Hydrogeology Concepts and Considerations for RCW 90.94 Streamflow Restoration in WRIA 13

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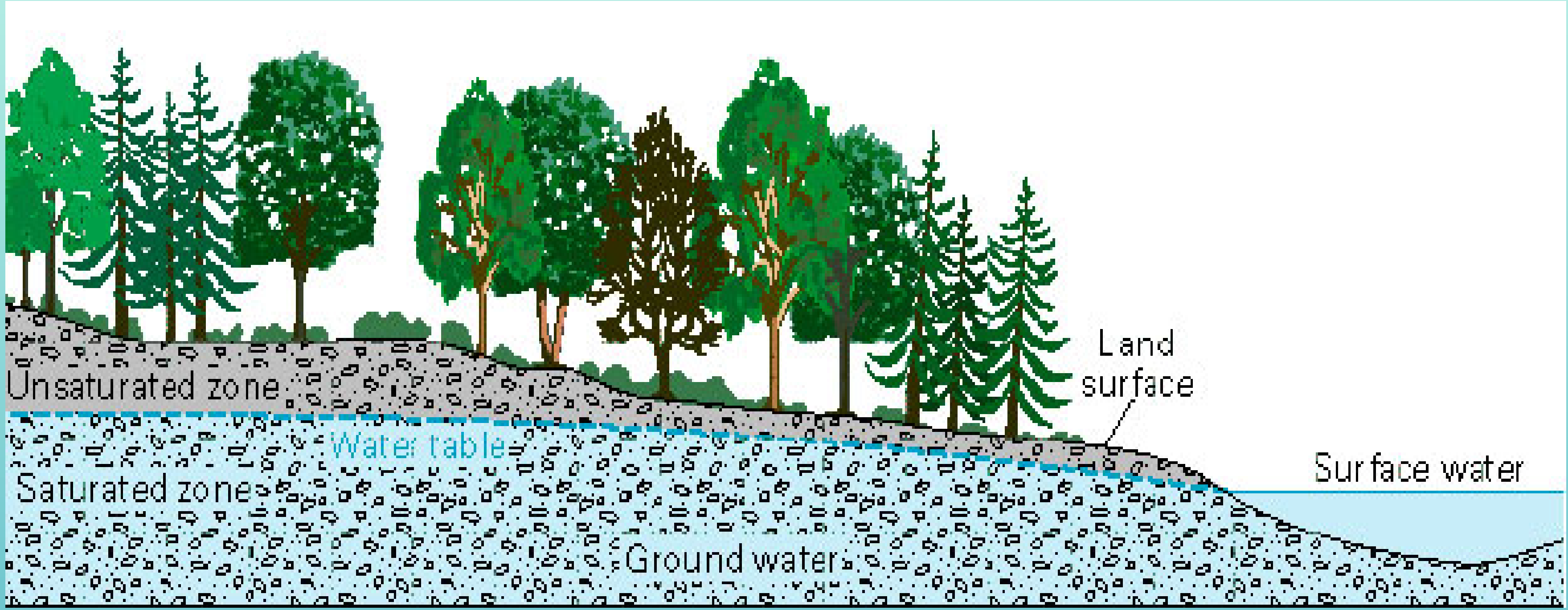
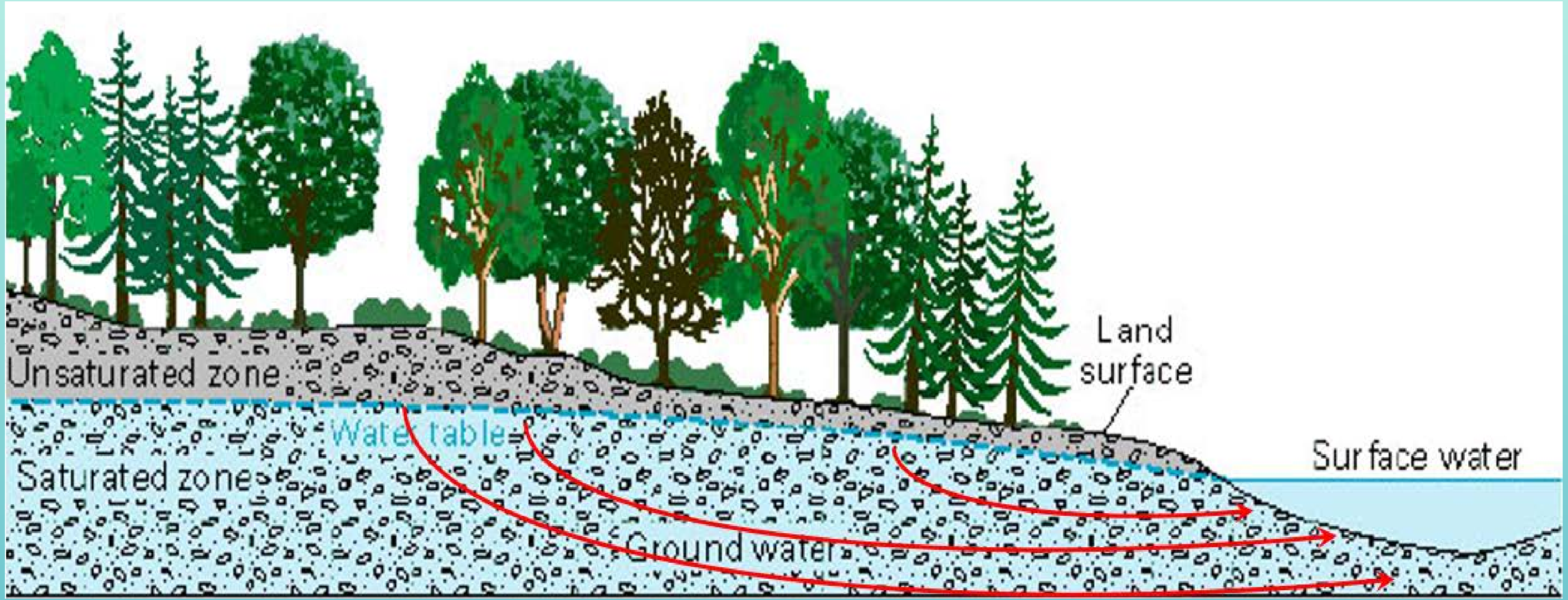
- All pore spaces (openings) below the water table are full of groundwater
- Tops of water tables generally mimic surface topography, and fluctuate seasonally and from year to year



USGS Water Science School

Under natural conditions, groundwater moves from areas of recharge to areas of discharge at springs or along streams, lakes, and wetlands



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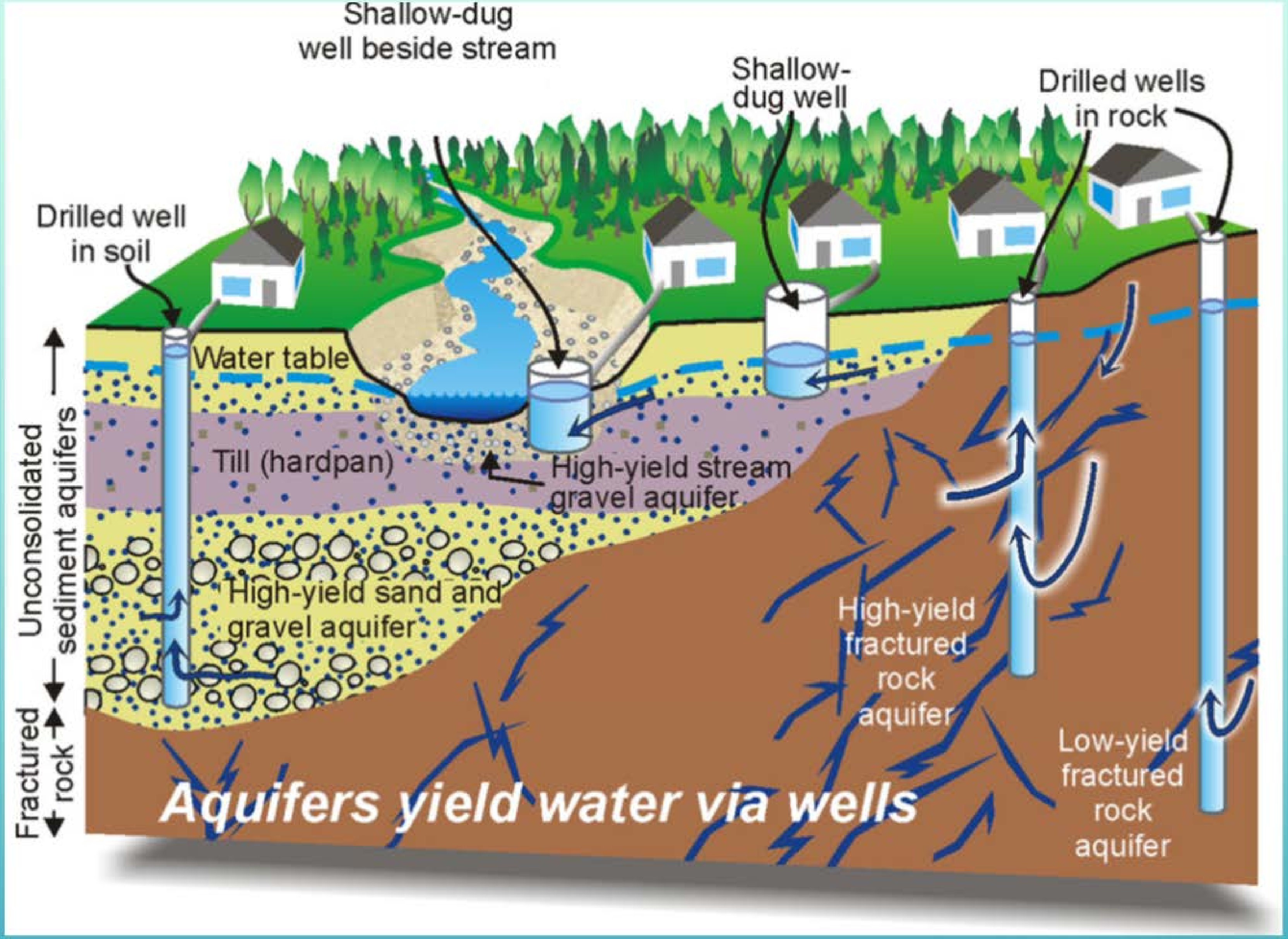
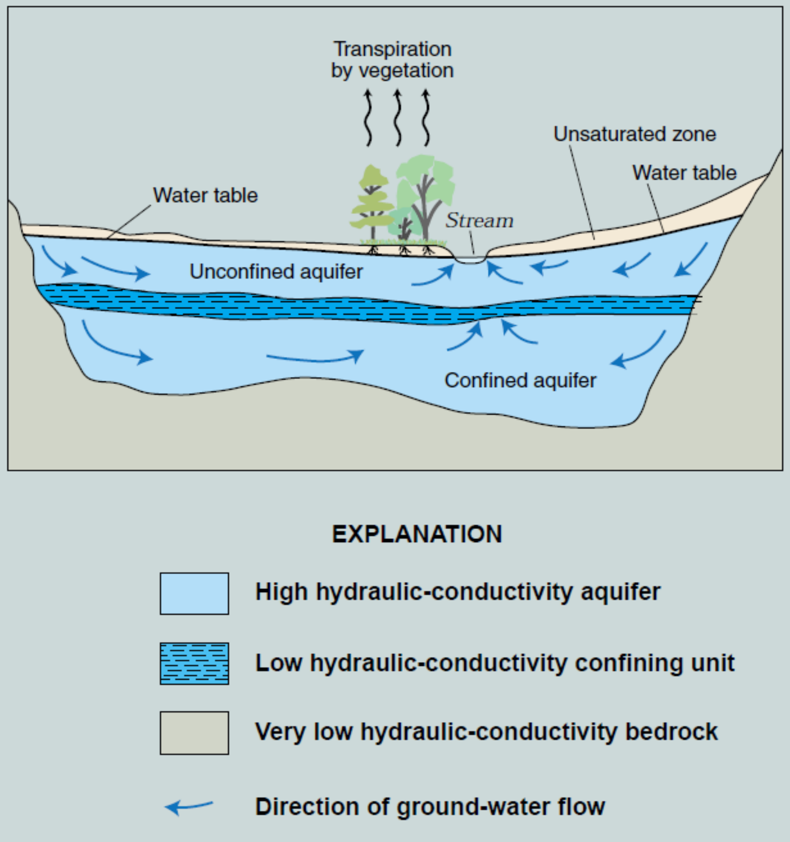
<u>Aquifer</u> -- saturated geologic material permeable enough to yield economical quantities of water

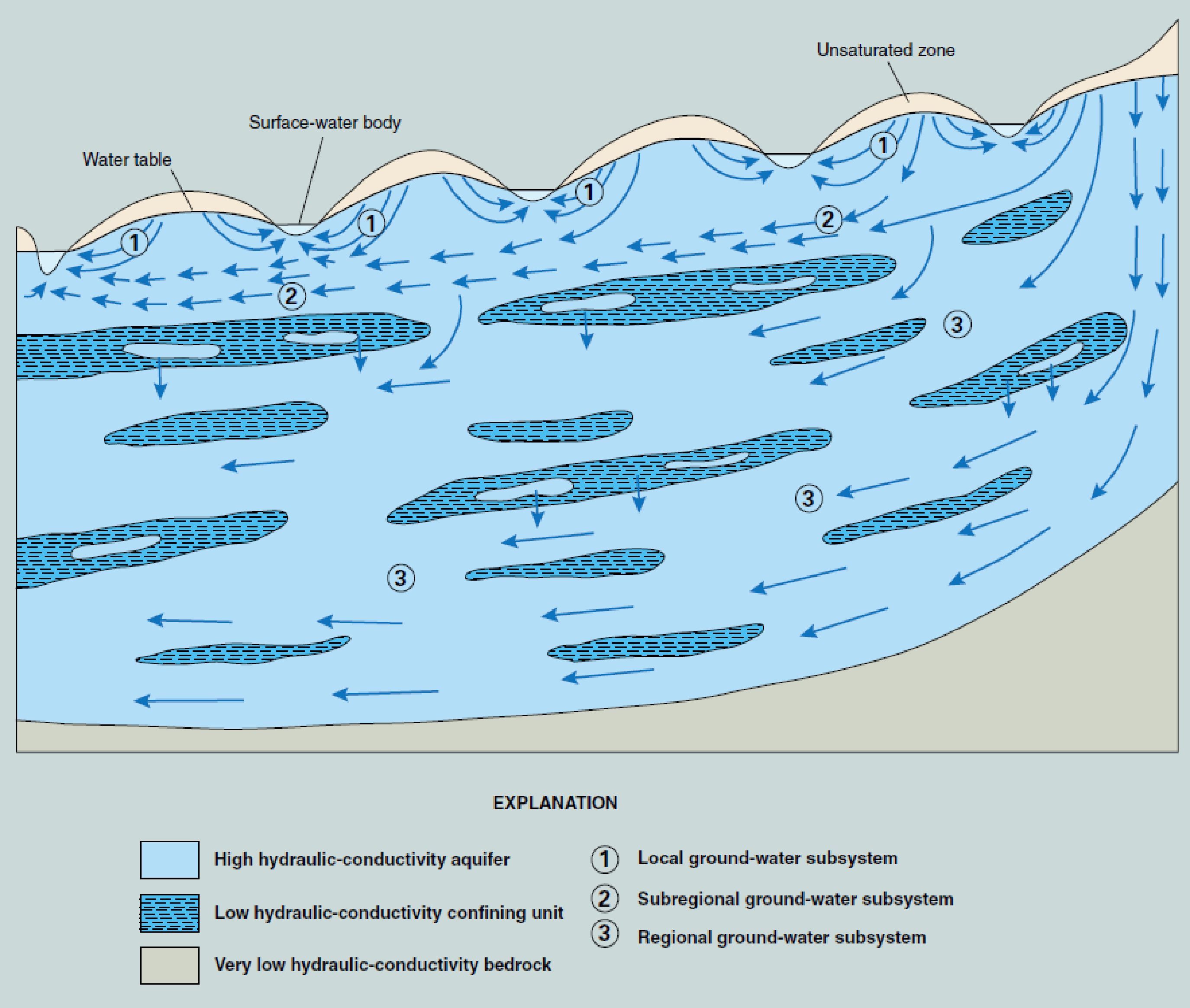
<u>Aquitard</u> -- saturated geologic material with low permeability; well yields low; also called "confining layer"

