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Exploring Watersheds: Assessing Drainage Basin Characteristics and Management Approaches for Channel and Overland Flows

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Abstract

A watershed also known as a drainage basin or catchment area, constitutes a fundamental hydrological unit encompassing a delineated land surface from which all runoff converges into a common drainage system, channel, or water body. Recognized as vital frameworks for resource assessment and sustainable development planning, watersheds epitomize the intricate interplay between land and water resources, offering optimal synergies for holistic management approaches. This paper embarks on a comprehensive exploration of watershed dynamics, encompassing the hydrological cycle's continuous stream of water through precipitation, evaporation, and plant transpiration. The hydrological cycle orchestrates a perpetual exchange of water among the Earth's spheres—atmosphere, land, and ocean—sustaining life and shaping landscapes. Within this cycle, running water emerges as a principal sculptor, reshaping terrains through erosion, transport, and sediment deposition, thereby crafting diverse landforms such as canyons, valleys, deltas, alluvial fans, and floodplains. This study focuses on the intricacies of channel and overland flows within watersheds, elucidating their roles in landscape transformation and hydrological connectivity. Through a meticulous assessment of drainage basin characteristics—including topography, land use/land cover, soil properties, vegetation dynamics, and climatic regimes—insights are gleaned into the complex interplay shaping hydrological processes, runoff generation, and sediment transport within watersheds. Utilizing advanced geospatial techniques and hydrological modeling, the spatial variability of these characteristics is elucidated, empowering stakeholders with crucial information for informed decision-making in watershed management and planning endeavors. By synthesizing diverse research insights and best practices, this paper serves as a beacon for policymakers, resource managers, and stakeholders vested in fostering resilience and sustainability within watersheds. Through a holistic understanding of drainage basin characteristics and the adoption of innovative management approaches, the quest for water security, environmental integrity, and socio-economic resilience is advanced amidst the backdrop of evolving hydrological regimes and anthropogenic pressures

Keywords: Watershed, drainage basin, hydrological cycle, run off, stream, channel flow, overland flow.

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INTRODUCTION

A watershed is a region of land that collects all the water flowing across and draining from it into a body of water. It merges with other watersheds to create a network of rivers and streams that gradually flow into larger bodies of water. To put it another way, a watershed is a region of land that collects precipitation and directs it toward a lake, stream, or marsh. The creek frequently has a level floodplain on both sides, which is created when mud and silt are deposited across wide, low-lying areas by sporadic floods. When a stream's flow is increased beyond what the stream channel can hold, flooding occurs [1]. During strong storms, water can occasionally travel overland as a sheet wash, or a thin coating of channeled water. Typically, sheet washes happen in dry climates or in situations where the earth is so saturated that it can no longer hold water. Sheetwash movement eventually creates tiny channels known as rills, which combine to create longer-lived, more substantial streams.

WATERSHED MANAGEMENT

Watershed is an ideal unit to cooperate among different regular assets, man, creatures, environment and so on as they all make a one- of-a-kind geo-hydrological element. Therefore, managing watersheds becomes crucial for the management of resources and ecosystems. A watershed is a territory of land and water limited by a waste separation inside which the surface runoff gathers and streams out of the watershed through a solitary source into an ale waterway or lake [1, 2]. Watershed innovation is utilized in Rain took care of regions. Watershed the board suggests a successful preservation of soil and water assets for manageable creation of food, grub, lumber and other farming and woodland assets. It includes the executives of land surface, vegetation, surface water assets to ration the dirt and water for quick and long-haul advantages to the ranchers, network, and society in general. Seepage framework is partitioned in numerous classes relying on the size, zone of spill over, and so forth beginning from district, bowl, catchment, sub-catchment, watershed and so on Catchment zone is the water gathering region or run off zone "All the territories from which water streams out into a waterway or water pool".

