HYDROGEOLOGY OF THE PACIFIC NORTHWEST

A SUMMARY DISCUSSION

NGWA Pacific NW Expo – February 2012

Presented by:

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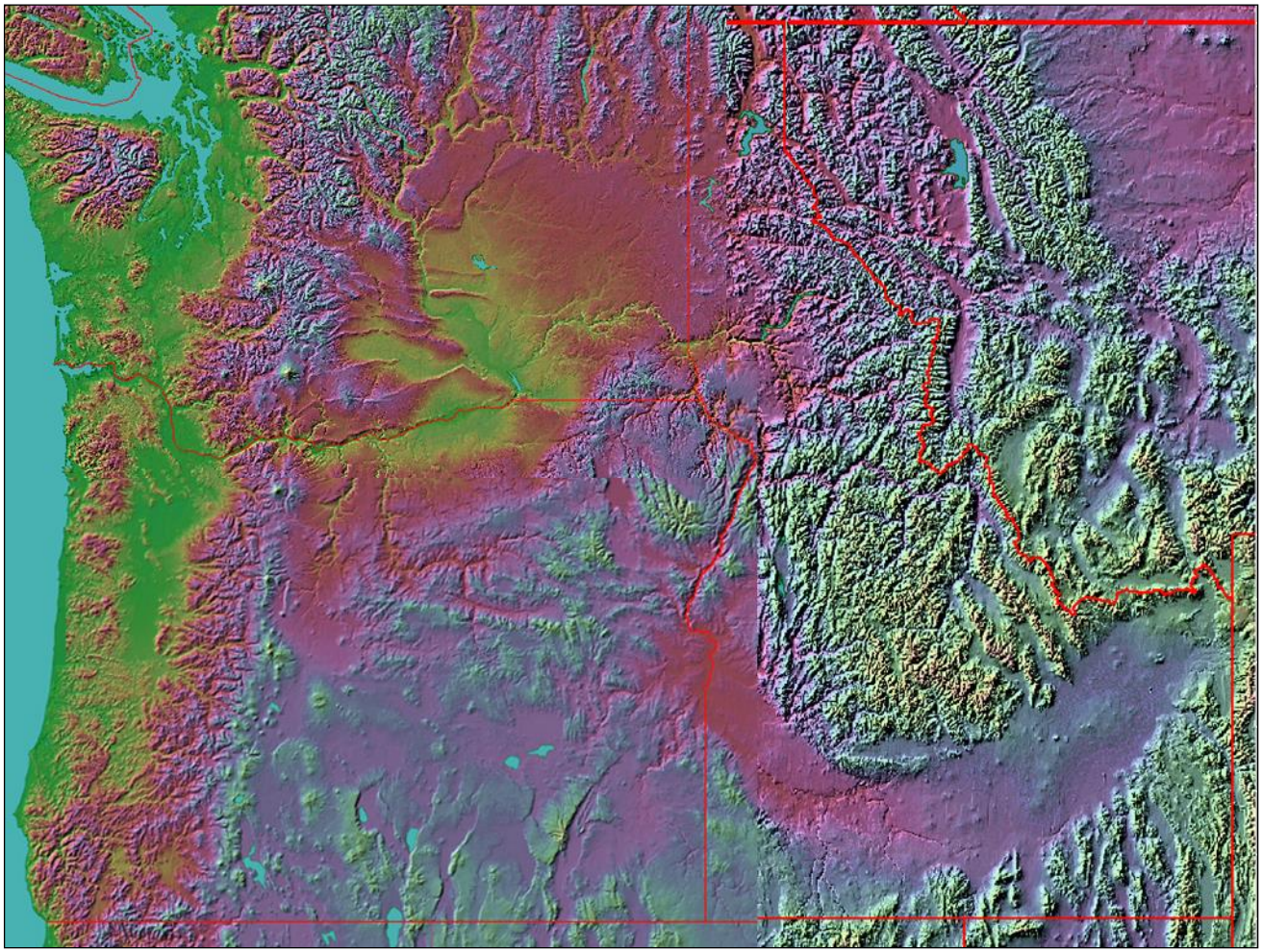
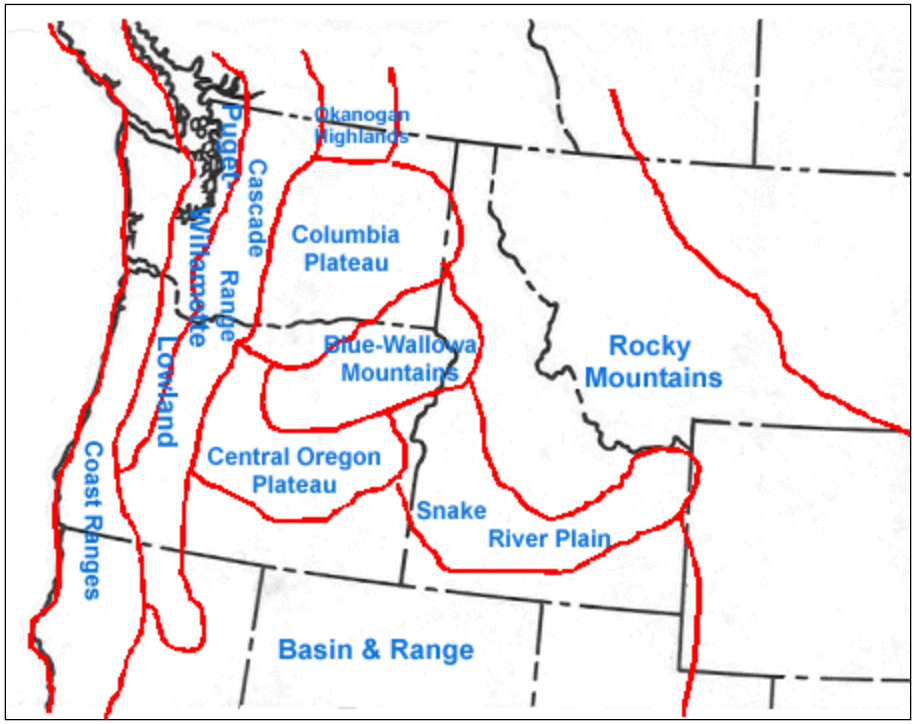
The Pacific Northwest is a complicated area



Physiographic regions of the Pacific Northwest



USGS National Groundwater Atlas

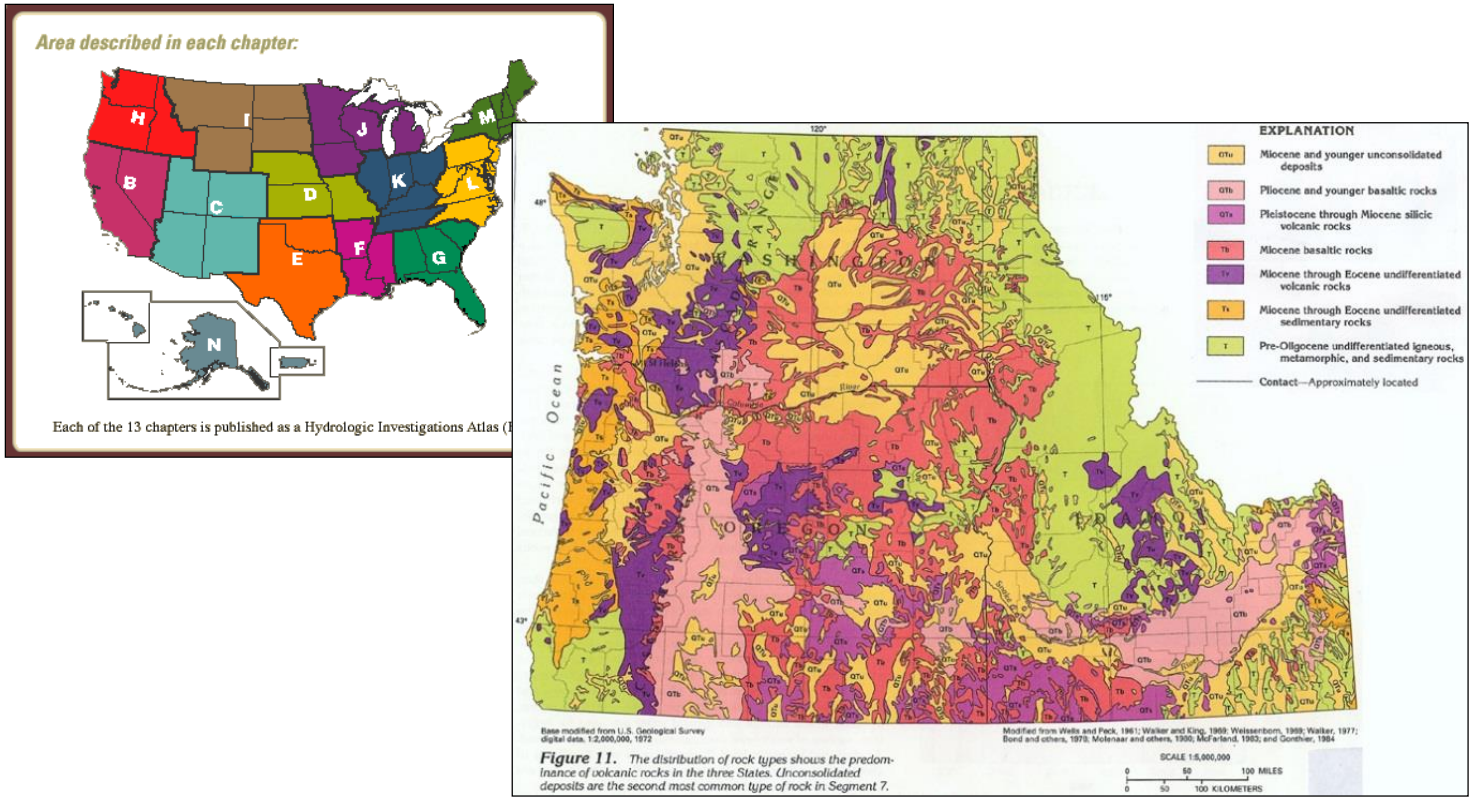


Figure 11. The distribution of rock types shows the predominance of volcanic rocks in the three States. Unconsolidated deposits are the second most common type of rock in Segment 7.

Whitehead, R.L. 1994. Ground Water Atlas of the United States: Idaho, Oregon, Washington. US Geological Survey Report HA 730-H.
http://pubs.usgs.gov/ha/ha730/ch_h/index.html

Precipitation – where it all starts

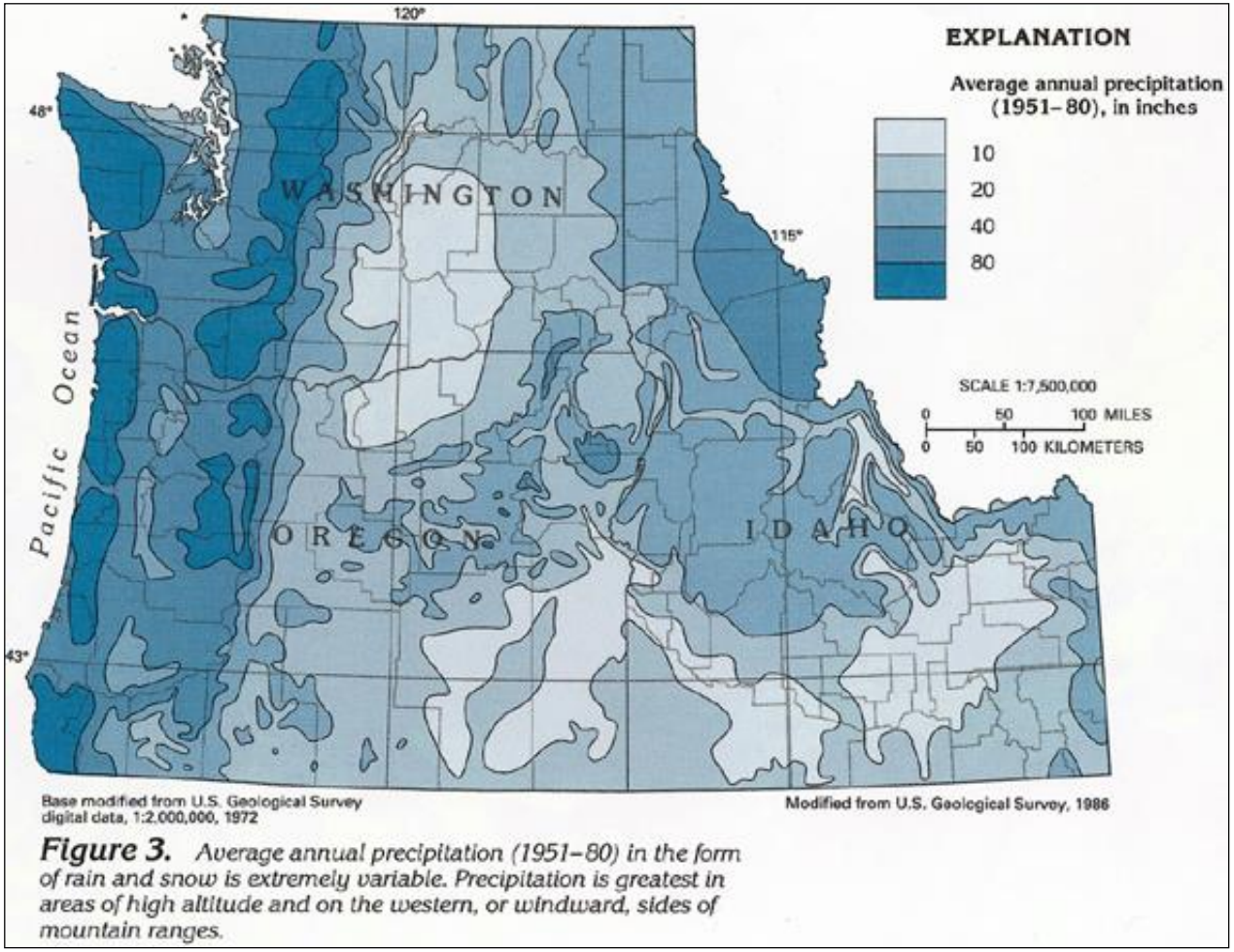


Figure 3. *Average annual precipitation (1951–80) in the form of rain and snow is extremely variable. Precipitation is greatest in areas of high altitude and on the western, or windward, sides of mountain ranges.*

Water use by area (million gallons per day)

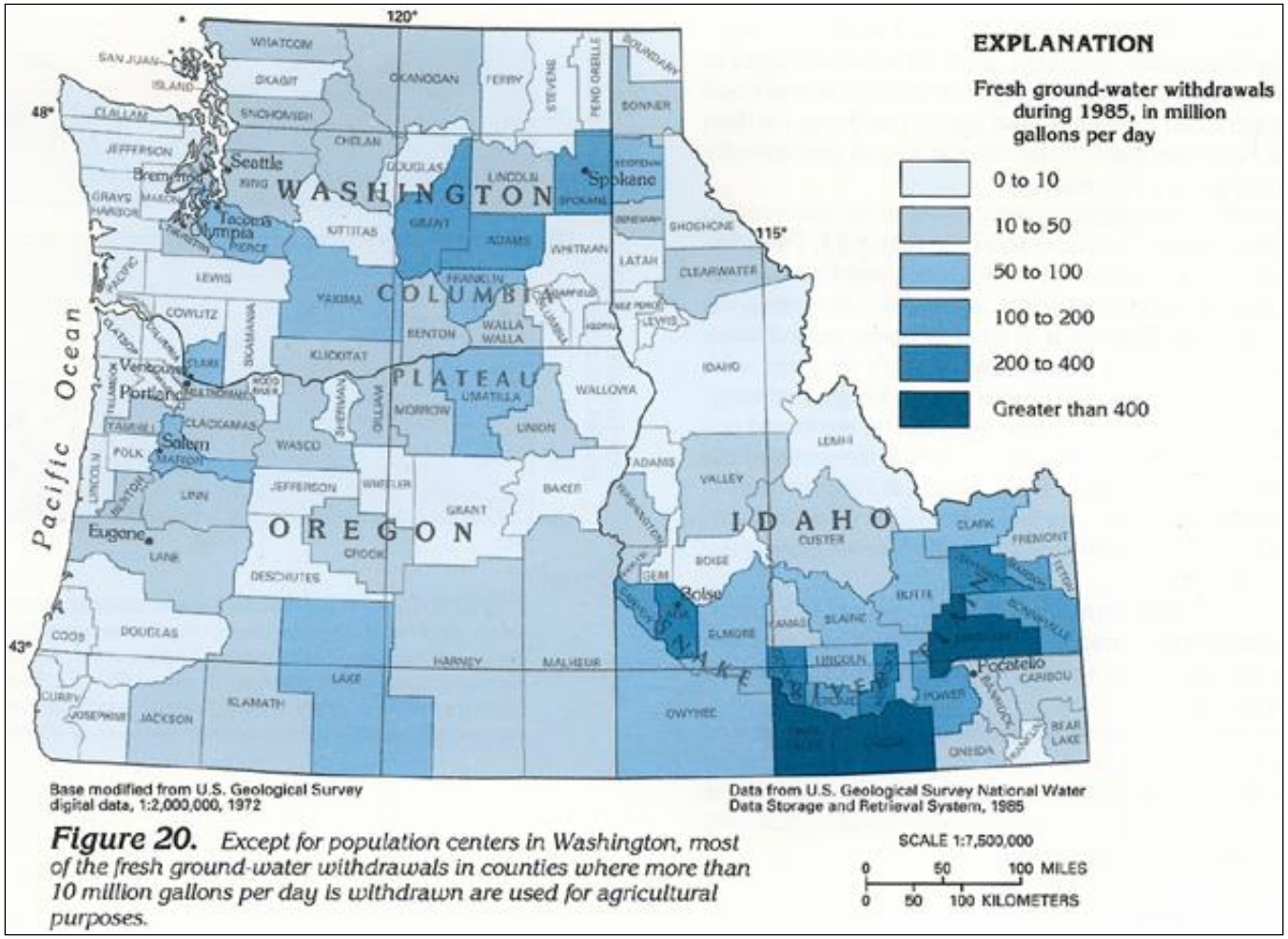


Figure 20. *Except for population centers in Washington, most of the fresh ground-water withdrawals in counties where more than 10 million gallons per day is withdrawn are used for agricultural purposes.*

Distribution by type of use

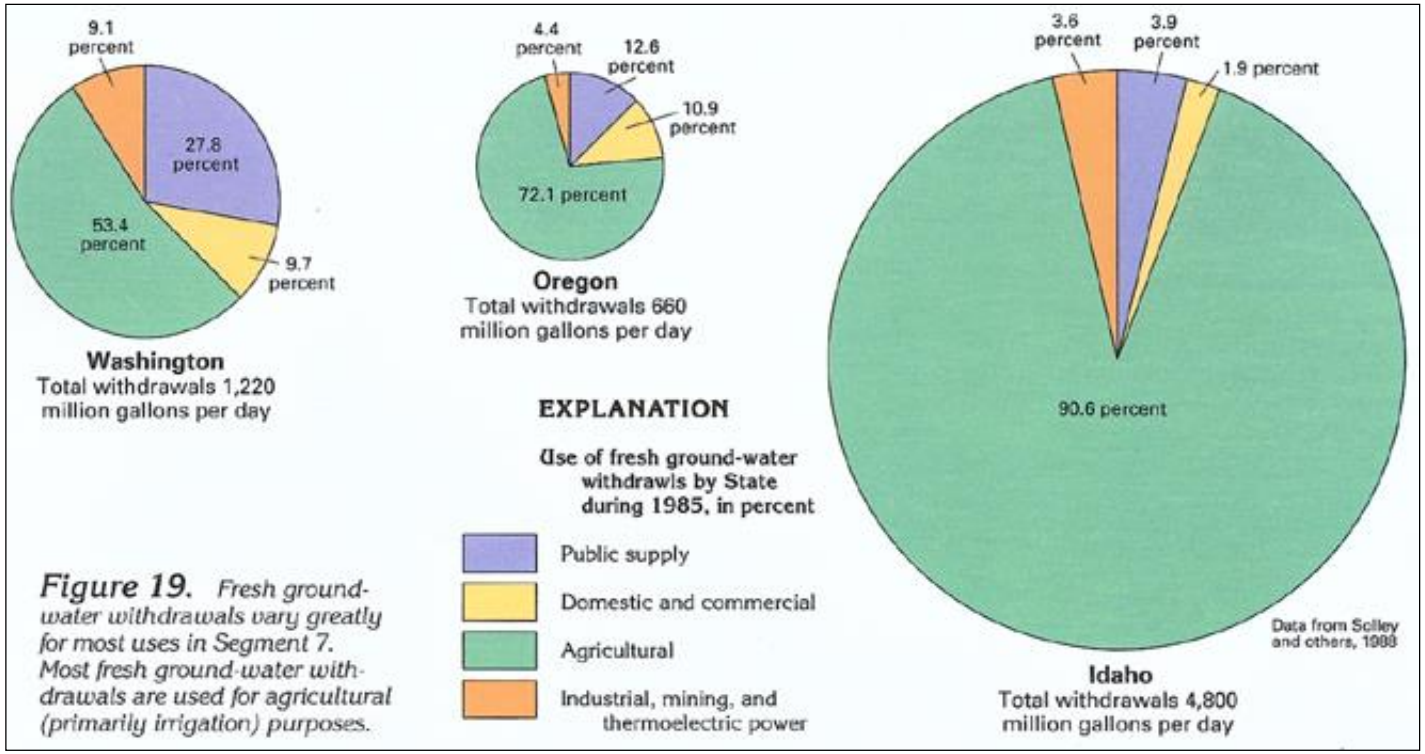
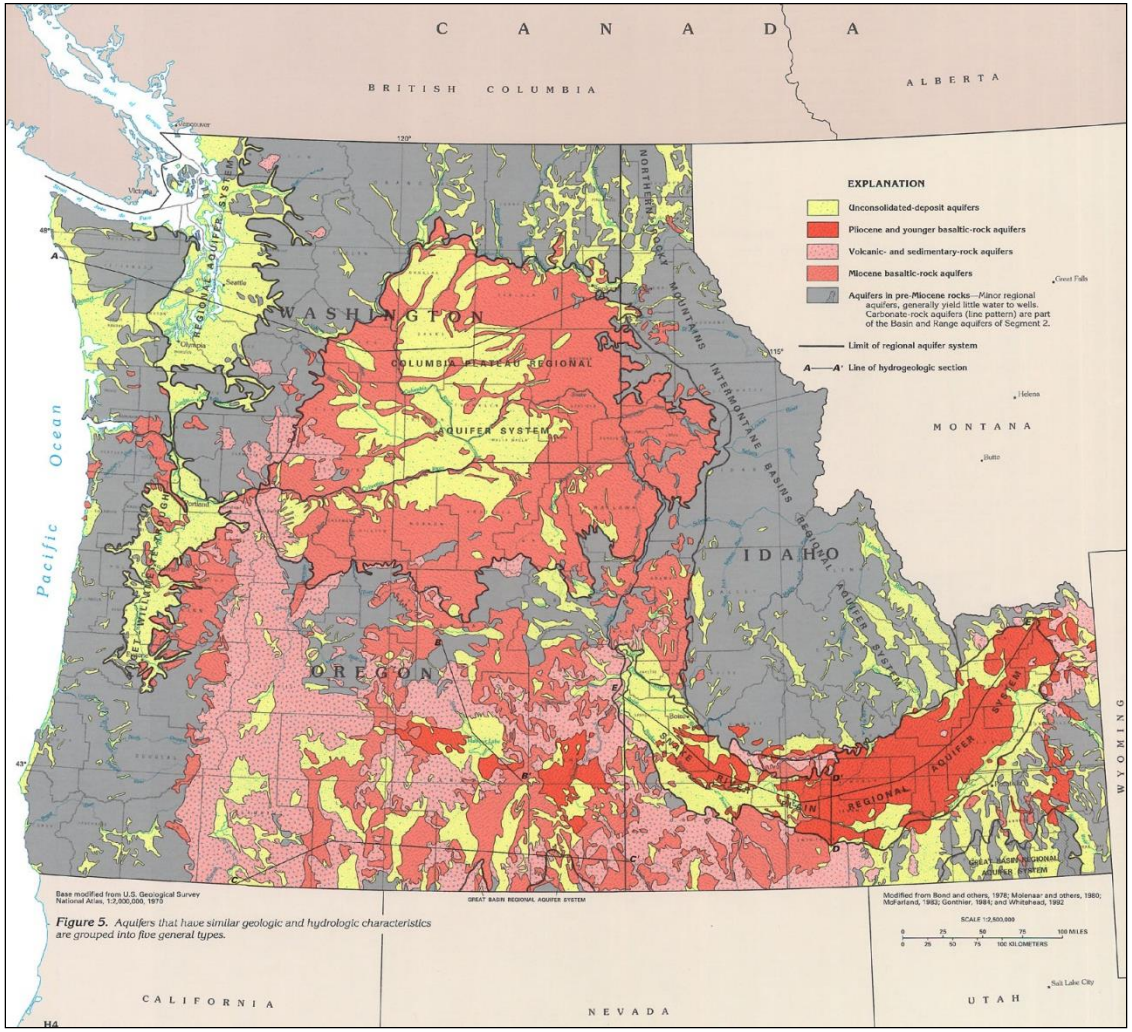


Figure 19. Fresh ground-water withdrawals vary greatly for most uses in Segment 7. Most fresh ground-water withdrawals are used for agricultural (primarily irrigation) purposes.