<u>Confined Aquifer</u> -- saturated material below aquitard permeable enough to transmit useful water quantities



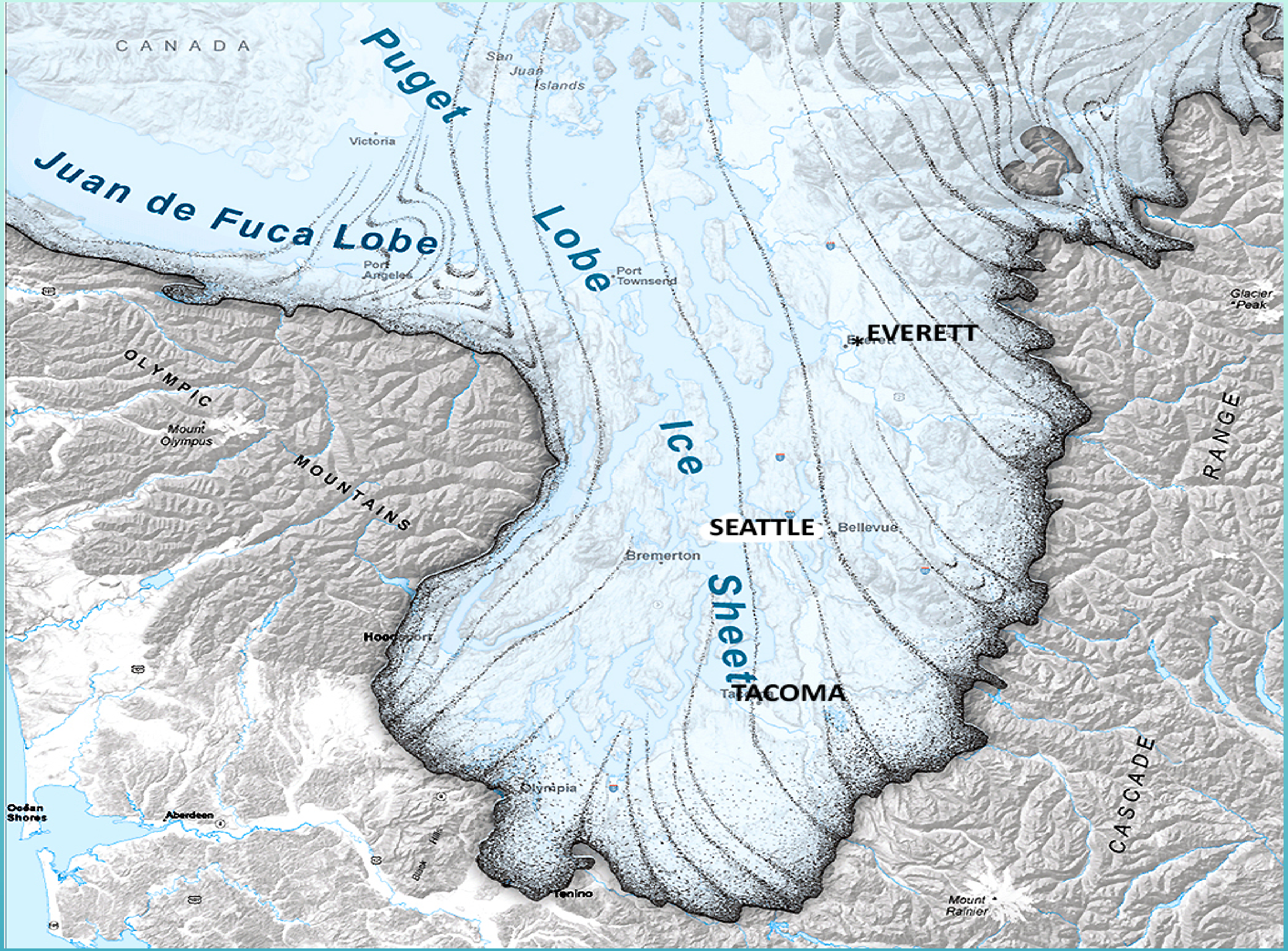
Canadian Geoscience Education Network
https://www.cgenarchive.org/bowen-island-underground.html





USGS Circular 1186

Vashon Glaciation lasted about 19,000 to 16,000 BP



Washington Department of Natural Resources

Pierce County Geology

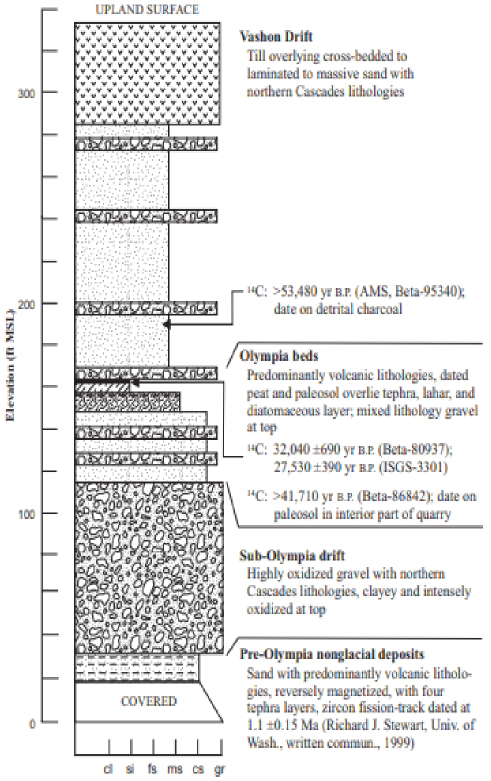
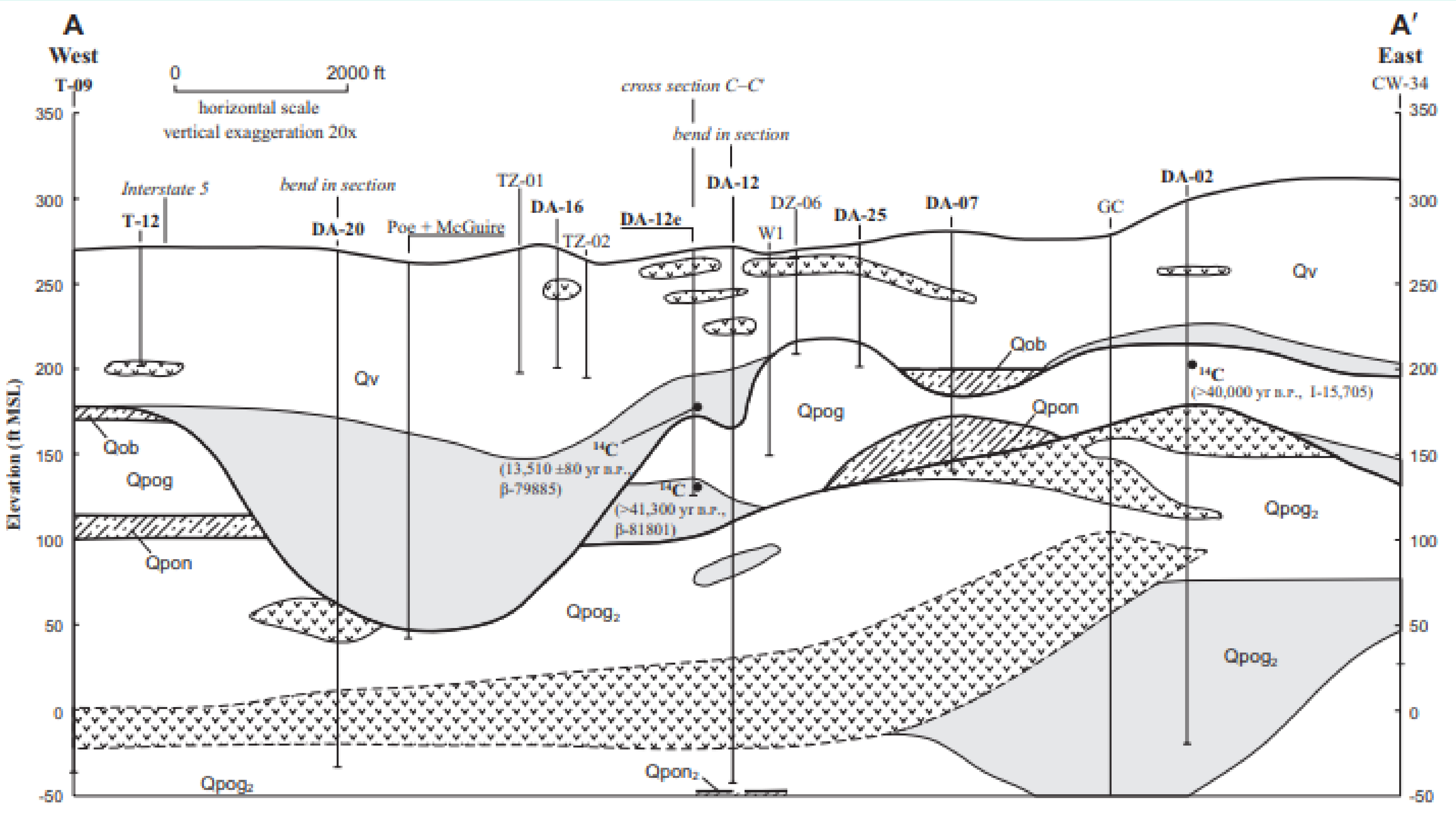
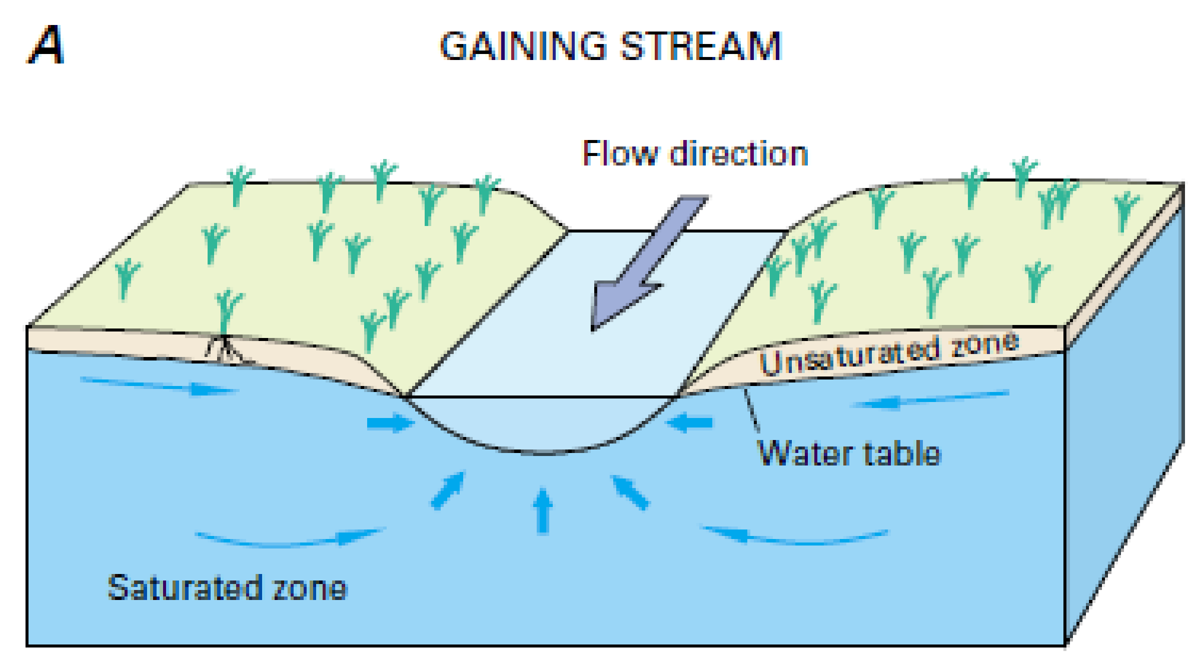


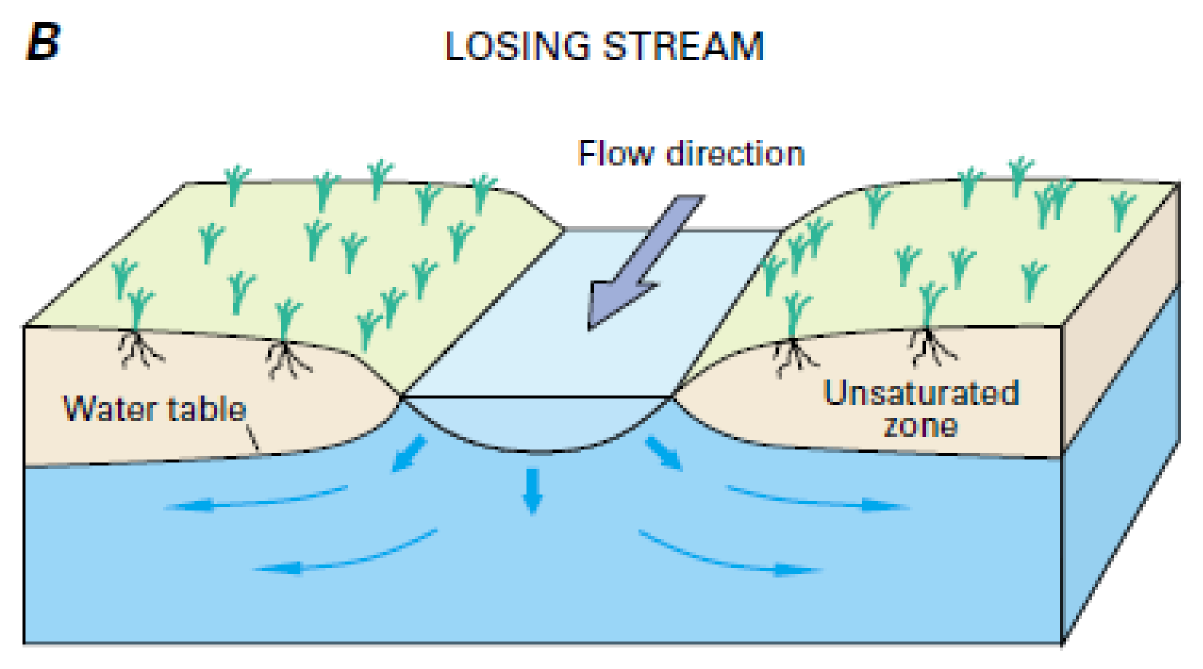
Figure 6. Woodworth quarry composite measured section, Poverty Bay 7.5-minute quadrangle, lat 47.2729 N, long 122.3728 W.