OBJECTIVES OF WATERSHED MANAGEMENT

To enhance food, fodder, and fuel production, control pollution, minimize over-exploitation of natural resources, store water, control floods, reduce sedimentation, preserve wildlife, control erosion, conserve soil and water, generate employment through industrial development, recharge groundwater to ensure regular water supply for consumption, industry, and irrigation, and provide recreational facilities [1].

CLASSIFICATION OF WATERSHED

Watersheds can be ordered utilizing any quantifiable qualities in the zone like-size, shape, area, ground water abuse, and land use. Nonetheless, the primary arrangement of watershed is talked about comprehensively based on size and land use. Two watersheds of a similar size may act diversely if they don't have comparable land and channel stages. The classification of various watershed arrangements is as below.

Size

The primary ramifications of watershed size show up as far as spatial heterogeneity of hydrological measures. The spatial changeability of watershed attributes increments with size; consequently, huge watersheds are generally heterogeneous. As the watershed size builds, stockpiling increments. In view of size, the watersheds are separated into three classes.

- *Small Watersheds:* Small watersheds are those where surface runoff and land features are predominant. The channel stage is generally less obvious. The watershed is profoundly delicate to extreme focus and brief length rainfalls.
- *Medium Watersheds:* Being medium in size, the usefulness in these watersheds *is* simple because of open methodology. Instead of size, the state of the watershed assumes a predominant job. Overland stream and land stage are conspicuous.
- *Large Watersheds:* These basins are less vulnerable to brief, heavy rainfall events. The channel organizations and channel stage are all around created, and, hence, channel stockpiling is prevailing.

- *Land Use:* Land use characterizes the qualities of watersheds which influence the different hydrological measures inside the watershed. Depending on the land use, the watershed's characteristics can be listed below.
- *Agricultural Watershed:* Agricultural watershed is the watershed wherein agrarian exercises (crop development) are predominant. It encounters maybe the most progressively critical land-use change. This normally prompts expanded penetration, expanded disintegration, and additionally diminished overflow. Sadness stockpiling is likewise expanded by farming activities. At the point when the fields are fruitless, falling raindrops will in general conserve the dirt and invasion is diminished. There is less improvement of streams in horticultural watersheds.
- *Urban Watershed:* These are the watershed territories having greatest control for the comfort of person. These are overwhelmed by structures, streets, roads, asphalt, and parking garages. These highlights diminish the penetrating area territory and increment impenetrability. As waste frameworks are misleadingly fabricated, the common example of water stream is considerably adjusted [2], [3]. For a given precipitation occasion, interference and despondency stockpiling can be critical, however invasion is impressively diminished. Thus, there is articulated expansion in runoff and articulated abatement in soil disintegration. Along these lines, a metropolitan watershed is more helpless against flooding if the seepage framework is lacking.
- *Mountainous Watershed:* These watersheds receive a lot of snowfall due to their higher heights. Because of steep slope and generally less permeable soil, invasion is less, and surface overflow is overwhelmingly high for a given precipitation occasion. The zones downstream of the mountains are helpless against flooding. Because of snow liquefy, water yield is critical in any event, during spring and summer.
- *Forest Watershed:* These are where characteristic backwoods cover overwhelms other land employments. In these watersheds, capture is critical, and evapotranspiration is a prevailing segment of the hydrologic cycle. The ground is typically covered with leaves, stems, branches, and other debris. As a result, when it rains, the trees and ground cover absorb the water, which prolongs the period of infiltration. There are times when virtually little surface runoff occurs, and subsurface flow becomes dominating. Since woodlands oppose streams of overland water, the pinnacle release is decreased.
- *Desert Watershed:* Desert watersheds typically have little to no vegetation**.** The dirt is generally sandy and minimal yearly precipitation happens. Stream advancement is insignificant. At whatever point there is precipitation, the vast majority is consumed by the permeable soil, some of it dissipates, and the leftover runs off just to be absorbed during its excursion. There is restricted groundwater reviving because of the event of less precipitation in these watersheds.
- *Coastal Watershed:* The watersheds in waterfront zones may mostly be metropolitan and are in unique contact with the ocean. Their hydrology is extensively affected by backwater from wave and flowing activity of the ocean. Typically, these watersheds get high precipitation, generally of cyclonic kind, don't have direct control in stream, and are helpless against extreme neighbourhood flooding.
- *Marsh or Wetland Watershed:* Such terrains are practically level and include bogs, swamps, water courses, and so forth. They have rich natural life and a lot of vegetation. As water is no restricting variable to fulfil evaporative interest, vanishing is prevailing. Precipitation is ordinarily high, and penetration is negligible. Most of the precipitation overflows. The flood hydrograph tops slowly and goes on for quite a while.
- *Mixed Watershed:* These are, where various land use/land cover exists either due to common settings or because of a mix of normal and human collaboration exercises. In these watersheds, a mix of at least two of the past orders happens and none of the single qualities overwhelm the zone. In India, a large portion of the watersheds are of blended nature of attributes, where farming, woods, settlements (metropolitan and rustic) and so ashore use happens.

