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Welcome to the course

Applied Hydrology

CENG 6603

Course Outline

Introduction

Precipitation data analysis

- Rainfall Data Processing and Quality Test
- Mean Areal Precipitation:
- Design Storms

Rainfall-Runoff Analysis

- Linear System Theory and Rainfall-Runoff Analysis
- River and Reservoir Flood Routing

Stochastic Analysis of Stream flow

- Hydrologic Statistics
- Statistical test for trend and data quality
- Frequency Analysis
- Stochastic and empirical models

Hydrologic Design Risk and uncertainty Analysis

- Hydrologhical Risks
- Uncertainty Analysis

Advanced Hydrology

- Environmental Hydrology, Eco-hydrology, and Global Climate Change
- Radar and Remote sensing Hydrology
- Isotope Hydrology
- Hydrological Information System

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TEXTBOOKS AND REFERENCES

- APPLIED HYDROLOGY I: DETERMINISTIC HYDROLOGY, Notes based on Professor J.E. Nash's Lectures
- Baxter E. Vieux (2004): **DISTRIBUTED HYDROLOGIC MODELING USING GIS,** Water Science and Technology Library, Volume 48 2004, ISBN: 978-1-4020-2459-7 (Print) 978-1-4020-2460-3 (Online)
- Bras, R. L. (1990). **HYDROLOGY - AN INTRODUCTION TO HYDROLOGIC SCIENCE**, Addison-Wesley Publishing Co.
- Chong-yu Xu (2002) **TEXTBOOK OF HYDROLOGIC MODELS ,** Uppsala University, Department of Earth Sciences and Hydrology
- **Chow, V. T., Maidment, D. R., Mays, L. W. (1988) APPLIED HYDROLOGY, McGraw-Hill Book Co.**
- Eagleson, P. S. (1970). **DYNAMIC HYDROLOGY**, McGraw-Hill Book Co.
- Keith J. Beven (2009), **ENVIROMENTAL MODELING: AN UNCERTAIN FUTURE?** 1ST Edition, ISBNI3: 978-0-415-46302-7, Routledge, 2 park Square, Milton park, Abingdom
- **Keith J. Beven (2012), RAINFALL-RUNOFF MODELLING: THE PRIMER, 2nd Edition, ISBN: 978-0-470-71459-1, 488 pages, February 2012, Wiley-Blackwell**
- Lee, K.T. and Yen, B.C. (1997). "**GEOMORPHOLOGY AND KINEMATIC-WAVE BASED HYDROGRAPH DERIVATION,"** J. Hydraulic Engrg., ASCE, 123(1), 73-80.
- Lee, K. T., Chang, C.-H. (2005). **"INCORPORATING SUBSURFACE-FLOW MECHANISM INTO GEOMORPHOLOGY-BASED IUH MODELING."** J. Hydrology, 311, 91-105
- McCuen, Richard H (1998). **HYDROLOGIC ANALYSIS AND DESIGN**, 2ed, Prentice Hall Upper Saddle River, New Jersey 074
- Paul J. Wood, David M. Hannah , Dr Jonathan P. Sadler (Editors)(2007) **HYDROECOLOGY AND ECOHYDROLOGY: PAST, PRESENT AND FUTURE,** 1st Edition, John Wiley & Sons Ltd
- Rao A. Ramachandra (2000) **FLOOD FREQUENCY ANALYSIS,** CRC Press. Boca Raton, London New work, Washington D.C.
- Yen, B. C. and Lee, K. T. (1997). **"UNIT HYDROGRAPH DERIVATION FOR UNGAUGED WATERSHEDS BY STREAM-ORDER LAWS,"** J. Hydrologic Engrg., ASCE, 2(1), 1-9.

Course Handling

Expectation

- Upon completion of the course, Students will be able to:
  - Understand basic hydrologic processes with their driving forces
  - Process quality time series and areal rainfall
  - Analysis the hydrograph based on linear and nonlinear theory and modeling
  - Perform River and Reservoir Routing
  - Evaluate the different risks possibly encountered through hydrological design
  - Evaluate the uncertainties of parameters to be attended the natural system Understand basic ground water concepts
  - be aware on the future trends of hydrology

Delivery system

- Lecture (Instructor leading)
- Assignments, Reviews and Projects presentation (Student leading)

Communication

- possible in
  - Email: (**bb_academy@yahoo.com**)
  - on face at class and office
  - **but not in phone except for class issue**
- **Evaluation**

– Assignments	30%
– Projects	20%
– Final Exam	50%

WORDS of the Day

The secret of getting ahead is getting started

Mark Twain

Chapter One : Introduction

Hydrologic Cycle and water budget equation

Hydrological Process

- Basic drivers of hydrological processes
- Infiltration Excess Hydrological Process
- Saturation Excess hydrological process

General System Model,

- Descriptive vs. Predictive,
- Single vs. Multiple Events,
- Lumped vs. Distributed Models
- Stochastic vs. Deterministic Models

Basics of Hydrology

- **The "Golden Rule" of hydrology.....**

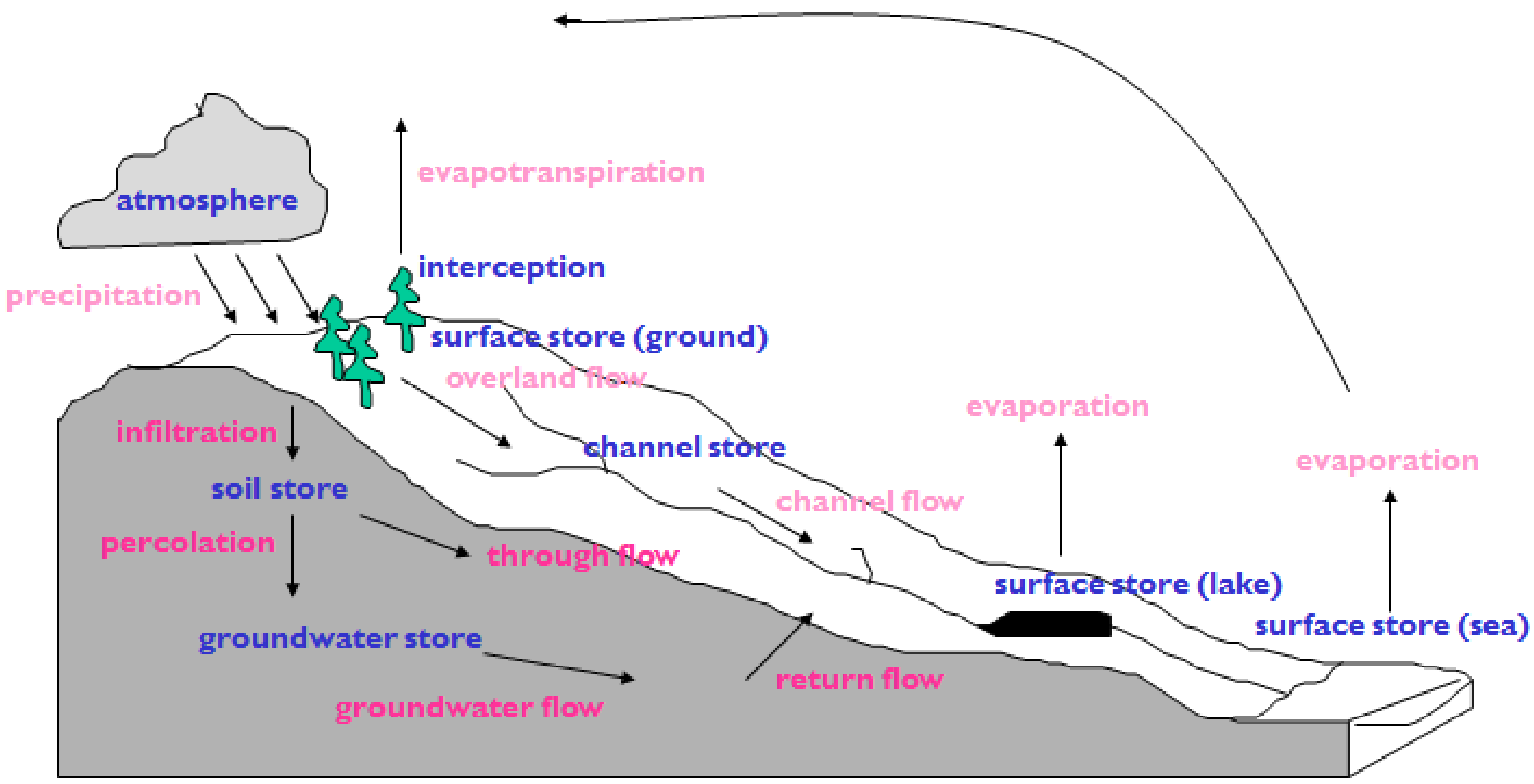
  "water flows down hill"

  - under force of gravity
  - But, may move up through system via:
    - capillary action in soil
    - hydraulic pressure in groundwater aquifers
    - evapotranspiration

