Hydrogeology Concepts and Considerations for RCW 90.94 Streamflow Restoration in WRIA 10 & 12

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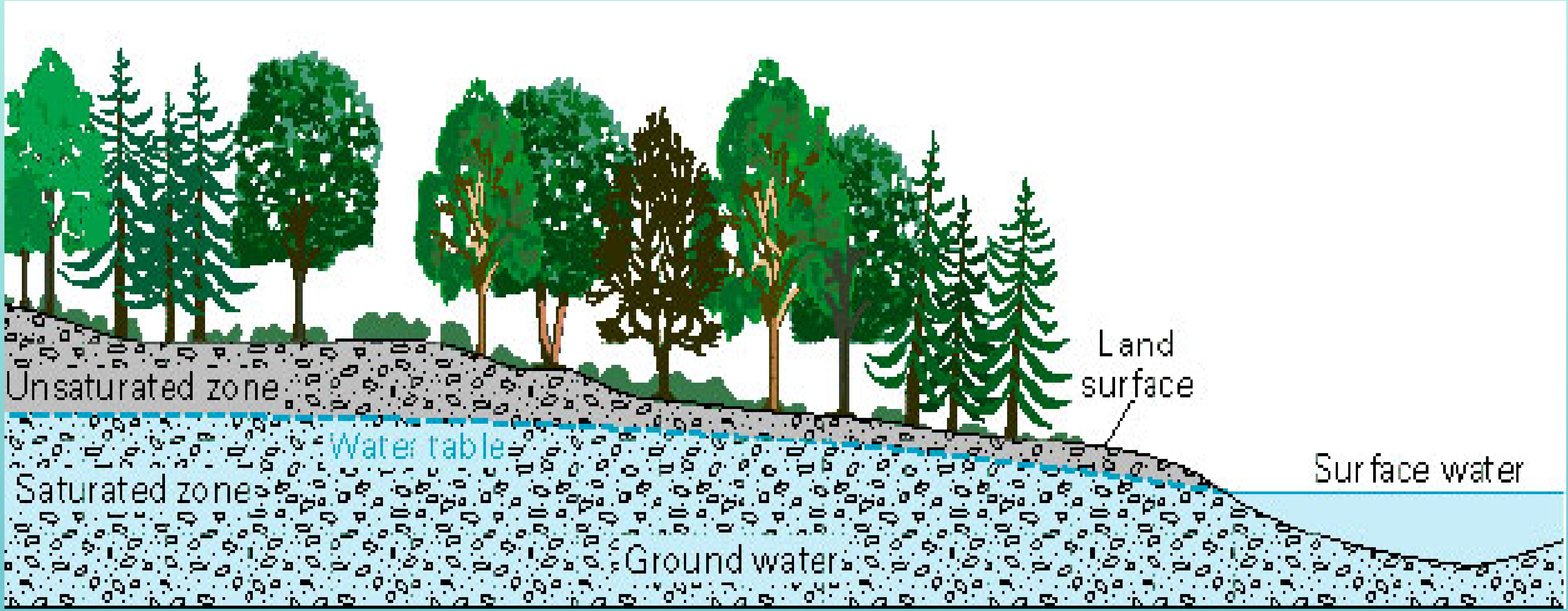
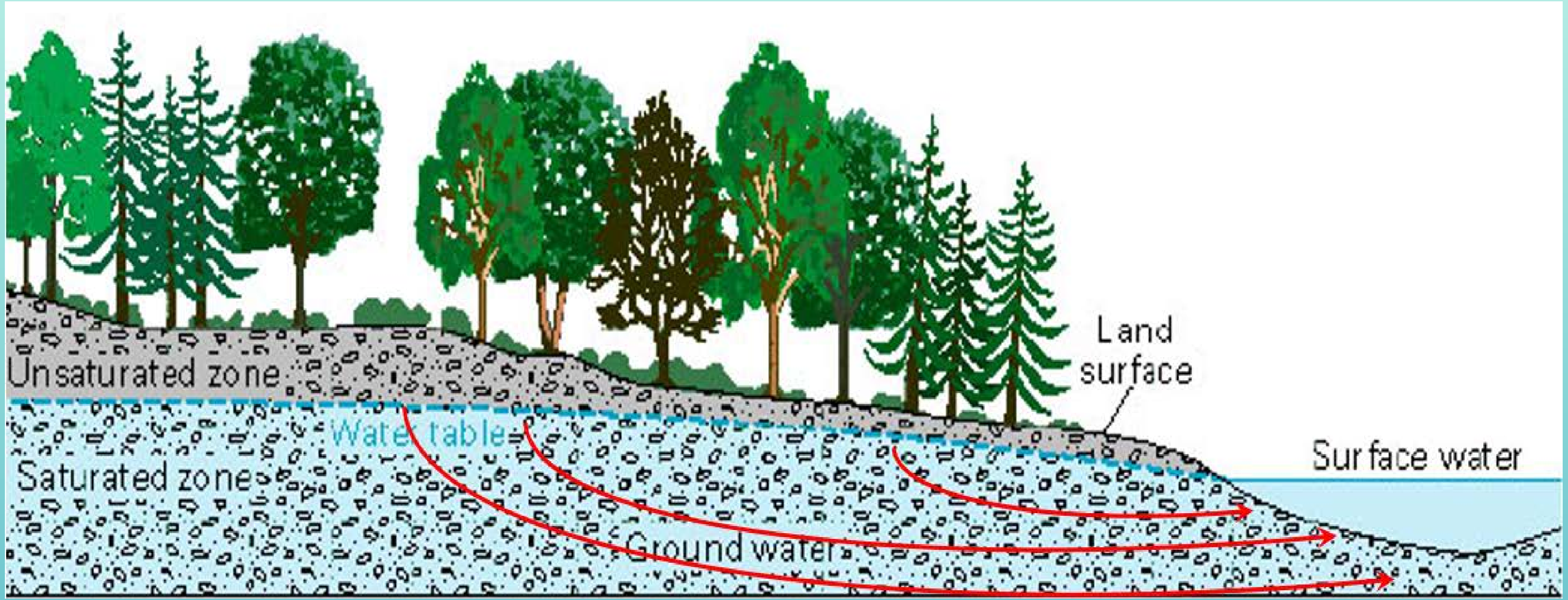
DEPARTMENT OF ECOLOGY State of Washington

- 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

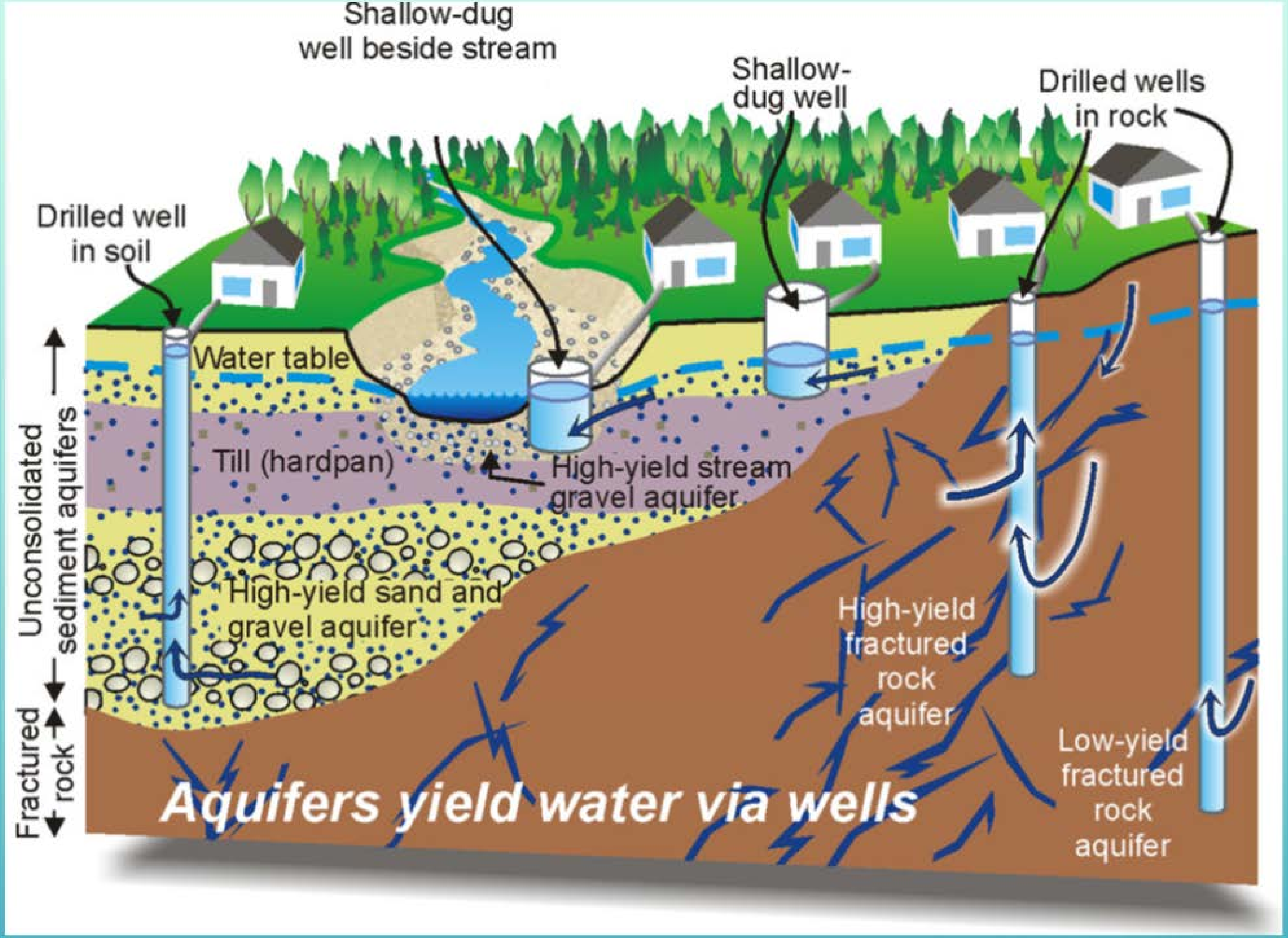


USGS Water Science School

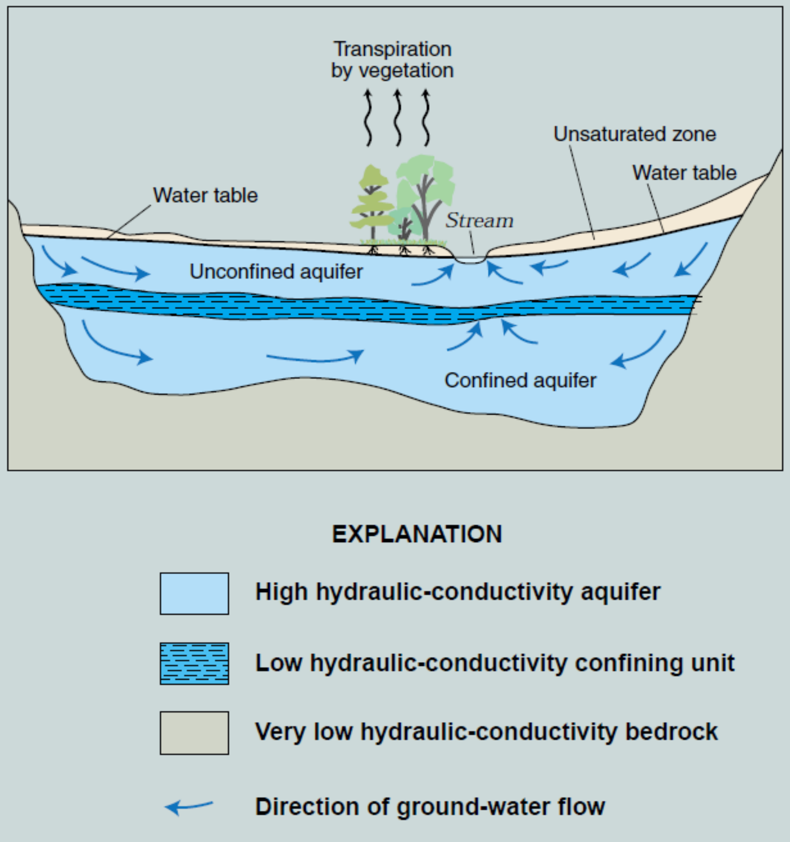
Aquifer -- saturated geologic material permeable enough to yield economical quantities of water

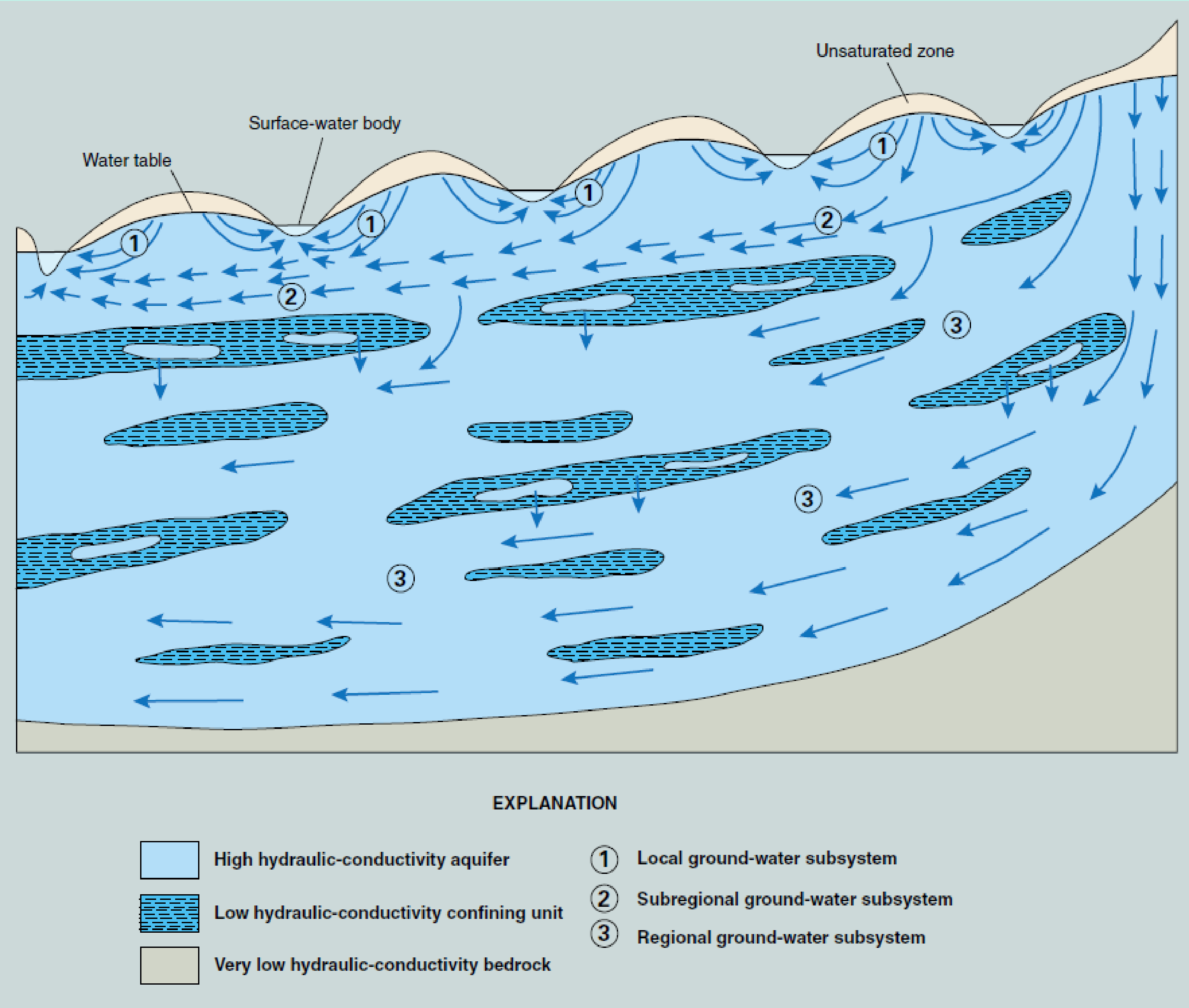
Aquitard -- saturated geologic material with low permeability; well yields low; also called "confining layer"

Confined Aquifer -- saturated material below aquitard permeable enough to transmit useful water quantities



