Engineering Hydrology

Lecture-1 Introduction

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February, 2025

Course Learning Outcomes

Course Learning Outcomes: After completion of this course, you will be able to:

CLO-1: Apply measurement techniques of the components of the hydrologic cycle, water balance and filling of missed data;

CLO-2: Examine rainfall-runoff relationship and hydrograph;

CLO-3: Examine the probability of occurrence;

CLO-4: Analyze the water movement in to, over, and through the soil surface;

CLO-5: Design capacity of reservoir;

CLO-6: Design runoff volume and time of distribution of the runoff hydrograph from urbanization effect.

Lecture outcomes

At the end of following this lecture, you will be able to:

1. **List** main experiences from the previous courses.
2. **Extract** your plan during this course work.
3. **Explain** the important concepts of hydrologic cycle at global and Ethiopian levels.

Contents of the Lecture

- **Course outline**
- **Pre-requisite courses**
- **Basic concepts on Engineering Hydrology**
- **Hydrologic Cycle**
- **The Hydrology of Ethiopia**

Outline of the course

Course contents

Introduction
Chapter 1
Chapter 2
Chapter 3
Chapter 4
Chapter 5
Chapter 6
Chapter 7
Course summary

Week	Topics
Week 1	INTRODUCTION
Week 2	CHAPTER 1: HYDROLOGY AND ITS MEASUREMENT
Week 3-5	CHAPTER -2 RAINFALL-RUNOFF RELATIONSHIPS
Week 6-7	HAPTER -3 FLOOD ROUTING
Week 8-9	CHAPTER-4 FREQUENCY ANALYSIS
Week 10-11	CHAPTER-5 STOCHASTIC HYDROLOGY
Week 12	CHAPTE- 6 RESERVOIR CAPACITY DETERMINATION
Week 13	CHAPTE- 7 URBAN HYDROLOGY
Week 14	COURSE SUMMARY

- See Course Outline/ Syllabus

Pre-course assessment – Pre-requisite course

- **General Physics**

  Chapter 3: Fluids Mechanics
  3.2 Density and Pressure in Static Fluids
  3.4 Moving Fluids & Bernoulli's Equation

- **Engineering Mechanics I (Statics)**

  Chapter 1: Scalars and Vectors
  Chapter 2: Force Systems

- **Hydraulics**

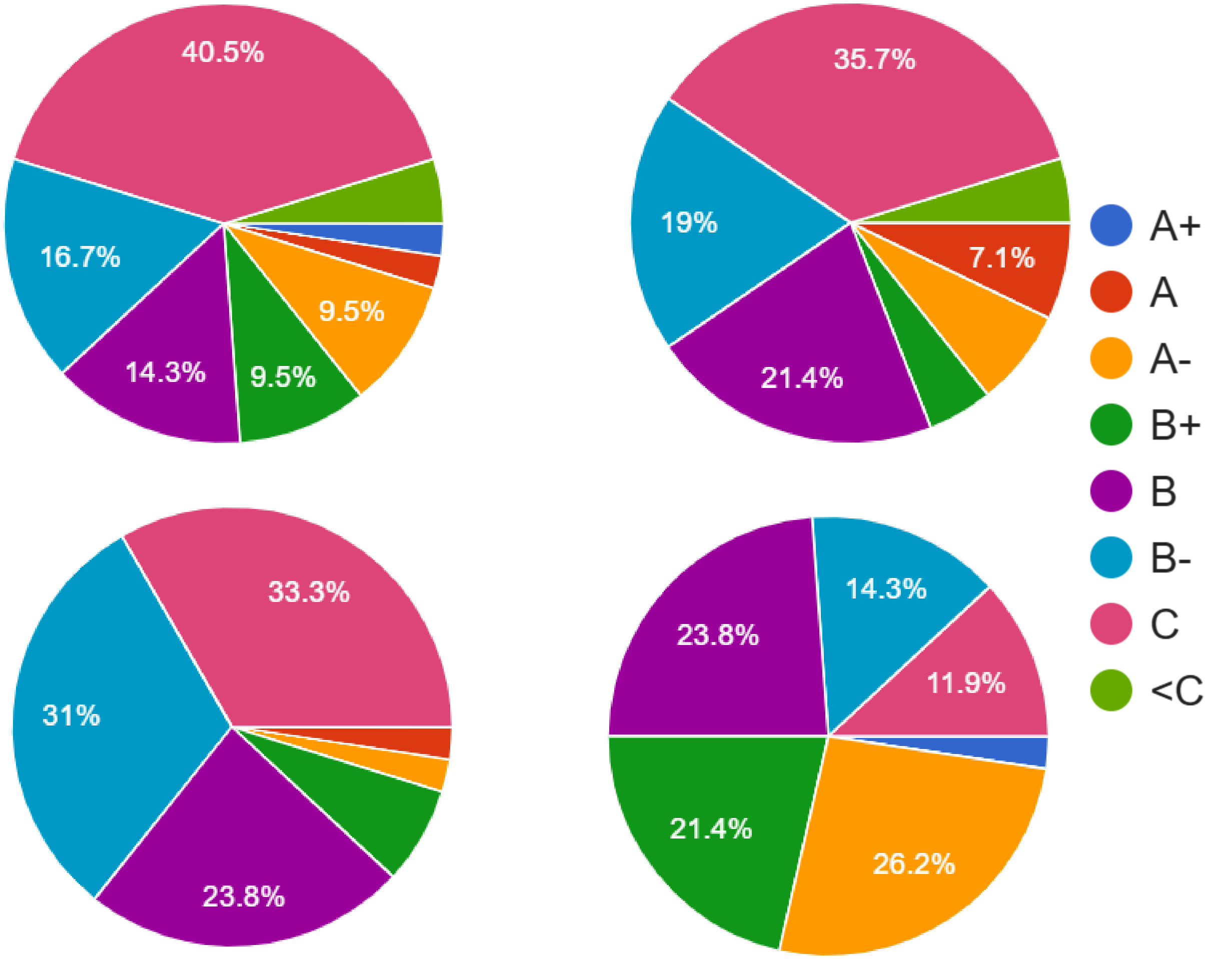
  CHAPTER -3 Hydrostatics of fluids
  CHAPTE- 4 Kinematics of fluid flow
  CHAPTER-5 Dynamics of fluid flow
  CHAPTER -6 Closed Conduit Flow

- **Open Channel Hydraulics**

  1. Open channel flow
  2. Energy and momentum in open channel
  3. Computer application tools

Pre-course assessment – Past achievements

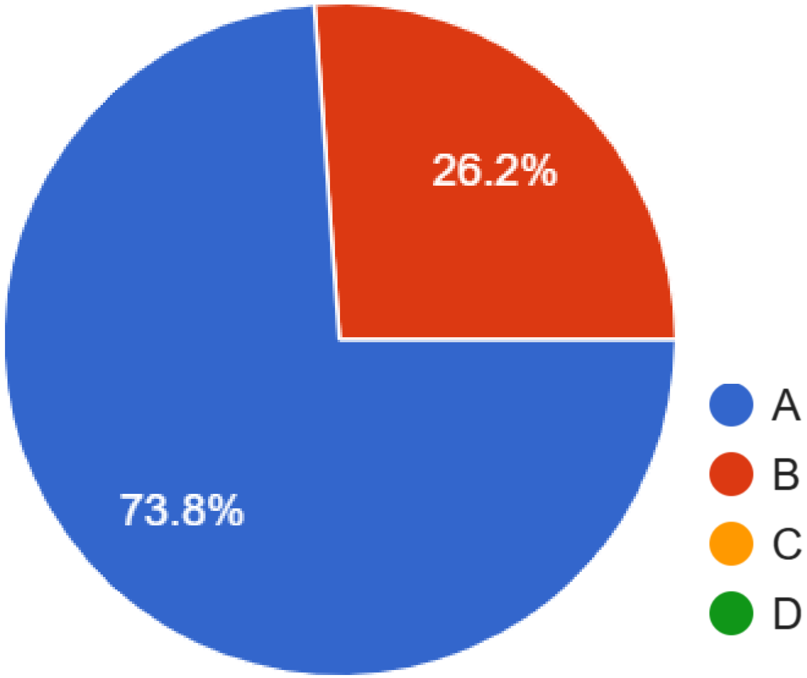
Phys1001 | Statics CEng2103



Hydraulics CEng2106 | OCH CEng3107

- **General Physics**
  - ✓ 14.3% A and 10.8% B, & **40.5 A & B**.
- **Engineering Mechanics I (Statics)**
  - ✓ 14.2% A and 45.2% B, & **59.4 A & B**.
- **Hydraulics**
  - ✓ 4.8% A and 61.9% B, & **66.7 A & B**.
- **Open Channel Hydraulics**
  - ✓ 28.6% A, 59.5% B, & **88.1 A & B**.

