Natural Water Resources and Global/Regional Water Crisis

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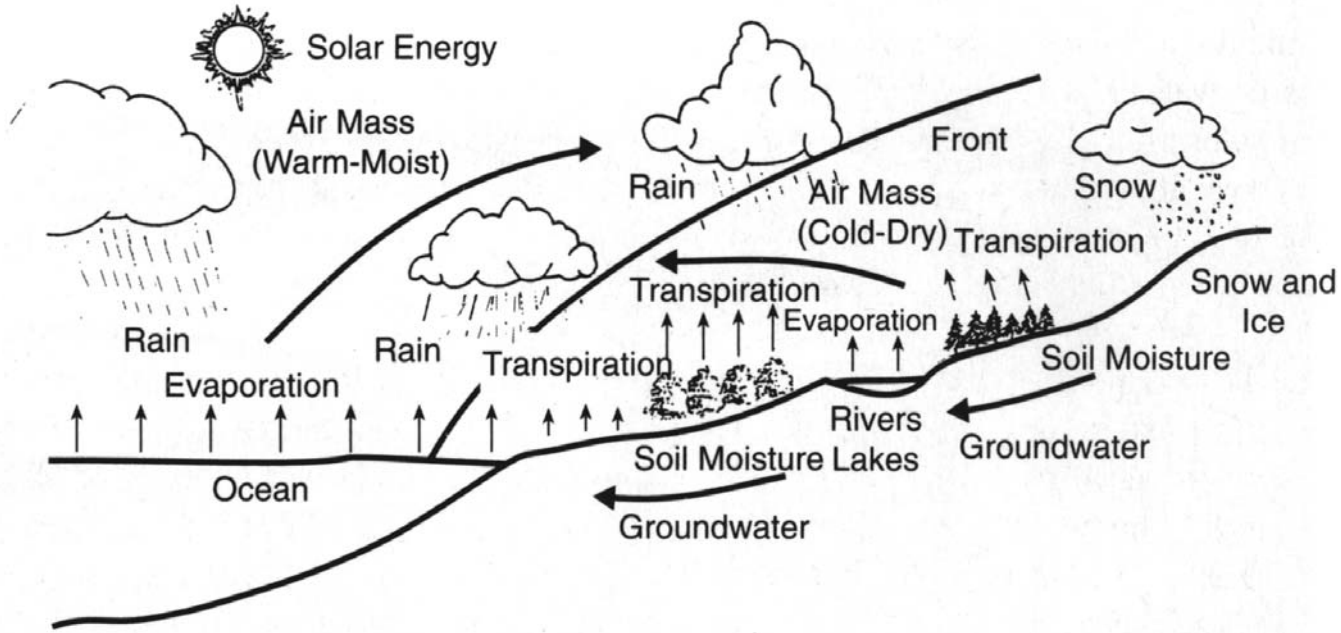
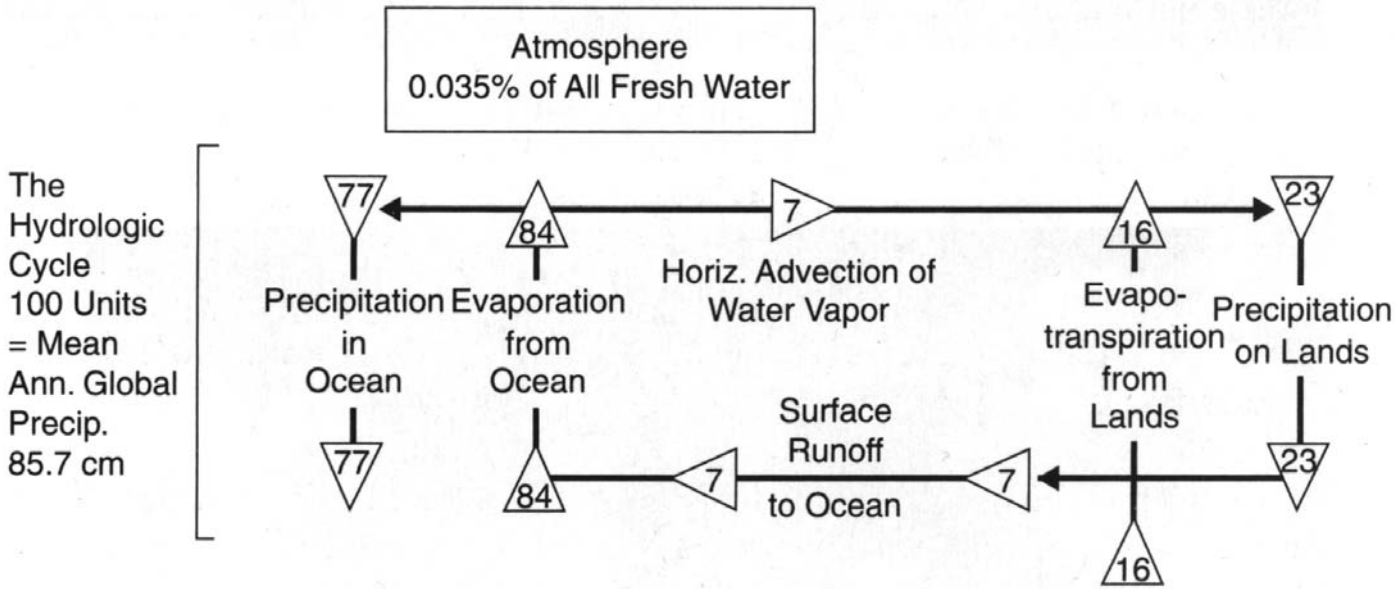
1. Hydrologic Cycle of the World