Hydrogeology of the Pacific Northwest



The third dimension …

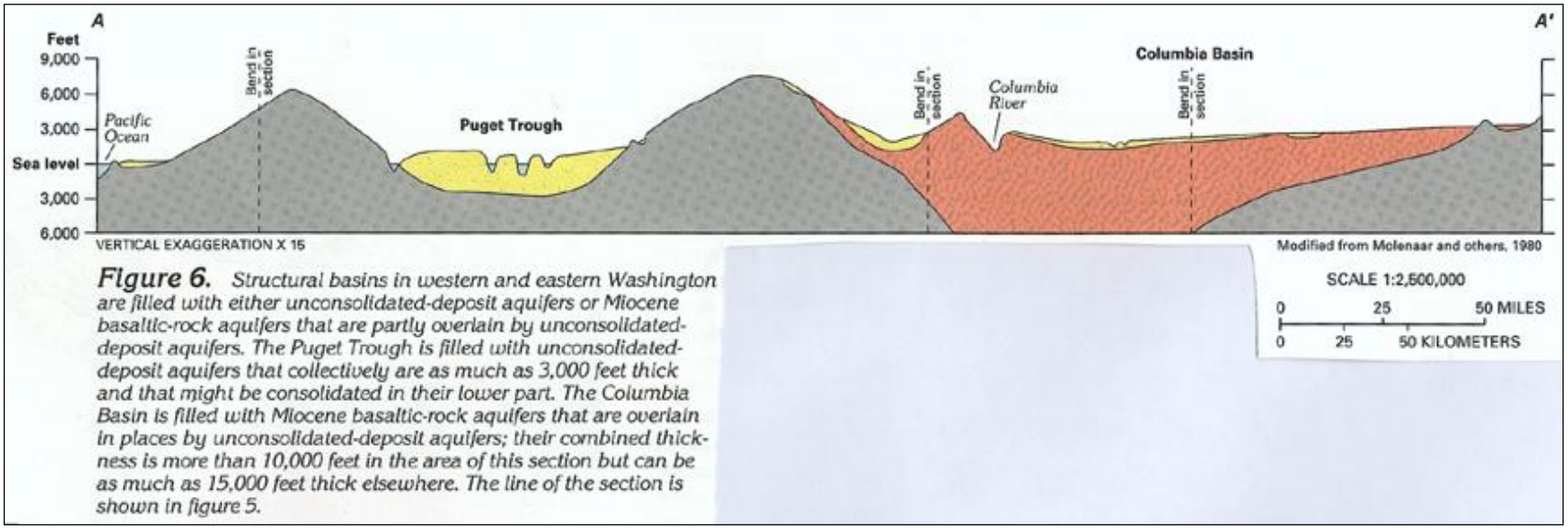


Figure 6. *Structural basins in western and eastern Washington are filled with either unconsolidated-deposit aquifers or Miocene basaltic-rock aquifers that are partly overlain by unconsolidated-deposit aquifers. The Puget Trough is filled with unconsolidated-deposit aquifers that collectively are as much as 3,000 feet thick and that might be consolidated in their lower part. The Columbia Basin is filled with Miocene basaltic-rock aquifers that are overlain in places by unconsolidated-deposit aquifers; their combined thickness is more than 10,000 feet in the area of this section but can be as much as 15,000 feet thick elsewhere. The line of the section is shown in figure 5.*

What do we mean by “aquifer?”

You can think of an aquifer as something that “is”

- Something in the ground that contains water

or

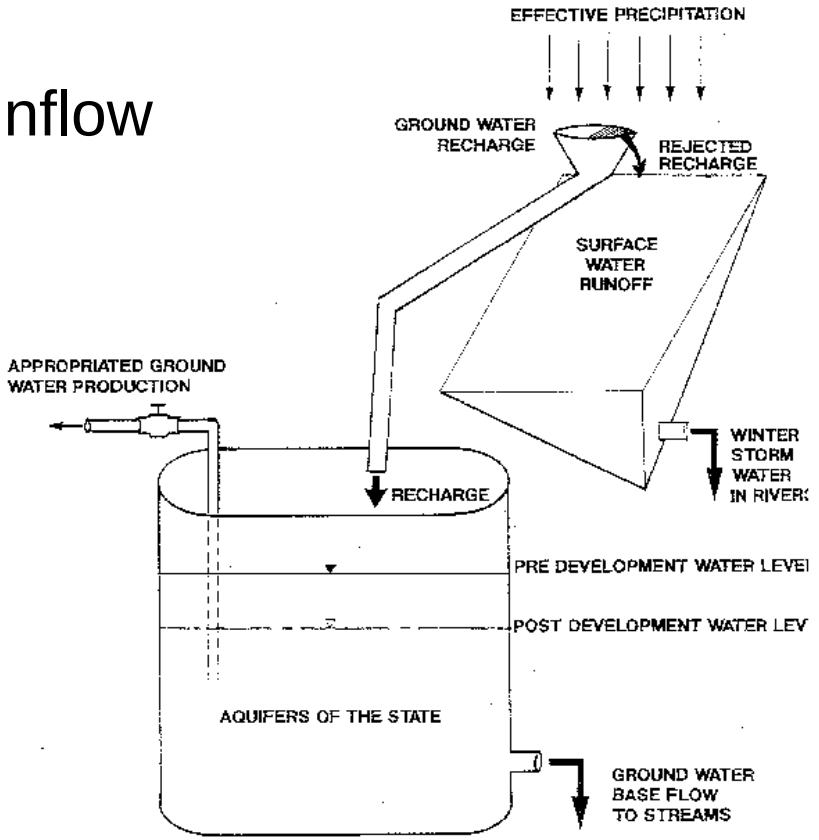
You can think of an aquifer as a set of processes that are happening

- Something that moves water

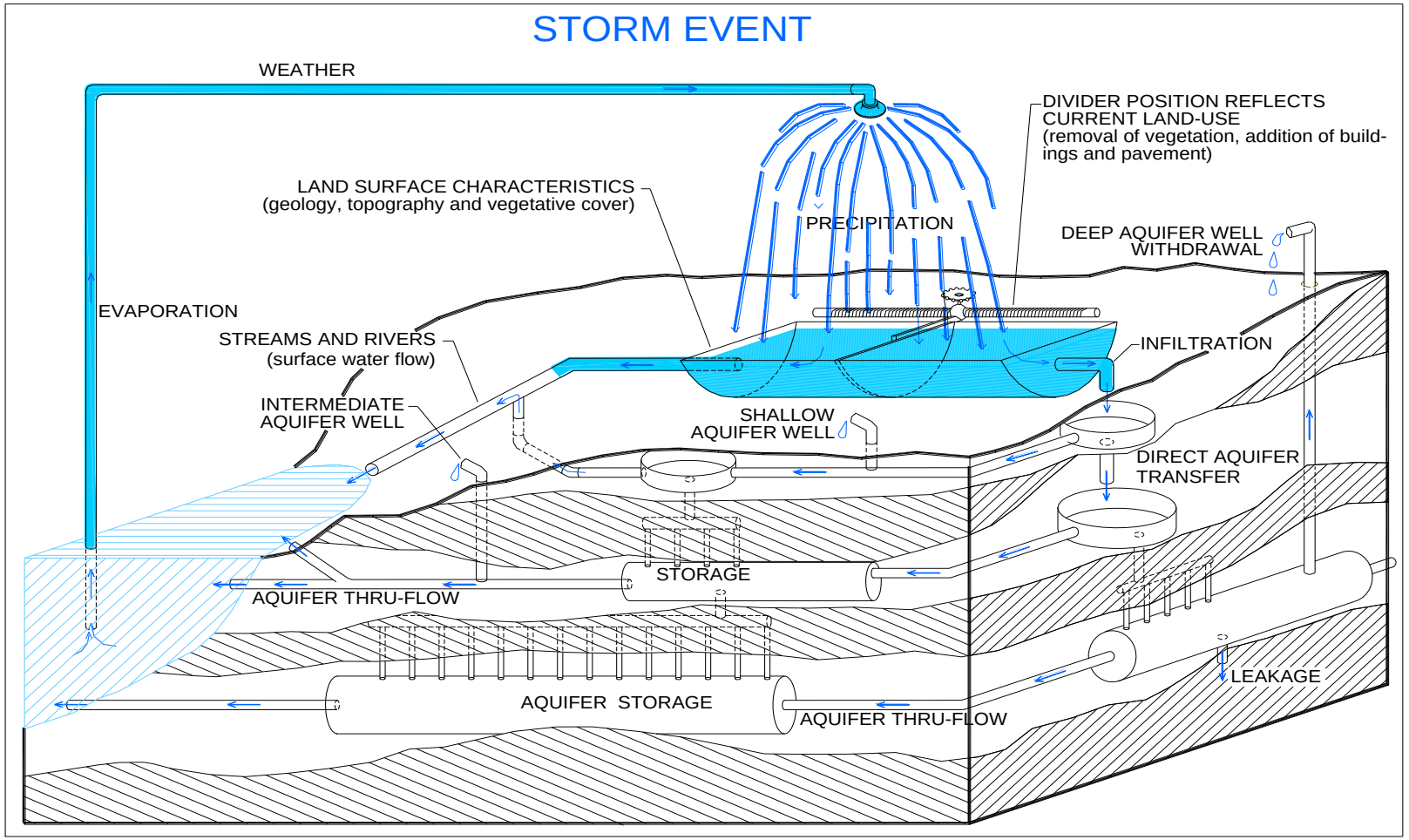
Plumbing analogy (simple version)

A storage tank with inflow and outflow pipes

- Inflow happens more uniformly over the tank
- Outflow can happen in more than one place



Aquifers are usually part of larger systems



These concepts are a good way to look at aquifers

- Some aquifers have good storage characteristics but small inflow pipes
- Some have very good transmission ability but little storage
- Some are marginal all around

- LET'S KEEP THIS IN MIND AS WE GO FORWARD

Aquifer topics

Three specific aquifer systems:

- Snake River Plain Aquifer System
- Columbia Basin Basalt Aquifer System
- Puget – Willamette Trough Aquifer Systems

Four generalized aquifer systems:

- Valley fill
- Basin fill
- Fractured rock
- Coastal aquifers

The Snake River Plain Aquifer

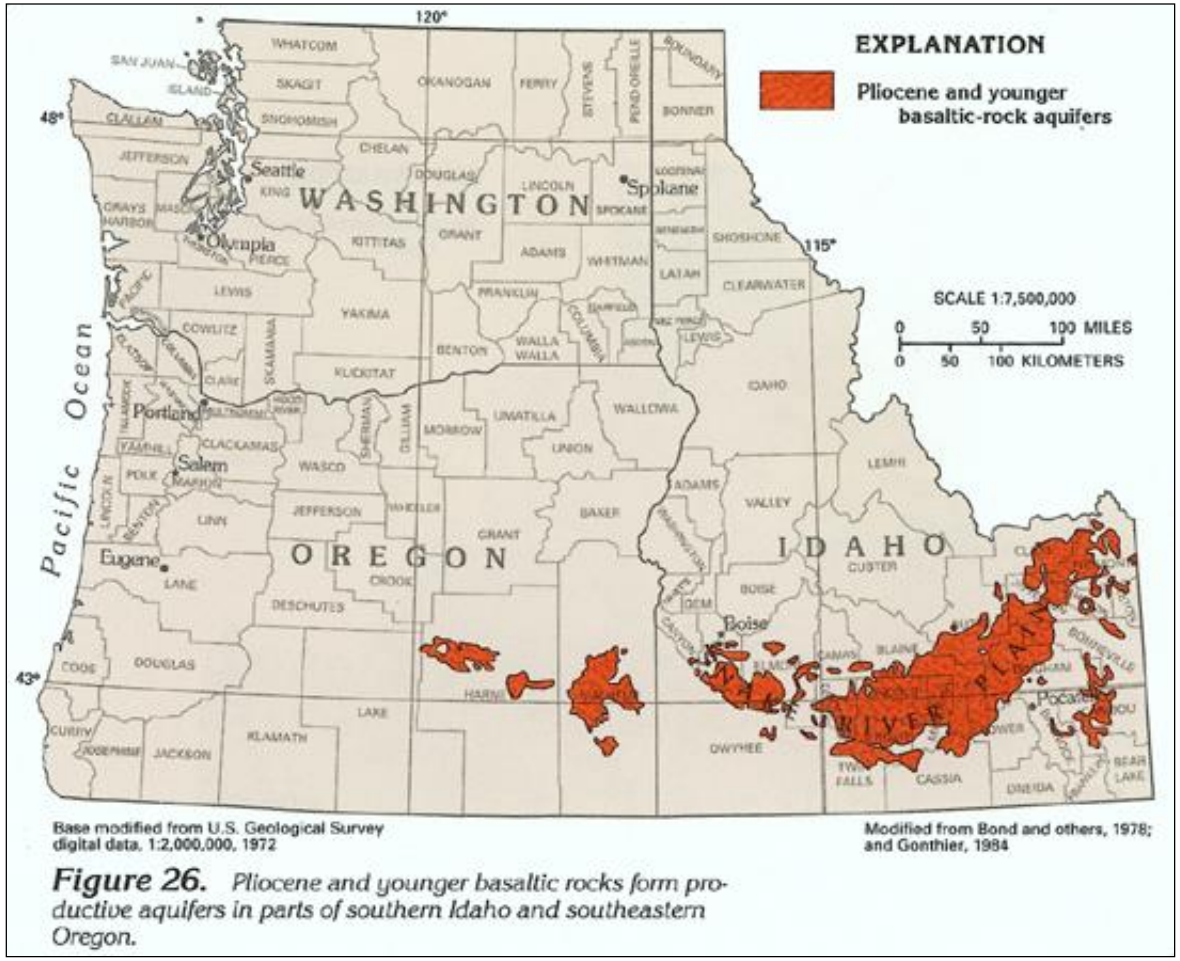


Figure 26. *Pliocene and younger basaltic rocks form productive aquifers in parts of southern Idaho and southeastern Oregon.*

Snake River Plain basalts

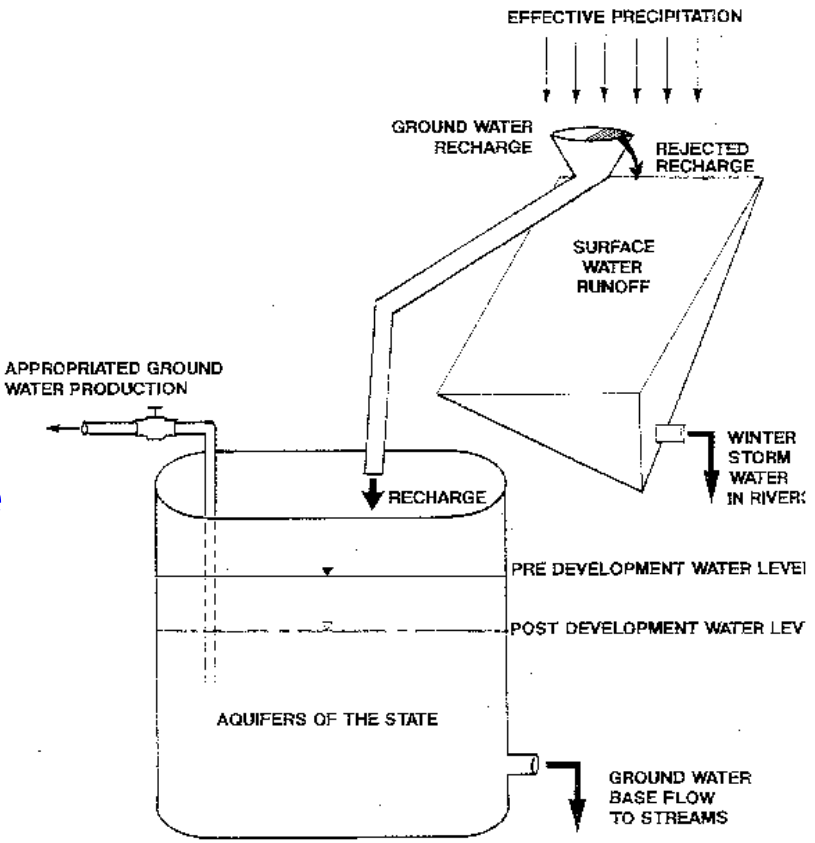
- This area has some of the most productive wells in the world
- Wells tend to be shallower than in the Columbia Plateau
- Relatively young rock 500,000 to as little as a few thousand years ago
- Covers nearly 16,000 mi^2 including sediment dominated area to the west
- Basalt flows and unconsolidated units are interbedded

Snake River Plain basalts (continued)

- Basalt flowed from large fissures as very fluid lava (much like the Hawaiian flows of today)
- Flows are permeable at the top and bottom and not permeable in the centers
- Many flows stacked one on the other with sediments sometimes laid down between flows
- As much as 3,000 feet thick in the middle of the area thinning to the edges (average flow thickness about 25 feet)

Snake River Plain Aquifer hydrology

- Medium recharge over a large area
- Huge storage capability
- Outflows focused mostly along primary streams and Snake river
- Recharge is fairly uniform over the full 16,000 square mile area but low
- Very high production from wells (up to 7,000 gpm reported)



Water from basalt

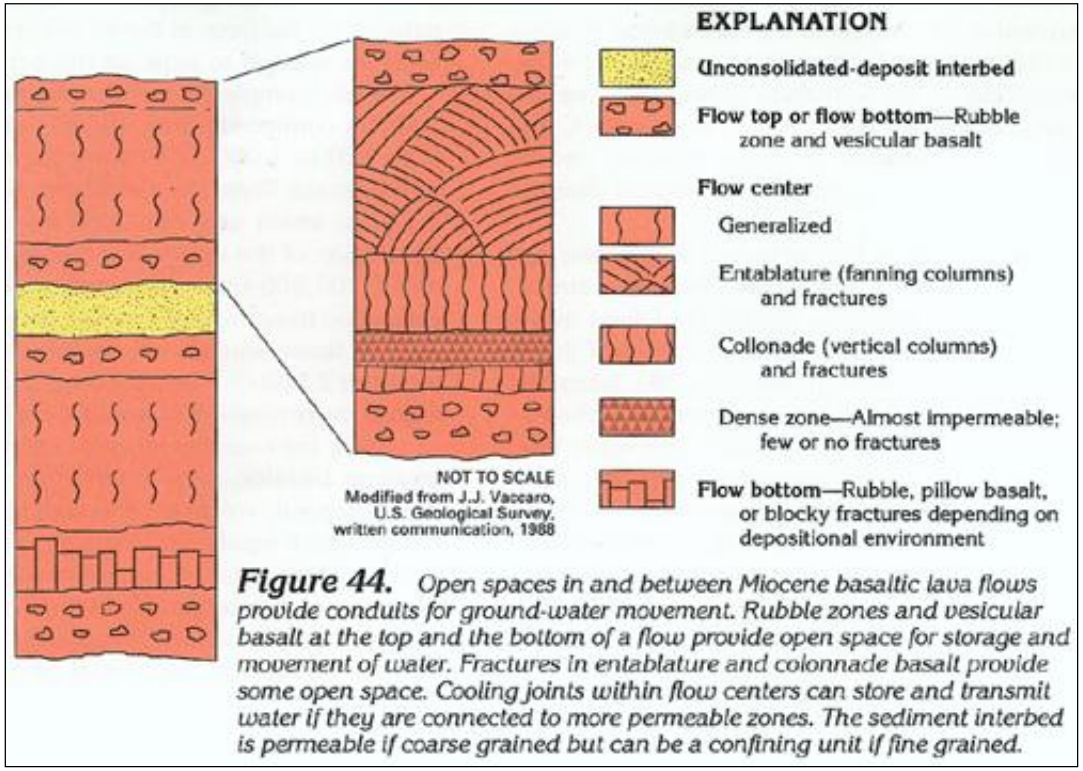


Figure 44. *Open spaces in and between Miocene basaltic lava flows provide conduits for ground-water movement. Rubble zones and vesicular basalt at the top and the bottom of a flow provide open space for storage and movement of water. Fractures in entablature and colonnade basalt provide some open space. Cooling joints within flow centers can store and transmit water if they are connected to more permeable zones. The sediment interbed is permeable if coarse grained but can be a confining unit if fine grained.*