WATERSHED CHARACTERISTICS

The runoff hydrograph is often predicted to be sharper, with a greater peak and shorter duration, in more compacted watersheds. The runoff hydrograph for a watershed that is partially long and narrow and partially compact is anticipated to be a complex mixture of the hydrographs described above. Understanding the intricate relationship between the linear, aerial, and relief characteristics of the topography in any given watershed requires morphometric analysis of the watershed.

Databases with different land surface features (slope, height, extent, etc.) and drainage parameters (coding, ordering, flow direction, etc.) are compiled for this purpose. To direct the strategy for water resource development planning, morphometric characteristics (stream order, stream length, drainage density, stream frequency, bifurcation ratio, shape index, circulatory ratio, etc.) are examined and tabulated [4], [5].

IMPORTANCE OF WATERSHED MANAGEMENT

Runoff from rainfall or snowmelt can introduce significant pollution into lakes or rivers. Managing watersheds is essential to enhance food, fodder, and fuel production, conserve soil and water, and control pollution of water and other natural resources within the watershed. This is accomplished by determining the many forms of pollution found in the watershed, comprehending the distribution and transportation of pollutants, and creating plans for technical interventions to control pollution.

The natural resources and water quality of a watershed are impacted by all activities within it. A watershed's resource quality can be impacted by a variety of factors, including domestic chores like gardening, lawn maintenance, and water diversion, agricultural practices, runoff from developed areas, and new land development [6], [7]. Watershed management planning comprehensively identifies activities impacting the watershed's health and makes recommendations to address them, reducing adverse pollution impacts. Moreover, watershed management is vital because the planning process fosters a partnership among stakeholders, policymakers, and implementers within the watershed.

This partnership is crucial for successful management of land and water resources, as all parties have a vested interest in the watershed's health. Additionally, it provides an efficient way to prioritize implementation of watershed management plans, especially when resources are limited [10].

DRAINAGE BASINS

Any body of surface water that is flowing, from a tiny trickle to a massive river, is referred to as a stream. The drainage basin of a stream is the area from where the water originates (Figure 1). Rain or snow in a drainage basin eventually finds its way into its stream, unless groundwater flow causes some water to traverse into a nearby basin.

DRAINAGE PATTERNS

This describes the arrangement of streams within a drainage basin, often reflecting structural and/or lithological controls of underlying rocks Drainage patterns provide valuable information about the composition of the land surface. Analysis of stream patterns on satellite photos, aerial photographs, or topographic maps can be done with practice, interpretation, and identification of geological formations and rock kinds (Figure 2).

There are several major drainage patterns:

- *Dendritic Drainage Pattern:* This pattern develops in areas where the rock type remains uniform throughout the basin and where geological processes like folding or faulting haven't created structures influencing river systems. Weak rock structure typically forms dendritic drainage patterns. Tributaries join at sharp angles and flow in the same direction as the main stream.