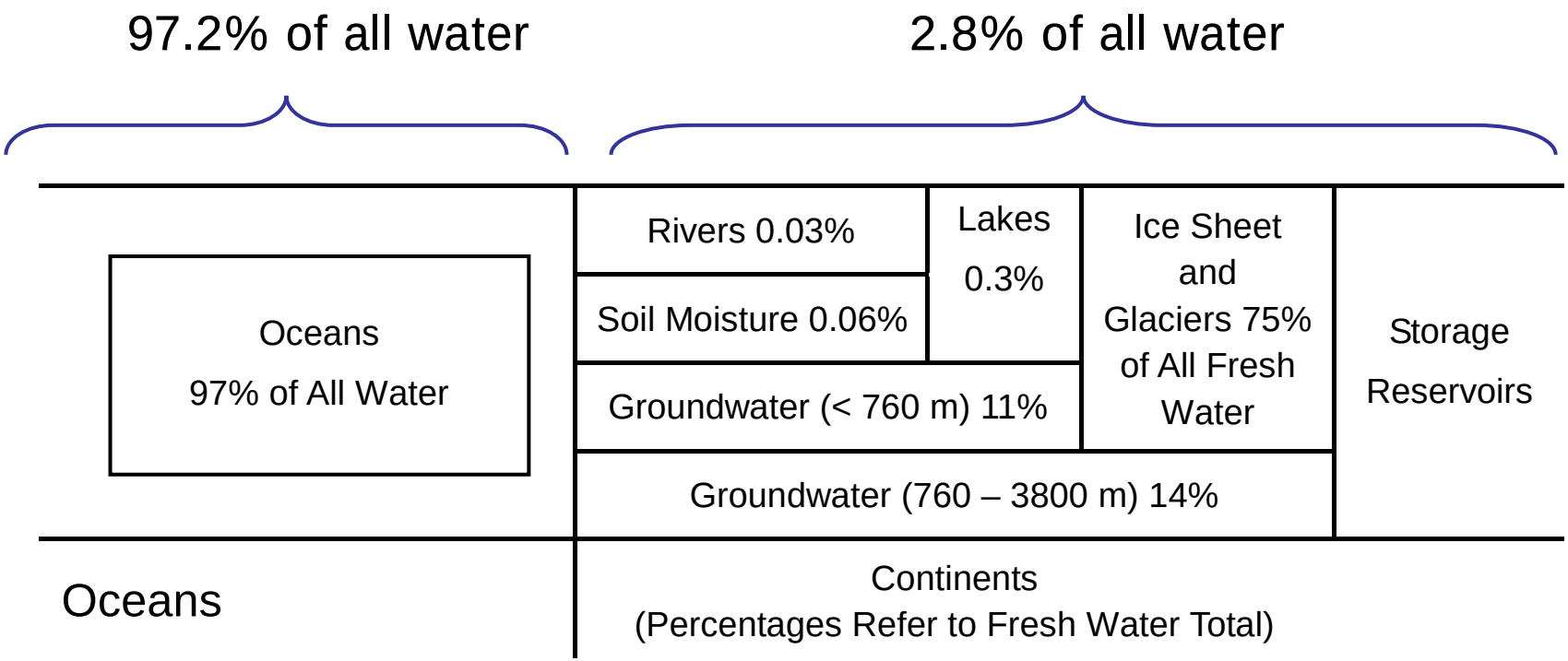
- **Hydrologic cycle – the movement of water between air, sea, lakes and rivers, land, soils, glaciers, and living organisms.**
- **Total water in the world – 1.4×10^{18} m^3 (enough to uniformly cover the entire earth to a depth of 2.7 km)**
- **Ocean coverage – about 70%**