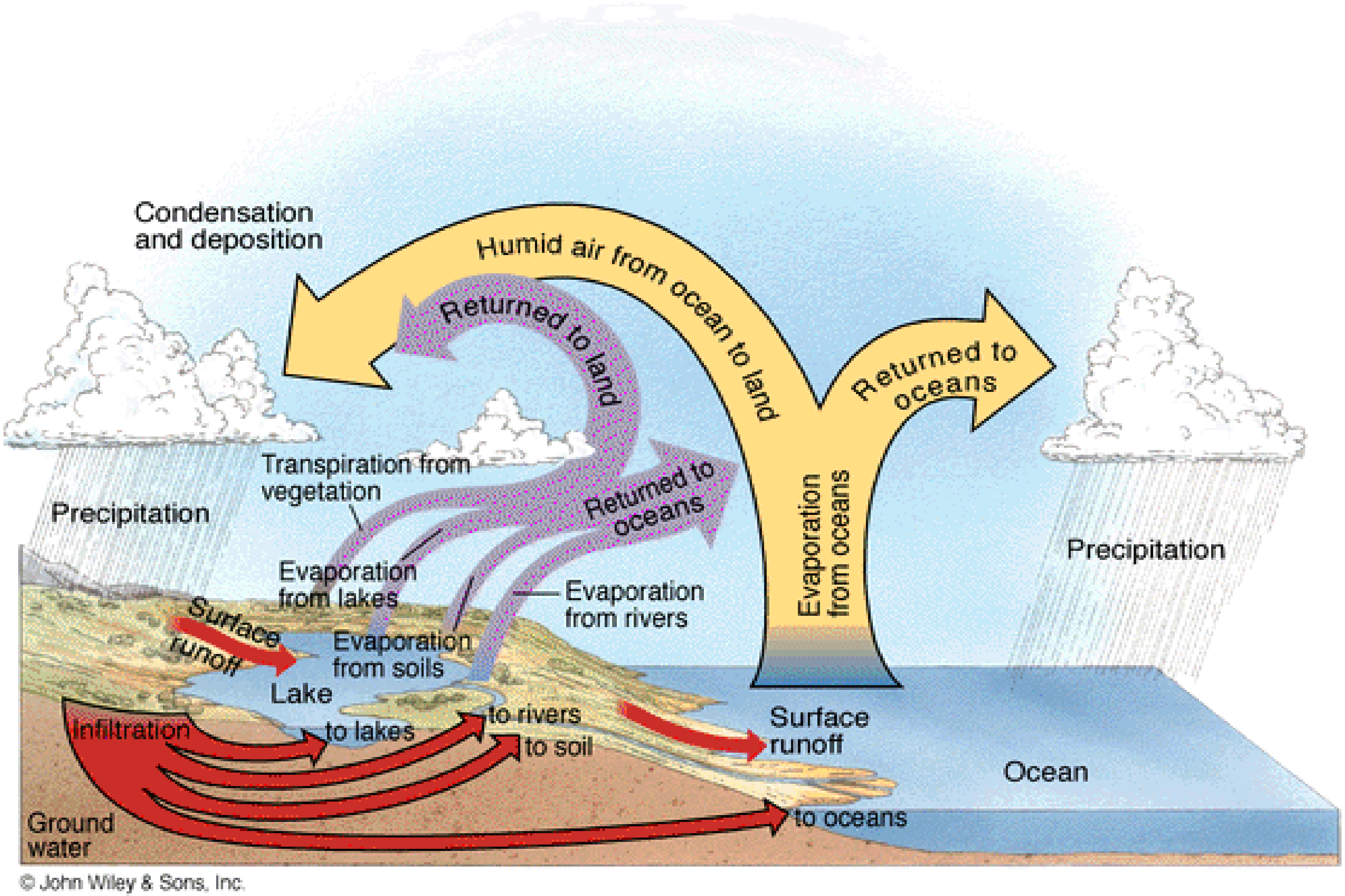
The hydrological cycle

- Representation of:
  - flows
    - water
    - energy
    - suspended/dissolved materials
  - inputs/outputs to/from sub-systems
    - catchment/watershed
    - atmosphere
    - water stores (soil, bedrock, channel, etc.)

