Water in Subsurface Environment

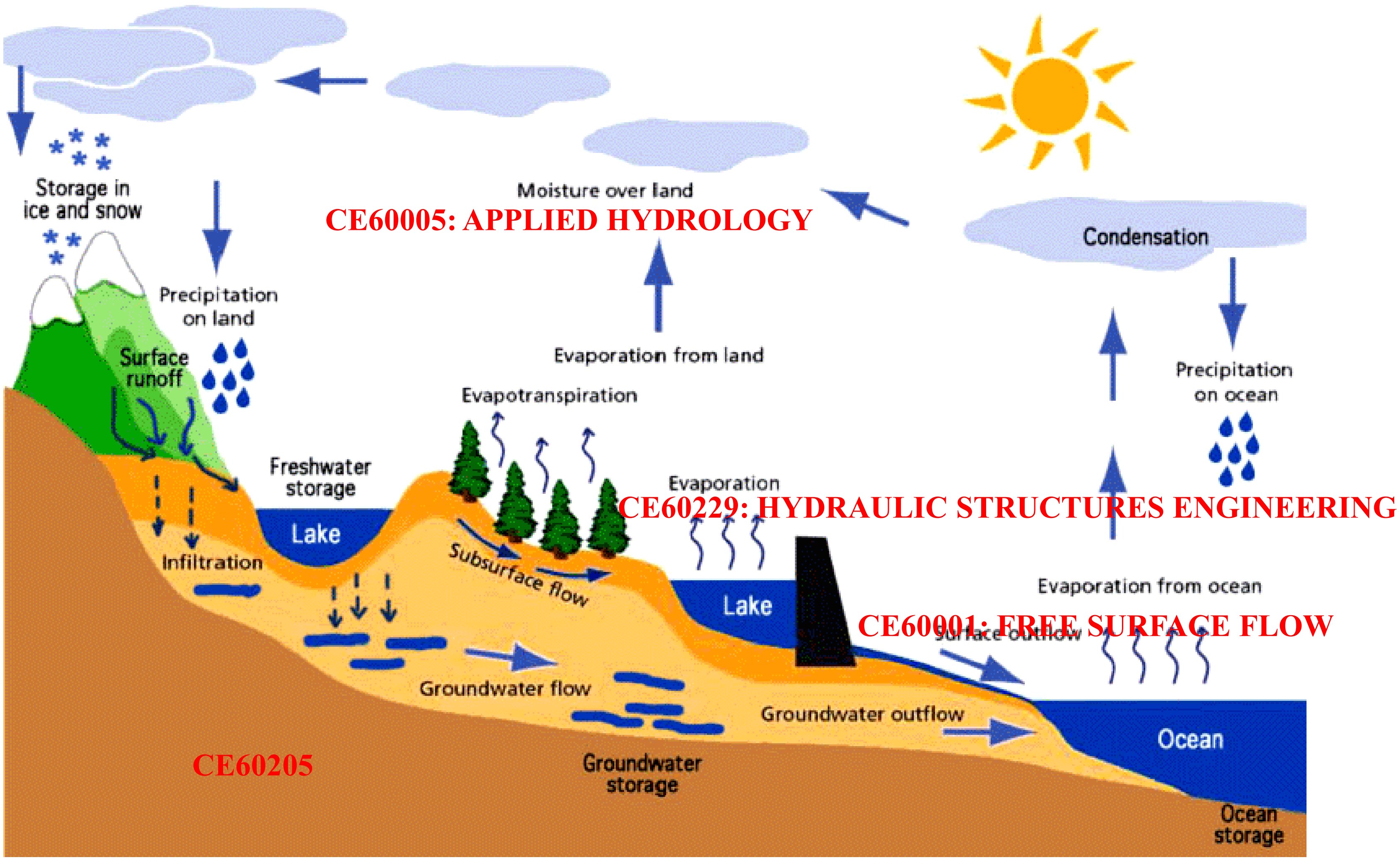
Groundwater Engineering| CE60205

Lecture:01

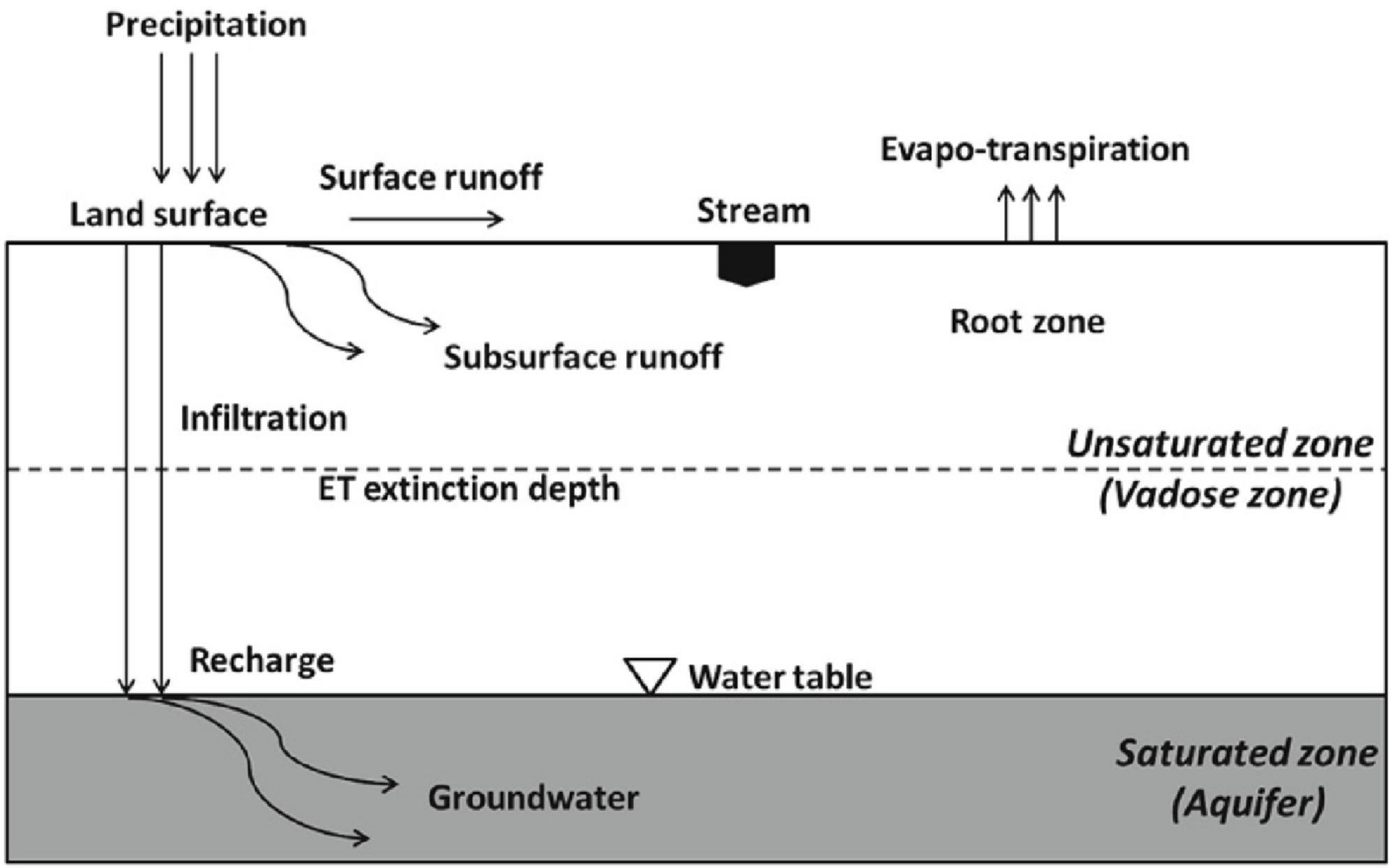
Learning Objective

- **To understand location of water in subsurface**
- **To apply water budget equation**
- **To understand effect of subsurface on groundwater hydrograph**

