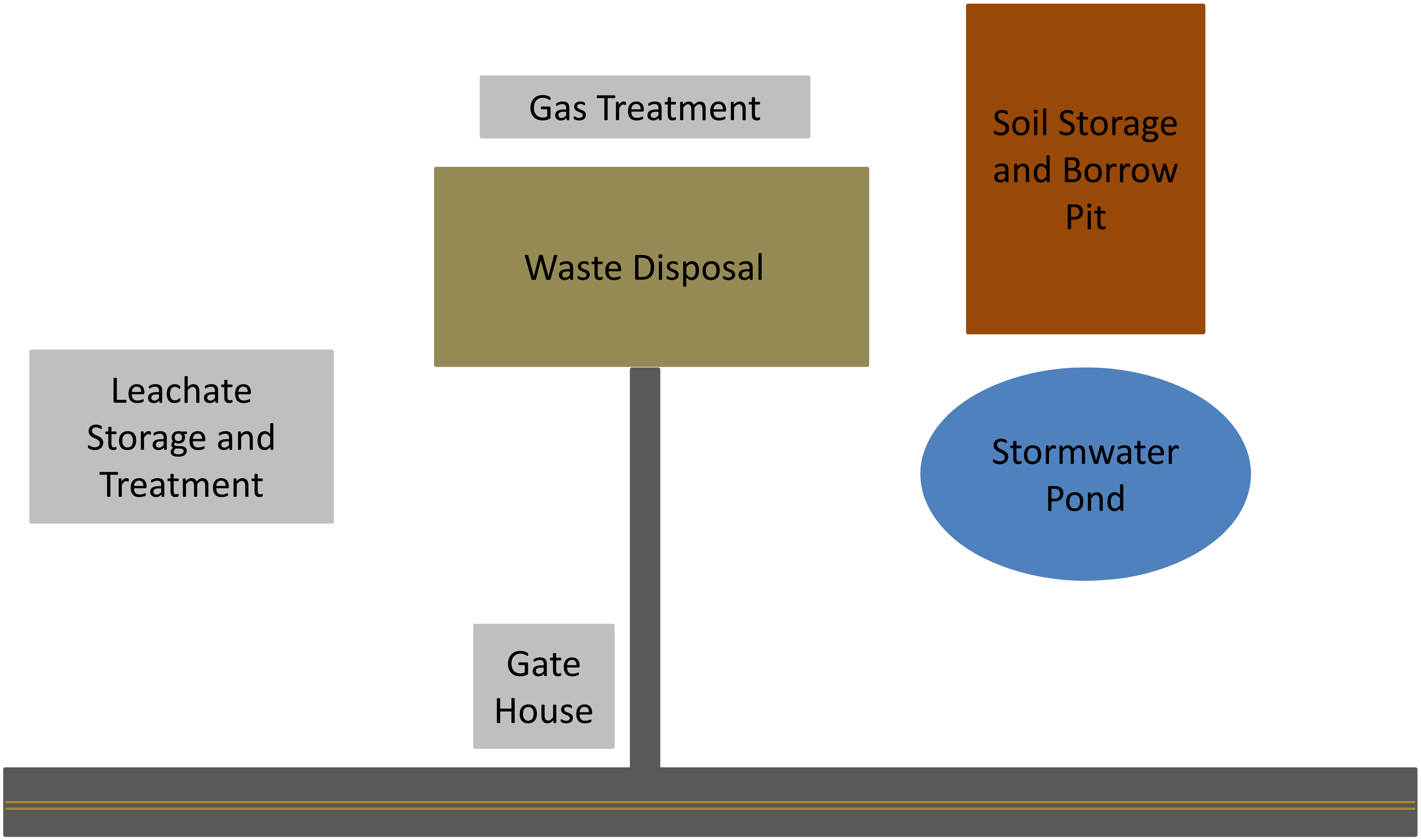