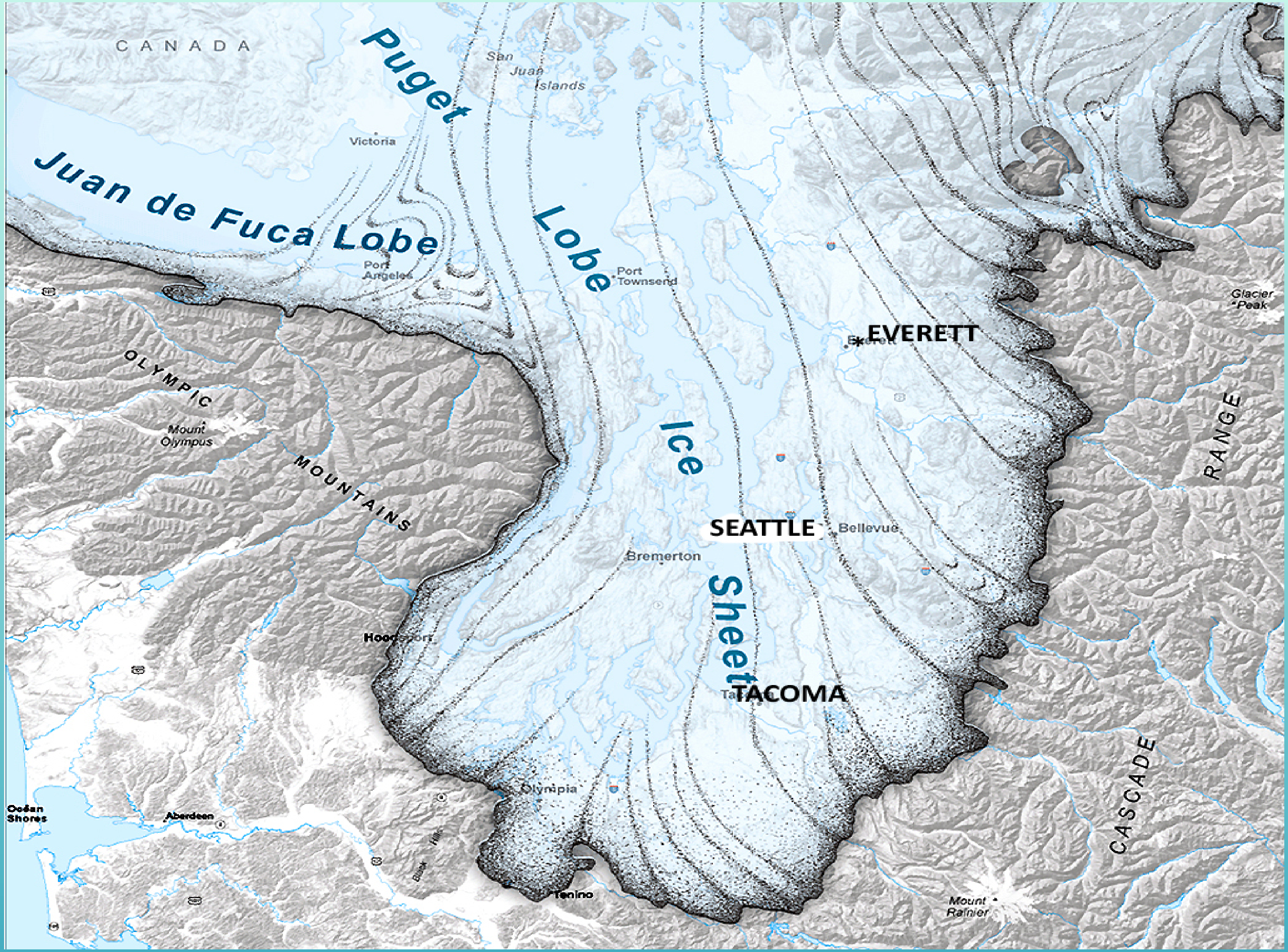
Canadian Geoscience Education Network
https://www.cgenarchive.org/bowen-island-underground.html





USGS Circular 1186

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



Washington Department of Natural Resources

Pierce County Geology

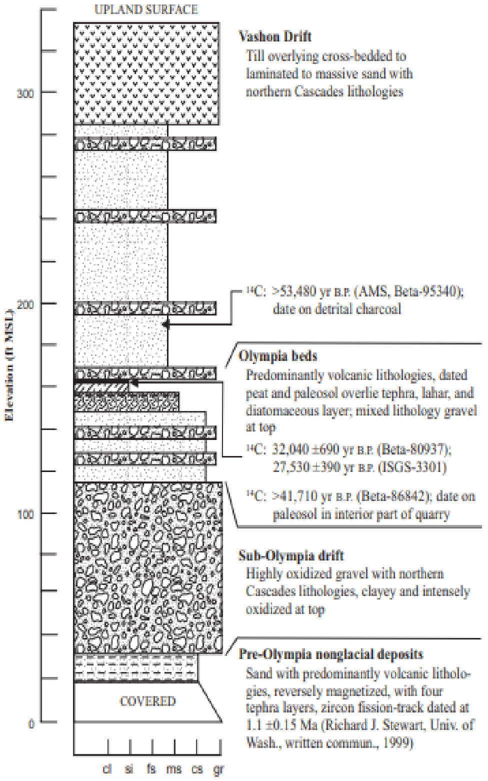
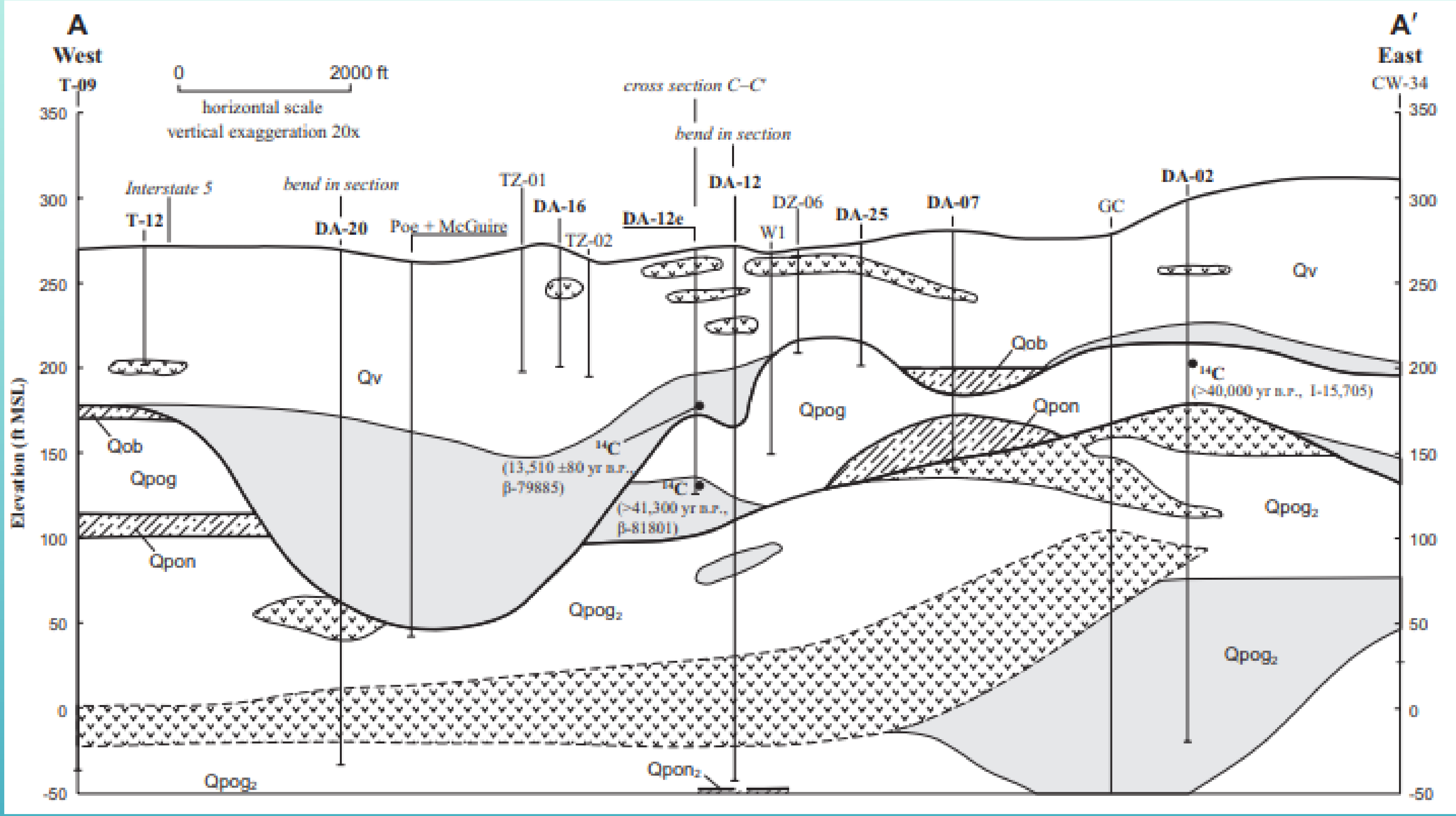
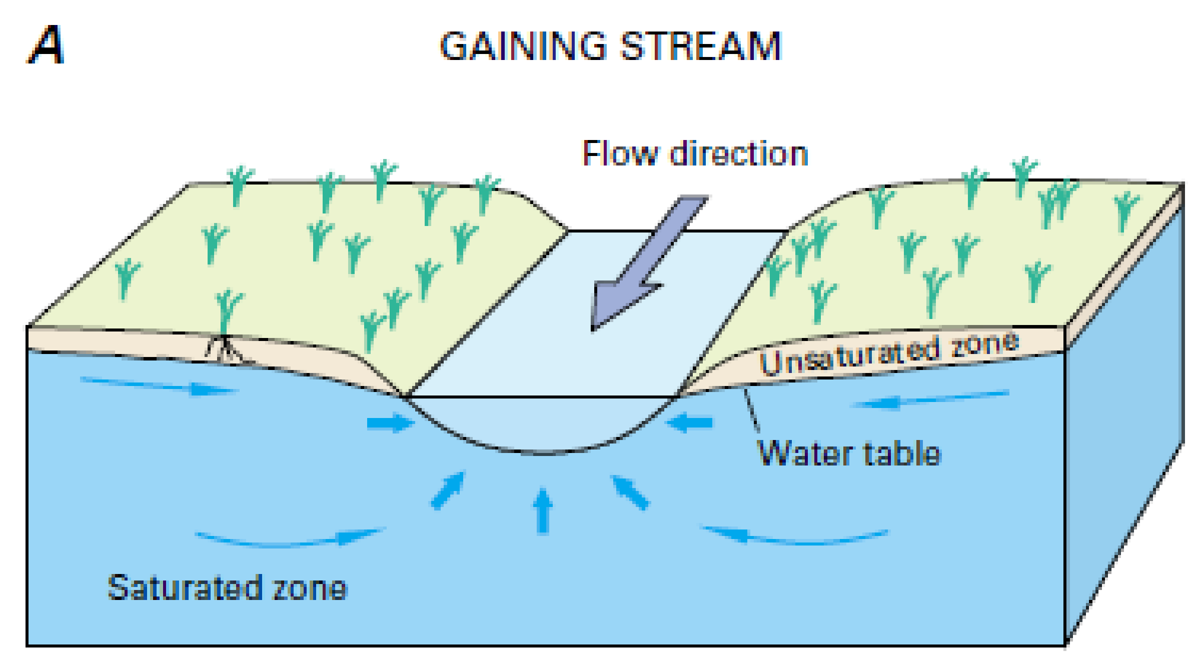


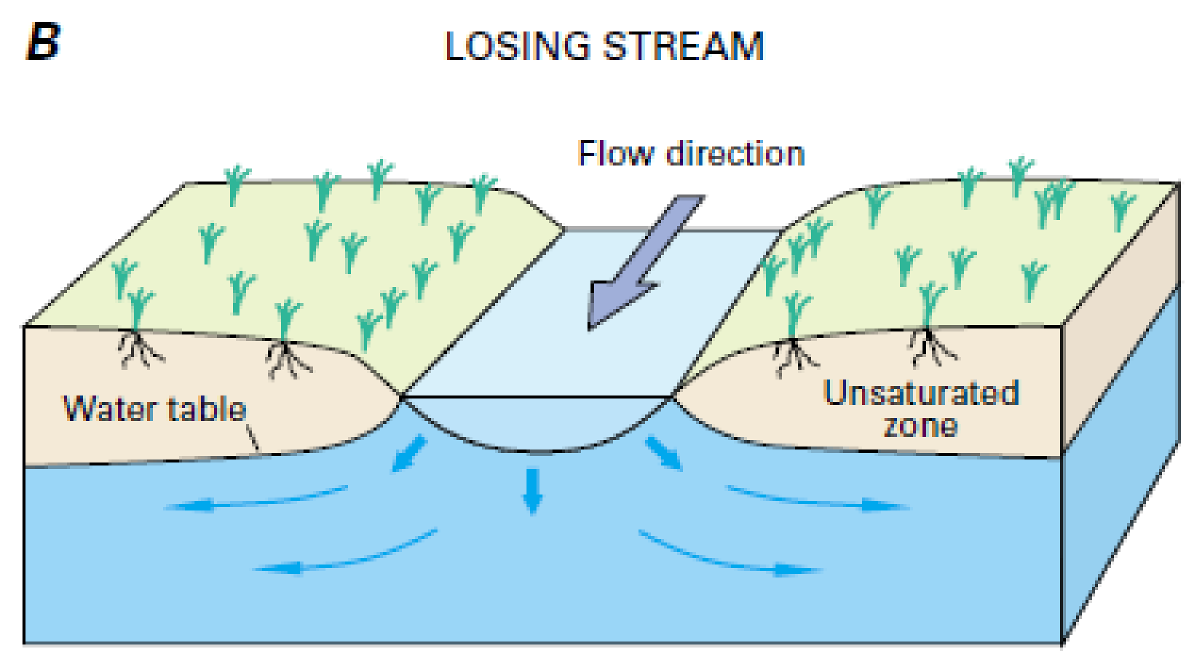
Figure 6. Woodworth quarry composite measured section, Poverty Bay 7.5-minute quadrangle, lat 47.2729 N, long 122.3728 W.



WA DNR Report of Investigations 33

Groundwater – Surface Water Relationships





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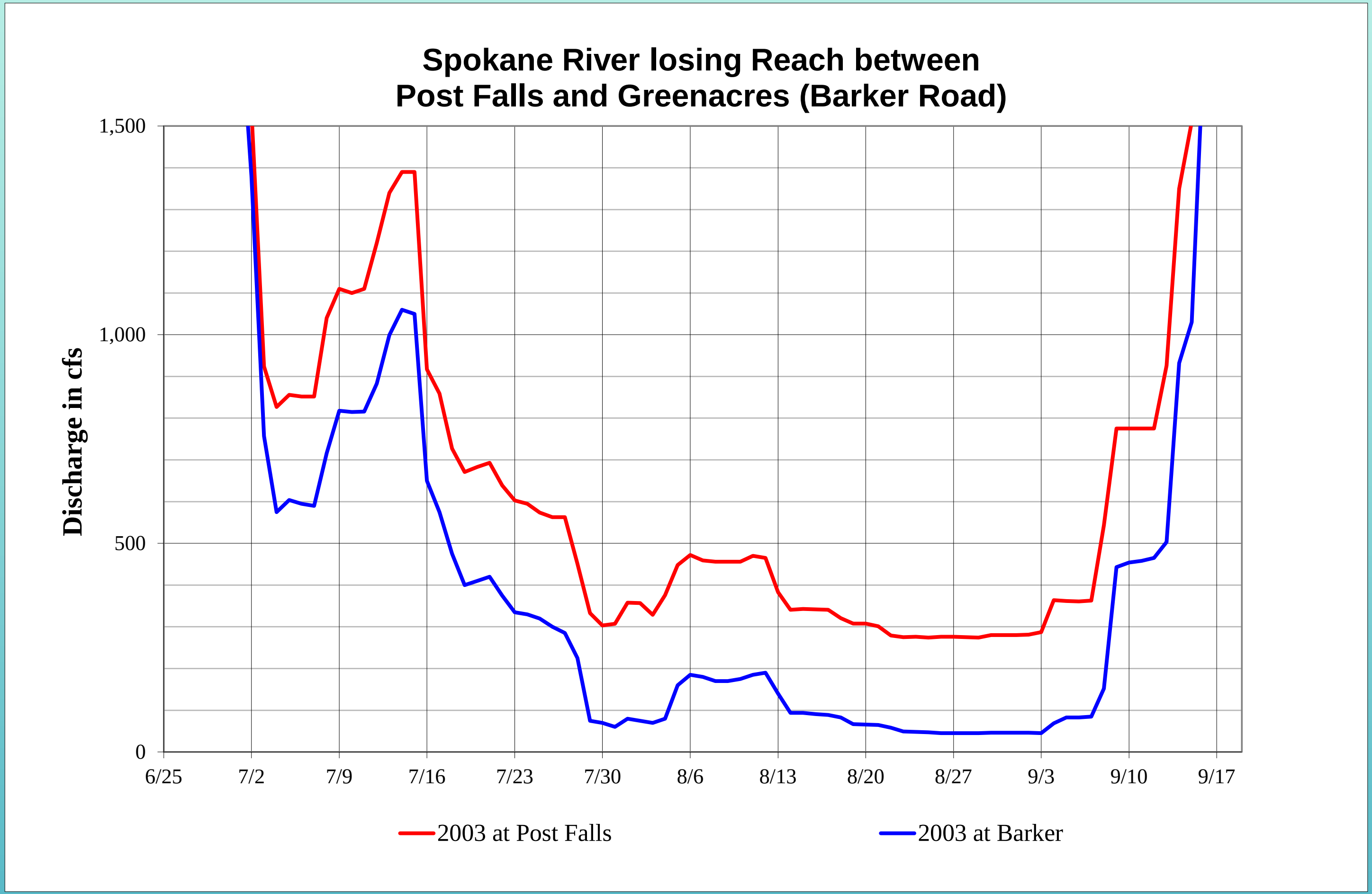
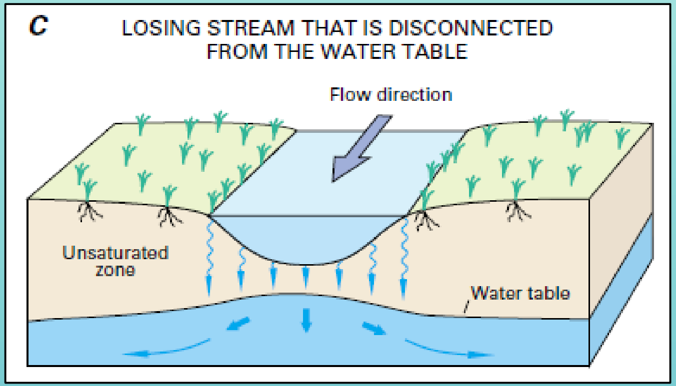