The Hydrologic Cycle

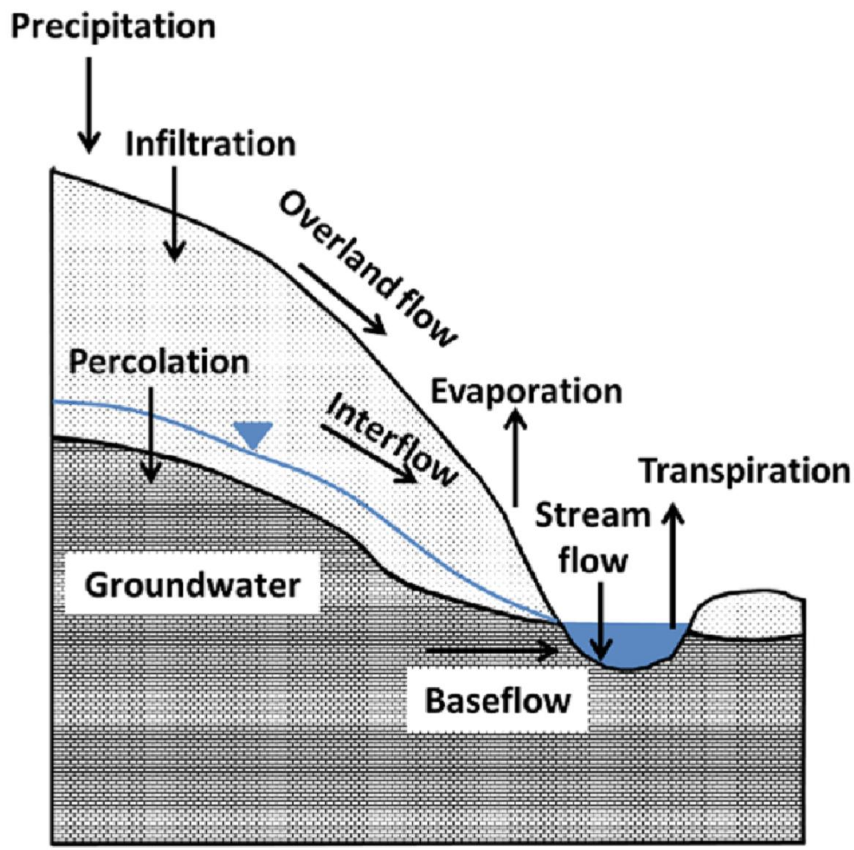


Subsurface Zones

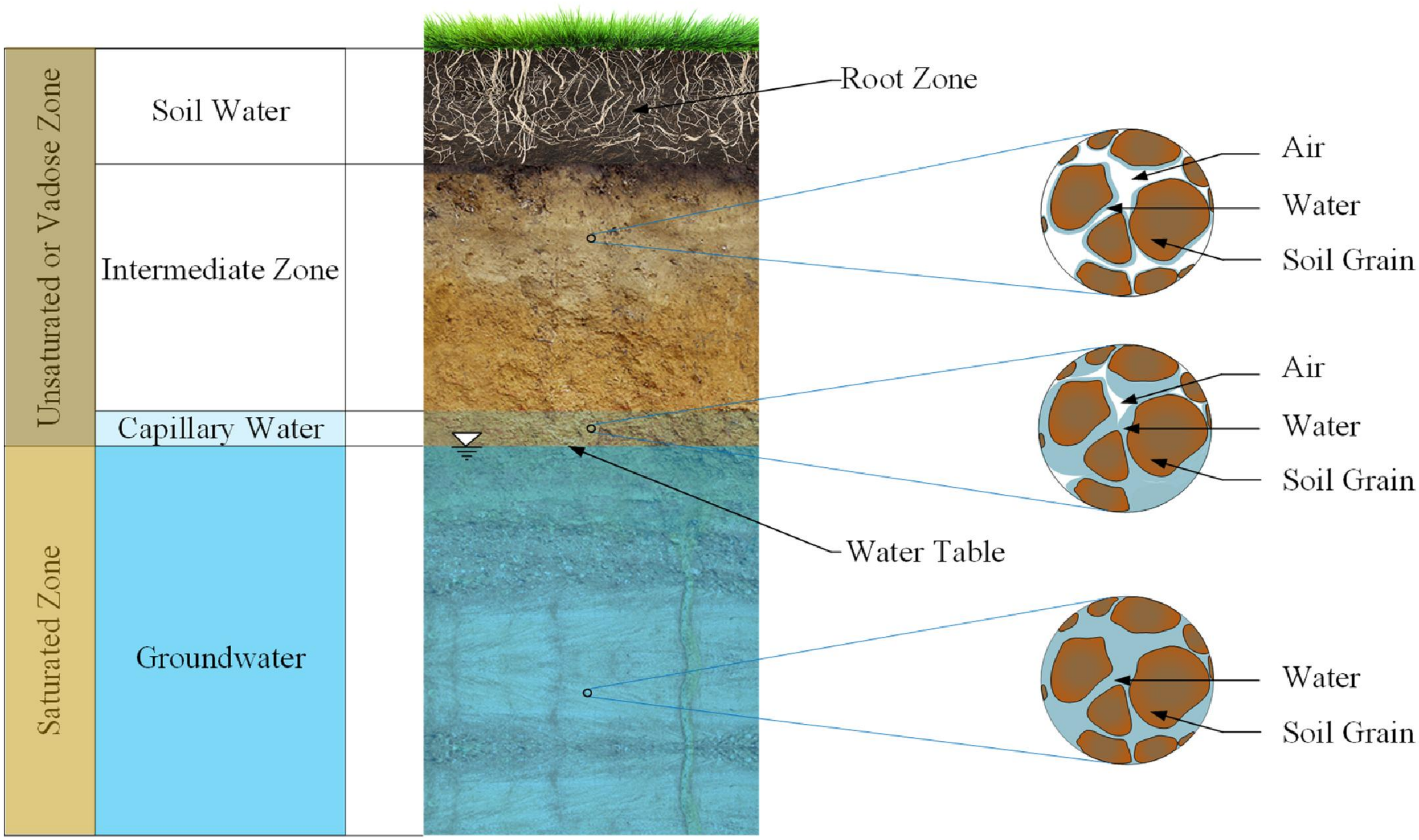


Terrestrial hydrosystems divided into vadose and phreatic zones

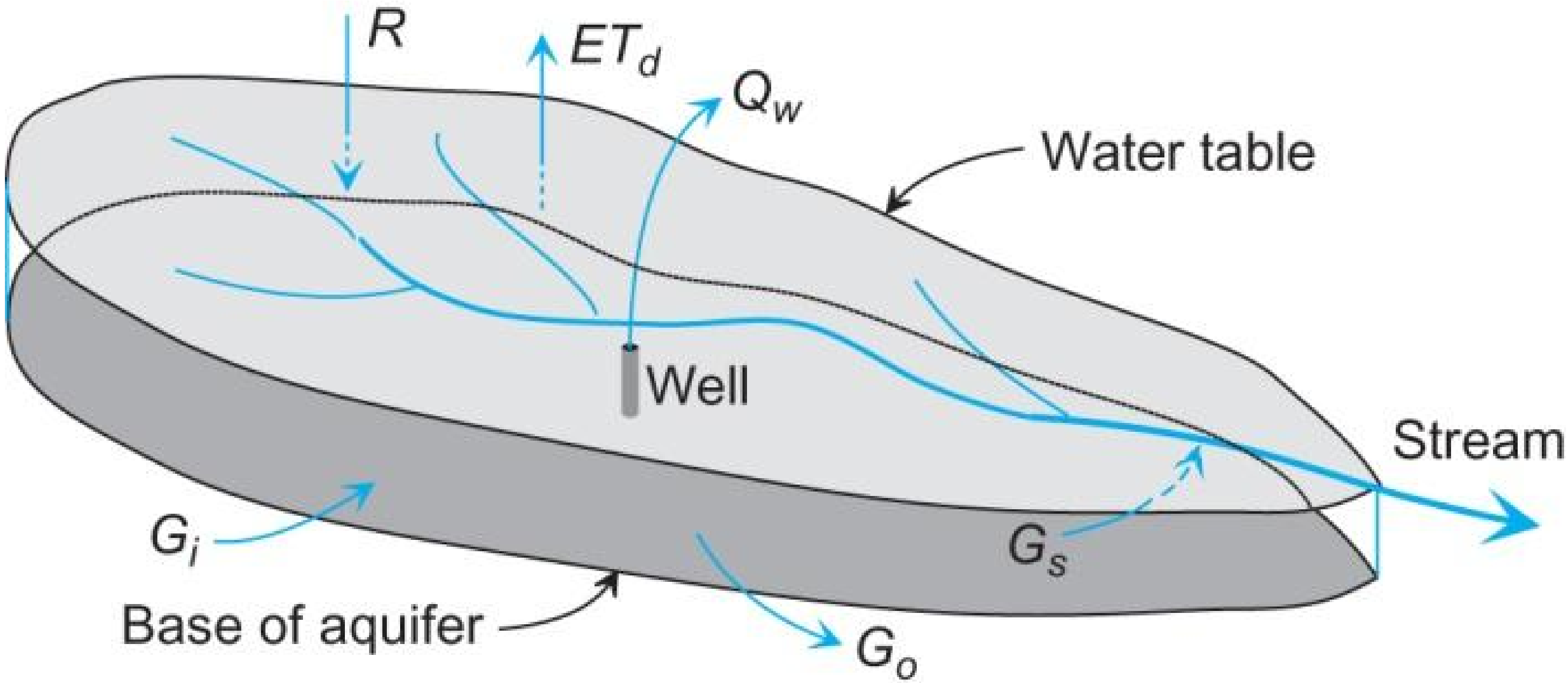
Subsurface Zones (Contd.)



