Groundwater Seminar
City of Boulder
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What is groundwater?
What is groundwater?

- Groundwater is:
  - The water that exists beneath the ground surface filling pore spaces in soils and sediments or cracks and crevices in rocks
  - That portion of rain and snow that percolates into the ground
  - That part of the subsurface water that is in the saturated zone
Groundwater can be found in:

- pore spaces in soils and sediments or cracks and crevices in rocks beneath the ground surface
  - If water filled - the Saturated Zone (phreatic zone)
  - If air and water - the Unsaturated Zone (vadose zone)
  - The top of the saturation zone is the Water Table
  - Where the saturated zone produces groundwater at a useable rate - it is called an Aquifer
Where is groundwater?
AQUIFER TYPES

- Alluvial Aquifer
  - **Unconfined** – water table conditions

- Bedrock Aquifer
  - **Unconfined** – water table conditions
  - **Confined** – pressurized conditions
    - Artesian – potentiometric surface above aquifer
    - Flowing Artesian – potentiometric surface above land
Where is groundwater?
Why is groundwater so enigmatic?

- Groundwater...
  - Is difficult to readily observe over a large area from the surface
  - Moves between pore spaces and in cracks and crevices (therefore not very exciting)
  - Does not exist as underground streams or lakes (except under very specific geologic conditions)
  - Can be variable due to seasonal and hydrologic influences
Why is groundwater so enigmatic?
Does groundwater flow and, if so, how?

» Yes, groundwater flows...

» Relatively slowly through bedrock and somewhat faster through soils and sediments (there are exceptions)

» In response to differences in water pressure and elevation (i.e., water flows downhill)

» Roughly in a direction and rate represented by the general slope of the overlying surface topography
Does groundwater flow and, if so, how?

- Factors affecting groundwater flow:
  - **Gradient** (i) – the slope of the water table (i=Δh/Δl); the steeper the gradient, the faster the movement.
Factors affecting groundwater flow:

- **Porosity (Φ)** - the space between solid particles of soil or rock that can be filled with fluid.
Does groundwater flow and, if so, how?

Factors affecting groundwater flow:

- Sorting - the degree of similarity of sedimentary particles in a sediment
Factors affecting groundwater flow:

- Permeability or hydraulic conductivity (k) - a measure of the ease with which fluids can pass through a body of soil or rock.
Does groundwater flow and, if so, how?

- Factors affecting groundwater flow:
  - Permeability ranges are known for various rock types
Fundamental Flow Equation

Darcy’s Law – named after Henry Darcy (1856). His equation describes fundamental groundwater flow.

\[ Q = k i A \]

- **Q** = Flow
- **k** = Hydraulic conductivity
- **i** = gradient
- **A** = cross-sectional area perpendicular to flow
Does groundwater flow and, if so, how?

- Other Equations:
  - Theis – nonequilibrium radial flow equation
  - Thiem – equilibrium flow equation
So what do we know about the subsurface?

- A lot surprisingly, but mostly inferred
  - Geotechnical Engineering – boreholes drilled to assess subsurface conditions and soil/rock properties
So what do we know about the subsurface?

- A lot surprisingly, but mostly inferred
  - Geology – from published or field mapping and from exploration (water, oil, gas, mineral) wells
So what do we know about the subsurface?

- A lot surprisingly, but mostly inferred

- [Hydrogeology](#) – from published or field testing, local/regional water table observations, pumping tests, tracer tests, water quality analyses, and modeling
What can available subsurface information tell us?

- Groundwater flow direction and travel time
What can available subsurface information tell us?

- Inferred upgradient influence and downgradient impacts
What can available subsurface information tell us?

- Extent of contaminant plume or well influence area
What can available subsurface information tell us?

- Water supply well locations
Is the subsurface or inferred information fool-proof?

Absolutely
How do we use and manage the groundwater resource?

- Water Supply Wells
  - Permitting
  - Design and Construction
  - Testing
How do we use and manage the groundwater resource?

- Property or Foundation Protection
  - Underdrains and Sumps
How do we use and manage the groundwater resource?

- Construction Dewatering Systems
  - Well Points
How do we use and manage the groundwater resource?

- Containment Devices
  - Slurry Walls
Is there a connection between groundwater and surface water?

- YES, without question. However, the connection may...
  - Not be obvious
  - Be seasonal or episodic
  - Change over longer periods of time
Water moves in relation to elevation differences (i.e., downhill)

Surface water and groundwater want to move deeper, unless hydraulically prevented

Water will follow the path of least resistance

Sometimes the path of least resistance is lateral
How is groundwater and surface water connected?

- **Stream or Ditch Systems:**
  - **Gaining**
    - Humid regions
    - Wet season
  - **Losing**
    - Arid regions
    - Dry season
  - **Disconnected**
How does this knowledge assist a municipal planning board?

- There is a basic set of information that can be obtained for all properties relative to understanding the groundwater resource.
- There are some logical underlying physical principles and properties which govern groundwater movement.
- There are cause-and-effect relationships (in both directions) between proposed development and groundwater.
How does this knowledge assist a municipal planning board?

- Basic set of information

- A minimum of 3 monitoring wells for flow direction and gradient

- Full year of observations (to see seasonal variability)
How does this knowledge assist a municipal planning board?

- Logical principles and properties
  - Upgradient (background)
  - Downgradient (effects)
  - Subsurface Materials
  - Barriers and conduits
How does this knowledge assist a municipal planning board?

- Provides a basic understanding regarding potential cause-and-effect relationships (two-way) between a proposed development and groundwater
  - Pervious vs. Impervious Areas
  - Stormwater Designs
  - Utility Trenches
  - Dewatering Systems
  - Underground Parking Structures
How does this knowledge assist a municipal planning board?

- Pervious vs. Impervious Areas

The water cycle in a natural area vs. The water cycle in a suburban or urban area.
How does this knowledge assist a municipal planning board?

- Stormwater Systems
How does this knowledge assist a municipal planning board?

- Utility Trenches
How does this knowledge assist a municipal planning board?

- Dewatering Systems
How does this knowledge assist a municipal planning board?

- Underground Parking Structures
How does this knowledge assist a municipal planning board?

- Potential upgradient and downgradient effects on:
  - Wetlands
  - Native Vegetation (trees)
  - Streams
  - Ditches
  - Wells
  - Water Quality
How does this knowledge assist a municipal planning board?

- Wetlands and Native Vegetation
How does this knowledge assist a municipal planning board?

- Streams and Ditches
How does this knowledge assist a municipal planning board?

- Wells

- pumping lowers the cone of depression
- original water table (O.W.T.)
- overpumping lowers the cone of depression

OVERPUMPING
- lowers the cone of depression
- dries up the stream
- original home owner must spend $$$$ to drill a deeper well
How does this knowledge assist a municipal planning board?

- Water Quality
Questions

Answers