- *Trellis Drainage Pattern:* Folding and faulting produce structures that affect river systems, or it originates in locations where softer and harder rocks alternate.
- *Rectangular Drainage Pattern:* This pattern is made up of main streams and tributaries with portions that are roughly the same length and right-angle bends. It depicts streams that split rocks into rectangular blocks by following noticeable fault or joint systems.
- *Radial Drainage Pattern:* It is made up of streams that emerge from the sides of uplands that are formed like domes or cones. From a high center location, subsequent streams radiate or diverge outward, resembling the spokes of a wheel. The slopes of a young, unbreeched domal structure or a volcanic cone are the finest places for this pattern to form.

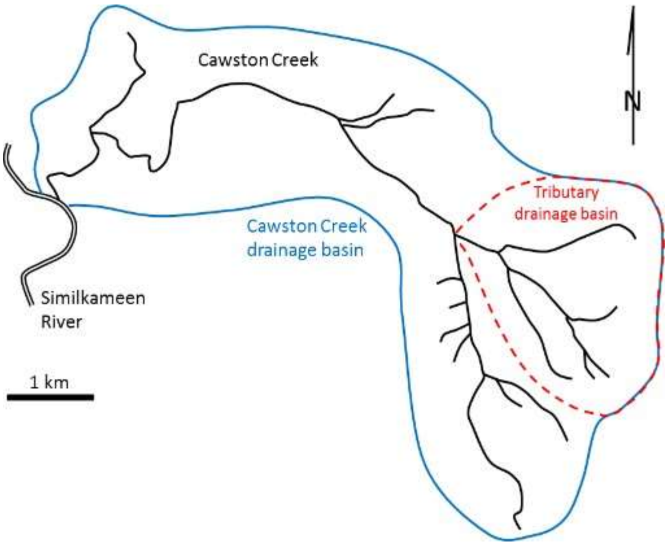

Figure 1. Cawston Creek near Keremeos, B.C. The blue line shows the extent of the drainage basin. The dashed red line is the drainage basin of one of its.

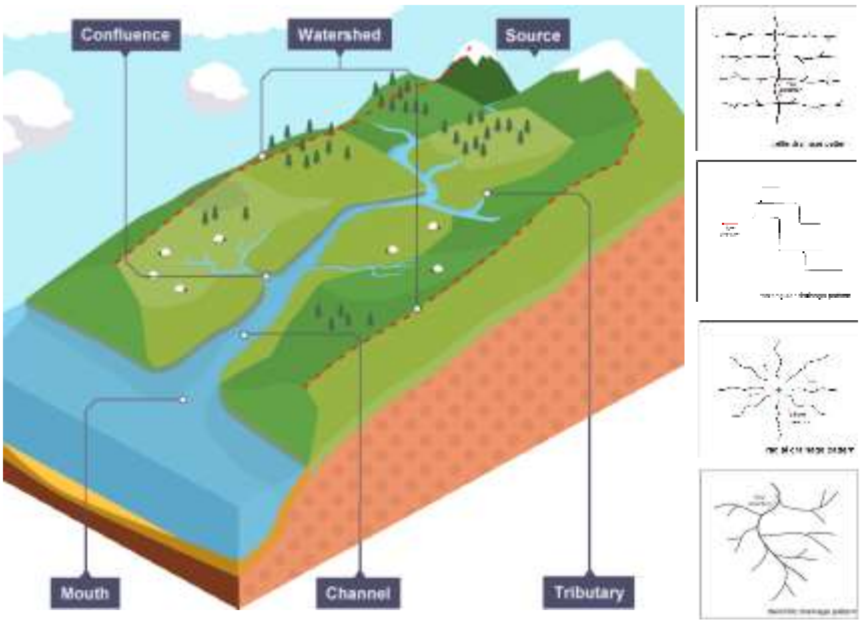

Figure 2 Basic nomenclature of a drainage basin,(right) Different drainage patterns : (i) dendritic, (ii) trellis, (iii) rectangular, (iv) radial

