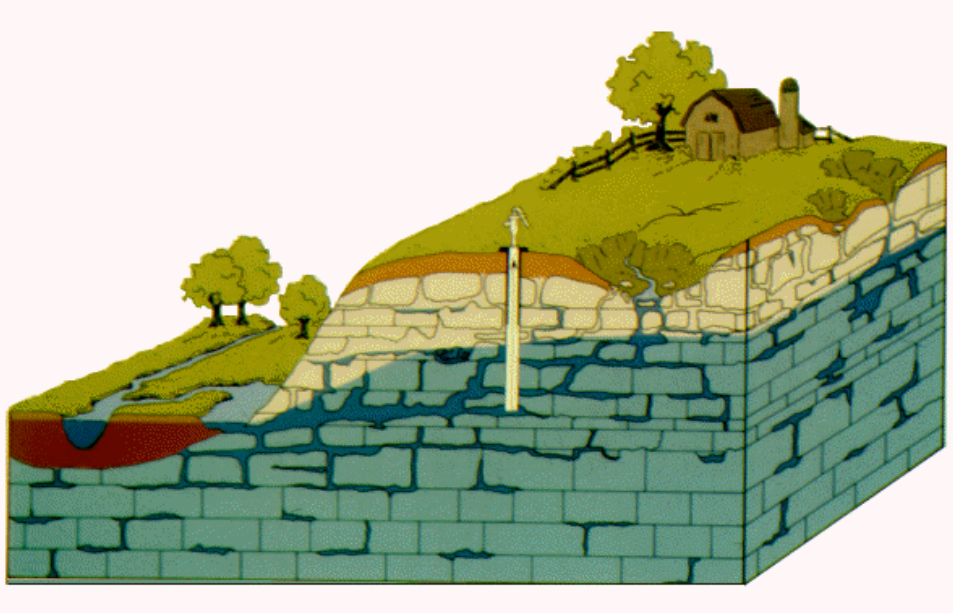
3. Basic Hydrology – Part 2



West Virginia Water Resources Training Workshops

Presented by the Interstate Commission on the Potomac River Basin

Sponsored by the West Virginia Department of Environmental Protection

With funding from the American Reinvestment & Recovery Act

Outline

- Aquifers and their characteristics
- Groundwater flow
- Groundwater in West Virginia
- Technologies for determining local availability

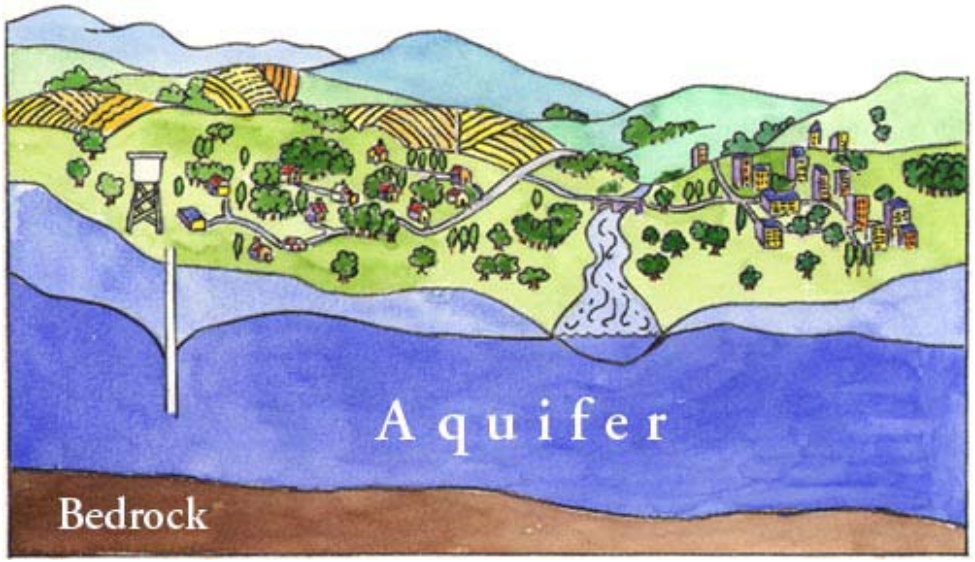
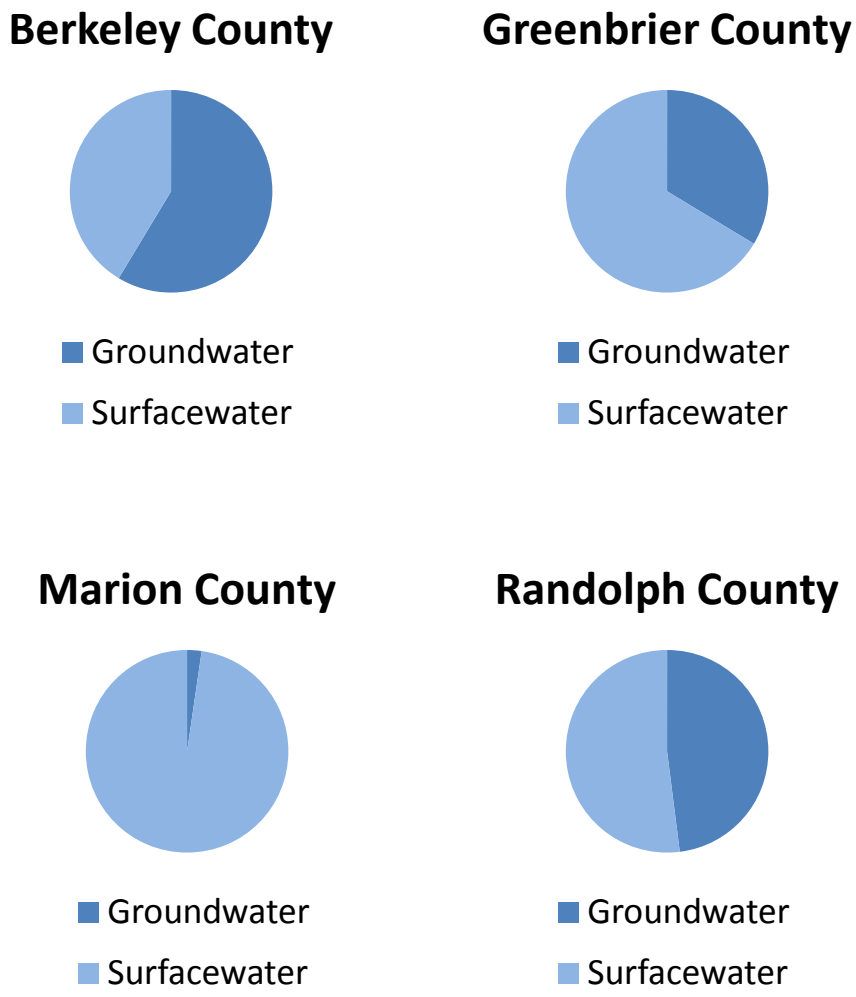


Figure from City of Chilliwack, British Columbia, at http://www.gov.chilliwack.bc.ca/main/pageimages/1259/aquifer.jpg

Importance of Ground Water

- More than 30% of the earth's fresh water
- Over 20% of all water used in the US
- In West Virginia, supplies
  - 3% of total water use
  - 20% of public water supply
  - 98% of self-served domestic households
  - 41% of population
- Primary source of stream flow during dry weather!