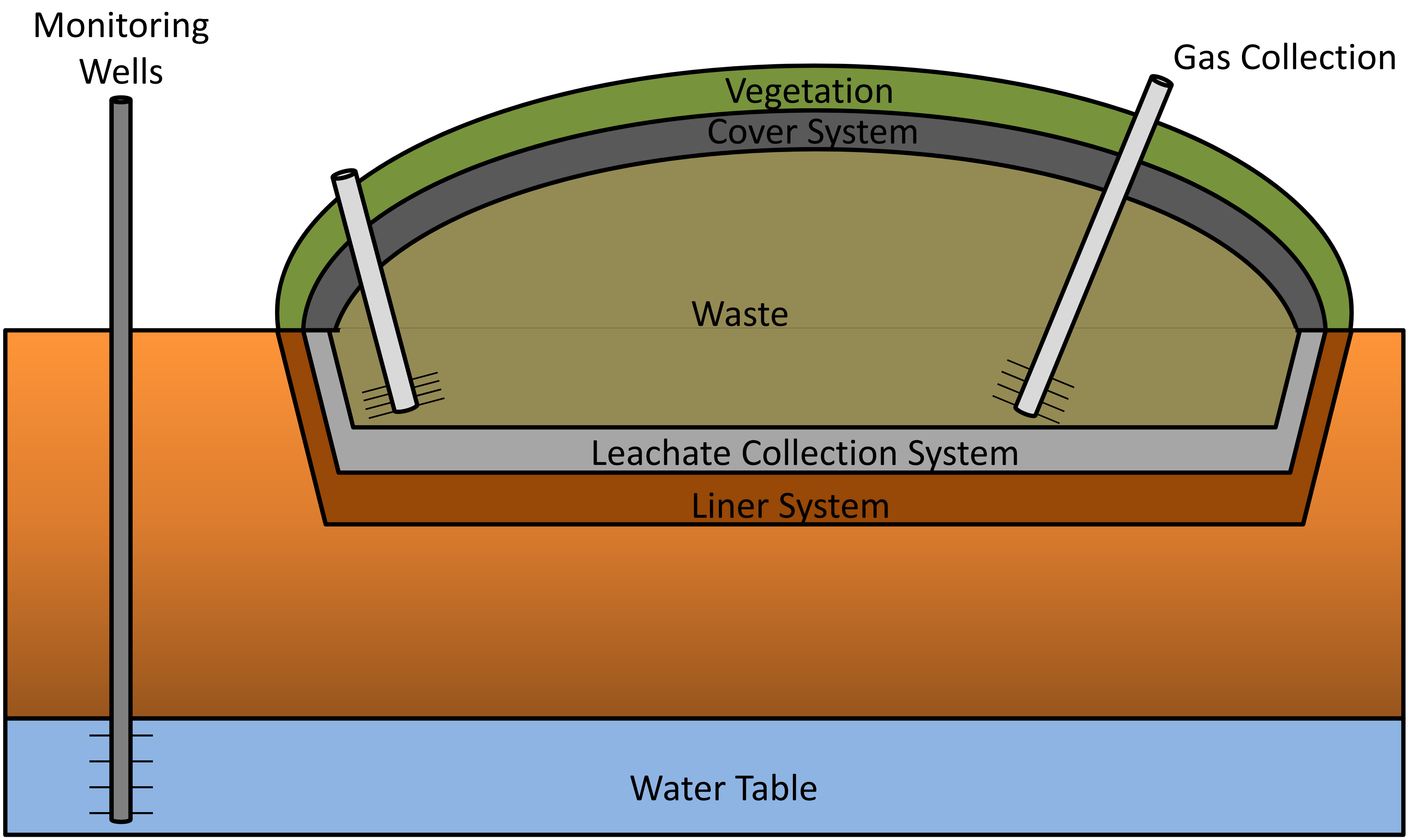
Design and Operation of Landfills