Pre-course assessment – your experiences



- **General Physics**
  - ✓ 14.3% A and 10.8% B, & **40.5 A & B**.
- **Engineering Mechanics I (Statics)**
  - ✓ 14.2% A and 45.2% B, & **59.4 A & B**.
- **Hydraulics**
  - ✓ 4.8% A and 61.9% B, & **66.7 A & B**.
- **Open Channel Flow**
  - ✓ 28.6% A, 59.5% B, & **88.1 A & B**.

Your plan CEng3108: 100% A & B!

What can we do to achieve our plan based on your past experience?

Pre-course assessment – comments given

- **To be considered for better achievement:**
  - ✓ Connect to pre-requisite experience
  - ✓ Have good teaching skill
  - ✓ Clear and concise power point with adequate examples would be great.
  - ✓ Interest to learn
  - ✓ Focus on **team works and tutorials**
  - ✓ Give us extra things **(like video)** to better know the subject
  - ✓ Study materials well-supported by hydrological principles, and **relevant to the context of the discussion**
  - ✓ Study hard
  - ✓ Making the course **easy to understand**
  - ✓ Concentration on **problem solving and explanation** on key foundational concepts.
  - ✓ To have a god communication with the teacher
  - ✓ Share **the study material as soon as before or the class ends**.
  - ✓ Teach us with all **your heart**, as **our Father of Knowledge.**
  - ✓ I want to know every chapters well
  - ✓ Completing the course in time

Pre-course assessment – comments

- **To be considered as negative effect on better achievement:**
  - ✓ Information from senior students that the course is **a little heavy** and **difficult** to understand.
  - ✓ Lecturer who **don't understand students**
  - ✓ **Wasting time on irrelevant topics**.
  - ✓ **Unable to give enough time** for the study
  - ✓ Learn **without exercise**
  - ✓ If it lacks technical **accuracy**.
  - ✓ **Late study**
  - ✓ **Making the course hard to understand**
  - ✓ **Sound**
  - ✓ **Not covering all** the units of the courses
  - ✓ **Discuss each topics briefly**
  - ✓ **Bad time management**
  - ✓ **Low effort** to prepare on the course
  - ✓ If there's **no active learning** class
  - ✓ **Refusal:** Unwillingness to **learn or engage**.

Let's give minutes to highlight the main comments to harvest more from the course.

Pre-course assessment

Factors affecting your course achievements

Positively affecting:

- Connect to pre-requisite experience
- Good teaching skill
- Concise power point with examples
- Interest to learn
- Focus on team works and tutorials
- Give us extra materials like video
- Study hard
- Making the course easy to understand
- Concentration on problem solving approach
- To have a god communication with the teacher
- Share the study material ontime
- Teach us with all your heart
- Completing the course in time

Negatively affecting:

- ✓ Frustration
- ✓ Less interest to understand nature, the hydrosphere
- ✓ Misunderstanding within educator and learner
- ✓ **Wasting time on topics not related the CLO**
- ✓ **Unable to give enough time** for the study
- ✓ Learn/study **without exercise**
- ✓ **Late study**
- ✓ **Complication the course**
- ✓ **Low sound of the instruction**
- ✓ **Not covering all** the units of the courses
- ✓ **Brief discussion**
- ✓ **Bad time management**
- ✓ **Low effort** to prepare on the course
- ✓ If there's **no active learning** class
- ✓ Unwillingness to **learn or engage**.

Hydrology – definition

➢**Hydrology** - is the science that treats all the waters of the earth and its hydrosphere at **solid**, **liquid** and **gaseous** state either it is stored or flowing, and their

- occurrence,
- circulation and distribution,
- chemical and physical properties, and
- their reaction with their environment including their relations to living things

Engineering Hydrology

Engineering hydrology deals with the:

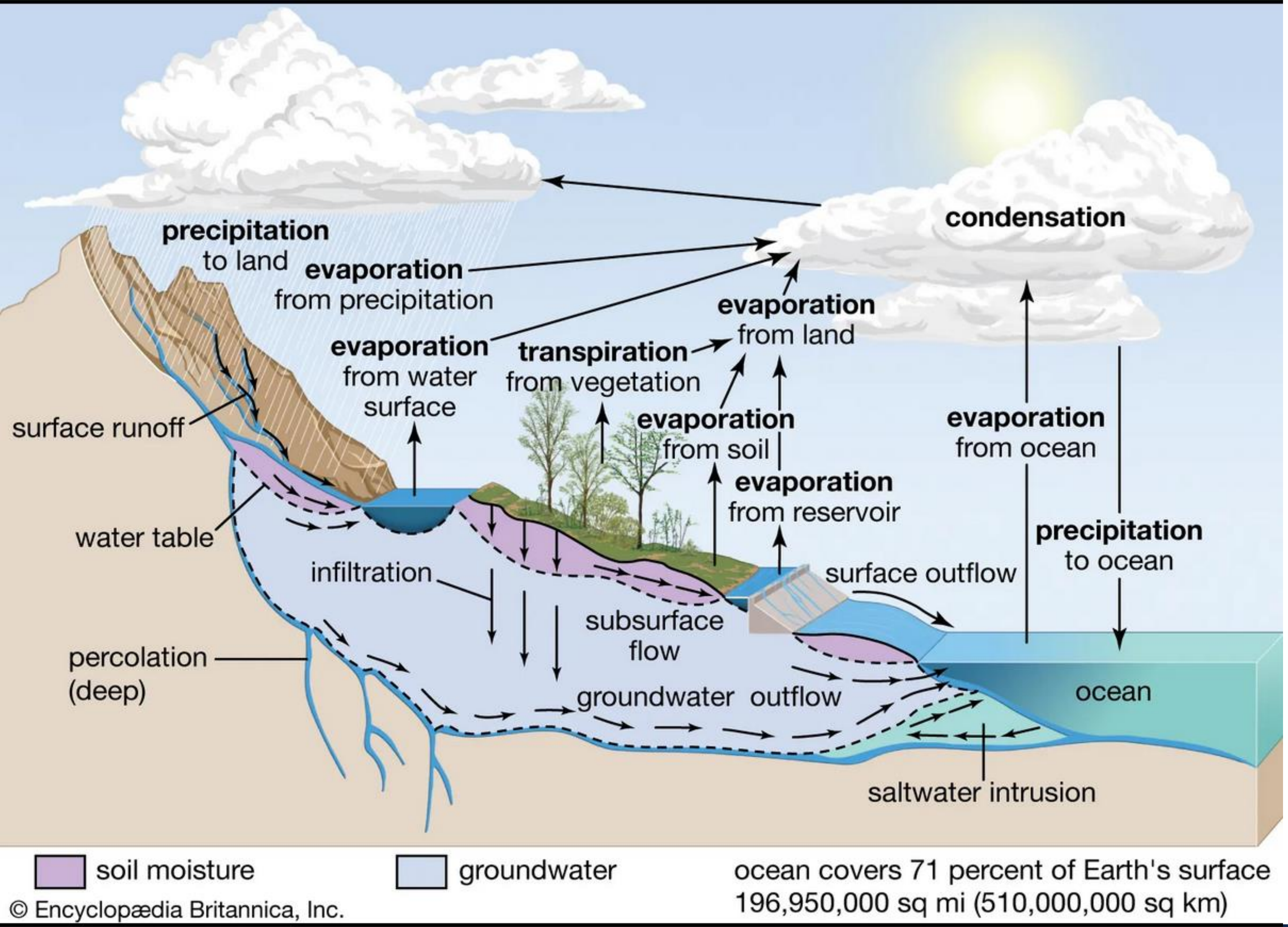
- Estimation of water resources
  - Design flows, storage,
  - Design rainfall
- Study of hydrologic **processes** and their interaction
- Study of problems **extreme events**
  - ➢ such as floods and droughts, and
  - ➢ strategies to combat extreme events.

