Introduction

GG22A: GEOSPHERE & HYDROSPHERE
Hydrology

What is hydrology?

- The study of water
  - More particularly: the study of the circulation of atmospheric* and terrestrial *fresh* water

* specifically, as it hits or leaves the surface

Science and technology

- Science aims to *understand things*
  - *hydrological science seeks to understand the hydrological cycle*
- Technology aims to *do things*
  - *hydrological technology involves the application of mathematical procedures to practical problems involving water*

Hydrological science

- *"The business of hydrology is to solve the water balance equation"*

  Dooge (1987)

- *"Hydrologists are now being forced to consider the atmosphere and the land surface as an interactive coupled system, a perspective which draws us closer to the geophysicist's viewpoint of global scale processes"*

  Eagleson (1986)

Hydrology as technology

- For example, develop equations to predict the magnitude of the mean annual flood:
  - Qbar = 0.203 AREA0.94 SOIL1.23 RSMD1.03

Global water reservoirs and fluxes

- About 97% occurs as saline water.
- More than 50% of remaining fresh water is "locked up" as ice sheets and glaciers.
- Mobile fresh water represents only about 0.3%.

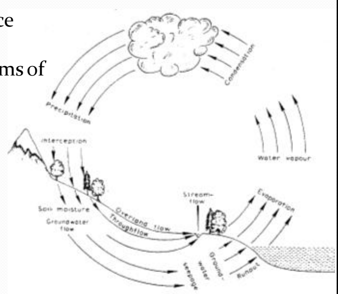
	Values ($km^3 \times 10^3$)	*Percentage of total*	*Range of values in recent literature ($km^3 \times 10^3$)*
Reservoir			
Ocean	1 350 000.0	97.403	1.32–1.37 × 10^6
Atmosphere	13.0	0.000 94	10.5–14.0
Land	35 977.8	2.596	
Rivers	1.7	0.000 12	1.0–2.1
Freshwater lakes	100.0	0.007 2	30.0–150.0
Inland seas, saline	105.0	0.007 6	85.4–125.0
Soil water	70.0	0.005 1	16.5–150.0
Groundwater	8 200.0	0.592	7.0–330.0 × 10^3
Ice caps/glaciers	27 500.0	1.984	16.5–29.2 × 10^3
Biota	1.1	0.000 08	1.0–50.0
Annual flux			
Evaporation	496.0		446.0–577.0
Ocean	425.0		383.0–505.0
Land	71.0		63.0–73.0
Precipitation	496.0		446.0–577.0
Ocean	385.0		320.0–458.0
Land	111.0		99.0–119.0
Runoff to oceans	41.5		33.5–47.0
Rivers	27.0		27.0–45.0
Groundwater	12.0		0.0–12.0
Glacial meltwater	2.5		1.7–4.5

Three key concepts:

1. Cycle
2. System
3. Continuity

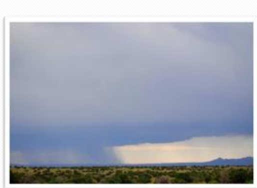
The hydrological cycle

- The interdependence and continuous movement of all forms of water.



The hydrological cycle

- Water vapour in the atmosphere condenses and may give rise to precipitation.



The hydrological cycle

- In the terrestrial part of the cycle, not all of the precipitation reaches the ground, but is intercepted by vegetation and buildings to be re-evaporated.

The hydrological cycle

- Precipitation reaching the ground follows one of three routes:
  - Route 1: it remains as surface storage and is re-evaporated.

The hydrological cycle

- Route 2: it flows over the surface into streams and lakes
  - It may then re-evaporate, seep to the groundwater or flow into the sea.
- Route 3: it infiltrates into the ground as soil moisture
  - It may then evaporate, move by throughflow to streams, or move by downward percolation to the groundwater.

The hydrological cycle

- The cycle implies a smooth sequential movement, but it can be short-circuited:
  - Precipitation may be evaporated back to the atmosphere.
  - Precipitation may fall on a lake and re-evaporate without touching the land surface.
  - It may move to the groundwater storage zone and be "locked up".
  - The cycle is also modified by human activity.

The hydrological cycle

- Water movement within the cycle is irregular and many phases of the cycle are spasmodic.
  - Rainfall is often spasmodic.
  - Streamflow and Evaporation may also be spasmodic.

The hydrological cycle

- The cycle permits the relationship between the components to be expressed, but has limited practical value when concerned with water movement in a specific area.
- Hydrological studies in drainage basins have taken a systems approach to many practical aspects.

The hydrological system

- Each drainage basin is an individual system receiving inputs (*precipitation*) and transforming it via flow routes and storages into the principal outputs (*evaporation* and *runoff*).
- These inputs and outputs, flow routes and storage can be *quantified*.