All West Virginia values derived from USGS 2005 data

Definitions

- Aquifer: (Latin: water + to bear) A saturated permeable geologic layer that will yield usable quantities of water

- Water table: Boundary between the saturated and unsaturated zone

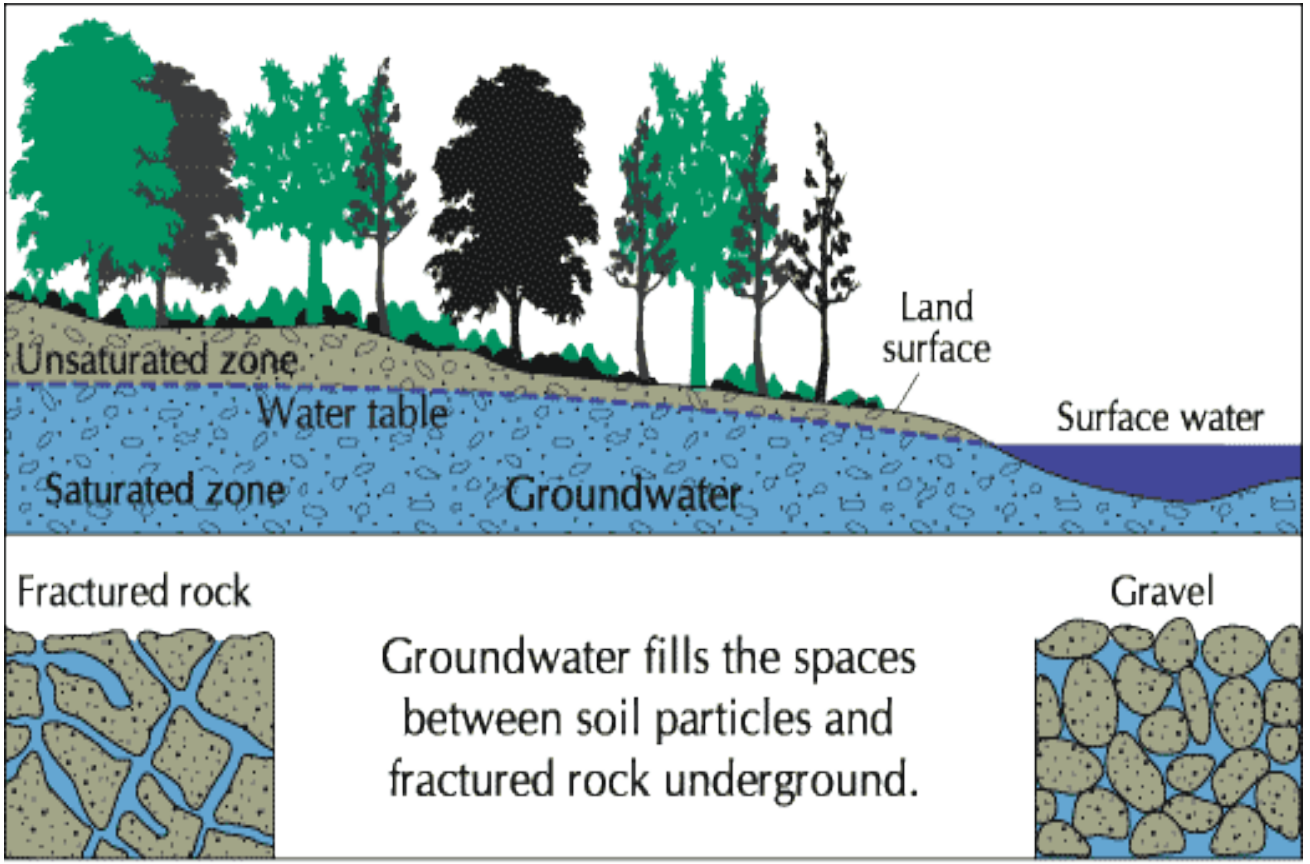


Figure from USGS, available from The Groundwater Foundation, at http://www.groundwater.org/gi/whatisgw.html

Two Types of Aquifers

- Unconfined (or water table aquifer): directly beneath the unsaturated zone
- Confined: between two impermeable "confining" layers

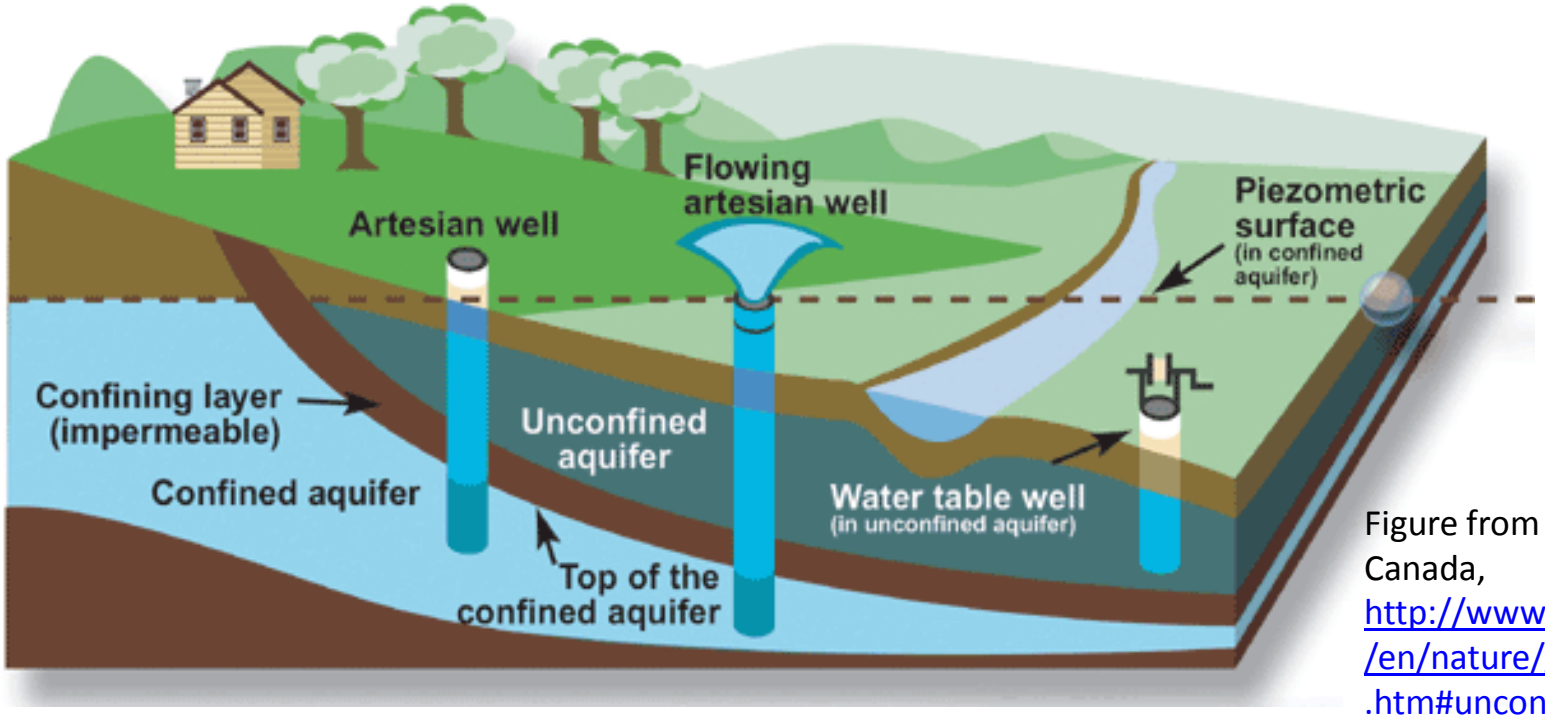


Figure from Environment Canada, http://www.ec.gc.ca/water/en/nature/grdwtr/e_move.htm#unconfined

Groundwater & the Hydrologic Cycle

- Source of groundwater is “recharge” from precipitation
- Groundwater discharges to lakes and streams