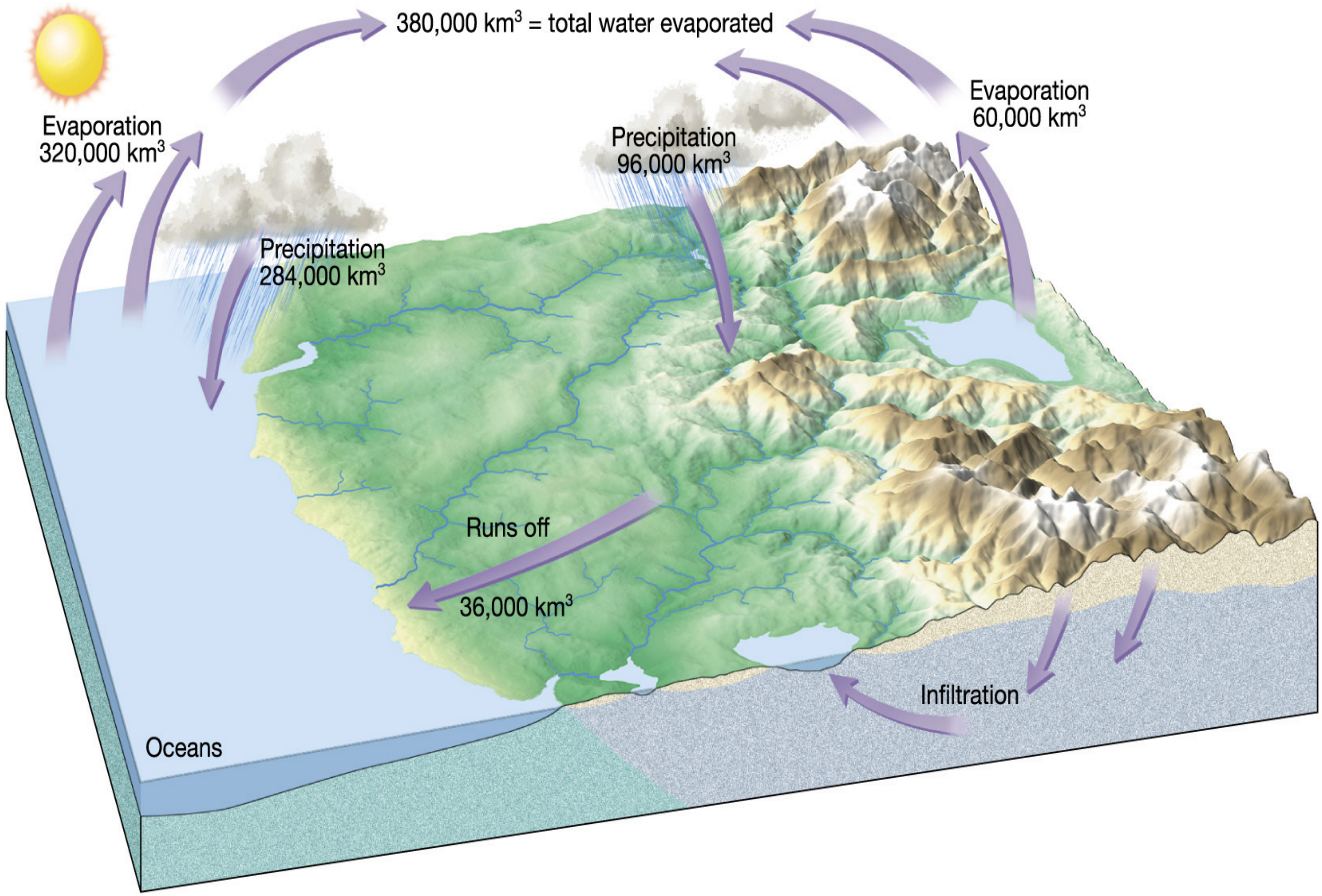
HYDROLOGICAL CYCLE: Standard concept



HYDROLOGICAL CYCLE:
System Circulation

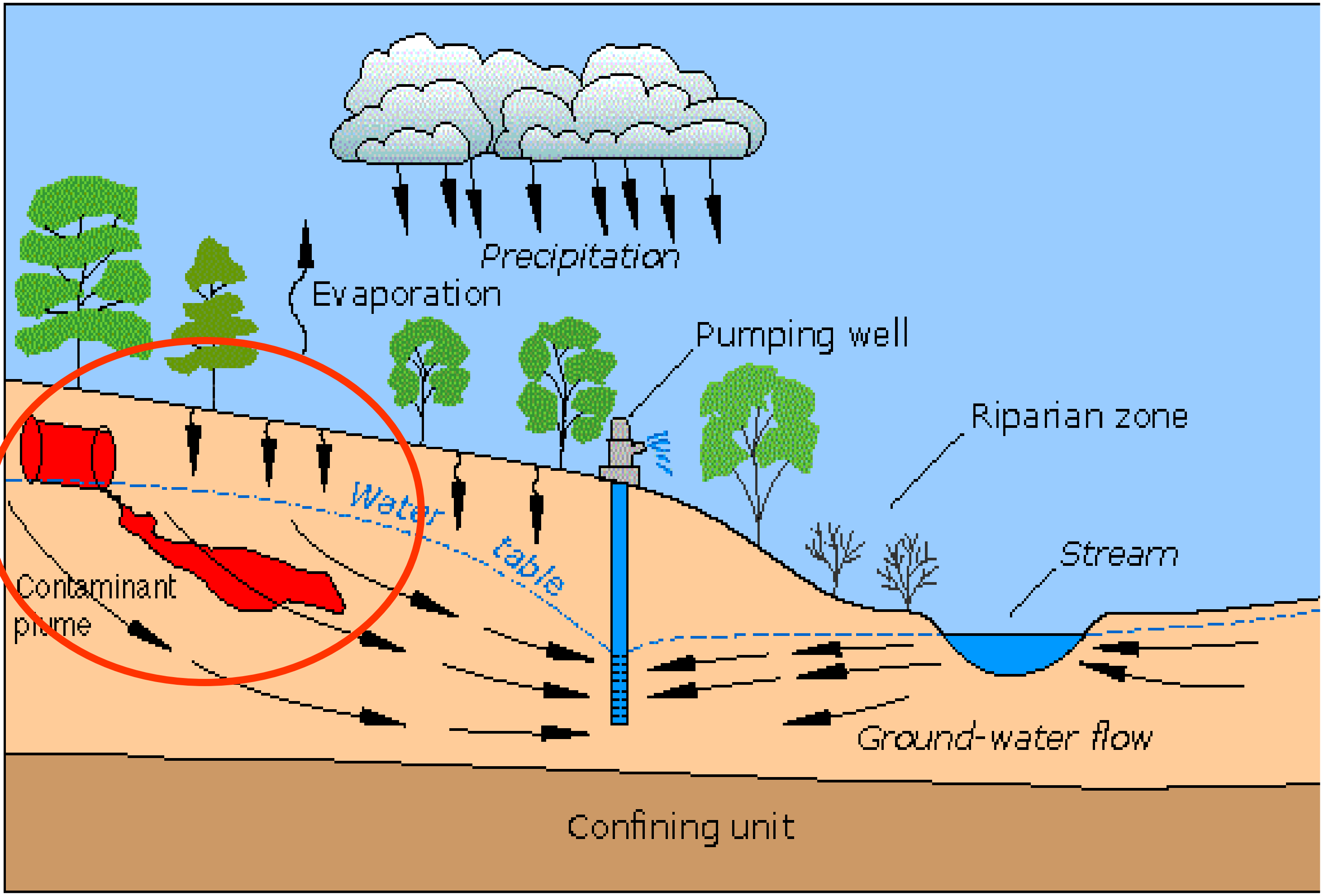


HYDROLOGICAL CYCLE: Quantified



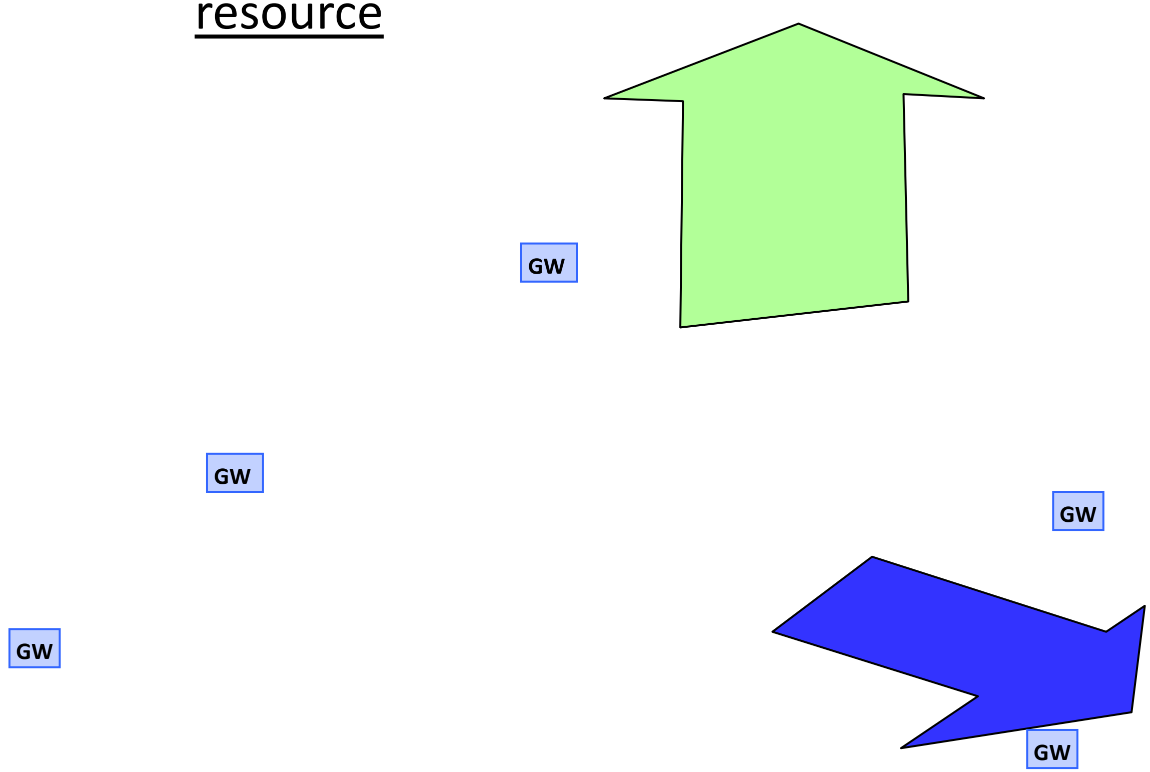
HYDROLOGICAL CYCLE:

Quality Aspect



HYDROLOGICAL CYCLE:
Blue and Green Water - perspective

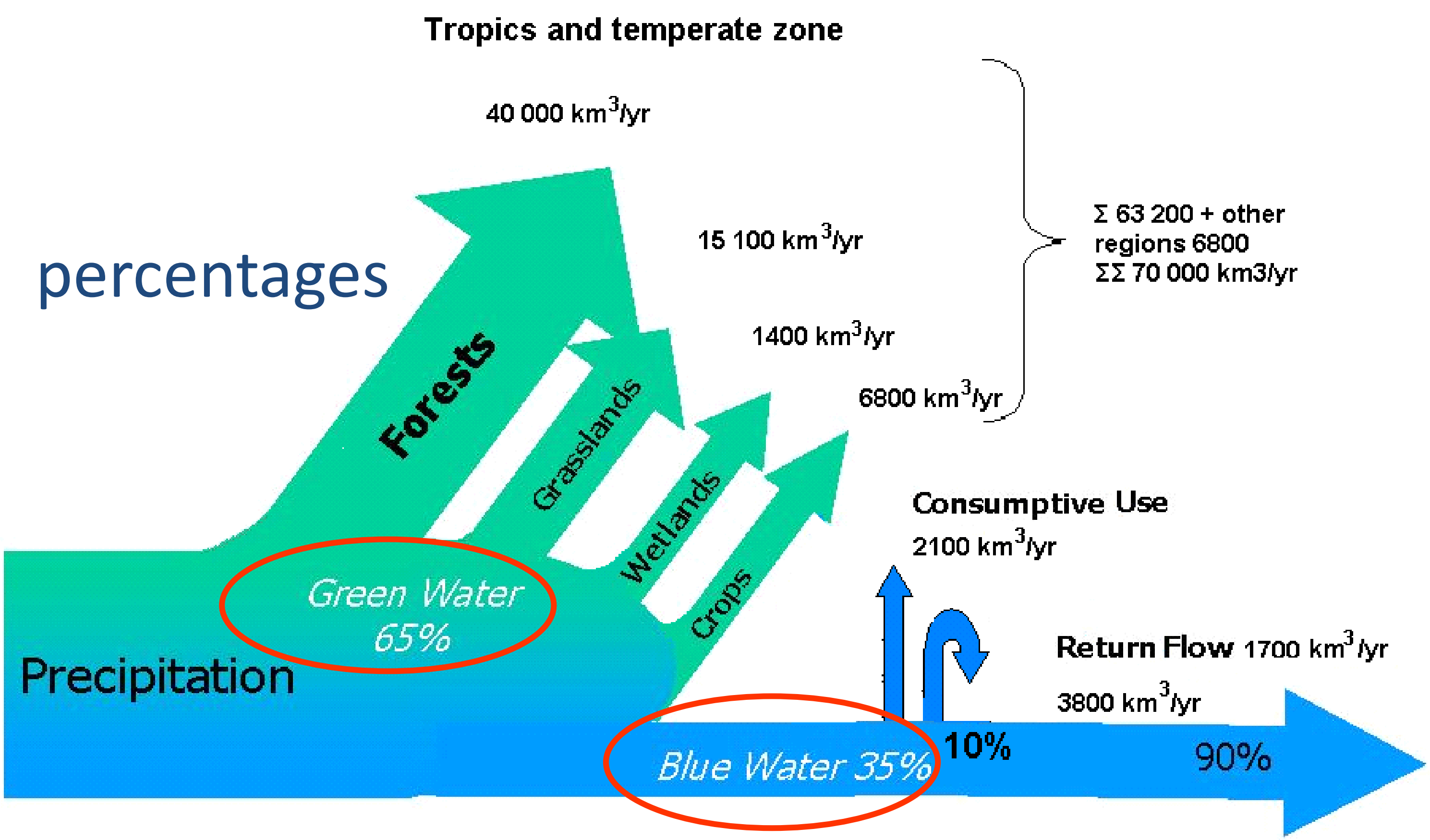
Precipitation – the basic water resource



Adapted from: GWP (M. Falkenmark), 2003, Water Management and Ecosystems: Living with Change

HYDROLOGICAL CYCLE:

Blue and Green Water – Pathways



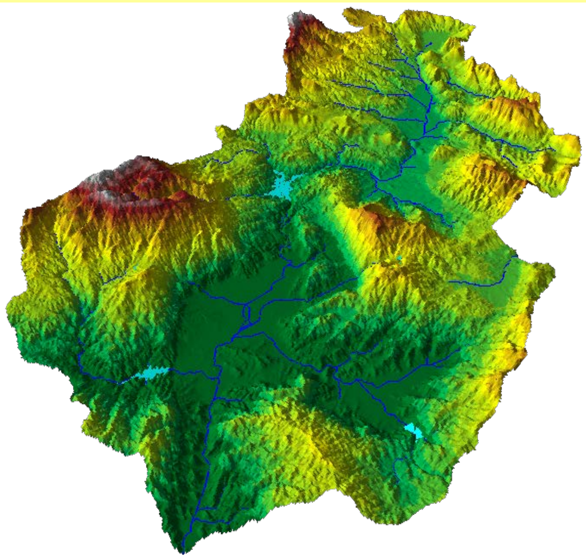
Consumptive water use by terrestrial ecosystems as seen in a global perspective. (Falkenmark in SIWI Seminar 2001).

