The background features a light beige gradient with several large, flowing, abstract shapes in purple, green, and blue. Interspersed among these are numerous small, yellow, starburst-like shapes of varying sizes.

Lecture 1

Introduction to

Hydrogeology

What is Groundwater?

The water contained in interconnected pores located below the water table in an unconfined aquifer or located in a confined aquifer. (Fetter,2001)

Water beneath the earth's surface, often between saturated soil and rock, that supplies wells and springs. (Answers.com)

Water in the zone of saturated.

What is Subsurface Water?

- All water which is subterranean, whether solid, liquid or gaseous. (*Bowen*)

地下水的概念

- 地下水是指赋存于地面以下岩土空隙中的水，包气带及饱水带中所有含于岩石空隙中的水均属之。（广义）

(Subsurface water)

- 地下水仅指赋存于饱水带岩土空隙中的水。（狭义）

(Ground water)

What is Hydrogeology?

Mead(1919) defined hydrogeology as “the study of the occurrence and movement of subterranean waters”.

Meinzer(1923) used the term geohydrology to describe in principle the same physical process.

Hydrogeology is “the study of the occurrence, movement and chemistry of groundwater in its geological environment”.

水文地质学的定义

- 研究地下水的形成、分布、运动规律、物理和化学性质以及同其他水体的相互关系的科学。（全国科学技术名词审定委员会，水利科技名词，1997）
- 水文地质学是研究地下水的科学。它研究与岩石圈、水圈、大气圈以及人类活动相互作用下地下水水量和水质的时空变化，并研究如何运用这些规律去兴利除害，为人类服务。（王大纯，1995）

What is Hydrology?

Hydrology is a scientific study of the waters occurring on the Earth. Particularly the relationship between precipitation and evaporation upon the occurrence and character of ground water.

<http://waterquality.ifas.ufl.edu/FAQs/FAQs-general.htm#Hydrology-1>

Hydrology is the science that deals with water as it occurs in the atmosphere, on the surface of the ground, and underground. (USGS)