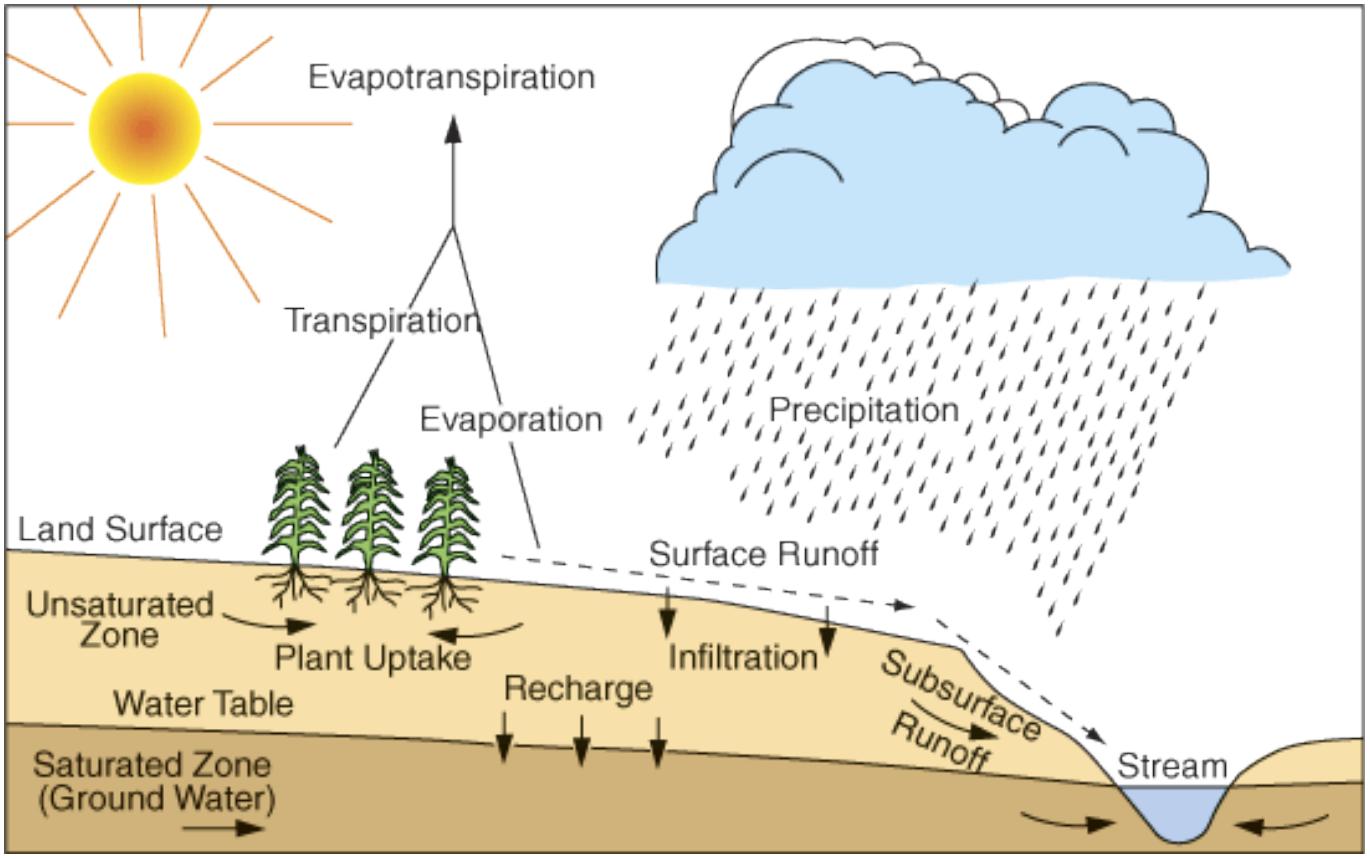
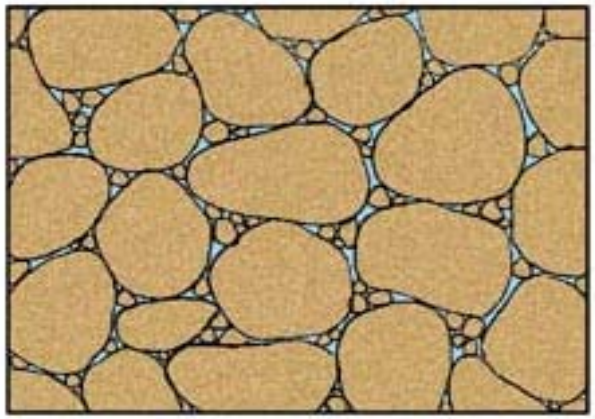
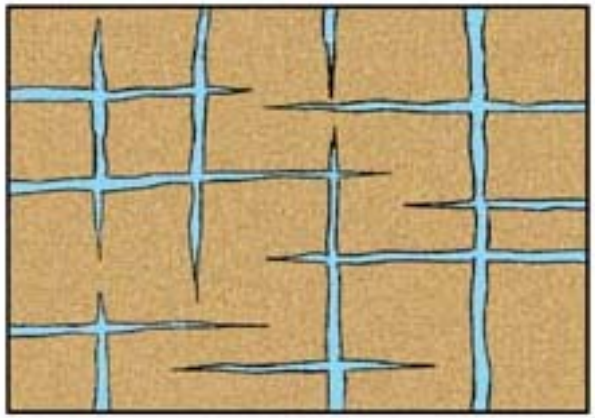


Figure from Kansas Geological Survey, at www.kgs.ku.edu/Publications/pic22/pic22_2.htm

Aquifer Porosity

- Porosity: percentage of a solid material taken up by empty spaces (voids)
- Effective porosity: percentage taken up by interconnected voids





<u>Unconsolidated material</u>	
Gravel:	25 – 40%
Sand:	25 – 50%
Clay:	40 – 70%
<u>Fractured rock</u>	
Limestone, dolomite:	5 – 50%
Karst:	5 – 50%
Sandstone:	5 – 30%
Shale:	0 – 10%
Crystalline rock:	0 – 10%

Source: Freeze and Cherry, 1979

Figure from Tasmania Online - Department of Primary Industries, Parks, Water and Environment, at www.dpiw.tas.gov.au/.../RPIO-4YD8NU?open

Aquifer Permeability - Transmissivity – Hydraulic Conductivity

- Permeability: a solid's capability to allow fluids to pass through
- Two common measures of rate at which water moves through an aquifer
  - Hydraulic conductivity: units of, e.g., feet per day
  - Transmissivity: units of, e.g., feet squared per day

Higher permeability **<-> higher transmissivity** **<-> higher hydraulic conductivity :** • Sands • Gravels • Carbonate rock (karst)	**Lower permeability** **<-> lower transmissivity** **<-> lower hydraulic conductivity:** • Clays • Silts • Fractured shales • Fractured crystalline rock

Fractured Bedrock Aquifers

- Groundwater resides both in regolith and in fractures in the rock
  - Regolith: upper layer of soil and other unconsolidated material
  - Bedding planes: horizontal fractures
  - Joints: vertical fractures
- Alignment of fractures affects flow direction (anisotropy)

Figure from J.C. Marechal, at http://jcmarechal.unblog.fr/files/2009/01/fig2anisotropy.jpg