- Soils and hydrogeology
- Site selection criteria
- Site layout and landfill operations
- Liner design
- Water balance
- Biological reactions in landfills
- Leachate quality
- Gas production
- Groundwater & Post-Closure monitoring
- Regulation

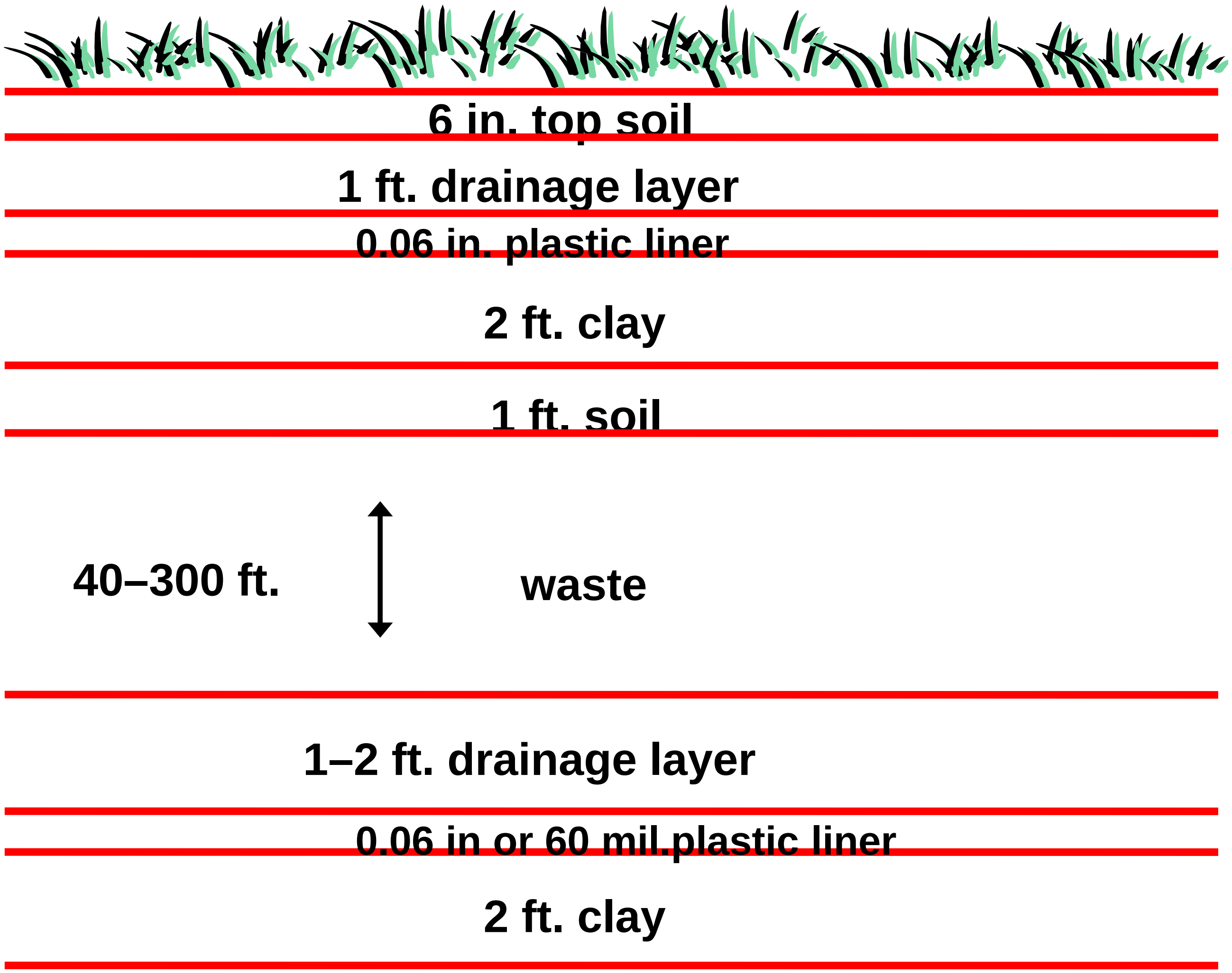
Landfill Site Plan (simplified)



Landfill Cross Section (simplified)



Conceptual Landfill Liner System



Definition - Sanitary Landfill

- At a minimum - wastes are compacted and covered on a daily basis
- Historically
  - Open dump or burning pit
  - Problems with rodents and insects, odors, leachate

An open dump in Sudan (UNEP)

Definition - Sanitary Landfill

- Today a highly engineered facility for isolation of waste from the environment
  - Operational plan
  - Gas collection
  - Leachate collection and treatment
  - Groundwater monitoring
  - Closure plan
  - Post- closure monitoring program

The Design Process

1 Solid waste management planning

– Is a landfill needed?

  – Local or regional?