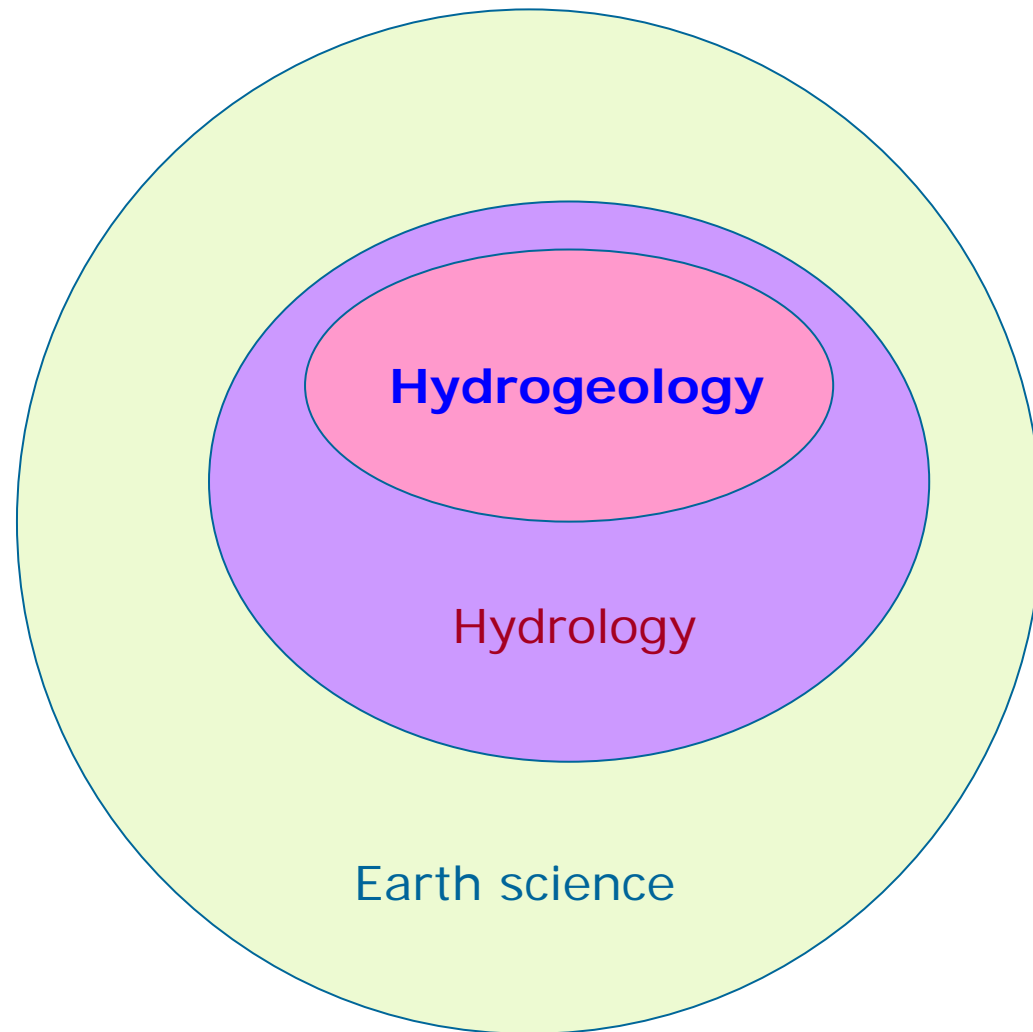
水文学的定义

- 研究地球各种水体的发生、循环及分布，水体的生物、化学和物理性质，以及水体与其周围环境（包括生物界）的相互作用的科学。（全国科学技术名词审定委员会，水利科技名词，1997）
- 水文学是研究自然界各种水体，如河流、湖泊、冰川、沼泽、海洋、地下水及大气中的水汽的运动、变化和分布规律的学科。（王红亚，水文学概论，北京大学，2007）

水资源学的定义

- 研究水资源的产生、循环规律和开发利用及管理的科学。（全国科学技术名词审定委员会，水利科技名词，1997）
- 水资源学（science of water resources）研究地球水资源的形成、分布、运动和演变规律，及应用这些规律解决人类对水的需求和由此引起的环境问题的科学。水资源学具有自然科学和技术科学的属性，并涉及社会科学领域中的一些问题。（陈家琦）

Relationship
among
Hydrogeology,
Hydrology,
and Earth
sciences



Relation with other sciences

Basic Sciences

mathematics physics chemistry...

Other Earth sciences

geology hydrology meteorology geochemistry...

Other sciences

environmental sciences agriculture pedology
ecology economics sociology
resources sciences ...

interdiscipline

Branch of Hydrology

Hydrogeology + Chemistry \longrightarrow Hydrogeochemistry

Hydrogeology + Stochastic \longrightarrow Stochastic Hydrogeology

Hydrology + Stochastic \longrightarrow Stochastic Hydrology

Hydrology + Pedology \longrightarrow Pedo-hydrology

Hydrology + Ecology \longrightarrow Eco-hydrology

Courses

- **Foundation of Hydrogeology**
- **Dynamics of GW/Hydraulics of GW/GW
Hydraulics**
- **Hydrogeochemistry**
- **Isotopic Hydrogeology**
- **Mineral Deposit Hydrogeology**
- **Engineering Hydrology**
- **Statistical Hydrology**
- **Vadose Zone Hydrology/ Unsaturated Hydrology**

Application of Hydrogeology

- *Water resources engineering*
- *Hydraulic engineering*
- *Drainage engineering*
- *Environmental engineering*

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Water resources engineering

For the design of water resources engineering works including water wells and well field, hydrogeological assessment are needed. Wells supply groundwater to user areas to satisfy water demand.

In recent decennia, the use and demand have increased considerably.

In arid area, groundwater is the most important water resources.