WA DNR Report of Investigations 33

Groundwater – Surface Water Relationships





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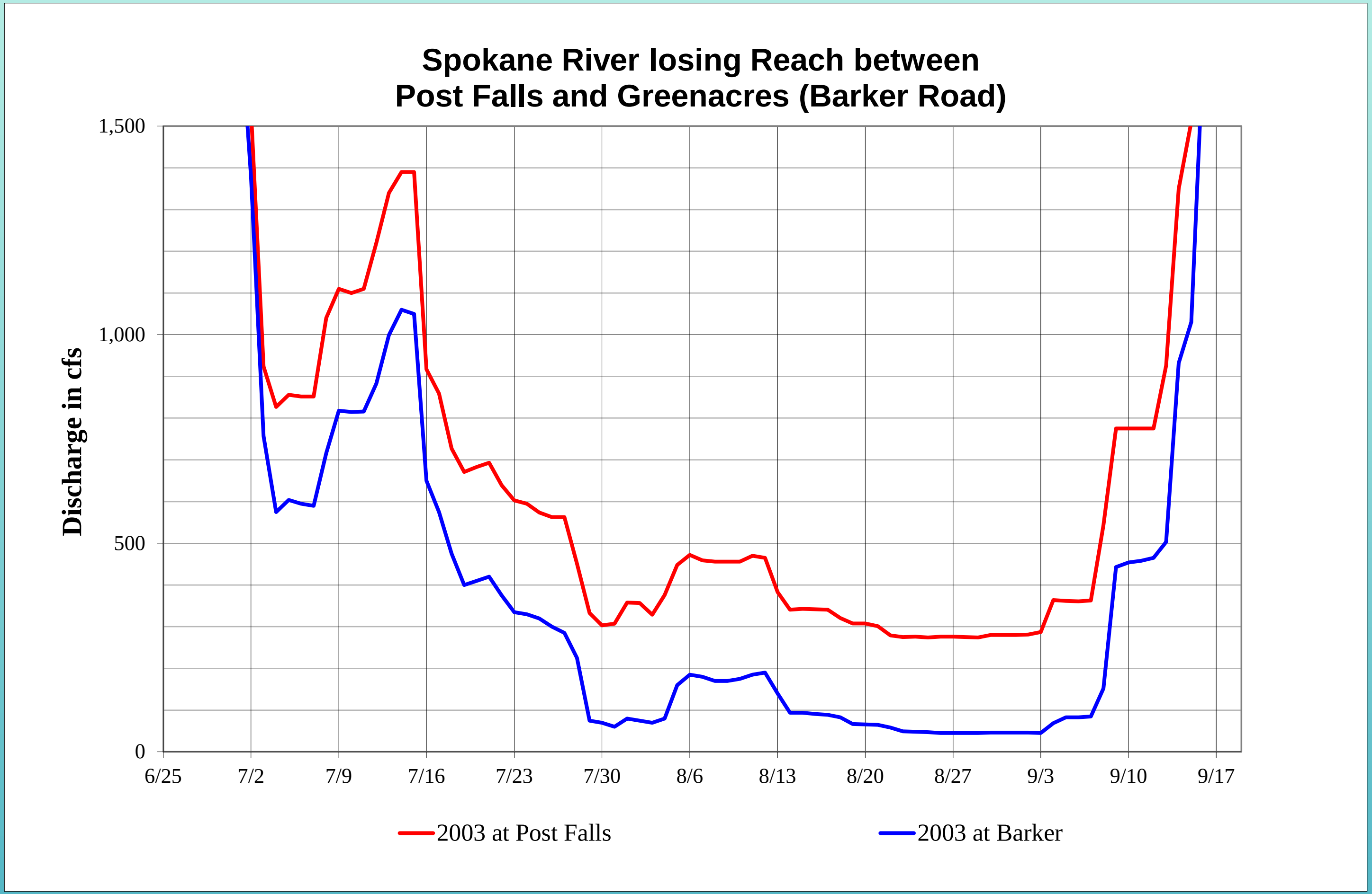
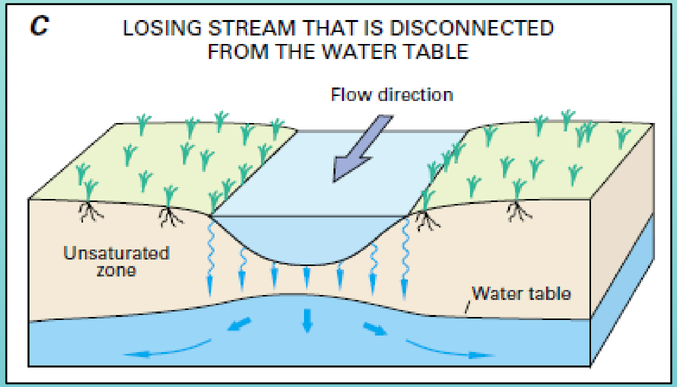
Spokane River is a losing reach…





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20 Hydrogeologic Framework and Groundwater/Surface-Water Interactions, South Fork Nooksack River Basin, Washington

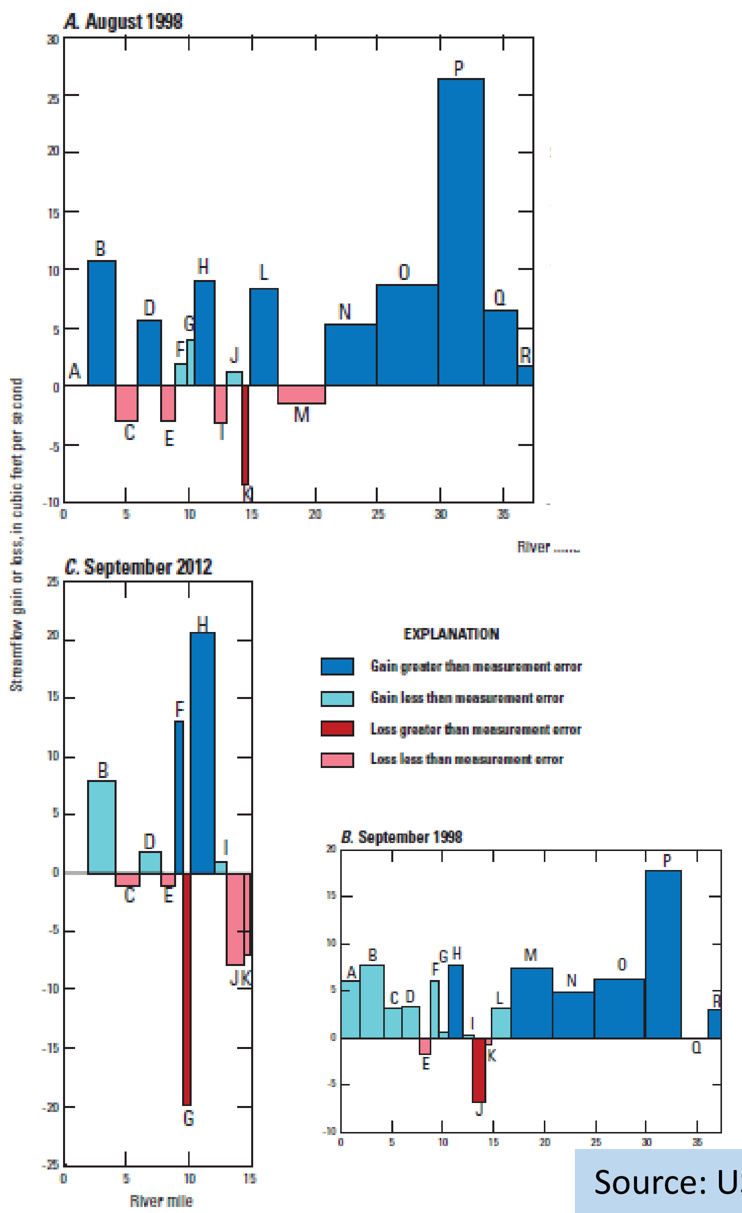


Figure 10. Seepage gains and losses measured during the seepage runs in August 1998 (*A*), September 1998 (*B*), and September 2012 (*C*), South Fork Nooksack River Basin, northwestern Washington.

Source: USGS SIR 2014–5221

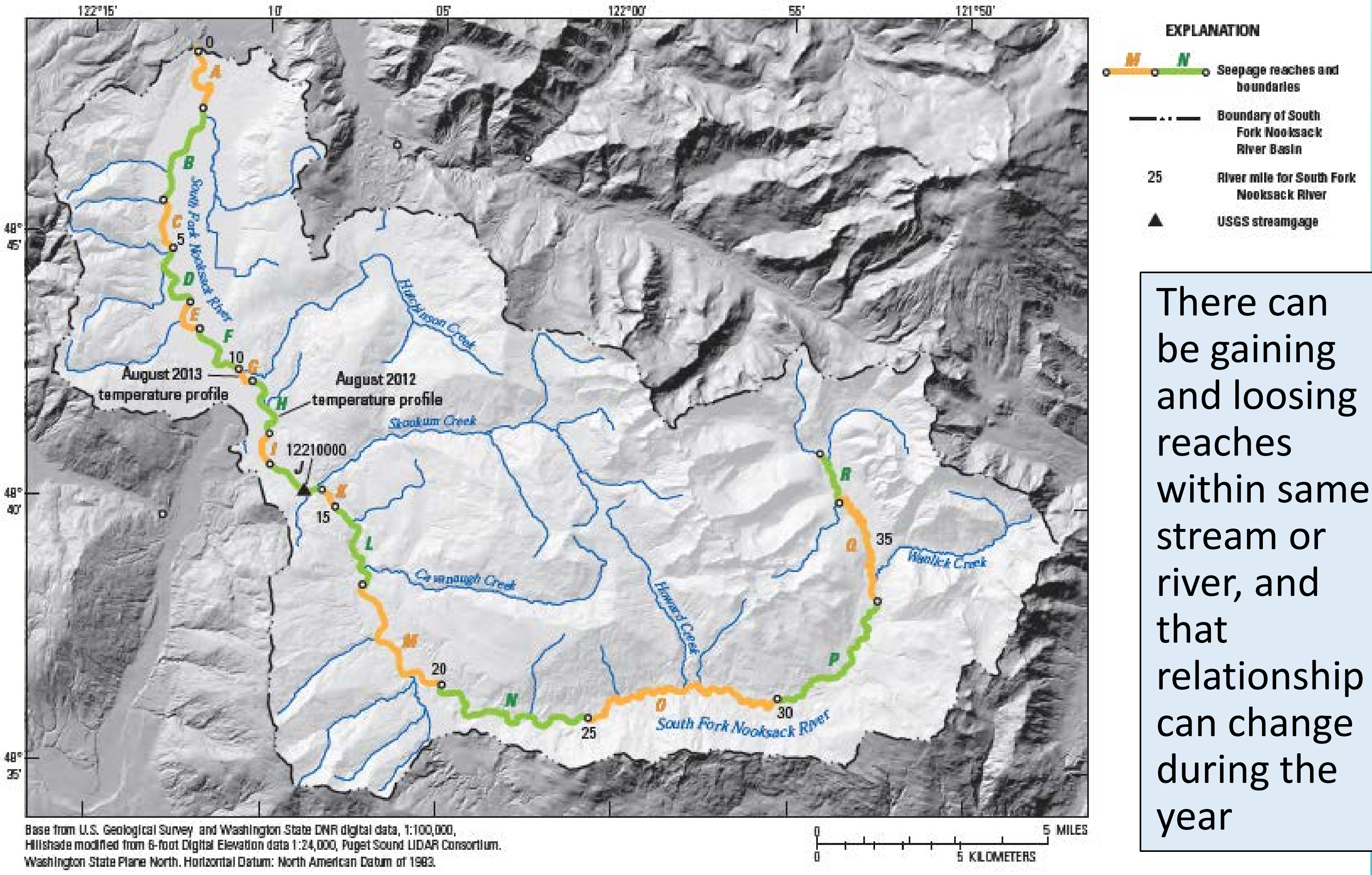
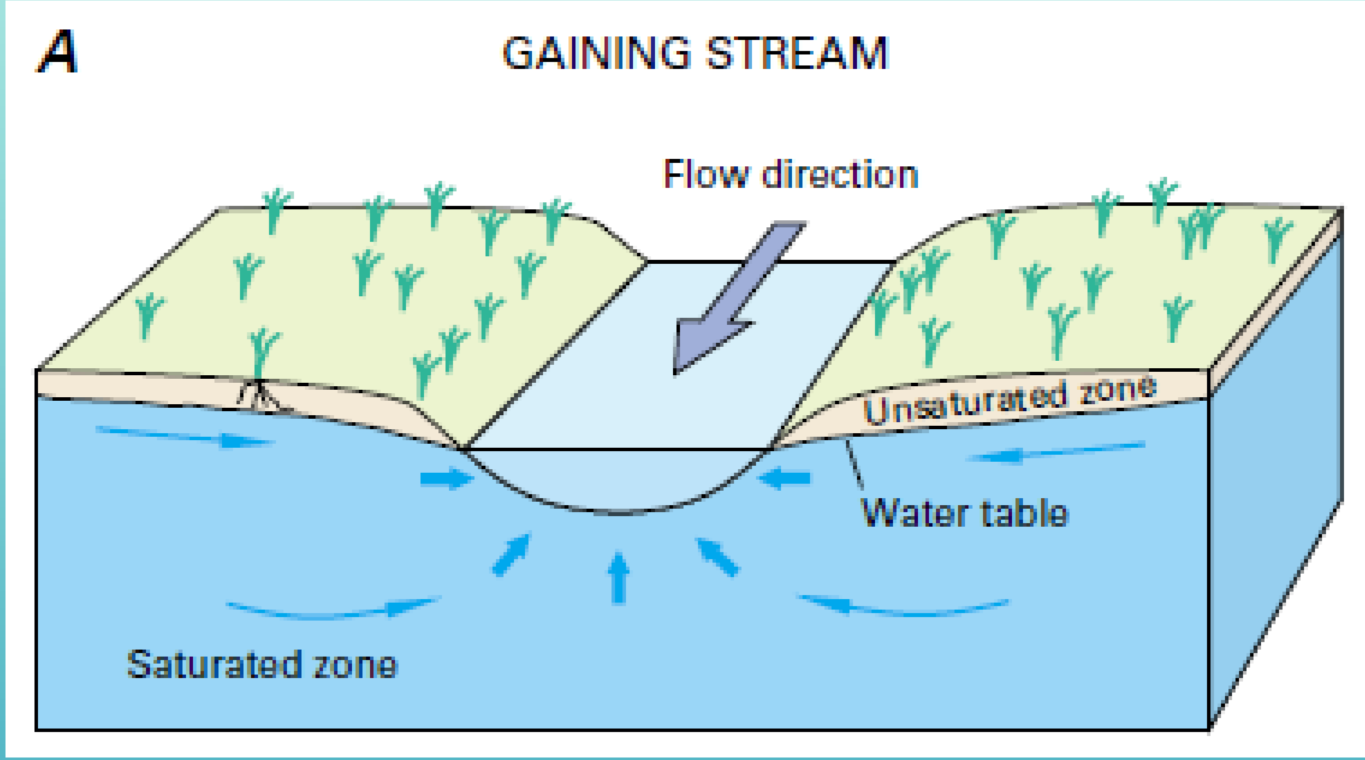


Figure 9. Seepage reaches (A–R) during seepage runs in August and September 1998 and September 2012, South Fork Nooksack River Basin, northwestern Washington.

There can be gaining and loosing reaches within same stream or river, and that relationship can change during the year

Magnitude of gains and losses can fall within measurement error of individual flows, making things harder to interpret

Baseflow: component of streamflow derived from groundwater inflow or discharge.