Regulatory issues in the Snake River Plain

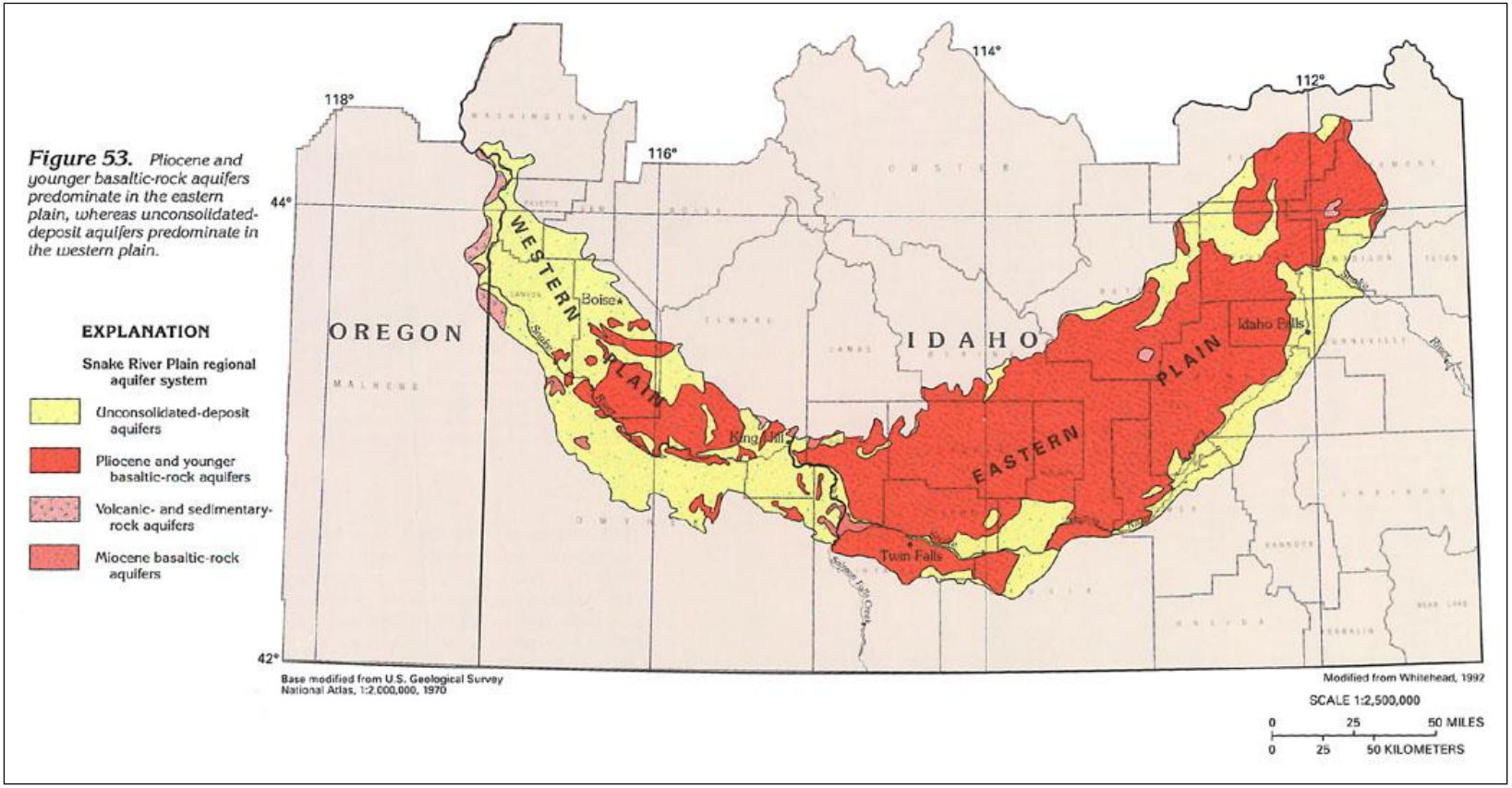
- A water right is needed to use the water
- "Water Calls" causing problems in some areas

I need some help here. Can some of you answer these questions:

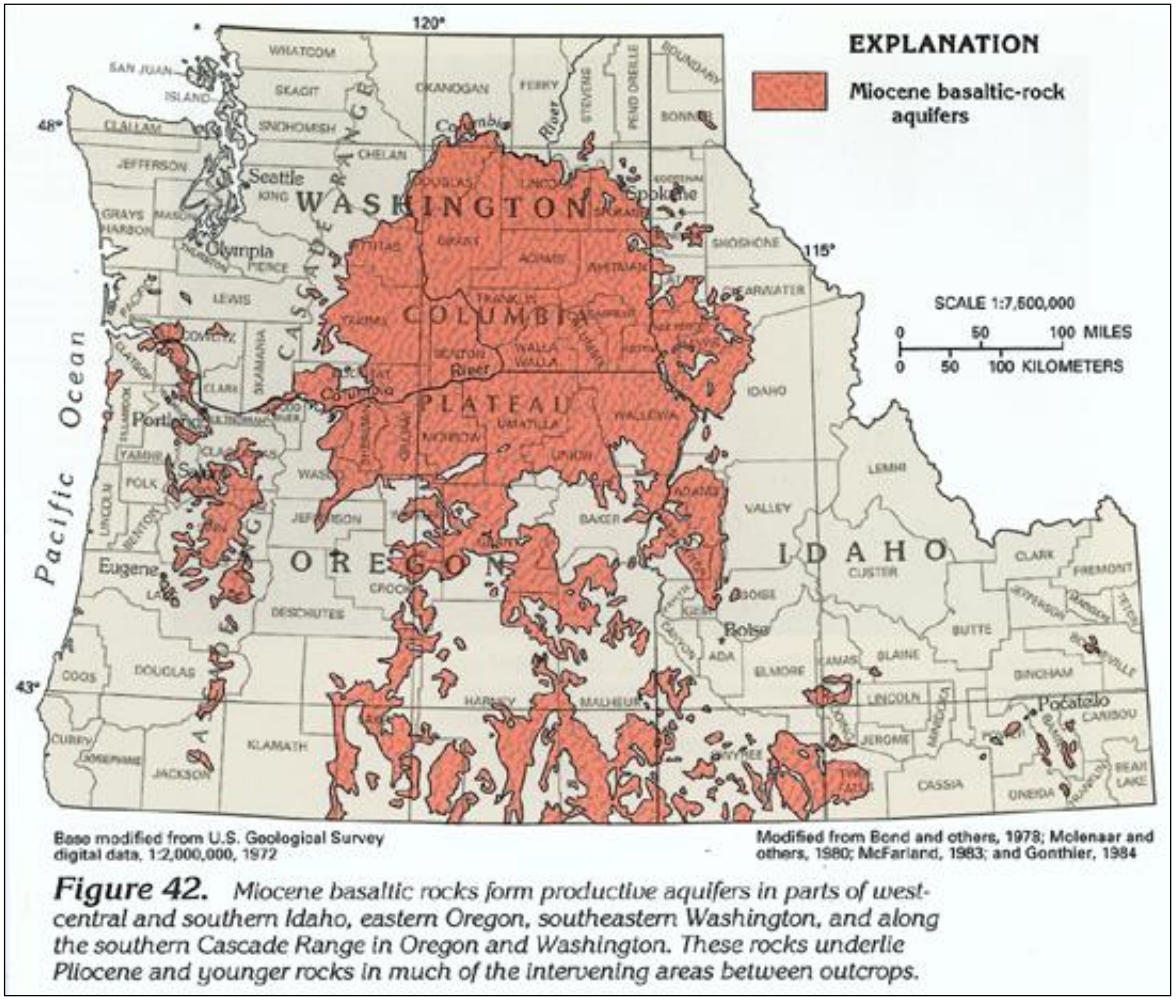
What drilling rules apply?

What are the procedures for a typical drilling project?

Open discussion on Snake River Plain



The Columbia River Basalt aquifers



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1972

Modified from Bond and others, 1978; Molenaar and others, 1980; McFarland, 1983; and Gonthier, 1984

Figure 42. *Miocene basaltic rocks form productive aquifers in parts of west-central and southern Idaho, eastern Oregon, southeastern Washington, and along the southern Cascade Range in Oregon and Washington. These rocks underlie Pliocene and younger rocks in much of the intervening areas between outcrops.*

Columbia River Basalt Group

Much older than the Snake River Plain basalts (16.5 to 6 million years old)

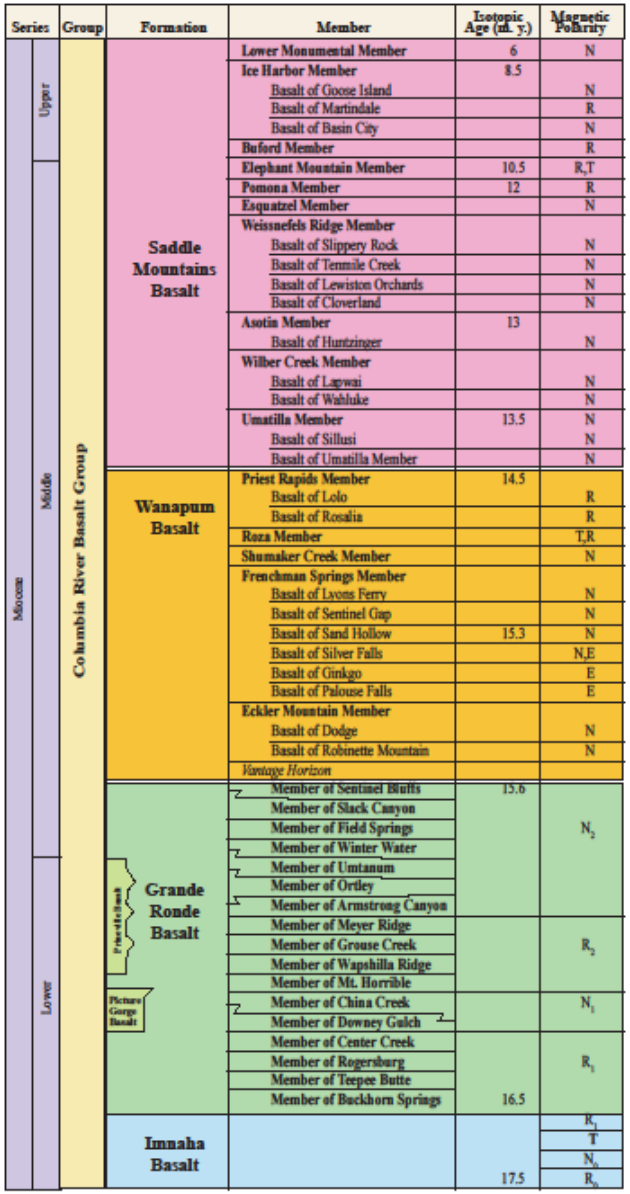
Very thick sequence with hundreds of individual flows

The basalts are divided into three formations:

- more than 85% is Grand Ronde (16.5 to 15.6 my)
- 5-10% Wanapum (15.5 to 14.5 my)
- 1% Saddle Mountains (14 to 6 my)

Columbia River Basalt Group

- 3 Formations typically discussed
- Each Formation with many members
- Each member with many flows



Series	Group	Formation	Member	Isotopic Age (m. y.)	Magnetic Polarity
Miocene	Columbia River Basalt Group	Saddle Mountains Basalt	Lower Monumental Member	6	N
			Ice Harbor Member	8.5	
			Basalt of Goose Island		N
			Basalt of Martindale		R
			Basalt of Basin City		N
			Buford Member		R
			Elephant Mountain Member	10.5	R,T
			Pomona Member	12	R
			Esquatzel Member		N
			Weissenfels Ridge Member		
			Basalt of Slippery Rock		N
			Basalt of Tenmile Creek		N
			Basalt of Lewiston Orchards		N
			Basalt of Cloverland		N
			Asotin Member	13	
			Basalt of Huntzinger		N
			Wilbur Creek Member		
			Basalt of Lapwai		N
			Basalt of Wahluke		N
			Umatilla Member	13.5	N
			Basalt of Sillusi		N
			Basalt of Umatilla Member		N
		Wanapum Basalt	Priest Rapids Member	14.5	
			Basalt of Lolo		R
			Basalt of Rosalia		R
			Roza Member		T,R
			Shumaker Creek Member		N
			Frenchman Springs Member		
			Basalt of Lyons Ferry		N
			Basalt of Sentinel Gap		N
			Basalt of Sand Hollow	15.3	N
			Basalt of Silver Falls		N,E
			Basalt of Ginkgo		E
			Basalt of Palouse Falls		E
			Eckler Mountain Member		
			Basalt of Dodge		N
			Basalt of Robinette Mountain		N
			Vantage Horizon		
		Grande Ronde Basalt	Member of Sentinel Bluffs	15.6	
			Member of Slack Canyon		
			Member of Field Springs		N_2
			Member of Winter Water		
			Member of Umtanum		
			Member of Ortley		
			Member of Armstrong Canyon		
			Member of Meyer Ridge		
			Member of Grouse Creek		R_2
			Member of Wapshilla Ridge		
			Member of Mt. Horrible		
			Member of China Creek		N_1
			Member of Downey Gulch		
			Member of Center Creek		
			Member of Rogersburg		R_1
			Member of Teepee Butte		
			Member of Buckhorn Springs	16.5	
		Imnaha Basalt			R_3
					T
					N_3
				17.5	R_0

Nomenclature of the Columbia River Basalt Group (from Reidel and others, 2002)

Columbia River Basalts

- Flowed from fissures near the tri-state corner
- Thick and laterally extensive flows
- As much as 15,000 feet thick in central basin (over 300 separate flows)
- Interbedded sediment layers between flow events
- Permeable at flow tops & bottoms and in some interbedded sediments

Cross section of Columbia Plateau

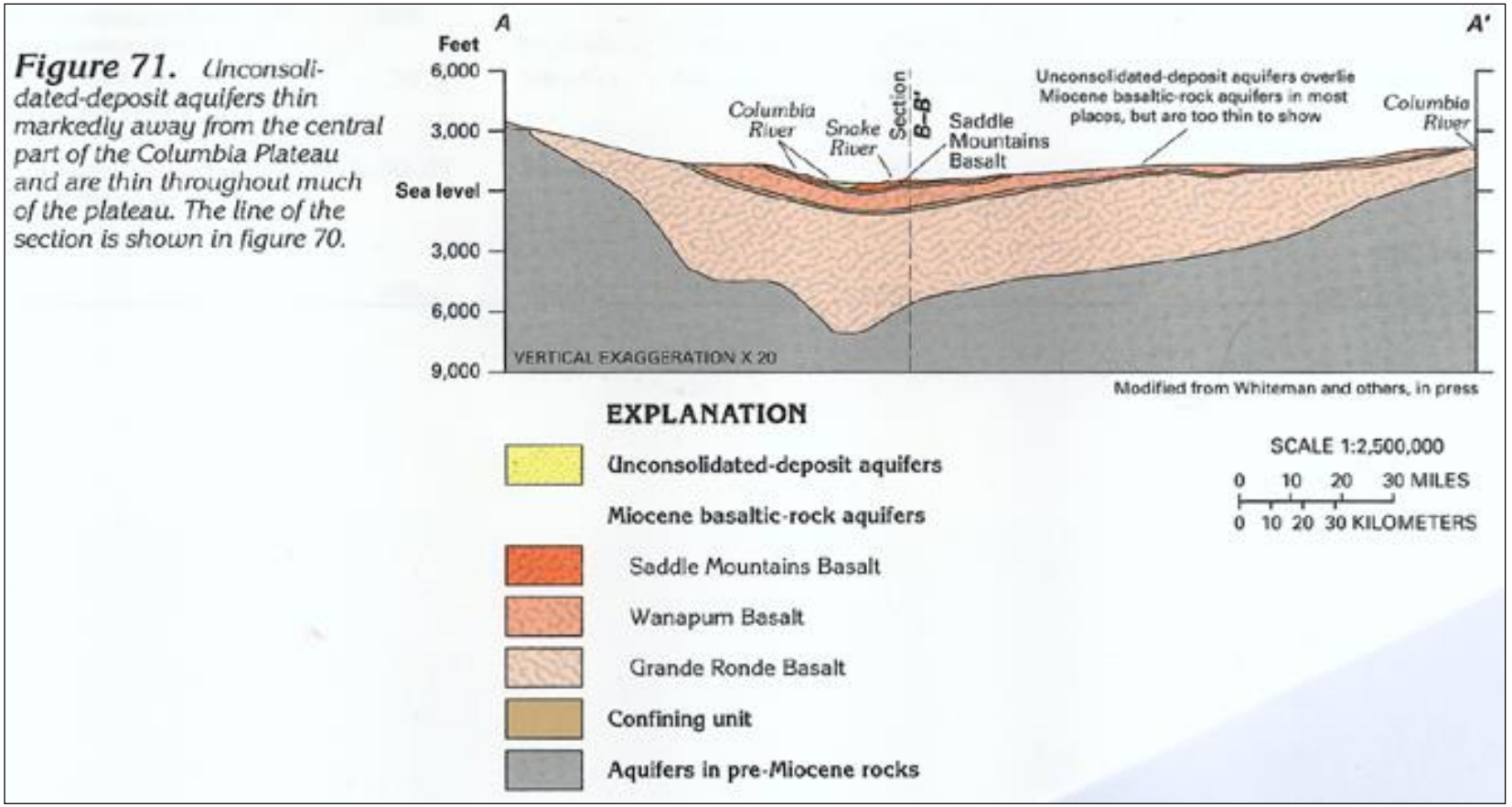


Figure 71. *Unconsolidated-deposit aquifers thin markedly away from the central part of the Columbia Plateau and are thin throughout much of the plateau. The line of the section is shown in figure 70.*

Unconsolidated sediments – Columbia Basin

- The aquifer system includes overlying basin-fill sediments
- Critical to recharge and irrigation return flow aspects
- Some very prolific wells

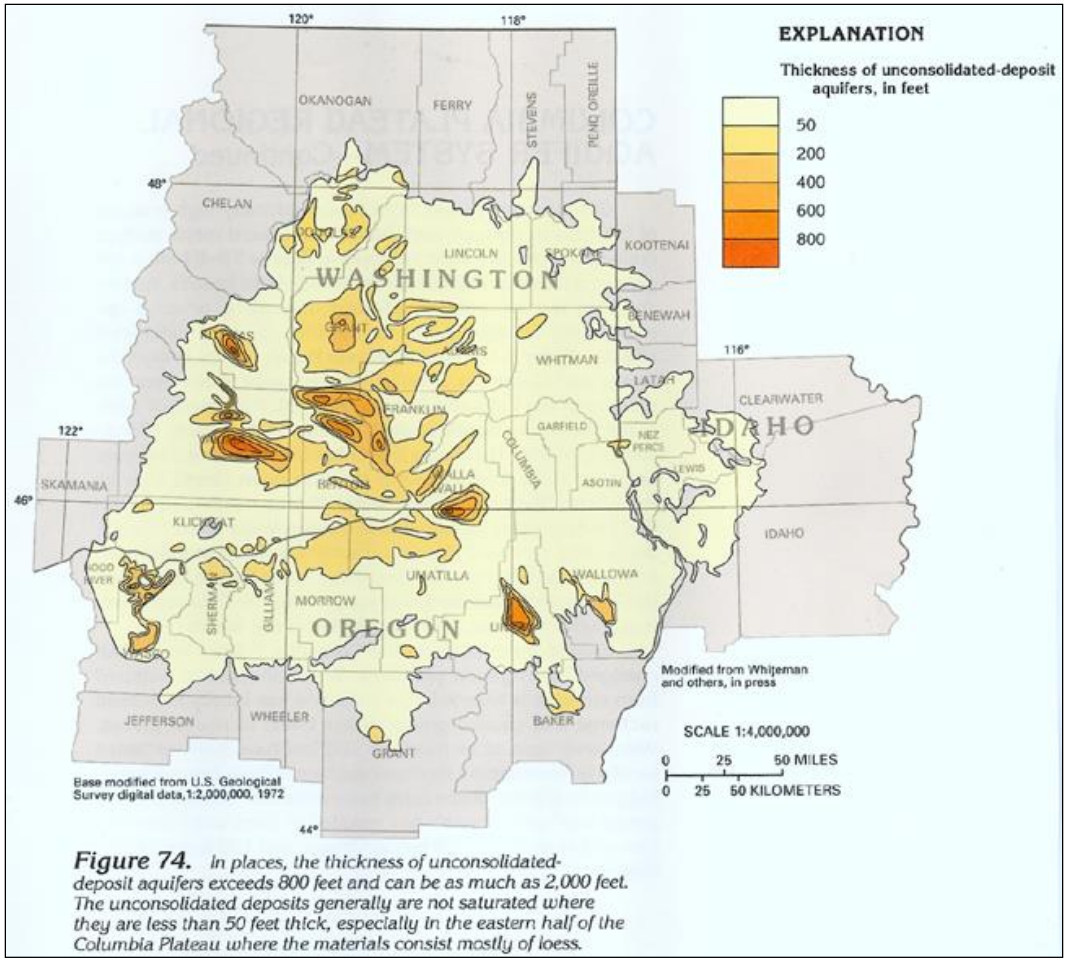
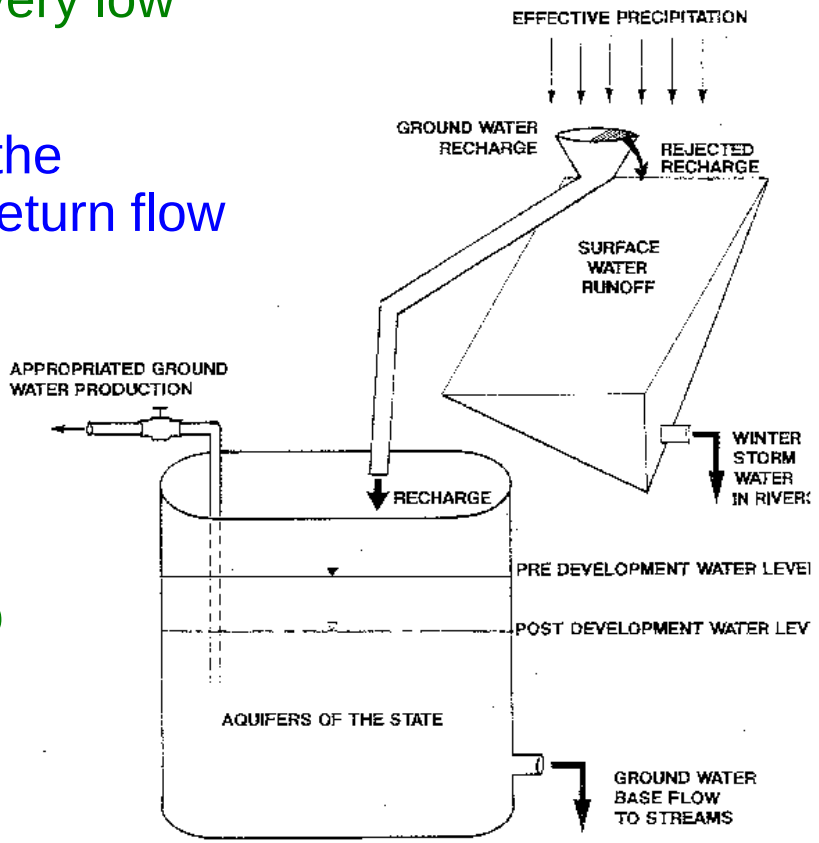