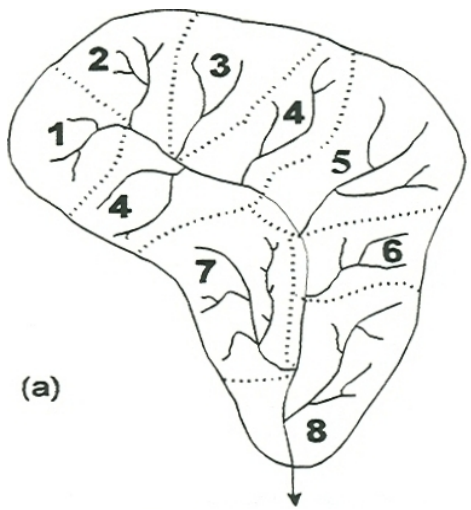
Water Budget Equation

Mass in flow – Mass outflow = Change in storage

$$P - Q - G - ET - \Delta S = 0$$

P = Precipitation
Q = Stream discharge
G = Groundwater Discharge
ET = Evapo-transpiration
ΔS = Change in Storage

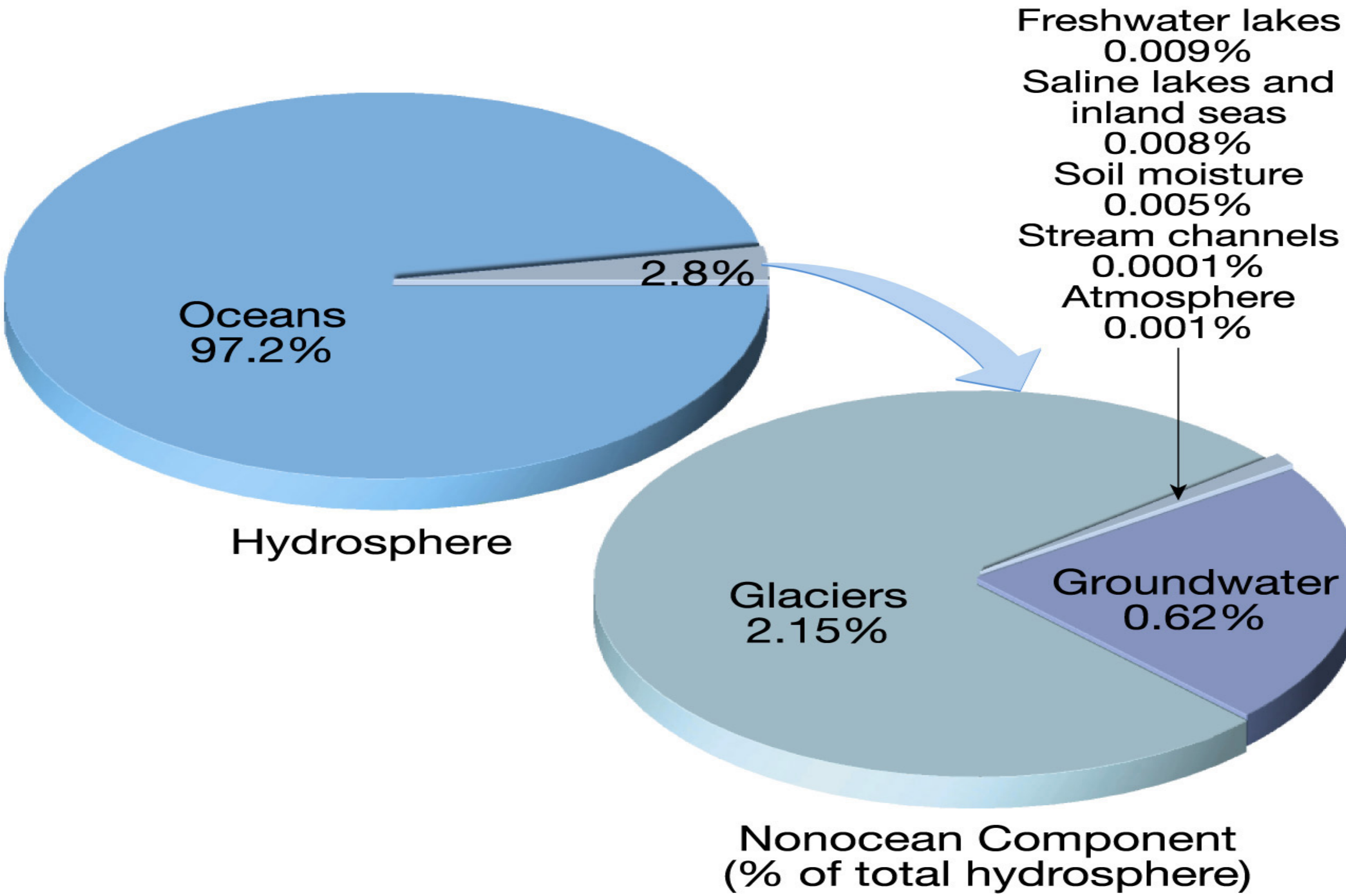




The Earth's Water Distribution

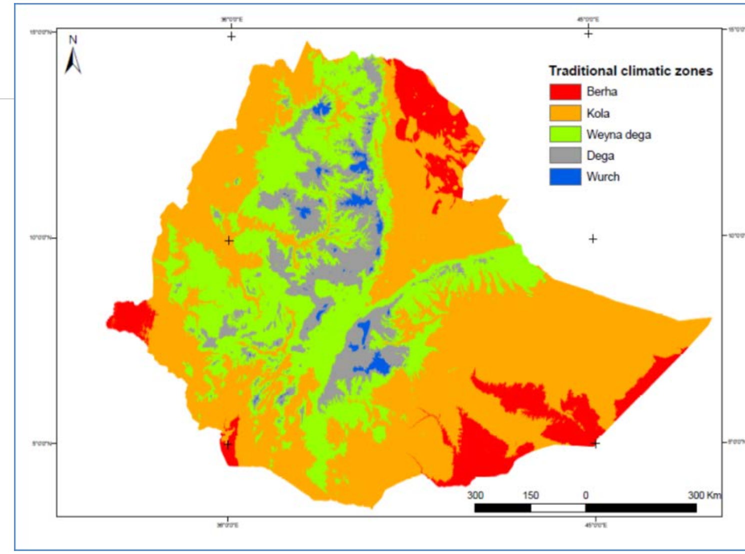
- 97% of the water on earth is in the oceans
- Only 3% of the water on earth is freshwater
- About 2.4% of the freshwater on earth is permanently frozen in glaciers and at the polar ice caps
- About 1/2 of 1 % of the water on earth is groundwater
- Only about 1/100 of 1% of the water on earth is in the rivers and lakes

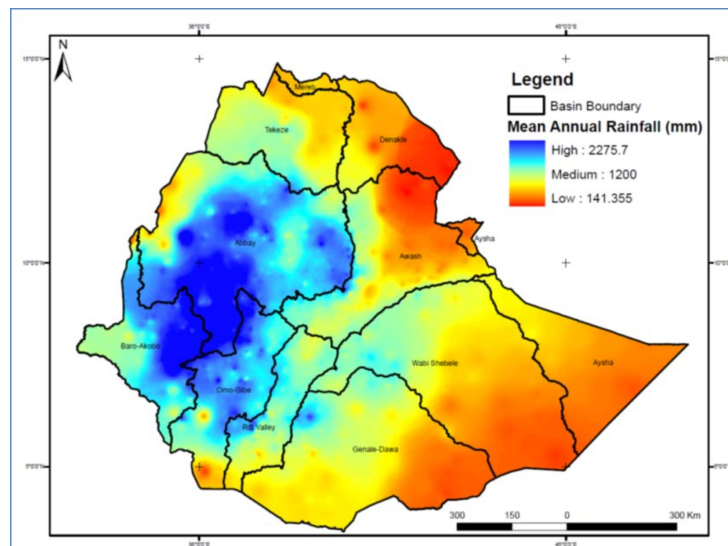
World Water


Freshwater lakes
0.009%
Saline lakes and
inland seas
0.008%
Soil moisture
0.005%
Stream channels
0.0001%
Atmosphere
0.001%
2.8%
Oceans
97.2%
Hydrosphere
Glaciers
2.15%
Groundwater
0.62%
Nonocean Component
(% of total hydrosphere)