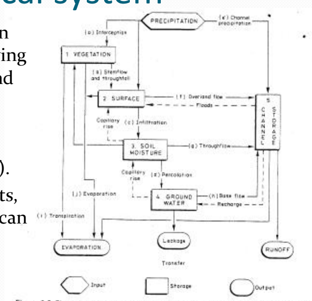


Figure 1.2 *The drainage basin hydrological system (from an original diagram by Professor J Lewin).*

The hydrological system

- The hydrological system has 5 principal storage zones:
  - 1. Vegetation
  - 2. Ground Surface
  - 3. Soil Moisture
  - 4. Groundwater
  - 5. Channel Storage
- Each can be regarded as sub-systems of the drainage basin hydrological system

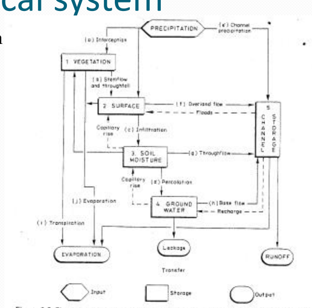


Figure 1.2 *The drainage basin hydrological system (from an original diagram by Professor J Lewin).*

The hydrological system

- Hydrological processes rarely operate free from human influence.

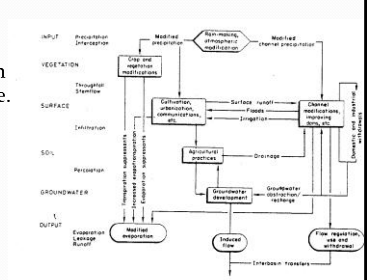


Figure 1.3 *Principal areas of human intervention in the hydrological system (from an diagram by Professor J. Lewin).*

The hydrological system

- The most important human modifications relate to:
  - 1. Large-scale modification of channel flow and storage by means of surface changes which affect surface runoff and the incidence and magnitude of flooding.
    - e.g. afforestation, deforestation, urbanization
  - 2. The development of irrigation and land drainage, modifying soil moisture characteristics, infiltration, runoff etc.
  - 3. Large-scale abstraction of groundwater and surface water for domestic and industrial uses.

Hydrological continuity

- Continuity of mass and energy:

$$\frac{ds}{dt} = P_t - E_t - Q_t$$

ds/dt = change in storage over time
P_t = precipitation
E_t = evaporation
Q_t = runoff

The global water balance

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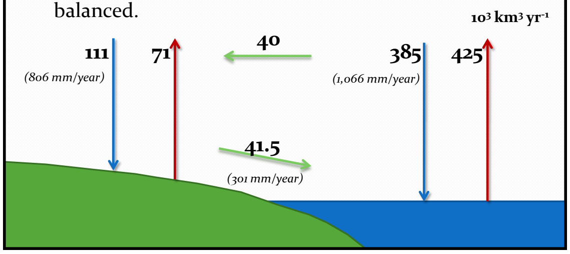
The global water balance

- The global annual flux of water between precipitation and evaporation appears to be approximately balanced.



The global water balance

- Attempts have been made to quantify the amounts of water following the main routes within the hydrological cycle.
  - It is possible to approximately calculate the global annual water balance (or hydrological balance budget):

$$P = E + R \pm S$$

P = Precipitation
E = Evaporation
R = Surface Runoff
S = Gains or Losses due to Changes in Storage

The global water balance

- The global water balance is largely a theoretical concept.
  - It is more realistic to calculate the water balance of a location or region.
  - These will differ greatly from the global water balance due to the influence of local factors (e.g. precipitation, temperature, vegetation, soils, relief, rock type).

The water balance in a tropical rainforest

- Well distributed, high annual precipitation (>2000 mm).
- Balanced by large-scale evaporation and transpiration (due to large biomass and high temperatures), and by runoff.

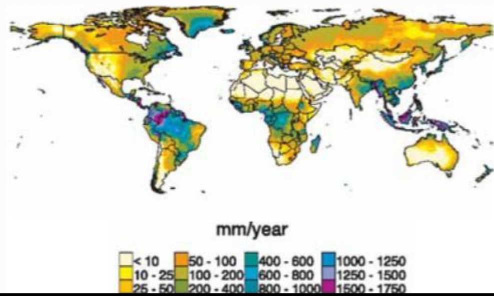
The water balance in a sub-tropical hot desert

- Annual precipitation <250 mm.
- Balanced dominantly by large-scale evaporation.
- Minimal runoff (except for ephemeral flows).

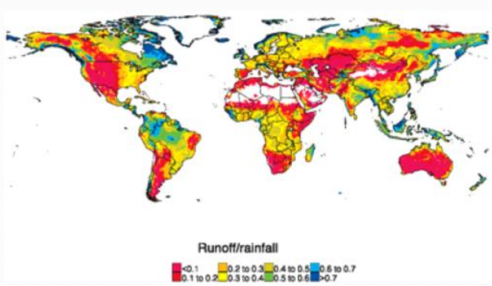
The water balance in a high-latitude region

- Annual precipitation generally low (<300mm).
- Balanced mainly by runoff from spring and summer melting.
- Reduced evaporation due to low temperatures and sparse vegetation.

Average annual runoff



Runoff as proportion of rainfall



The seasonal water balance of a region

- In seasonal climates, evaporation and transpiration may greatly exceed precipitation during the dry season, with the result that runoff becomes less significant.
  - Results in a water deficit.
- The opposite occurs in the wet season leading to a moisture excess.
  - Results in a water surplus.

Where next…?

- The next few lectures will focus on aspects of the hydrological cycle:

2. Precipitation
3. Interception
4. Evaporation
5. Water in the soil
6. Groundwater
7. Runoff generation

- Then we will look at some wider issues:

8. Hydrological modelling
9. Extreme events: flooding
10. Estimating flood risk