USGS Circular 1186

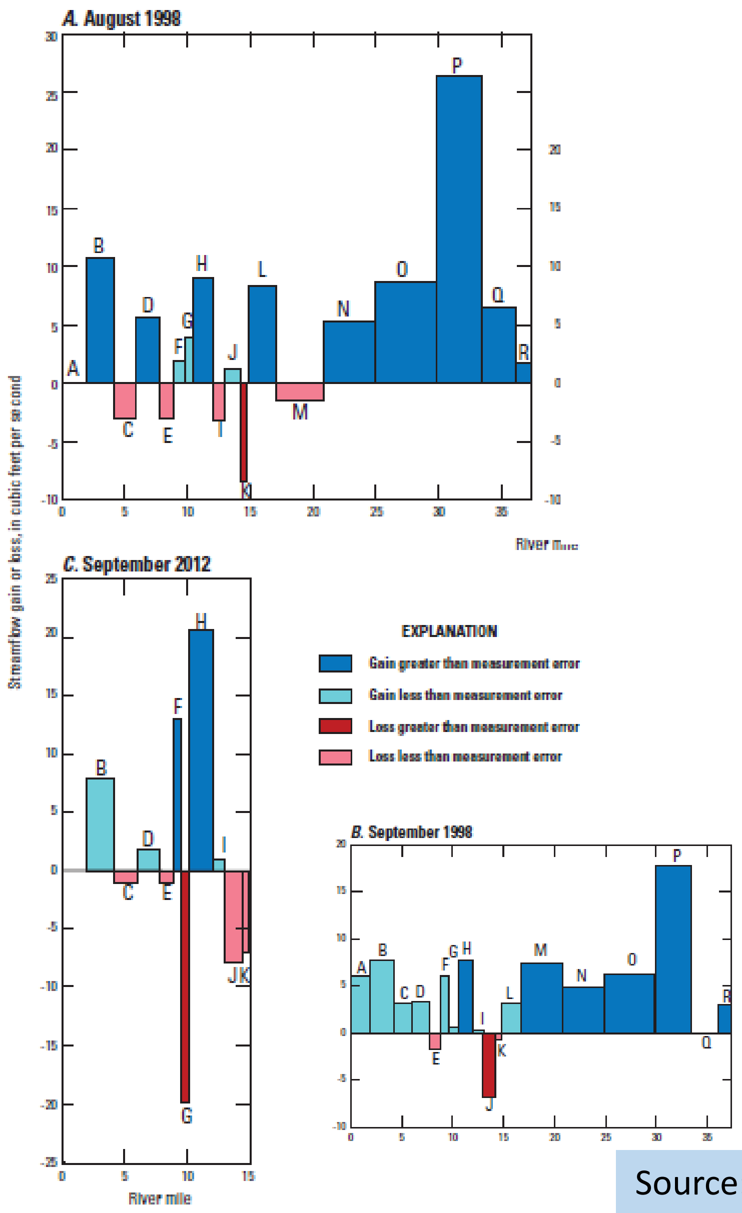


Figure 10. Seepage gains and losses measured during the seepage runs in August 1998 (*A*), September 1998 (*B*), and September 2012 (*C*), South Fork Nooksack River Basin, northwestern Washington.

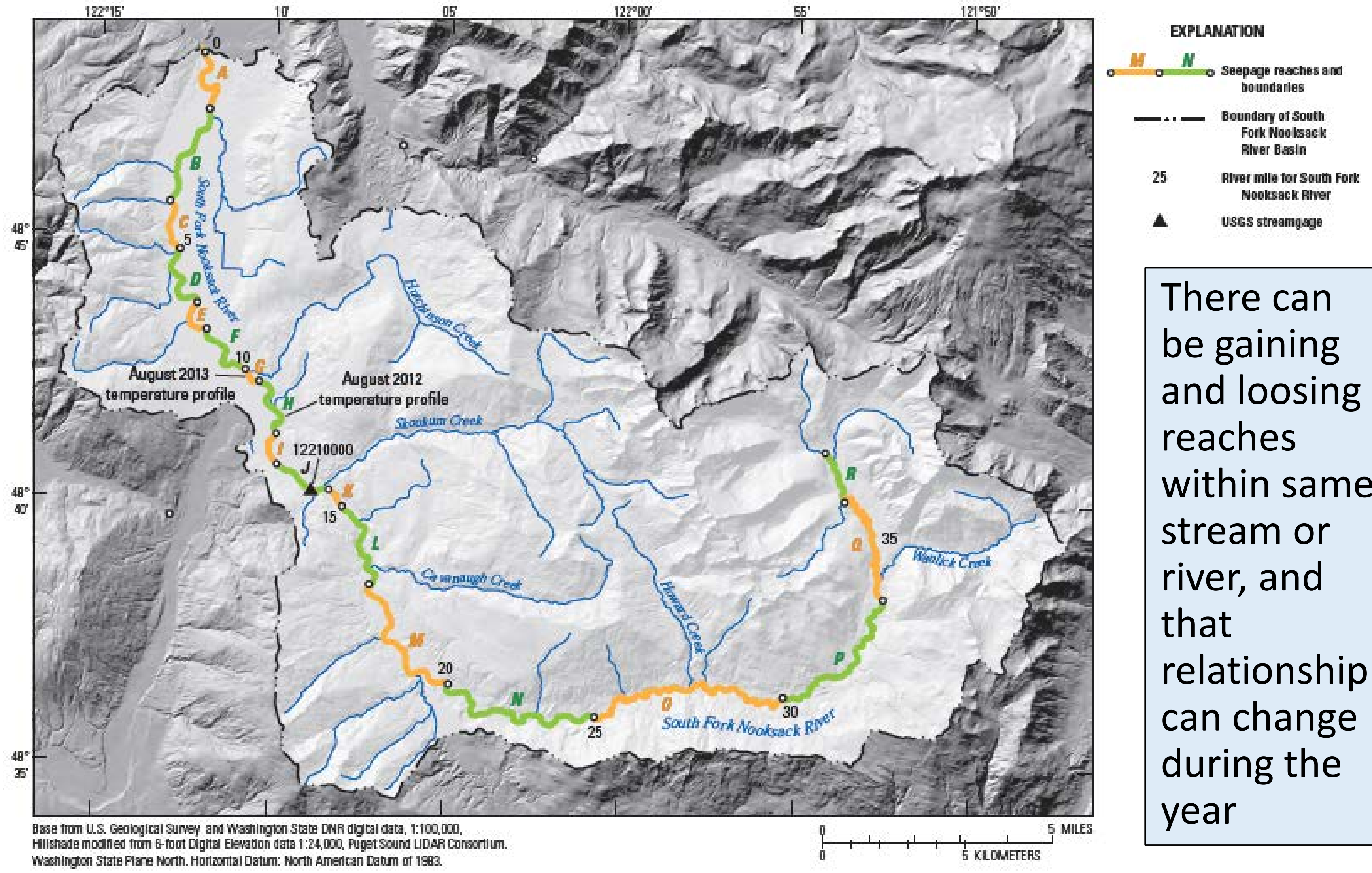


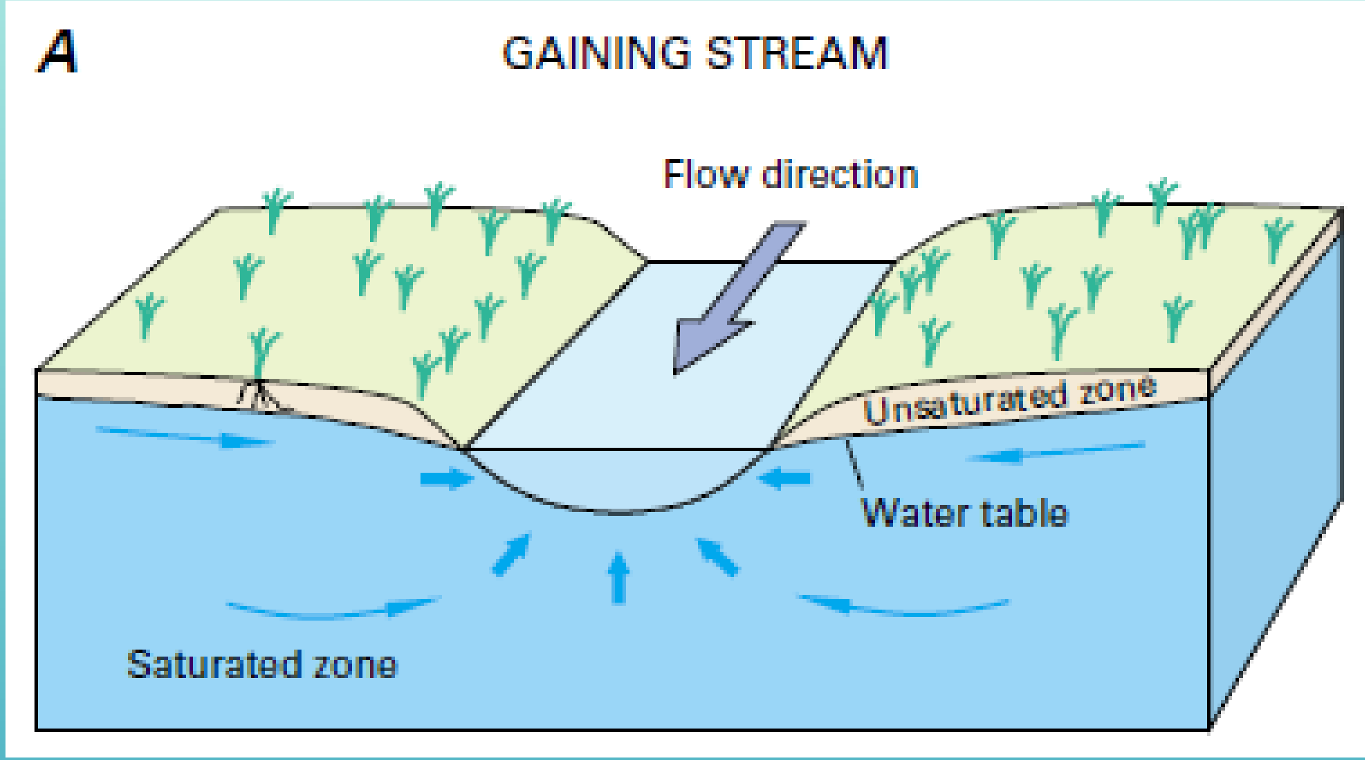
Figure 9. Seepage reaches (A–R) during seepage runs in August and September 1998 and September 2012, South Fork Nooksack River Basin, northwestern Washington.

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

Source: USGS SIR 2014-5221

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

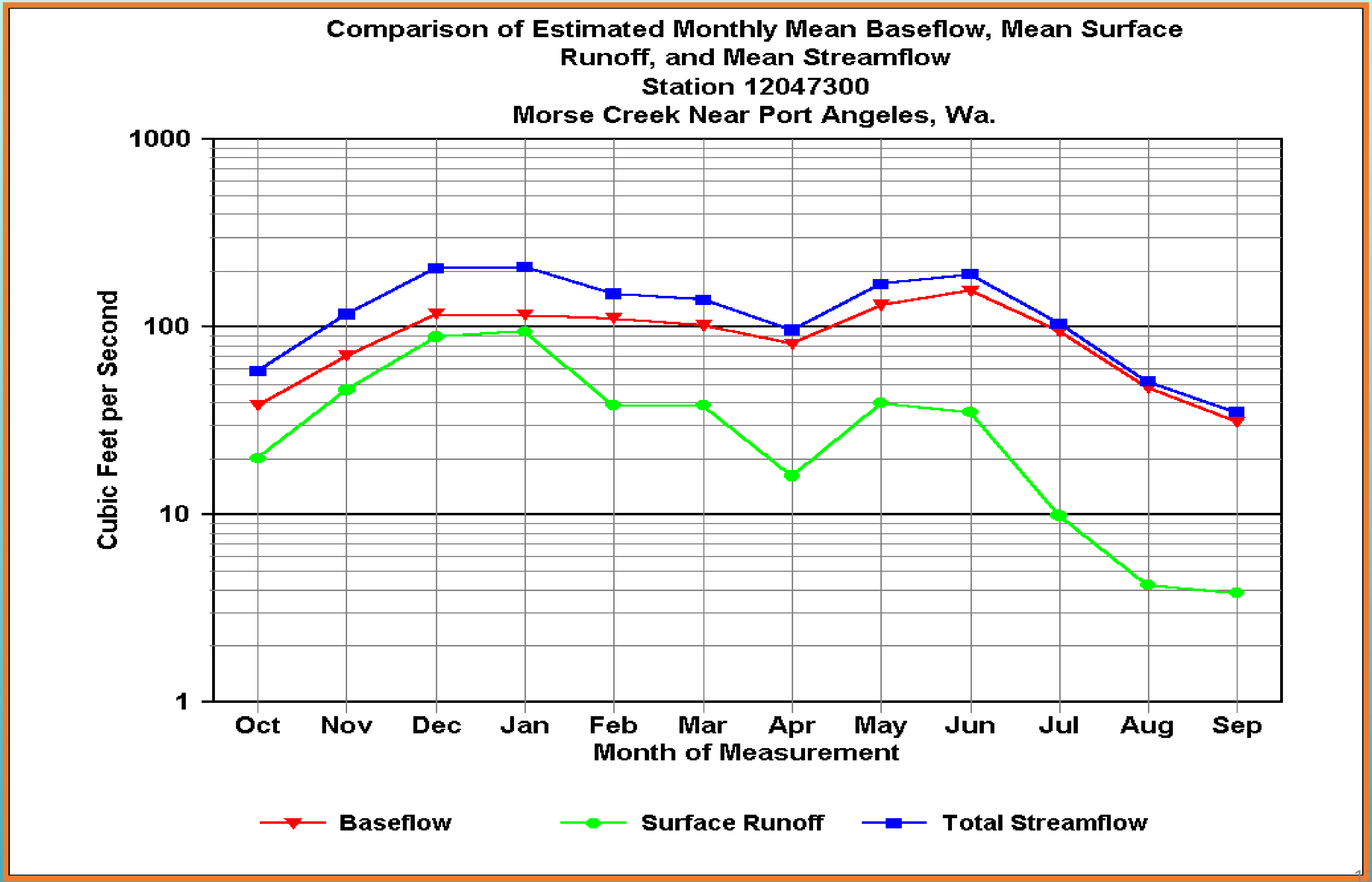
Baseflow: component of streamflow derived from groundwater inflow or discharge.



