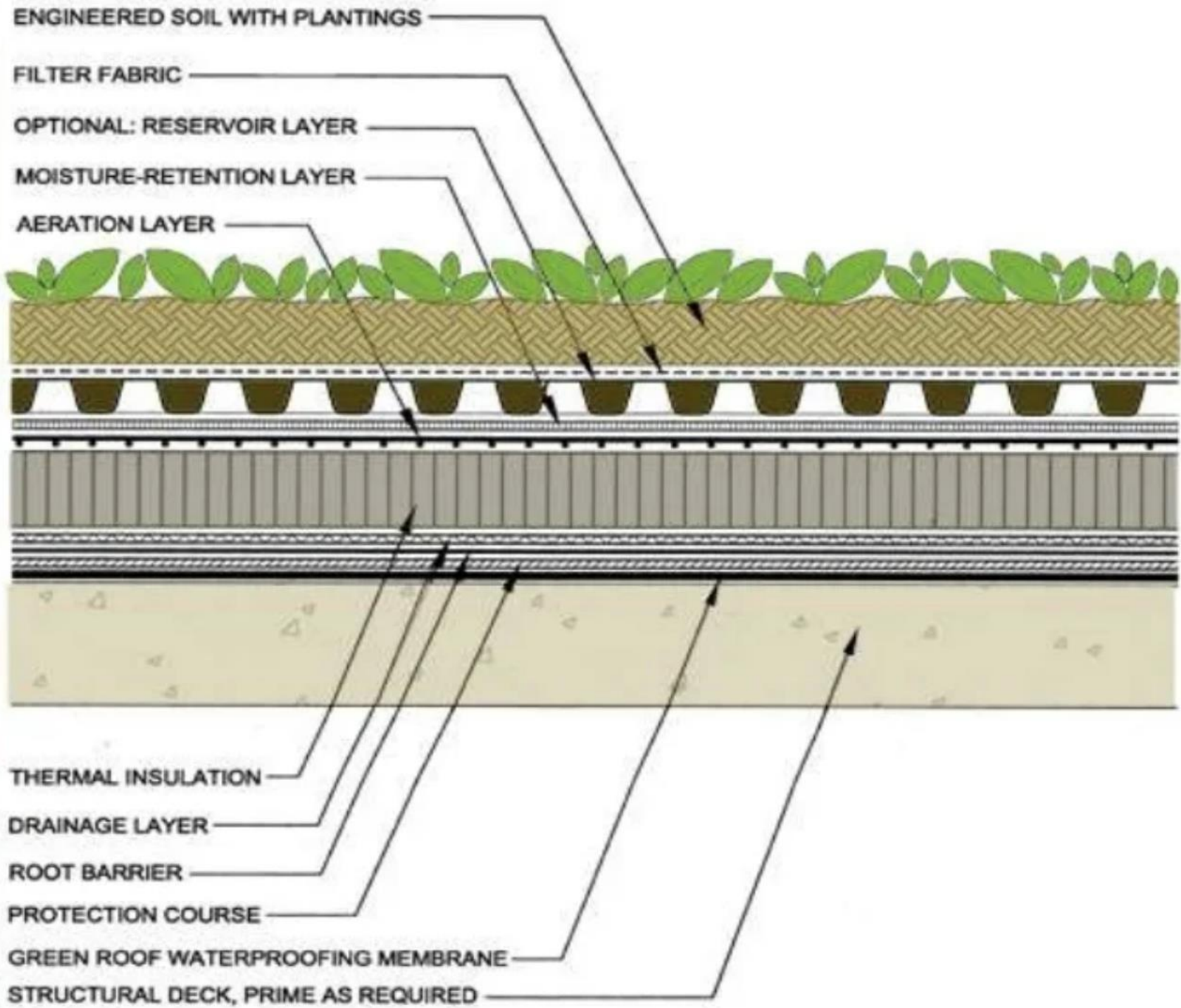


VEGETATED (grassed) SWALE
FIGURE 2A
*not to scale



GREEN ROOFS

1. A SYSTEM OF ROOFING
2. THAT USES PLANT LIFE FOR ROOF COVERING INSTEAD OF TRADITIONAL COVERING MATERIALS
3. LAYERS OF SOIL AND VEGETATION INSTALLED ON ROOFTOPS THAT CAPTURE RUNOFF
4.
 - I. PROVIDE AN EXCELLENT INSULATION TO THE BUILDING
 - II. REDUCING ENERGY CONSUMPTION SIGNIFICANTLY
 - III. ACT AS A NATURAL FILTER FOR RAINWATER
 - IV. ALLOWS EVAPORATION TO REDUCE THE VOLUME AND DISCHARGE RATE OF STORM WATER



LIVING GRASS ROOF HERIOT WATT UNIVERSITY



Thrifty Traveller



POROUS PAVEMENT

1. A PERMEABLE PAVEMENT SURFACE WITH A STONE RESERVOIR UNDERNEATH
2. THE PAVEMENTS ALLOW STORM WATER TO INFILTRATE DIRECTLY INTO THE SOIL
3. OFTEN APPEARS THE SAME AS TRADITIONAL ASPHALT OR CONCRETE BUT IS MANUFACTURED WITH INCORPORATES VOID SPACES THAT ALLOW FOR INFILTRATION.