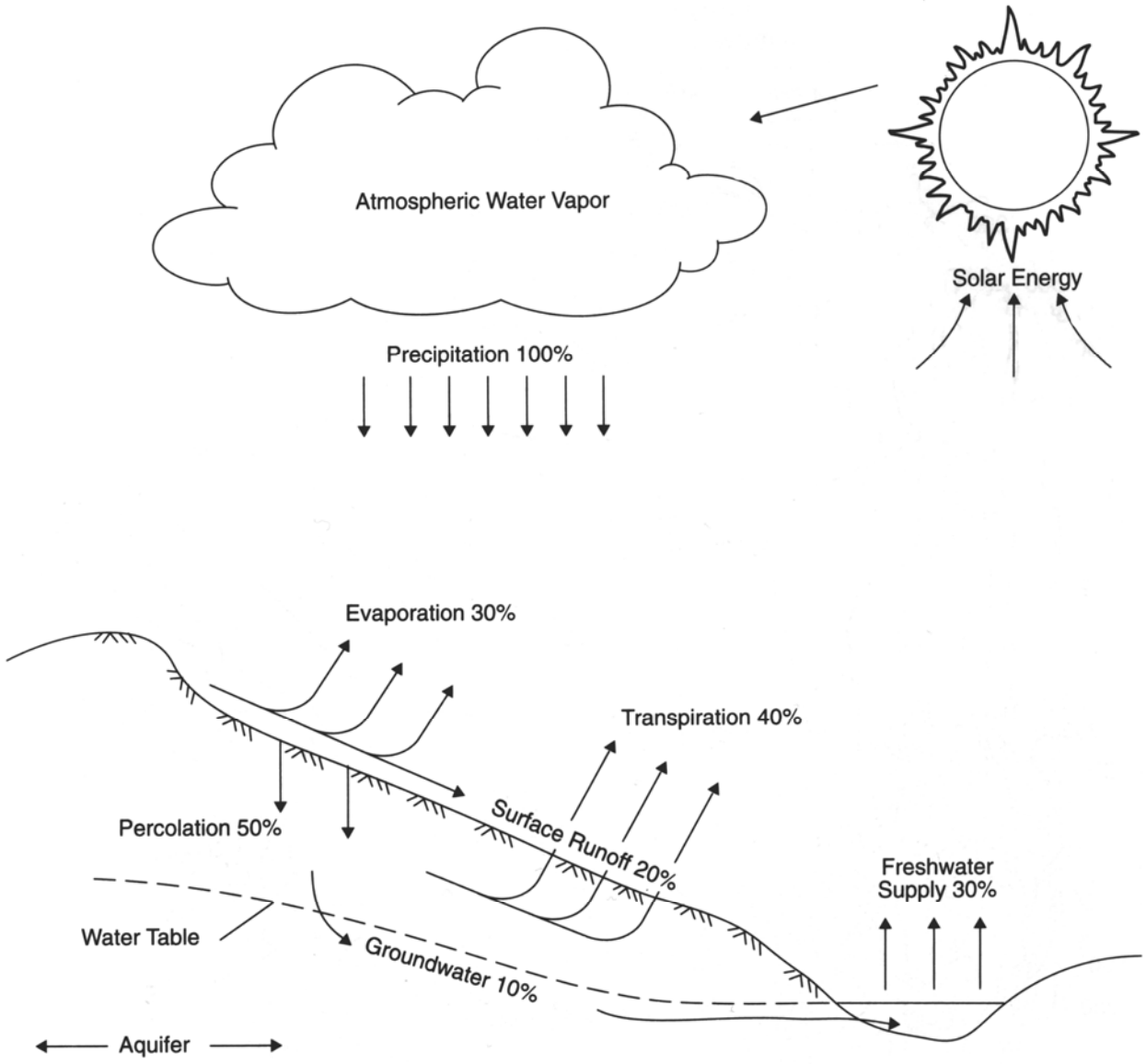
Worldwide Hydrologic Cycle

Break down of water resources



Characteristic Residence Time of Water in Various Compartments of the Hydrosphere

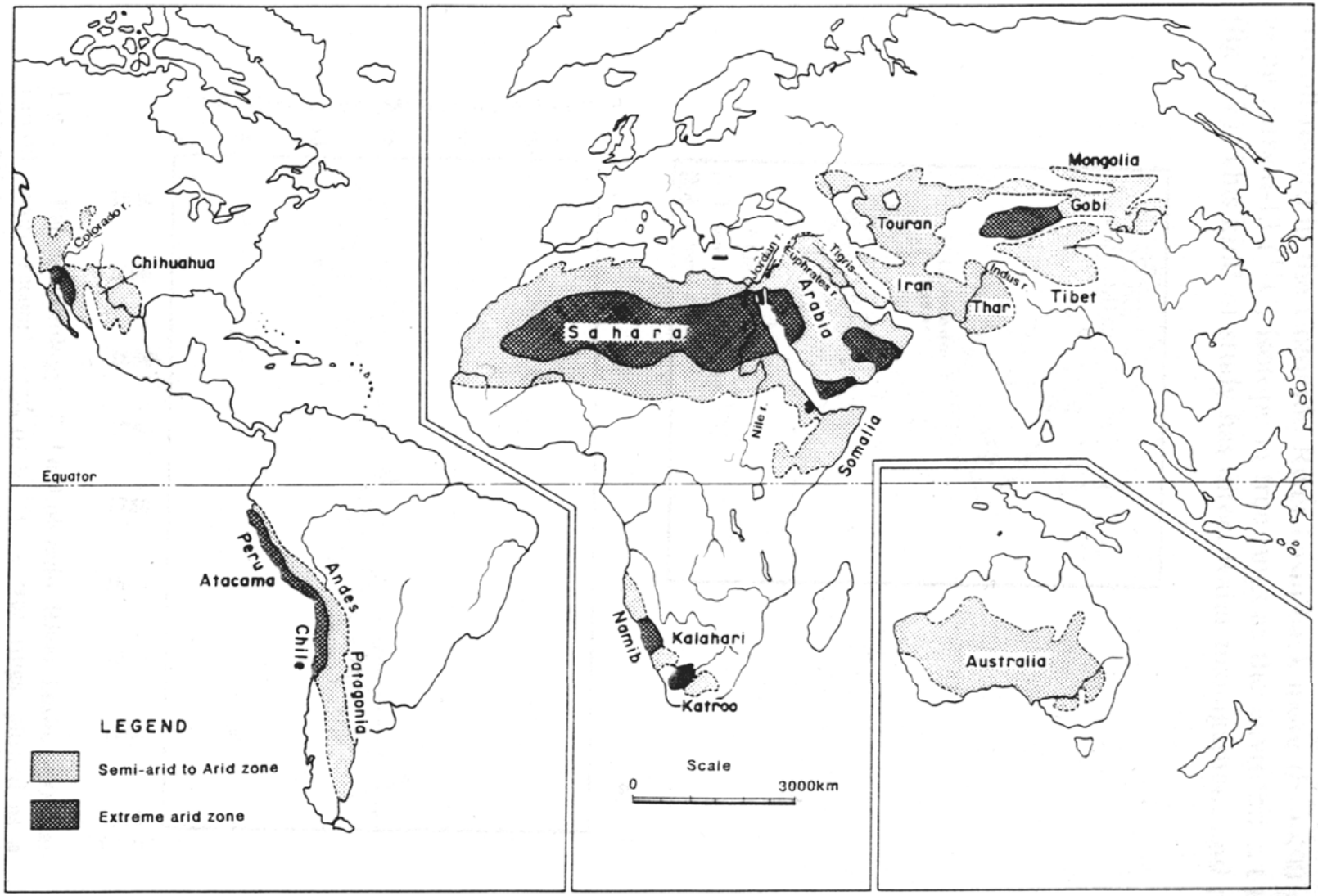
Atmosphere	9 days
Rivers	2 weeks
Soil moisture	Months
Large lakes	10 years
Shallow groundwater	Ten to hundreds of years
Mixed layer of ocean	120 years
World ocean	3000 years
Deep groundwater	Up to 10,000 years
Antarctic ice cap	10,000 years