Hydraulic engineering

Water works or water-associated works that are designed by hydraulic and civil engineers including diversion weirs (分水堰) in rivers, dams at reservoirs, dikes and embankments along rivers, road supports and foundations for buildings.

S1

For example, the spatial distribution and fluctuations in groundwater tables in an area are determining factors for the stability computations carried out for the design of water works.

S1

分水堰

SCB, 2007-11-6

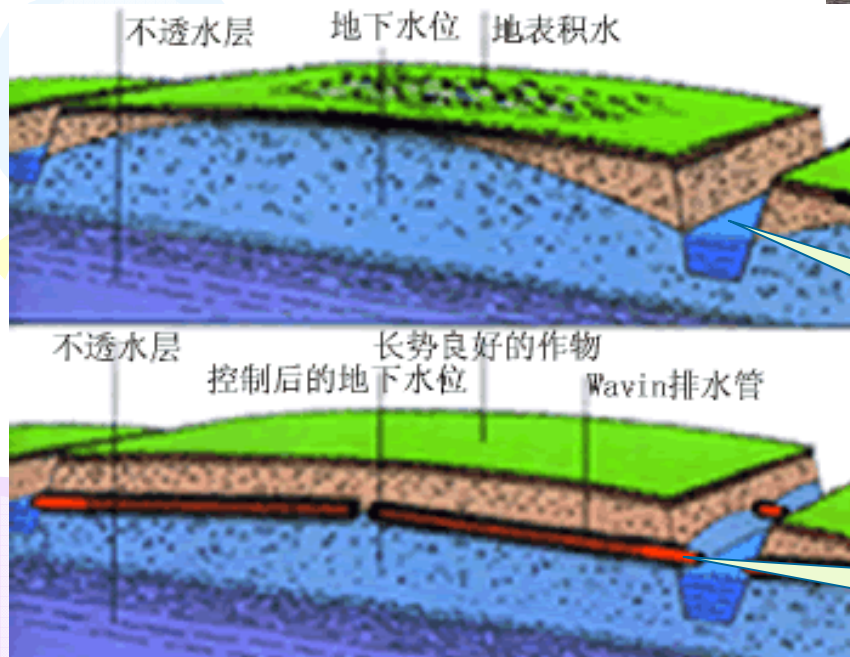


Drainage engineering

Dewatering (排水、降水) and drainage infrastructures are developed by engineering geologists, mining experts, and agricultural engineers.

For engineering geologists and mining experts hydrogeological assessments are valuable when they compute pump capacity to be installed in building pits.

Knowledge of hydrogeology is also crucial to the agricultural engineer who wishes to install horizontal drainage systems or vertical drainage schemes consisting of wells.