Subsurface Zones (Contd.)



Hydrologic Balance



Hydrologic Balance (Contd.)

flux in − flux out = rate of change in water stored within

Fluxes into this region include the inlet stream flow (I) and the net groundwater discharge (G). Fluxes out of this region include the outlet stream flow (O) and evaporation (E) from the surface. Hydrologic balance in this case requires

$$I + G - O - E = \frac{dV}{dt}$$

where dV/dt is the change in reservoir volume per time.

Hydrologic Balance (Contd.)

- Hydrologic Balance

$$R + G_i - G_o - G_s - ET_d - Q_w = \frac{dV}{dt}$$

- If, over a long time span, there is an approximate steady-state balance where flow in equals flow out, then the transient term disappears and the balance equation becomes

$$R + G_i - G_o - G_s - ET_d - Q_w = 0$$

Hydrologic Balance (Contd.)

$Q_w = 0$ describes the balance:

$Q_w > 0$ $\quad Q_w = -dV/dt$

R and G_i may increase, while G_o, G_s, and ET_d may decrease.

$$R + G_i - G_o - G_s - ET_d - Q_w = 0$$

Safe yield of aquifers

- The yield of an aquifer is defined as the rate at which water can be withdrawn without depleting the supply to such an extent that withdrawing at a rate higher than that is no longer economically feasible.

Groundwater Balance

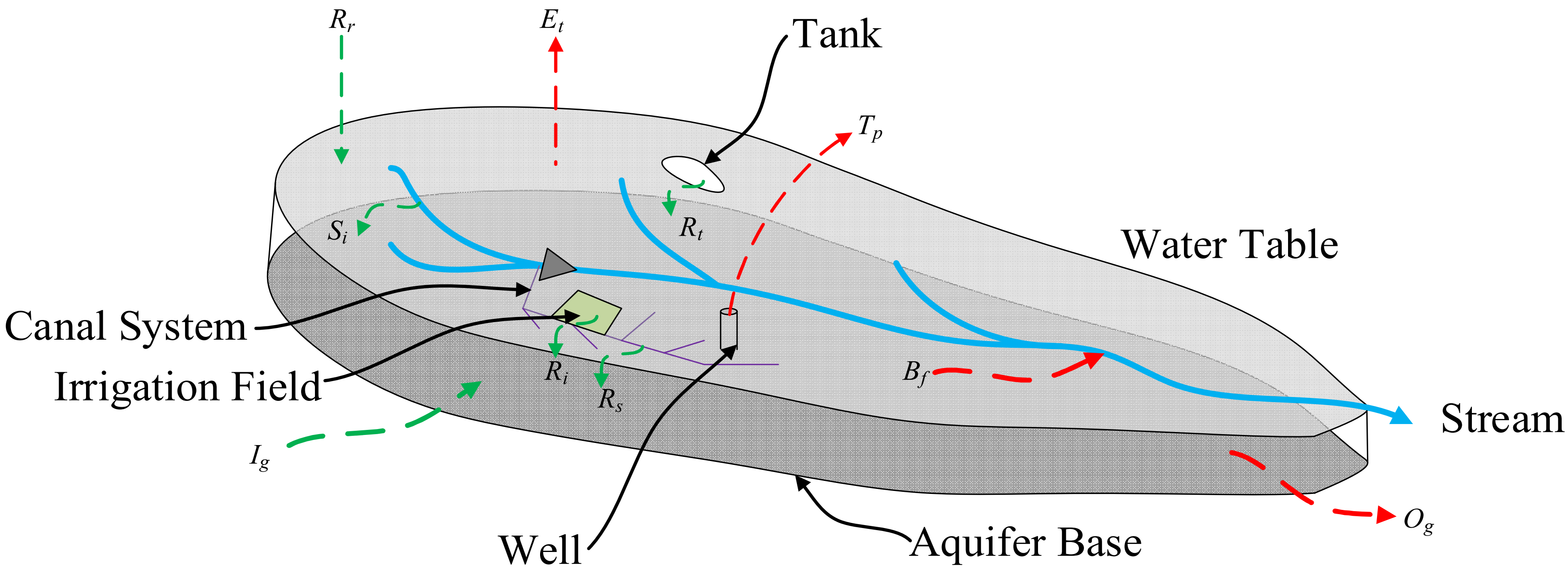
- Input to the system – outflow from the system = Change in storage of the system

$$\Delta S = R_r + R_s + R_i + R_t + S_i + I_g - E_t - T_p - B_f - O_g$$

where:

ΔS is the change in groundwater storage
R_r is the recharge from rainfall
R_s is the recharge from canal seepage
R_i is the recharge from field irrigation
R_t is the recharge from tanks
S_i is the influent seepage from rivers
I_g is the inflow from other basins
E_t is the evapotranspiration from groundwater
T_p is the draft from groundwater
B_f is the baseflow, the part of the groundwater inflows to rivers
O_g is the outflow to other basins.

Groundwater Balance (Contd.)



$$\Delta S = R_r + R_s + R_i + R_t + S_i + I_g - E_t - T_p - B_f - O_g$$

Data requirement

- Rainfall data
- Land use data and cropping patterns
- River stage and discharge data
- River cross sections
- Canals discharge and distributaries data, and the possible seepage from canals
- Tanks depth, capacity, area, and seepage data
- Water table data
- Groundwater draft (the number of each type of well operating in the area, their corresponding running hours each month, and their discharge)
- Aquifer parameters

GEC

Reprint

DETAILED GUIDELINES FOR IMPLEMENTING THE GROUND WATER ESTIMATION METHODOLOGY

GEC-97

CENTRAL GROUND WATER BOARD
MINISTRY OF WATER RESOURCES
GOVERNMENT OF INDIA
2009

REPORT OF THE
GROUND WATER RESOURCE ESTIMATION COMMITTEE
(GEC-2015)

METHODOLOGY

Ministry of Water Resources, River Development & Ganga Rejuvenation
Government of India

NEW DELHI
October, 2017

Water balance in confined aquifers

$$W_{sc,i} = W_{sc,i-1} + W_{per} - W_{pc}$$

where:

$W_{sc,\,i}$ is the amount of water stored in the confined aquifer on day i (mm)

$W_{sc,\,i-1}$ is the amount of water stored in the confined aquifer on day i–1 (mm)

W_{per} is the amount of water percolating from the unconfined aquifer into the confined aquifer on day i (mm)

W_{pc} is the amount of water removed from the confined aquifer by pumping on day i (mm).

Water balance in unconfined aquifers

$$W_{su,i} = W_{su,i-1} + R_r - B_f - W_{sd} - W_{per} - W_{pu}$$

where:

$W_{su,\,i}$ is the amount of water stored in the unconfined aquifer on day i (mm)
$W_{su,\,i-1}$ is the amount of water stored in the unconfined aquifer on day i–1 (mm)
R_r is the amount of recharge entering the aquifer on day i (mm)
B_f is the base flow to the main channel on day i (mm)
W_{sd} is the amount of water moving into the soil zone in response to water deficiencies on day i (mm)
W_{per} is the amount of water percolating from the unconfined aquifer into the confined aquifer on day i (mm)
W_{pu} is the amount of water removed from the unconfined aquifer by pumping on day i (mm).