Applications of Hydrology in Engineering

- to design and operation of water resources engineering projects,

  - ✓ Irrigation, water supply, flood control, hydropower and navigation.
  - ✓ The capacity of storage structures such as reservoirs
  - ✓ The magnitude of flood flows to enable safe disposal of the excess flow
  - ✓ The minimum flows and peak of flows
  - ✓ The interaction of the flood wave and hydraulic structures, such as dams, levees, weirs, bridges, and culverts.

Hydrologic Cycle



Water system in the hydrosphere

- Water balance components

Fig. 1- The water cycle
Source: [1] Meg Matthias, "Water cycle". Britannica, undated

https://cdn.britannica.com/89/62689-050-66A0068F/water-hydrologic-cycle-land-surface-atmosphere-ocean.jpg

https://www.britannica.com/science/water-cycle

Water balance

- The hydrologic cycle can be represented by a closed equation.
  - ✓ This cycle represents the principle of conservation of mass, as the **continuity equation**.
  - ✓ The continuity equation in the hydrologic cycle called the **water balance equation**.

The water balance can be expressed:

(1) for a short interval or for a long duration;

(2) for a natural drainage basin or an artificially separated boundary like lakes, reservoirs, and groundwater basins; and

(3) for the phase above the ground surface, that below the surface, or the entire phase.

Water balance

- Three applications of the water balance equation:
  (1) a water balance equation for **large basin areas/catchments**,
  (2) a water balance equation for water **bodies/reservoirs**, and
  (3) a water balance equation for direct **runoff/stream or canal segments**.

In its general form, the equation may be represented by:

$$\boldsymbol{P + Q_{SI} + Q_{GI} - E - Q_{SO} - Q_{GO} - \Delta s - n = 0} \text{ [L}^3 \text{ or L}^3\text{T}^{-1}\text{]}$$

Where,

P = precipitation

$\boldsymbol{Q_{SI}}, \boldsymbol{Q_{GI}}$ = surface and groundwater inflow into control volume

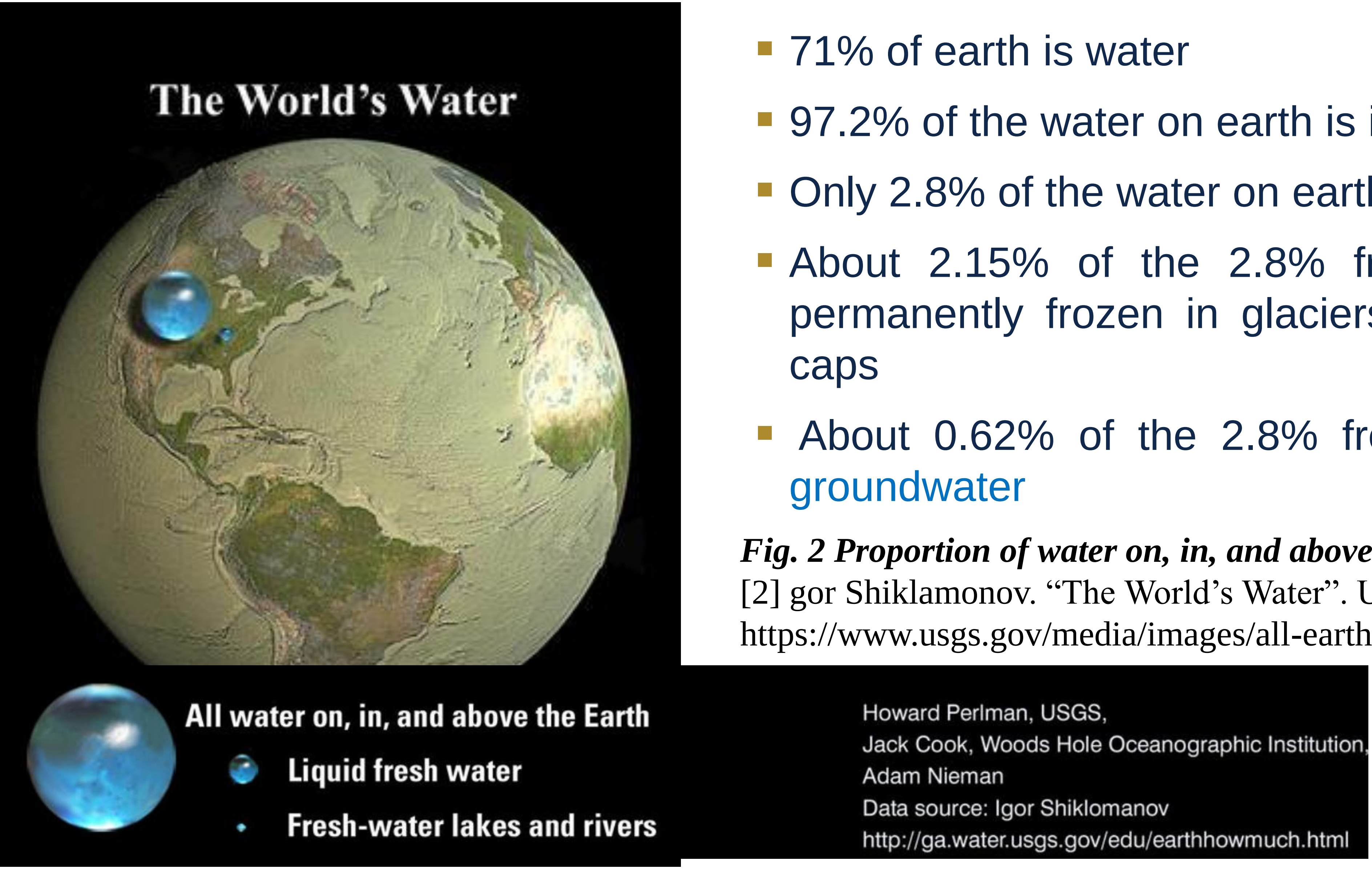
E= evaporation (including transpiration)

$\boldsymbol{Q_{SO}}, \boldsymbol{Q_{GO}}$ = surface and groundwater outflow from the control volume

$\boldsymbol{\Delta s} =$ change of storage volume within the control volum

$\boldsymbol{n}$ = some error or discrepancy terms

Hydrologic Cycle



- 71% of earth is water
- 97.2% of the water on earth is in the oceans
- Only 2.8% of the water on earth is freshwater
- About 2.15% of the 2.8% freshwater on earth is permanently frozen in glaciers and at the polar ice caps
- About 0.62% of the 2.8% fresh water on earth is groundwater

Fig. 2 Proportion of water on, in, and above the Earth

[2] gor Shiklamonov. “The World’s Water”. USGS, Undated, https://www.usgs.gov/media/images/all-earths-water-a-single-sphere