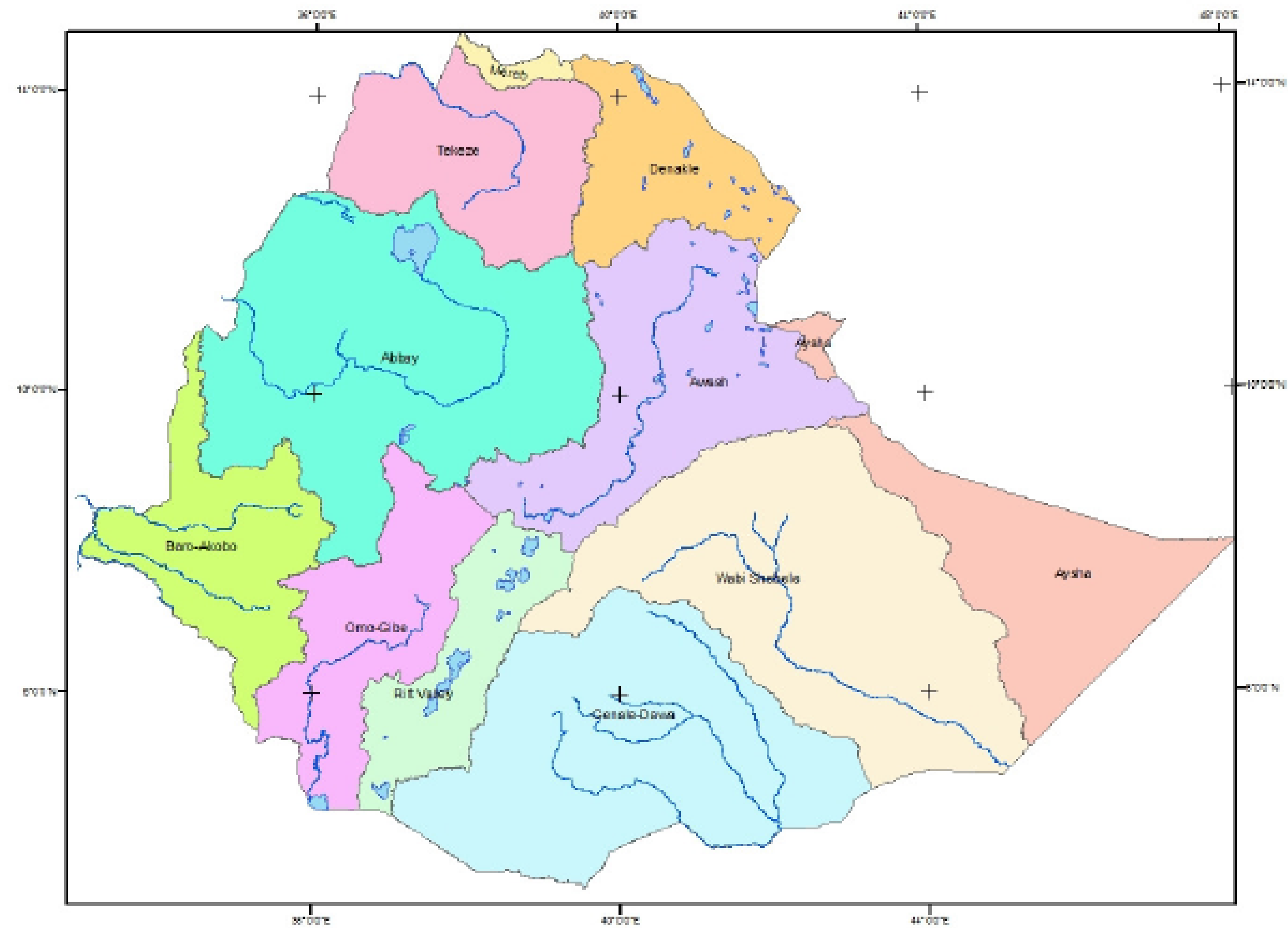
ETHIOPIA

- **Area:** 1.13million square kilometer (1,119,683km² of dry land and 7,444km² water)
- **Altitude:**
  - 125m below sea level (Danakil Depression) and
  - 4600m above sea level (Ras Dashen Mountain)
- **Temp:**
  - Mean annual temperature between $15^0 – 20^0$
- **Rainfall:**
  - Mean annual rainfall 200– 2200mm





ETHIOPIA MAJOR BASINS



ETHIOPIA WATER RESOURCE

Basin	Basin Area		Surface water potential		Ground water potential	
	Sq.Km	% of total	X10^9 m3/yr	% of total	X10^6 m3/yr	% of total
Abbay	204000	18.00	52.62	47.07	1800	70.86
Omo-Ghibe	79000	7.00	17.96	16.06	100	3.94
Baro-Akobo	75912	6.70	11.81	10.56	130	5.12
Tekeze	86500	7.63	8.20	7.33	200	7.87
Genale-Dawa	171042	15.10	5.88	5.26	30	1.18
Rift Valley	52739	4.65	5.63	5.04	100	3.94
Awash	112696	10.00	4.60	4.11	140	5.51
Wabi Sheble	202697	17.84	3.16	2.83	40	1.57
Ogaden	77121	6.80	0.86	0.77	-	-
Denakil	62882	5.54	0.86	0.77	-	-
Mereb	5900	0.52	0.65	0.58	-	-
Aysha	2223	0.20	0.22	0.02	-	-
	1133880		111.8		2540	

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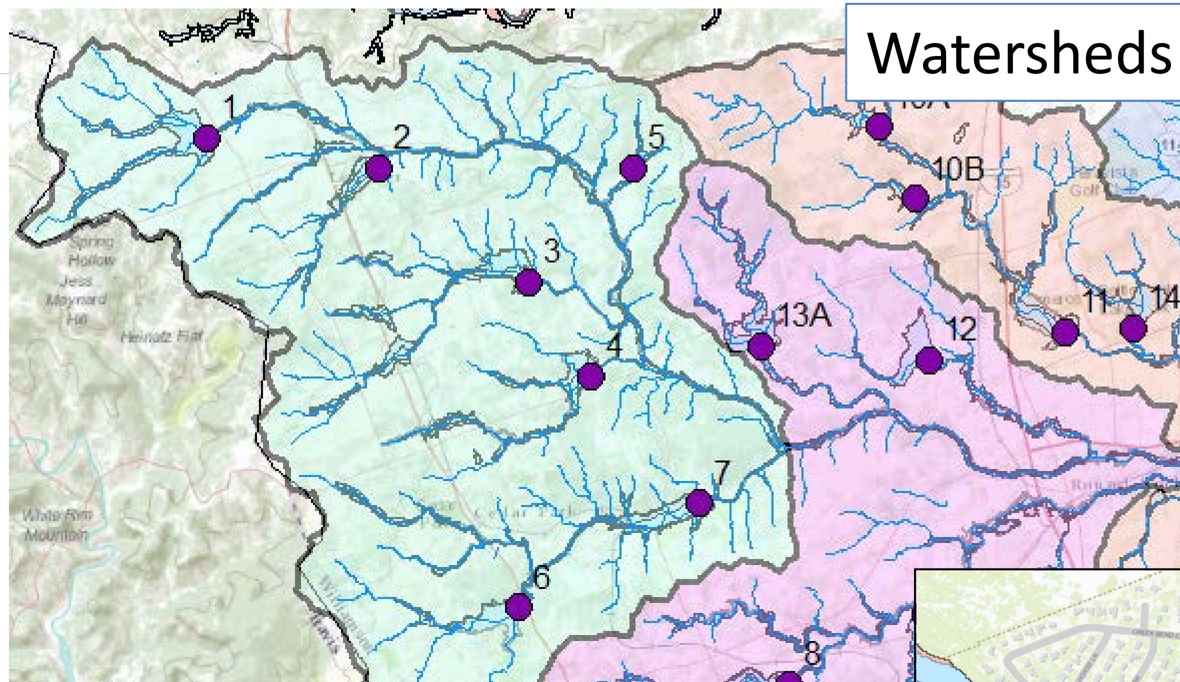
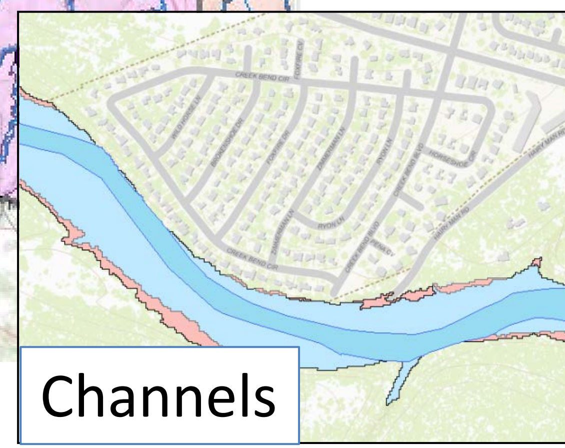
Hydrologic System