2 Site identification

– Assess available land and eliminate unlikely candidates (wetlands, archaeology,floodplain, airport, politics)

– Technical feasibility study - start spending money

3 Site design and preparation of permit application

The Design Process

4 Receipt of permit

5 Preparation of construction drawings and specifications

  – Request for bids

6 Construction

  – Certify construction QA/QC

7 Obtain operating permit

8 Operation

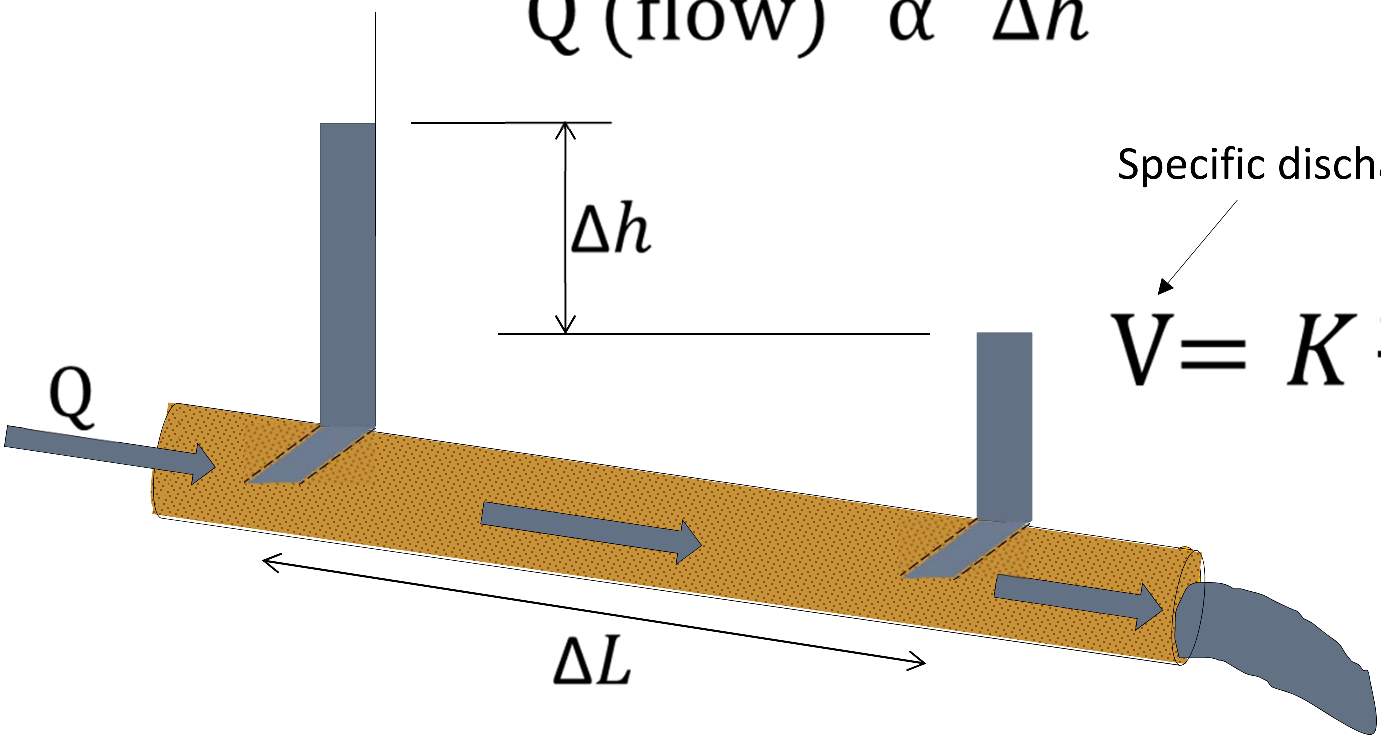
Groundwater and Soil Properties

- How water moves underground
  - must be able to understand potential impacts of a landfill on groundwater
  - direction of groundwater flow
  - changes in groundwater quality
- How are soils classified
- What soils are appropriate as liners, daily cover, drainage layers

Darcy’s Law

- Defines the flow of fluids through porous media (soil)