Water balance

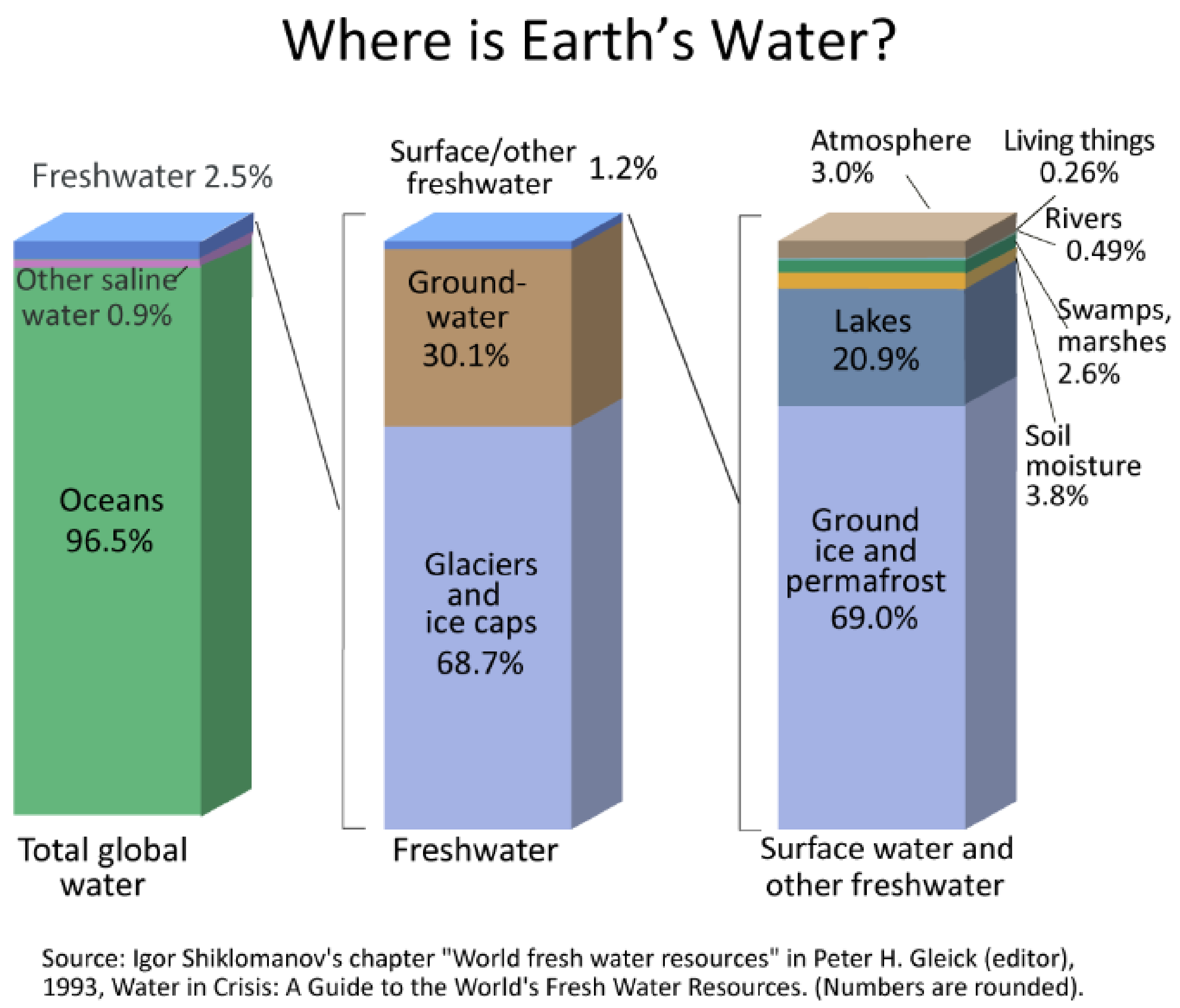


Fig. 3 Proportion of water on, in, and above the Earth
Sources: [3] How Much Water is There on Earth? | U.S. Geological Survey (usgs.gov)
https://www.usgs.gov/special-topics/water-science-school/science/how-much-water-there-earth

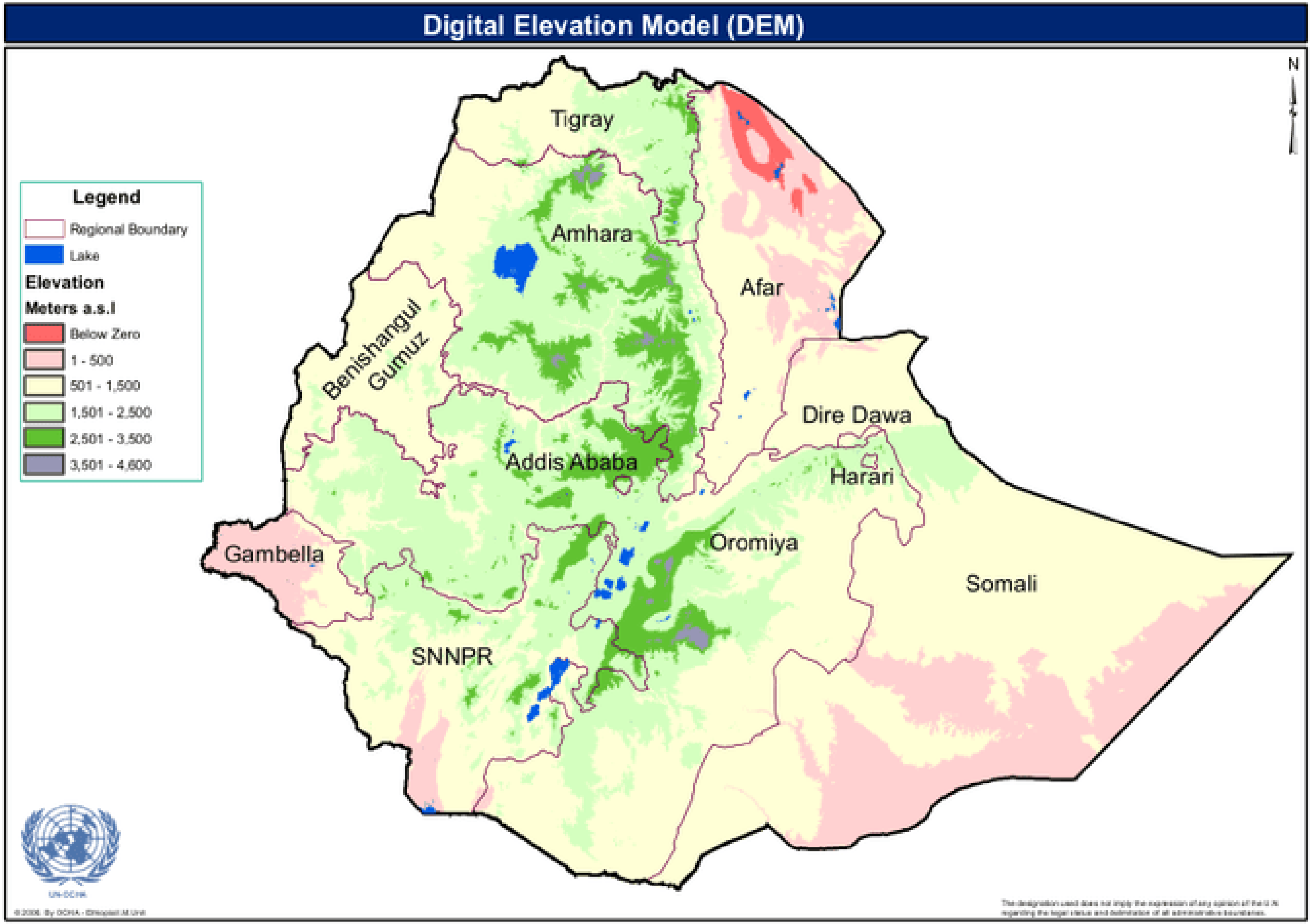
Water balance

Water source	Water volume, in cubic miles	Water volume, in cubic kilometers	Percent of freshwater	Percent of total water
Oceans, Seas, & Bays	321,000,000	1,338,000,000	--	96.54
Ice caps, Glaciers, & Permanent Snow	5,773,000	24,064,000	68.7	1.74
Groundwater	5,614,000	23,400,000	--	1.69
Fresh	2,526,000	10,530,000	30.1	0.76
Saline	3,088,000	12,870,000	--	0.93
Soil Moisture	3,959	16,500	0.05	0.001
Ground Ice & Permafrost	71,970	300,000	0.86	0.022
Lakes	42,320	176,400	--	0.013
Fresh	21,830	91,000	0.26	0.007
Saline	20,490	85,400	--	0.006
Atmosphere	3,095	12,900	0.04	0.001
Swamp Water	2,752	11,470	0.03	0.0008
Rivers	509	2,120	0.006	0.0002
Biological Water	269	1,120	0.003	0.0001

Table 1 Proportion of water Sources [3] https://www.usgs.gov/special-topics/water-science-school/science/how-much-water-there-earth

Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources (Oxford University Press, New York)

Hydrology of Ethiopia – Topography



1. **Which part is with higher elevation?**
2. **Which part is with lower elevation even below sea level?**
3. **What do they mean for hydrology?**

Fig. 4- Topography of Ethiopia.
Source: [4] UN-OCHA. "Ethiopia: Digital elevation model (DEM)", 2006, https://reliefweb.int/map/ethiopia/ethiopia-digital-elevation-model-dem

Hydrology of Ethiopia – Rainfall

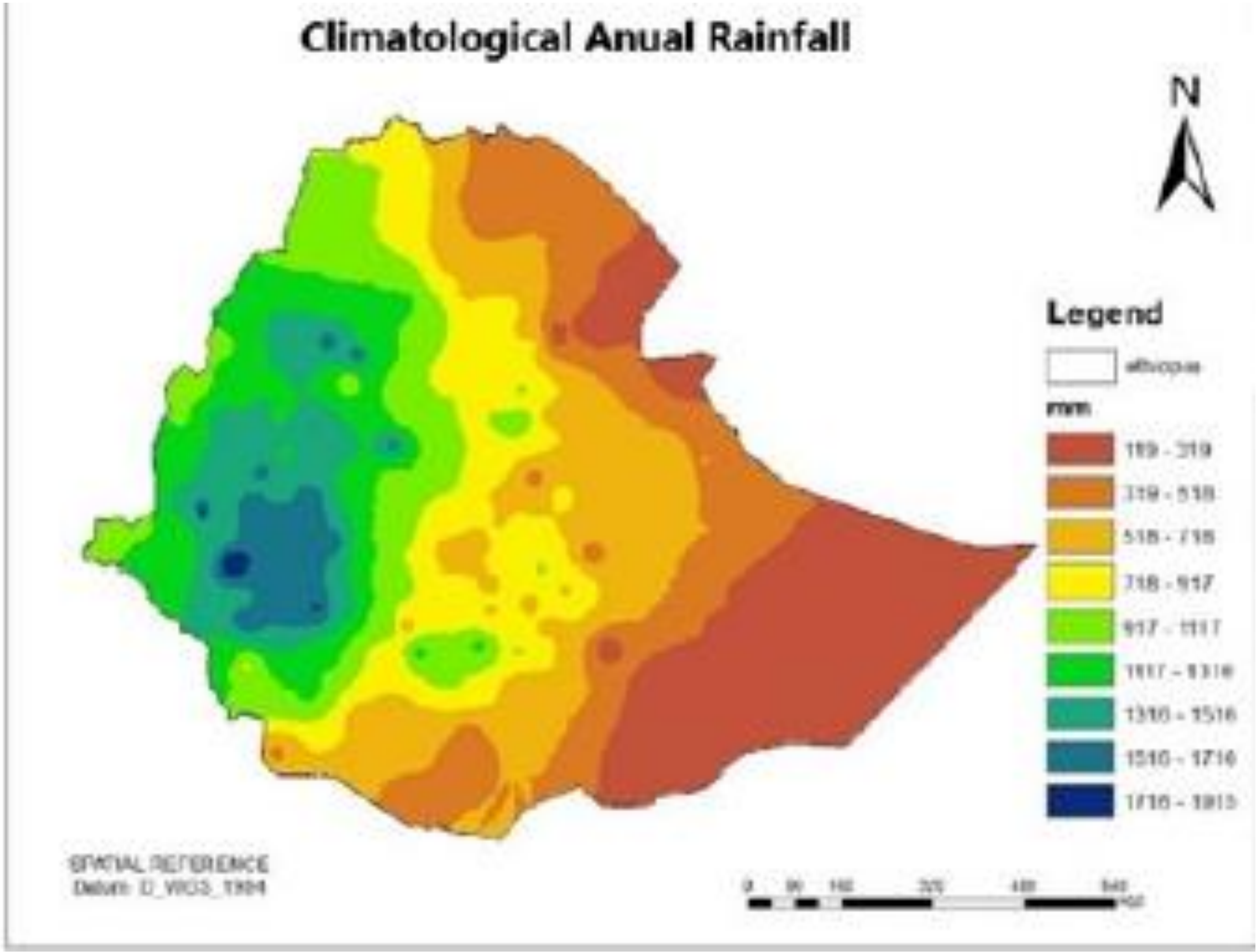
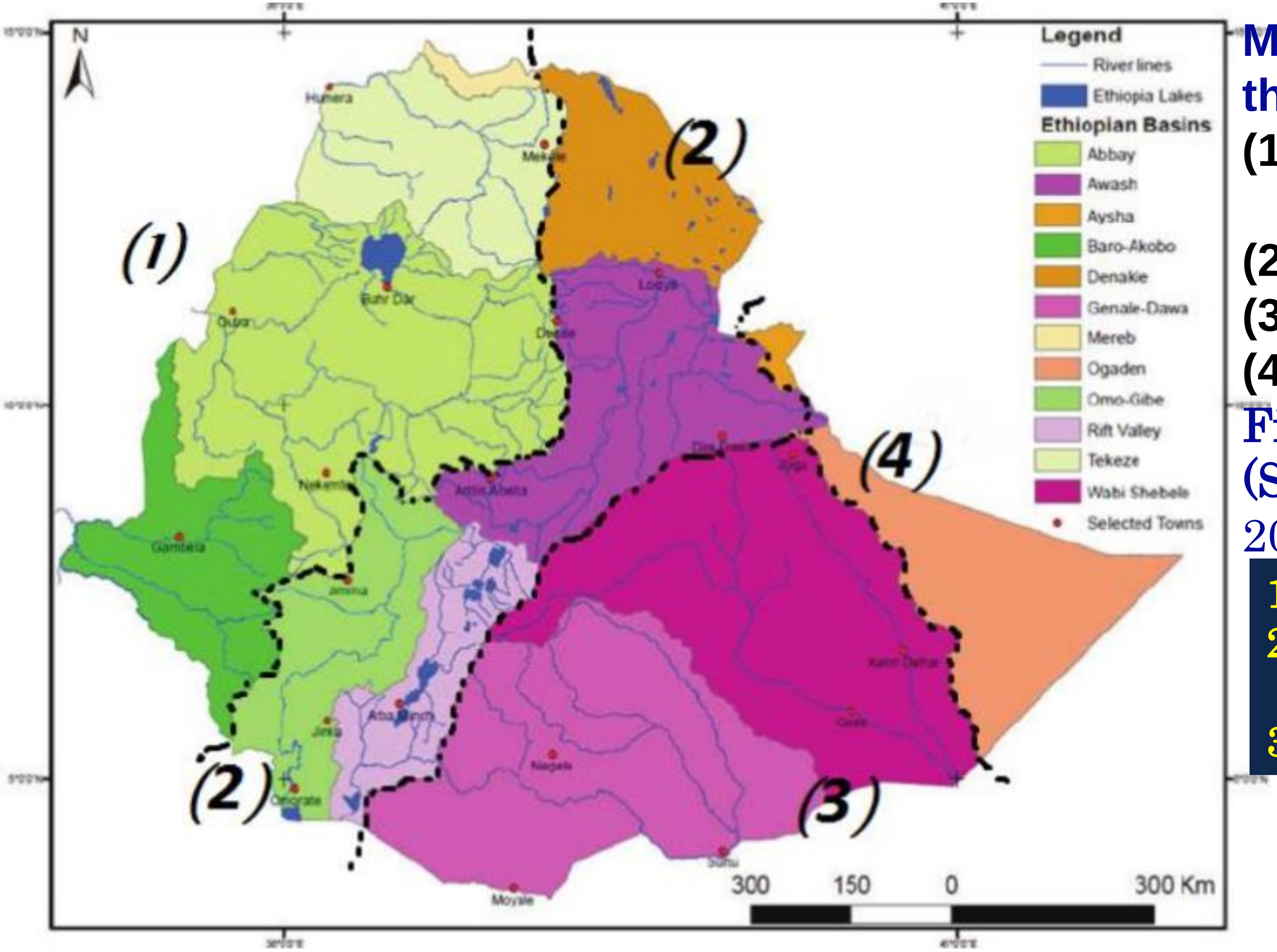


Fig. 5- Annual Climatological Rainfall from NMA (National Meteorological Agency) data 1986-2018 used 175-point station data.
Source: [5](Mekuanint, 2022)

1. **Which parts earn high and low annual rainfall?**
2. **What does it mean with respect to elevation and drainage basin?**

Hydrology of Ethiopia – Drainage system



Major drainage systems of Ethiopia with their river basins:

(1) Ethiopian Blue Nile with Abbay River Basin,

(2) Rift Valley,

(3) Shebele-Juba, and

(4) East Cost

Fig. 6- River Basins of Ethiopia
(Source: [6] Modified form of Birhanu, 2014 and in press as (Derib, 2025)

1. How many drainage basin we have?
2. Which basin has high surface water and irrigable land?
3. Which basin has high annual rainfall?