Hydrologic Cycle in a River Basin

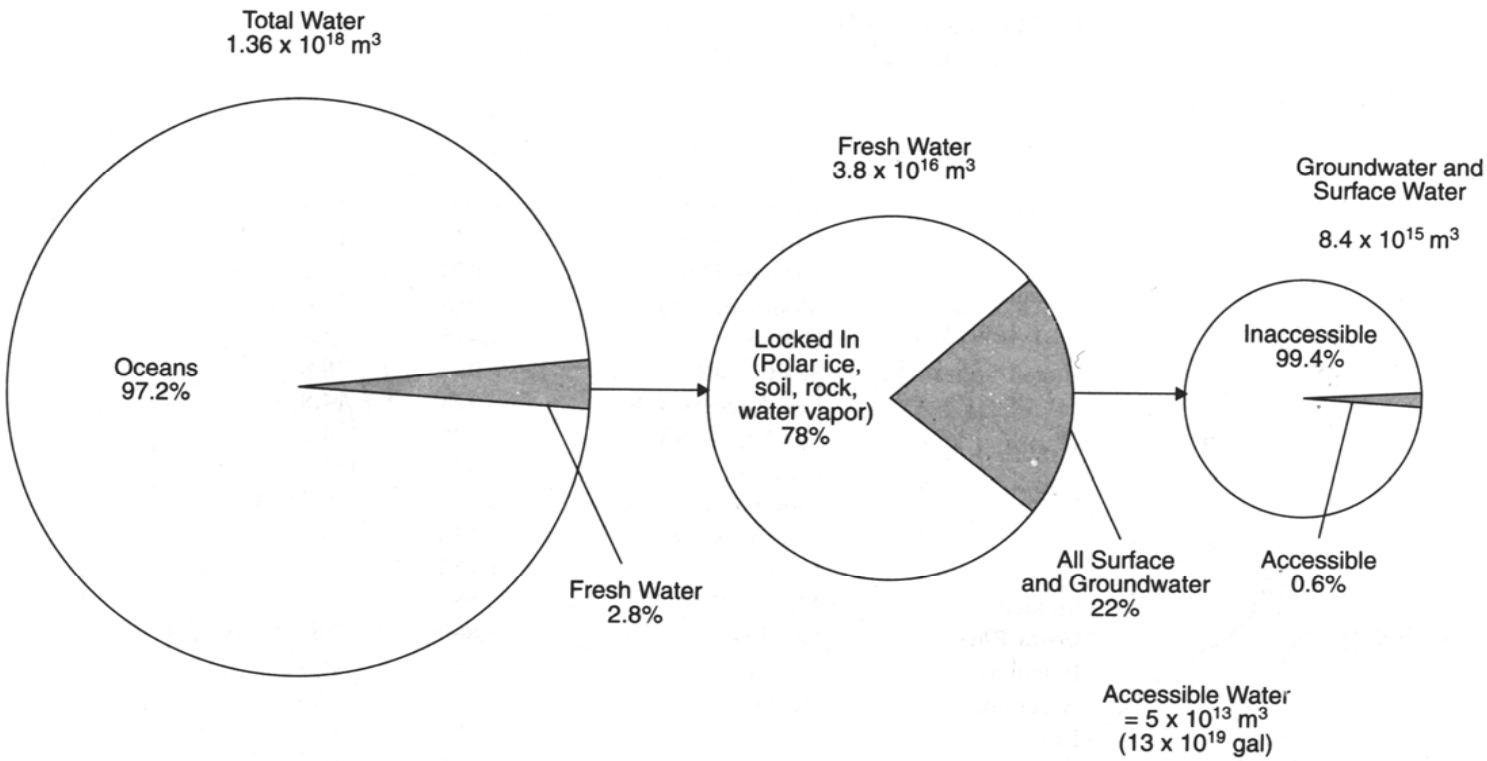
2. Annual Precipitation

- **Uneven distribution of rainfall throughout the world – 10800 mm/yr at Cherrapunji, India, 8690 mm/yr at Buena Vista, Columbia, but 30 mm/yr at Cairo, Egypt, 80 mm/yr at Riyadh, Saudi Arabia.**
- **Uneven distribution of rainfall throughout China – 1600-2200 mm/yr at Guangzhou and Hong Kong, but less than 80 mm/yr at Kashi, Xinjiang.**



World Arid Zones

3. Quantity of Water Available and Global Water Crisis



Water Sources As a Percentage of Total Supply

Reasons for Water Shortage

- Low percentage of accessible water
- Unequal distribution of accessible water
- Rapidly rising demand with population increase
- Pollution of water supplies close to urban areas

Present Condition of Water Use

- **Theoretically accessible water –**

  Total accessible water from water balance calculation – 5 x 10^{13} m^3/yr

  World population – about 6 x 10^9 people

$$\frac{5\times10^{13}\,m^3}{6\times10^{9}\,people}=8333\,L/capita\cdot day$$

- **Actual world per capita use – 35 L/capita·day**

Problems in Developed and Developing Countries

- **Developed countries – having the technology and water management organization to support a higher standard of living based on a high rate of water use – water withdrawals becoming so high that even these facilities cannot keep with the demand.**
- **Developing countries – lacking the facilities to properly treat and distribute the water resources within their reach.**

4. Regional Water Crisis and Related Conflicts

Top 10 countries with the least per capita water resources

Country	Annual Renewable Water Resources (km^3/yr)	Population ('000)	Water Resources per Capita (m^3/yr)
Kuwait	0.02	1,914.40	10.45
Malta	0.02	389.94	41.03
United Arab Emirates	0.15	2,605.96	57.56
Qatar	0.05	565.44	93.73
Libya	0.60	5,289.73	113.43
Saudi Arabia	2.40	20,346.23	117.96
Singapore	0.60	4,018.11	149.32
Jordan	0.88	4,913.12	179.11
Yemen	4.10	18,348.75	223.45
Israel	2.15	6,040.43	355.94

Top 10 countries with the richest per capita water resources

Country	Annual Renewable Water Resources (km^3/yr)	Population ('000)	Water Resources per Capita (m^3/yr)
Iceland	170.00	279.29	608,684.13
Suriname	200.00	417.16	479,433.50
Guyana	241.00	760.51	316,891.36
Congo	832.00	3,018.43	275,640.35
Papua New Guinea	801.00	4,809.22	166,555.25
Gabon	164.00	1,230.09	133,323.79
Solomon Islands	44.70	447.43	99,904.34
Canada	2,901.00	30,756.70	94,320.92
Norway	392.00	4,469.03	87,714.78
New Zealand	327.00	3,778.00	86,553.64

Top 10 countries with the richest annual renewable water resources

Country	Annual Renewable Water Resources (km^3/yr)	Population ('000)	Water Resources per Capita (m^3/yr)
Brazil	6,950.00	170,406.28	40,784.88
Russia	4,498.00	145,491.17	30,915.97
Canada	2,901.00	30,756.70	94,320.92
China	2,800.00	1,275,132.87	2,195.85
Indonesia	2,530.00	212,092.02	11,928.78
USA	2,478.00	283,230.24	8,749.07
Bangladesh	2,357.00	137,439.26	17,149.39
India	2,085.00	1,008,937.36	2,066.53
Venezuela	1,317.00	24,169.74	54,489.62
Myanmar	1,082.00	47,748.94	22,660.19