Q (flow) α Δh



Specific discharge

$$V = K \frac{\Delta h}{\Delta L}$$

Driving force

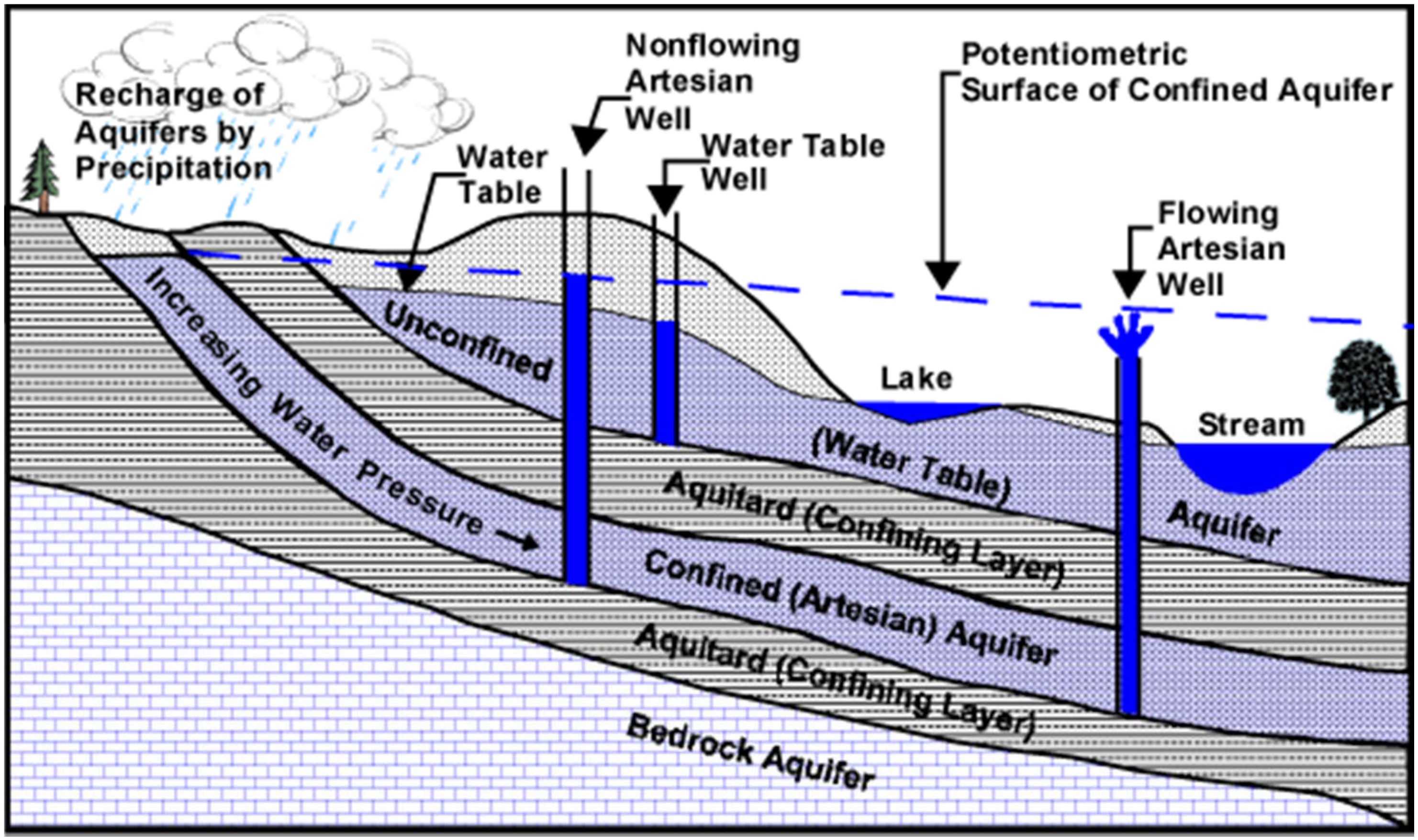
Typical Values of Hydraulic Conductivity

Gravel	1 - 10^{-2} cm/sec
-Stone (#57)	1
-Pea gravel	10^{-1}
Sand	10^{-2} - 10^{-4}
- clean coarse sand	10^{-2}
- well graded	10^{-4}
Silt	10^{-5} - 10^{-6}
Clay	$< 10^{-6}$
Refuse	10^{-3} - 10^{-8} ??

Groundwater Flow in Aquifers

- Aquifer
  - transmits significant quantities of water under normal hydraulic gradients
- Confined Aquifer
  - an aquifer between 2 low conductivity layers
- Unconfined Aquifer
  - water table forms the upper boundary

Groundwater Flow in Aquifers



http://www.in.gov/dnr/water/7258.htm

Site Assessment - Soils

- In order to evaluate the feasibility of a site, the available soils and underlying groundwater must be characterized
  - What types of soil are present on site?
  - Permeability of on-site soils:
    - Use for liner, drainage layer, cover material
  - Is there enough?
  - Availability of off-site soils
  - Depth to bedrock

Site assessment - Soils

- Perform soil borings and characterize soils visually and by lab analysis
- Borings per acre:
  - Suitability – 1/acre
  - Detailed design – 10/acre