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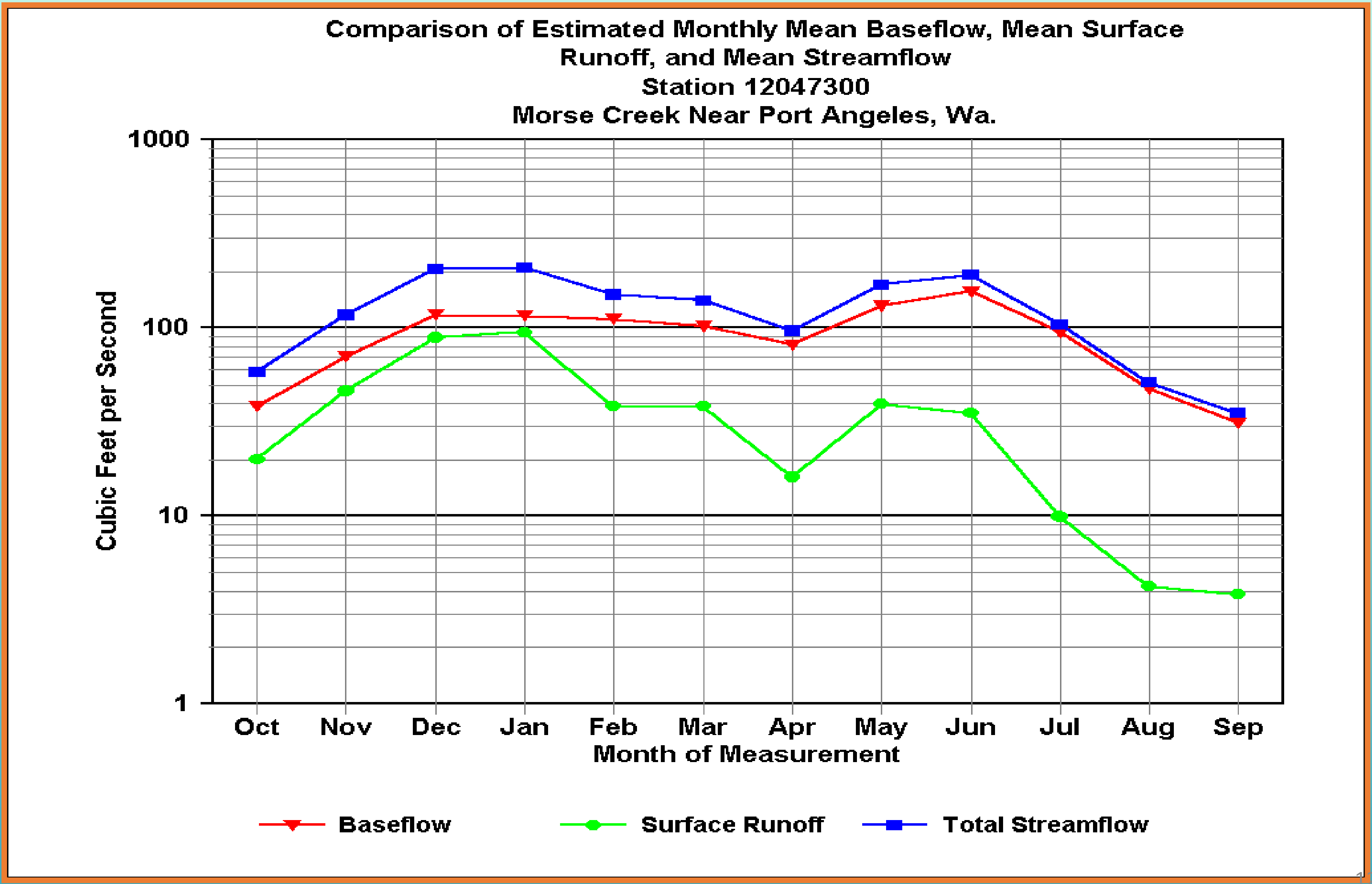
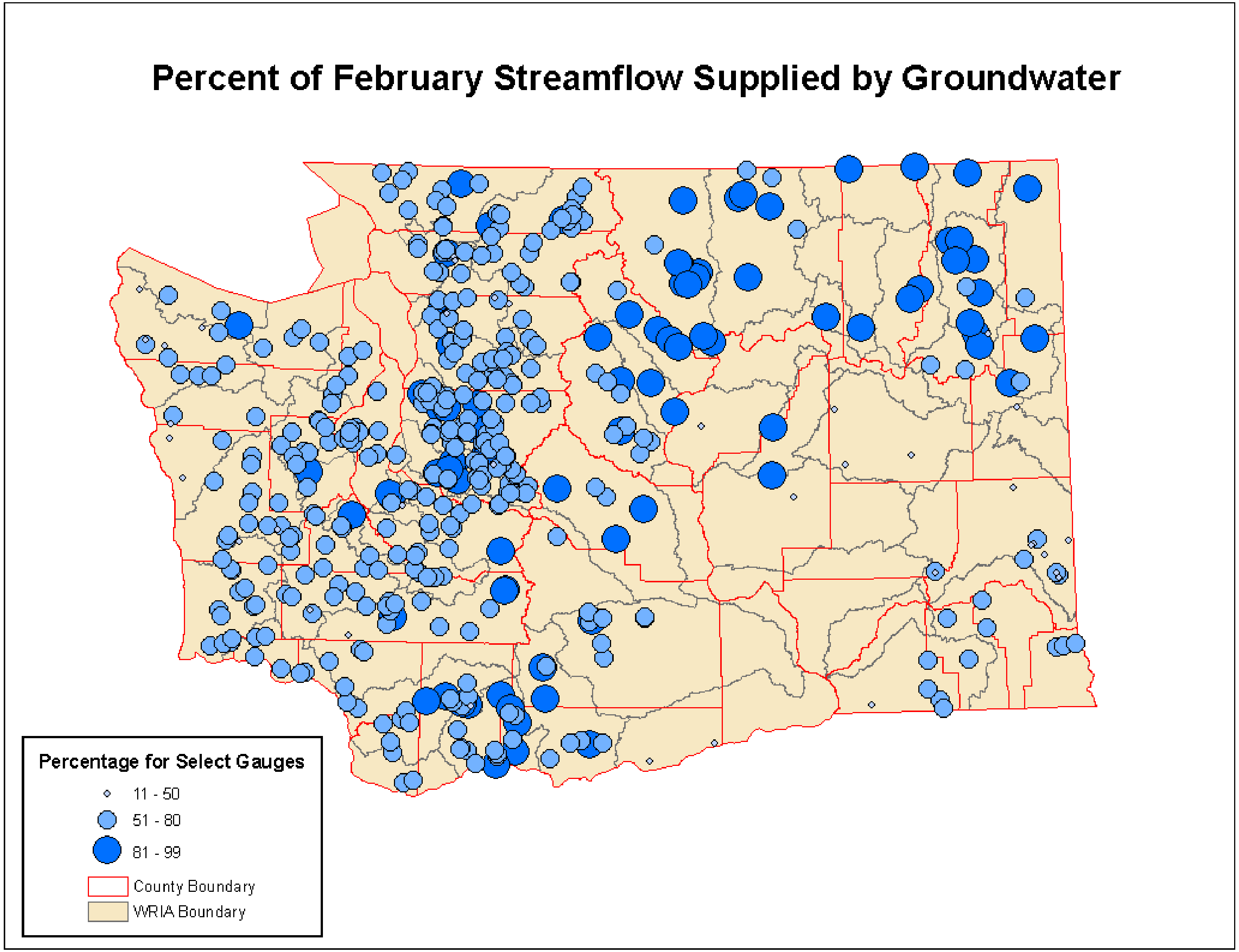
Baseflow is important for both water quantity and temperature.

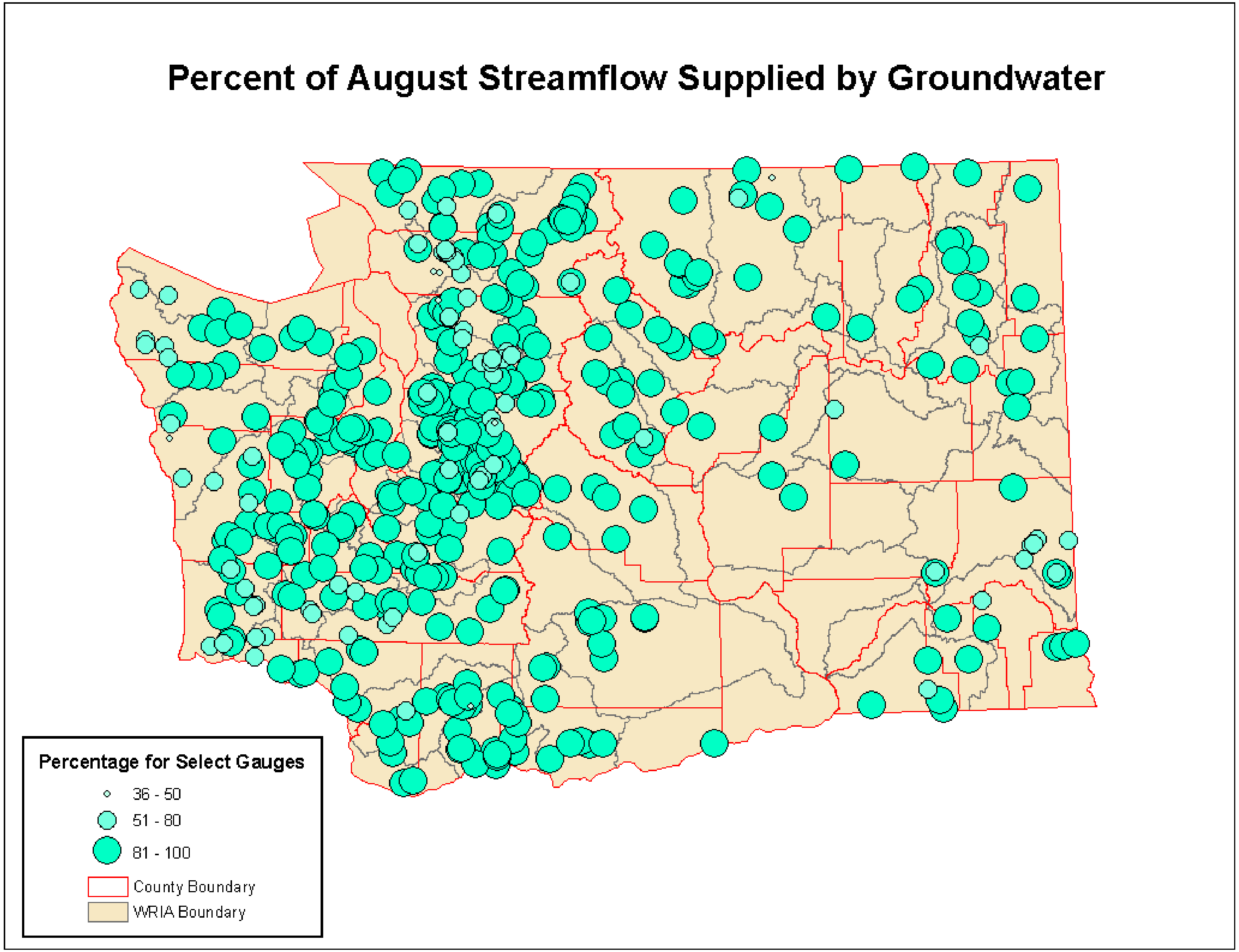
Note: vertical axis presented in **log scale**

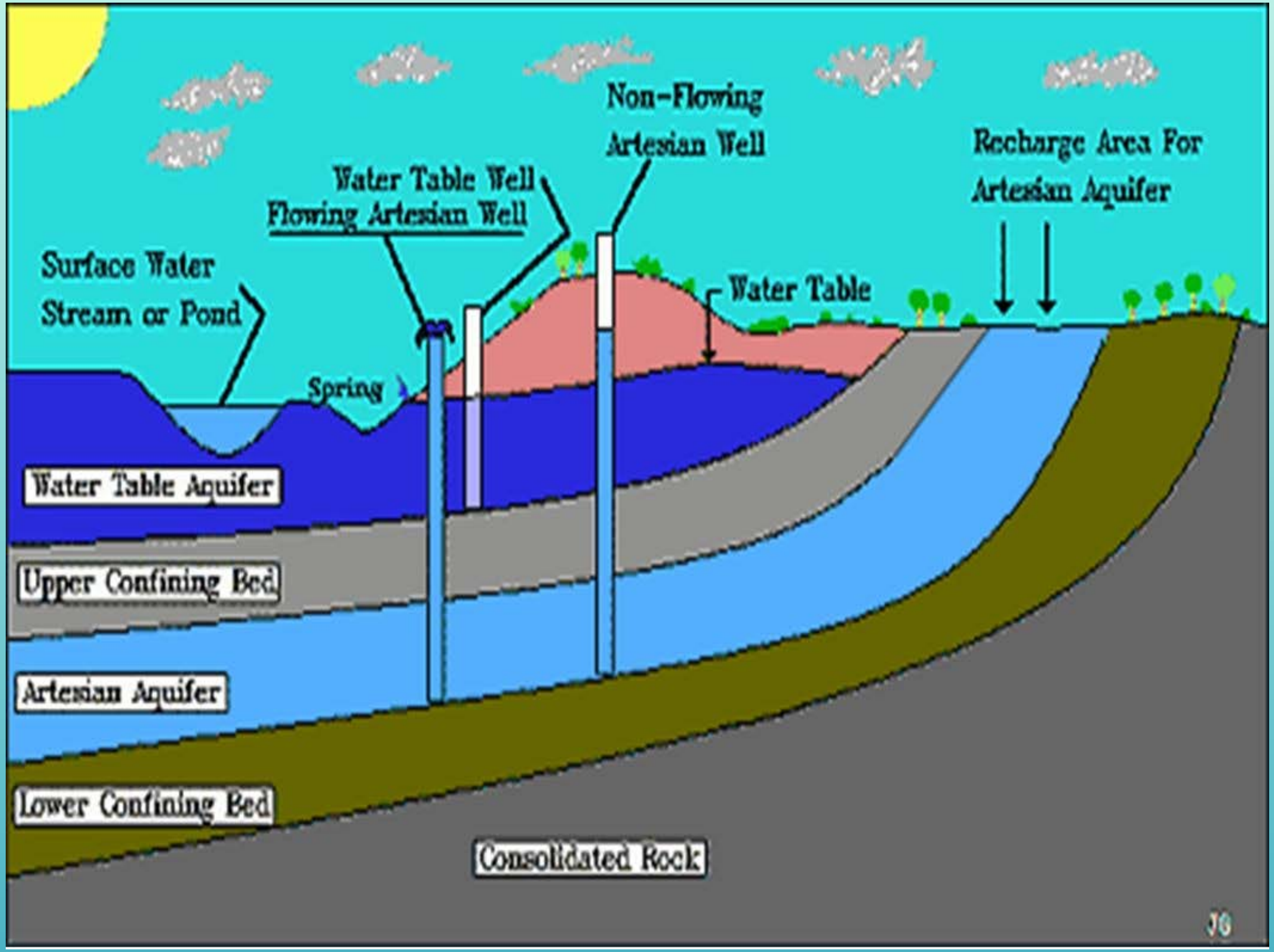


Baseflow maintains summer streamflow throughout most of Washington



In Washington groundwater baseflow contributes 68% of total annual flow for 594 studied gages (WSB 60)

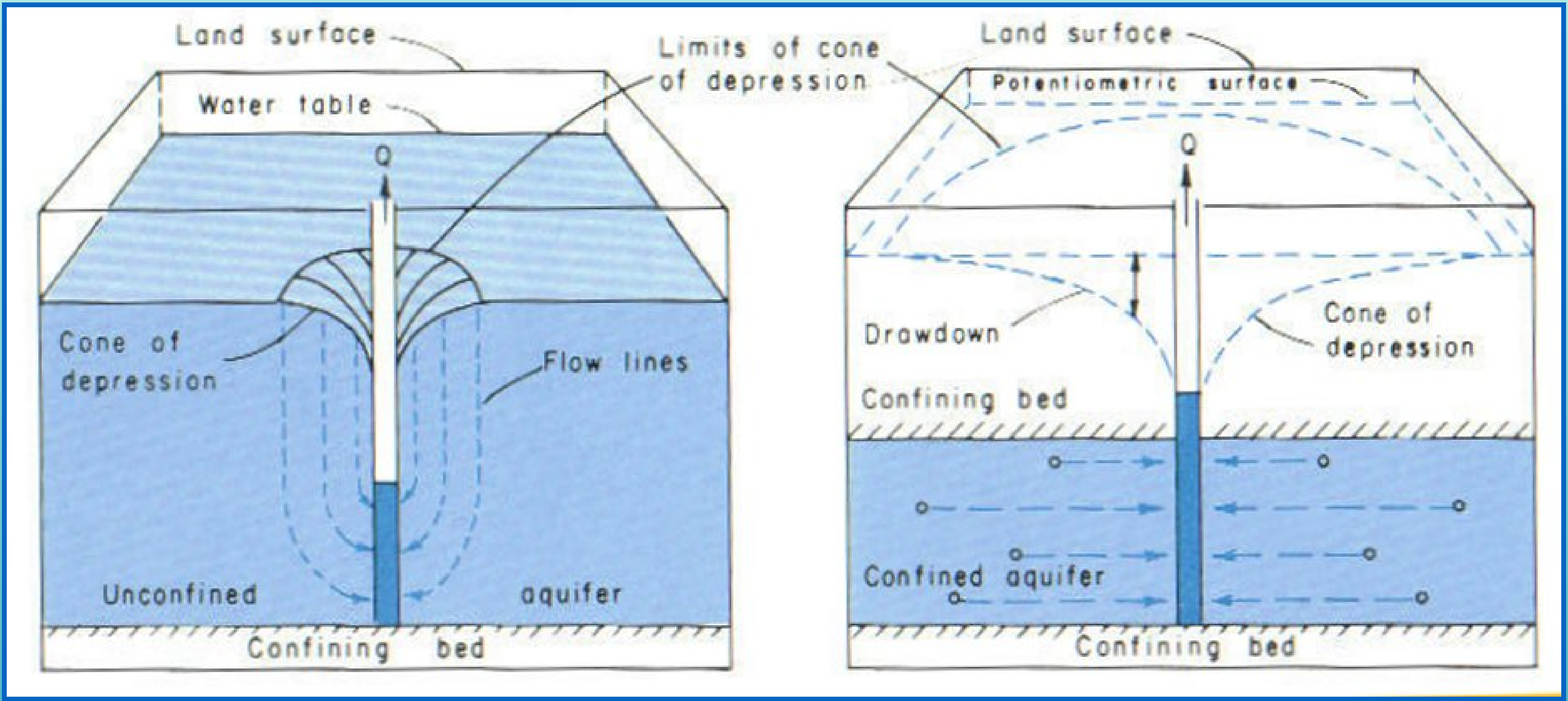




http://www.dennisalbert.com/AAADrilling/Aquafier.htm

When well is drilled into a confined aquifer and water level rises above the confining unit, the well is referred as an artesian well. If water flows out of well at land surface it is referred to as artesian flowing well.