Figure 74. *In places, the thickness of unconsolidated-deposit aquifers exceeds 800 feet and can be as much as 2,000 feet. The unconsolidated deposits generally are not saturated where they are less than 50 feet thick, especially in the eastern half of the Columbia Plateau where the materials consist mostly of loess.*

Columbia Basin aquifer hydrology

- Large recharge area but very low precipitation
- Additional recharge from the mountains and irrigation return flow
- Very large storage capacity
- Very good flow through the aquifers
- Well focused discharge to the Columbia and major tributaries
- Very large withdrawal from wells



Basalt aquifers – Columbia Basin

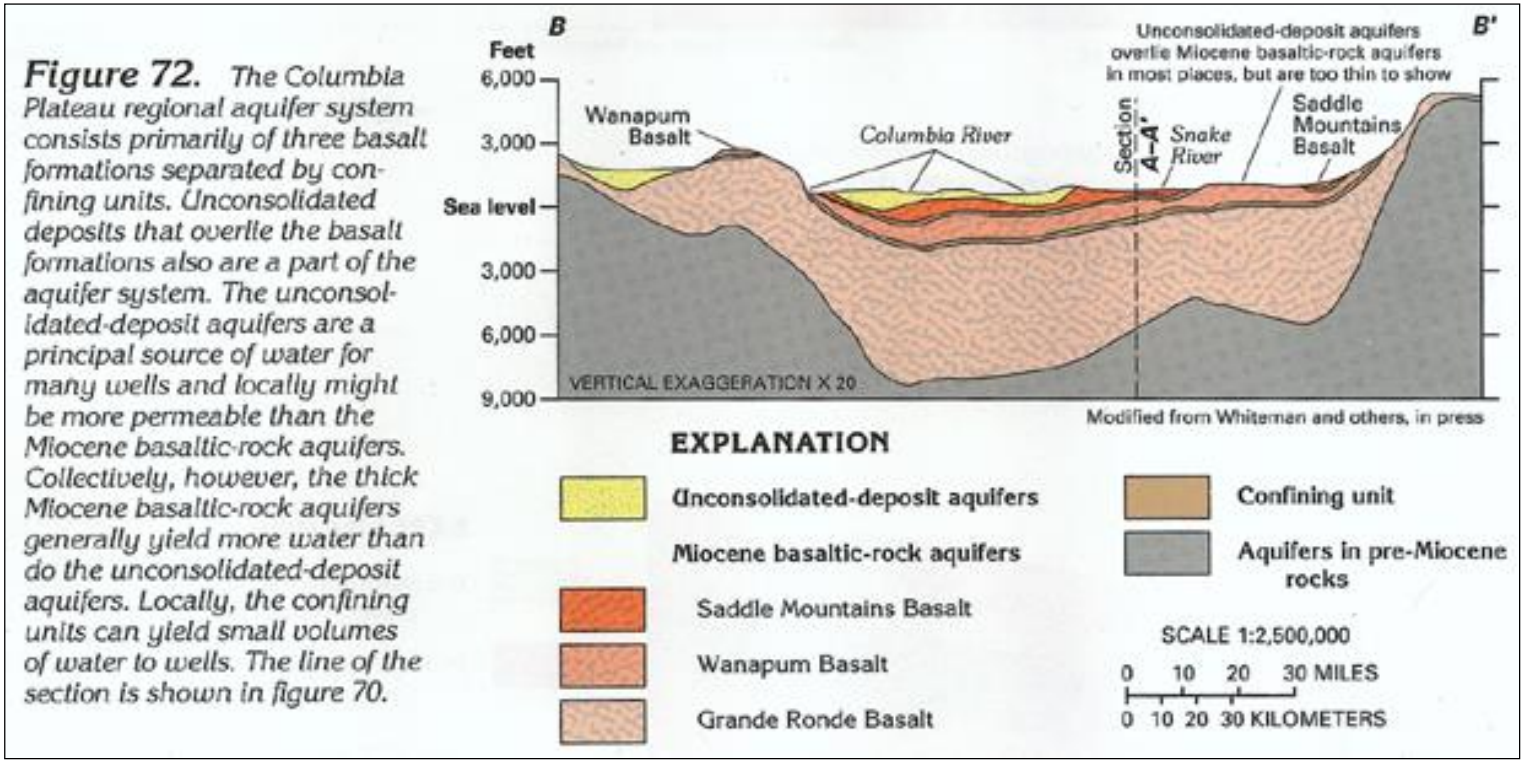


Figure 72. *The Columbia Plateau regional aquifer system consists primarily of three basalt formations separated by confining units. Unconsolidated deposits that overlie the basalt formations also are a part of the aquifer system. The unconsolidated-deposit aquifers are a principal source of water for many wells and locally might be more permeable than the Miocene basaltic-rock aquifers. Collectively, however, the thick Miocene basaltic-rock aquifers generally yield more water than do the unconsolidated-deposit aquifers. Locally, the confining units can yield small volumes of water to wells. The line of the section is shown in figure 70.*

Groundwater Flow - Columbia Plateau

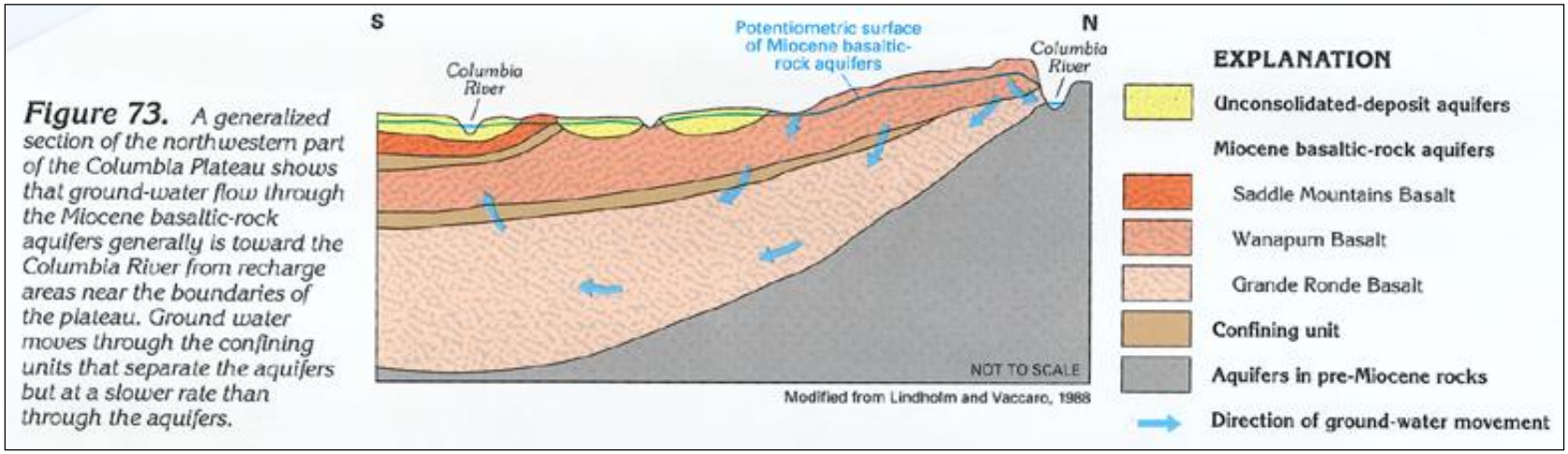


Figure 73. *A generalized section of the northwestern part of the Columbia Plateau shows that ground-water flow through the Miocene basaltic-rock aquifers generally is toward the Columbia River from recharge areas near the boundaries of the plateau. Ground water moves through the confining units that separate the aquifers but at a slower rate than through the aquifers.*

Regulatory discussion

- Water right needed, sometimes a Bureau of Reclamation Certificate as well
- Some areas closed to further allocation (Odessa area, for instance)
- Water rights often require a specific target subgroup (i.e. must be Grande Ronde)
- Air rotary and reverse circulation drilling techniques are most typical
- YOU TELL ME!

Open discussion on Columbia Basin Aquifers

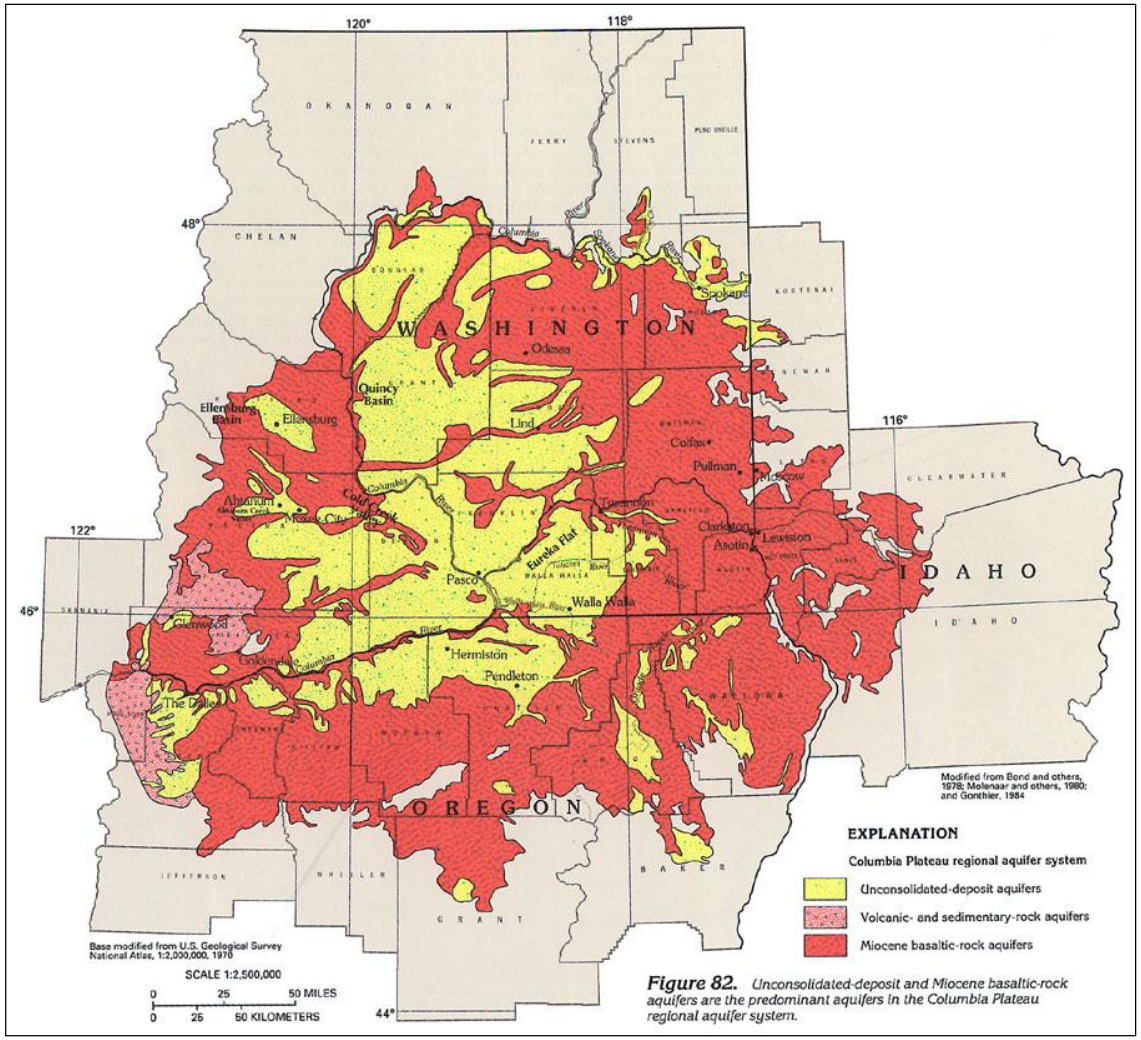


Figure 82. *Unconsolidated-deposit and Miocene basaltic-rock aquifers are the predominant aquifers in the Columbia Plateau regional aquifer system.*

The Puget/Willamette Trough

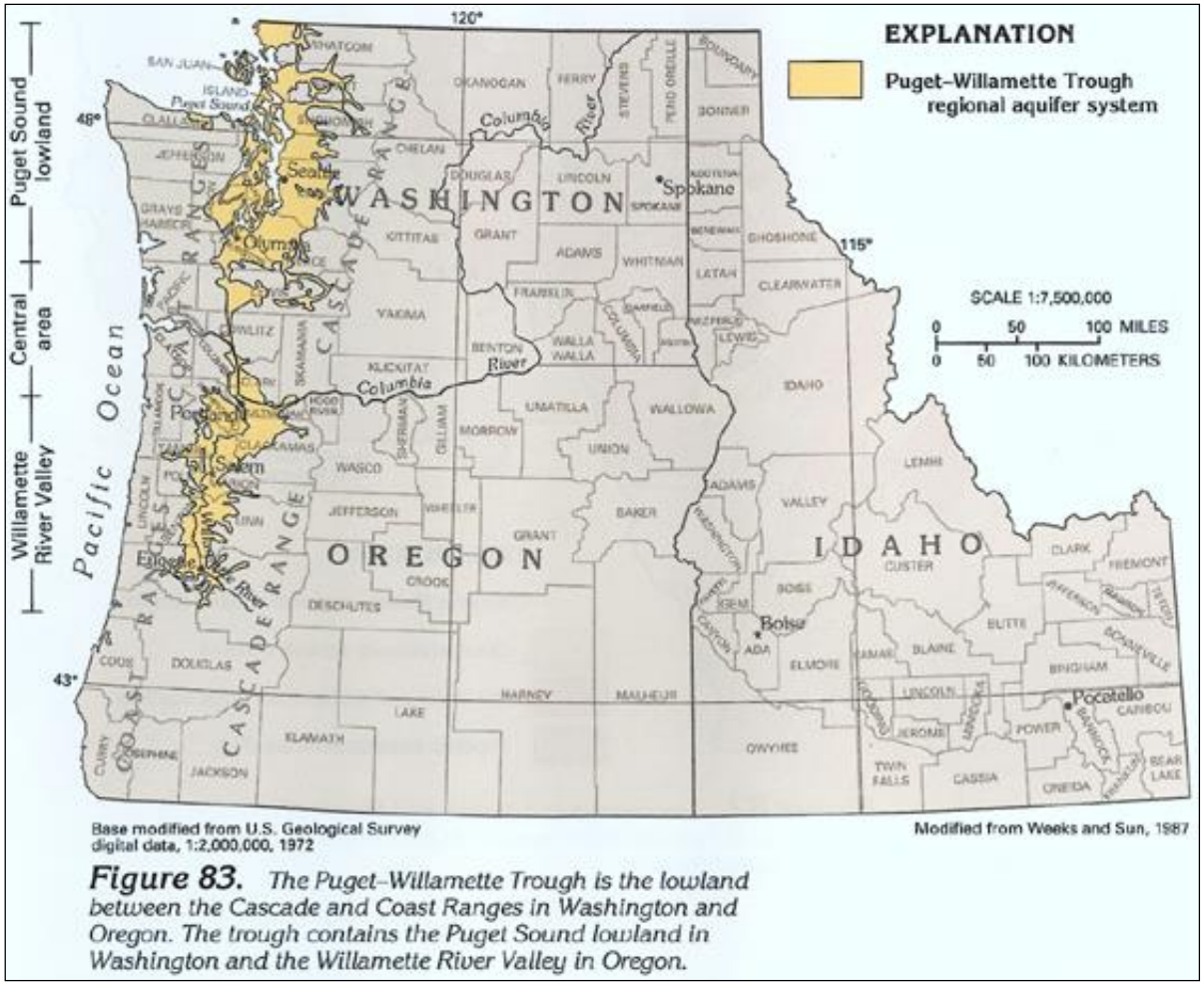
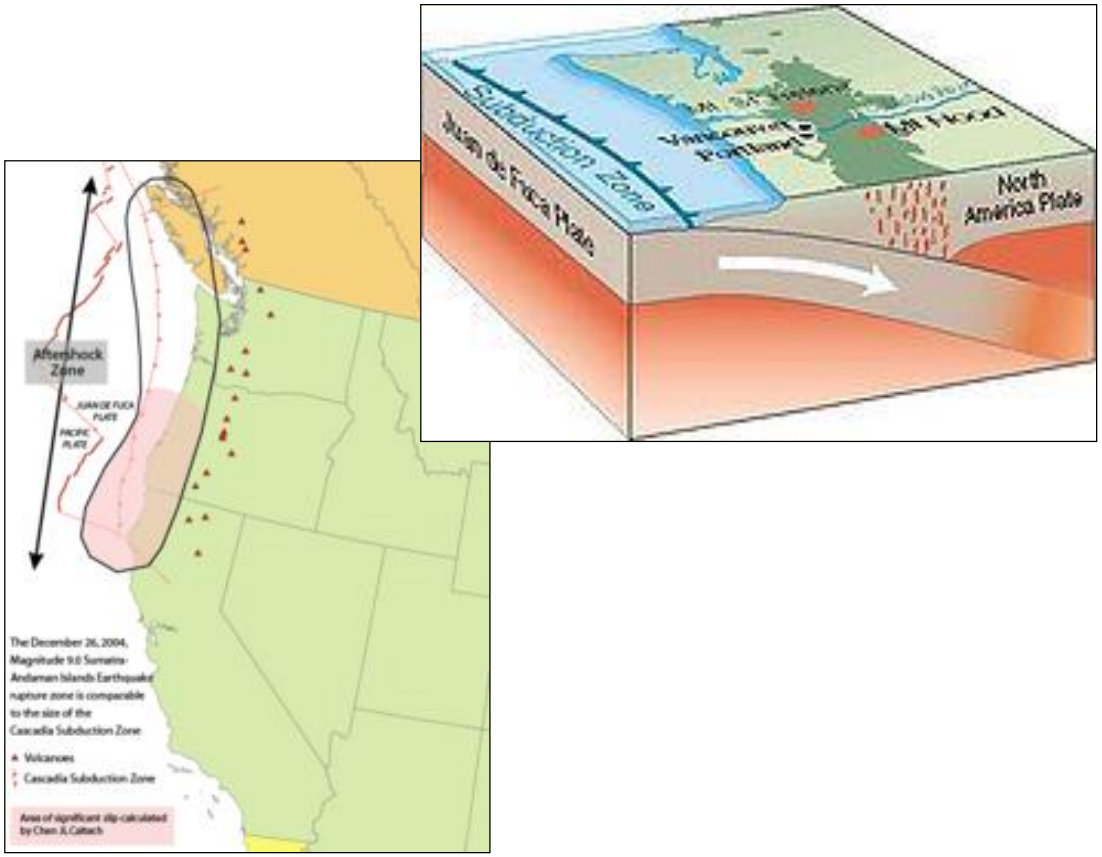


Figure 83. *The Puget–Willamette Trough is the lowland between the Cascade and Coast Ranges in Washington and Oregon. The trough contains the Puget Sound lowland in Washington and the Willamette River Valley in Oregon.*

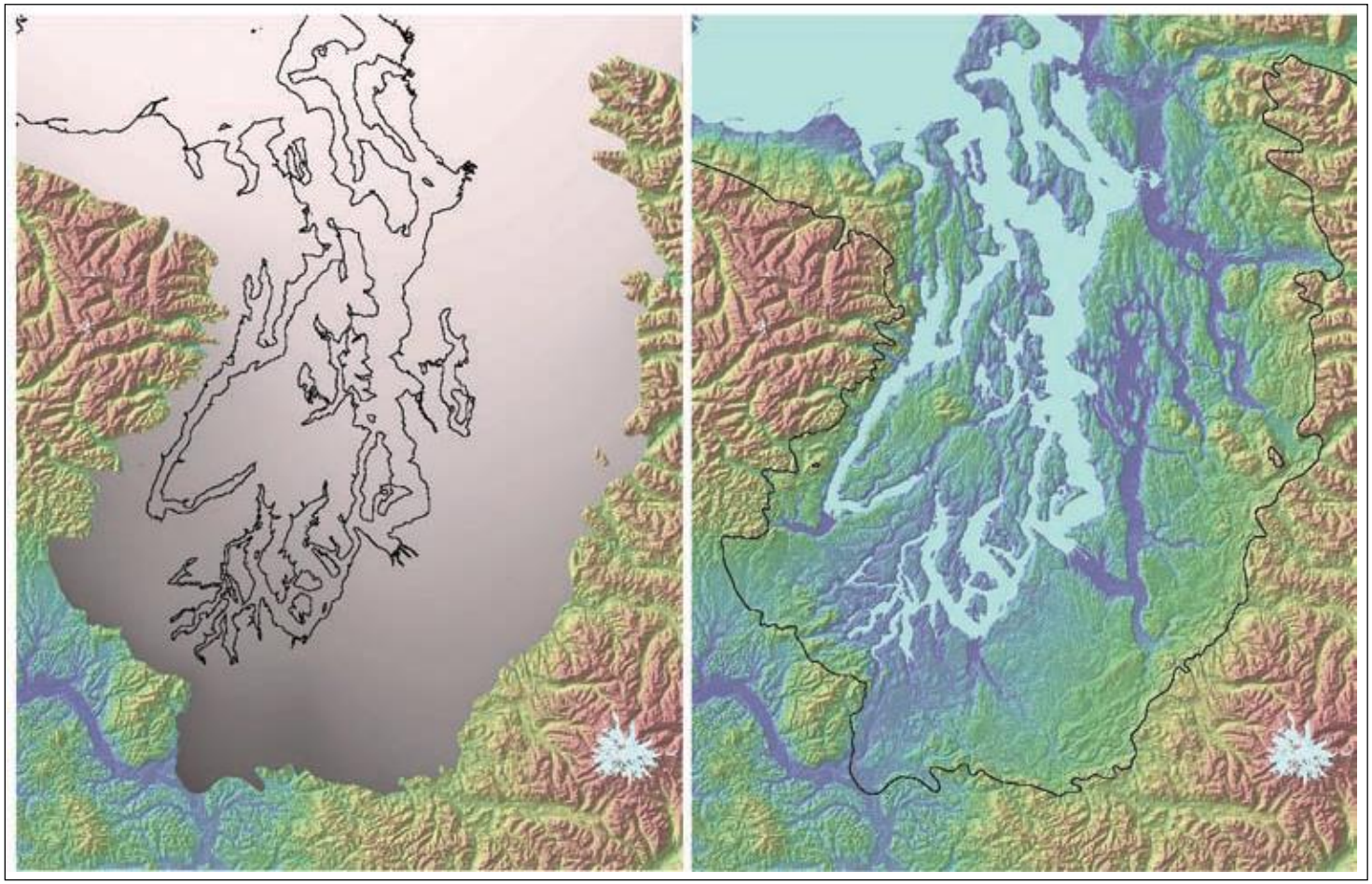
Structural geology of the trough



Unconsolidated aquifers of the Puget Sound region

- Complex glacial and interglacial deposits
- Silt and clay interbedded with sand and gravel with a bunch of other stuff thrown in
- More than 2,000 feet thick in some places
- Multiple glaciations and interglacial periods