Water balance in unsaturated zone

$$\Delta S_{\mathrm{unsat}} = W_{\mathrm{inf}} + W_{\mathrm{cap}} + I_g - W_{\mathrm{per}} - E_t - B_f$$

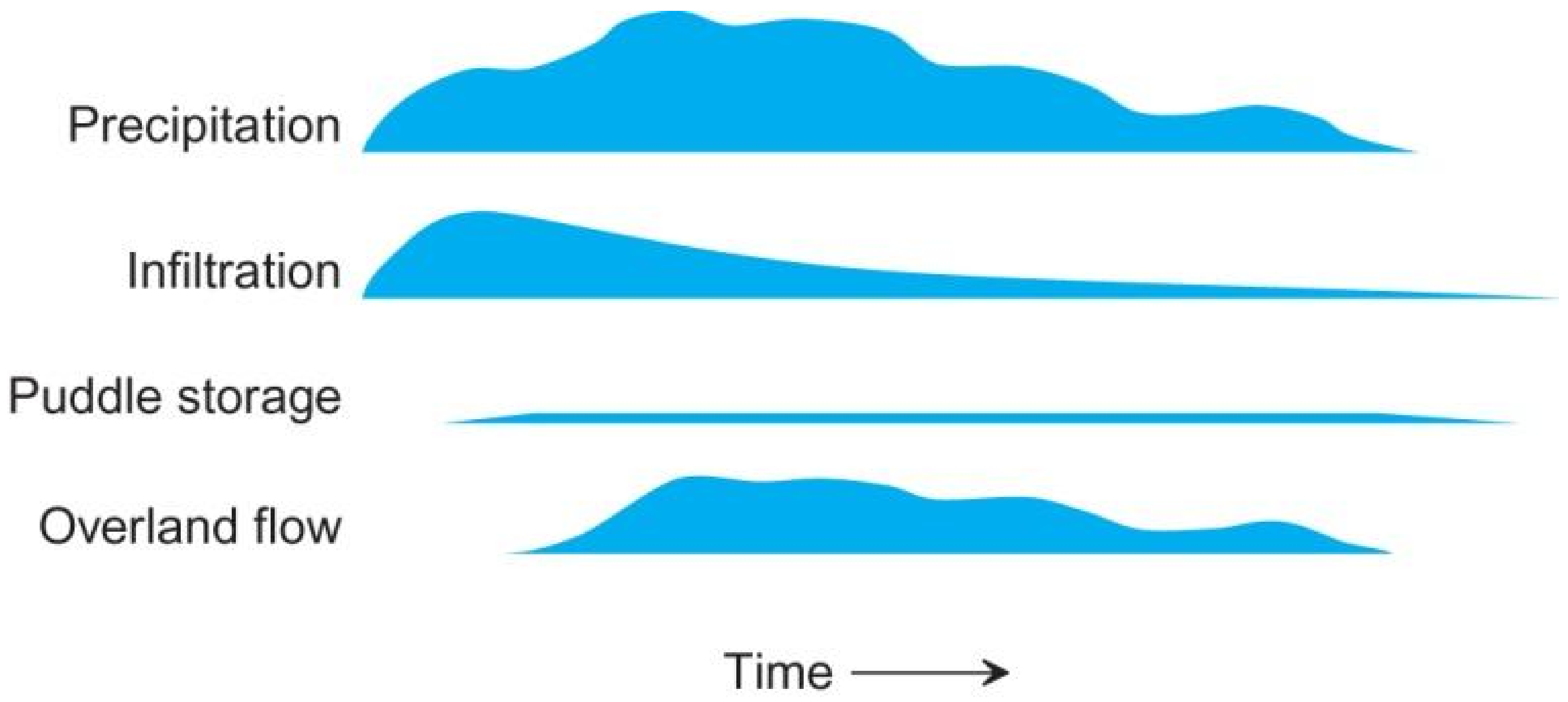
where:

$\Delta S_{\mathrm{unsat}}$ is the storage change in unsaturated zone for the reflected time interval (mm)

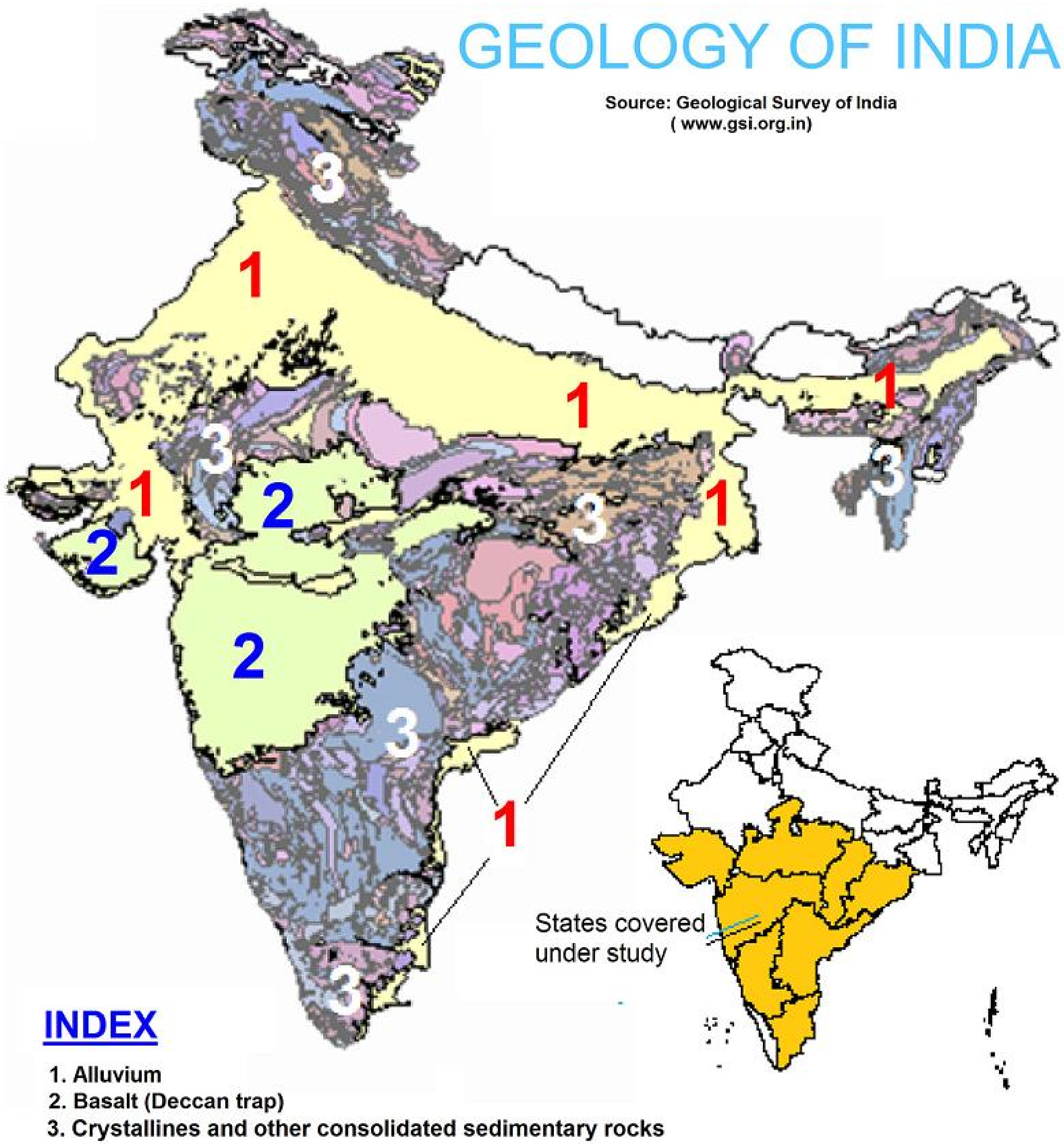
W_{inf} is the amount of recharge entering the zone by infiltration (mm)

W_{cap} is the amount of recharge entering the zone by capillary rise (mm)