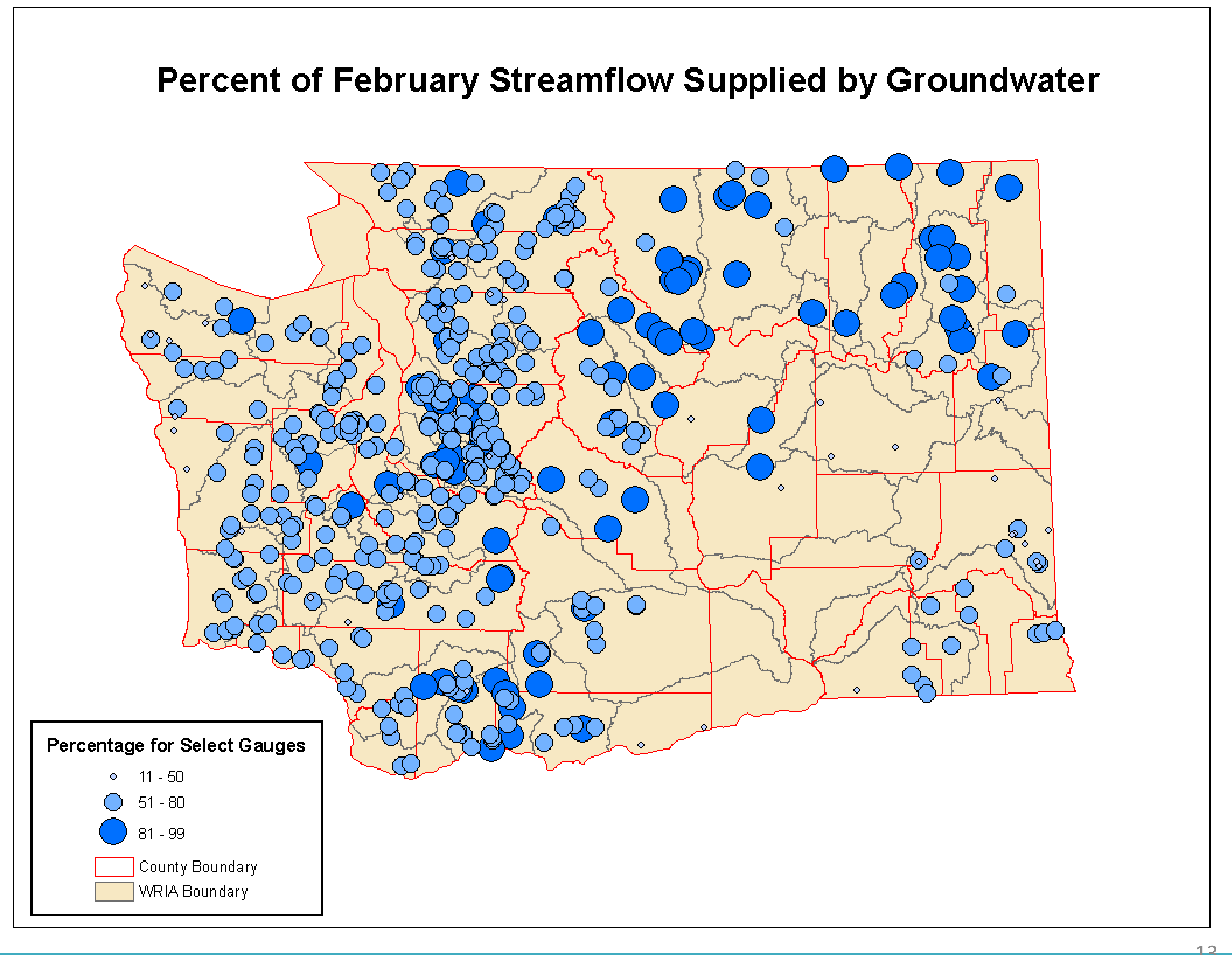
USGS Circular 1186

Baseflow is important for both water quantity and temperature.

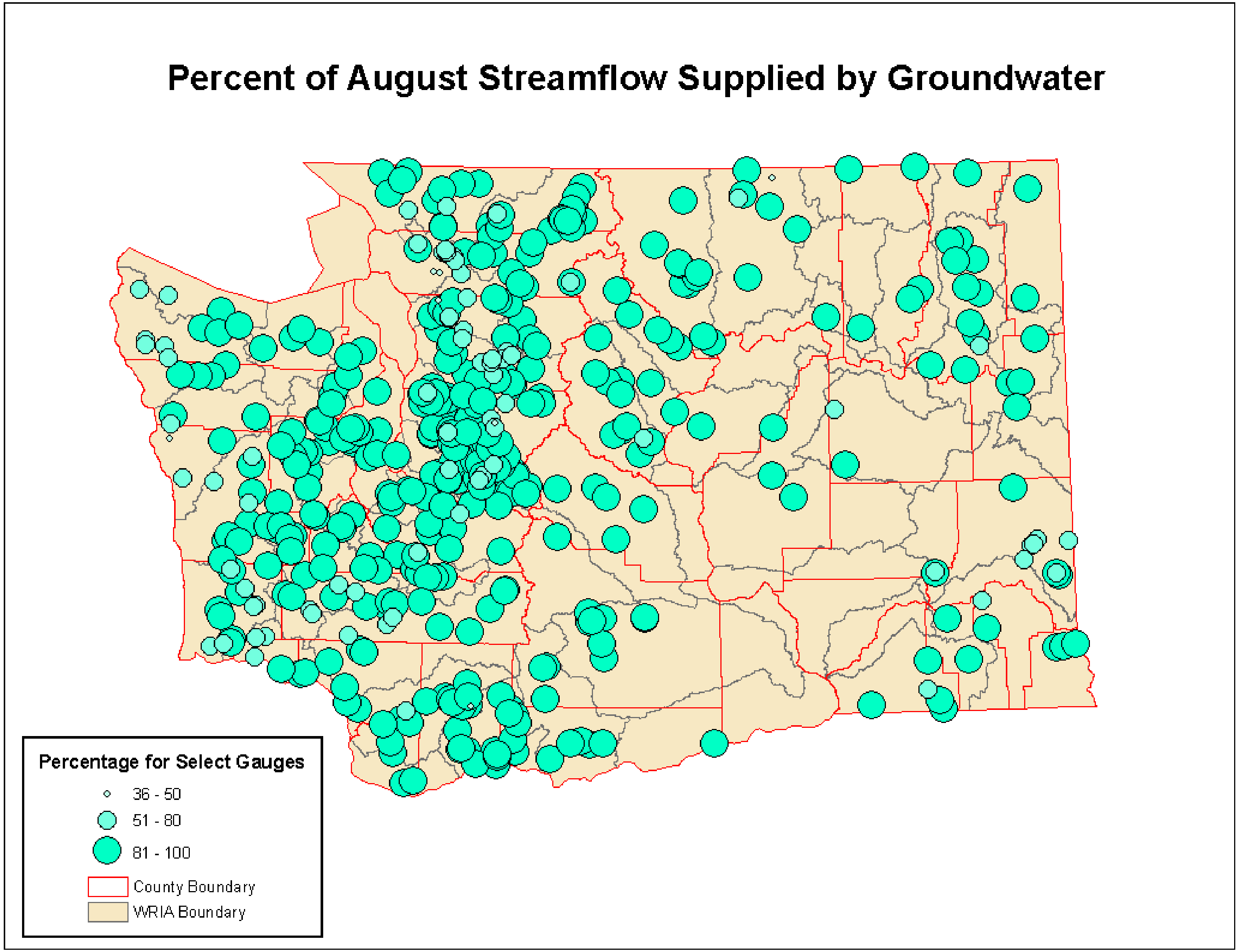
Note: vertical axis presented in **log scale**

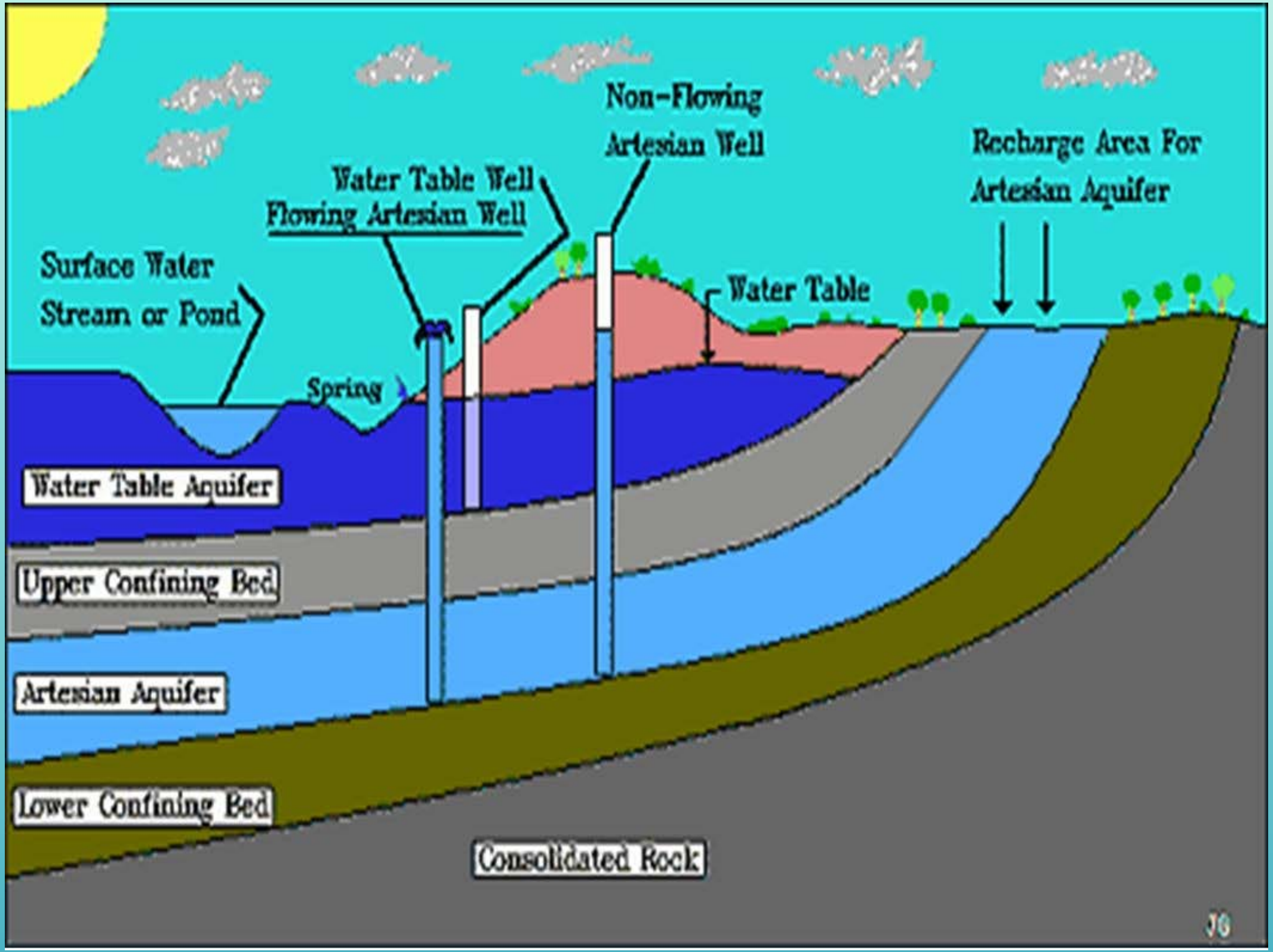


Baseflow maintains summer streamflow throughout most of Washington



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

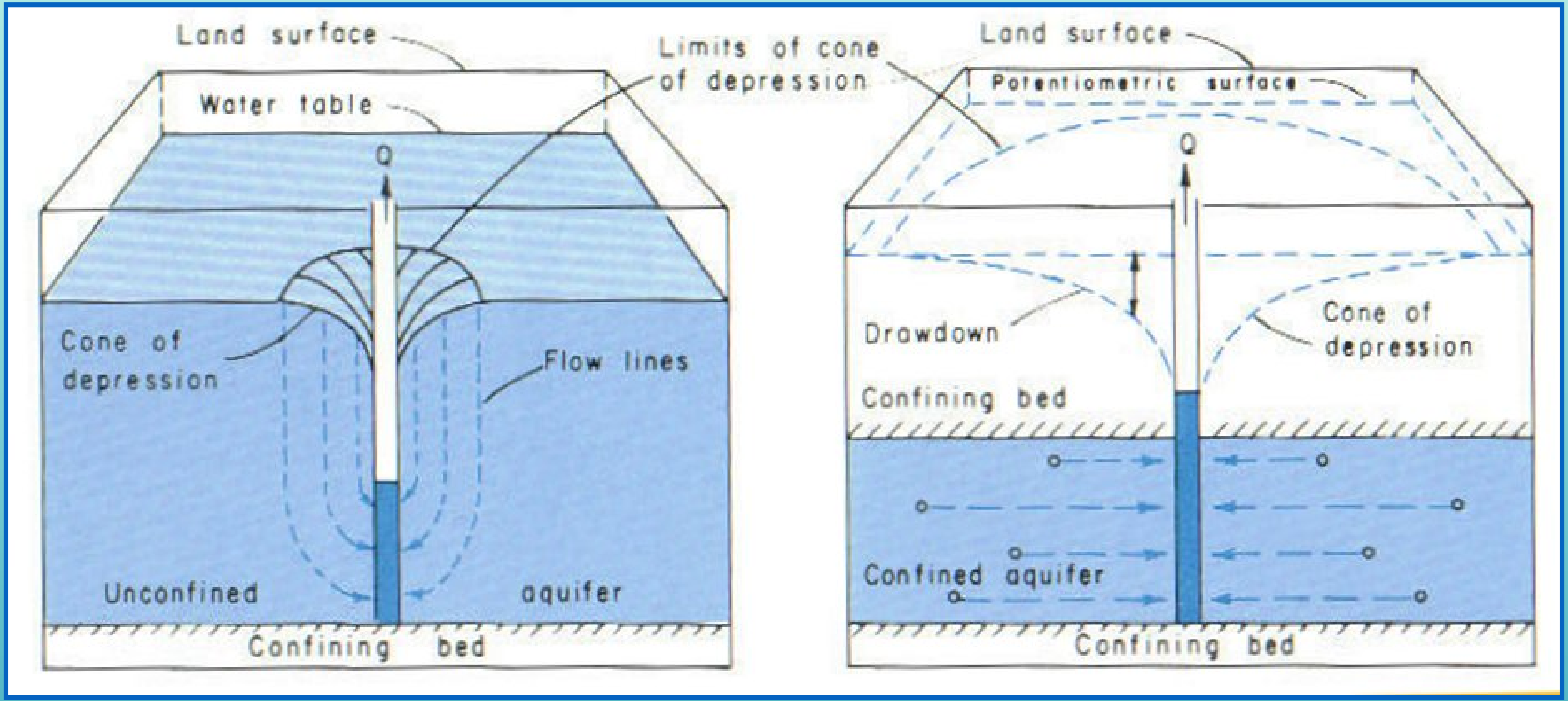




http://www.dennisalbert.com/AAADrilling/Aquafier.htm

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

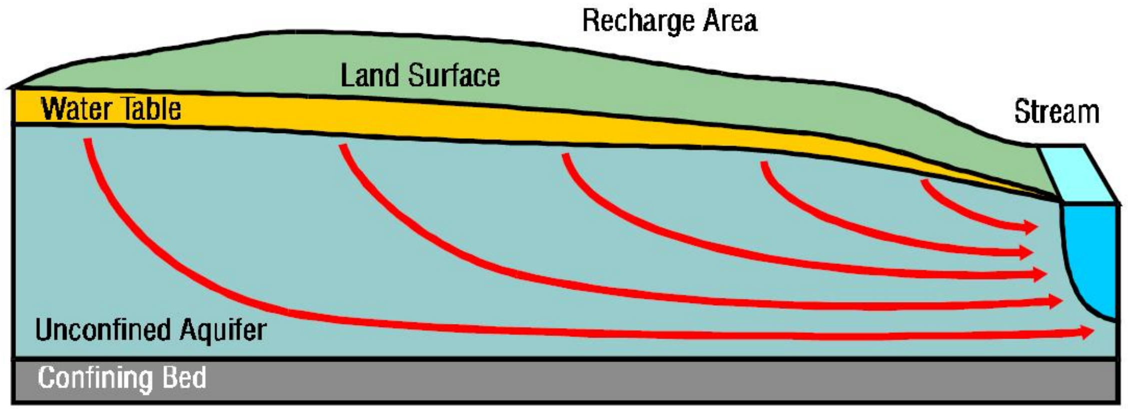
Pumping groundwater from a well (conservation of mass) always causes…

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

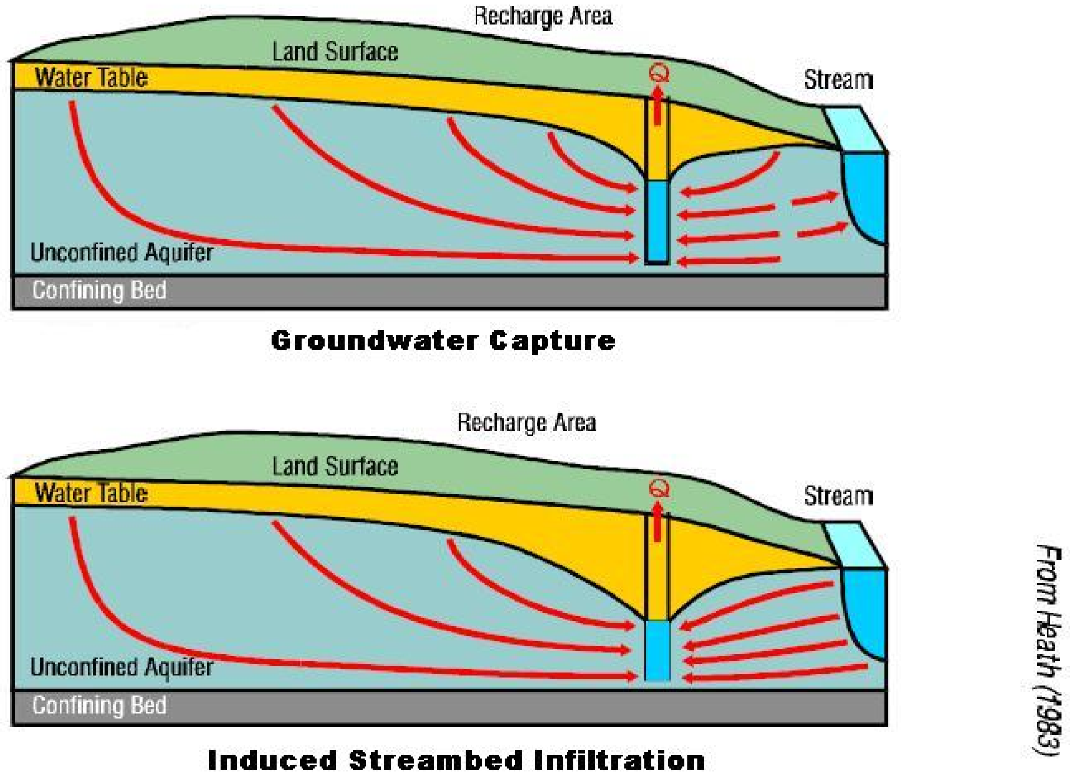
(2) diversion to the pumping well of groundwater that was moving slowly to its natural, possibly distant, area of discharge.