Pumping a well forms a cone of depression



Heath, 1983

Unconfined

Confined

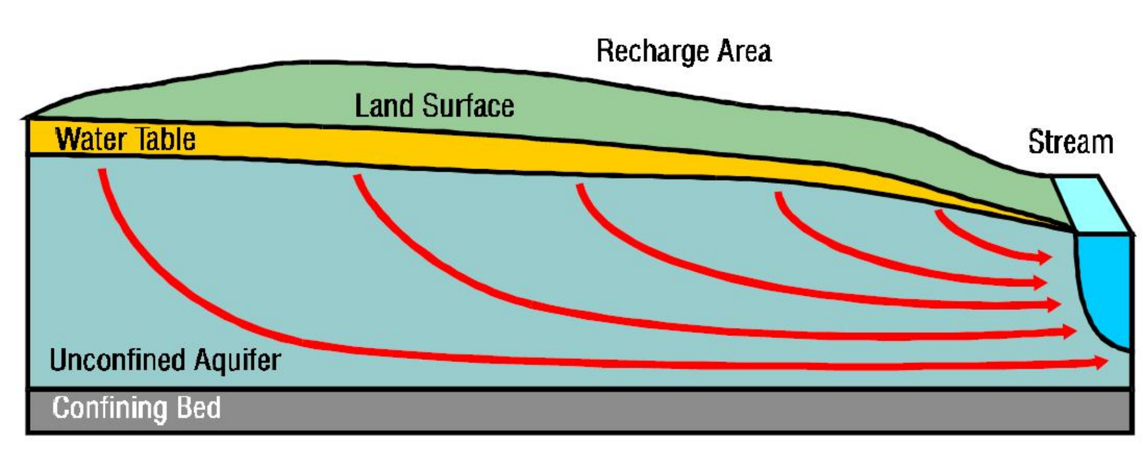
Pumping groundwater from a well (conservation of mass) always causes…

(1) decline in groundwater level (head) at and near the well, and

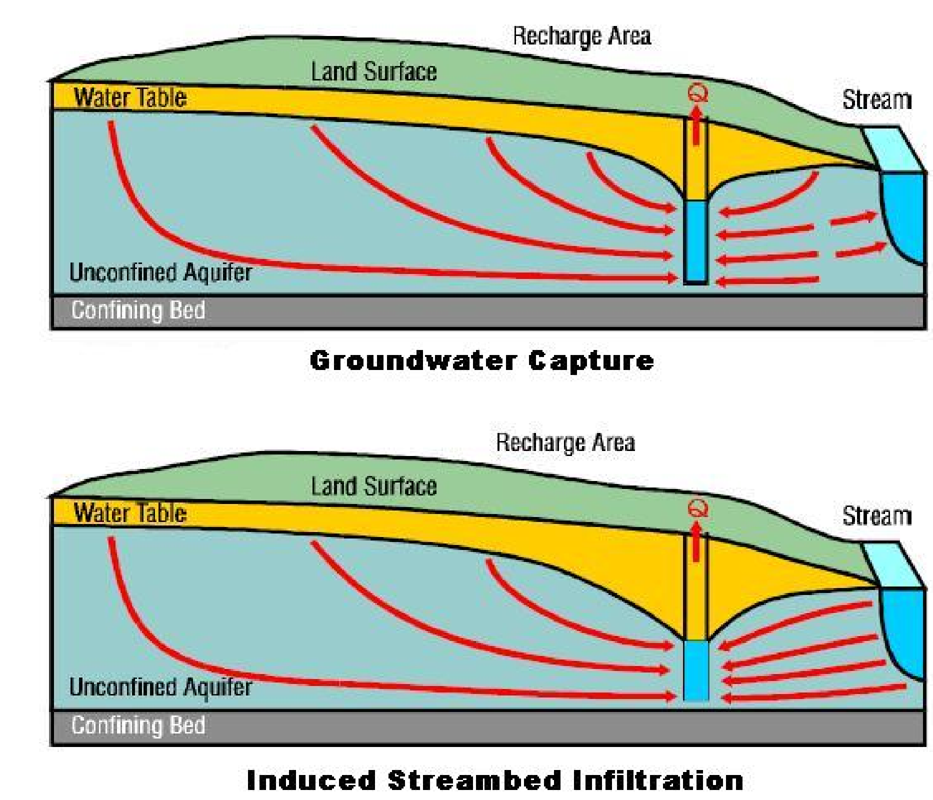
(2) diversion to the pumping well of groundwater that was moving slowly to its natural, possibly distant, area of discharge.

Groundwater pumping can generally deplete streamflow in two ways:

- **Groundwater capture** - interception of groundwater flow that is tributary to a stream. This effect usually continues after pumping ends.
- **Induced streambed infiltration** - groundwater pumping pulling surface water from a stream toward a well.



Discharge (D) = Recharge (R)

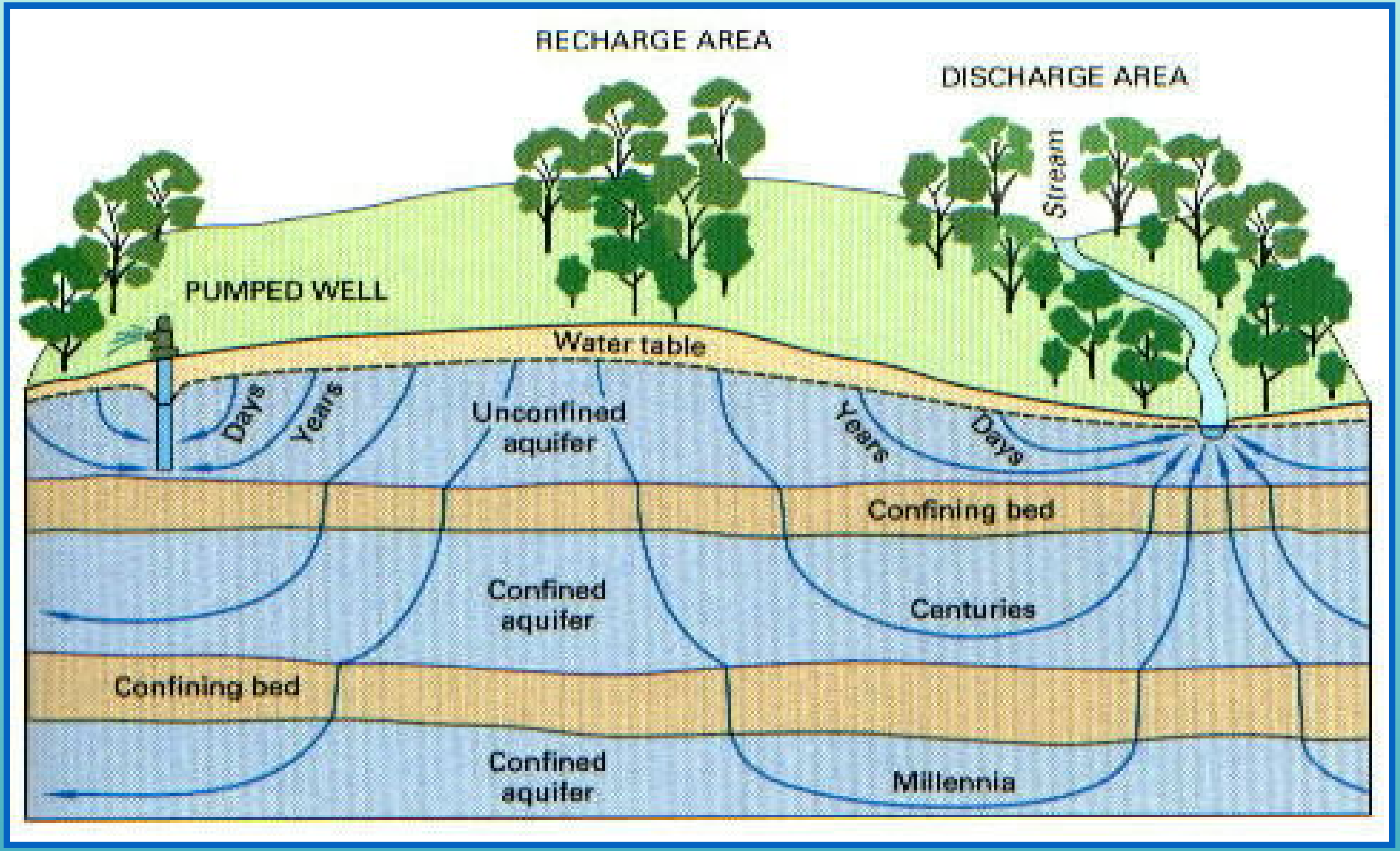


From Heath (1983)

Groundwater Velocities are Generally Low

- Groundwater movement normally occurs as slow seepage through pore spaces in unconsolidated earth or networks of fractures and solution openings in consolidated rocks.
- A velocity of 1 foot per day or more is a high rate of movement, and velocities can be as low as 1 foot per year or decade.
- By contrast streamflow velocities generally are measured in feet per second. A velocity of 1 foot per second equals about 16 miles per day.

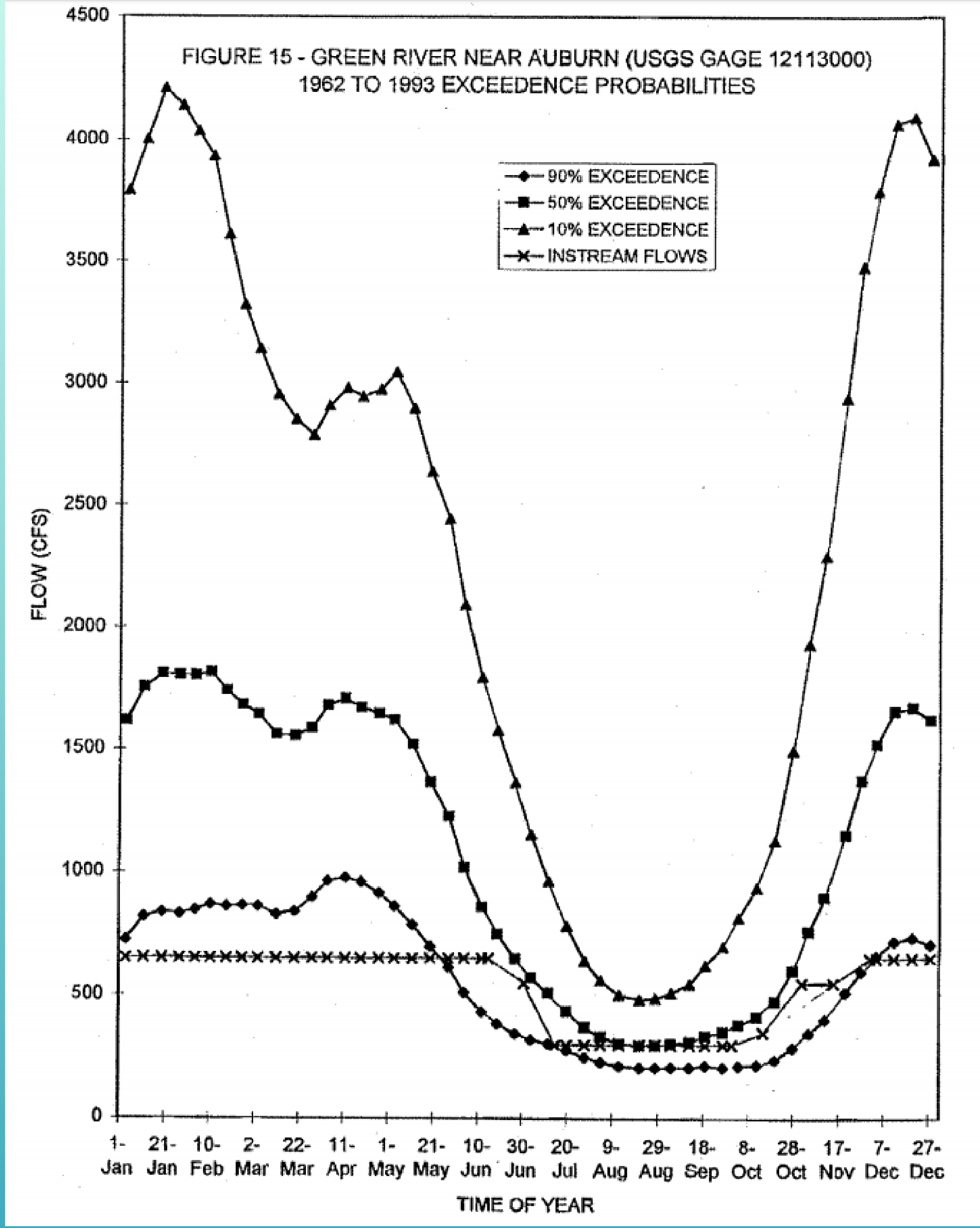
Groundwater travel time is not an indication of the speed at which pumping effects propagate



USGS Circular 1139

With regard to water rights and surface water availability in Washington, concerns usually involve…

or



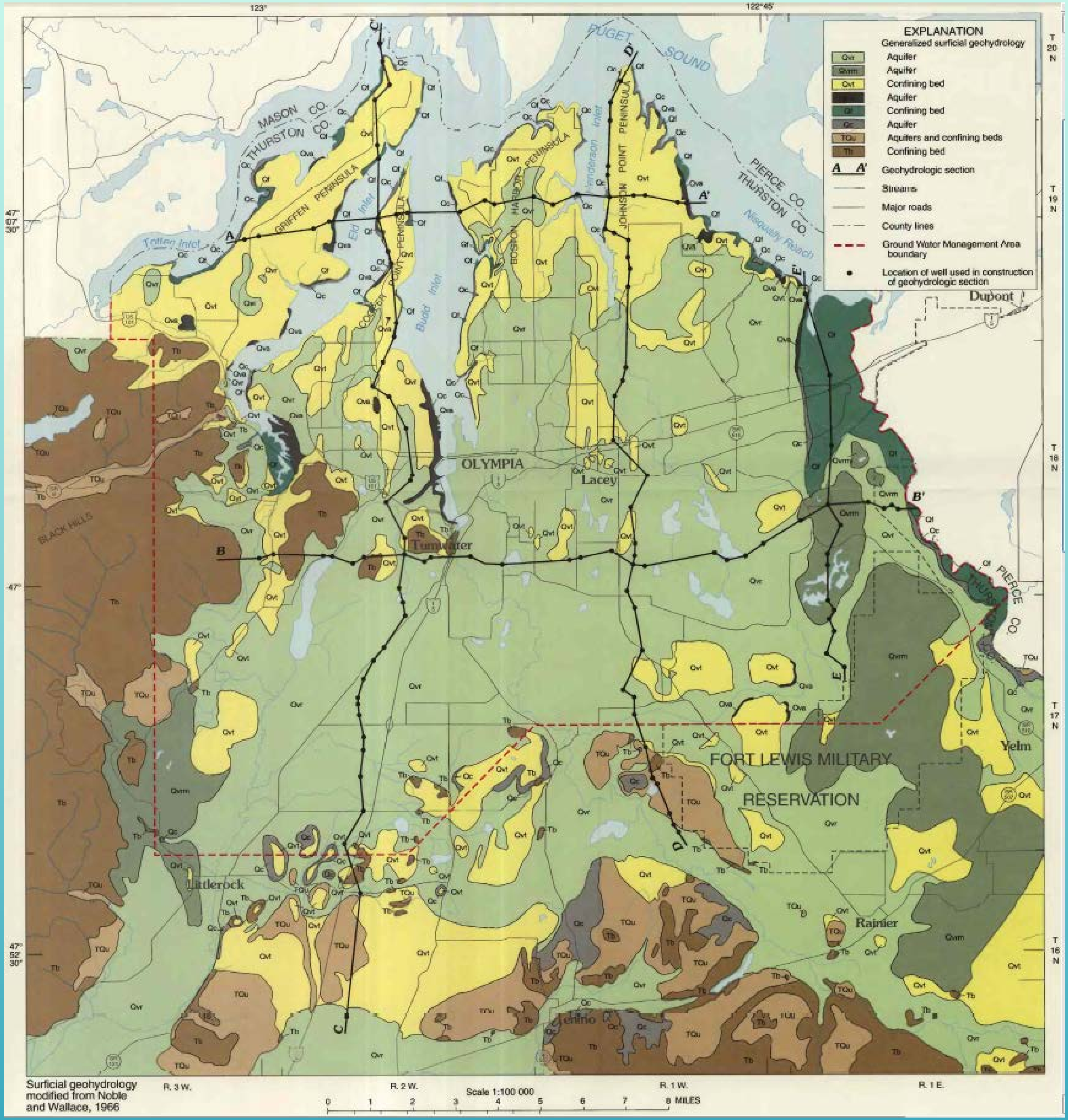
WRIA 13 Hydrogeology

Significant WRIA 13 Hydrogeology Studies

Hydrology and Quality of Ground Water in Northern Thurston County, Washington; USGS Water-Resources Investigations Report (WRIR) 92-4109 [Revised] (Drost, et al., 1992)