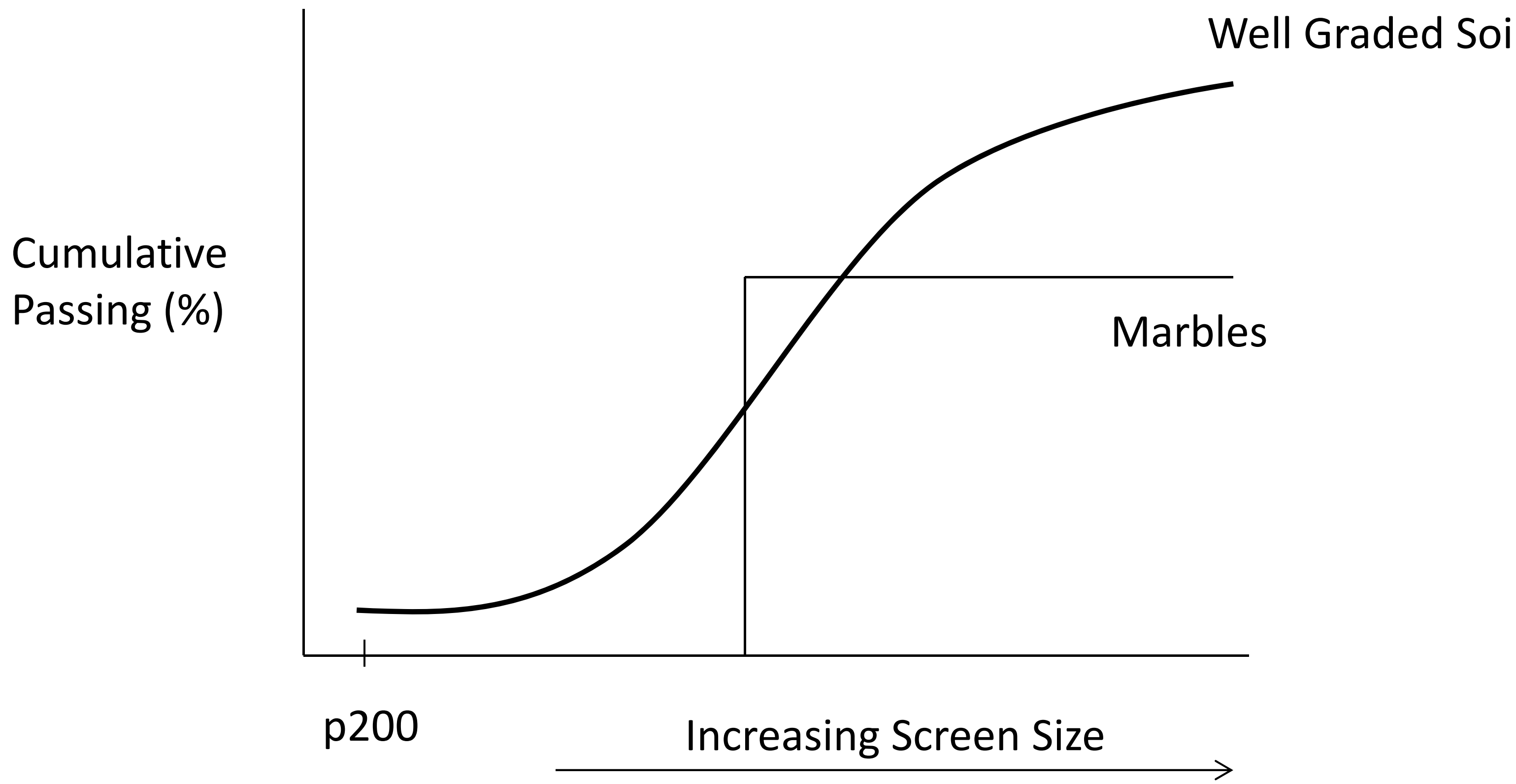
Major Divisions

- Gravel
  - Rounded pebbles, no cohesion
- Sand
  - Granular loose grains, easily visible, no cohesion, settles rapidly
- Silt
  - Barely visible grains, no cohesion, will settle in water in 30-60 minutes
- Clay
  - Invisible cohesive particles, will remain suspended in water for a minimum of several hours

Clays

- The fines fraction is frequently referred to as the p200 fraction - the fraction passing a 200 screen
  - A small decrease in p200 can result in a large increase in conductivity due to changes in grain size distribution

Grain Size Analysis



Clays

- Slippery when wet
- Difficult to work with or drive on
- Absorb large quantities of water and swell, then shrink as they dry, developing large cracks
  - Freeze/thaw

Can we make clay?