Infiltration and Recharge



INDIA


GEOLOGY OF INDIA
Source: Geological Survey of India
(www.gsi.org.in)
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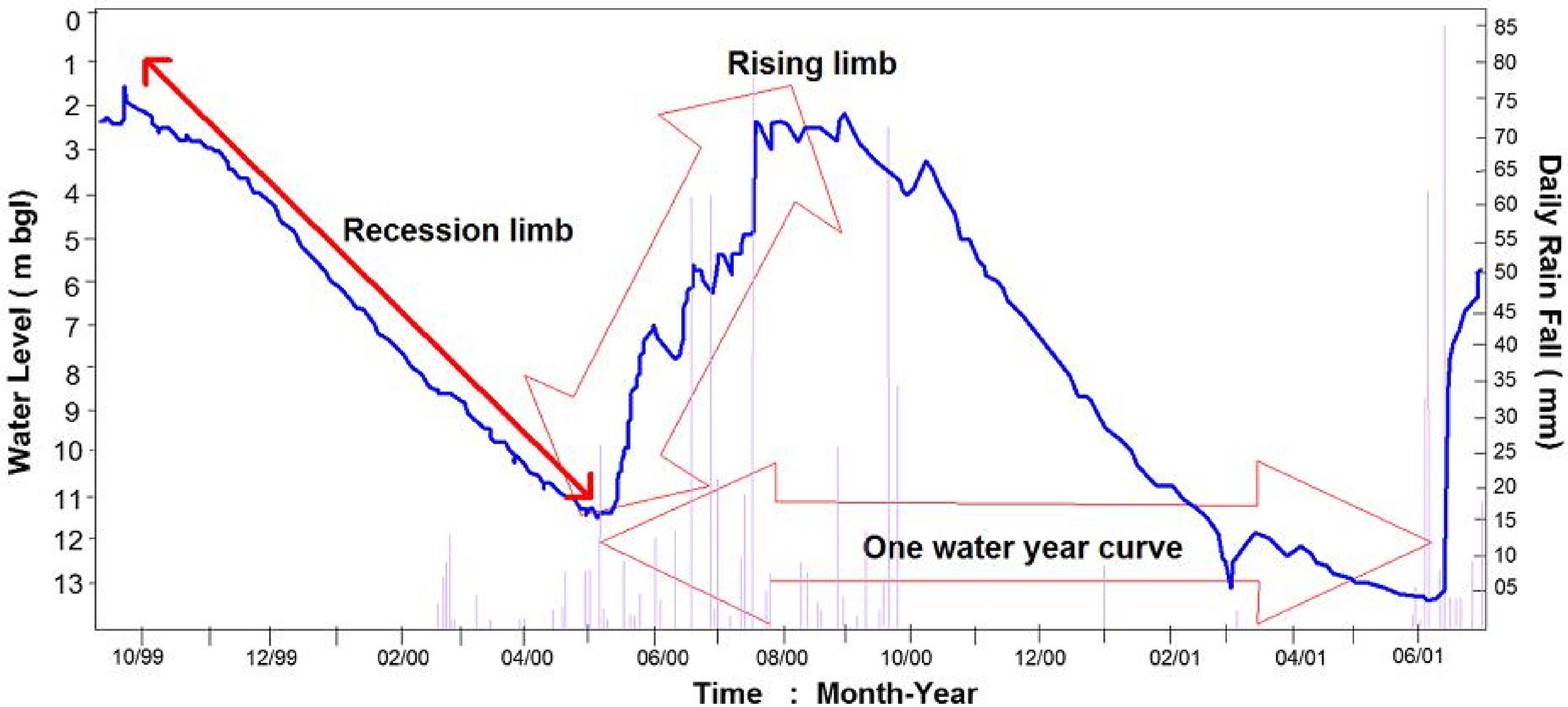
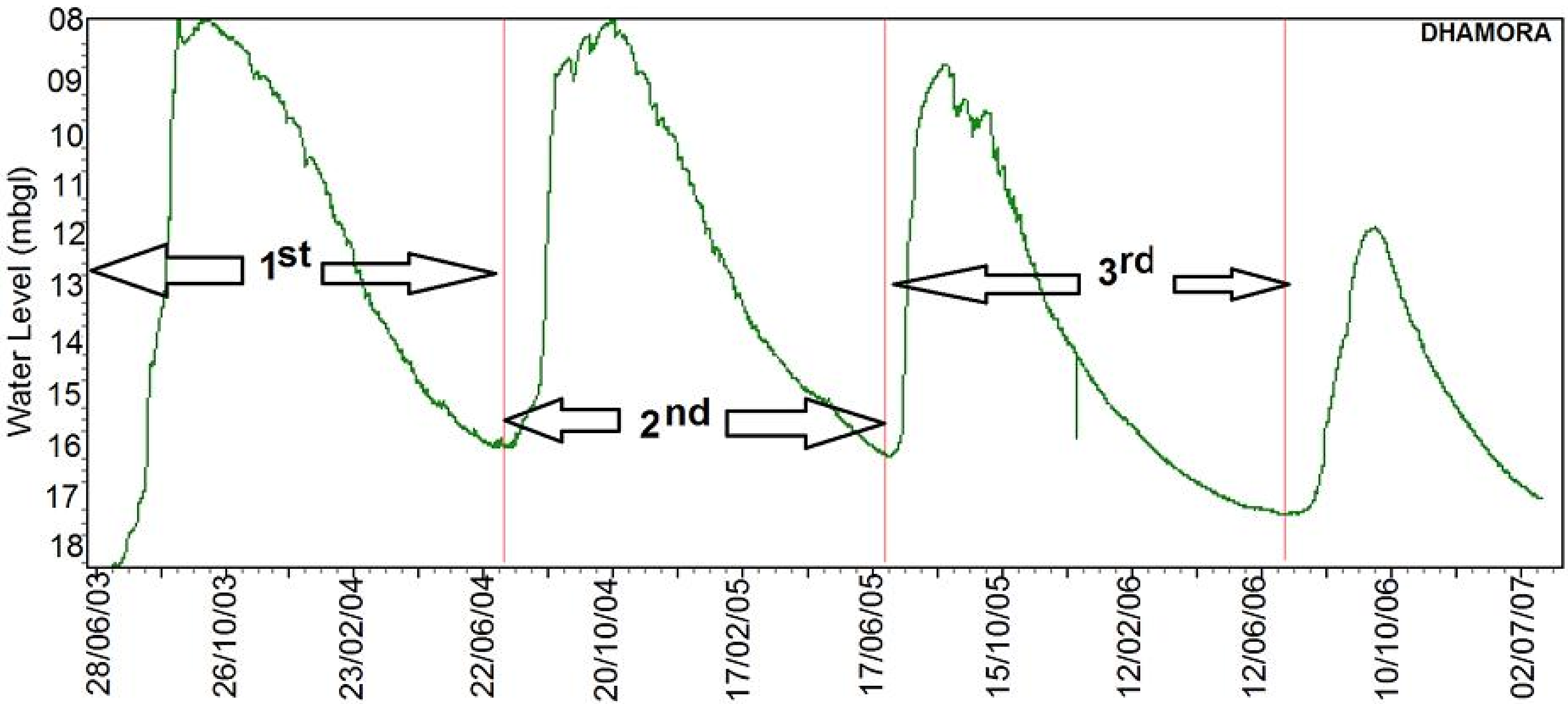
States covered
under study
INDEX
1. Alluvium
2. Basalt (Deccan trap)
3. Crystallines and other consolidated sedimentary rocks

Hydrograph

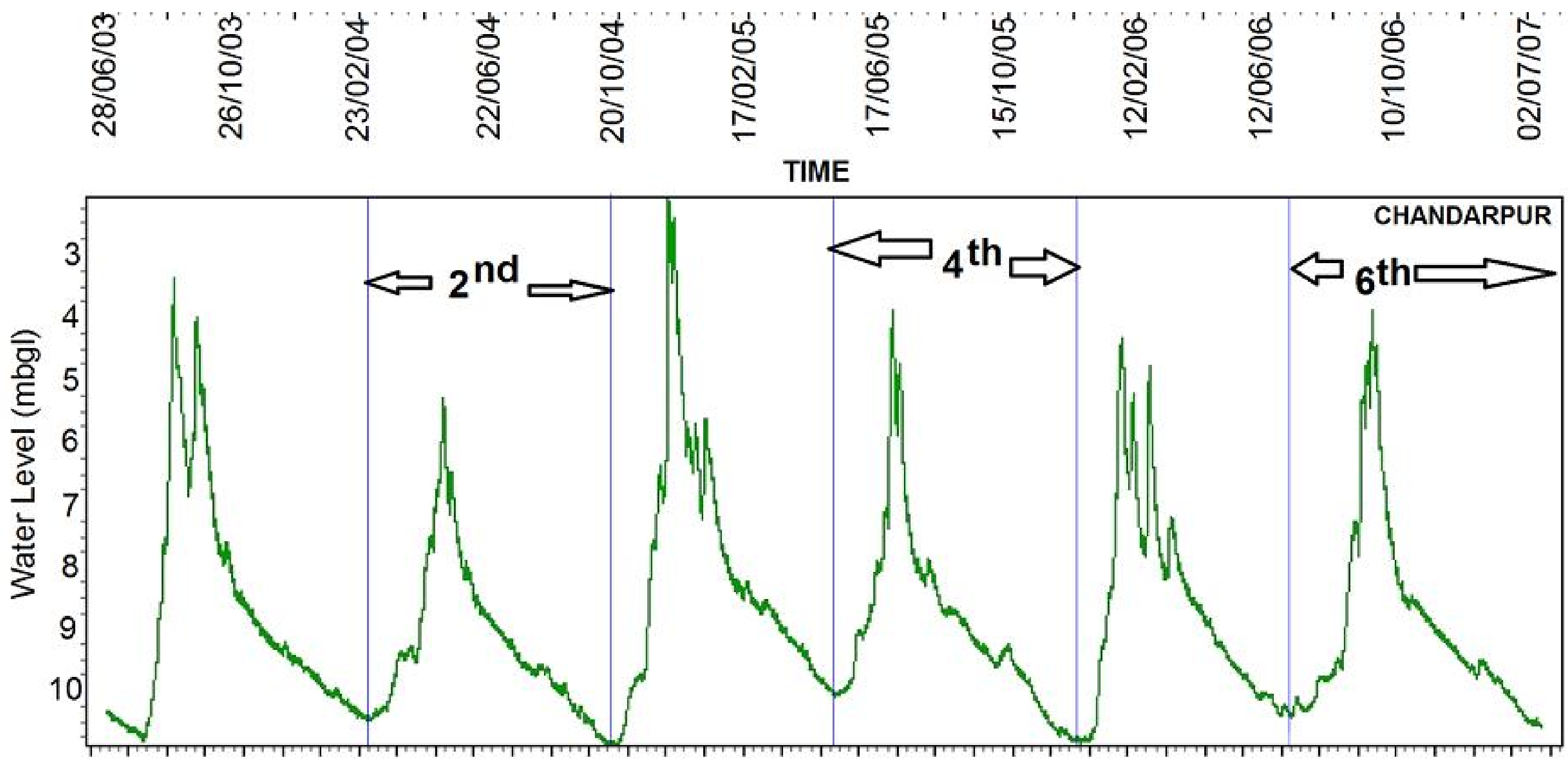


A typical true hydrograph generated from data collected by an automatic water level recorder fitted in a well (piezometer). Note the daily rainfall hyetograph and corresponding rise in water level during monsoon period. Location: Raipur

Hydrograph (Contd.)