Topmix Permeable has an average permeability rate of 600 litres, per minute, per m²



POROUS PAVEMENT



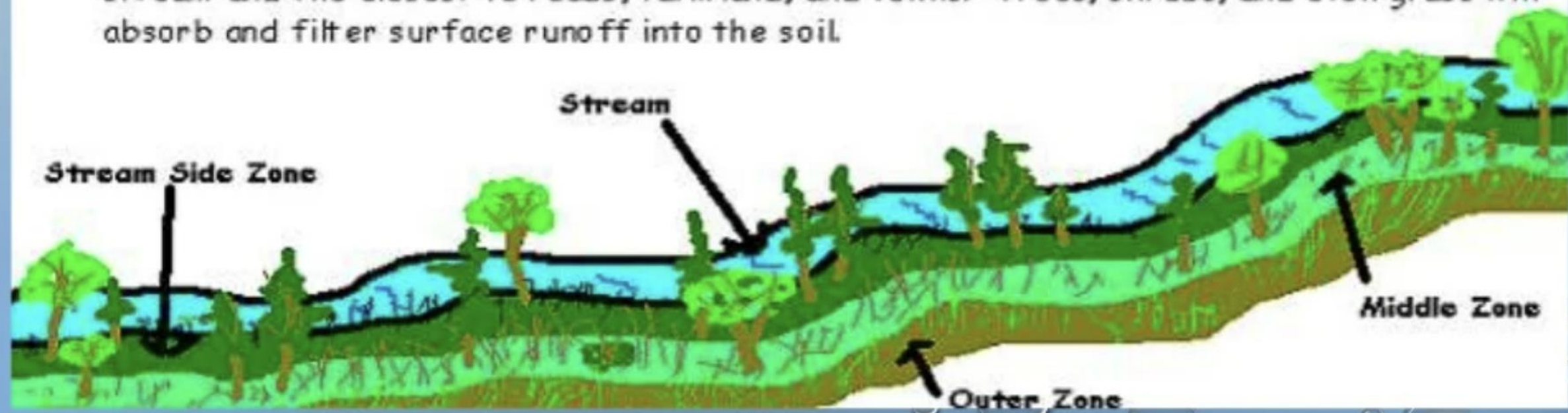
Press Esc to exit full screen

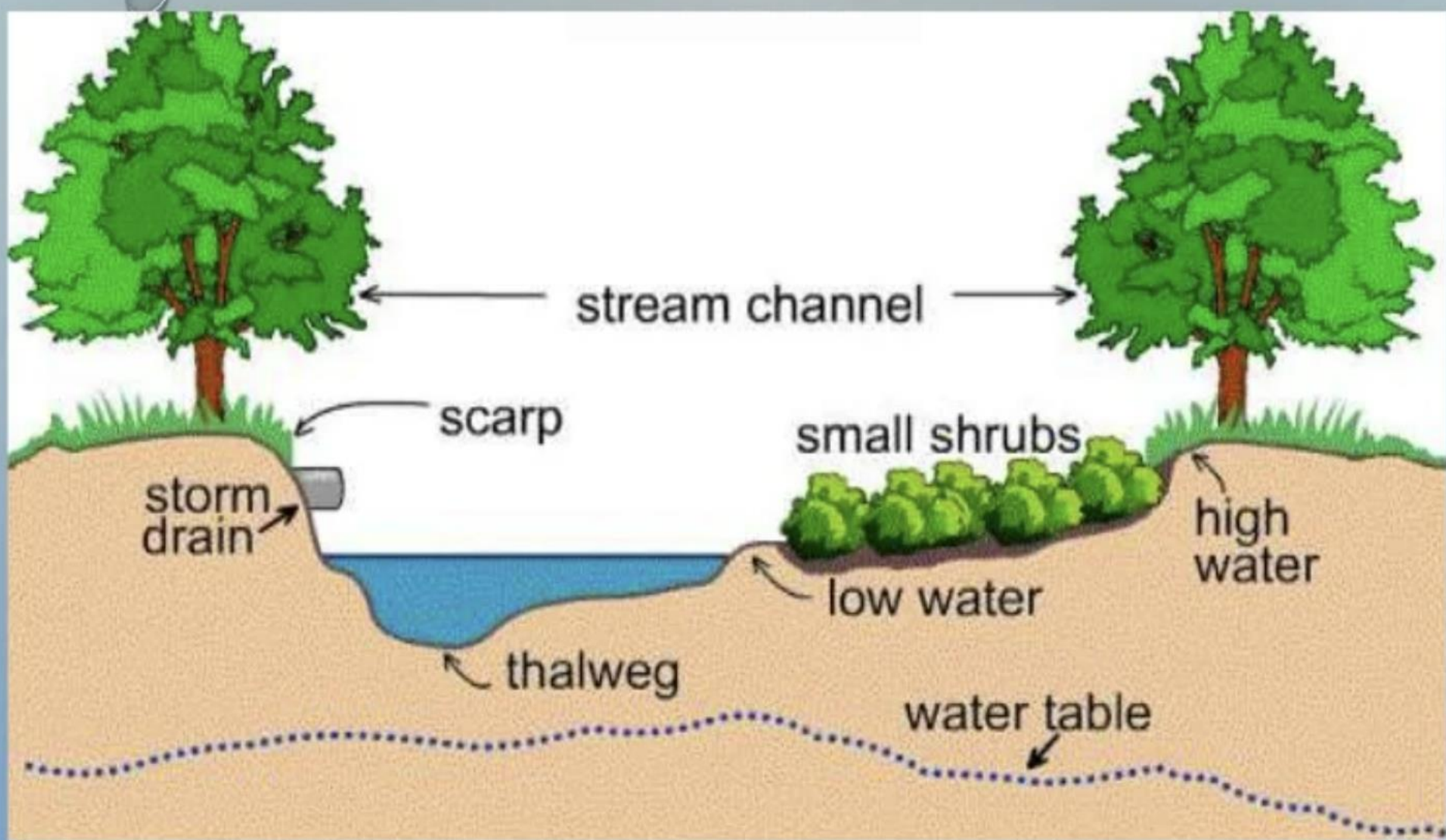
STREAM BUFFER RESTORATION

1. NATIVE TREES AND BUSHES PLANTED ALONG THE STREAM OR DITCH
2. STRIPS OF TREES AND OTHER VEGETATION BUFFER HELPS IMPROVE WATER QUALITY AND MAXIMIZED STREAM DAMAGE
3. BY FILTERING AND SLOWING POLLUTED RUNOFF

Three Types of Buffer Zones:


1. **STREAM SIDE ZONE** = This is the closest zone to the stream. The trees and other types of plants physically protect the stream from runoff, erosion, and provide shade to cool the water. A mature wooded forest and dense shrubs are preferred to hold the soil together and provide suitable habitat for fish.
2. **MIDDLE ZONE** = This is the zone that filters, slows down, and absorbs runoff before it enters the stream. Wet lands or a wooded forest capture and store sediment, nutrients, and other pollutants. On farmland, shrubs and grasses work just as well as a forest.