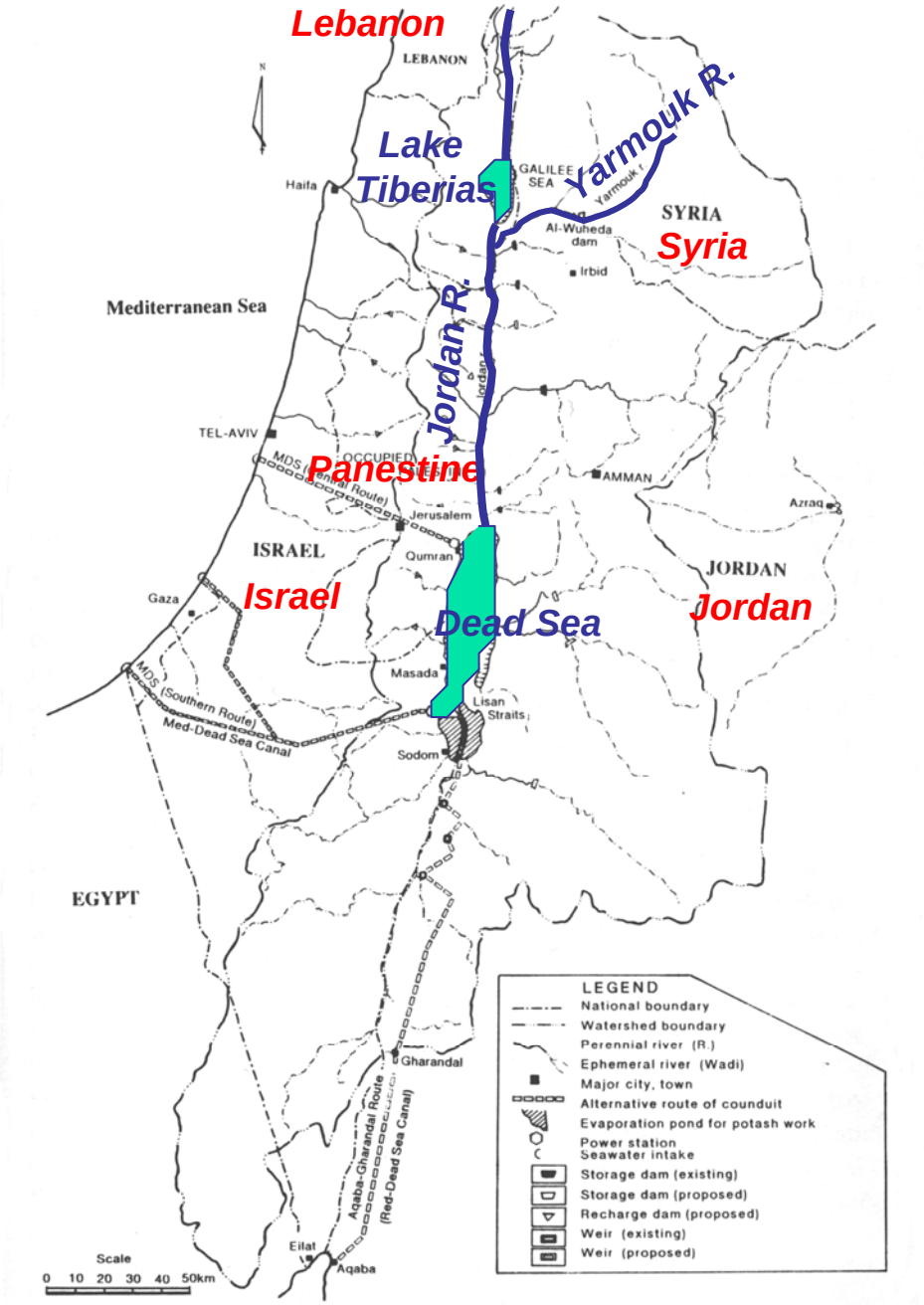
Case I: Water Crisis and Related Conflicts in Jordan River Basin


View No. 1 – North Jordan River
Lake Tiberias
Syria
Israel
Jordan River
Jordan
To Dead Sea

View No. 2 – South Jordan River and the Dead Sea

Basic Data –

- **Total length:**
  - **228 km**
- **Riparian countries:**
  - **Lebanon**
  - **Syria**
  - **Israel/Panestine**
  - **Jordan**
- **Catchment area:**
  - **18300 km^2**
- **Three sections:**
  - **Upper reach**
  - **Yarmouk river**
  - **Lower reach**



The Jordan River Basin

Water Budget of the Upper Jordan River

	Flow (million m^3/yr)
Annual discharge of the headwater	
Dan River	245
Hasbani River	138
Banias River	121
Sub total	**504**
Annual discharge of the Huleh Valley	
Inflow into the valley	504
Local run-off	140
Local consumption (irrigation)	-100
Outflow into Lake Tiberias	**544**
Lake Tiberias	
Inflow into the lake	544
Rainfall over the lake	65
Local run-off and springs	135
Evaporation from lake surface	-270
Outflow to lower Jordan River	**474**

Total Water Budget of the Jordan River Basin

	million m^3/yr
From Lake Tiberias	480
From Yarmouk River	400
From lower Jordan Valley	500
Total	1380

Water Allocation Based on the Johnston Agreement

Country	Water allocated (million m^3/yr)	Percentage of the total (%)
Jordan	720	52
Israel	440	32
Syria	180	13
Lebanon	40	3
Total	1380	100