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)



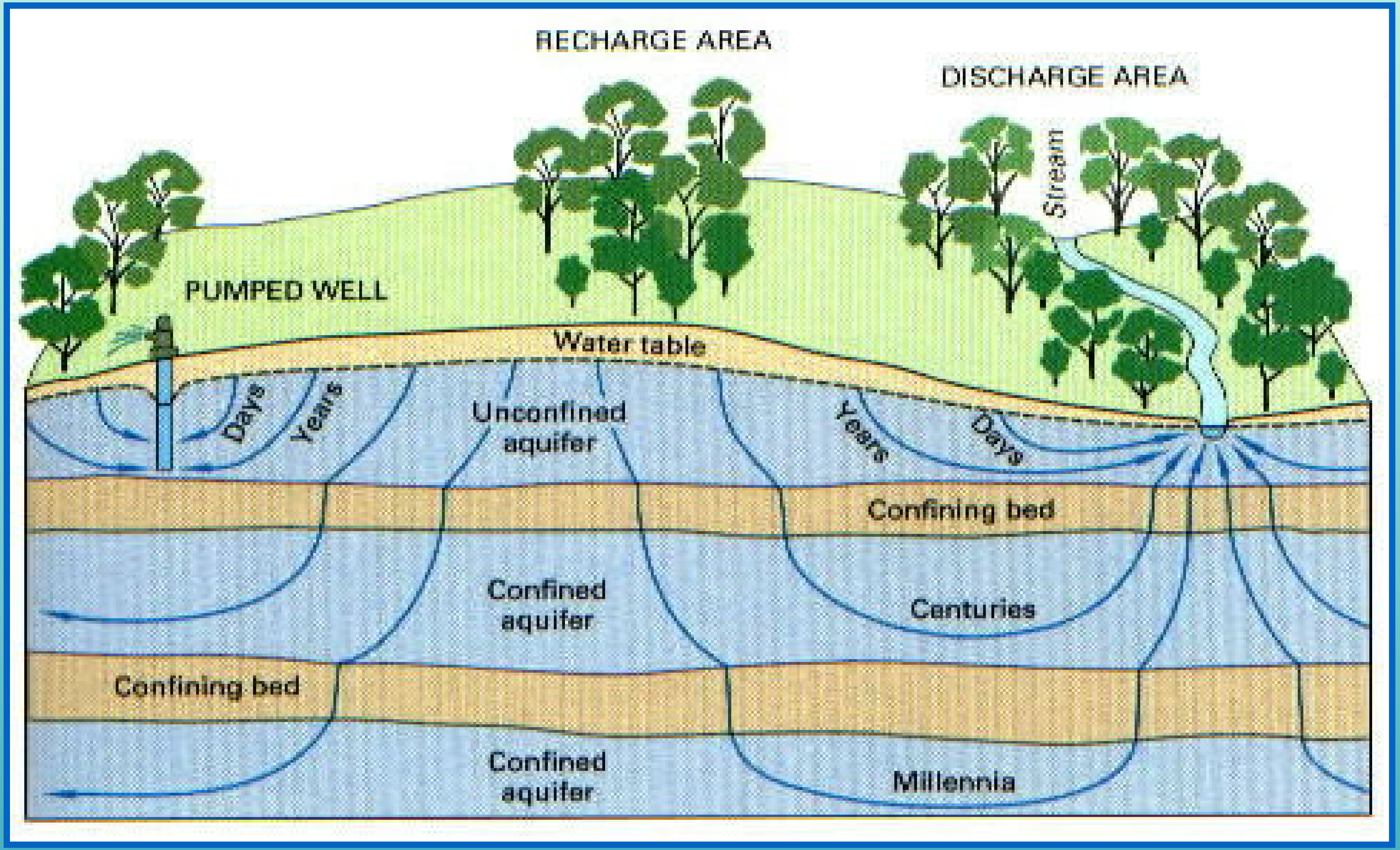
Groundwater Capture

Induced Streambed Infiltration

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.

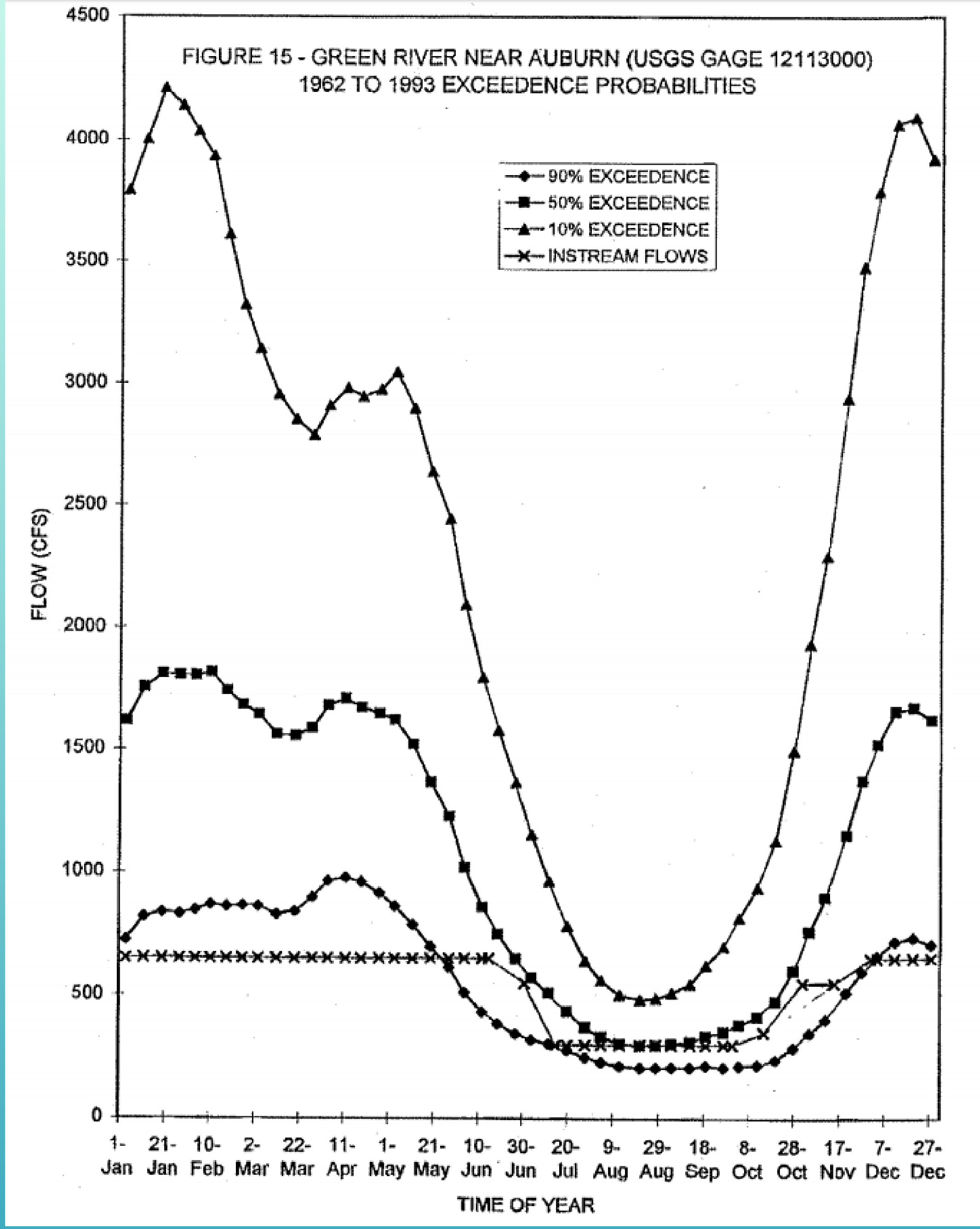
Groundwater travel time is not an indication of the speed at which pumping effects propagate



USGS C1139

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

or



WRIAs 10 & 12 Hydrogeology

Significant WRIAs 10 & 12 Hydrogeology Studies

Hydrogeologic Framework, Groundwater Movement, and Water Budget in the Chambers-Clover Creek Watershed and Vicinity, Pierce County, Washington, USGS Scientific Investigations Report (SIR) 2010-5055 (Savoca, et al., 2010)

Numerical Simulation of the Groundwater-Flow System in the Chambers–Clover Creek Watershed and Vicinity, Pierce County, Washington, USGS SIR 5086 (Johnson, et al., 2011)

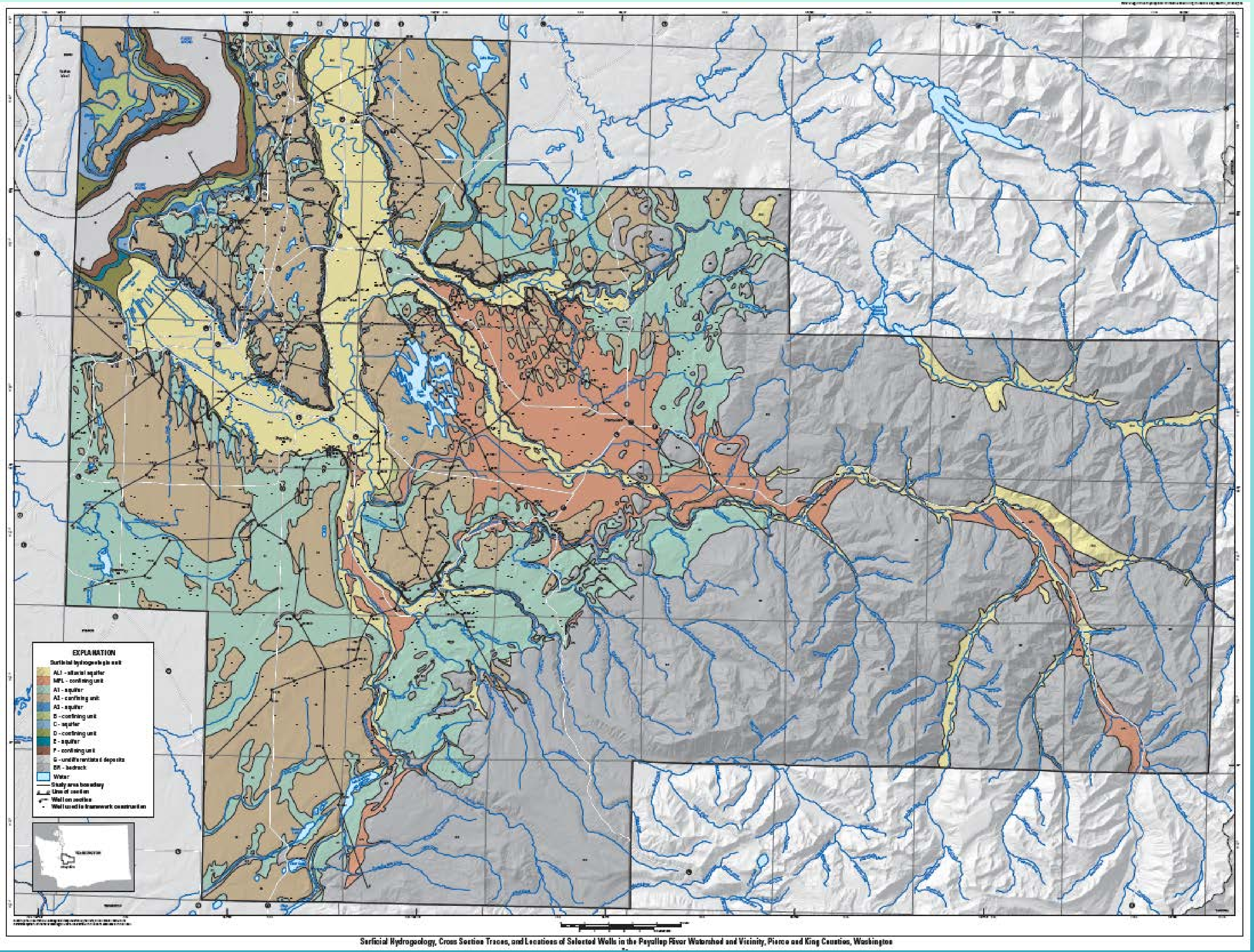
Hydrogeologic Framework, Groundwater Movement, and Water Budget in the Puyallup River Watershed and Vicinity, Pierce and King Counties, Washington, SIR 2015-5068, (Welch, et al., 2015)

Chambers-Clover Technical Assessment, Final Report. 2003 report prepared for Tacoma-Pierce County Health Department by consultants with assistance of Chambers-Clover Planning Unit

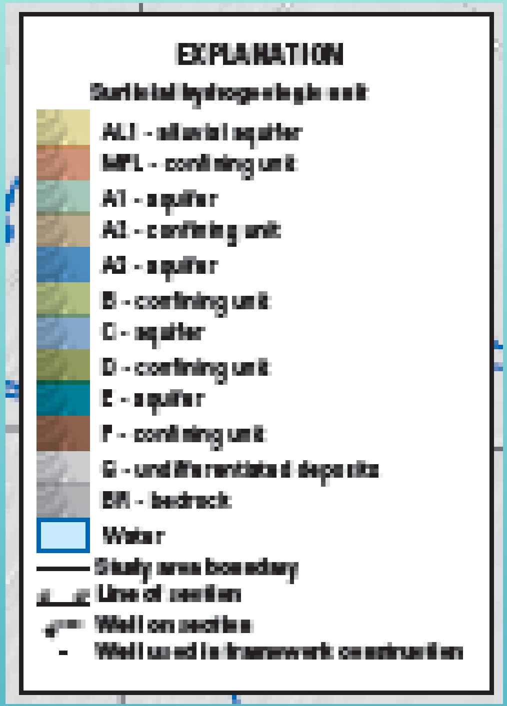
Puyallup watershed hydrostratigraphic and geologic and units.