Watersheds

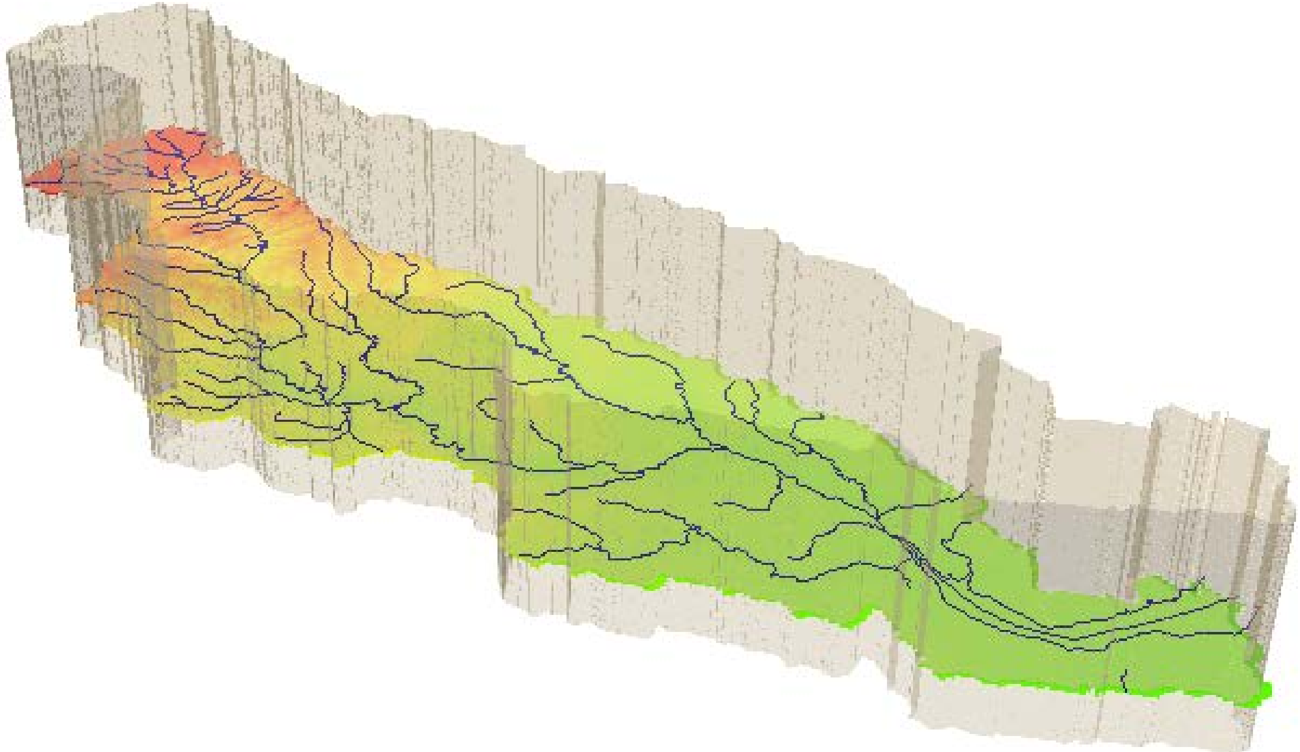
Reservoirs



Channels

We need to understand how all these components function together

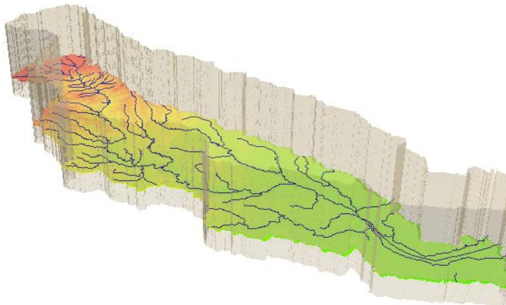
Hydrologic System

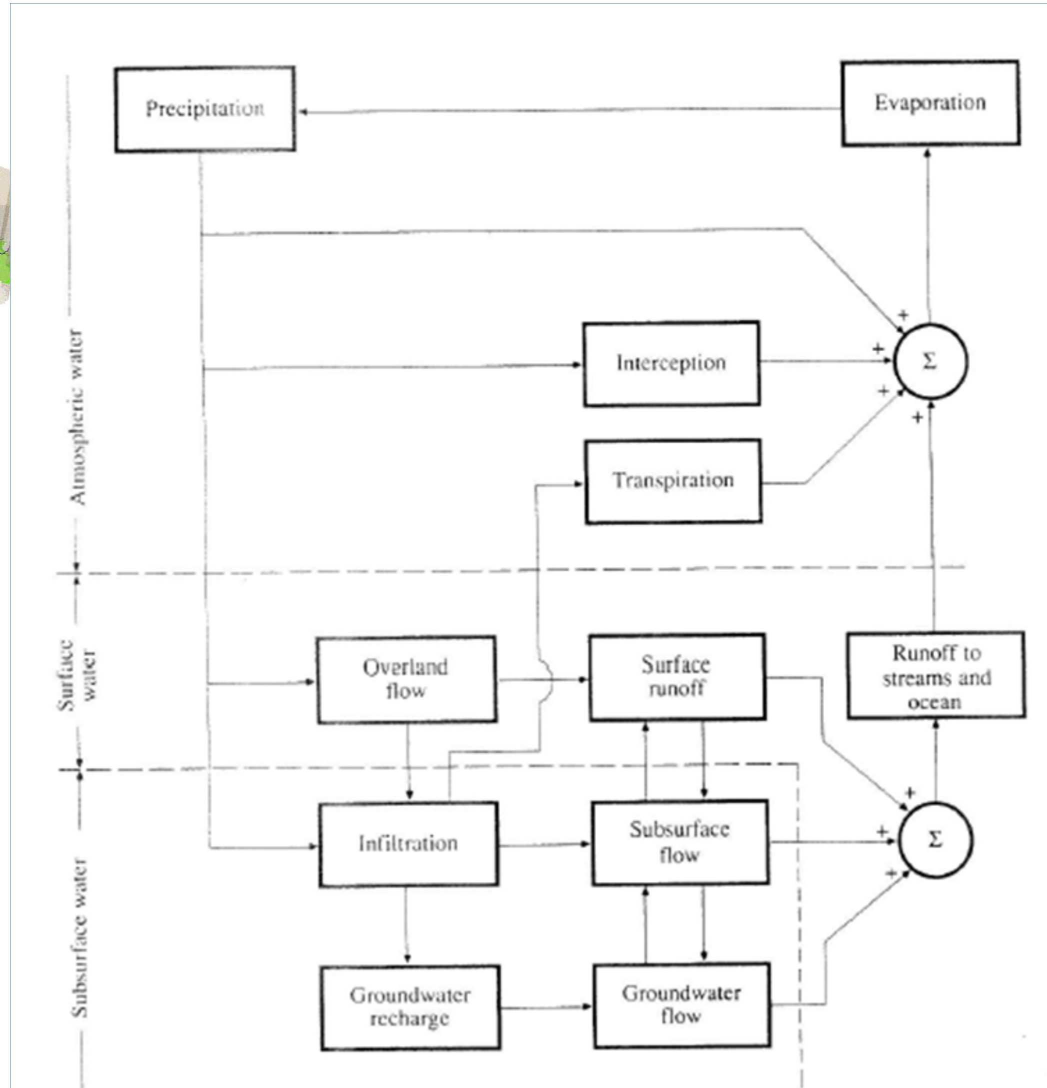


A hydrologic system is "a structure or volume in space surrounded by a boundary, that accepts water and other inputs, operates on them internally, and produces them as outputs"

Take a watershed and extrude it vertically into the atmosphere and subsurface, Applied Hydrology, p.7- 8

Hydrologic System





System Transformation

Inputs, I(t) → **Transformation Equation** $Q(t) = \Omega\, I(t)$ → Outputs, Q(t)

A hydrologic system transforms inputs to outputs

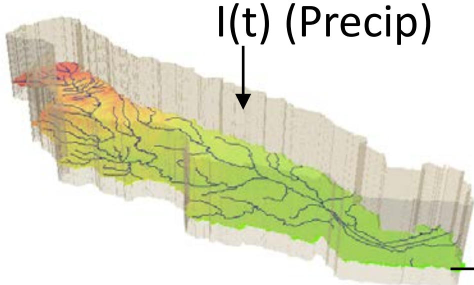
Hydrologic Processes

I(t), Q(t)