Geomorphology of Puget Sound area



Puget Sound sediments

Glacial materials

- Highly complex
- Laterally extensive but inconsistent
- Recessional and advance outwash, till, glacio-lacustrine deposits

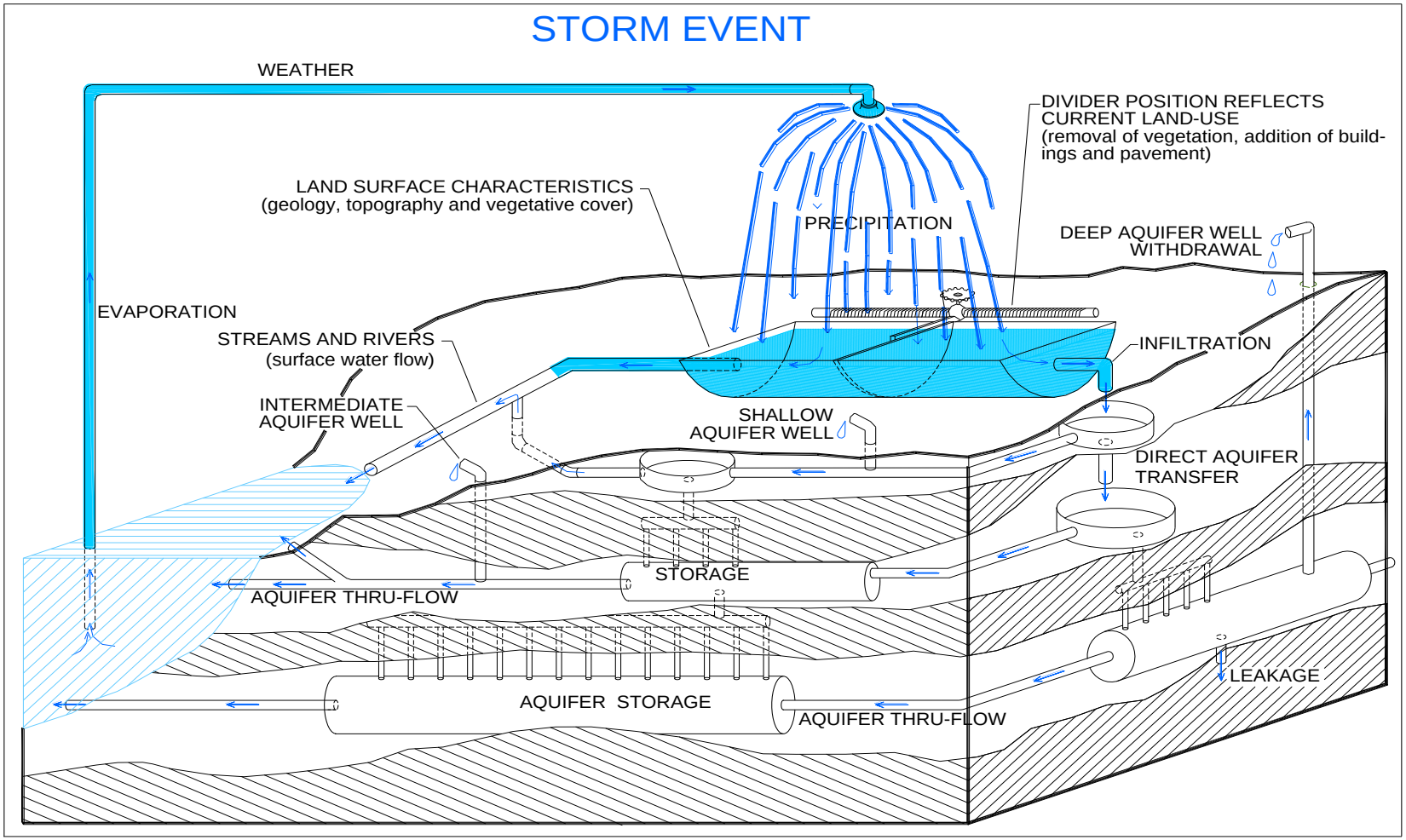
Non-glacial materials

- Generally finer-grained than glacial sediments
- Usually form regional confining layers
- Occasionally form good aquifers

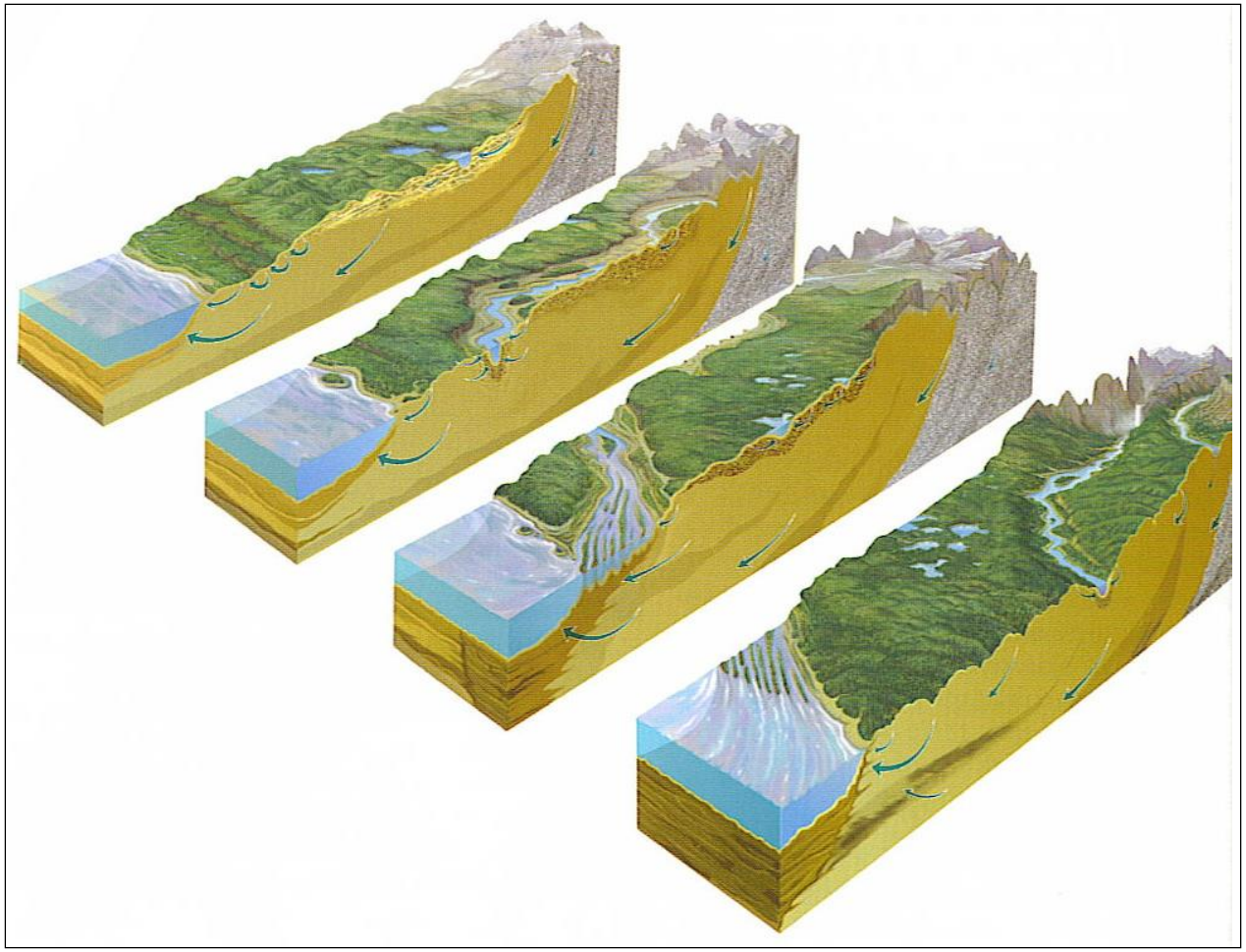
Puget Sound sediments (continued)

- Extremely complex, both laterally and with depth
- Locally, thin layers of clay and silt separate thin layers of sand and gravel
- Regionally, more permeable glacial sequences (100 feet and more) are separated by finer-grained silt and clay of interglacial deposits (10s to 100s of feet thick)
- Aquifer characteristics are unpredictable even over short distances

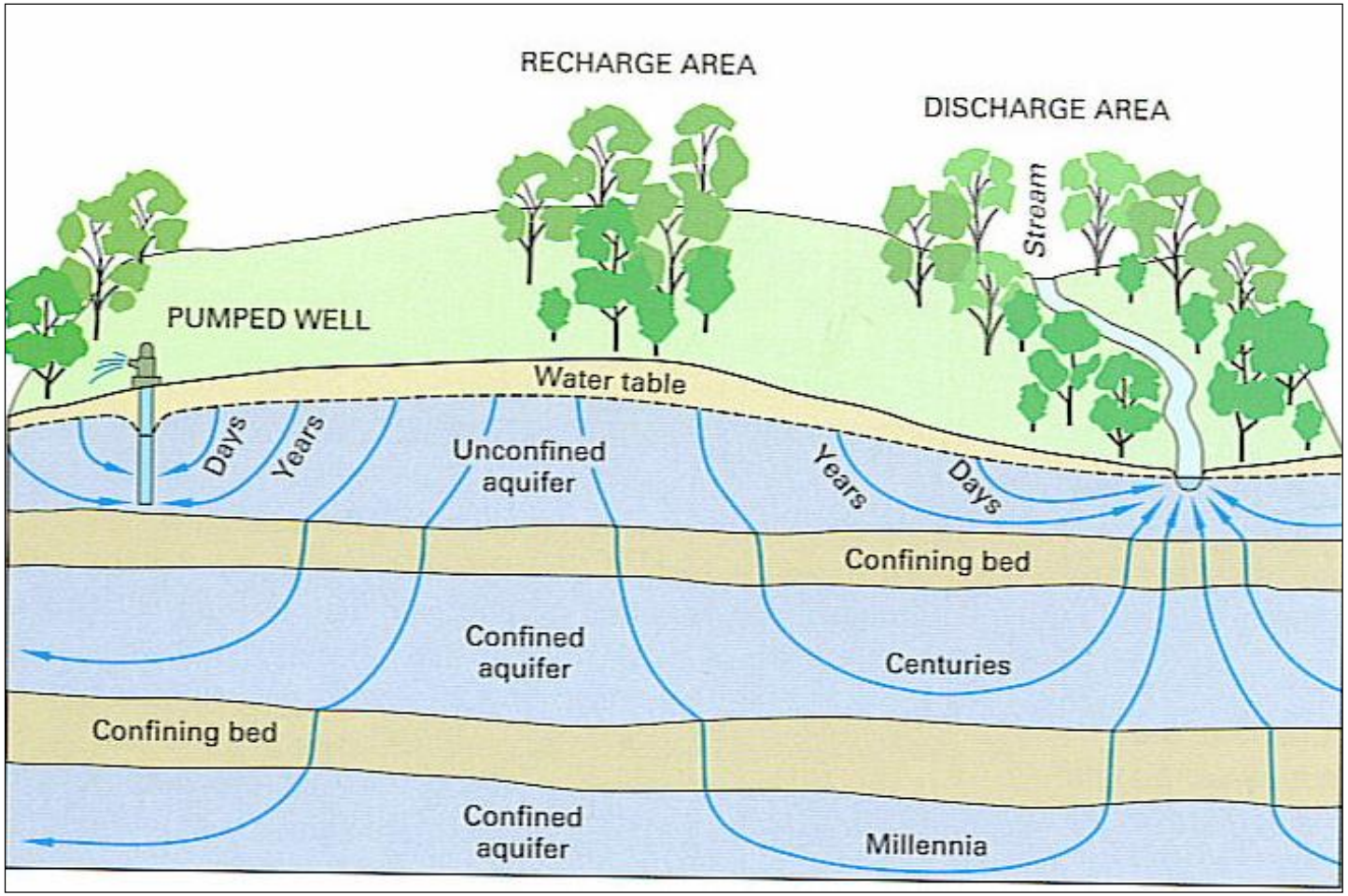
Puget Sound aquifer hydrology



Flow through unconsolidated sediments



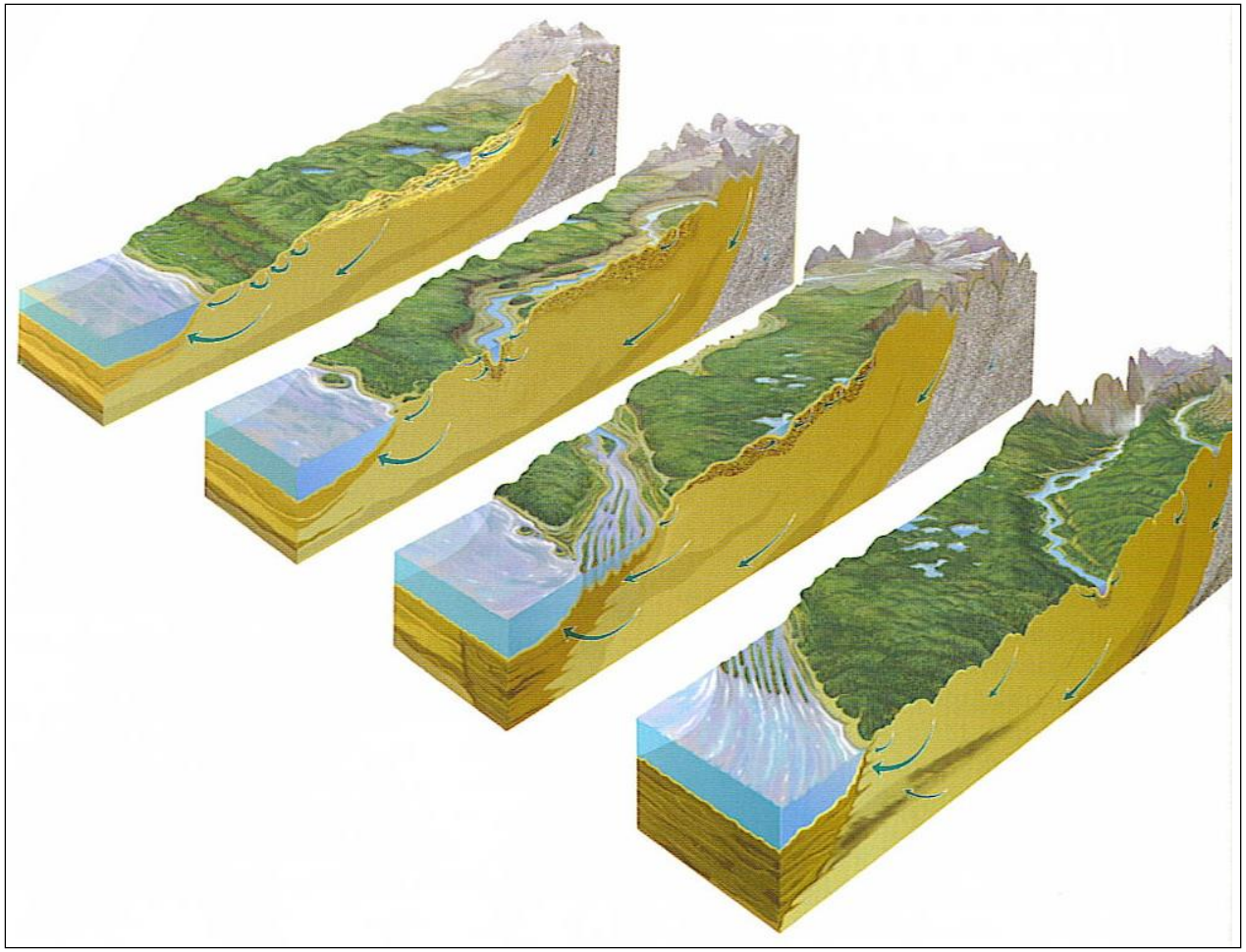
The timing of the flow varies



Regulatory discussion

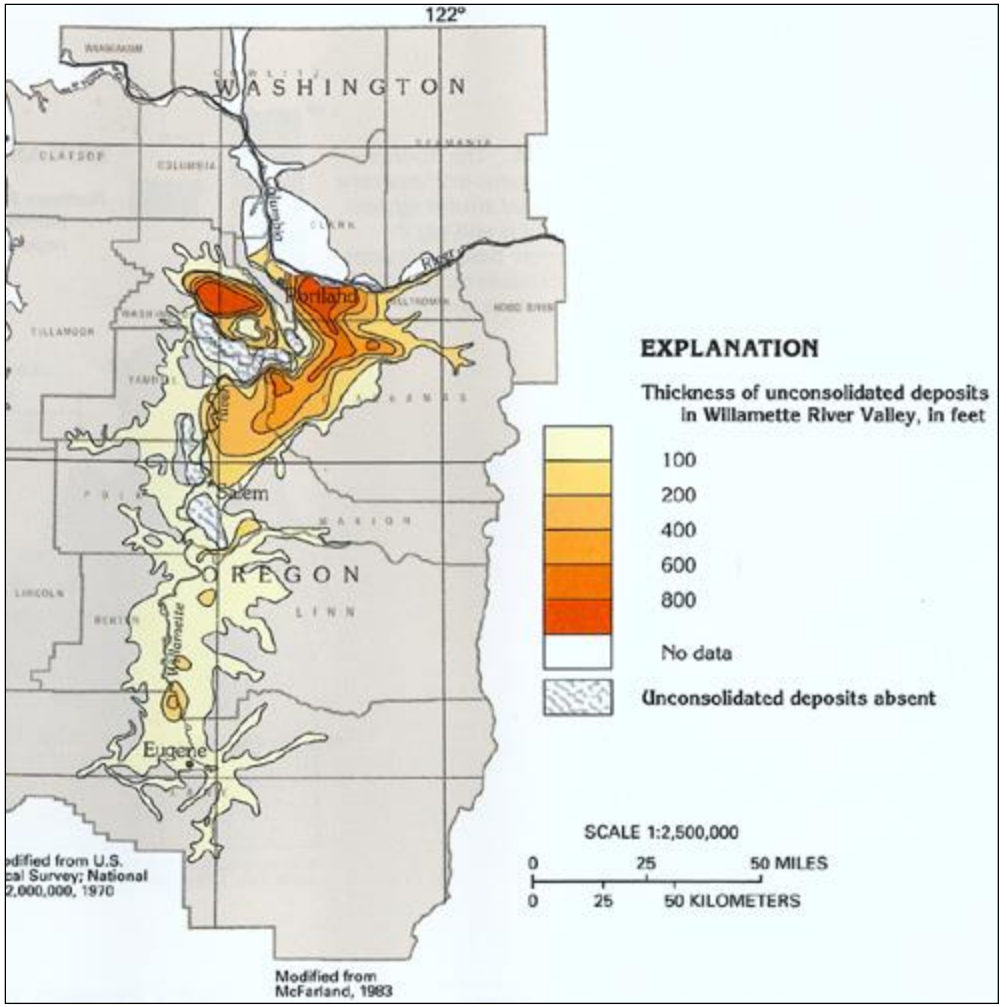
- Water rights needed for all but “exempt wells”
- Surface water WACs and “Watershed Planning” can make water right acquisition tricky in areas
- No particular drilling or construction constraints beyond normal standards
- County regulations and delegated authority must be recognized

Discussion on Puget Sound sediments



Willamette Trough

- Structural basin
- Filled with unconsolidated and semi-consolidated sediments
- Centered around Portland



Willamette Trough:
Portland area unconsolidated sediments

- Complex but non-glacial
- Valley-fill sequences of Willamette and Columbia Rivers
- Weirdness of the Bretz Floods (basin-fill?)
- Columbia River Basalts reaches beyond this basin to the Pacific
- Columbia River influences it all

Willamette Trough aquifers

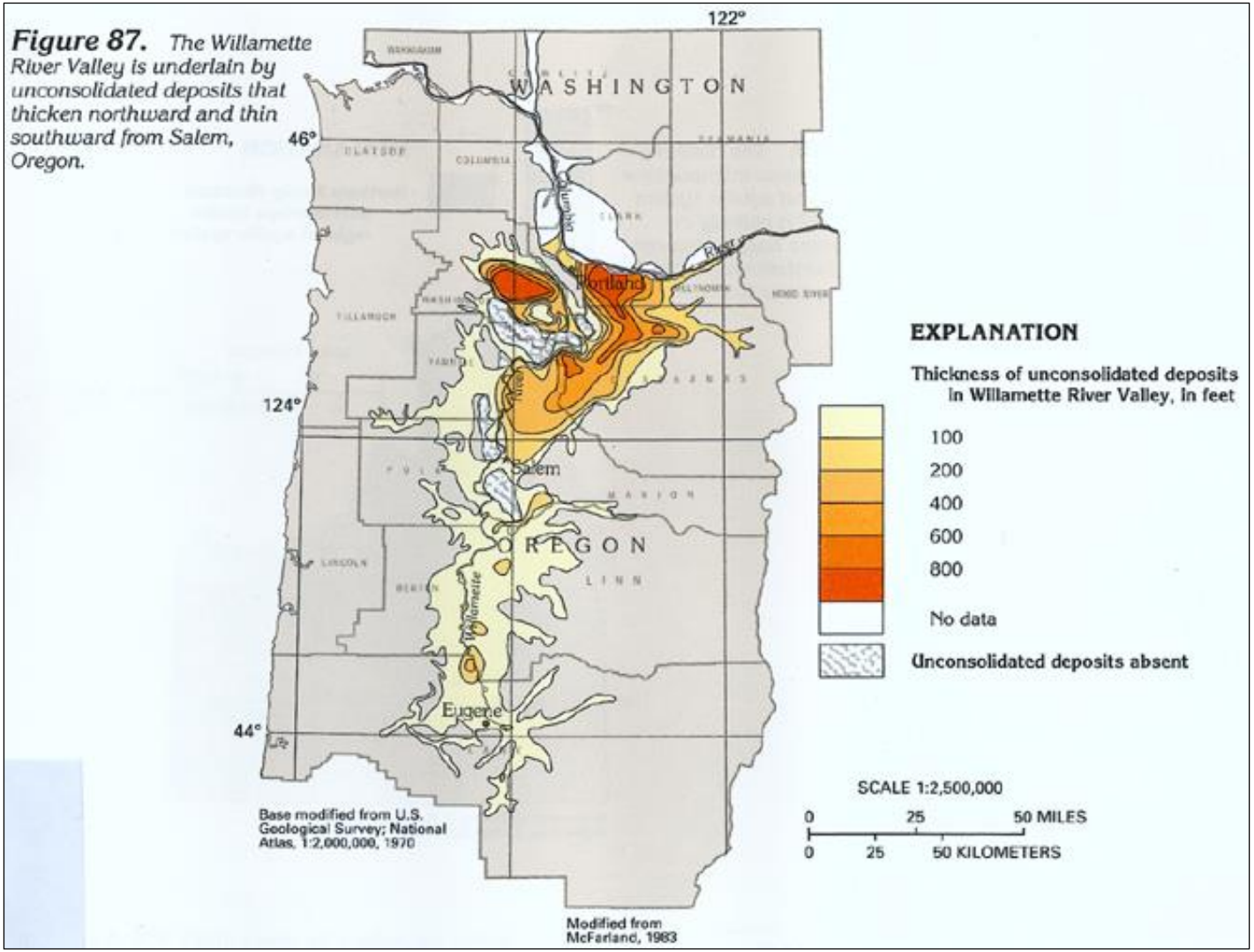


Figure 87. *The Willamette River Valley is underlain by unconsolidated deposits that thicken northward and thin southward from Salem, Oregon.*