- <u>Bentonite soil amendment</u>
  - 2 - 8% bentonite will achieve 10^{-8} cm/sec
  - ~30 $/yd^3 to mix bentonite into native soil and compact

LOG OF BORING NO. LG-9

CLIENT
PROJECT NAME
PROJECT LOCATION
BORING LOCATION Sta 126 + 34 Offset 1' lt
FOREMAN
INSPECTOR

JOB NO.
DATE 12/5-6-10/85
BORING METHOD HSA
ROCK CORE DIA. NX IN
SHELBY TUBE DIA. IN
CASING DIA. IN.

MATERIAL DESCRIPTION (SURFACE ELEVATION 250.8)	STRATUM DEPTH, FT.	DEPTH, FT.	Sample No. (Core Run #)	BLOWS/6 IN. THREE 6 IN INCREMENTS	RECOVERY In.	Casing Blows	BORING AND SAMPLING NOTES
Red brown, moist, very stiff, Silty CLAY, some medium to fine Sand (MH)			S-1	3 8/10	16		PP on S-1;qu = 2.0 tsf
Red brown, moist, very stiff, Silty CLAY and medium to fine Sand (MH)	5.5	5	S-2	6 9/12	18		PP on S-2;qu = 2.3 tsf
Tan to brown to black, moist, medium dense, coarse to fine SAND, trace Silt (SW)	8.0		S-3	6 8/8	16		
Tan, moist, very dense, coarse to fine SAND, some Silt, little fine gravel rock fragments (decomposed Gneiss) (SM)		10	S-4, S-5	80/2"	2		Spoon refusal at 8.5' attempted to core-broke thru hard seam of decomposed rock at 9.0'
Orange, tan, moist, very dense, coarse to fine SAND, trace Silt, trace fine gravel rock fragments, (decomposed Gneiss) (SW)	16.5	15	S-6, S-7	100/5", 100/1"	3, 0		15.5' to 16.0' drill thru hard seam
C-1, Gneiss, white to orange moderately hard, unweathered			C-1*		2		*Core barel malfunction Only 2" of recovery Barrel must be replaced
C-2 same C-1	20.0	20	C-2		30		RQD = 23/30"
Bottom of boring 20.0'							

WATER LEVEL OBSERVATIONS
NOTED ON RODS ____ FT.
AT COMPLETION 9'8" FT.
AFTER ____ HRS ____ FT.

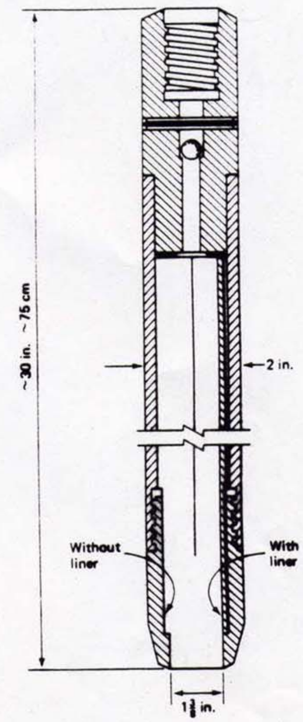
BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING
CA — CASING ADVANCER

SAMPLE TYPE
S- Splitspoon
U- Undisturbed
C- Core Run

IV. STANDARD PENETRATION TEST (SPT):

SPT "N - VALUE" is defined as the number of 30" drops of a 140# hammer required to drive a split-spoon sampler 12" into the ground at a given depth after the sampler has first been driven 6".

For example, if the number of blows for three 6" increments was 7, 8, and 10, the "N- value " would be 18.