DIFFERENCE BETWEEN WATERSHED AND DRAINAGE BASIN

Land areas that drain into a particular body of water, such as a lake, stream, river, or estuary, are referred to as river basins or watersheds. Every drop of water in a river basin empties into one major river. A smaller tract of land that empties into a smaller lake, stream, or marsh is referred to as a watershed. A river basin has many smaller watersheds (Table 1).

For example: The watershed of Yamuna + the watershed of Chambal + the watershed of Gandak + ... = The drainage basin of the Ganga River.

MAJOR DRAINAGE BASINS IN INDIA

Based on their mode of origin, nature, and characteristics, Indian drainage is classified into two main categories:

- The Himalayan drainage
- The Peninsular drainage

The following table illustrates the major differences between Himalayan and the Peninsular River system.

Table 1. Major differences between Himalayan and the Peninsular River system.

Characteristics	Himalayan River	Peninsular River
Place of origin	Himalayan mountains (covered with glaciers).	Peninsular plateau and central highland.
Nature of flow	Perennial; receive water from glacier and rainfall.	Seasonal; dependent on monsoon rainfall.
Type of drainage	Antecedent and consequent leading to dendritic pattern in plains.	Super imposed, rejuvenated resulting in trellis, radial, and rectangular patterns.
Nature of river	Long course, flowing through the rugged mountains experiencing head ward erosion and river capturing; In plains, meandering and shifting off course.	Smaller, fixed course with well-adjusted valleys.
Catchment area	Very large basin.	Relatively smaller basin.
Age of the river	Young and youthful, active, and deepening in the valleys	Old rivers with graded profile, and have almost reached their base levels.

FLOW

The volume of water a river delivers over a certain period of time is referred to as its flow. Water pouring over the land's surface is known as runoff, and it is primarily dependent on a number of causes.

- *Amount of Rainfall:* Runoff is directly proportional to rainfall. As rainfall increases, the likelihood of increased runoff also increases.
- *Soil Type:* Infiltration rate, the rate at which water enters the soil, depends mainly on soil type. Higher porosity (void space) soil permits more infiltration, which reduces surface runoff. For example, laterite soil.
- *Evaporation Capacity:* Higher evaporation capacity leads to reduced surface runoff.

OVERLAND FLOW

Overland flow refers to water flowing on the surface and directly meeting the channelIt happens as sheet flow across the surface of the land without concentrating in distinct channels. This kind of flow occurs before surface runoff gathers into channels and is its first expression. The deterministic techniques used in the theory of overland flow are based on the concepts of fluid mechanics and include unstable free surface flow, mass and momentum conservation, and laminar and turbulent flow. Spatial and temporal components of overland flow description result in differential equations that can be solved numerically.

- *Subsurface Flow:* This is internal flow, which is the flow of water as part of the water cycle beneath the surface of the Earth (Figure 3).
- *Base Flow:* The fraction of streamflow that is delayed shallow subsurface flow is referred to as base flow (Figure 4).

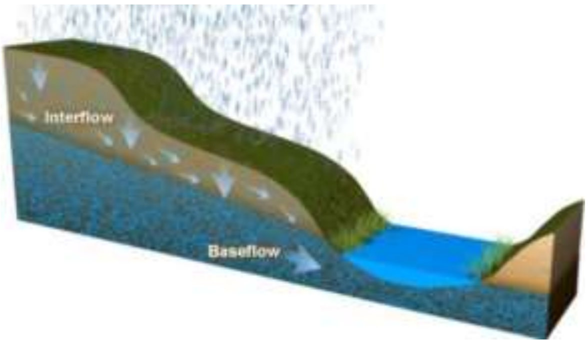

Figure 3. Subsurface flow.