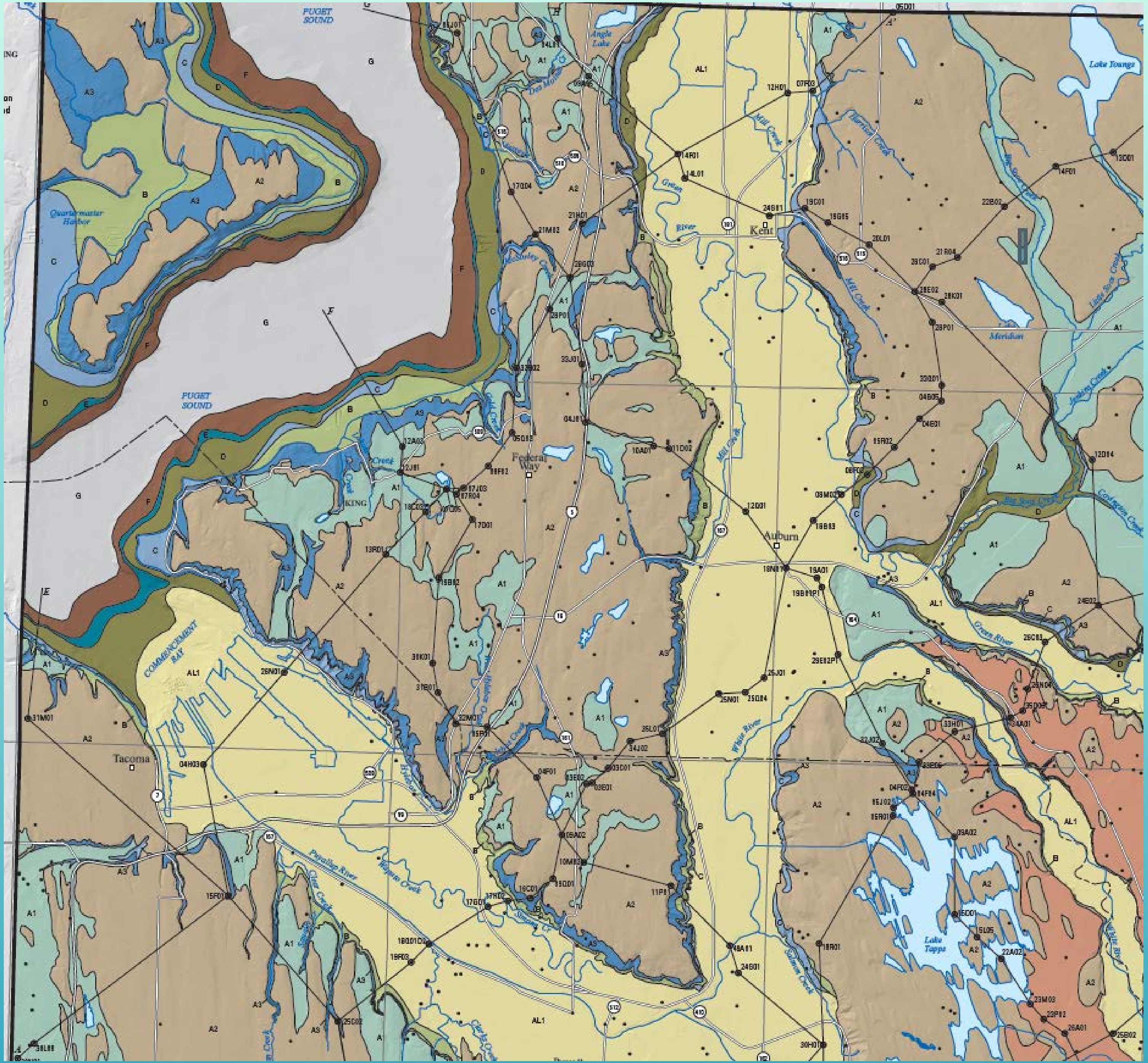
Period	Epoch	Hydrogeologic units defined in this study	Geologic units (from K.G. Troost, U.S. Geological Survey, written commun., 2008)	Geologic units in Schasse (1987) and Walsh (1987)	Hydrostratigraphic units in Robinson & Noble, Inc., and others (2003)	Stratigraphic units
Quaternary	Holocene, Pleistocene	AL1 upper alluvial aquifer	Qal, af, Qp	Qa,	Aquifer A: includes Steilacoom gravel, Vashon Till, Vashon advance outwash, Esperance Sand	Recent Holocene alluvium
		MFL confining unit		Qvl(o), Qvl(e)		Volcanic mudflow-lahar deposits
		AL2 lower alluvial aquifer				Older Holocene alluvium and ancient deltaic deposits beneath MFL within major river valleys (Dragovich and others, 1994)
		A1 aquifer	Qal, Qv, Qvr, Qvry, Qvs, Qw	Qa, Qgd, Qgo, Qgog, Qgos, Qp		Vashon Drift (Steilacoom gravel, recessional outwash
		A2 confining unit	Qvt, Qvi, Qvrl	Qgm, Qgt, Qgl		Vashon Drift (till, moraine, recessional ice-contact, and lacustrine deposits)
		A3 aquifer	Qva, Qpfc	Qga		Vashon Drift (advance outwash)
		B confining unit	m, af, Qal, Qb, Qf, Qls, Qns, Qob, Qpdc, Qpf, Qpoc, Qpon, Qtf, Qvlc, Qwbc	Qc(k)	Layer B	Olympia Beds (Kitsap Formation), Lawton Clay
		C aquifer	Qpog, Qpogc	Qgp	Aquifer C	Salmon Springs Drift, Penultimate Drift, Hayden Creek Drift, Wingate Hill Drift
		D confining unit			Layer D	Puyallup Formation
		E aquifer			Aquifer E	Stuck Drift
		F confining unit			Layer F	Alderton Formation
		G undifferentiated deposits			Aquifer G	Orting Drift and older deposits
Tertiary	Miocene to Eocene	Bedrock unit		Qap, Qap(h), Qapt(h), Qap(wh), Qapt(wh), and all pre-Quaternary deposits		Basement confining unit and some alpine glacial deposits

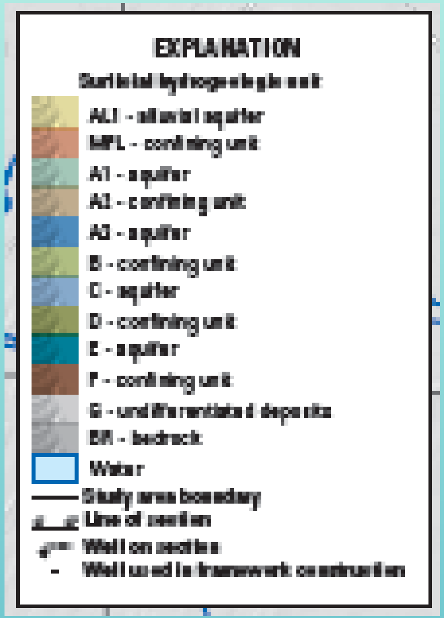
USGS SIR 2015-5068



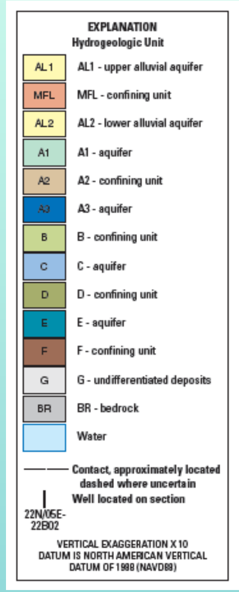
From USGS Puyallup River Watershed hydrogeologic characterization (USGS SIR 2015-5068)



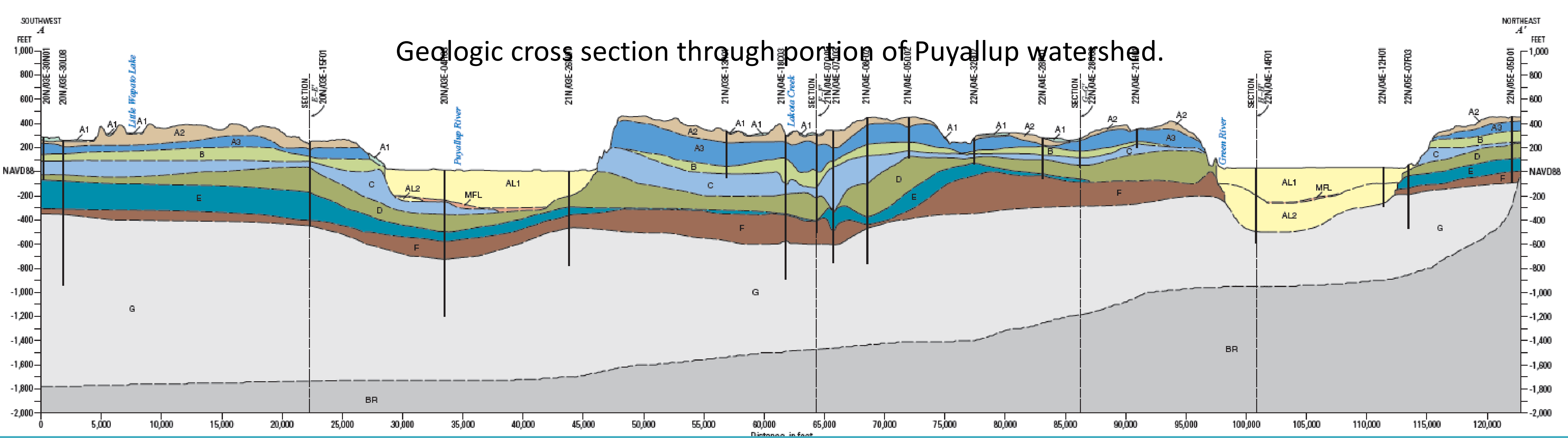




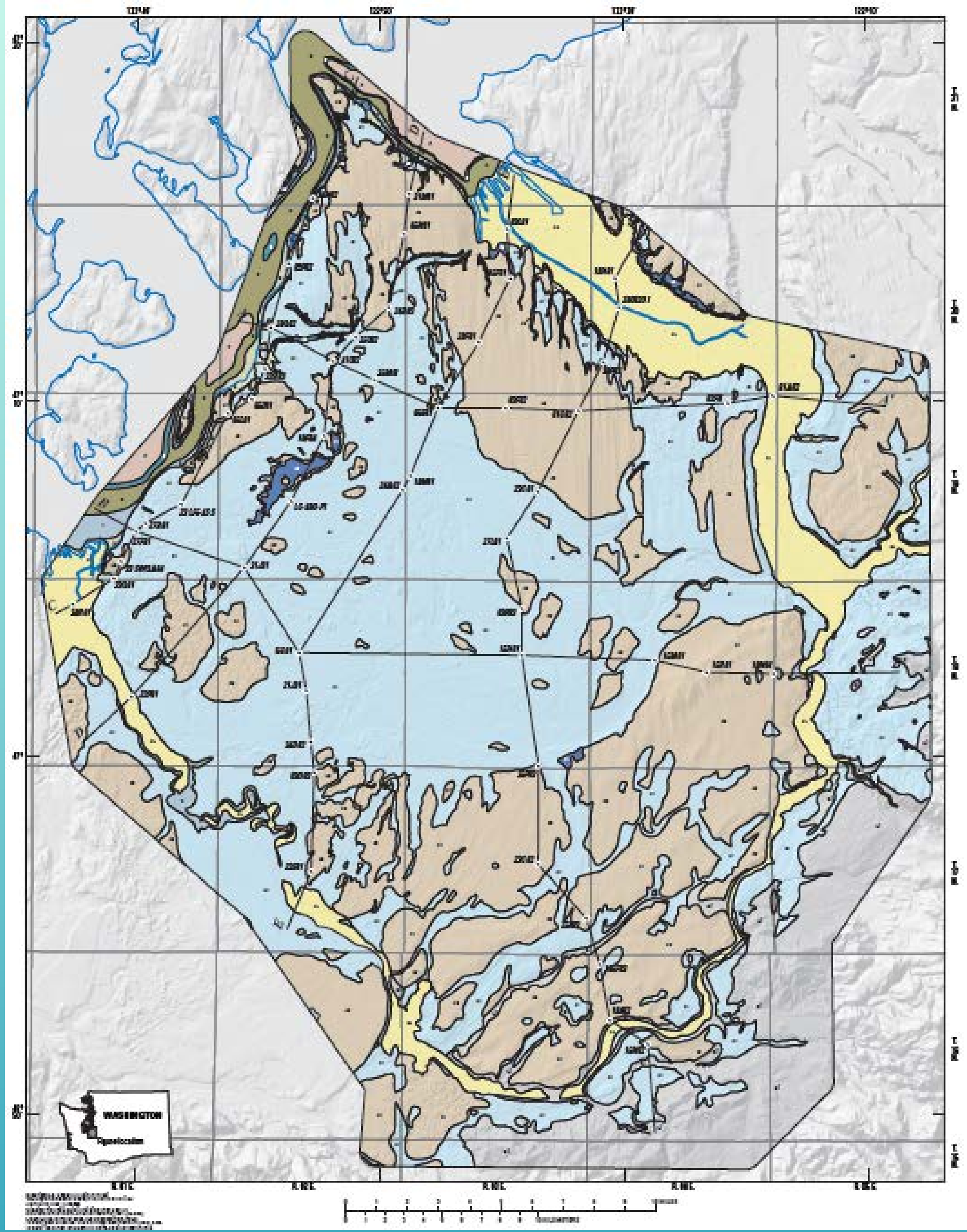
USGS SIR 2015-5068



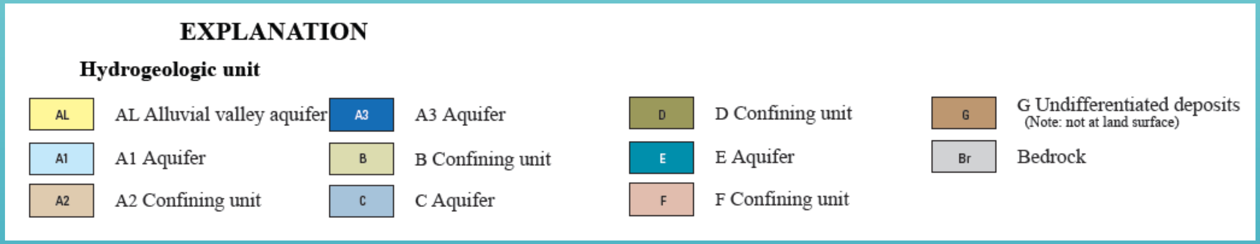
Geologic cross section through portion of Puyallup watershed.



USGS SIR 2015-5068



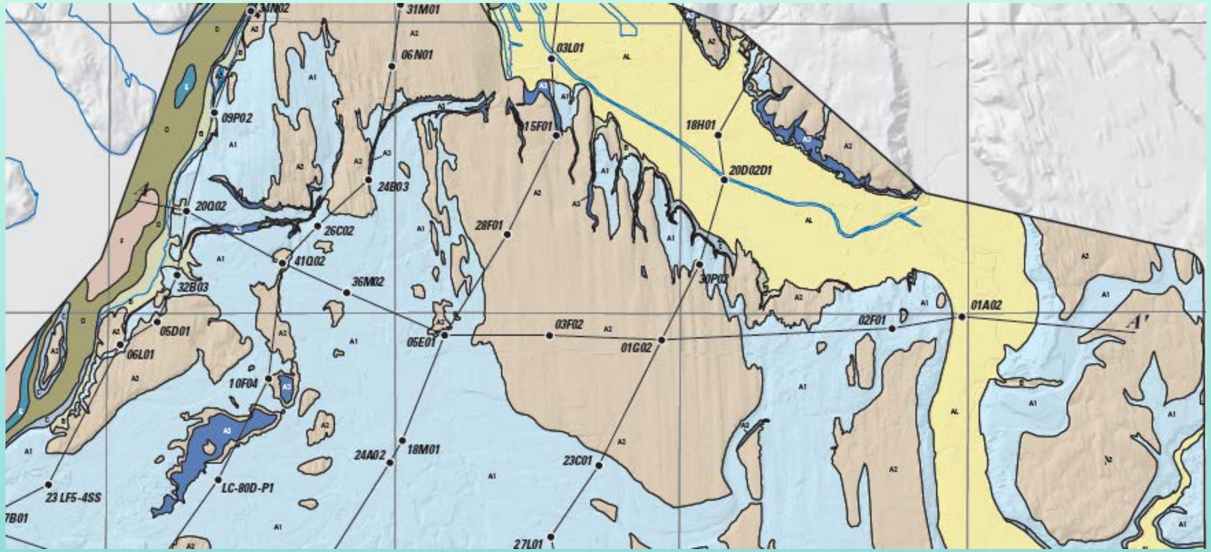
From USGS Chambers-Clover Creek watershed hydrogeologic characterization (USGS SIR 2010-5055)