3. **OUTER ZONE** = This is the "buffer" of the buffer. It is the farthest zone from the stream and the closest to roads, farm land, and towns. Trees, shrubs, and even grass will absorb and filter surface runoff into the soil.





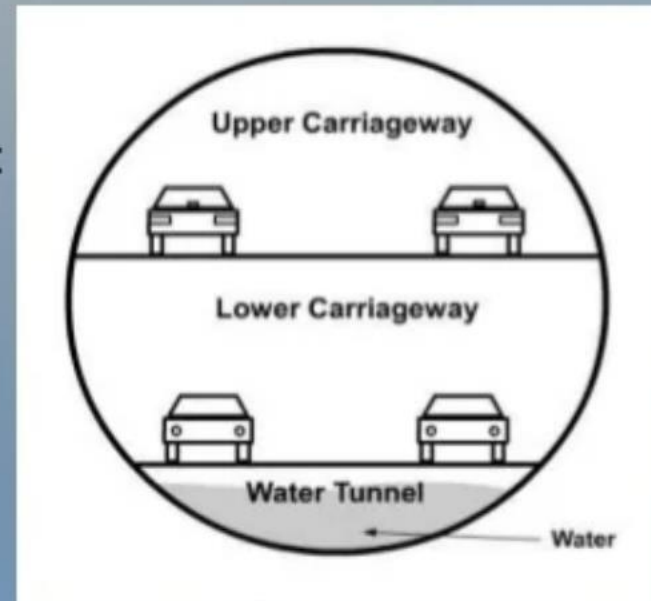
A lateral view (cross section) of a stream and its area of influence.



The background is a light blue gradient with several realistic water droplets of various sizes scattered in the corners. The text is centered in the middle of the page.

CASE STUDY
SMART TUNNEL

- “STORMWATER MANAGEMENT AND ROAD TUNNEL” = “SMART TUNNEL”
- A STORM DRAINAGE AND ROAD STRUCTURE IN KUALA LUMPUR, MALAYSIA.
- THE PROJECT IS IMPLEMENTED THROUGH **A JOINT VENTURE PACT** 合资协议 BETWEEN **MMC CORP BERHAD** AND **GAMUDA BERHAD**.
- THE **9.7KM** (6.0MI) TUNNEL IS **THE LONGEST STORMWATER TUNNEL IN SOUTH EAST ASIA** AND **SECOND LONGEST IN ASIA**.
- CONSTRUCTION COST : RM1887 MILLION
- **TWO** MAJOR COMPONENTS OF THIS TUNNEL :
 - STORMWATER TUNNEL
 - MOTORWAY TUNNEL





Drought Management