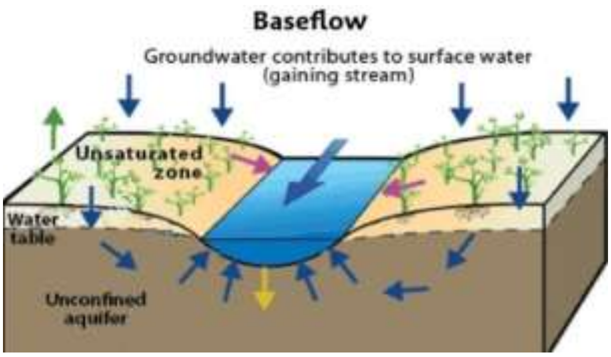

Figure 4. Base flow.

DEPENDING ON MOVEMENT AND SPEED

Flow can be categorized as follows:

- *Steady Flow:* If the parameters at a segment, including depth, discharge, or velocity, do not alter over time, the flow is said to be stable. Flow in a prismatic channel with continuous discharge is one example.
- *Unsteady Flow:* Flow is unsteady if characteristics like depth, discharge, and velocity change with time. An example is the flow of a river during a flood.
- *Subcritical Flow:* This happens at low speeds, where even a tiny disturbance has the ability to move upstream and change the circumstances there. Another name for it is peaceful flow.
- *Critical Flow:* Like subcritical flow, where a small disturbance can travel upstream and alter upstream conditions.
- *Supercritical Flow:* This happens when a tiny disturbance, like an elementary wave, is carried downstream at great speeds. Another name for it is shooting or fast flow.
- *Laminar Flow and Turbulent Flow:* Laminar flow occurs when flow is in the form of thin sheets (lamina) and the velocity is very small, typically a few centimeters per second (Figures 5 and 6). Turbulent flow occurs at high velocities where paths of particles are crossing each other, resulting in chaotic movement.

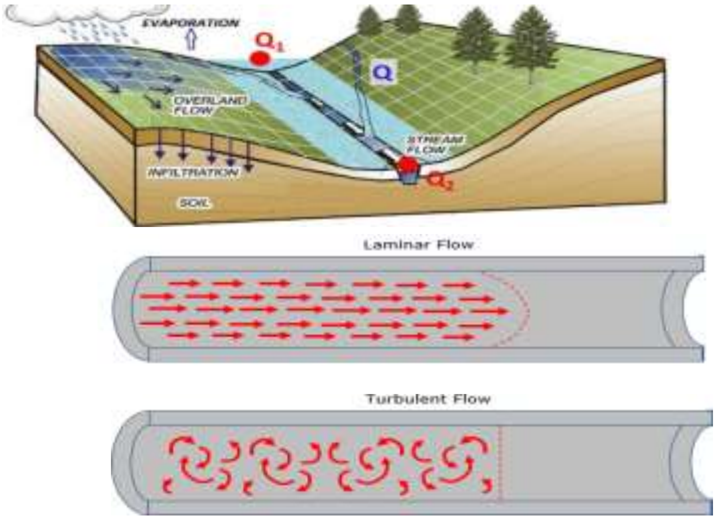

Figure 5. Laminar flow and Turbulent flow.