Middle and Southern portions of the Puget-Willamette Trough

Lewis and Cowlitz Counties of Washington

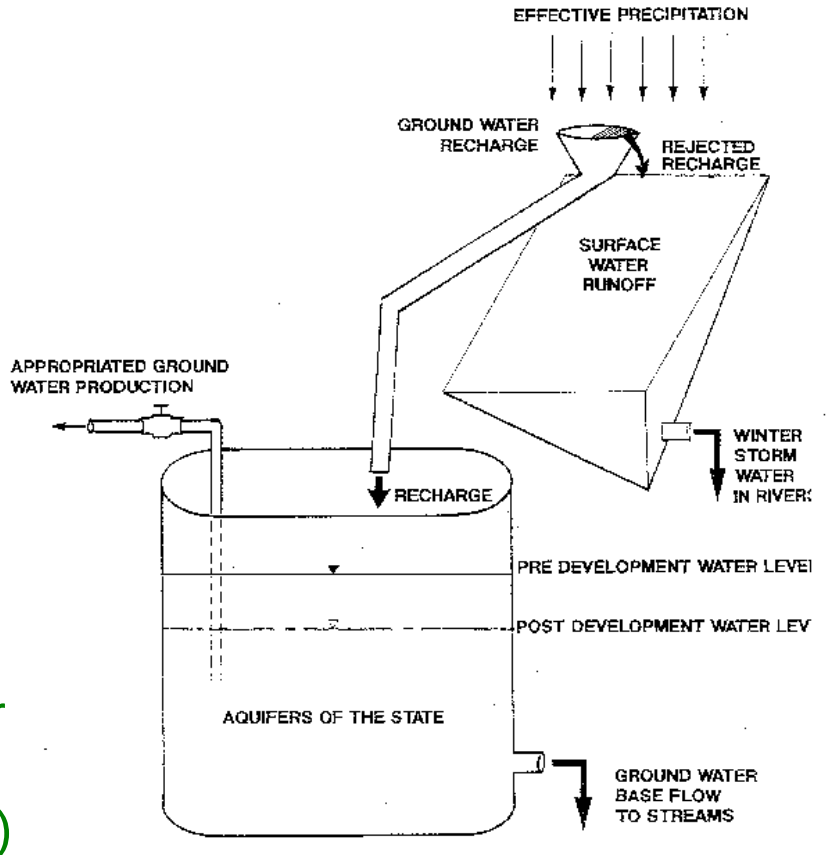
- Generally lower production wells
- Thinner sediments
- Lower permeability, more clay-rich sediments
- Some very old glacial deposits (Logan Hill Fm.)

Willamette Basin south of Portland

- More river related depositional environments
- Bretz Floods resulted in lake deposits (and some ice-rafted erratics)

Portland Basin hydrology

- Locally high storage capacity
- complex inflow patterns
- Several regional (sub-regional) aquifers
- Discharge predominantly to Columbia River above where basalts close the basin
- High capacity wells - for the west side of the Cascades (1,000+ gpm)



Regulatory discussion

- Water rights needed for all but exempt uses (15,000 gpd OR; 5,000 gpd WA)
- State-line allocation issues handled by special agreements
- Water rights written for specific aquifer zones

(I NEED YOUR INPUT HERE)

Discussion of the Willamette Trough sediments

Geographic vs. conceptual settings

- The Snake River Plain, Columbia River Basalt, and Puget Sound-Willamette Trough are related to the geology of a specific geographic area

- The remaining components are better considered as geologic/hydrologic concepts that apply to settings throughout the PNW

Unconsolidated valley-fill aquifers

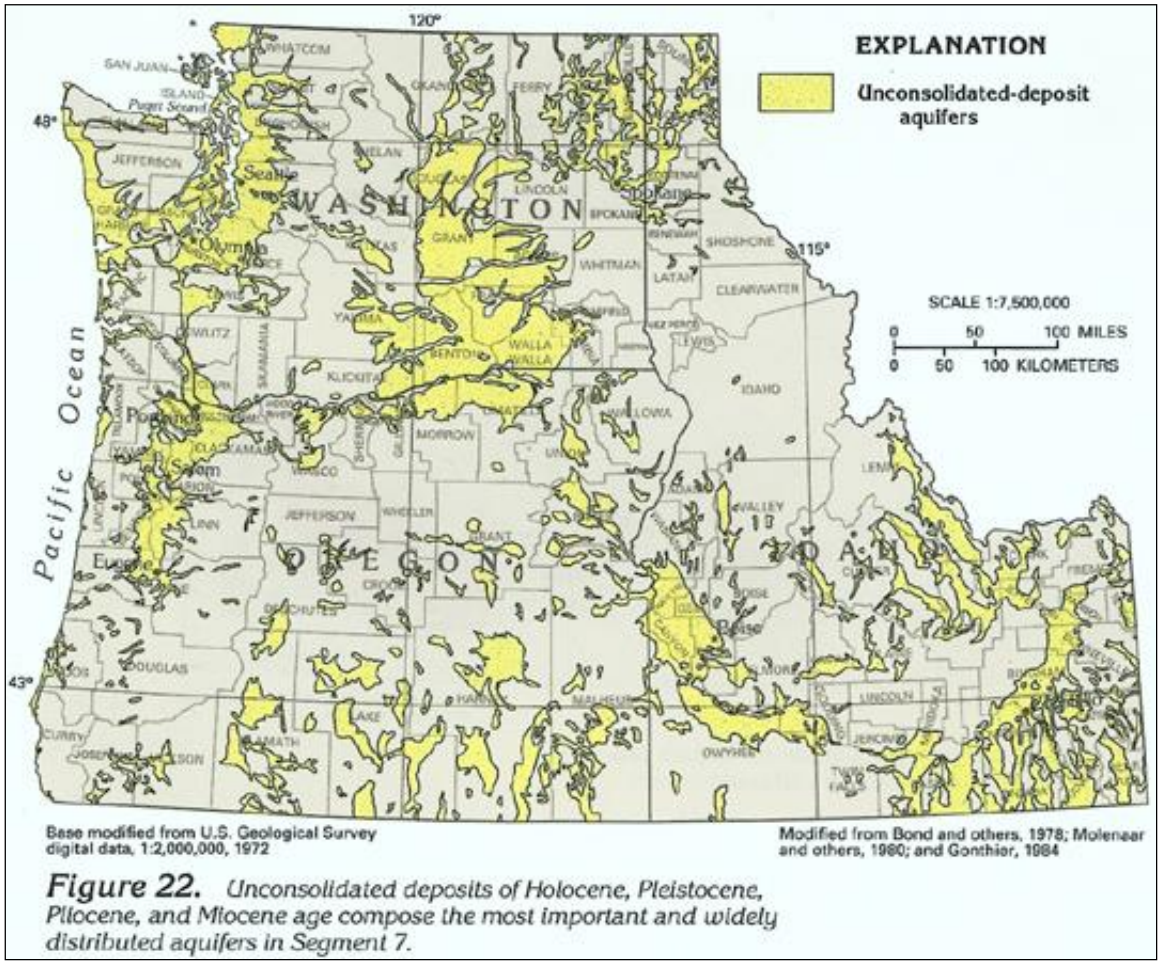


Figure 22. *Unconsolidated deposits of Holocene, Pleistocene, Pliocene, and Miocene age compose the most important and widely distributed aquifers in Segment 7.*

Unconsolidated valley-fill aquifers (continued)

- These aquifers are generally long and narrow features with layers of channel gravel and layers of overbank silt and fine sand
- Often valleys are temporarily dammed and clay can be deposited
- Some valleys are glaciated (till, morainal deposits), some have mudflows
- All are laterally variable in geology and hydrology
- Shallow drilling – generally, the bigger the valley, the deeper the sediment fill

Unconsolidated sediments

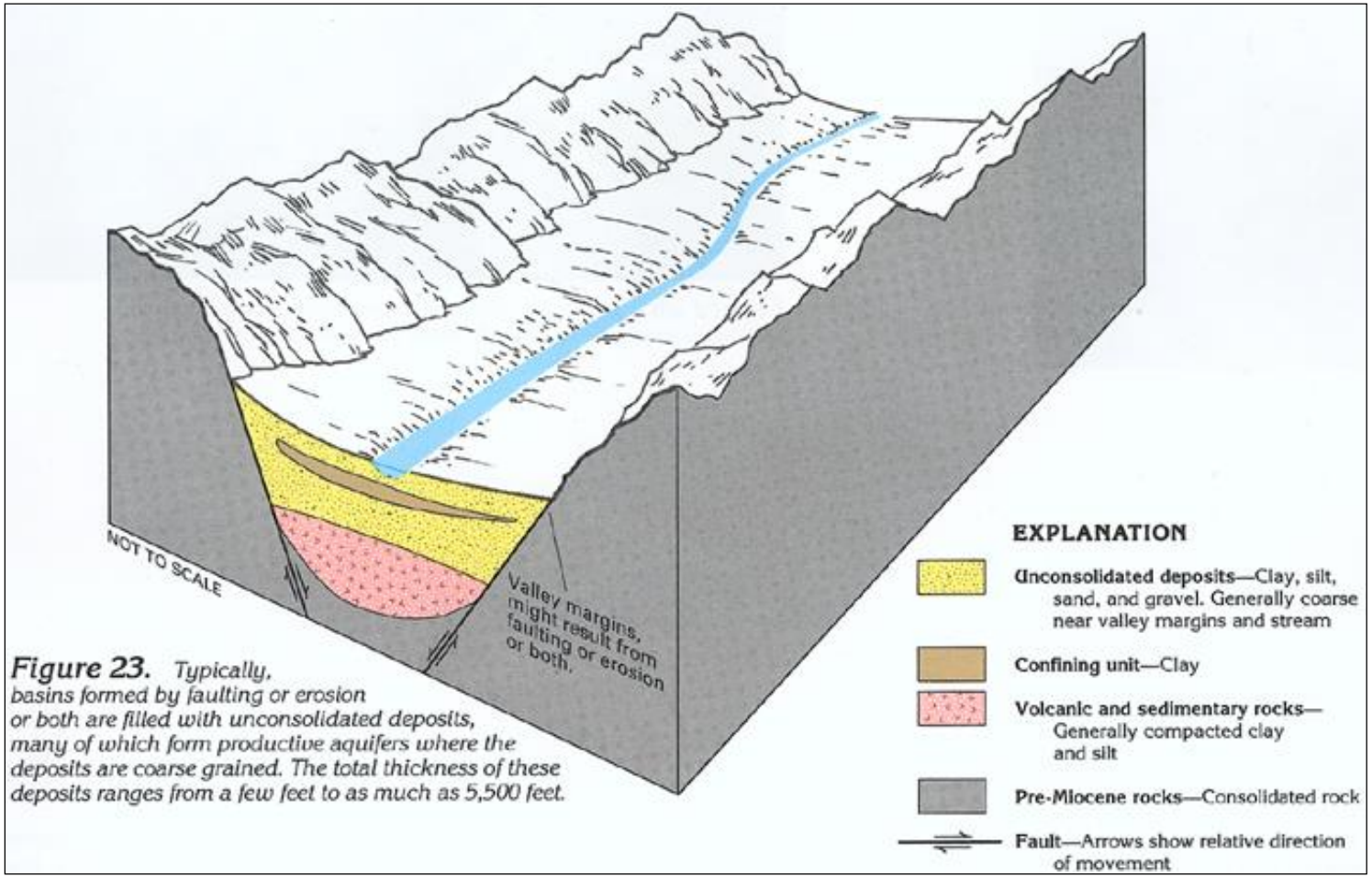
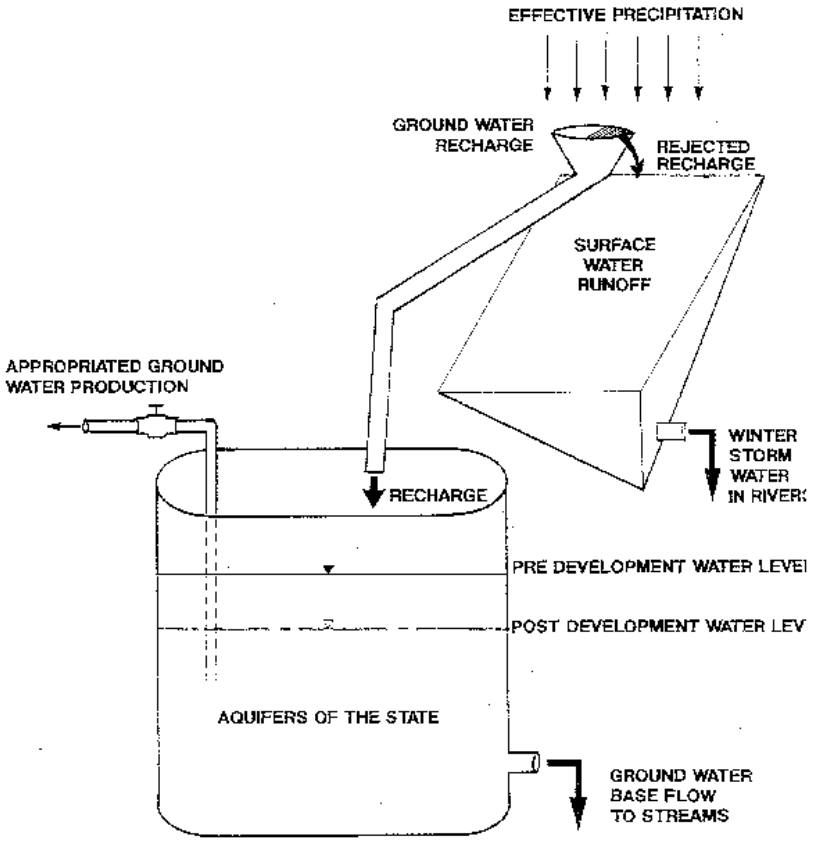


Figure 23. *Typically, basins formed by faulting or erosion or both are filled with unconsolidated deposits, many of which form productive aquifers where the deposits are coarse grained. The total thickness of these deposits ranges from a few feet to as much as 5,500 feet.*

River valley aquifer hydrology

- Storage highly variable (but these aquifers do not usually dewater)
- Recharge and surface water continuity provide inflow
- Local discharge almost always to the surface water system (sometimes a long way downstream)
- Withdrawal from wells generally will influence streams in some way



Regulatory discussion

- The interconnection of groundwater and surface water dominates concerns
- Where instream flows are set, mitigation virtually always required for water rights
- Even exempt wells are being limited in some places due to stream concerns
- Well construction in flood plains or flood ways may have specific sealing needs
- Valley aquifers are often regional discharge points – base flow to the stream

Open discussion on valley-fill aquifers

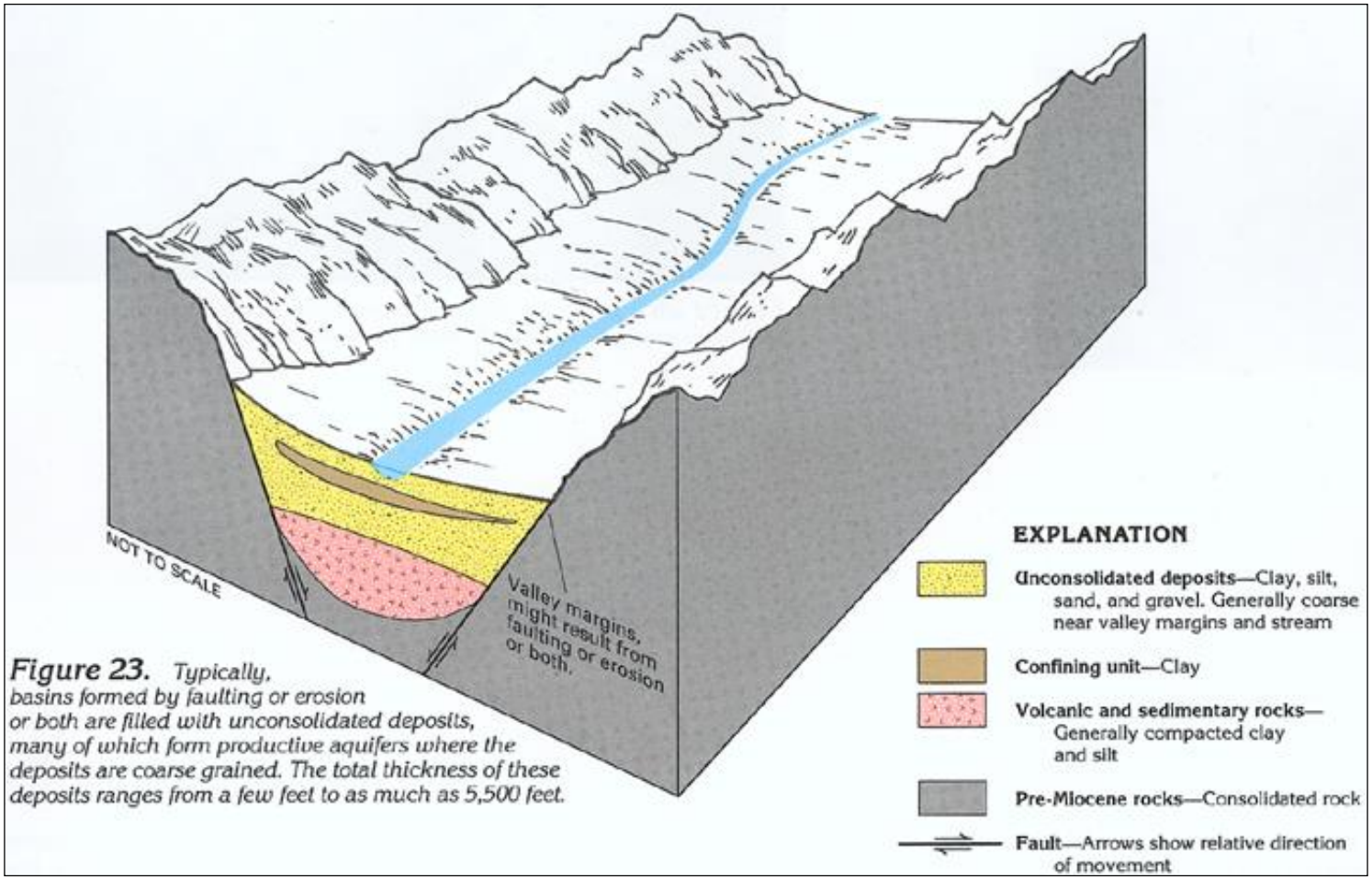


Figure 23. *Typically, basins formed by faulting or erosion or both are filled with unconsolidated deposits, many of which form productive aquifers where the deposits are coarse grained. The total thickness of these deposits ranges from a few feet to as much as 5,500 feet.*

Basin-fill sediments
(alluvial fans, lake sediments, etc.)