Groundwater Flow - Velocity

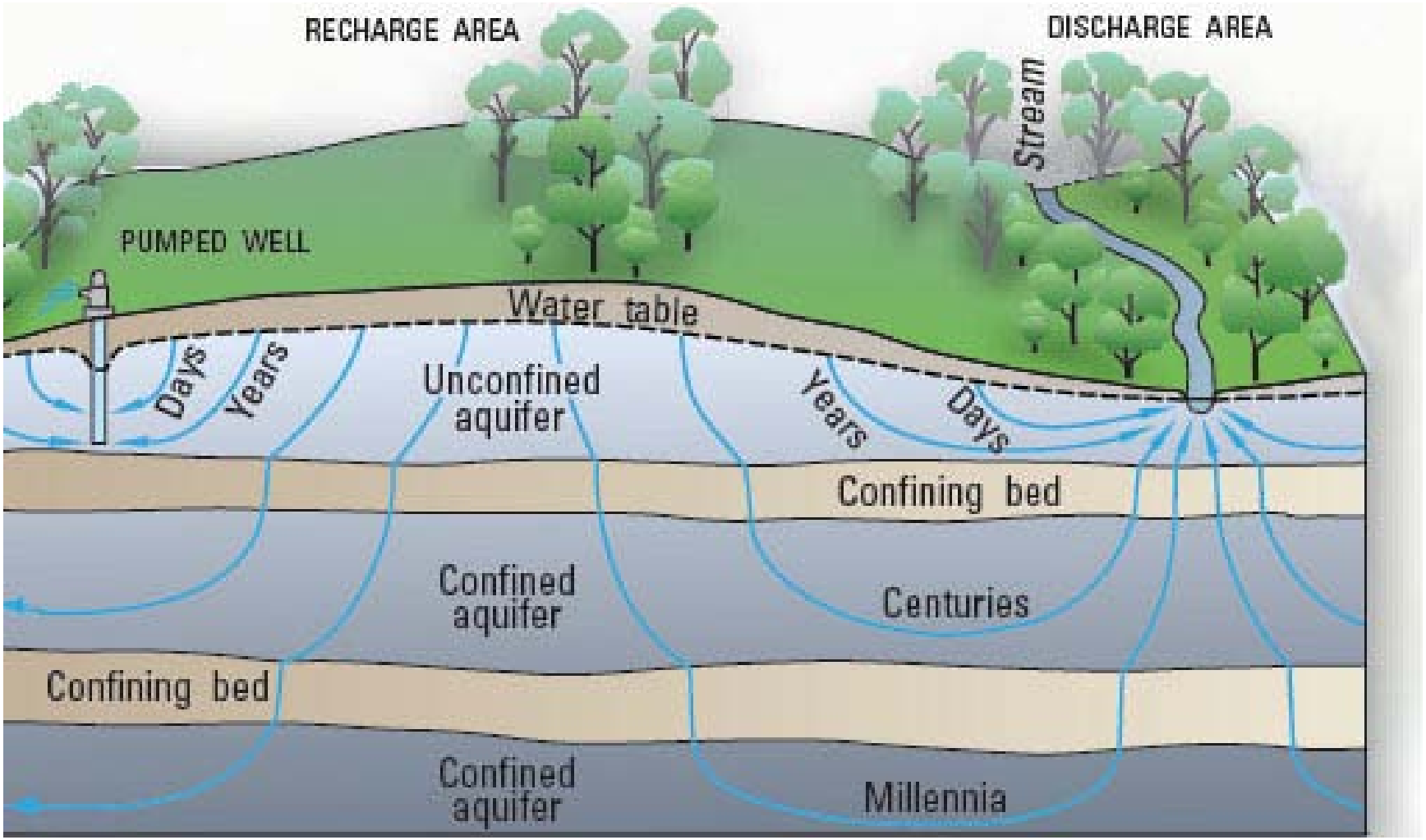


Figure from USGS,Georgia Water Science Center, at http://ga.water.usgs.gov/edu/watercyclegwdischarge.html

Groundwater Flow - Direction

- Flow in water table aquifer typically follows topography
- Flow in confined aquifers governed by hydraulic gradients

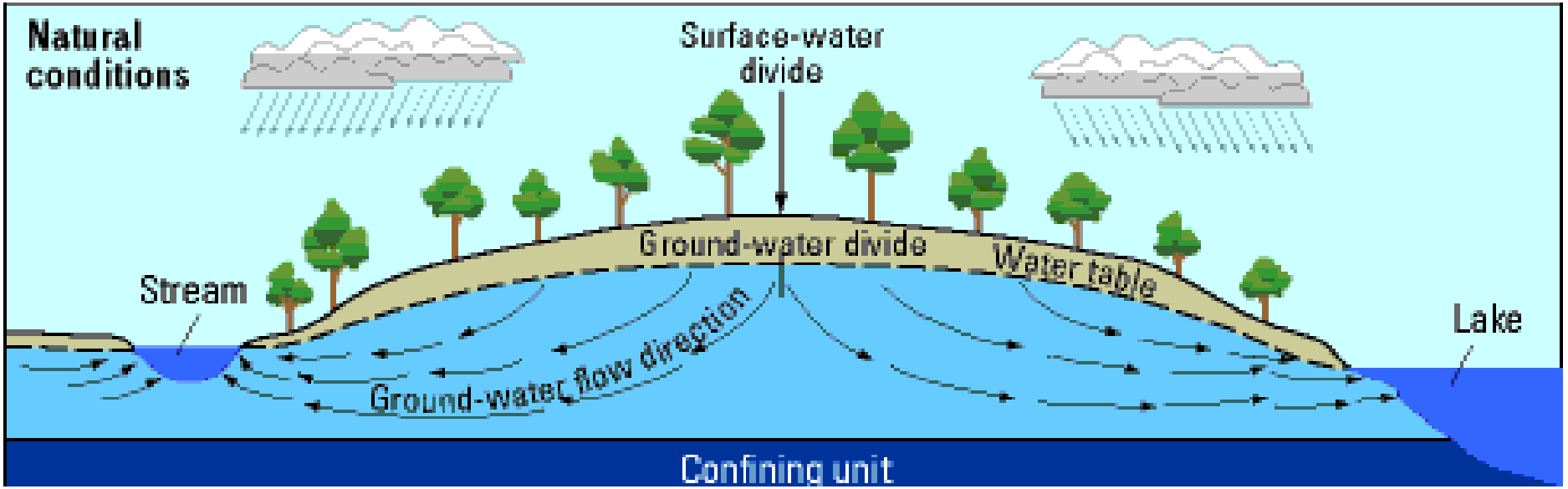
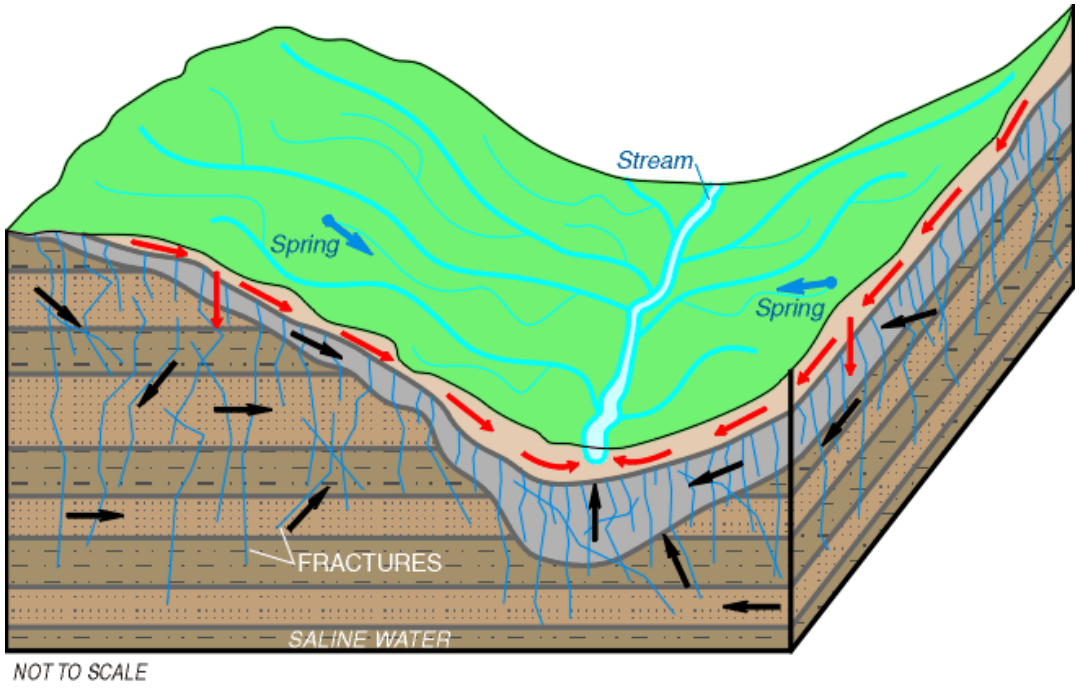