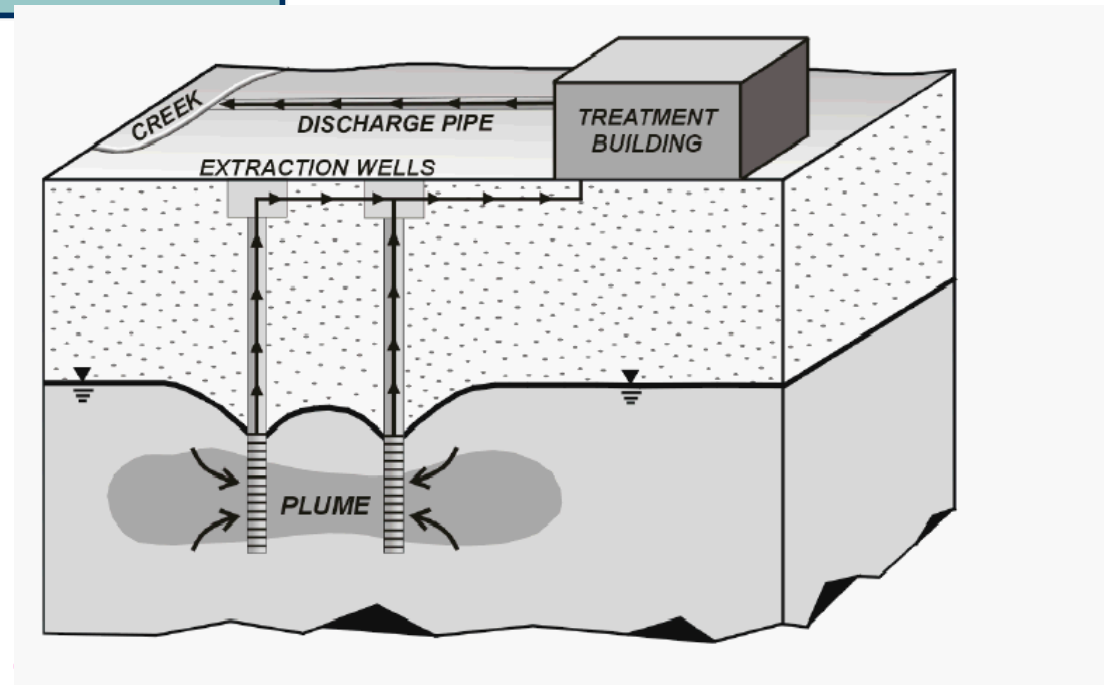
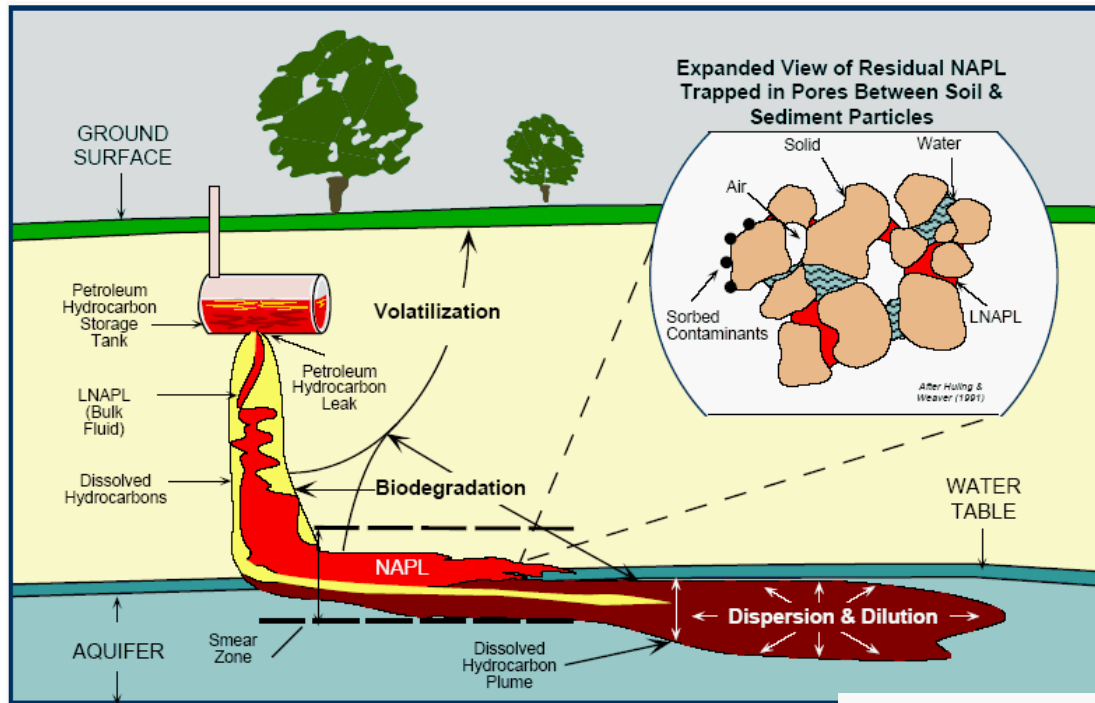
ditch drainage

tile drainage

Environmental engineering

Environmental engineering concerns the setting up of measures and the organization of operations to prevent and restore adverse effects on groundwater.