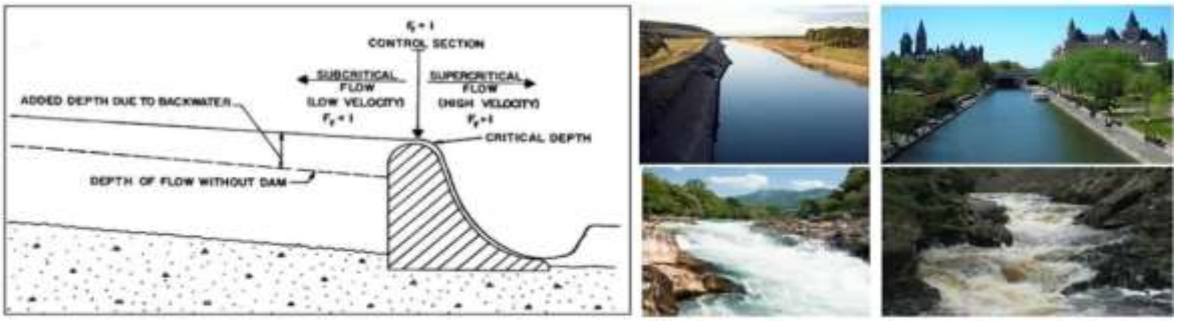

Figure 6. Flow over a small dam (Schematic).

CHANNEL FLOW OR STEAM FLOW

The shape of a generally shallow and narrow body of fluid, usually a river, river delta, or strait, makes up a channel, a type of landform. It has a similar meaning to "canal" and occasionally takes this shape. One of the main components of the water cycle is the movement of water through rivers, streams, and other channels.

- *Open Channel:* This type of flow has one surface that is free, not restricted by anything. One instance of open channel flow is a canal. Pipe flow lacks a free surface, but open channel flow does (Figure 7).
- *Artificial Channel:* These are constructed with certain uses in mind, including irrigation, water supply, or the development of water power. Their surface roughness is homogeneous, and their shape and alignment are regular. When the bed slope is constant and the cross-section is uniform, a channel is said to be prismatic. Rectangular, trapezoidal, circular, and parabolic channels are a few examples (Figure 8).
- *Natural channels:* These have irregular sections of varying shapes. When a channel's slope and cross-section vary, it is no longer prismatic. Rivers, streams, and estuaries are a few examples (Figure 9).

METHODS USED TO CALCULATE THE FLOW

- *Quick Rough Estimate:* This is a straightforward technique for calculating water flow in little streams. Watch what happens to a leaf that you drop into the stream. See how far the leaf floats by walking **:** downstream for about 30 meters, or 35 steps, at a typical speed. Calculate the water flow by measuring the leaf's journey distance.

- *Bucket Method:* With this technique, extremely tiny flows—less than five liters per second—can be accurately measured. To temporarily block the flow of the stream, build a tiny earthen dam over it. While constructing the dam, use bamboo, wood poles, or tree branches to hold the earth in place.
- *Float Method:* This technique provides medium accuracy measurements of modest to large water flows.It works best in calm streams and during periods of good weather, as excessive wind or rough water surfaces can affect accuracy. Float an object on the water's surface and measure its travel distance over a known period.

Figure 7. Open Channel.

Figure 8. Artificial Channel.

Figure 9. Natural Channe.

CONCLUSION AND INFERENCES

This study underscores the critical importance of watershed management for maintaining water resources and promoting sustainable development. By understanding the features of drainage basins and flow dynamics, effective management strategies can be implemented to mitigate the impact of runoff and ensure the conservation of land and water resources. The hydrological cycle's significance in regulating water distribution among various Earth system components is emphasized. In order to evaluate the overall health of a watershed and apply suitable management strategies, it is essential to comprehend the constant circulation of water between the atmosphere, land, and ocean.

Moreover, running water plays a dominant role in shaping landscapes through erosion, transportation, and deposition processes. Recognizing streams as primary agents of channel flow highlights the importance of managing stream systems effectively to prevent erosion, maintain water quality, and protect downstream areas. Managing headwater areas, typically located in mountainous terrain, is essential as they serve as the origin point for streams and significantly influence downstream flow dynamics. Implementing conservation measures in these high-elevation regions is crucial for maintaining water quantity and quality downstream.

Furthermore, integrated watershed management approaches consider the interactions between land and water resources, which are necessary for enhancing watershed resilience to natural and human disturbances. Synergistic effects between different management practices can further enhance watershed resilience.

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