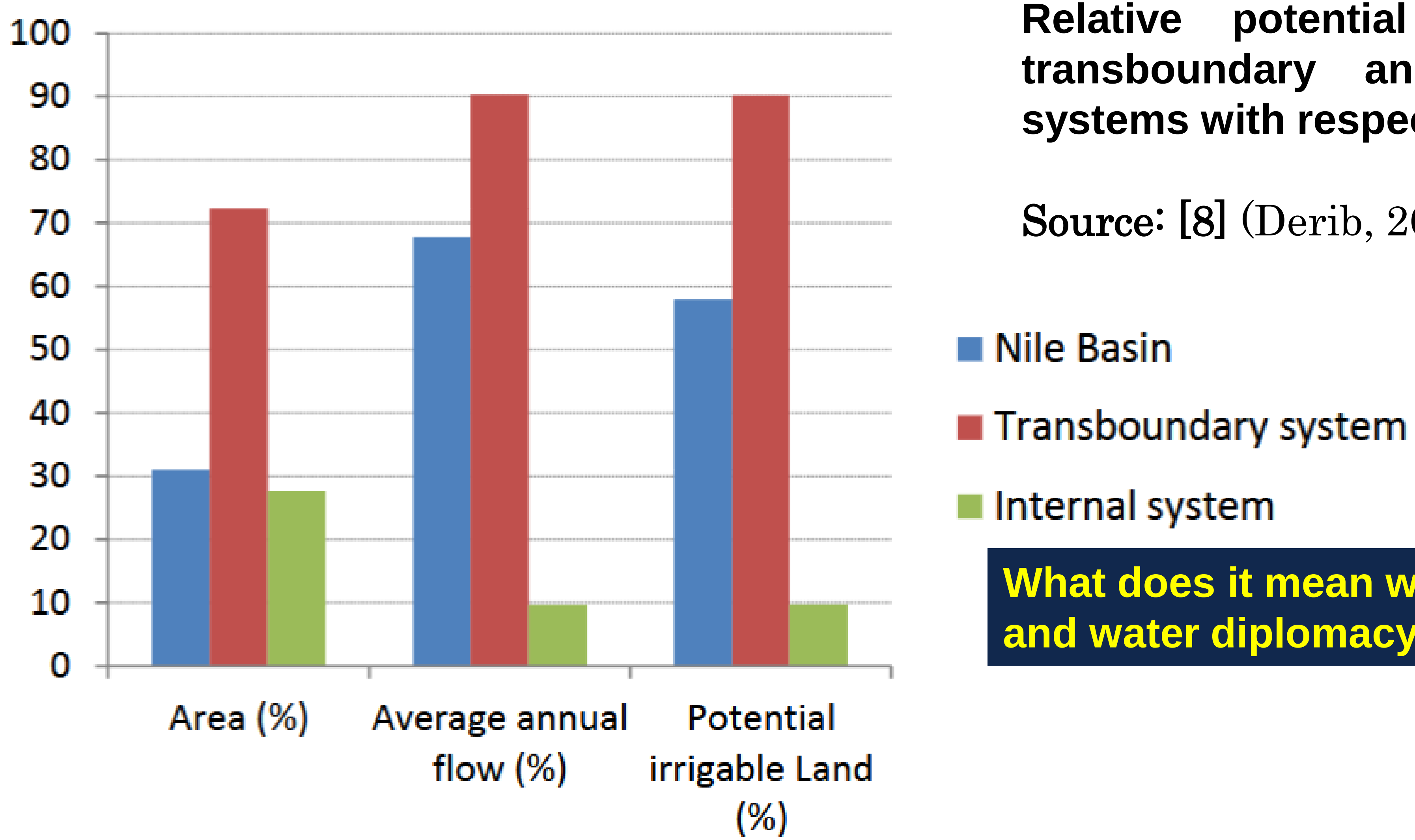
Hydrology of Ethiopia – Surface water

Major drainage system	River Basins	Area (% of total area)	Runoff (% of total runoff)	Potential Irrigable land (% total)	Gross hydroelectric potential (% total)
Nile Basin		**32.4**	**69.51**	**53.70**	**63.55**
	Abbay	17.6	43.9	22.8	50.8
	Baro-Akobo	6.5	18.9	28.5	8.9
	Setit-Tekeze/Atbara	7.8	6.1	2.3	3.9
	Mereb	0.5	0.6	0.0	0.0
Rift Valley		**27.9**	**23.25**	**9.56**	**26.97**
	Awash	9.9	3.7	3.75	2.9
	Denakil	6.5	0.7	0.00	0.0
	Omo-Gibe	6.9	14.4	1.90	23.6
	Central Lake	4.6	4.5	3.90	0.5
Shebelli-Juba		**32.7**	**7.24**	**36.74**	**9.48**
	Wabi-Shebelle	17.6	2.5	6.66	3.5
	Genale-Dawa	15.0	4.7	30.08	6.0
North East Coast		**7.0**	**0**	**0**	
	Ogaden	6.8	0		
	Aysha	0.2			
Total		**100.0**	**100**	**100**	**100**

Sources: FAO, 2005 and data from different river master plan studies

What does it mean with respect to development and water diplomacy?

Hydrology of Ethiopia – Surface water



Relative potential of Nile Basin, total transboundary and internal watercourse systems with respect to whole Ethiopia.

Source: [8] (Derib, 2015)

What does it mean with respect to development and water diplomacy?

Sanitation situation in Ethiopia

USAID FROM THE AMERICAN PEOPLE 2020 Sanitation Profile: Ethiopia

The sanitation profile provides an overview of the sanitation situation in Ethiopia and identifies key priority areas to achieve SDG6. The purpose of the profile is to support donors and government officials to have a common understanding of the sanitation situation in Ethiopia and to prioritize their efforts.

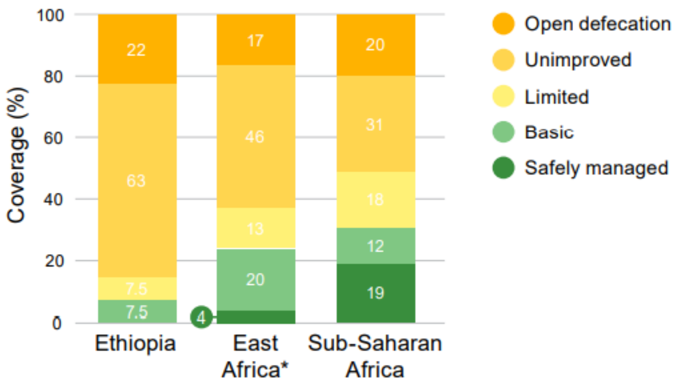
Population

115 MILLION	2.6%	21.7%	39.1%
POPULATION[1]	POPULATION GROWTH[1]	URBAN POPULATION[1]	URBAN POPULATION PROJECTION 2050[1]

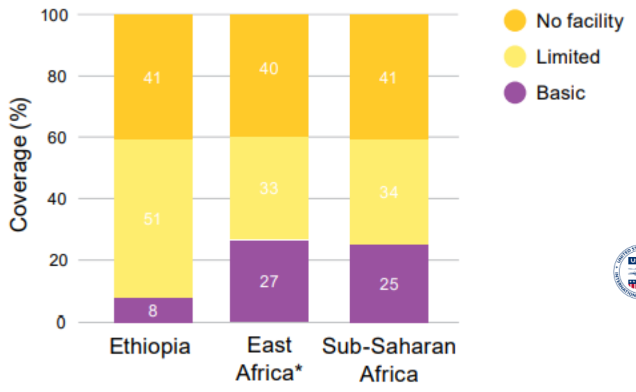
[9] USAID. "Sanitation Profile: Ethiopia 2020", 2020, https://amcow.ams3.cdn.digitaloceanspaces.com/resources/Sanitation%20Profile_Ethiopia_Final.pdf