Conceptual Model and Numerical Simulation of The Ground-Water-Flow System In the Unconsolidated Sediments of Thurston County, Washington; USGS Water-Resources Investigations Report (WRIR) 99-4165 (Drost, et al., 1999)

WRIA 13’s geology is composed of thick sequence of unconsolidated Quaternary glacial and interglacial deposits overlying Tertiary igneous and sedimentary bedrock



WRIR 92-4109

Table. 1. Lithologic and hydrologic characteristics of geohydrologic units in northern Thurston County

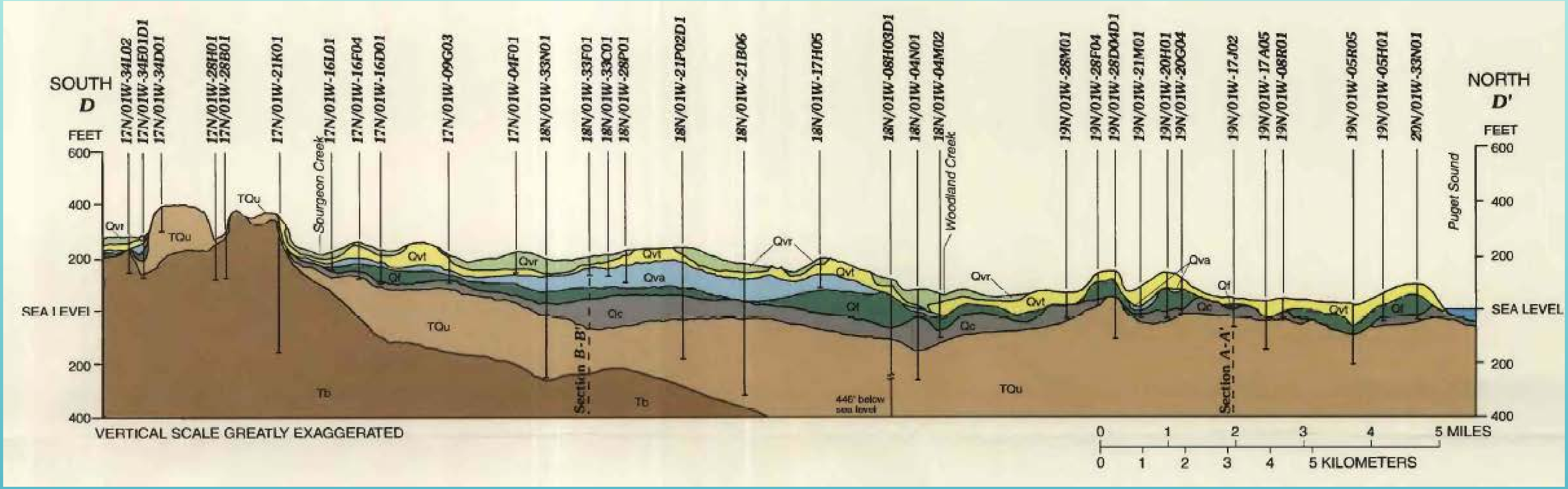
System	Series	Geologic unit		Geohydrologic unit, in this report[1]	Typical thickness (feet)	Lithologic characteristics	Hydrologic characteristics
Quaternary	Holocene		Alluvium	Qvr Qvrm	10-50	Alluvial and deltaic sand and gravel along major water courses. Moderately to well-sorted glacial sand and gravel, including kettled end moraine	An aquifer where saturated. Ground-water is mostly unconfined. Perched conditions occur locally.
Quaternary	Pleistocene	Vashon Drift	Recessional outwash and end moraine				
Quaternary	Pleistocene	Vashon Drift	Till	Qvt[2]	20-60	Unsorted sand, gravel, and boulders in a matrix of silt and clay.	Confining bed, but can yield usable amounts of water. Some thin lenses of clean sand and gravel.
Quaternary	Pleistocene	Vashon Drift	Advance outwash	Qva	15-35	Poorly to moderately well-sorted, well-rounded gravel in a matrix of sand with some sand lenses.	Ground water mostly confined. Used extensively for public supplies near Tumwater.
Quaternary	Pleistocene	Kitsap Formation		Qf[3]	15-70	Predominantly clay and silt, with some layers of sand and gravel. Minor amounts of peat and wood.	Confining bed, but in places yields usable amounts of water.
Quaternary	Pleistocene	Salmon Springs(?) Drift (Noble and Wallace, 1966) / Deposits of "penultimate" glaciation (Lea, 1984)		Qc	15-50	Coarse sand and gravel, deeply stained with red or brown iron oxides.	Water is confined. Used extensively for industrial purposes near Tumwater.
Quaternary	Pleistocene	Unconsolidated and undifferentiated deposits		TQu	Not known	Various layers of clay, silt, sand, and gravel of both glacial and nonglacial origin.	Contains both aquifers and confining beds. Water probably confined.
Tertiary	Miocene and Eocene	Bedrock		Tb	Not known	Sedimentary rocks consisting of claystone, siltstone, sandstone, and minor beds of coal. Igneous bodies of andesite and basalt.	Poorly permeable base of unconsolidated sediments. Locally an aquifer, but generally unreliable. Water contained in fractures and joints. Well yields relatively small. Numerous abandoned wells.

[1]The identification of geohydrologic units in this report is a "best estimate" based on drillers' logs and existing surficial geology maps.

[2]Includes "late Vashon lake deposits" (Washington State Department of Ecology, 1980). May include till of "penultimate" glaciation (Lea, 1984).

[3]Includes alluvium younger than Kitsap Formation in Nisqually River delta. May include some Vashon till (where multiple tills are present). May include till of "penultimate" glaciation (Lea, 1984).

WRIR 92-4109


SOUTH
D
NORTH
D'
FEET
600
400
200
SEA LEVEL
200
400
17N/01W-34L02
17N/01W-34E01D1
17N/01W-34D01
17N/01W-28H01
17N/01W-28B01
17N/01W-21K01
Sourgeon Creek
17N/01W-16L01
17N/01W-16F04
17N/01W-16D01
17N/01W-09G03
17N/01W-04F01
18N/01W-33N01
18N/01W-33F01
18N/01W-33C01
18N/01W-28P01
18N/01W-21P02D1
18N/01W-21B06
18N/01W-17H05
18N/01W-08H03D1
18N/01W-04N01
18N/01W-04M02
Woodland Creek
19N/01W-28M01
19N/01W-28F04
19N/01W-28D04D1
19N/01W-21M01
19N/01W-20H01
19N/01W-20G04
19N/01W-17J02
19N/01W-17A05
19N/01W-08R01
19N/01W-05R05
19N/01W-05H01
20N/01W-33N01
Puget Sound
Qvr
Qvt
Qva
Qf
Qc
TQu
Tb
Section B-B'
Section A-A'
446' below sea level
VERTICAL SCALE GREATLY EXAGGERATED
0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS

WRIR 92-4109

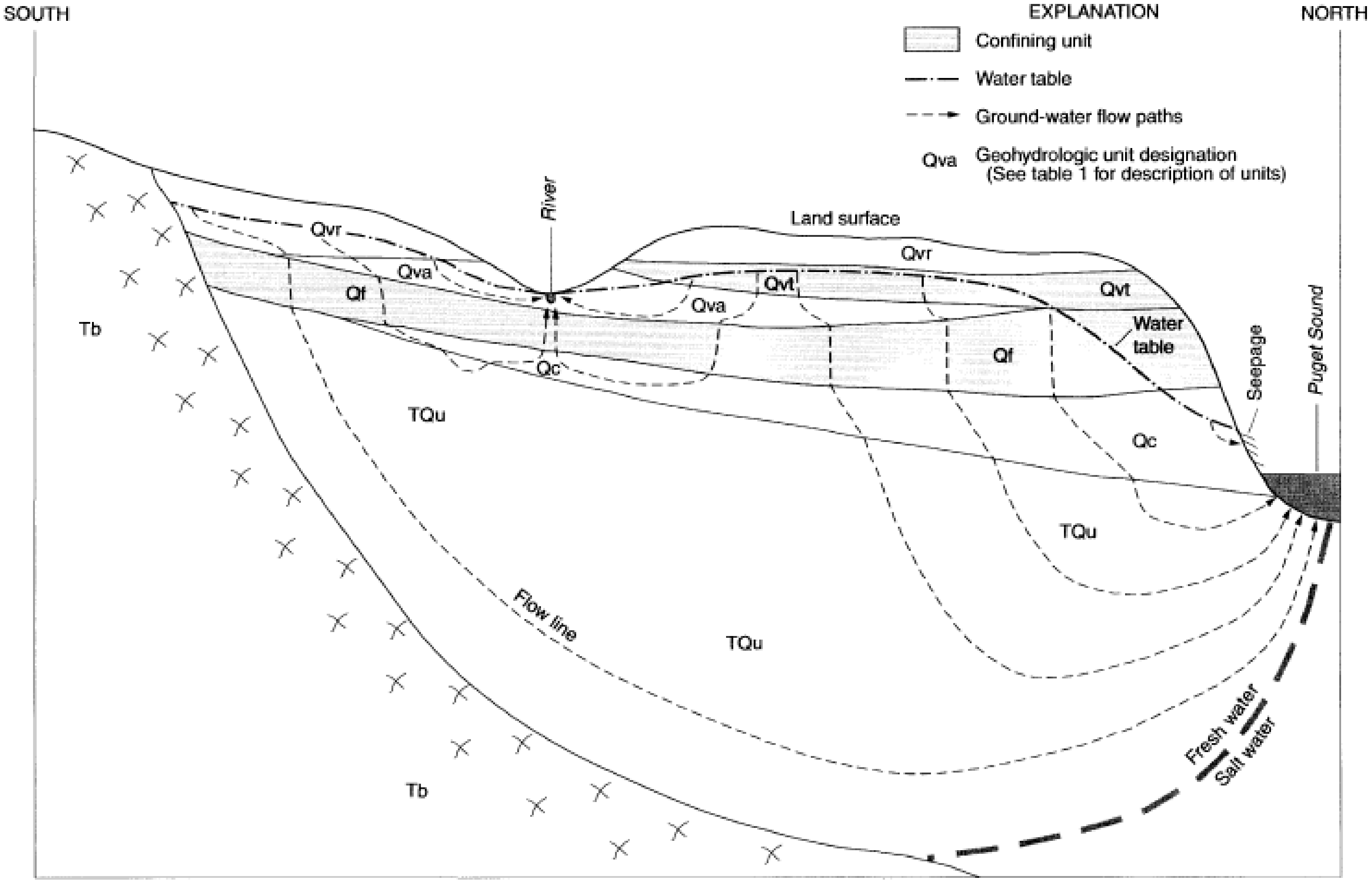
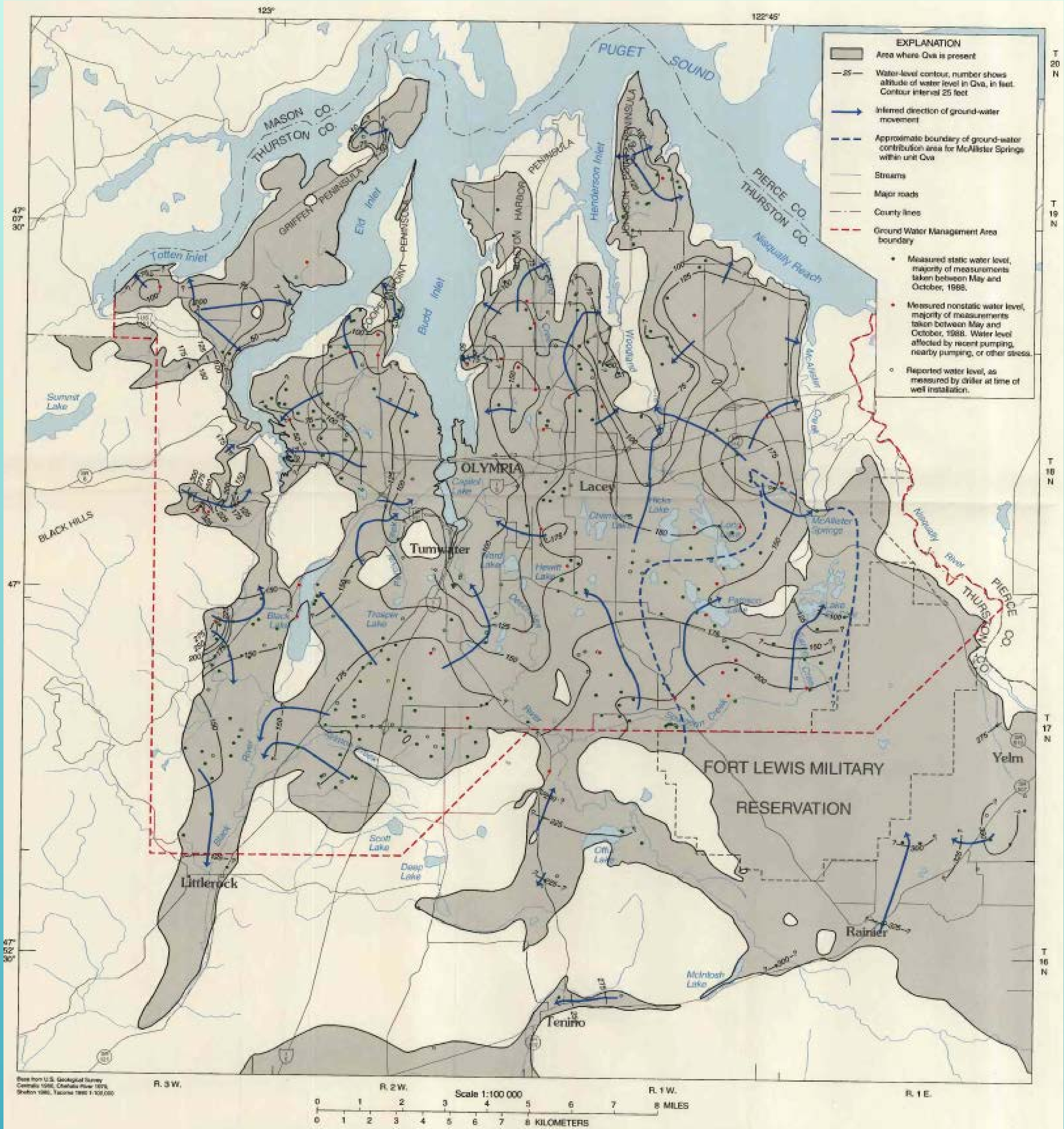
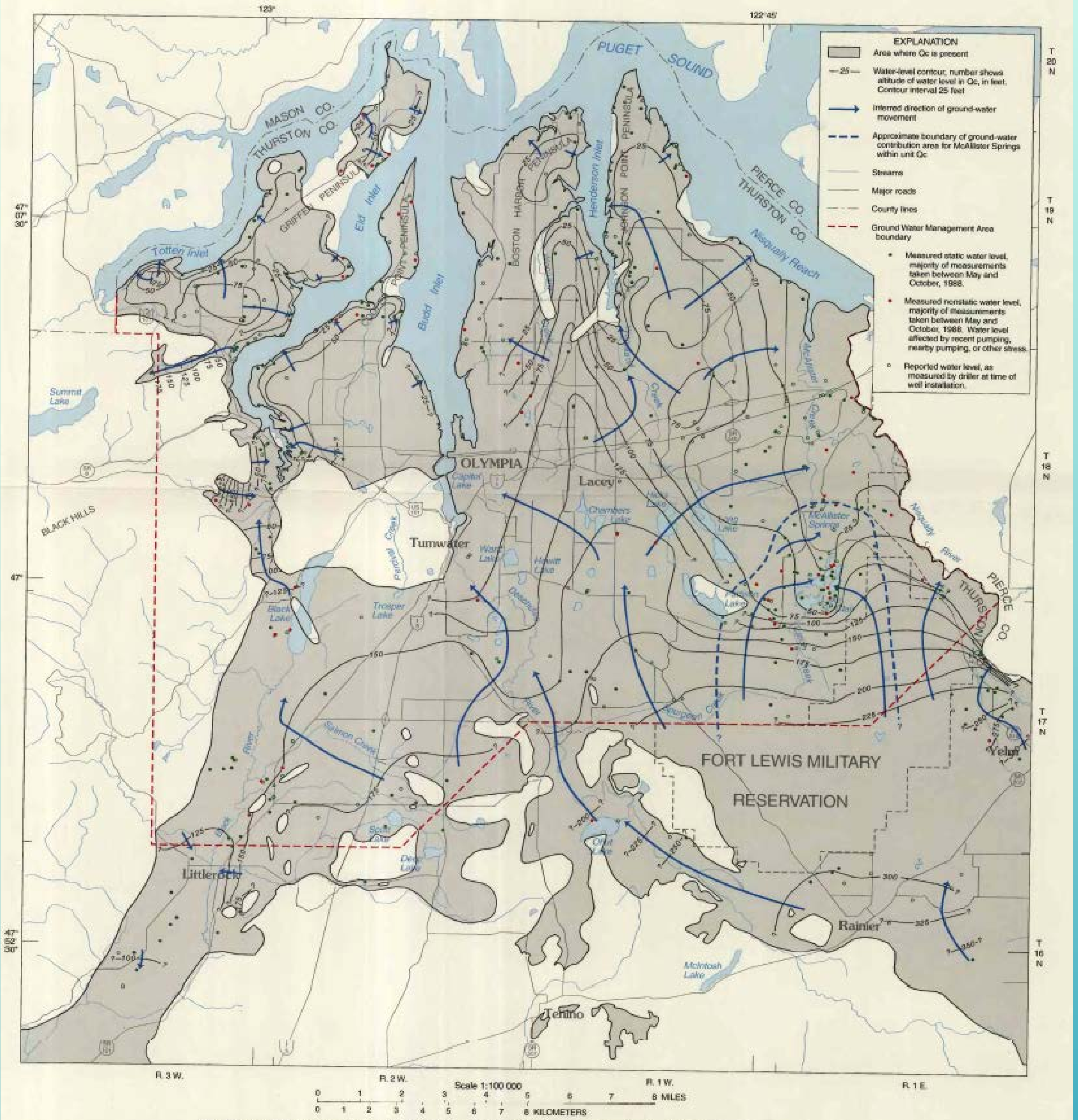