In particular in the past decennium, there has been full agreement amongst scientists that groundwater is a precious resource which has to be carefully assessed and managed.



Role of Hydrogeology

Hydrogeology is playing a central role in many engineering disciplines. However, it will be clear that not only hydrogeologists and engineers focus on hydrogeology. Increasingly so, other professionals including “**politicians** and other **decision makers**”, **environmentalists**, **biologists** and even **economists** have to pay attention to groundwater issues. Proper training in hydrogeological assessments is also an essential part of the game. Groundwater can not be taken for granted anymore. People will have to pay a larger price for the proper management and rehabilitation of groundwater resources in the foreseeable future.

History of hydrogeology

In the old Greek and Roman civilizations philosophers and scientists have speculated about “underground waters”. They were puzzled by spring, and the discharges of water in rivers in dry periods, long after precipitation has stopped. The Greek Plato (427-347 B.C.) and other philosophers offered a solution. They thought that groundwater originated from a cavern which was connected to the ocean. By the action of waves, water of the sea was transported from the ocean upward into caverns and from there to spring and rivers.

History of hydrogeology

The true explanation for the occurrence of springs and discharges in rivers during dry periods was put forward by the French scientists Perraut(1608-1680) and Mariotte(1620-1684). Perraut suggested that the amount of precipitation in the Seine catchment in France could easily account for all the discharge in the river Seine. Mariotte carried out infiltration experiments in the catchments and discharge measurements in the Seine. He found that precipitation could infiltrate into the ground and underlying rocks in appreciable quantities. Mariotte concluded that these rocks, acting as a storage medium, could sustain springs and a year around discharge in the Seine.

History of hydrogeology

In the 19th century, another development drew wide attention from other scientists in the field of hydrogeology. The French water engineer Darcy(1803-1858)made a start with groundwater hydraulics (Darcy, 1856). He did experiments with sand filters and formulated his well-known formula to compute the “flow rate” of groundwater in porous rocks.

Darcy's law
$$v = KI = -K \frac{dh}{dl}$$

K: permeability coefficient

I: hydraulic gradient

History of hydrogeology - formula

*Flow formulae based on ‘Darcy’s law’ have been developed. Scientists including Thiem(1906), **Theis**(1935)and **Jacob** (1950) developed formulae for radial flow to wells. The formula concern the flow of fresh groundwater with constant density. The range of formula includes expressions describing the **flow to wells** in various natural environments. Flow formula for **open and closed** groundwater systems , for “soft and hard” rocks and for **steady and non-steady** conditions were developed. The scientific efforts to develop appropriate formulae for the flow to wells and for the flow in areas with a **varying water density** were initially based on an analytical approach; i.e. on the application of analytical methods to solve the general groundwater flow equations.*

History of hydrogeology - modeling

From about 1960 less attention has been paid to the development of analytical methods. Models based on numerical methods became rapidly popular and they form the basis for most of the flow computations presently carried out. Compared with the flow equations based on analytical methods, models are much better suited to describe groundwater flow in area where the groundwater system is of a complex nature.

Also through the introduction of PC, the use of models increased quickly.

History of hydrogeology

— Flow systems analysis

One recent development in the hydrogeology has been the introduction of flow systems concept. Traditionally hydrogeological classifications were mainly based on the rock types in a particular area. In the flow system concept as formulated by Toth(1962), classifications were suggested which are based, not only on rock type, but also take into account groundwater flow distributions.

The flow systems concept provides a flexible approach towards groundwater analysis; in particular for areas where human interferences in the groundwater system have to be studied.

History of hydrogeology

— Hydrochemistry & groundwater contamination

*Other recent developments in the science of hydrogeology include the work done on **groundwater chemistry** and groundwater **contamination**. In this field, the behaviors of chemical components is studied with the objective to assess the flow paths of groundwater through rocks.*

Perhaps the most recent topic is the coupling of physical and physico-chemical processes in solute transport modeling.

THMC: Thermal-Hydro-Mechanics-Chemical