FOR COHESIVE SOILS:

***UNCONFINED COMPRESSIVE STRENGTH, q_u (TSF)**

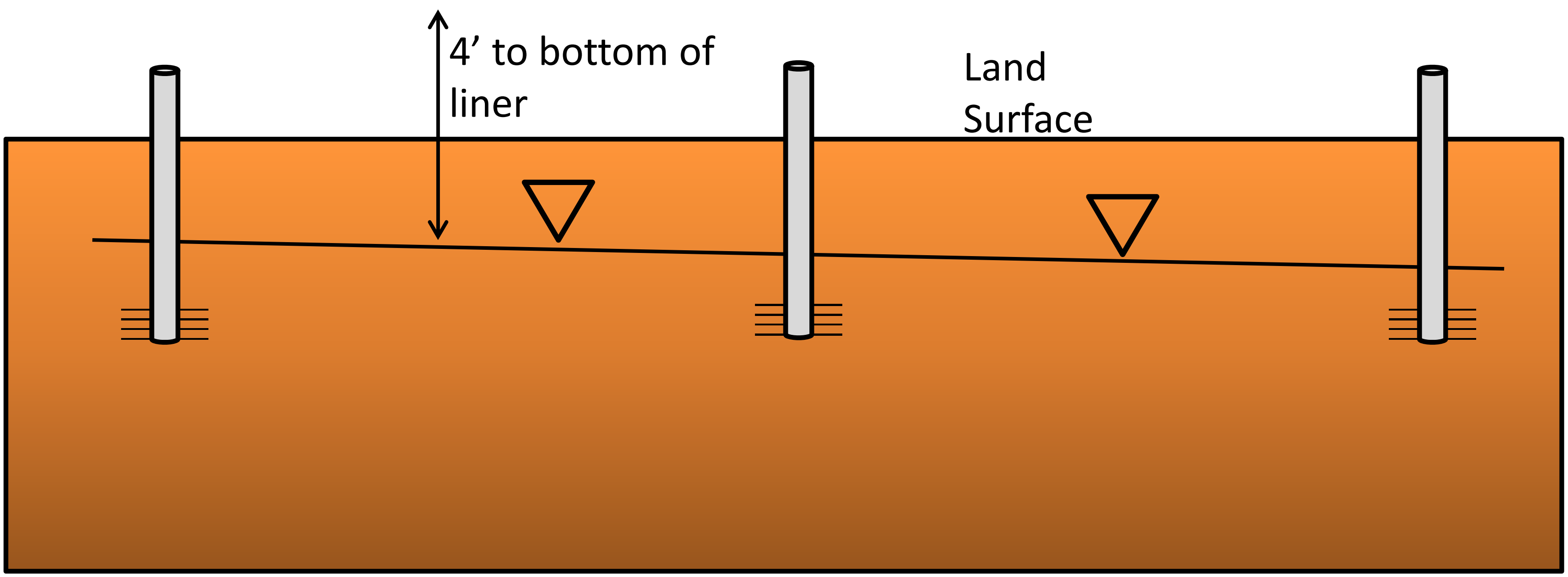
Consis-tency	Very Soft	Soft	Medium	Stiff	Very Stiff	Hard
N	< 2	2 - 4	4 - 8	8 - 15	15 - 30	>30
q_u	< 0.25	0.25- 0.5	0.5 - 1.0	1.0 - 2.0	2.0 -4.0	> 4.0

*Reference: Soil Mechanics in Engineering Practice by K. Terzaghi and R. Peck, Wiley, 1967.

Groundwater

- Seasonal high water table
  - Bottom elevation of liner must be at least 4 feet above water table
- Present and potential uses
  - (Well inventory)
- Groundwater quality
- Map of potentiometric surface

Potentiometric Surface



Groundwater

- A phased approach is used for assessment of soils and groundwater
  - Review existing regional data first
    - Soils conservation service
    - U. S. Geological survey
  - Collect site specific data
    - Expensive

Red Flags

- Archaeology

Red Flags

- Archaeology

Red Flags

- Presence of threatened or endangered species
  - Hire a botanist and biologist to walk the site
- 100 year floodplain
- Proximity to state parks, preserves, recreation areas

Red Flags

- Zoning
  - Need for easements/ right of ways
- Airports
  - 10,000 feet from a large airport
  - 5,000 feet from any airport
- Native American lands

Wetlands

- Allowed under federal law under special circumstances:
  - No practical alternative
  - Landfill will not violate water quality standards
  - Demonstrate no degradation of wetlands
  - Provide an offset for damaged wetlands
- States may impose stricter regulations

Infrastructure

- Size
- Potential to isolate from surroundings (buffer requirements in regulations)
- Access roads
  - weight limits
  - low overheads
  - road width
  - rail?

Infrastructure

- Utilities
- Leachate treatment
  - Access to a sewer and existing WWTP (with capacity) versus need for on-site treatment or hauling