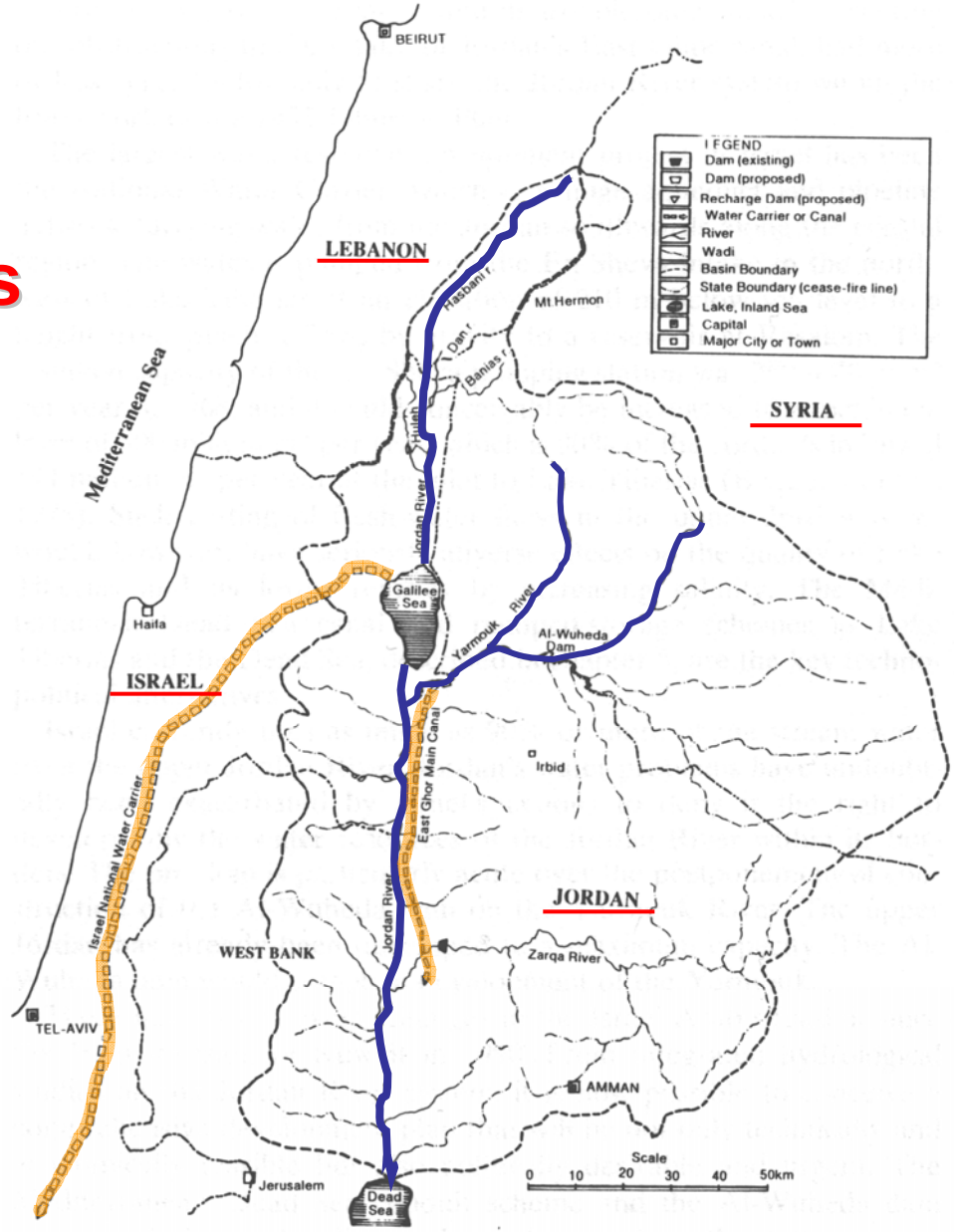
Water Projects Implemented by Riparian Countries

Lebanon: small scale projects

Syria: construction of dams on Yarmouk river

Israel: construction of National Water Carrier

Jordan: construction of East Ghor Main Canal



The Upper Jordan River System and Water Projects

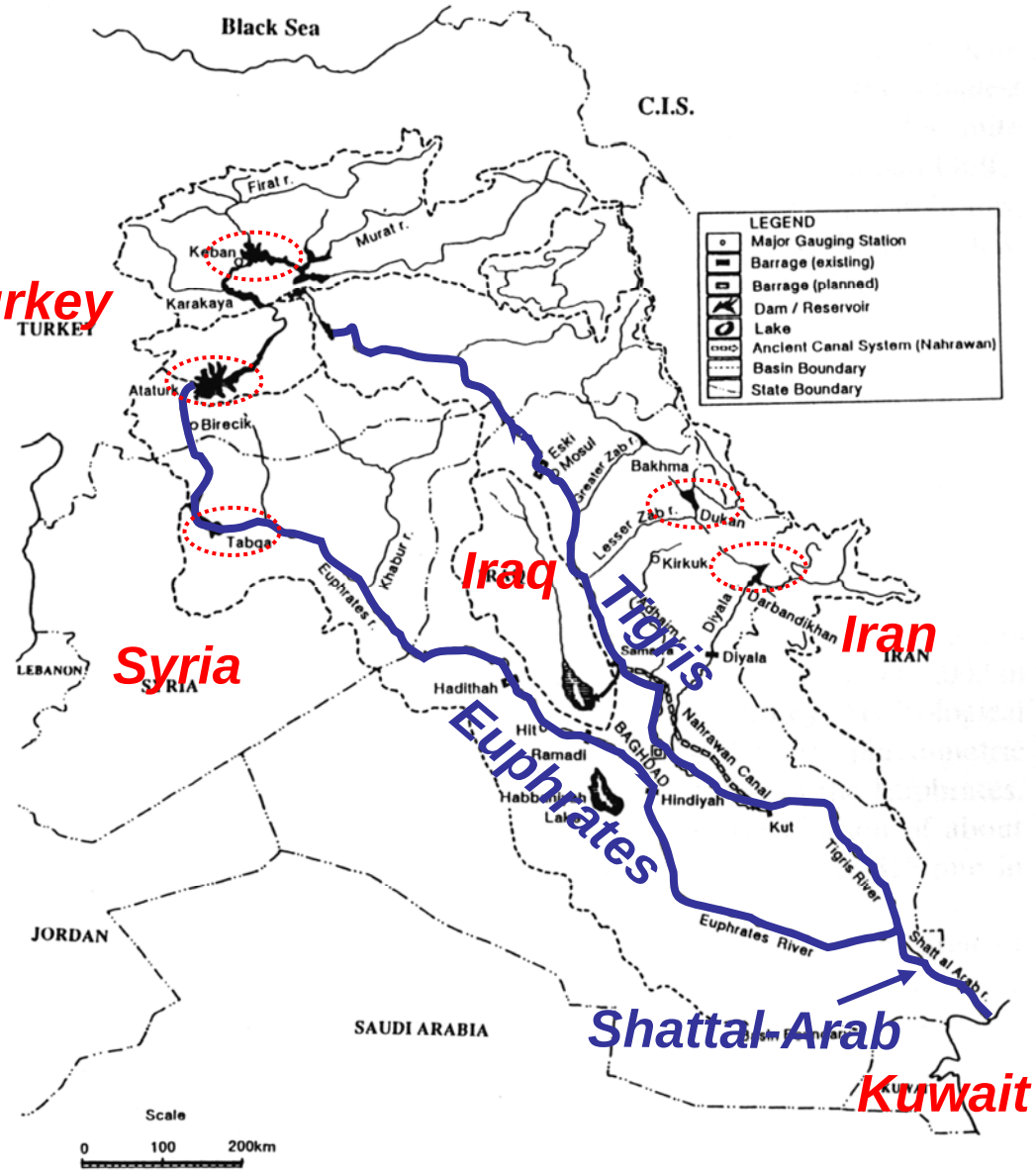
Water Conflicts Between Riparian Countries in J. R. Basin