Hydrograph (Contd.)

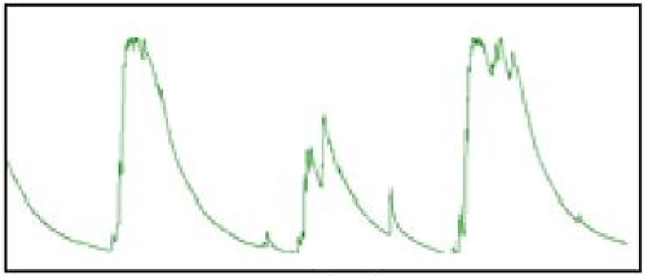


Recharge Phenomenon

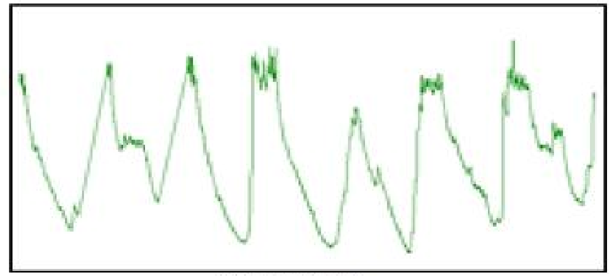
- •In response to monsoon recharge, groundwater rises to its shallowest level, generating the rising limb.
- •Based on the rainfall pattern and amount during monsoon, the peak is shaped per the aquifer character.
- •Hydrograph crests can be described as pointed, flat, or rounded.
- •The order of abundance of crest shape in the Peninsular hard rocks is pointed > flat > rounded
- •The crest shapes are characteristic and do not change for a particular well/piezometer. However, the magnitude or width may vary annually.
- •Pointed crests are either single-peak or multi-peaked.
- •The number of peak/peaks and their width varies annually based on rainfall pattern and quantity.

Crest of True Hydrograph

Pointed Crest

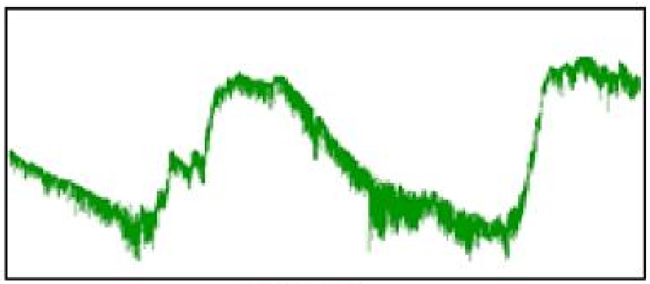


Boath

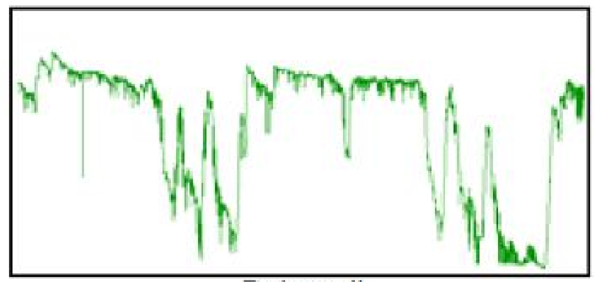


Dandepali

Flat top Crest

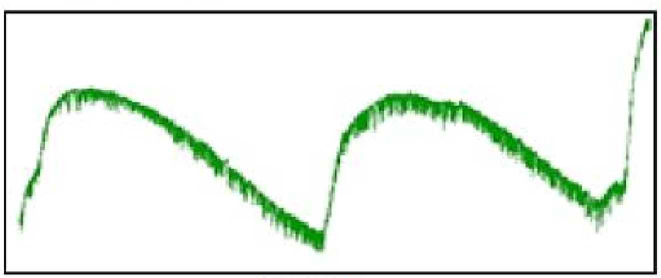


Tongpal

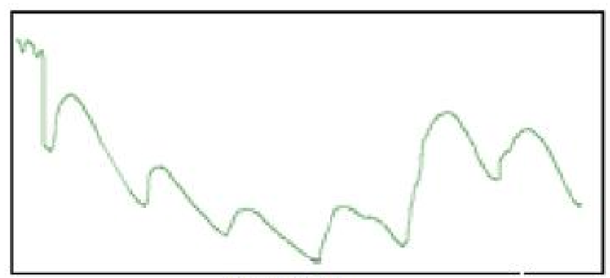


Belvandi

Rounded Crest

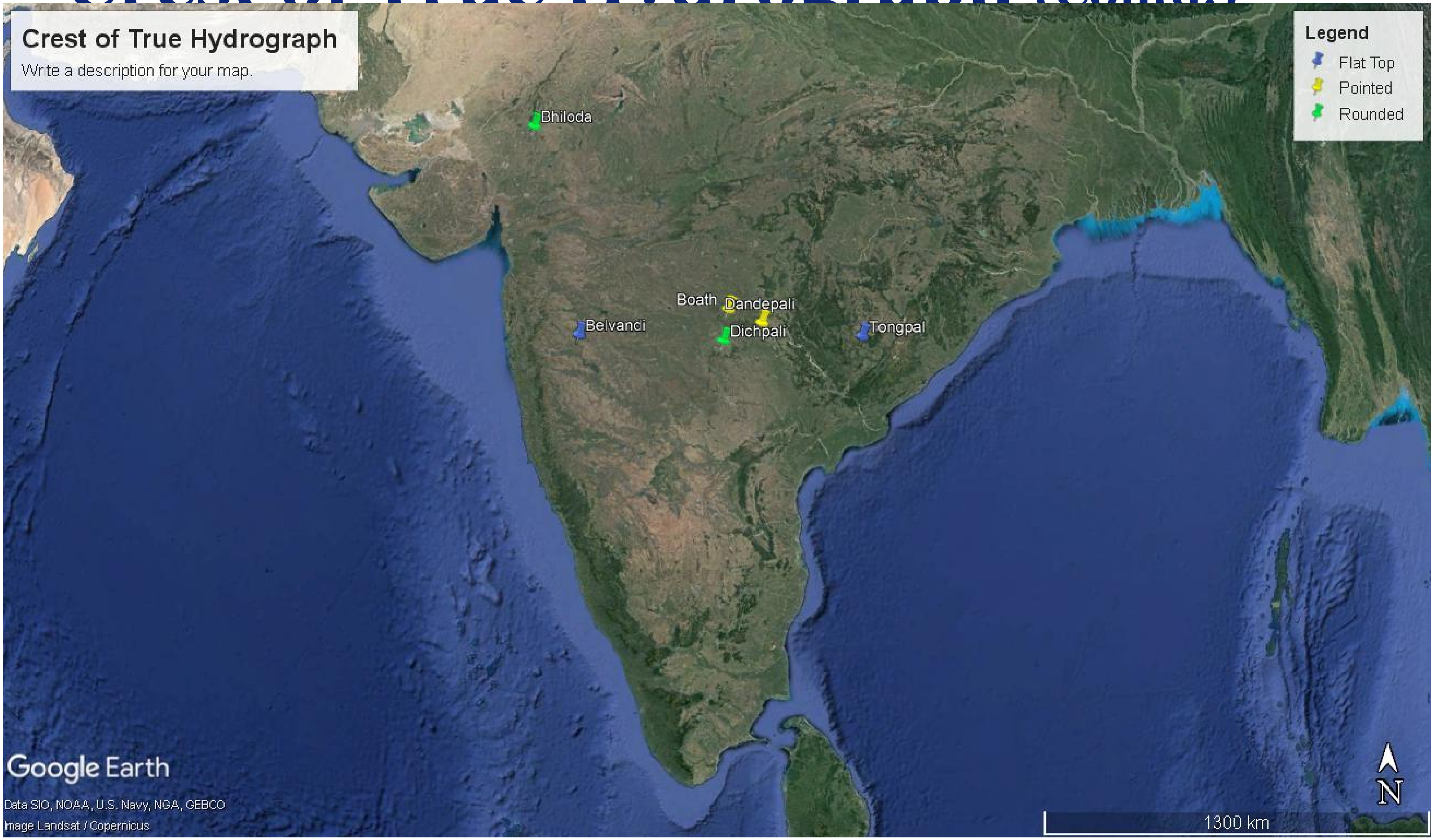


Bhiloda



Dichpali

Crest of True Hydrograph (Contd.)