Figure from USGS, at water.usgs.gov/ogw/pubs/WRI004008/figure05.htm

Groundwater Flow – in Fractured Rock



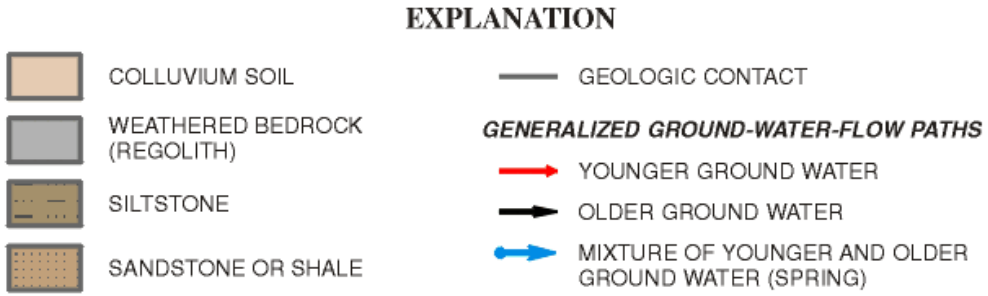


Figure 5. *Conceptual ground-water flow in a fractured-rock setting (modified from Harlow and LeCain, 1991).*

Flow in fractured bedrock is influenced by alignment of fractures

Figure from USGS, Maryland Water Science Center, at md.water.usgs.gov/.../fs-150-99/html/index.ht

Karst Aquifers

- Geology
  - Carbonate rocks - limestone, dolomite
  - Formation of large conduits
- Hydrology
  - High recharge
  - Productive wells
  - Sustained streamflows
- Water quality
  - Pollutants quickly transmitted by conduits

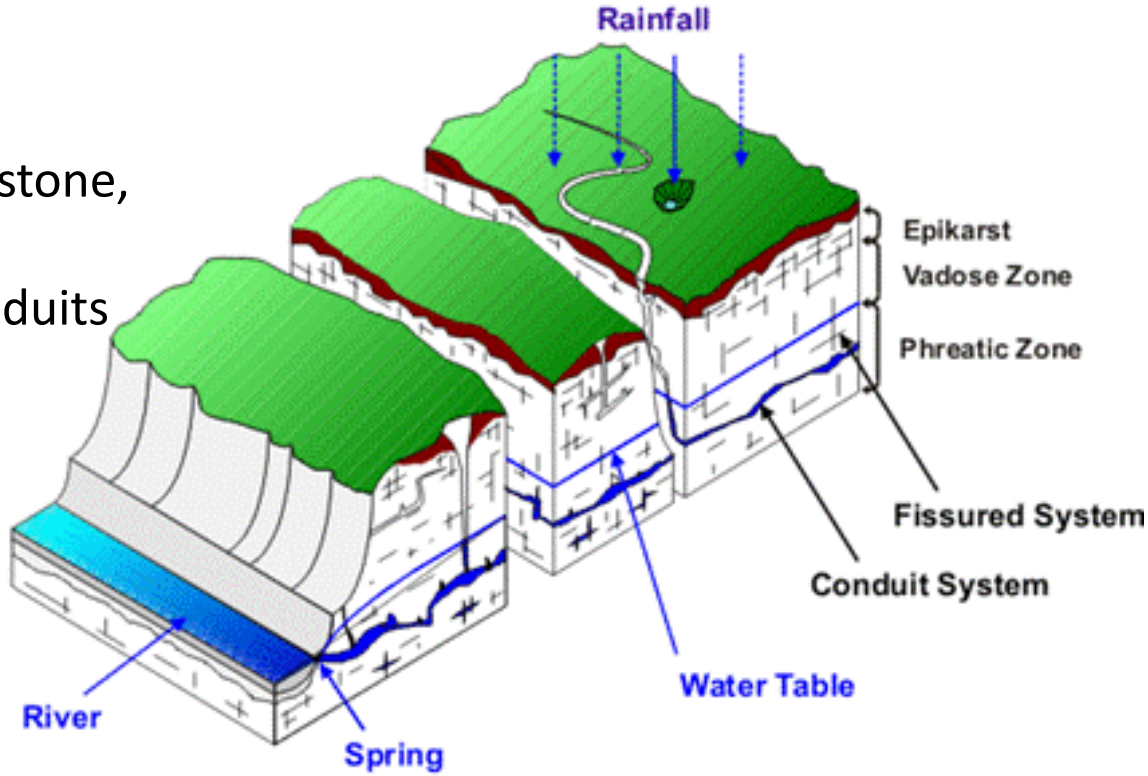
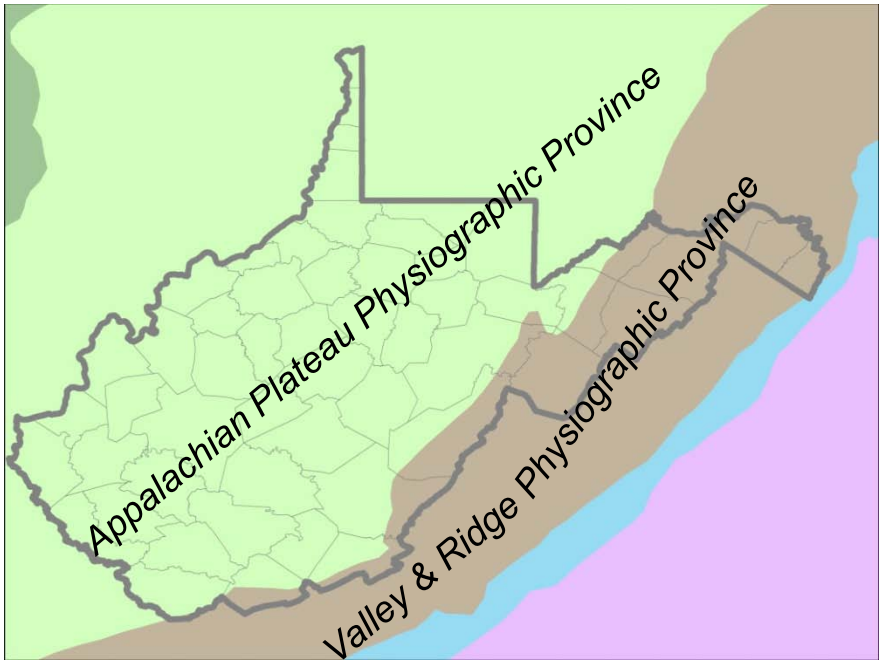