Figure 5. Conceptual model of the ground-water system beneath northern Thurston County.



a. Water Levels and Flow Directions in Geohydrologic Unit Qva,1988



b. Water Levels and Flow Directions in Geohydrologic Unit Qc,1988

WRIR 92-4109

Model grid for Qvr aquifer from *Conceptual Model and Numerical Simulation of the Ground-Water-Flow System in the Unconsolidated Sediments of Thurston County, Washington*, USGS WRIR 99-4165

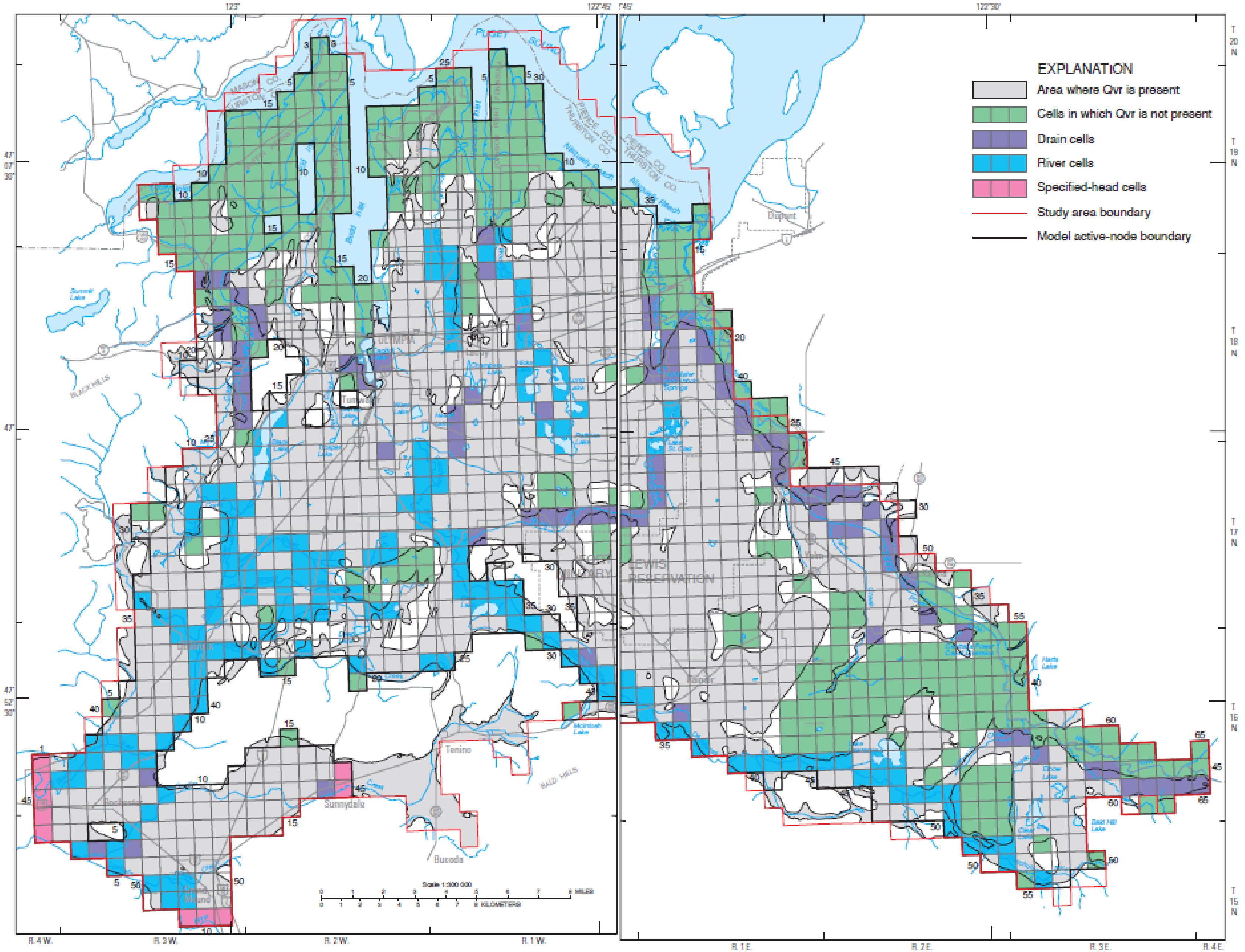
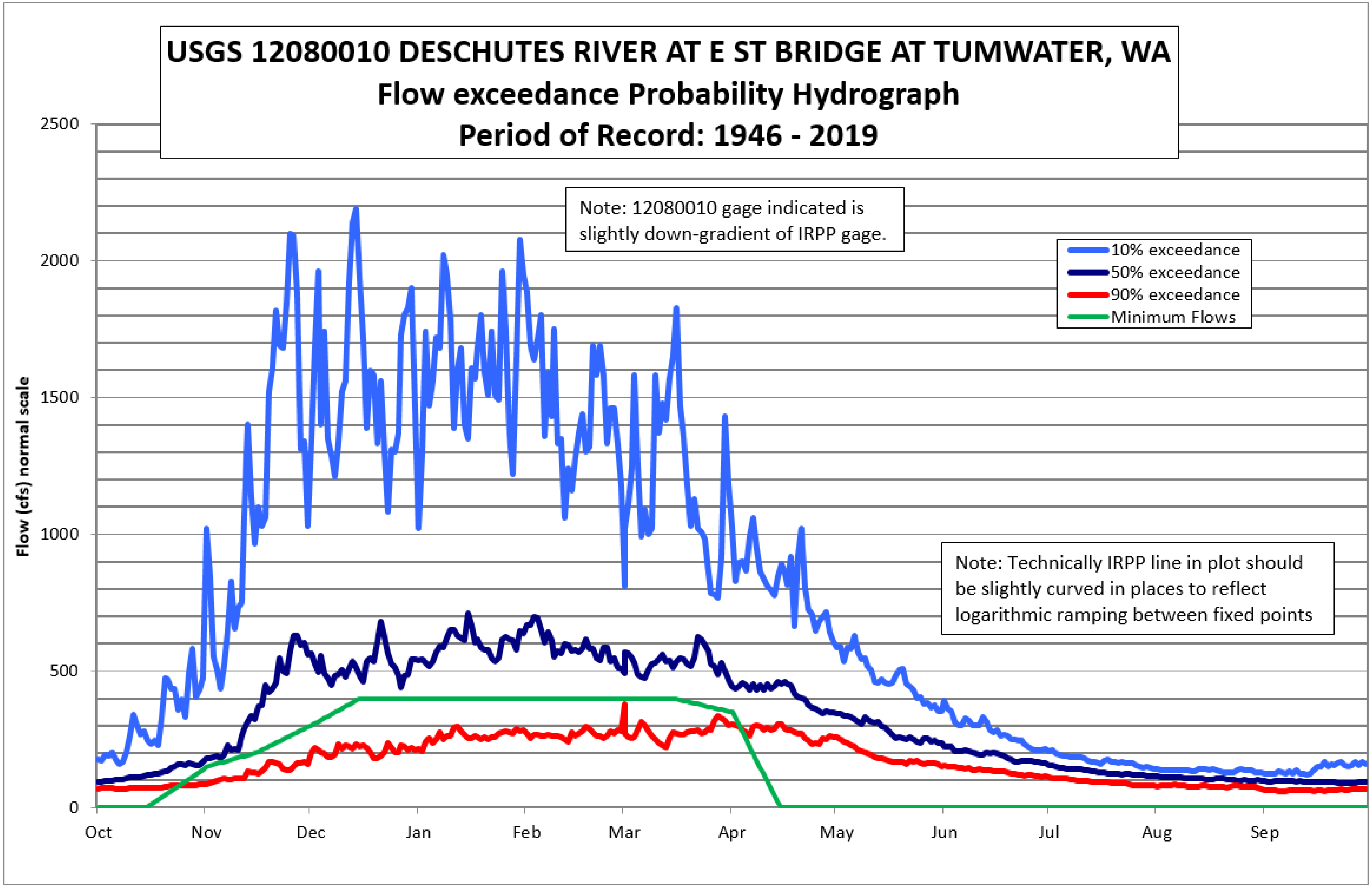


Figure 23a. Model grid and boundaries, and locations of specified-head, drain, and river cells for Layer 1-Qvr

Figure 23a. continued.

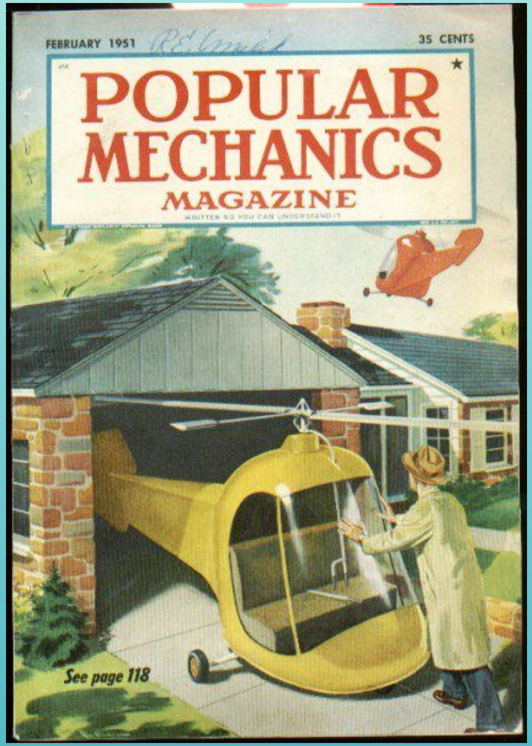


USGS 12080010 DESCHUTES RIVER AT E ST BRIDGE AT TUMWATER, WA
Flow exceedance Probability Hydrograph
Period of Record: 1946 - 2019
Note: 12080010 gage indicated is slightly down-gradient of IRPP gage.
10% exceedance
50% exceedance
90% exceedance
Minimum Flows
Note: Technically IRPP line in plot should be slightly curved in places to reflect logarithmic ramping between fixed points
Flow (cfs) normal scale
2500
2000
1500
1000
500
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep

RCW 90.94 Considerations

RCW 90.94 Planning Groups must describe Future Permit-Exempt Well Consumptive Use over Next 20 Years

- Ecology recommends relying on more than one method for estimating numbers of future wells including: population projections, historic building permit data, and/or historic well log drilling rates.
- To account for portion of water not consumptively used, water use estimates can be adjusted to account for water that will not return to hydrologic system.