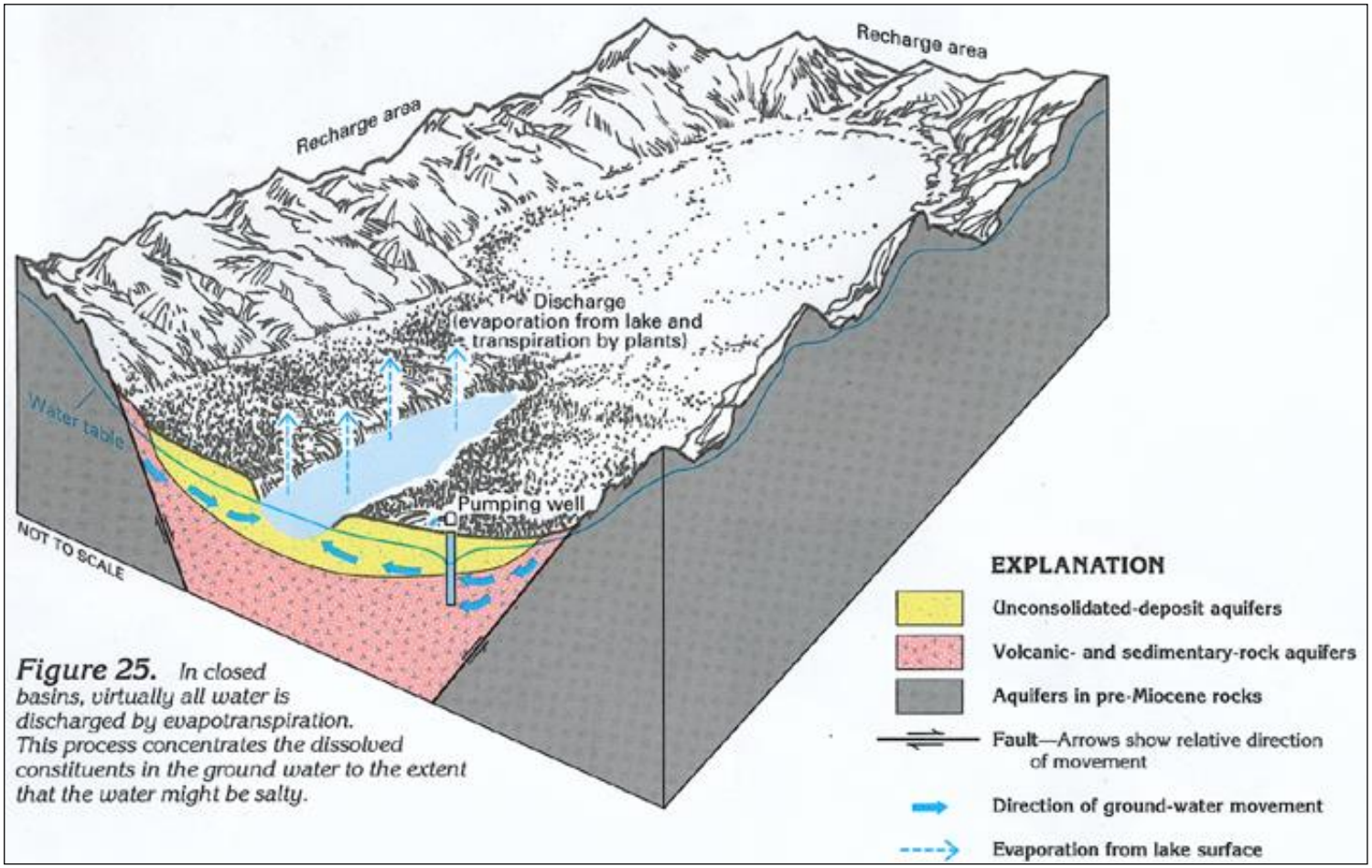
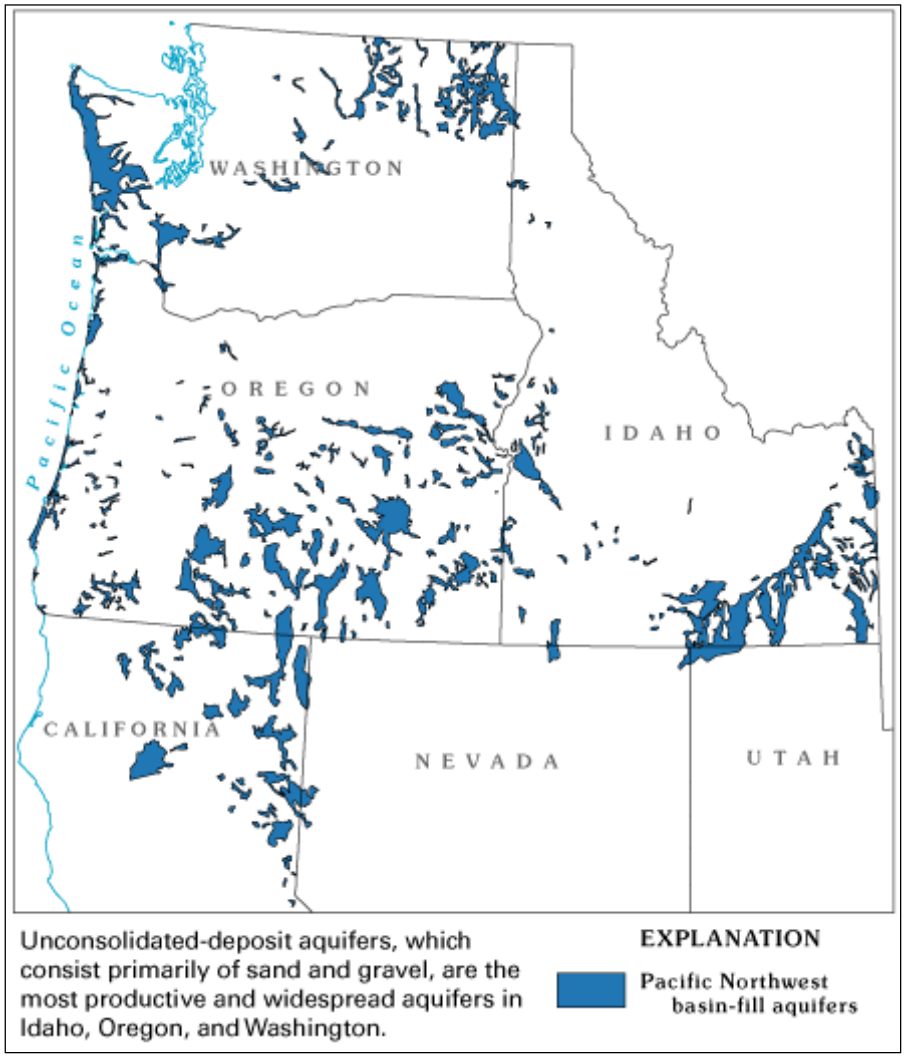


Figure 25. *In closed basins, virtually all water is discharged by evapotranspiration. This process concentrates the dissolved constituents in the ground water to the extent that the water might be salty.*

Sediment-filled basins of the Pacific Northwest



Sediment-filled basins over basalt aquifers

- Many basins in the Columbia Plateau and Snake Plain Regions
- Sediments usually hundreds of feet thick
- Unconsolidated to semi-consolidated materials
- Generally quite old

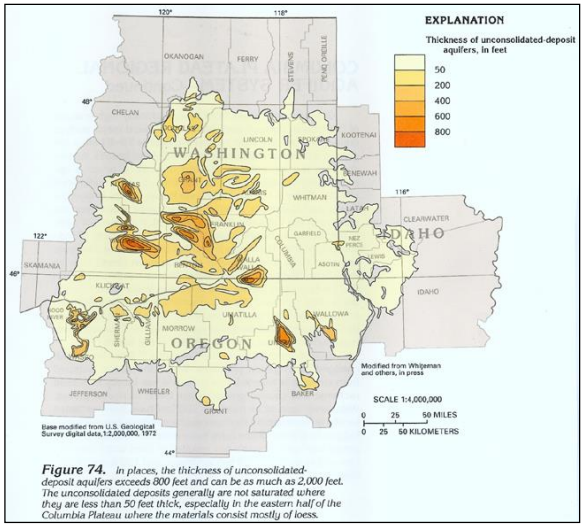


Figure 74. *In places, the thickness of unconsolidated-deposit aquifers exceeds 800 feet and can be as much as 2,000 feet. The unconsolidated deposits generally are not saturated where they are less than 50 feet thick, especially in the eastern half of the Columbia Plateau where the materials consist mostly of loess.*

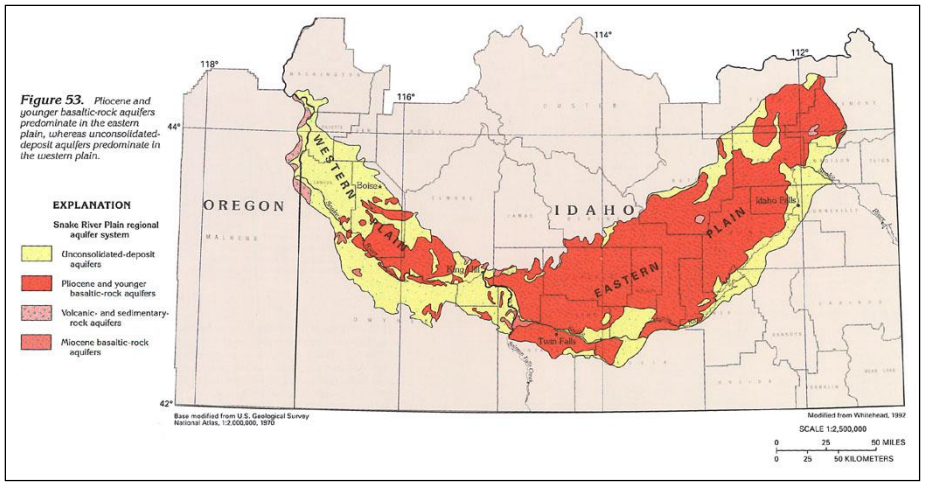


Figure 53. *Pliocene and younger basaltic-rock aquifers predominate in the eastern plain, whereas unconsolidated-deposit aquifers predominate in the western plain.*

Basin-fill aquifers

- These features reflect the washing of sediments into a bowl
- Alluvial fan deposits around the edge
- Lake sediments toward the center
- Evaporite deposits in larger basins under desert conditions

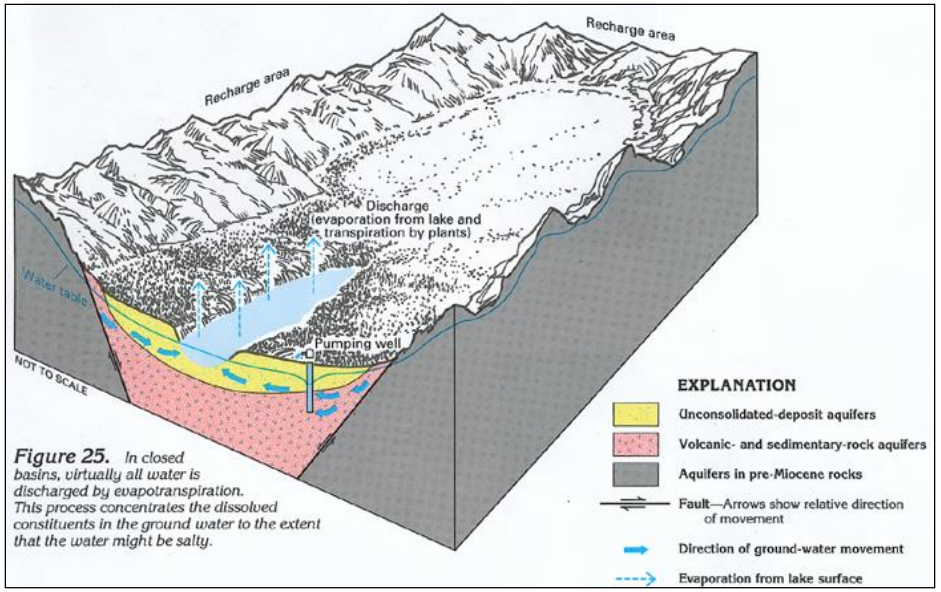
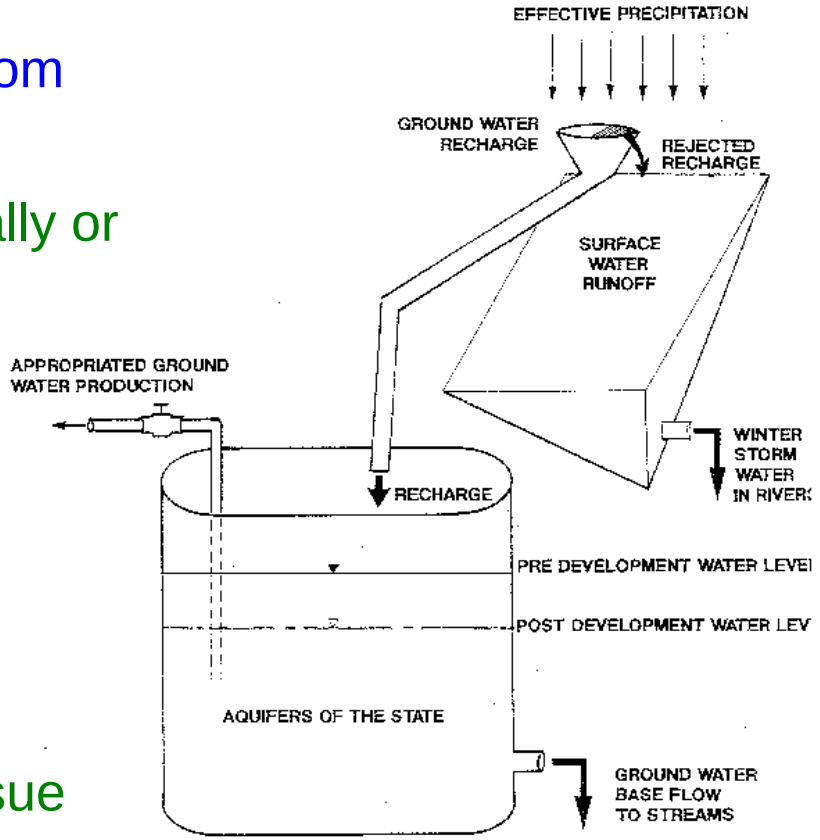


Figure 25. *In closed basins, virtually all water is discharged by evapotranspiration. This process concentrates the dissolved constituents in the ground water to the extent that the water might be salty.*

- The material is generally from the uplands that surround them – glacial deposits and volcanic ash also in some basins

Basin-fill aquifer hydrology

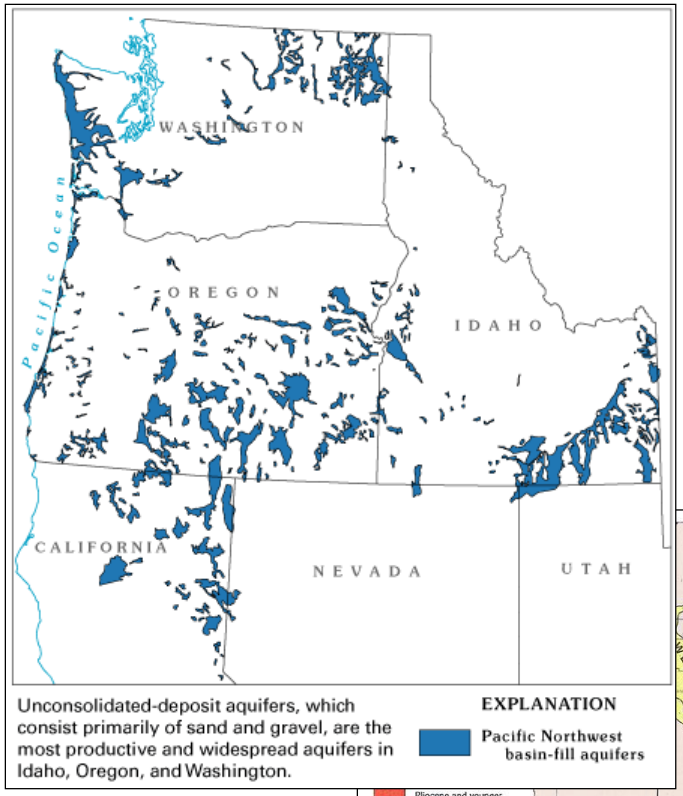
- Some basins are actually a “tank”
- Water sheds into them from surrounding mountains
- Some water leaks vertically or laterally through the rock
- Much water is stored
- Well production varies
- Much water evaporates, creating salt flats and “soap” lakes
- Water quality often an issue



Regulatory discussion

- Water rights needed for non-exempt wells
- Closed basins might not be ESA issue so instream flows not always important
- More important to check water quality since some eastside basins are not suitable for DOH applications
- Since these are closed systems, over-allocation is a bigger problem (aquifer water levels may be declining – check)

Basin-fill aquifers discussion



Unconsolidated-deposit aquifers, which consist primarily of sand and gravel, are the most productive and widespread aquifers in Idaho, Oregon, and Washington.

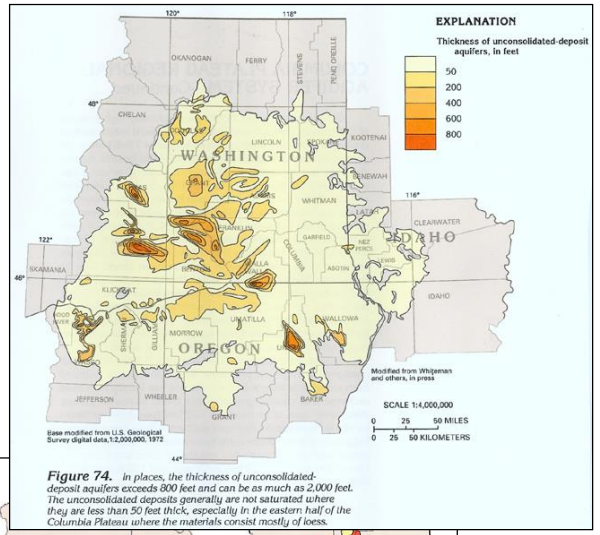
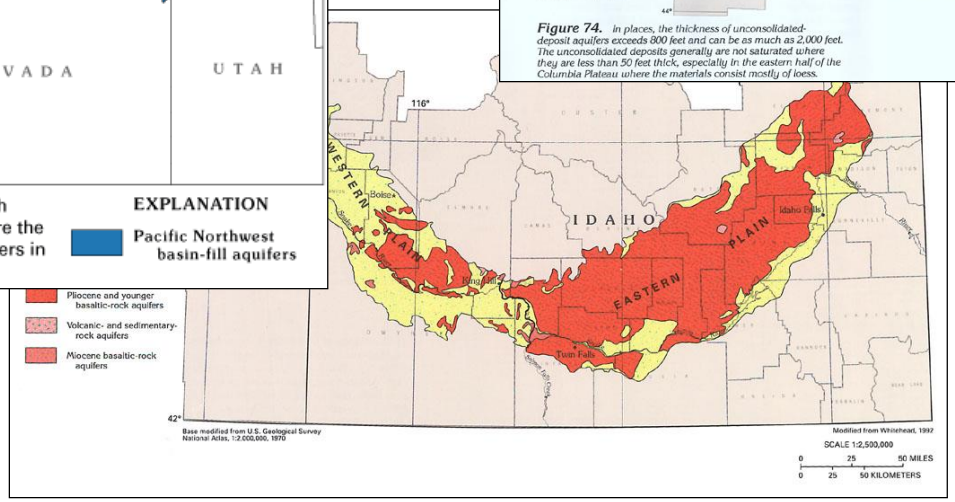


Figure 74. In places, the thickness of unconsolidated-deposit aquifers exceeds 800 feet and can be as much as 2,000 feet. The unconsolidated deposits generally are not saturated where they are less than 50 feet thick, especially in the eastern half of the Columbia Plateau where the materials consist mostly of loess.



Fractured rock aquifers

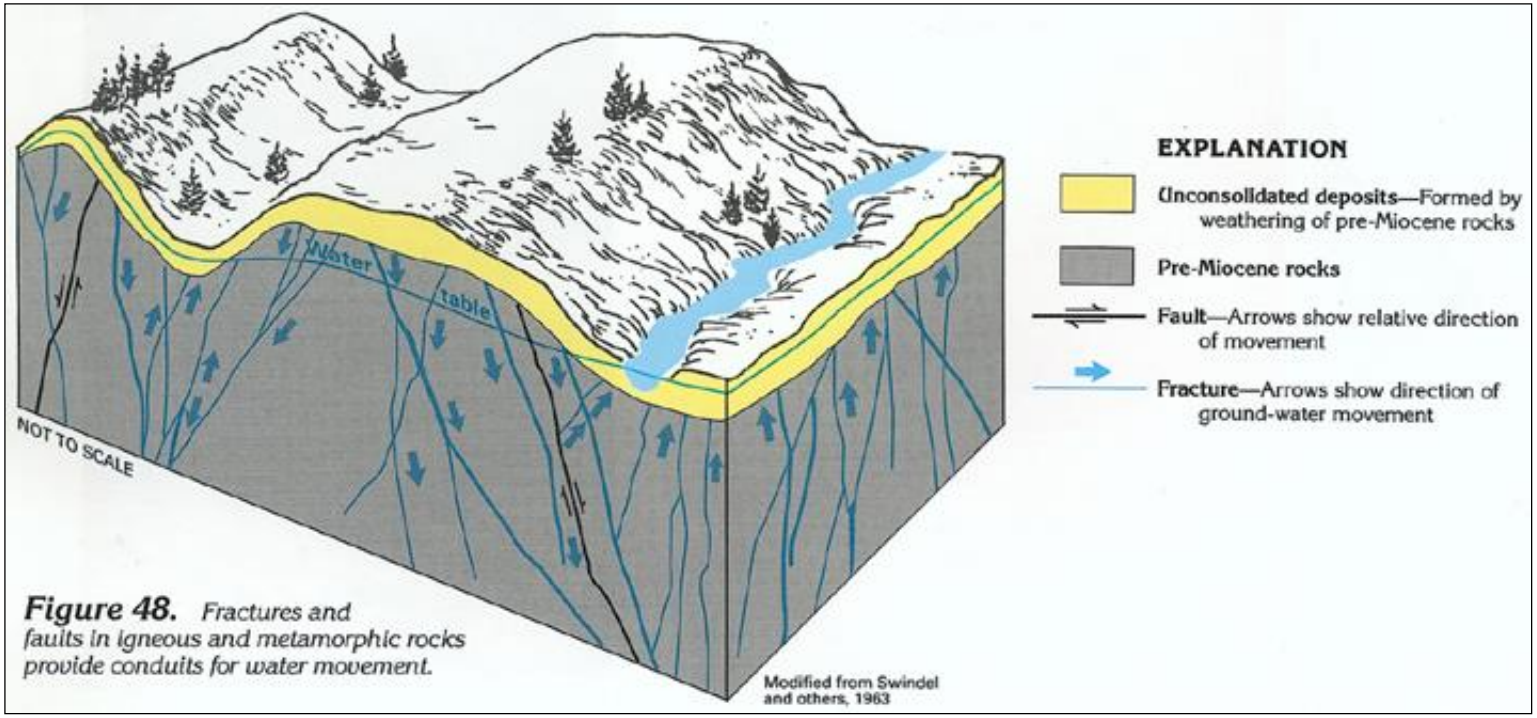


Figure 48. *Fractures and faults in igneous and metamorphic rocks provide conduits for water movement.*