Hydrologic conditions

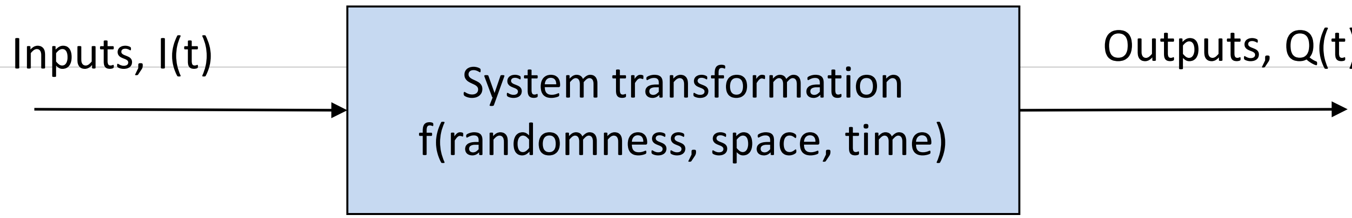
Physical environment

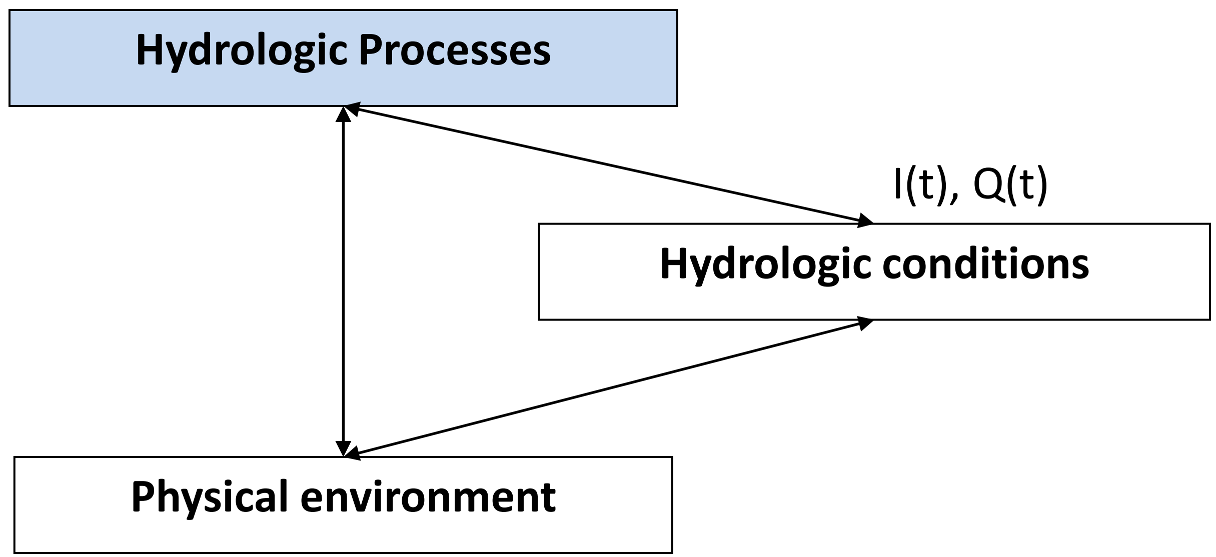
I(t) (Precip)



Q(t) (Streamflow)

Stochastic transformation





How do we characterize uncertain inputs, outputs and system transformations?

Ref: Figure 1.4.1 Applied Hydrology

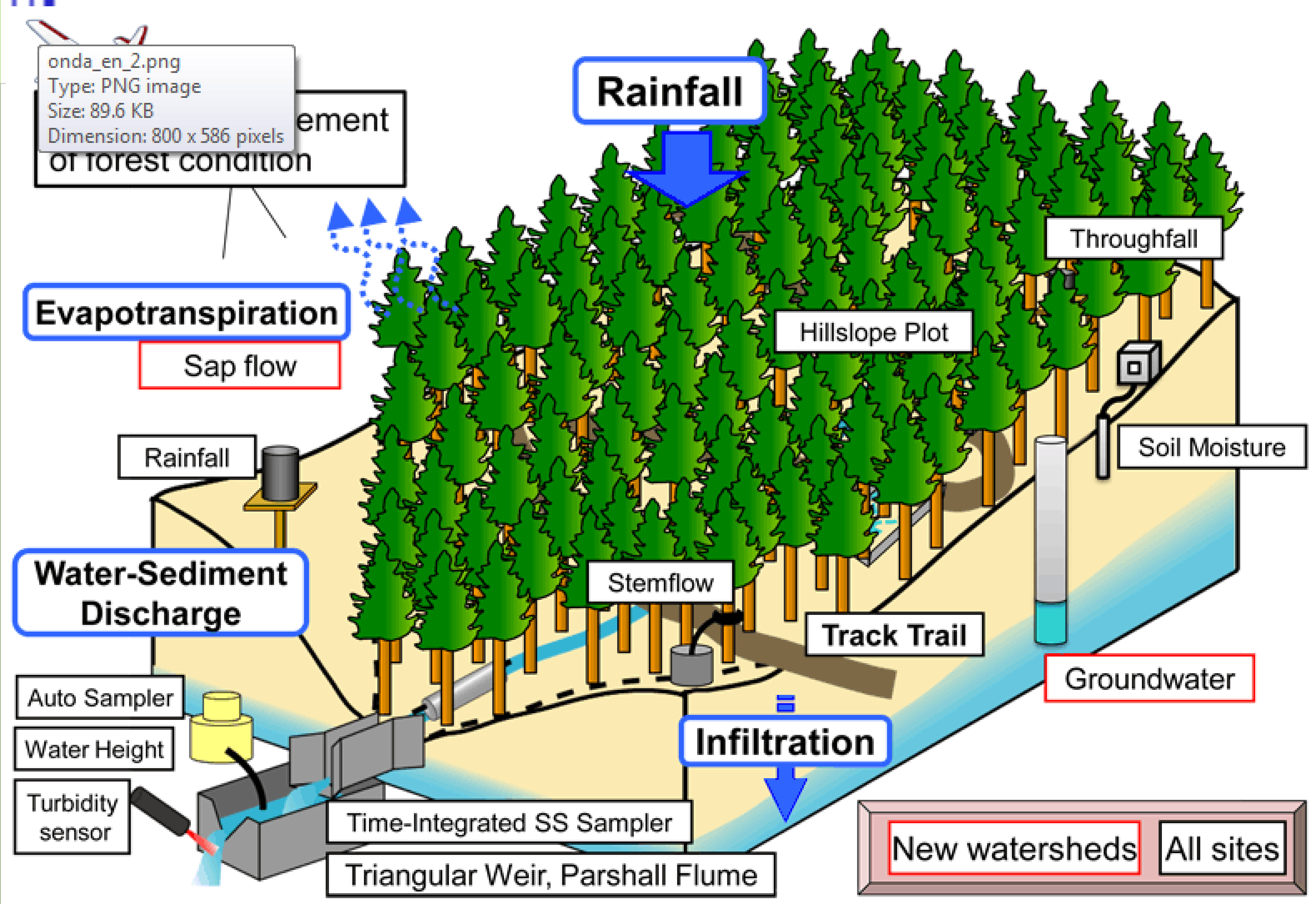
Hydrologic Process

- An understanding of hydrological processes is essential for assessing water resources as well as the changes to the resources caused by changes in the land use or climate.

- Hydrological simulation models which represent hydrological processes can be successful, if they are built on a sound understanding of the processes.

- Major hydrological processes are
    - rainfall interception,
    - Evapotranspiration
    - soil water content,
    - Runoff
    - generation and suspended sediment transport.

Hydrologic Process



Infiltration VS Saturation Excess

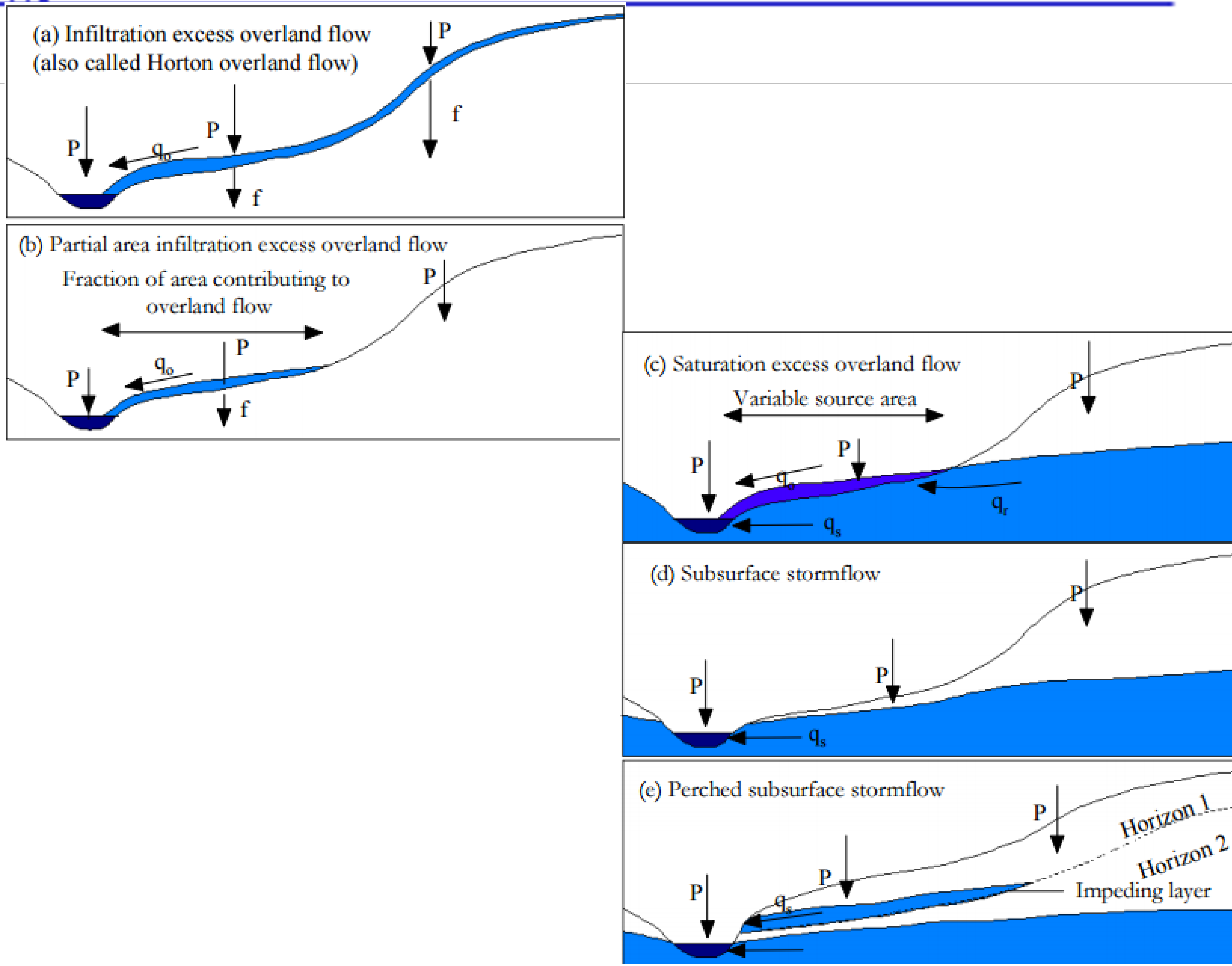
Infiltration Excess Overland Flow

- There is a maximum limiting rate at which a soil in a given condition can absorb surface water input.
- This was referred to by Robert E. Horton (1933), one of the founding fathers of quantitative hydrology,
- the infiltration capacity of the soil, and hence this mechanism is also called Horton overland flow.
- When surface water input exceeds infiltration capacity the excess water accumulates on the soil surface and contribute to overland flow runoff;