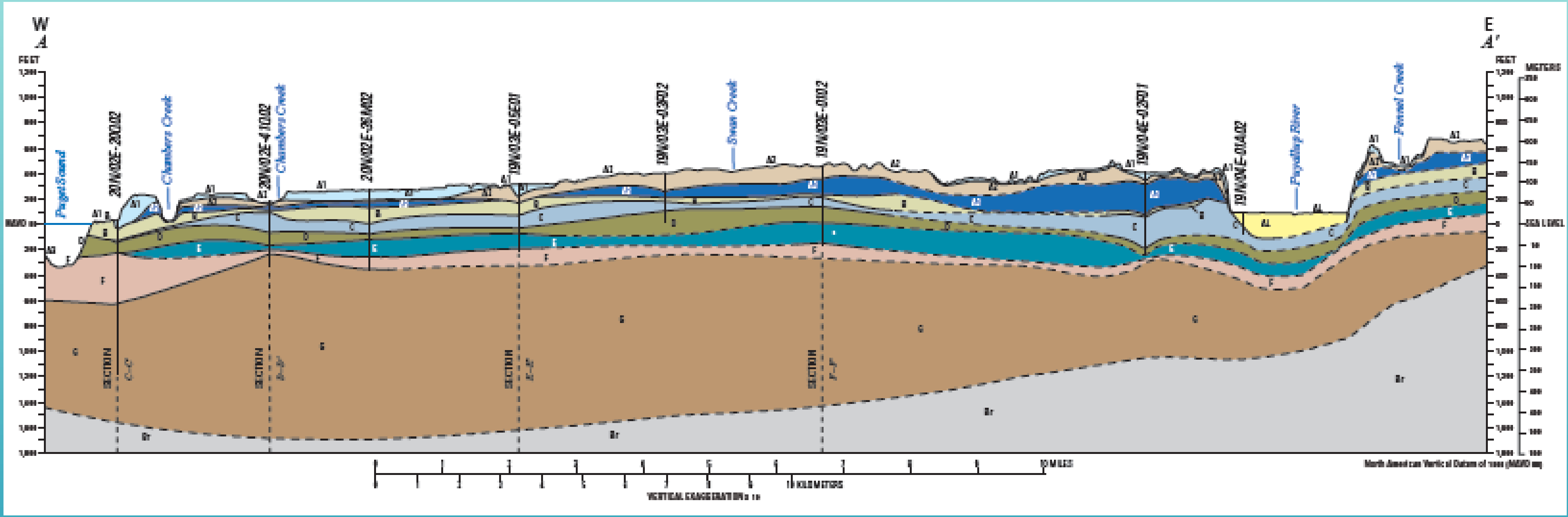
EXPLANATION

Hydrogeologic unit

AL — AL Alluvial valley aquifer	A3 — A3 Aquifer	D — D Confining unit	G — G Undifferentiated deposits (Note: not at land surface)
A1 — A1 Aquifer	B — B Confining unit	E — E Aquifer	Br — Bedrock
A2 — A2 Confining unit	C — C Aquifer	F — F Confining unit	

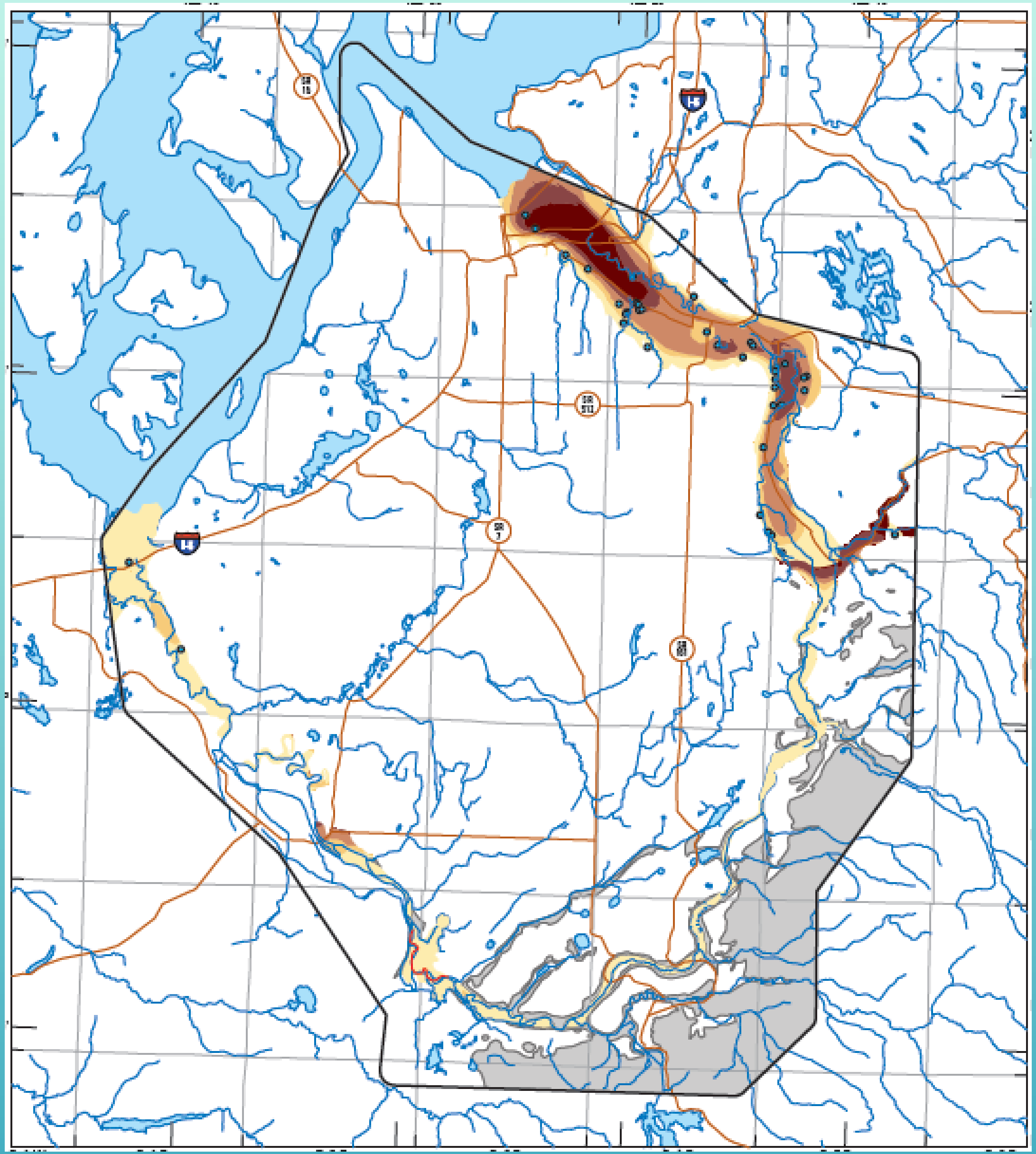


USGS SIR 2010-5055



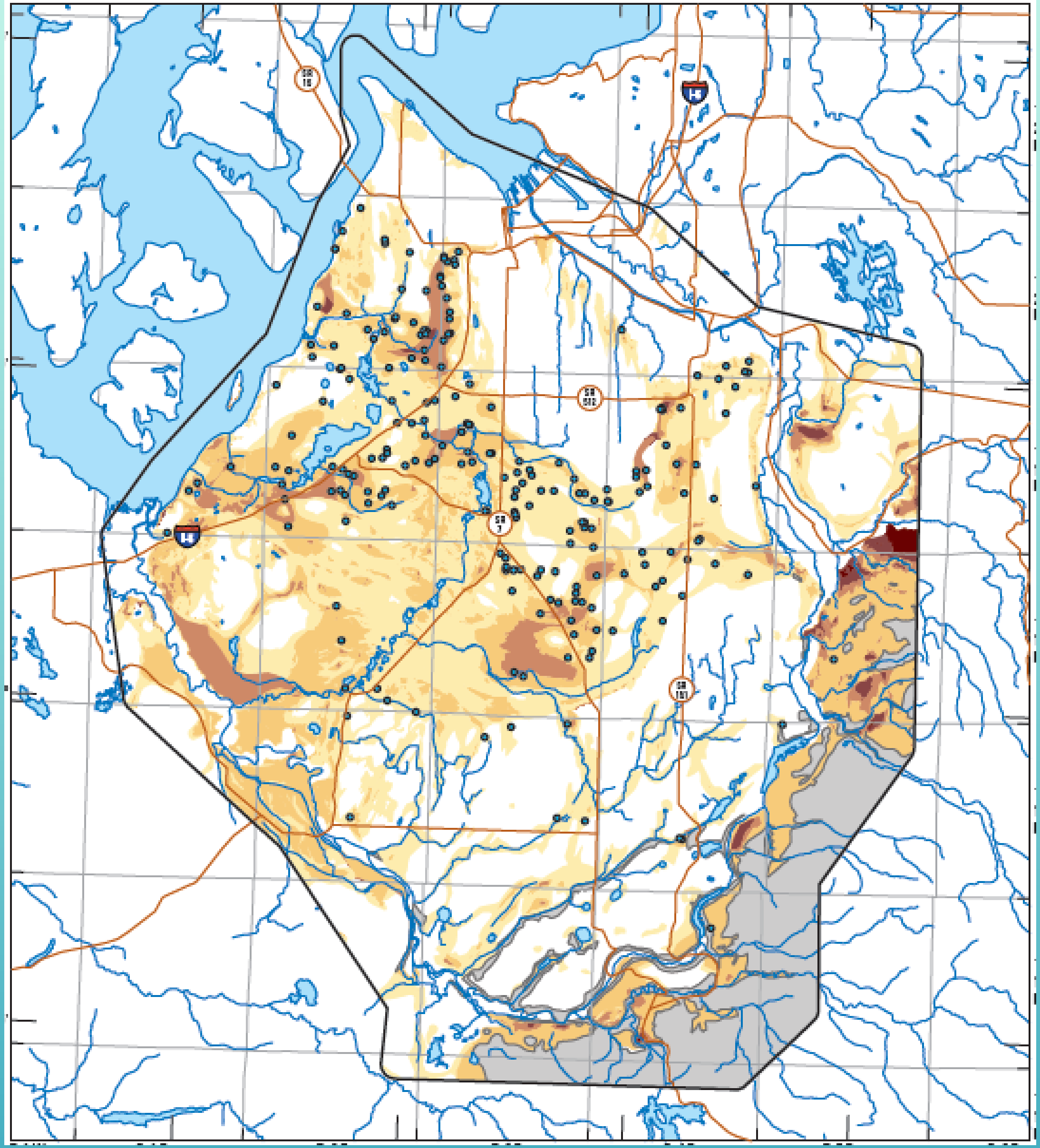
Sequence in USGS SIR 2010-5055 indicating extent of all eight aquifers (youngest to oldest)