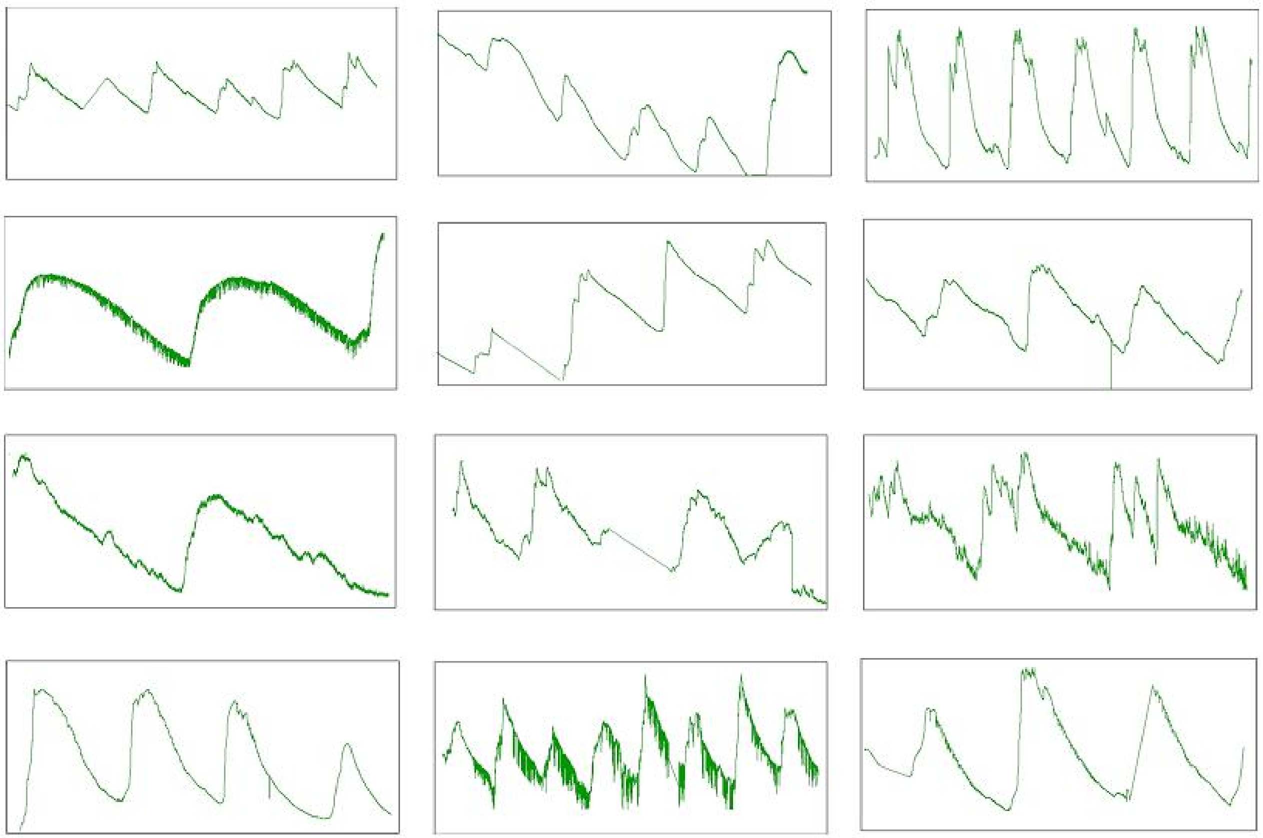


Discharge Phenomenon

- In response to the base flow and or the draft, the water level starts declining after the monsoon thus generating the recession limb.
- The combination of rising and recession limb pattern can be classified into three types, viz.
  - (a) V type curve
  - (b) U type curve
  - (c) S type curve.

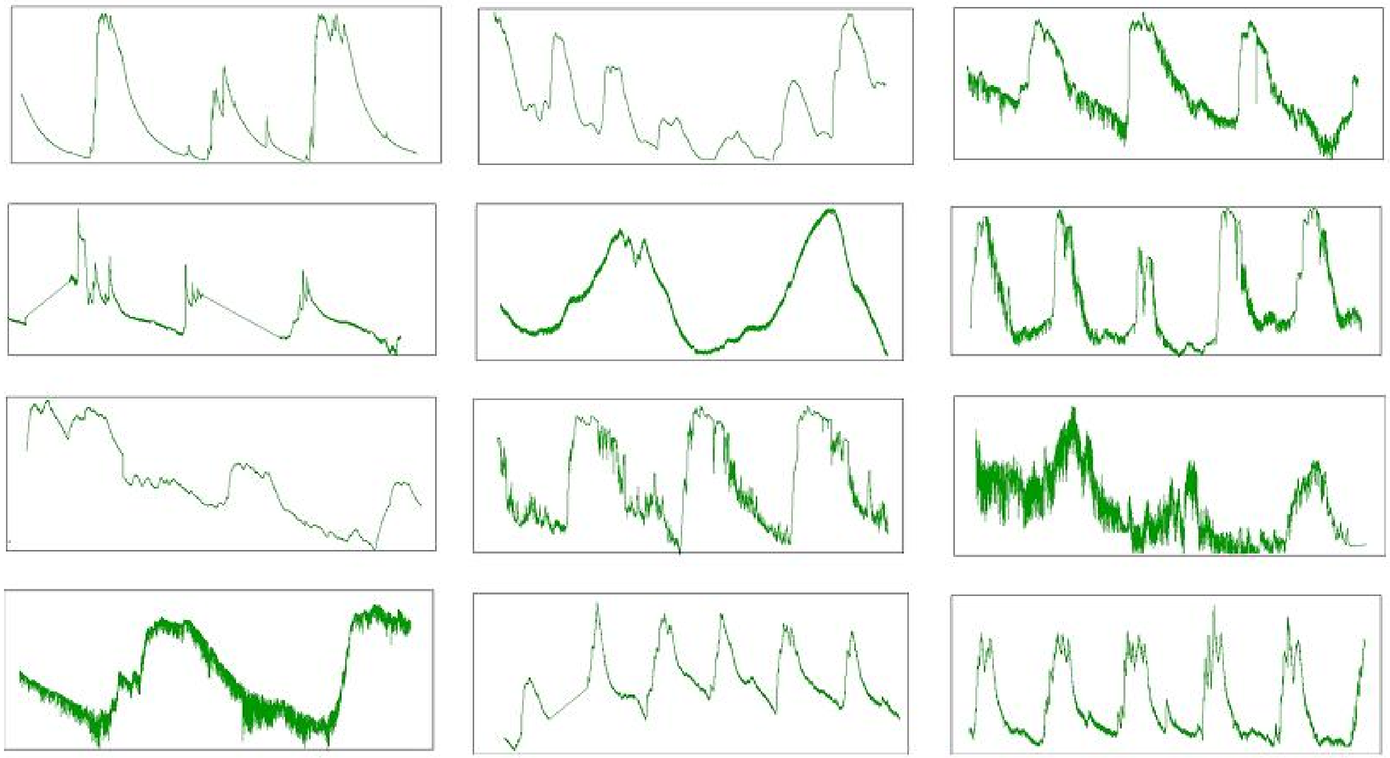
V type curves

- V type curves are those curves where both rising and recession limbs have nearly same slope angle though the rising limbs may sometimes be steeper then recession limbs. Also, they generally don't show any break in slope trend throughout the limb



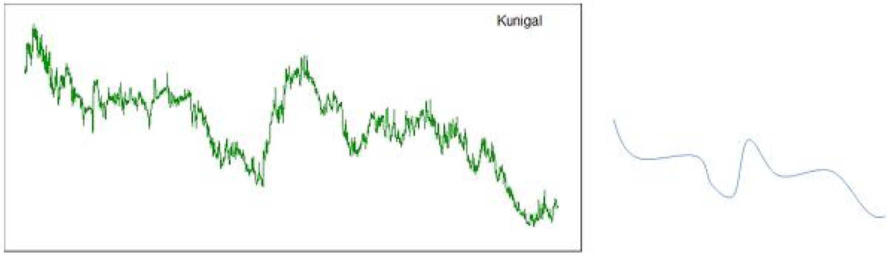
U type curves

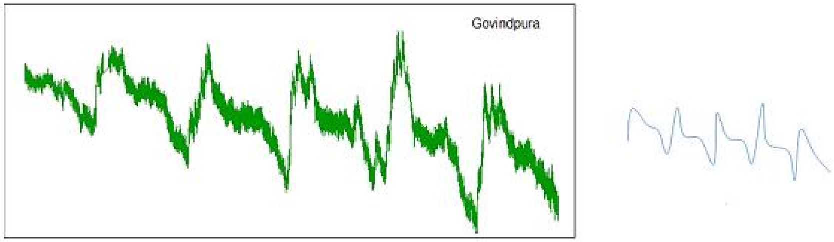
- U type curves are those curves where rising limb has a nearly uniform slope, but the recession limb shows a definite break in the slope. The initial discharge is gentle followed by a fast phase of discharge and then again a slowdown giving rise to U shaped curve.
- Sometimes the slope is initially steep and subsequently gentle after some period of discharge and a combination of U and V type is developed. The lowest part of the trough is not very sharp in angle, rather it is nearly flat or curved.