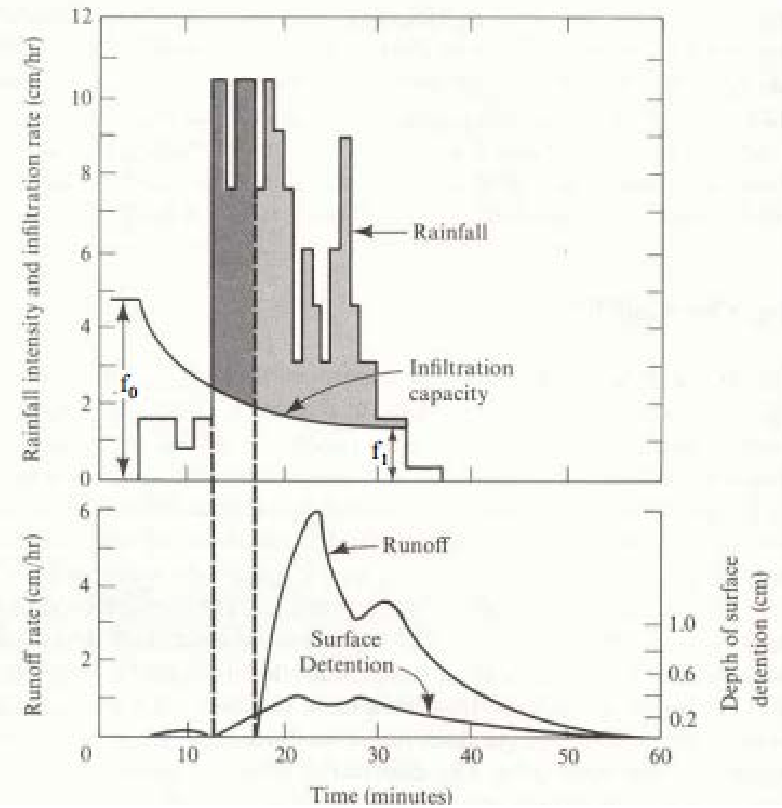
Saturation Excess Overland Flow

- In most humid regions infiltration capacities are high because vegetation protects the soil from rain-packing and dispersal
- Under such conditions surface water input intensities generally do not exceed infiltration capacities and infiltration excess runoff is rare
- Overland flow can occur due to surface water input on areas that are already saturated. This is referred to as saturation excess overland flow,

Infiltration VS Saturation Excess

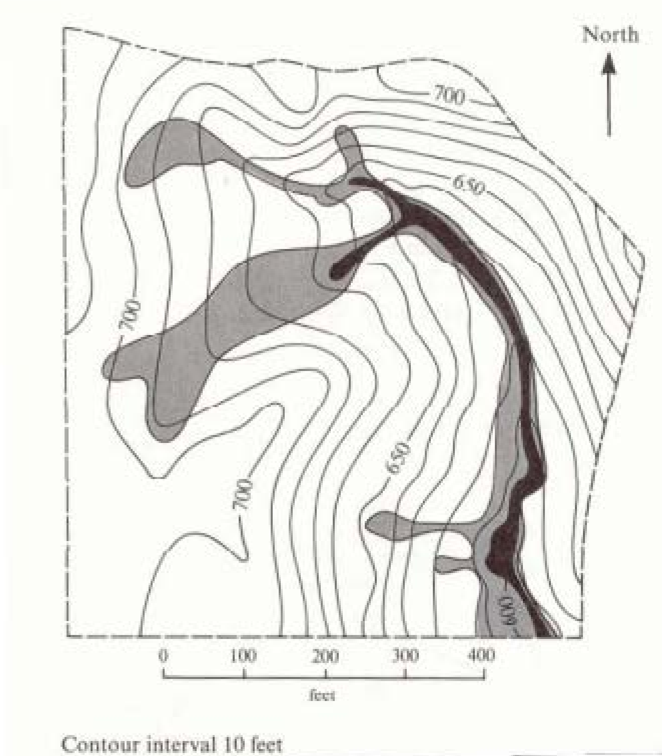


Infiltration vs Saturation Excess



Rainfall, runoff, infiltration and surface storage during a natural rainstorm.

(from Water in Environmental Planning, Dunne and Leopold, 1978)



Map of saturated areas showing expansion during a single rainstorm.

(from Water in Environmental Planning, Dunne and Leopold, 1978)

Review paper

DEFINITION AND UPSCALING OF KEY HYDROLOGICAL PROCESSES FOR APPLICATION IN MODELS

Report to the Water Research Commission

by
Simon Lorentz, Kevin Bursey, Olufemi Idowu, Cobus Pretorius & Kalala Ngeleka

WRC Report No 1320/1/08
ISBN 978-1-77005-722-7
June 2008

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Hydrologic Models

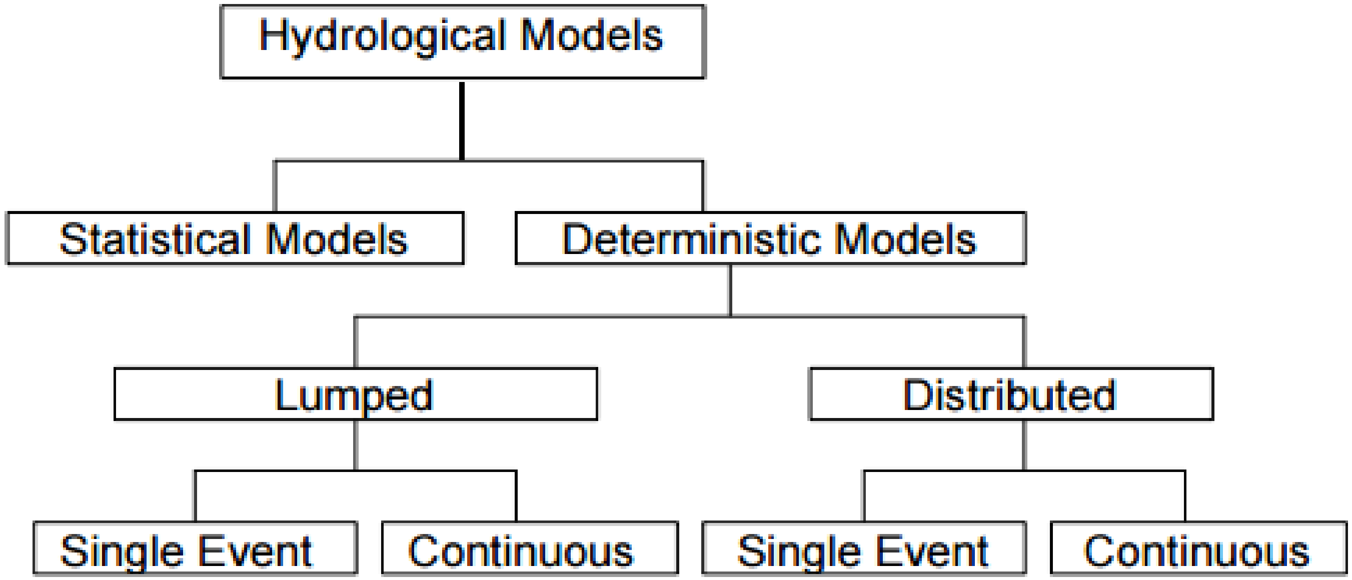
- Since the late 1950s many models have been developed to simulate the hydrologic processes occurring on watersheds.

- They are of many different types and were developed for different purposes. But many of them have structural similarities due to the same underlying assumptions used in developing them

- Hydrologic models compute runoff from precipitation in a drainage basin. Therefore their output is usually a hydrograph, which shows the outflow from the basin over time. From the hydrograph the peak flow magnitude and time to peak can be determined.

- Hydrological models can't determine
    - the water surface elevation within the basin
    - flood-plain boundaries,
    - But hydrological models will give input for a hydraulic model to determine them

Types of Hydrologic Models



- Statistical models include consideration of uncertainties in both the parameters and input data.

- It includes techniques such as simple statistical analysis, regression analysis, flood frequency analysis.

- Deterministic simulation models describe the behavior of the hydrologic processes in a watershed using mathematical expressions that interrelate the various phases of the hydrologic cycle.