Date	Countries Involved	Basis of Conflict	Violent Conflict?	Descreption
1948	Arabs, Israelis	Military tool	Yes	Arab forces cut of West Jerusalem's water supply in first Arab-Israeli war.
1951	Israel, Jordan, Syria	Political tool, Military tool, Development disputes	Yes	Jordan makes public its plans to irrigate the Jordan Valley by tapping the Yarmouk River; Israel responds by commencing drainage of the Huleh swamps located in the demilitarized zone between Israel and Syria; border skirmishes ensue between Israel and Syria.
1953	Israel, Jordan, Syria	Development dispute, Military target, Political tool	Yes	Israel begins construction of its National Water Carrier to transfer water from the north of the Sea of Galilee out of the Jordan basin to the Negev Desert for irrigation. Syrian military actions along the border and international disapproval lead Israel to move its intake to the Sea of Galilee.
1965-1966	Israel, Syria	Military tool, Political tool, Control of water resources, Development dispute	Yes	Fire is exchanged over "all-Arab" plan to divert the Jordan River headwaters and presumably preempt Israeli National Water Carrier; Syria halts construction of its diversion in July 1966.
1967	Israel, Syria	Military target and tool	Yes	Israel destroys the Arab diversion works on the Jordan River headwaters. During Arab-Israeli War Israel occupies Golan Heights, with Banias tributary to the Jordan; Israel occupies West Bank.
1969	Israel, Jordan	Military target and tool	Yes	Israel, suspicious that Jordan is overdiverting the Yarmouk, leads two raids to destroy the newly-built East Ghor Canal; secret negotiations, mediated by the US, lead to an agreement in 1970.

Case II: The Tigris-Euphrates Basin

Basic Data –

- **Length:**
  - **Tigris 1718 km**
  - **Euphrates 2330 km**
  - **Shattal-Arab 190 km**
- **Riparian countries:**
  - **Turkey**
  - **Syria**
  - **Iraq**
  - **Iran (near)**
  - **Kuwait (near)**
- **Catchment area:**
  - **423,800 km^2**
- **Mean annual flow:**
  - **Tigris 48.7 x 10^9 m^3/yr**
  - **Euphrates 35.2 x 10^9 m^3/yr**



The Tigris-Euphrates Basin

Major Conflicts between Riparian Countries

- **Conflict occurred in 1990 between Turkey, Iraq and Syria as Turkey finished construction of the Ataturk Dam with a gross reservoir storage volume of more than 40×10^9 m^3.**
- **In mid-1990s Turkey threatened to restrict water flow to Syria to fore it to withdraw support for Kurdish rebels in southern Turkey.**
- **Waters became military targets or military tools during the Iran-Iraq war and Gulf War.**

Inter-Basin Water Development Plan – "Peace Pipeline" Project

Reasons for "Peace Pipeline":