Figure by Dr. Steffen Birk, at www.uni-graz.at/steffen.birk/research.html

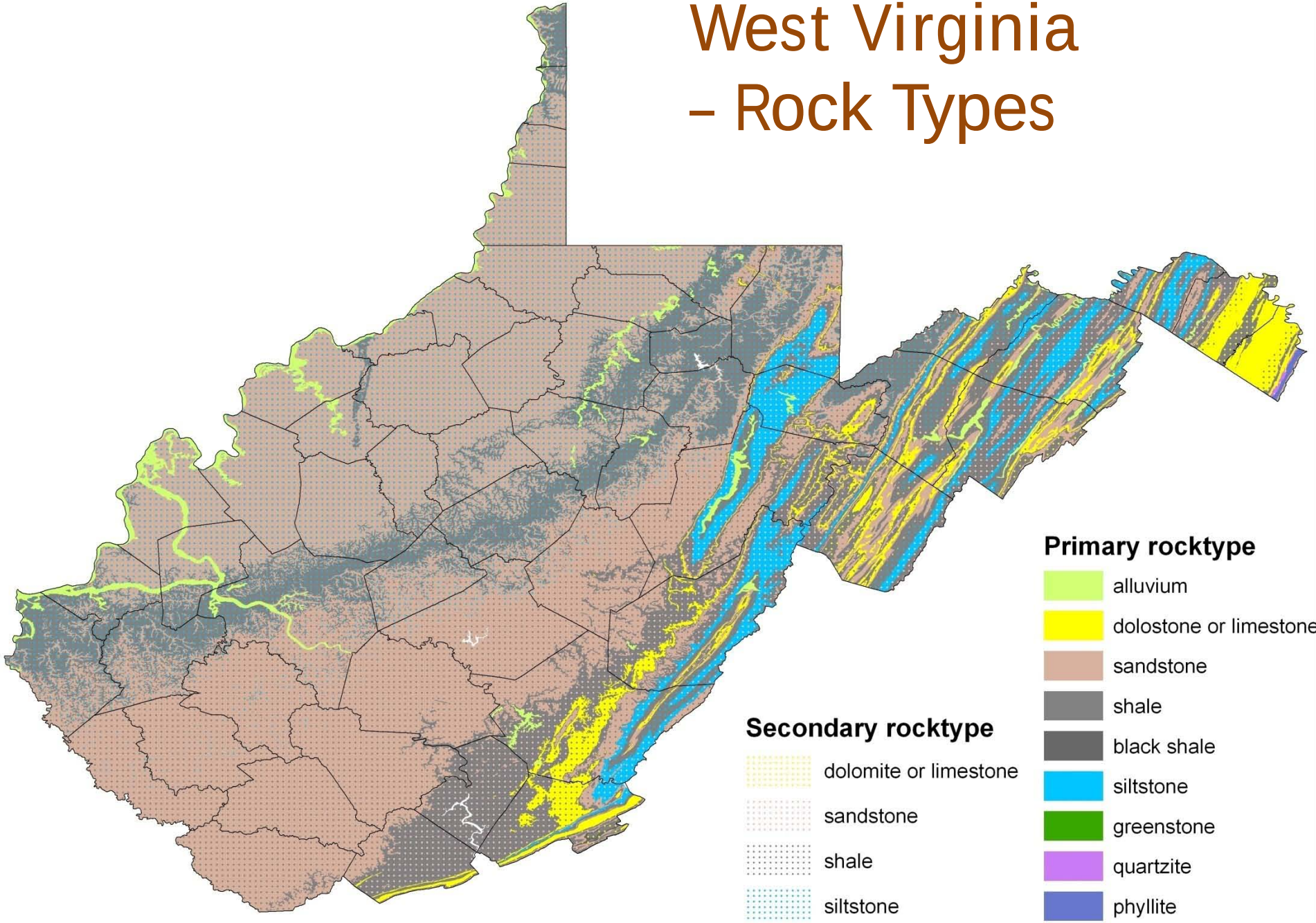
West Virginia - Hydrogeology

- Appalachian Plateau
  - Sedimentary rock - sandstone, shales, siltstone, carbonates; some limestone & coal beds
- Valley & Ridge
  - Folded sedimentary rock forming parallel valleys and ridges: sandstone, shales, carbonates, with coal beds



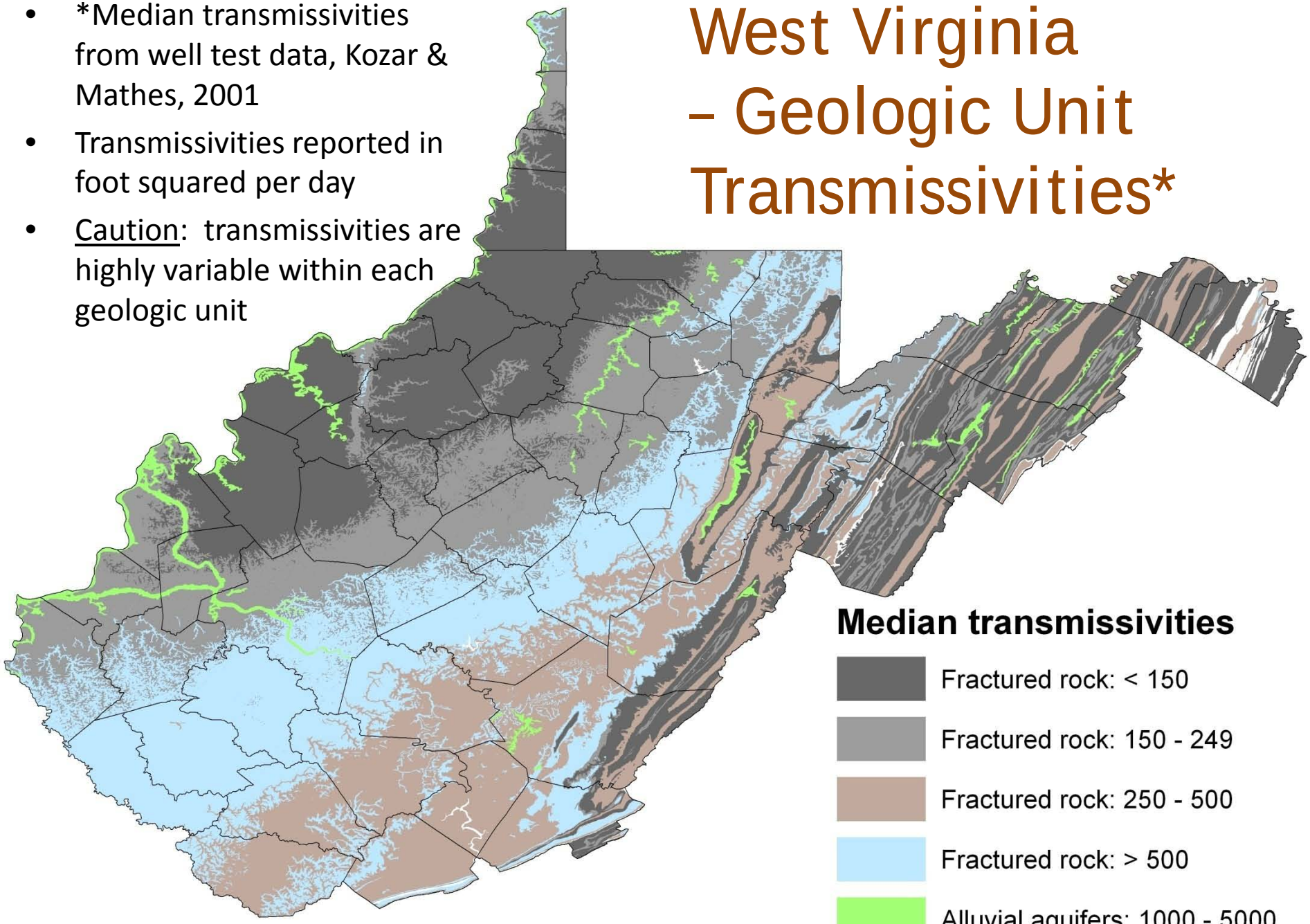
- Aquifers
  - Ohio River alluvial aquifer highly productive
  - Shale-dominated bedrock tends to have lower productivity wells
  - Bedrock aquifers: well productivity dependent on number of fractures
  - Artificially high transmissivities measured in wells bored in mine voids