Sanitation situation in Ethiopia

Total Household Sanitation Data (2017)[2]



Total Household Hygiene Data (2017)[2]

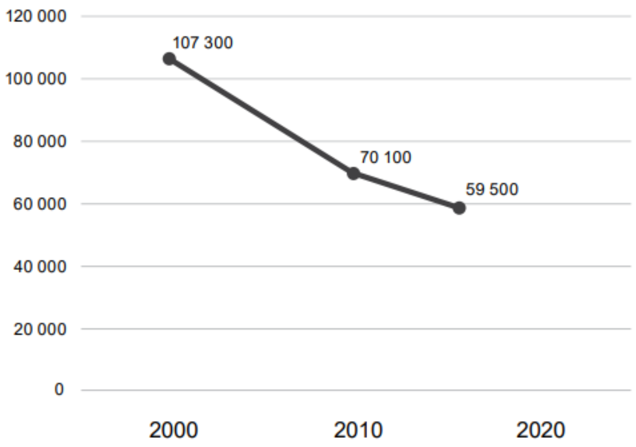


Source: [9] Sanitation Profile: Ethiopia 2020

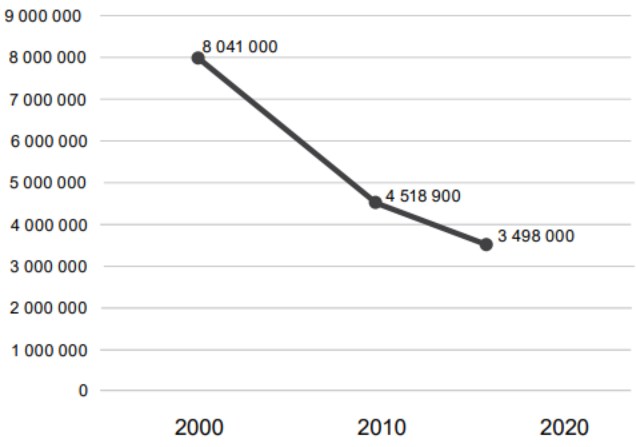
USAID FROM THE AMERICAN PEOPLE **2020 Sanitation Profile: Ethiopia**

Health

Deaths Due to Diarrheal Disease[3]

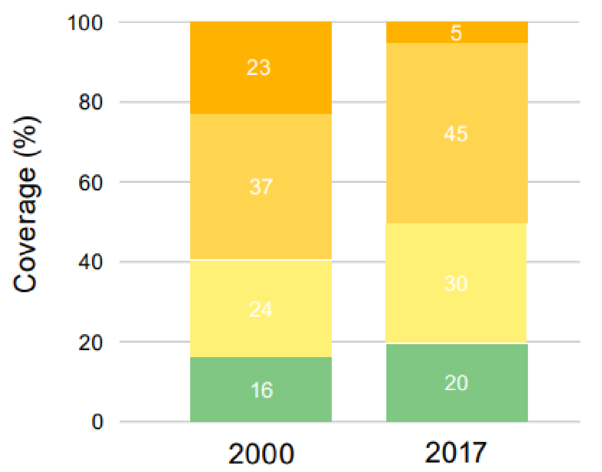


Disability-Adjusted Life Years (DALYs) Due to Diarrheal Disease[4]**



Sanitation situation in Ethiopia

Urban Sanitation



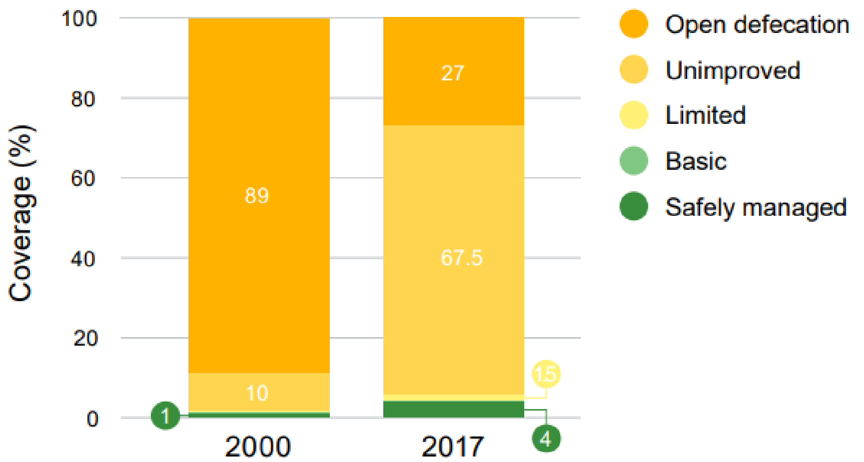
3% Households use a toilet linked to a sewer system. Although the sewer network has expanded since 2000, from 227 000 to 594 00 people, coverage has not increased due to population growth.

10% Households use a toilet linked to a septic system.

0% Increase in the use of safely managed sanitation facilities between 2000-2017.

23% Households have a basic handwashing facility (soap and water). 57% have limited and 20% have no handwashing facility.

Rural Sanitation



Source: [9] Sanitation Profile: Ethiopia 2020

0.7% Households use a toilet linked to a sewer system.

0.3% Households use a toilet linked to a septic system.

3% Increase in the use of safely managed sanitation facilities between 2000-2017.

4% Households have a basic handwashing facility (soap and water). 50% have limited and 46% have no handwashing facility.

USAID 2020 Sanitation Profile: Ethiopia

Water Development in Ethiopia

- As per the definition of the Ministry of Water & Energy of Ethiopia,
  - Access to water is defined as 15 liters of clean water to the rural people per head within **1.5 kilometres distance** and 20 liters of clean water to the urban people per head within 0.5 kilometer distance (GTP-1) and in GTP-2:
    - 25 l/c/day within a distance of **1 km** from the water delivery point for 85% of the rural population.
    - 100 l/c/day for category-1 towns/cities, 80 l/c/day for category-2 towns/cities, 60 l/c/day for category-3 towns/cities, 50 l/c/day for category-4 towns/cities, up to the premises and 40 l/c/day for category-5 towns/cities within a distance of 250m with piped system for 75% of the urban population.

Source: [10] MoWEI, 2015. Second Growth and Transformation National Plan for the Water Supply and Sanitation Sub Sector (2015/16 – 2019/20), Addis Ababa.