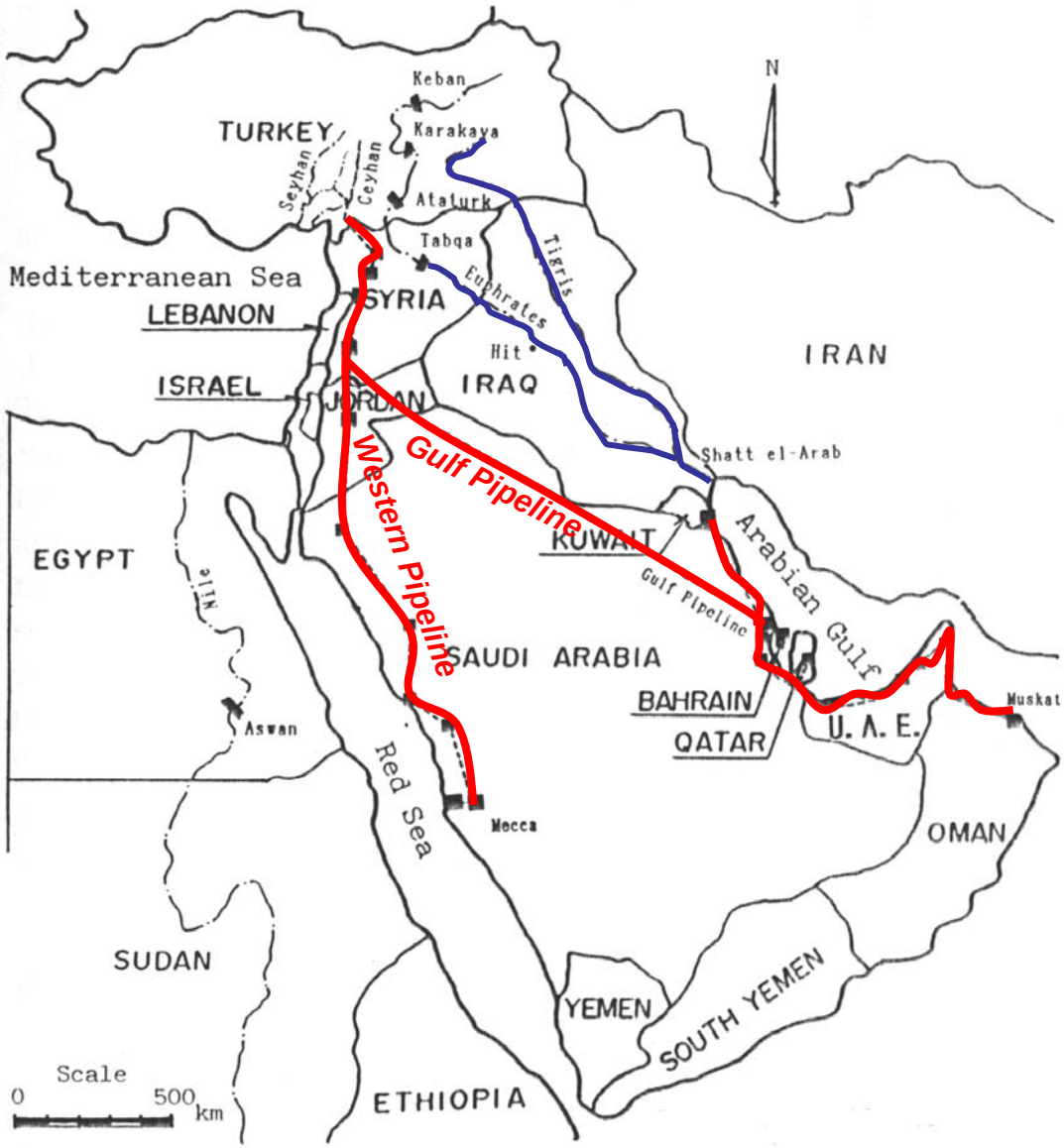
- **The abundant water in the Tigris-Euphrates basin are precious resource for not only the riparian countries, and also for the Middle-East region.**
- **With several large dams, Turkey has more water than its demand and therefore wants to gain benefit from "water selling".**

Western Pipeline:

Turkey – Syria – Jordan – Saudi Arabia (Mecca)

Gulf Pipeline:

Turkey – (Syria) – (Jordan) – Saudi Arabia – Kuwait – Bahrain – Qatar – U.A.E. – Oman



The Peace Pipeline Scheme

Water Supply Plan through the Peace Pipeline

State	City	(m^3/day)	State	City	(m^3/day)
Western Pipeline			**Gulf Pipeline**		
Turkey		300,000	Kuwait		600,000
Syria	Aleppo	300,000	Saudi Arabia	Jubail	200,000
	Hama	100,000		Damman	200,000
	Homs	100,000		Al-Khobar	200,000
	Damascus	600,000		Hofuf	200,000
Jordan	Amman	600,000	Bahrain	Manama	200,000
Saudi Arabia	Tabuk	100,000	Qatar	Doha	100,000
	Medina	300,000	U.A.E.	Abu Dhabi	280,000
	Yanbu	100,000		Dubai	160,000
	Jeddah	500,000		Sharjah/Ajman	120,000
	Mecca	500,000		Umm al-Qaiwain/ Ras al-Khaimah/ Fujarah	40,000
			Oman	Muscat	200,000
Total		3,500,000	Total		2,500,000

Constraints to the Peace Pipeline

- **Project cost: US$ 20 x 10^9 (1990 price)**
- **Water politics of different countries**
- **Unwillingness of Syria to implement the project**
- **Relationship of Arabic countries with Israel**

However, it is an option for consideration in the ongoing peace process.

Case III: Water Crisis in Saharan Africa

Water Resources of Selected Countries in Saharan Africa

Country	Annual Renewable Water Resources (km3/yr)	Population ('000)	Water Resources per Capita (m3/yr)
Libya	0.60	5,289.73	113.43
Algeria	14.30	30,291.34	472.08
Morocco	30.00	29,878.40	1,004.07
Egypt	86.80	67,884.48	1,278.64

Water Related Issues (1)

- ***Water stress and access.*** **Africa's population is expected to exceed 1 billion people by 2025. Although some African countries (in West and Central Africa) have more than enough water on a per capita basis, population growth and economic development create excess demand over supply for most countries. The percentage of population without access to clean water or adequate sanitation is increasing, particularly in the rural and peri-urban areas.**

Water Related Issues (2)

- ***Poverty and food security.*** **Making households water-secure and providing water to rainfed and irrigated areas for food production will be key to reducing poverty in Saharan Africa. This is crucial since, by the turn of the century, poverty affected an estimated 600 million people in Saharan Africa. The poor, most of whom live in rural areas, have limited access to clean water for domestic use and crop production, and adequate sanitation.**

Water Related Issues (3)

- ***Water-borne deceases.*** **Without sufficient supplies of clean water, water-borne and water-related diseases are common in the area. The diarrhea death rate of 17/1000 is the highest in the world. In urban areas, industrial pollution, poor sanitation practices, and discharge of untreated wastewater into surface and ground waters have caused widespread water contamination.**

Water Related Issues (4)

- ***Environment and aquatic systems*. An estimated 320 million hectares of vegetated lands have been degraded over the past several decades in Saharan Africa, causing flooding, reduced ground water recharge, and reduced stream baseflow. Poor cultivation , deforestation, and overgrazing have had similar effects.**

Water Related Issues (5)

- ***Dependency and subsidy.*** **Saharan Africa countries are very dependent on external financing, and throughout the region, water use is highly subsidized since water tariffs are set below the supply costs and often below the operation and maintenance costs. Consequently, cost recovery remains low, increasing the financial burden on the central government to provide capital for maintaining existing systems and developing new infrastructure.**

Sahara Desert with endless sand dunes and no vegetations

Arrival of sandstorms with strong wind blow

A shallow well is the only water resource for villagers

Wind also left beautiful footprints on a sand dune

Under a harsh environment, life is still joyful for boys

Girls are brave enough to front a camera – the colorful dresses and carefully braided hair showing their special beauty

Water –
every drop being precious !