West Virginia – Rock Types



West Virginia – Geologic Unit Transmissivities*

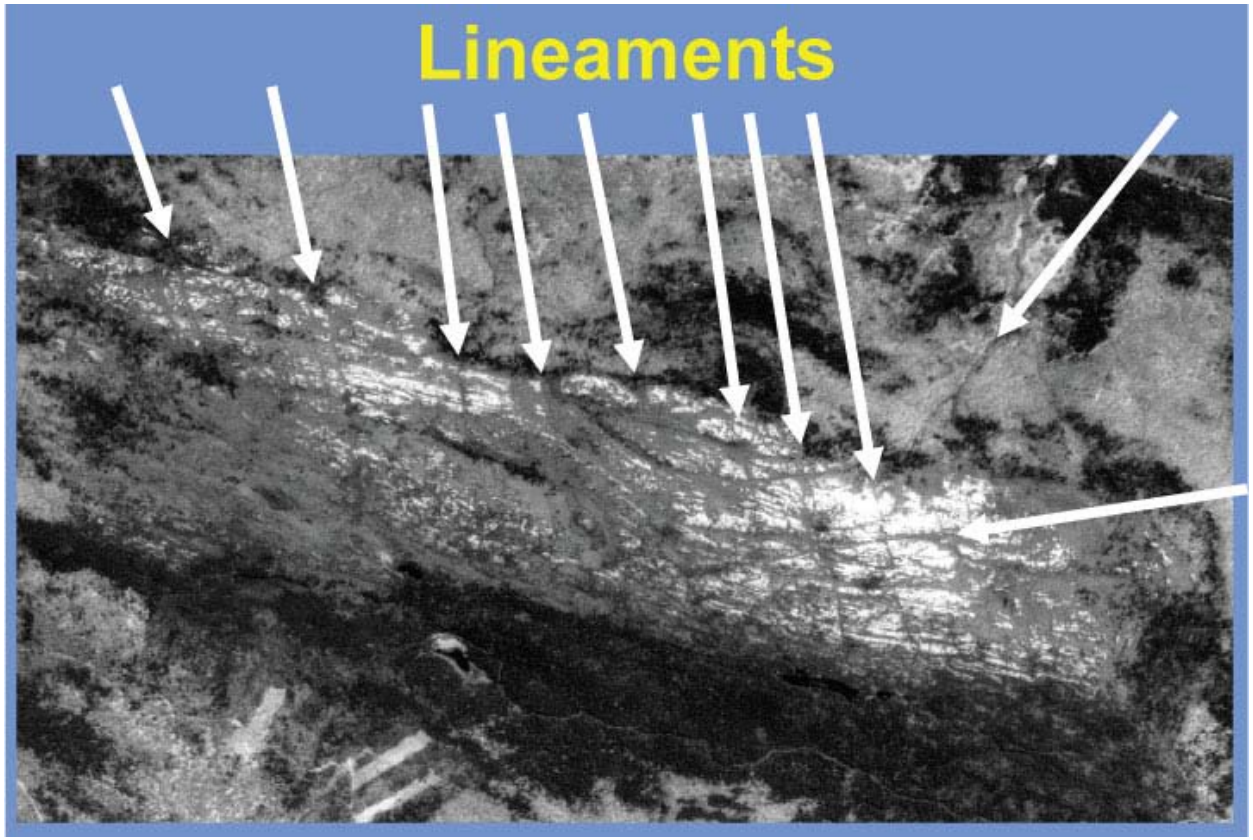
- *Median transmissivities from well test data, Kozar & Mathes, 2001
- Transmissivities reported in foot squared per day
- Caution: transmissivities are highly variable within each geologic unit



Local Groundwater Availability in Bedrock – Some Technologies

- Fracture trace analysis
- Borehole geophysical surveys

Fracture Trace Analysis



- Suitable in areas with fractured bedrock aquifers
- Make use of aerial photos or satellite imagery
- Identifies large-scale fracture zones

Lineament: a linear topographic feature that is believed to reflect underlying geologic structure.

Photo from USGS, at http://nh.water.usgs.gov/projects/nhwellyieldprob/about.htm

Borehole Geophysical Surveys

For identification of fractures and high transmissivity fracture zones

Bedding plane

VIDEO:
http://www.youtube.com/watch?v=Mrr2elBrONg

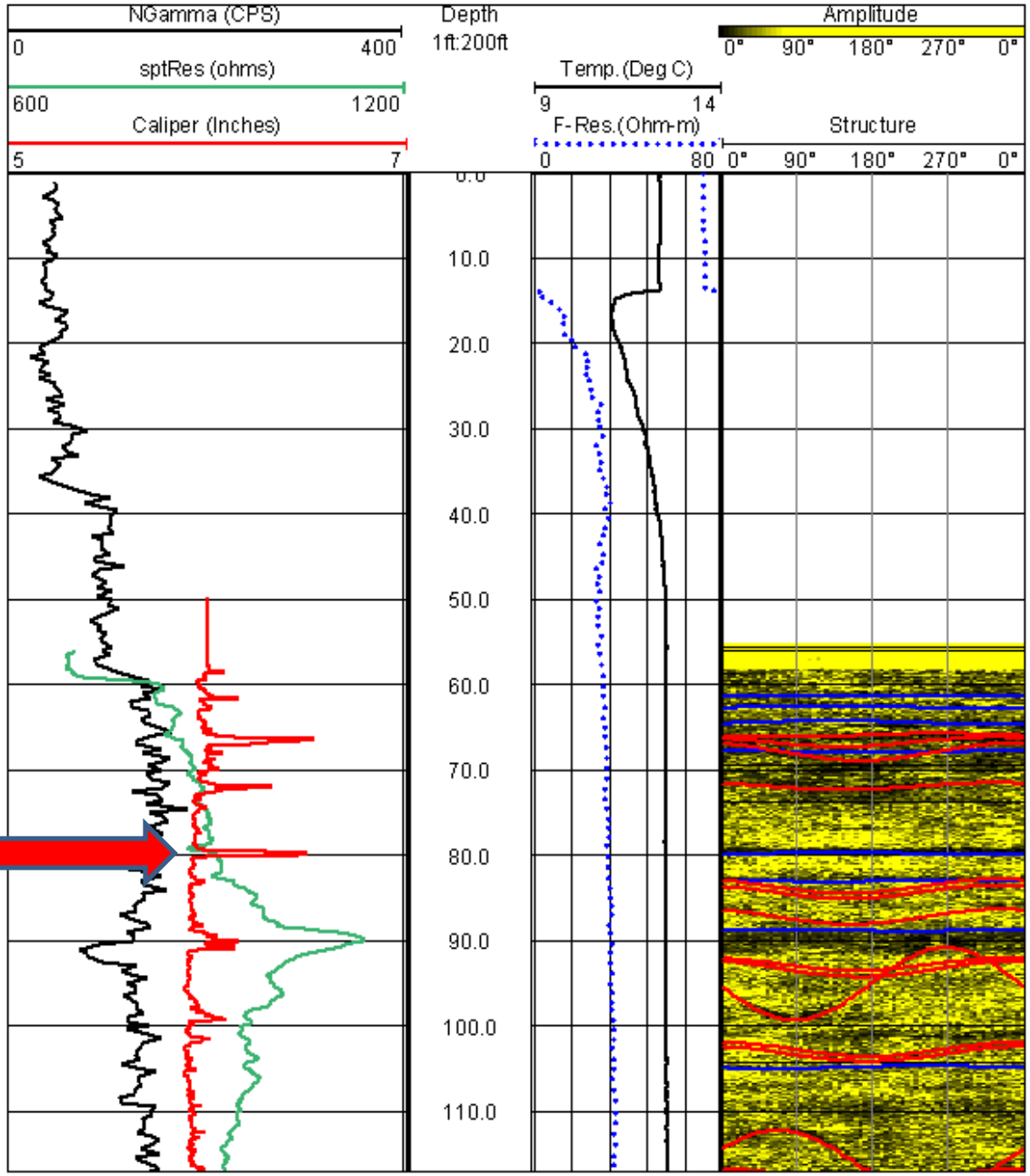
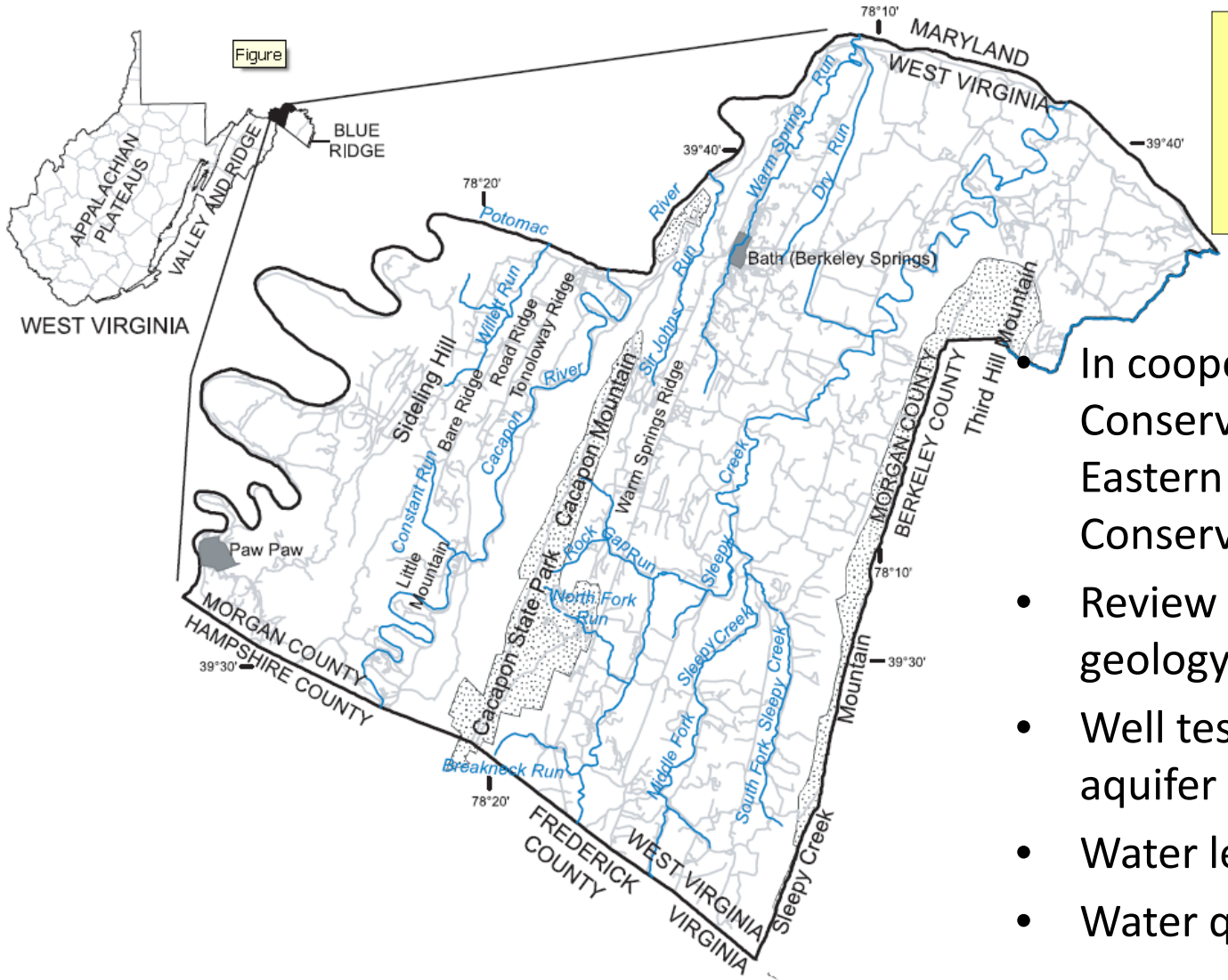