From Ecology ESSB 6091 Streamflow Restoration Water Use Estimate Recommendations

Household Consumptive Indoor Water Use (HCIWU):

60 gpd X 2.5 people per house X 365 days X 0.00000307 AF/gal. X 10%[1] cons. use = 0.017 AF/YR

Household Consumptive Outdoor Water Use (HCOWU):

	May	June	July	August	Sept.	Total
Irrig. requirements (in.)[2]	0.63	2.72	4.11	2.75	0.90	11.11

Assuming outdoor watering area of 0.4 acre:

Irrigation Requirements (in.) = 11.11 inches/12 inches per feet X 0.4 acres = 0.37 AF/YR

Factoring in assumed application efficiency of 75 percent,

0.37 acre-feet ÷ 75% application efficiency = 0.49 acre-feet

Factoring assumed outdoor water use consumption of 80%:

0.49 acre-feet x 80% consumed (20% return flow) = 0.39 acre-feet

Basin-wide Household Consumptive Water Use (BHCWU):

Consumptive water use by future permit-exempt domestic wells for WRIA or subbasin:

BHCWU = number of houses served by permit-exempt domestic wells X (HCIWU + HCOWU)

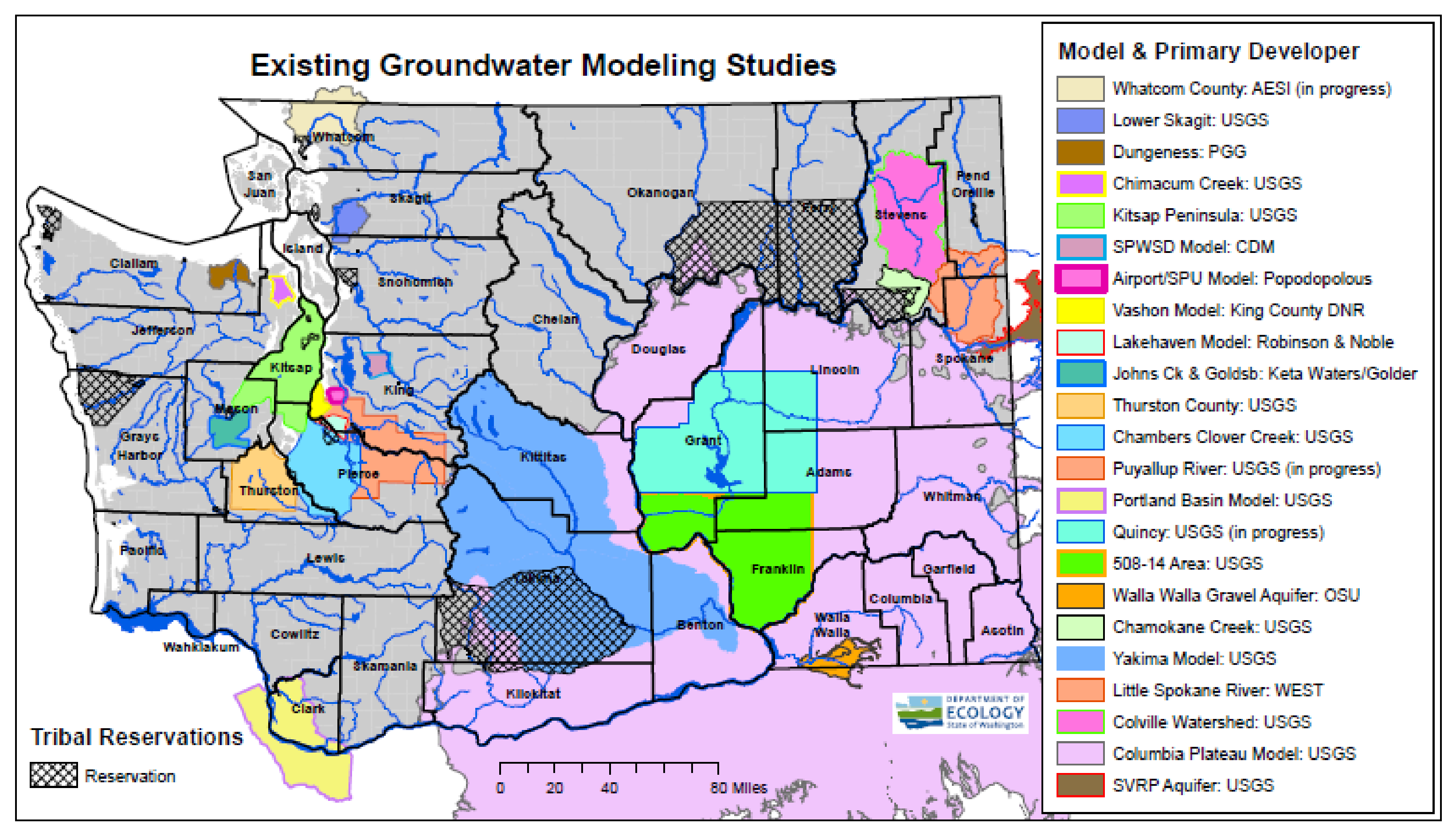
1. Assuming all houses discharge wastewater via septic systems
2. From Appendix A of the Washington Irrigation Guide (WAIG) (U.S. Department of Agriculture, 1997)

When & Where Consumptive Use Impacts Will Occur

- RCW 90.94 requires high priority offset projects to replace 20-year water use in-time and in same subbasin.
- Estimating timing of groundwater impacts on streams with precision is complicated due to lags between when a well is pumped and when those impacts propagate to a stream.

Need to Simplify

Due to hydrogeologic variability, uncertainty regarding new well locations, limited money, and limited time, planning groups will not be able to model pumping effects in detail.



Conceptual Groundwater Understanding

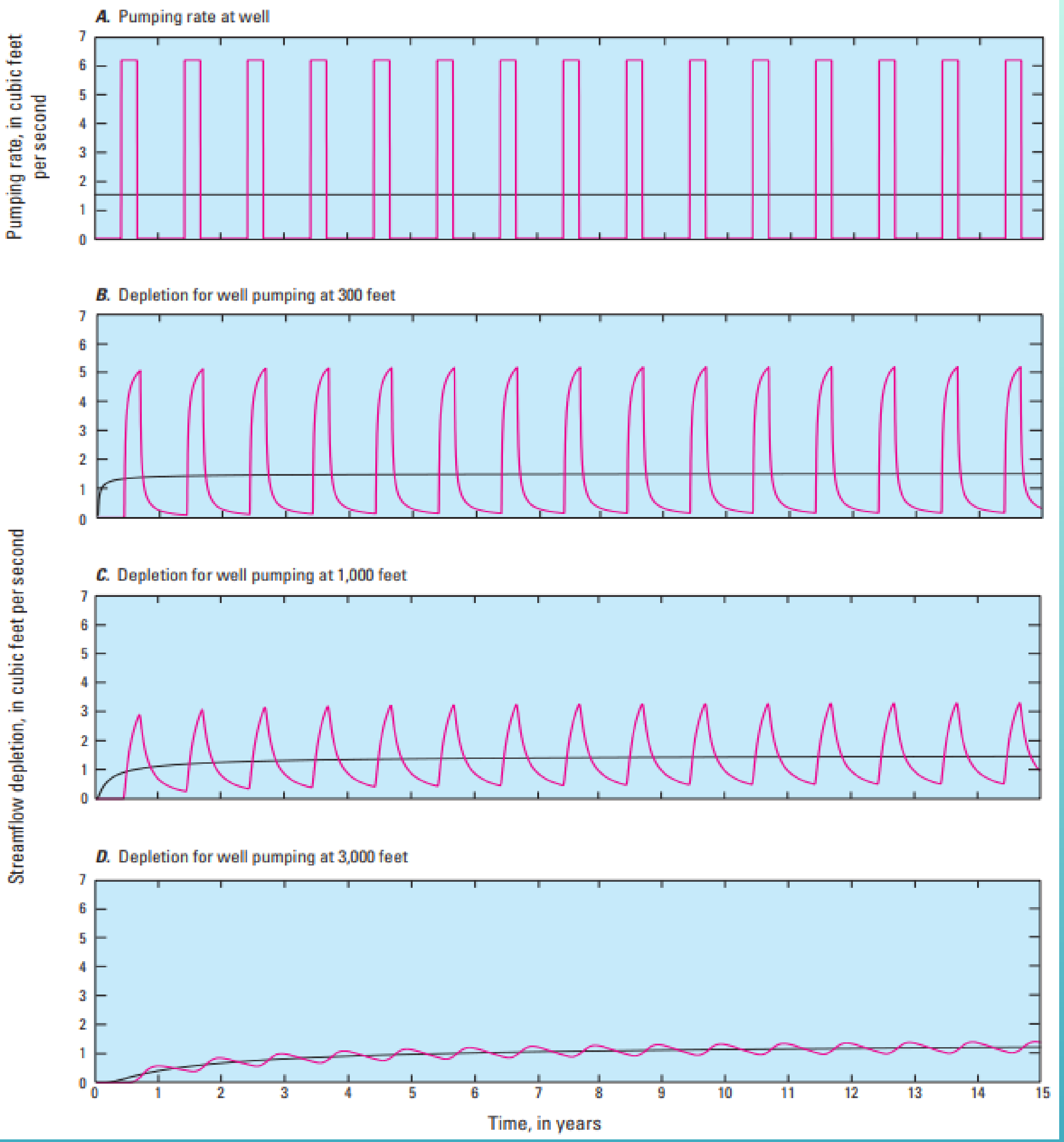
Conceptual groundwater models provide overall hydrogeologic understanding.

In water resources terms this generally considers:

- spatial delineations of recharge and discharge areas
- identification of pathways from unsaturated zones through saturated zones to groundwater receptors
- analyses and estimates of time scales of flow and effects of groundwater pumping

Seasonal vs. Steady State

- Magnitudes of aquifer pumping pulses decay over distance and time as effects spread out.
- In this example water-level changes range from a distinct pump-on – pump-off pattern, to a relatively constant impact.
- In most instances in western Washington it is reasonable to assume streamflow depletion will essentially be steady state - especially beyond distance of few thousand feet.



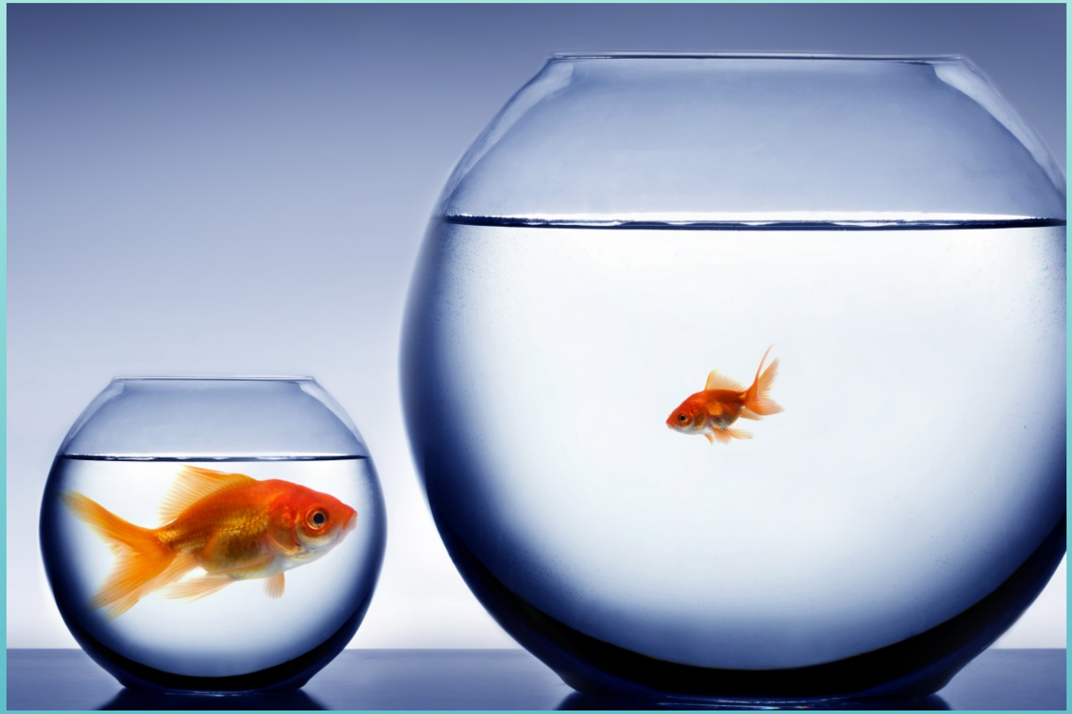
USGS Circular 1376

Spatial Considerations

- Even when planning groups assume steady state conditions, they will need to consider how steady state pumping effects are distributed spatially.
- Conceptually, one option is to assume all pumping effects will remain within a subbasin and be distributed evenly to all surface water bodies.
- In those instances where most future wells are likely to be shallow and congregated near a stream particularly important to fish, another option would be to conservatively assume depletion impacts are entirely attributed to streams closest to pumping well.

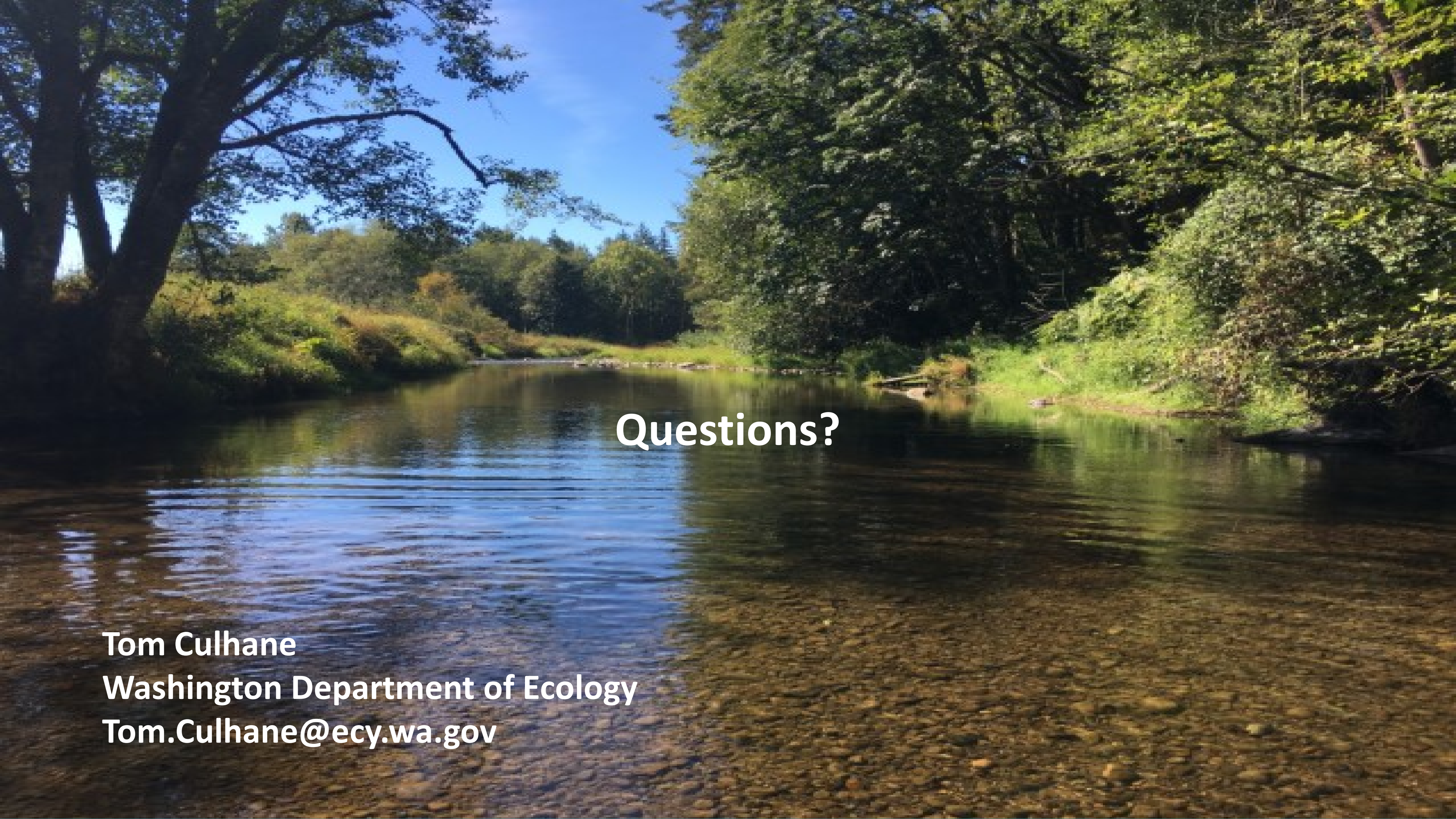
Significance of Scale

When evaluating the hydrologic impacts of new permit-exempt domestic wells or water offset projects on surface water an important consideration is what the magnitude of impacts or benefits will be relative to size of the water bodies.



Context of RCW 90.94

- Structure of mitigation under RCW 90.94 is fundamentally different then mitigation for groundwater permits.
- Typically water right permits require offsetting impacts of groundwater pumping in-time and in place.
- RCW 90.94 allows mitigation for permit-exempt domestic wells to occur anywhere within a WRIA, provided watershed plans achieve a Net Ecological Benefit (NEB).
- Per RCW 90.94 when Ecology reviews plan addendums it will be looking for:
    (1) "actions that the planning unit determines to be necessary to offset potential consumptive impacts to instream flows associated with permit-exempt domestic water use."
    (2) actions that "will result in a net ecological benefit to instream resources within the water resource inventory area."
- This means placing offset projects in places most beneficial to fish is probably more important than understanding specific impacts from permit-exempt domestic well pumping.



Questions?

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