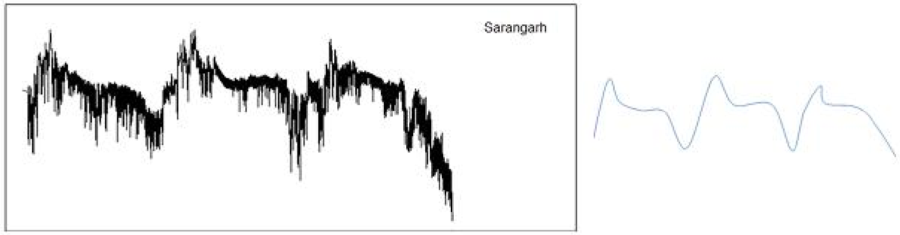


S type curves

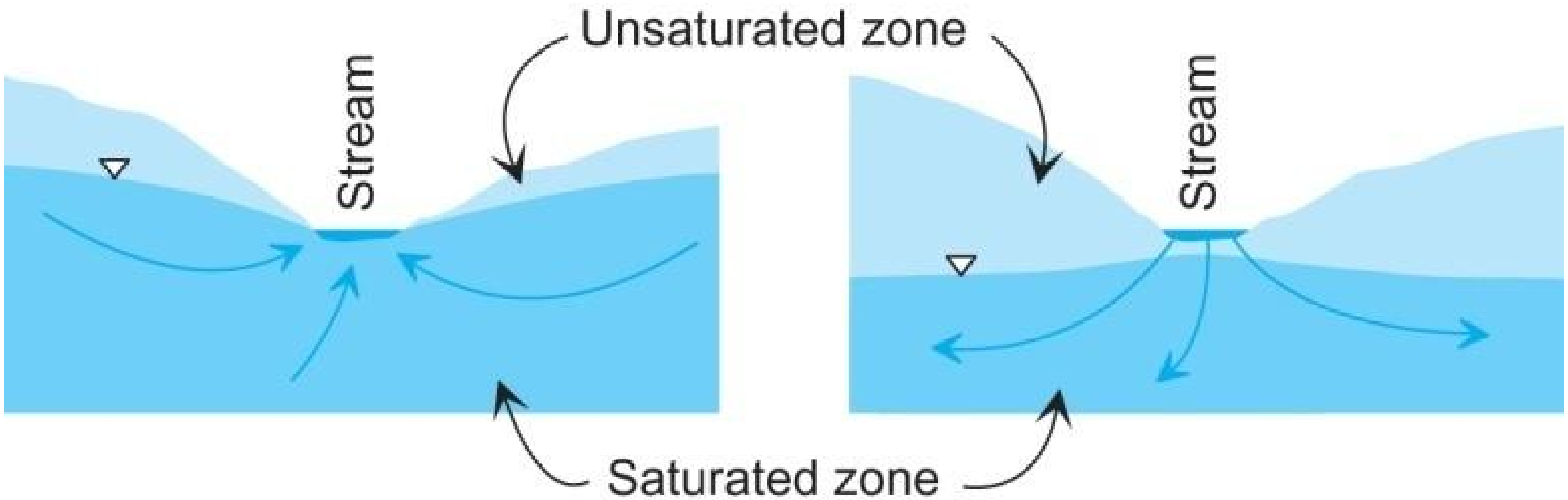
- S type curves are those, which have sharp initial and ultimate-slope of recession limb and in between flat or very gentle slope giving rise to two breaks in the actual slope of the recession limb.
- The S type curves indicate low seasonal fluctuation and are not very common



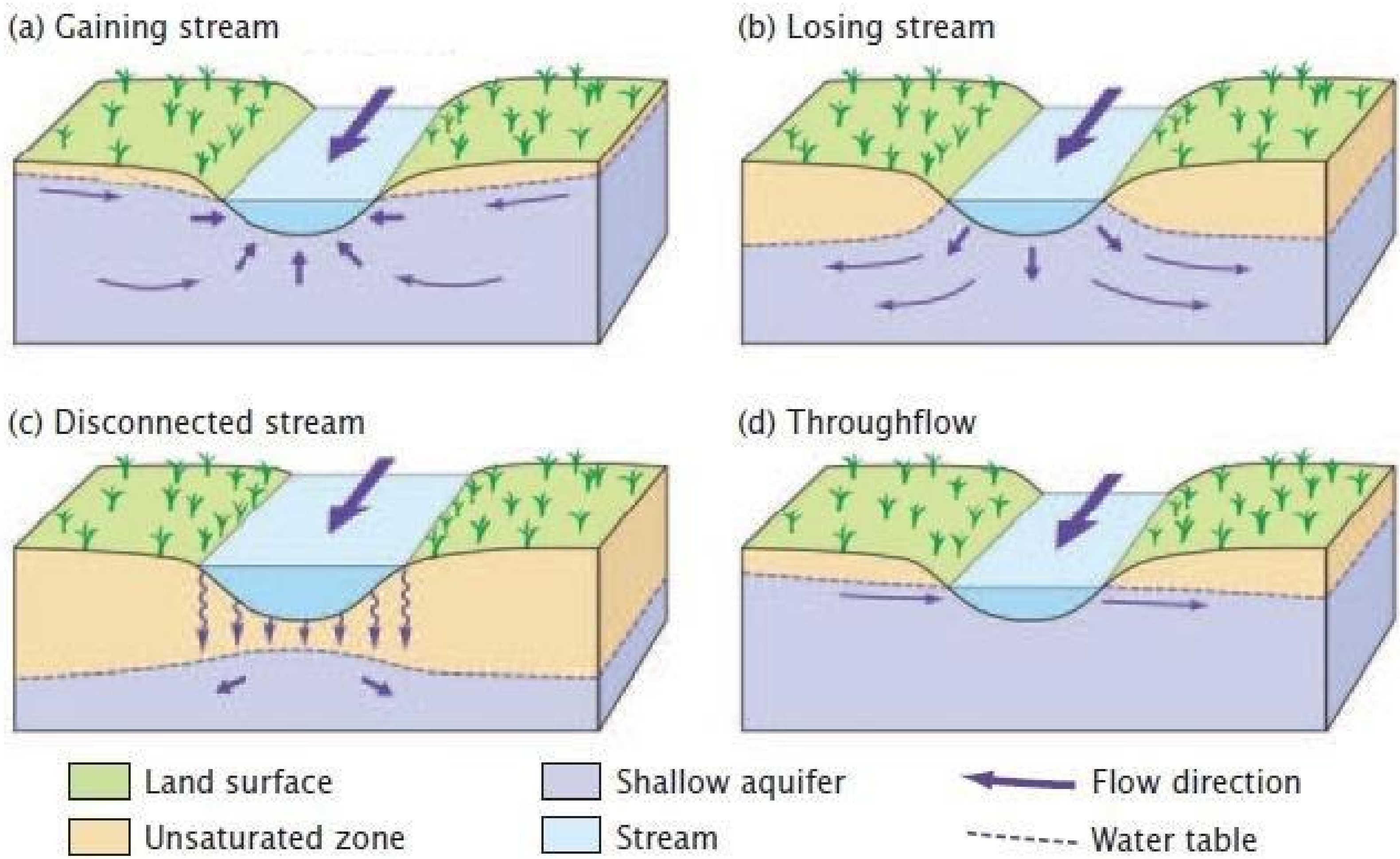




Groundwater Discharge to Surface Water Bodies



Stream-Aquifer Interaction



Learning Strategy

Chapter 1: Groundwater: The Big Picture

Appl Water Sci (2017) 7:801–812
DOI 10.1007/s13201-015-0293-z

CrossMark

ORIGINAL ARTICLE

Aquifer response to recharge–discharge phenomenon: inference from well hydrographs for genetic classification

Arunangshu Mukherjee[1,3] · Anita Gupta[1] · Ranjan Kumar Ray[1] · Dinesh Tewari[2]

Thank you