Figure from WVDEP

Morgan Co Groundwater Study

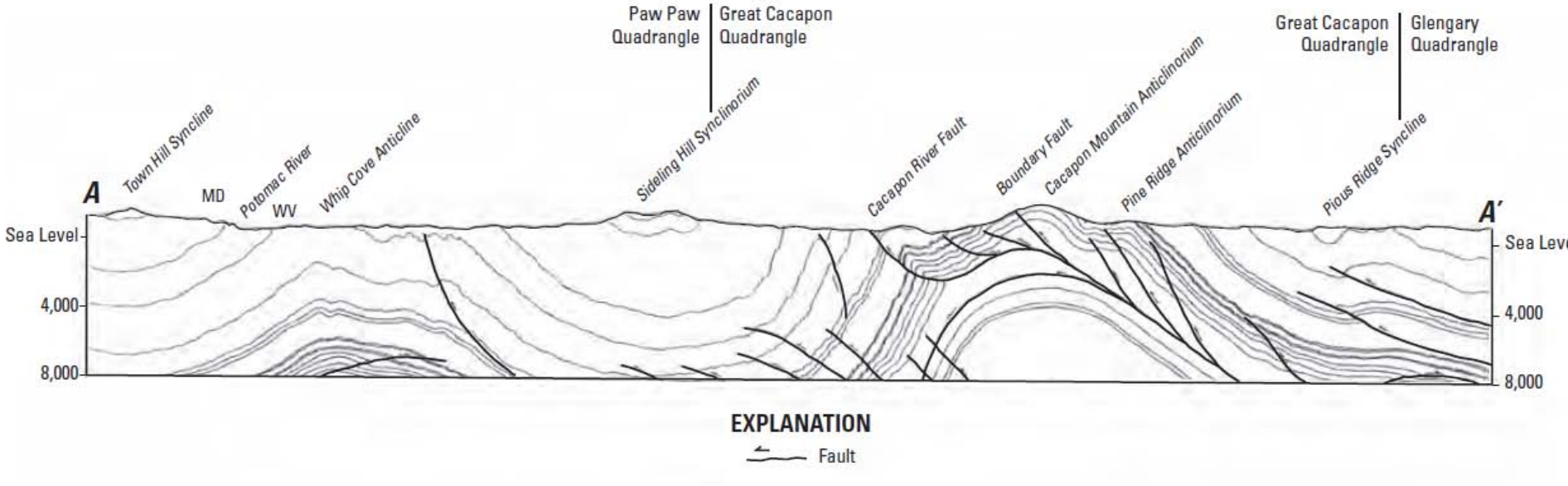


Hydrogeology, Aquifer Chemistry, and Ground-water Quality in Morgan County, West Virginia, by C.J. Boughton and K.J. McCoy, 2006, USGS SIR-2006-5198

- In cooperation with WV Conservation Agency & Eastern Panhandle Conservation District
- Review of local geology/hydrogeology
- Well tests to determine aquifer transmissivities
- Water level data at 84 sites
- Water quality data

Morgan Co Groundwater

Complicated folded geology influences location of recharge areas and flow paths



From Boughton and McCoy, 2006

Morgan Co Groundwater Study – Some Conclusions

- Well yields & aquifer transmissivities depend on presence of fractures & faults
- In nearby wells
  - Water levels may vary by 200 ft
  - Transmissivities may vary by factor of 100
- Over half of all wells tested had radon-222 concentrations above EPA Secondary Maximum Contaminant Level

From Boughton and McCoy, 2006

Conclusions

- Groundwater and surface water resources closely interconnected
- Groundwater availability in West Virginia largely determined by fractured rock geology
- WVDEP priority: data collection to allow better characterization of groundwater resources

Suggested Resources

- *Groundwater Atlas of the United States*, USGS, at http://pubs.usgs.gov/ha/ha730/gwa.html.
- *Aquifer-Characteristics Data for West Virginia*, M.D. Kozar and M.V. Mathes, USGS Water-Resources Investigations Report 01-4036. 2001, available at http://pubs.er.usgs.gov/usgspubs/wri/wri014036.
- West Virginia geologic map data, available from USGS at Preliminary integrated geologic map databases for the United States, by Suzanne W. Nicholson, Connie L. Dicken, John D. Horton, Keith A. Labay, Michael P. Foose, and Julia A.L. Mueller, Version 1.1, Updated December 2007, available at http://pubs.usgs.gov/of/2005/1324