Water Development in Ethiopia

THE FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA

MINISTRY OF WATER RESOURCES

ETHIOPIAN WATER SECTOR STRATEGY

2001

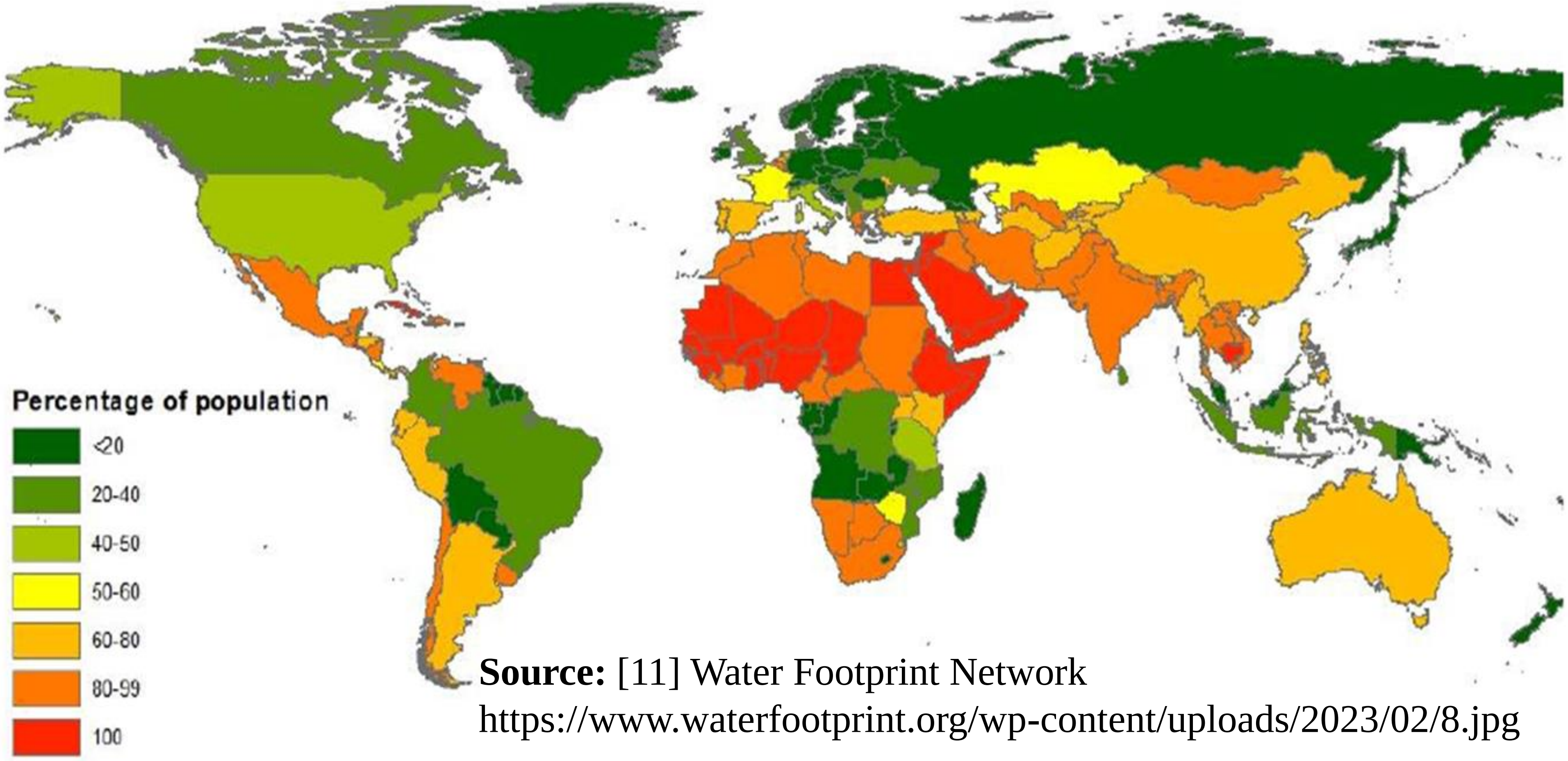
- **Ethiopian Water Supply Sector Policy:**
  - **Policy objective**: Enhance the well-being and productivity of the Ethiopian people through provision of **adequate, reliable and clean** water supply and to foster its tangible contribution to the economy by providing water supply services that meet the livestock, industry and other water users' demands.
  - Highest priority is for **human and livestock** consumption, which amounts to be less than 1 percent of total water usage.
  - Promote the development of water supply on **participation driven** and responsive approaches without compromising social-equity norms.

Water Development in Ethiopia

- **Ethiopian Water Supply Sector Policy:**
  - Create and promote a **sense of awareness in communities** of the ownership and their responsibilities for operation and maintenance of water supply systems and develop participatory management practices.
  - Enhance the development of **different indigenous water sources** being used by communities to improve rural water supply.
  - Ensure that rural drinking water and livestock water supply undertakings shall be integral part of the overall socio-economic development, centred on self-reliance, **community participation** and management.
  - **Fair and equitable** share of transboundary river waters.

❖Engineering hydrology is very important!

Availability parameters



Source: [11] Water Footprint Network
https://www.waterfootprint.org/wp-content/uploads/2023/02/8.jpg

World Map showing percentage of population experiencing severe water scarcity at least one month of a year.

Water availability parameters

Water is

- Scarce
- Variable
  - ✓ Temporal
  - ✓ Spatial
- Deteriorating
  - ✓ Quantity
  - ✓ Quality

❖Engineering hydrology is very important to understand future availability!

Water stress occurs when the **demand for water exceeds the available amount** during a certain period or when poor quality restricts its use.

- the ability to meet human and ecological demand for fresh water.
- **Water availability, water quality, and water accessibility** are the three components that are comprised by water stress.

Water scarcity is the lack of sufficient available water resources to meet the demands of water usage **within a region**.

- reflects the **physical abundance** of fresh water rather than whether that water is **suitable for use**.

Water risk refers to the possibility of an entity experiencing a **water-related challenge** (e.g., water scarcity, water stress, flooding, infrastructure decay, drought).

The Way Forward

- Read more about
  - fundamental experiences from your prerequisite courses
- Formulate groups for assignments and project, and
- be familiar with:
  - Google Earth
  - ArcMap/ArcGIS
  - Google Earth Engine (GEE)

Google Earth Engine

References

[1] https://www.britannica.com/science/water-cycle

[2] gor Shiklamonov. “The World’s Water”. USGS, Undated, https://www.usgs.gov/media/images/all-earths-water-a-single-sphere

[3] https://www.usgs.gov/special-topics/water-science-school/science/how-much-water-there-earth

[4] UN-OCHA. (2006), “Ethiopia: Digital elevation model (DEM)”, https://reliefweb.int/map/ethiopia/ethiopia-digital-elevation-model-dem

[5] Mekuanint T G. Rainfall Trends Over Ethiopia.Int J Environ Sci Nat Res. 2022; 30(4): 556297.DOI: 10.19080/IJESNR.2022.30.556297

[6] Berhanu, B., Y. Seleshi and A. M. Melesse.2014. Surface Water and Groundwater Resources of Ethiopia: Potentials and Challenges of Water Resources Development,In: Melesse, A., W. Abtew and S. Setegn (eds.). Nile River Basin: Ecohydrological Challenges, Climate Change and Hydropolitics, Springer, New York.

[7] FAO AQUASTAT (2005) Irrigation in Africa in figures: Ethiopia–AQUASTAT Survey 2005 http://www.fao.org/nr/water/aquastat/countries_regions/ETH/CP_ETH.pdf Cited 18 Jul 2013

[8] Derib, S. D. (2015) Balancing water availability and water demand in the Blue Nile: A case study of Gumara watershed in Ethiopia. Ecology and Development Series Bd. 95. PhD Thesis, University of Bonn.

[9] USAID. “Sanitation Profile: Ethiopia 2020”, 2020, https://amcow.ams3.cdn.digitaloceanspaces.com/resources/Sanitation%20Profile_Ethiopia_Final.pdf

[10] MoWEI. (2015) Second Growth and Transformation National Plan for the Water Supply and Sanitation Sub Sector (2015/16 – 2019/20), Addis Ababa.

[11] Water Footprint Network https://www.waterfootprint.org/wp-content/uploads/2023/02/8.jpg

Home assignment:

Try to do on your exercise book and will see during tutorial time.

1. Define the word “Hydrology” based on occurrence, physical state , state of motion of water and describe it with respect to Ethiopian water
2. Define “Engineering Hydrology” and its importance for water resources development.
3. Sketch the systematic representation of hydrologic or water balance, label the components and describe what water balance mean for your sketch.
4. Consider the case around (Ethiopia) and identify:
    a) Which part is with higher elevation?
    b) Which part is with lower elevation even below sea level?
    c) What do these elevation mean for hydrology?
    d) How many drainage basin (Ethiopia) has?
    e) Which basin has high surface water and irrigable land?
    f) Which parts of (Ethiopia) receive high and low annual rainfall?
    g) What does this rainfall mean with respect to elevation and drainage basin?
    h) How is the surface water distribution of (Ethiopia) with respect to inland and transboundary drainage basin?
    i) What does this distribution mean with respect to water development and water diplomacy?

Thank you very much for your active attendance!!