Fractured-rock environments

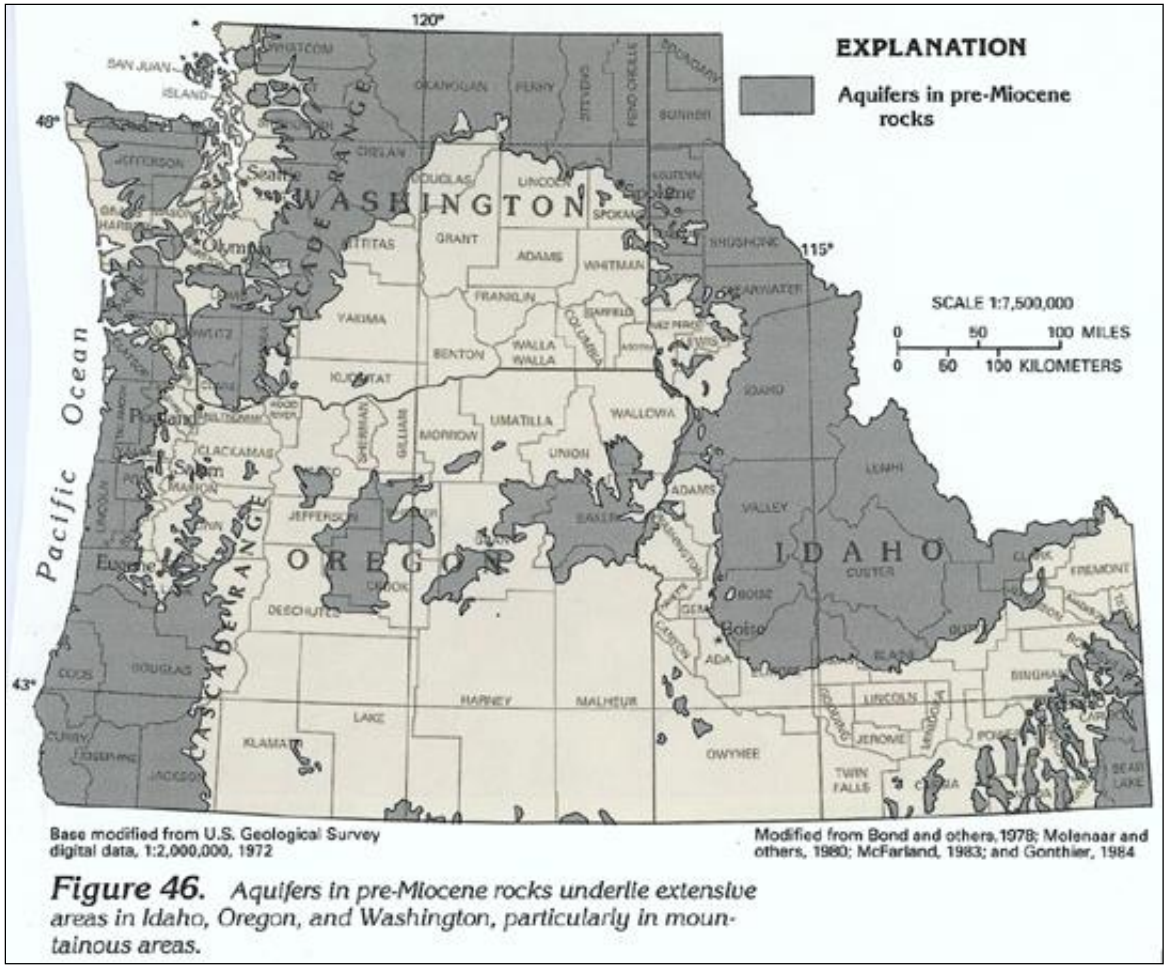


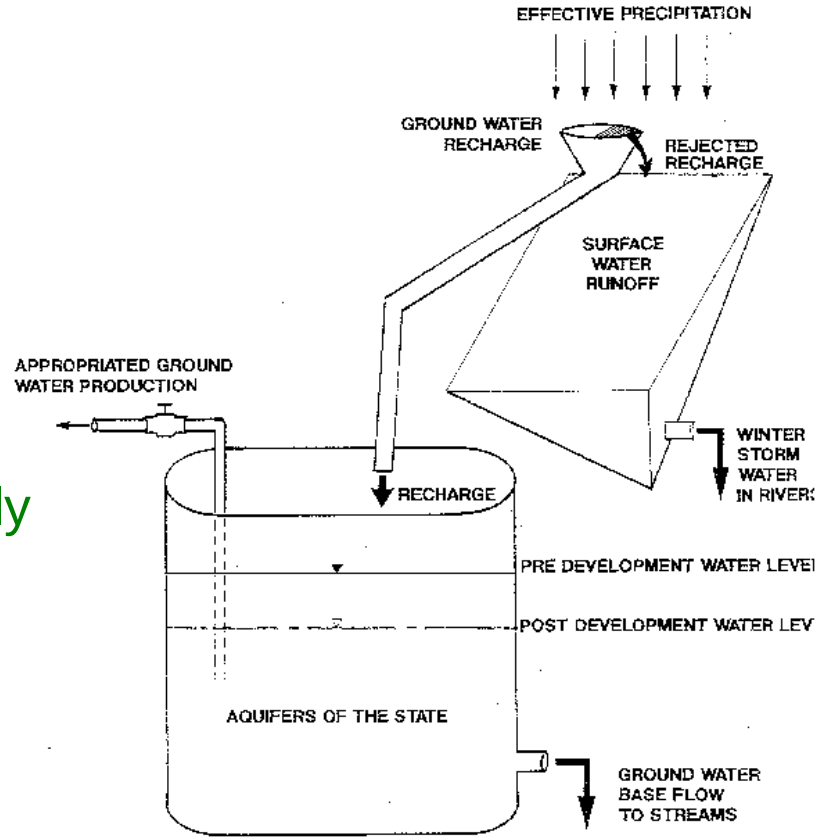
Figure 46. *Aquifers in pre-Miocene rocks underlie extensive areas in Idaho, Oregon, and Washington, particularly in mountainous areas.*

Fractured-rock environments

- This section is about the rock “aquifers” outside of the basalt regions
- Mountains have hard rock with only secondary permeability
- Some sedimentary rock found with primary permeability – but not much
- It is mostly about fractures

Fractured rock aquifer hydrology

- Structure is more like a radiator than a tank
- Fractures have very little storage
- Amount of interconnection of fractures varies – usually quite low
- Recharge typically limited
- Usually low flow and local systems



Fractured rock wells lie to you

- The instantaneous production is often higher than the aquifer will support long-term
- Fractures can be local features – no storage to back them up
- Because of low storage, seasonal variability of water levels can be high
- Recognizing the best place to complete or how much to drill is an art form – trust those that know the area

- The fractured-rock setting is really tricky and very deceiving – **test carefully**

Regulatory discussion

- Typical water right issues are present, but fracture patterns can strongly influence impairment
- Impacts to instream flows and springs are more likely
- County and DOH concerns regarding source reliability more likely – test data more critical
- Generally, the surface seal must go into the rock

Open discussion on fractured-rock aquifers

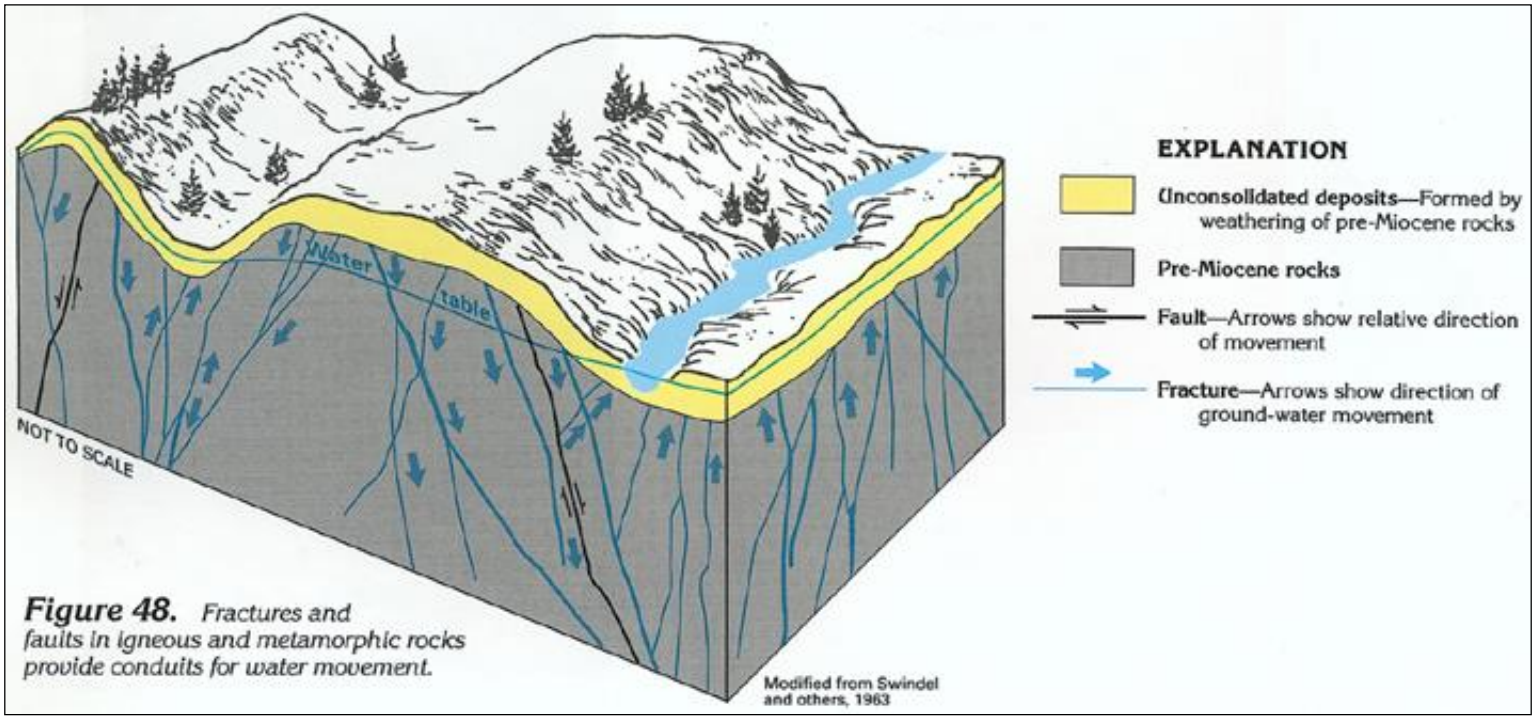
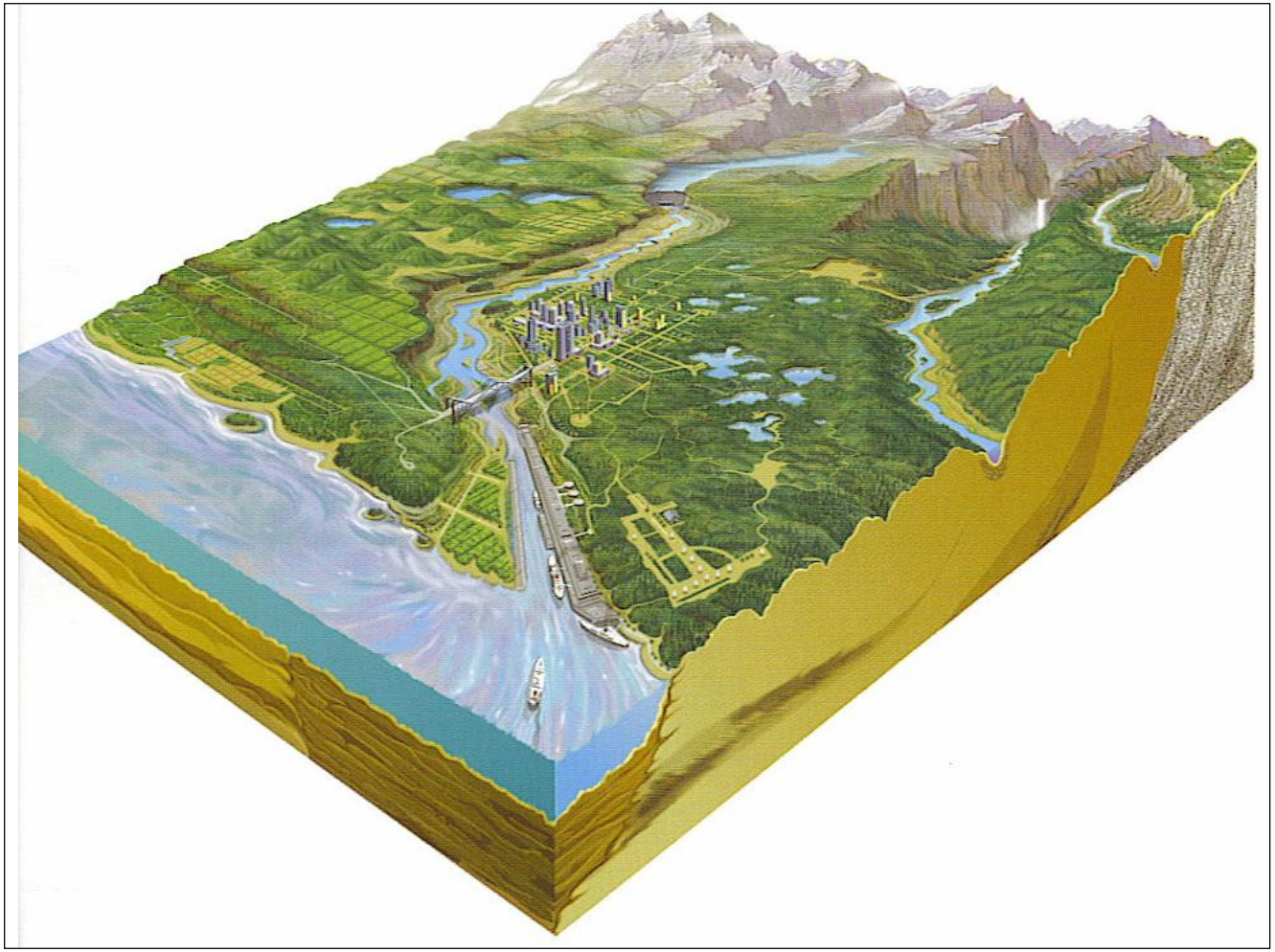


Figure 48. *Fractures and faults in igneous and metamorphic rocks provide conduits for water movement.*

Coastal unconsolidated sediments



Coastal aquifer systems

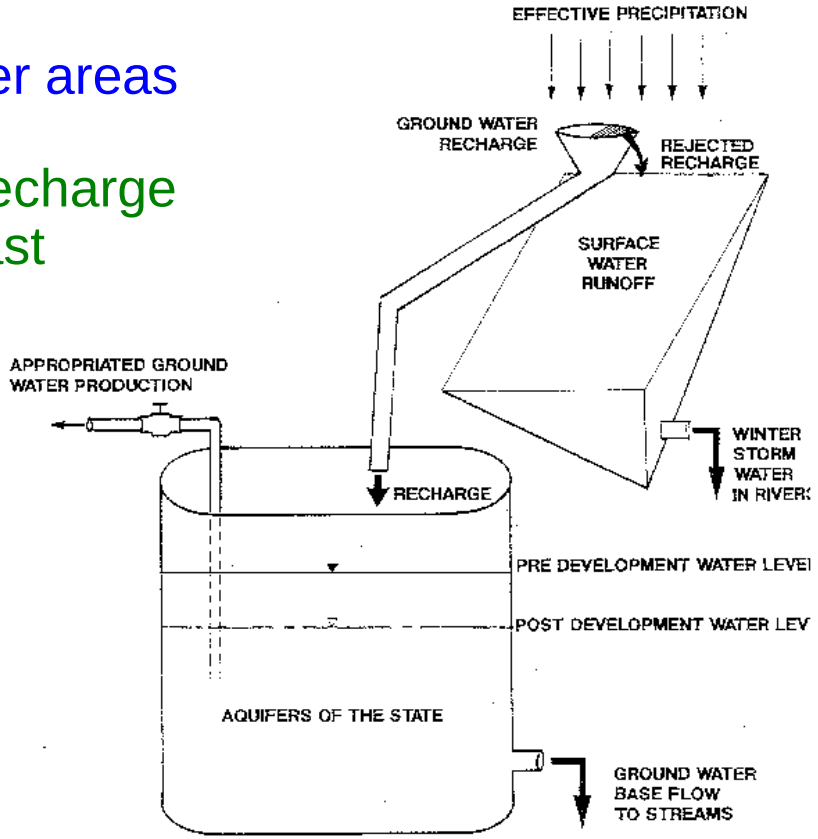
- Coastal aquifers are usually thin and often sand-dominated – Puget Sound region is different
- Sediments can be thicker and more productive near estuaries
- Aquifers discharge directly to the sea

Geologic discussion

- Flat beaches typically dominated by sand deposits
- Steeper coastlines get gravel and even landslide deposits
- Where stream valleys are present, the valley-fill processes still dominate
- Fractured rock coastal aquifers are even more dangerous – fractures can be pipes to the sea
- The coast has only been the coast in recent time, sea level was 300 feet (or more) lower 12,000 years ago – the coast was miles farther west

Hydrology of coastal aquifers

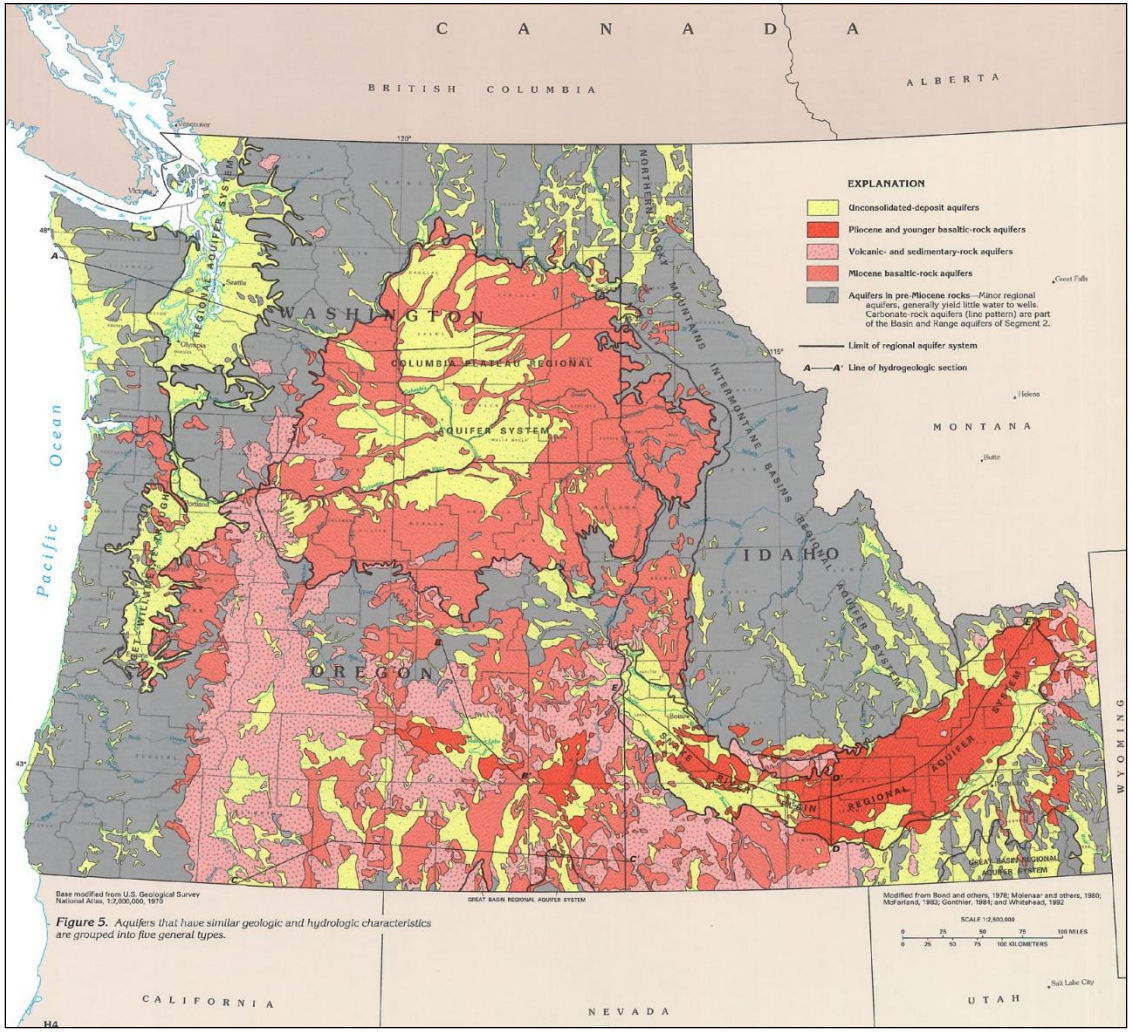
- Generally moderate storage
- Direct recharge over smaller areas
- Typically a component of recharge is from mountains to the east
- Discharge typically not focused but more uniform along the coast line
- Relatively small withdrawal from wells
- If you pump too much, the sea comes to you



Regulatory discussion

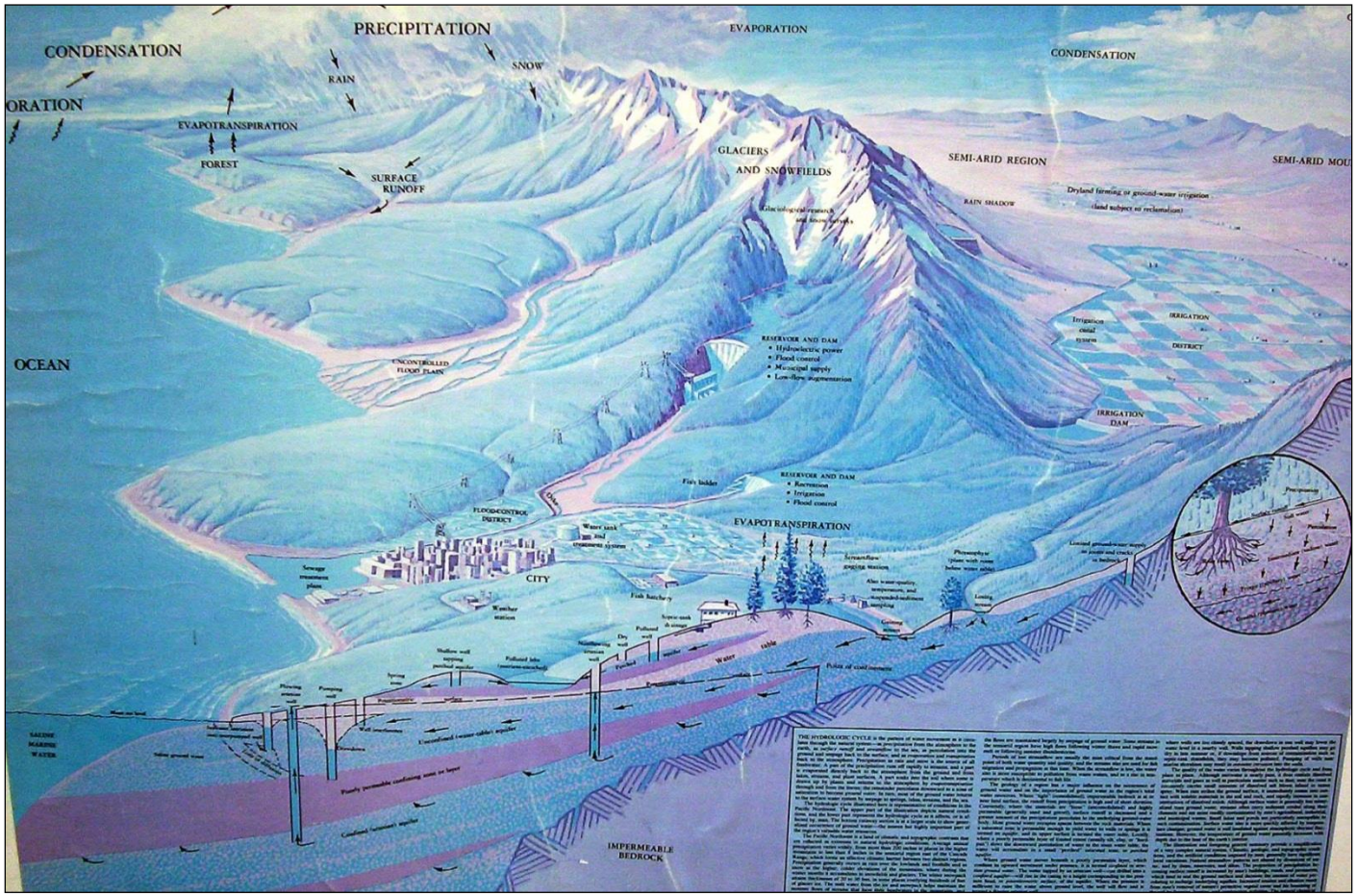
- The water right permit (often) has protocols a driller needs to follow
- Water rights usually require regular chloride testing – set the well up for it
- If sea-water intrusion is suspected in an area, drilling may be restricted
- Impairment of another water right can be water quality related also (you don't have salt water but the neighbor with the beach house does)
- Test water quality of a zone before completion

Hydrogeology of the Pacific Northwest



Questions? Something to add?

DIAGRAM BY: Dee Molinaar



Feel free to contact me: Mike Krautkramer

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