Unit: AL alluvial valley aquifer



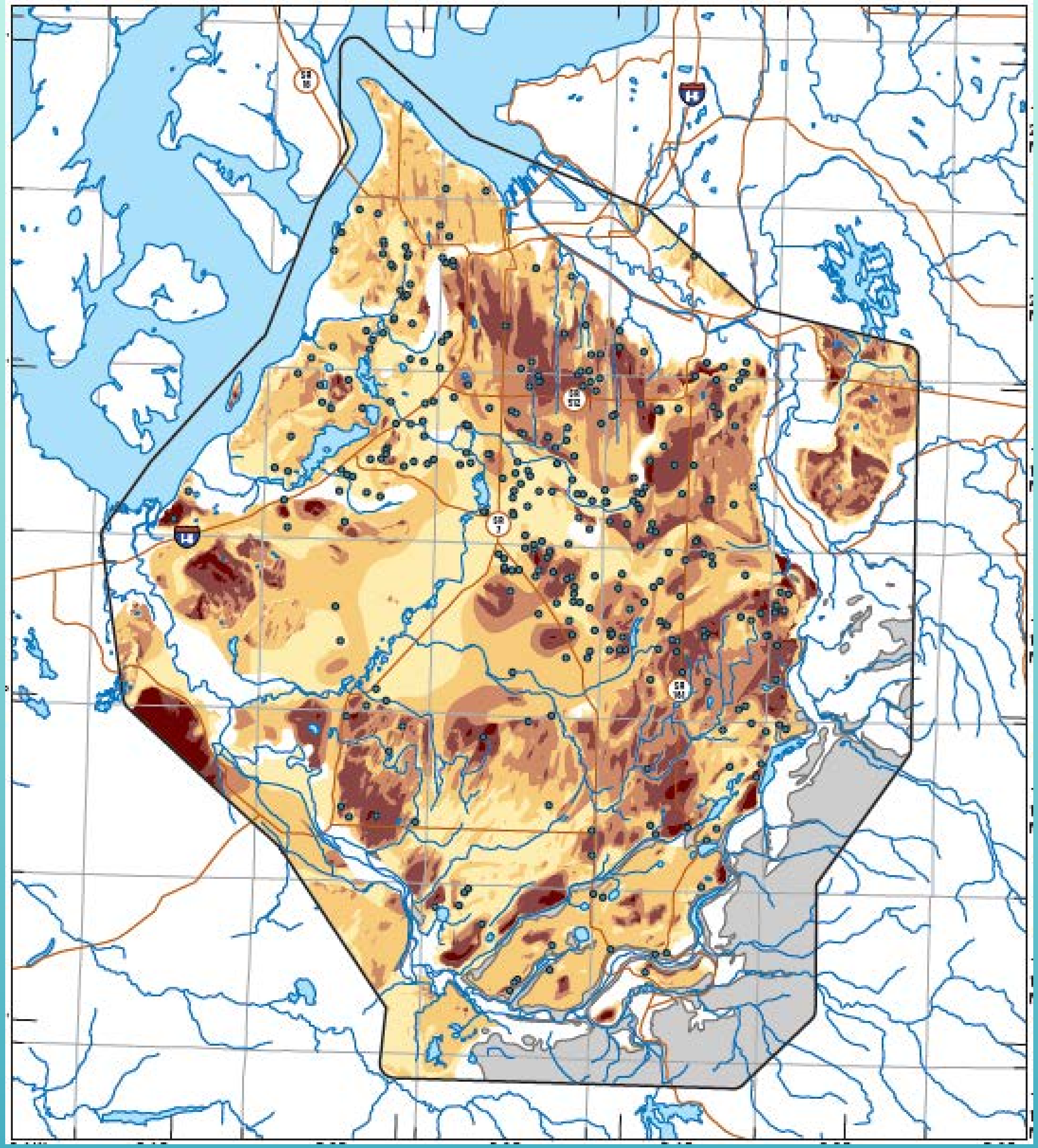
USGS SIR 2010-5055

Unit: A1 aquifer



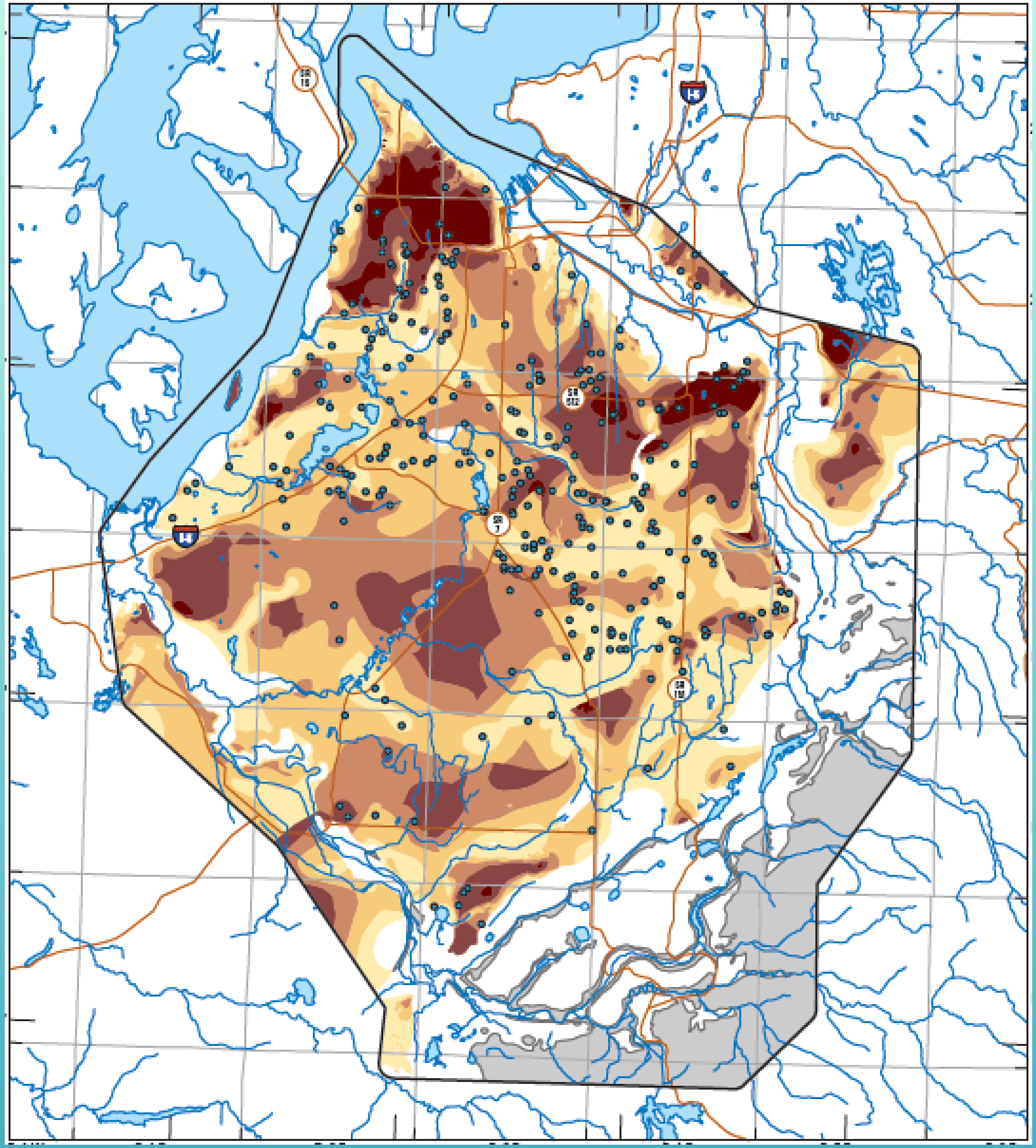
USGS SIR 2010-5055

Unit: A2 confining unit



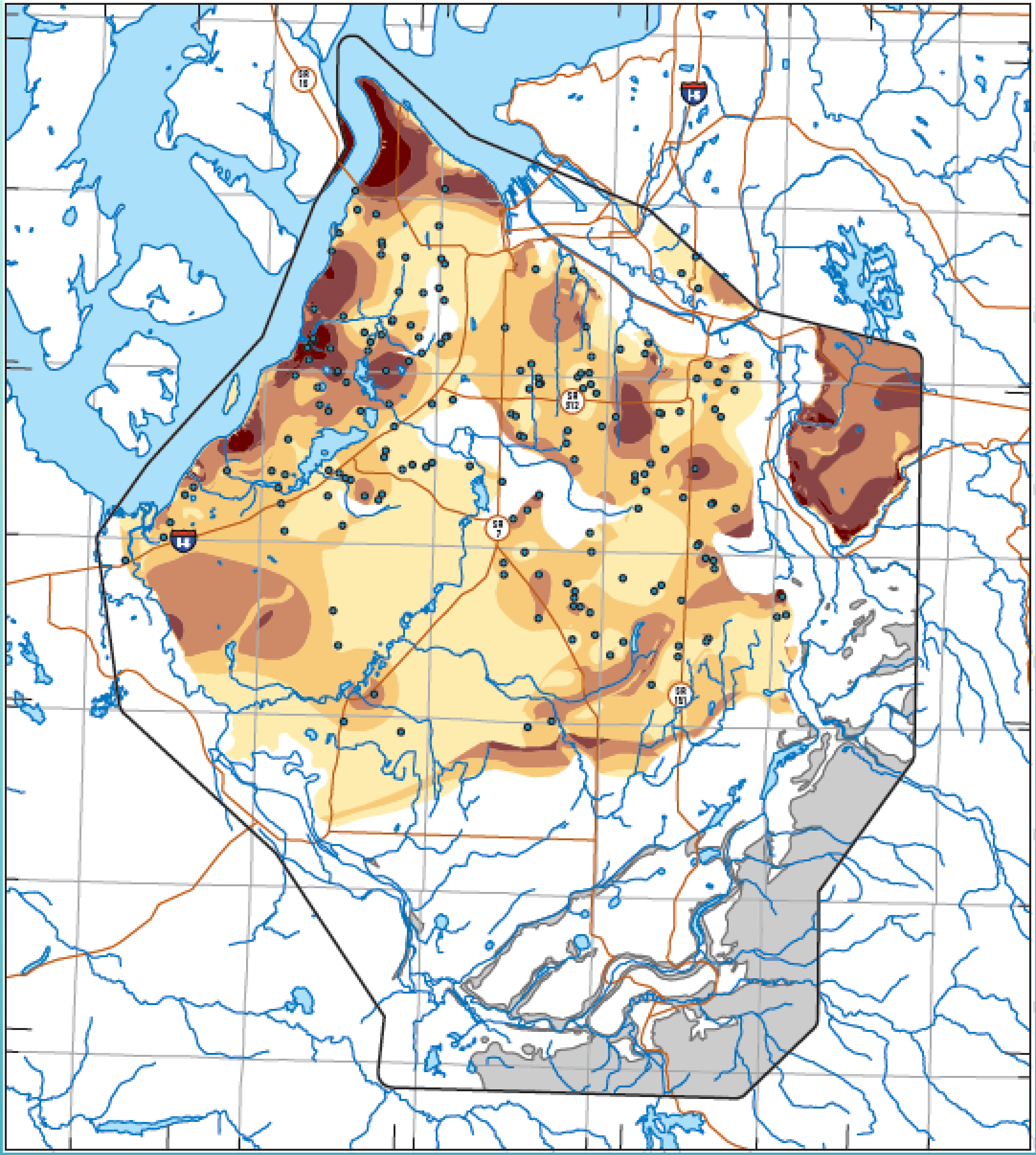
USGS SIR 2010-5055

Unit: A3 aquifer



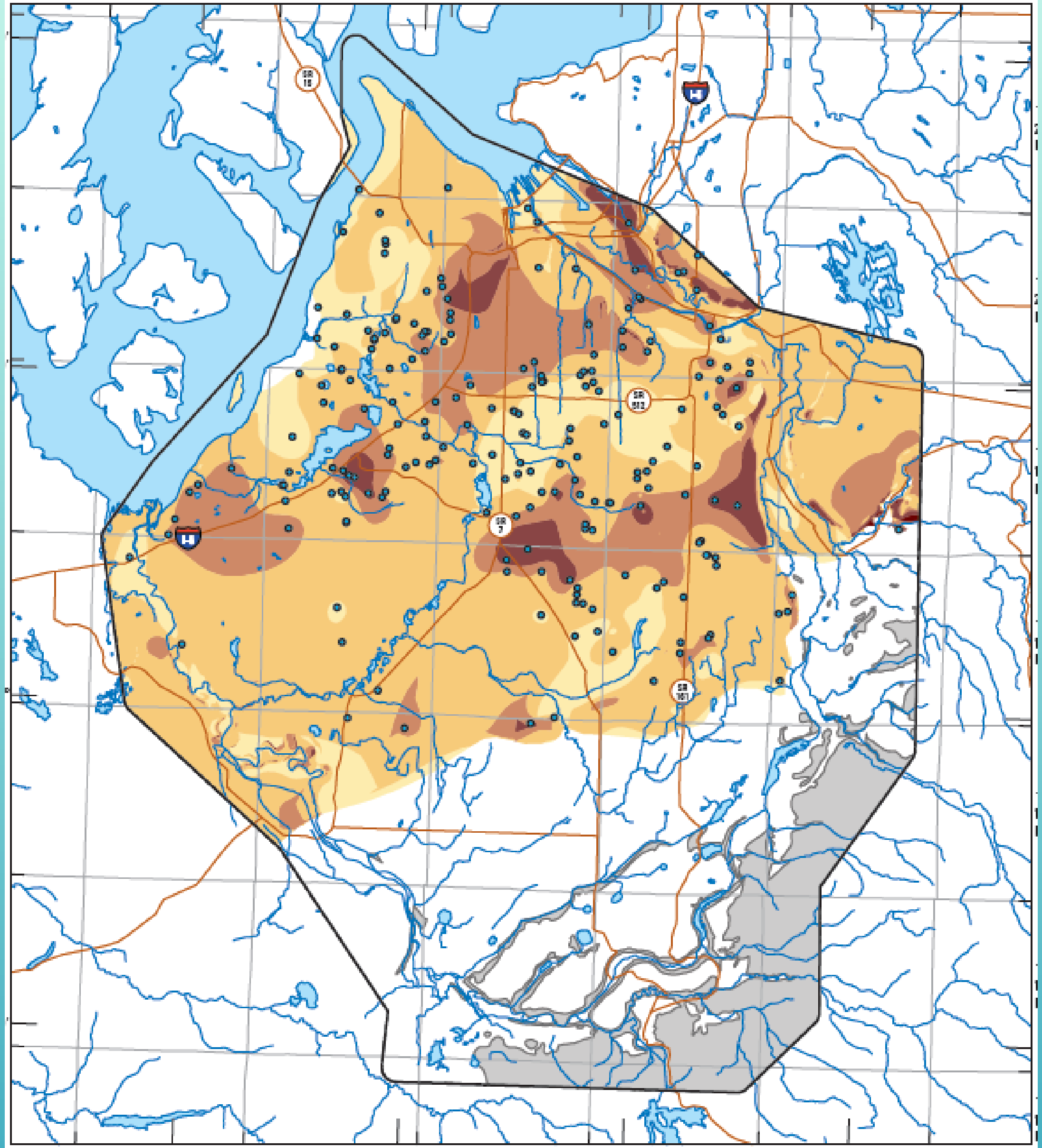
USGS SIR 2010-5055

Unit: B confining unit



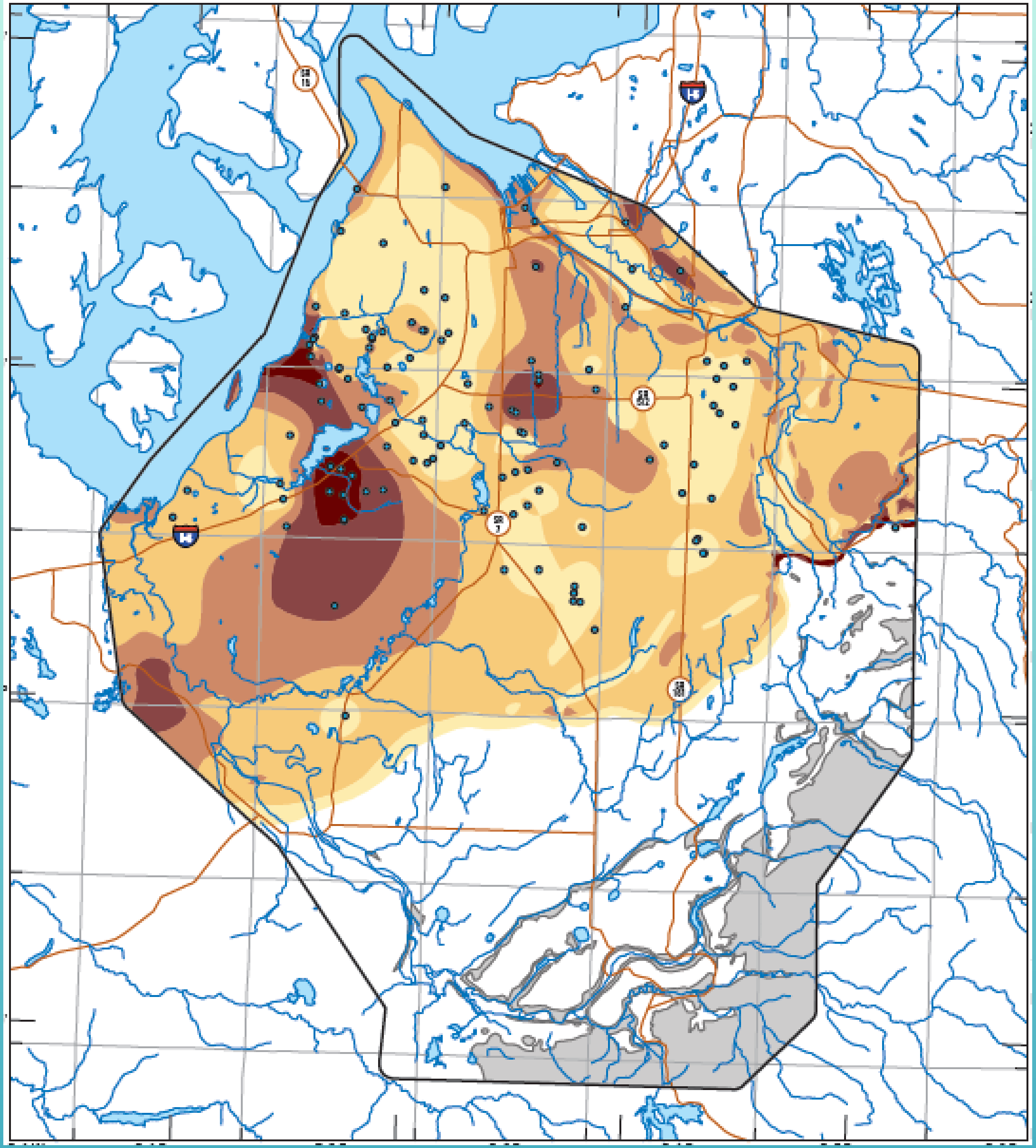
USGS SIR 2010-5055

Unit: C aquifer



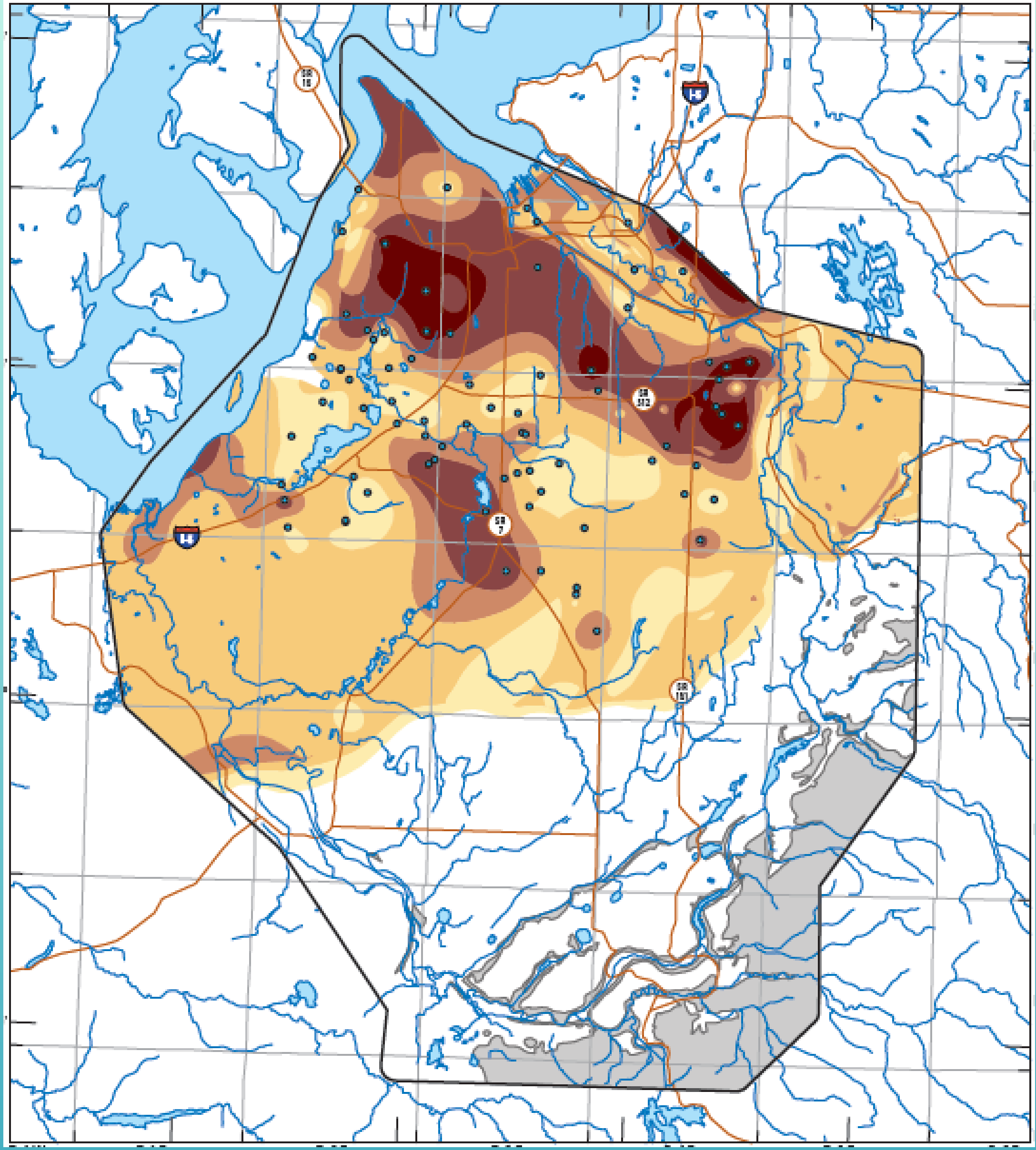
USGS SIR 2010-5055

Unit: D confining unit



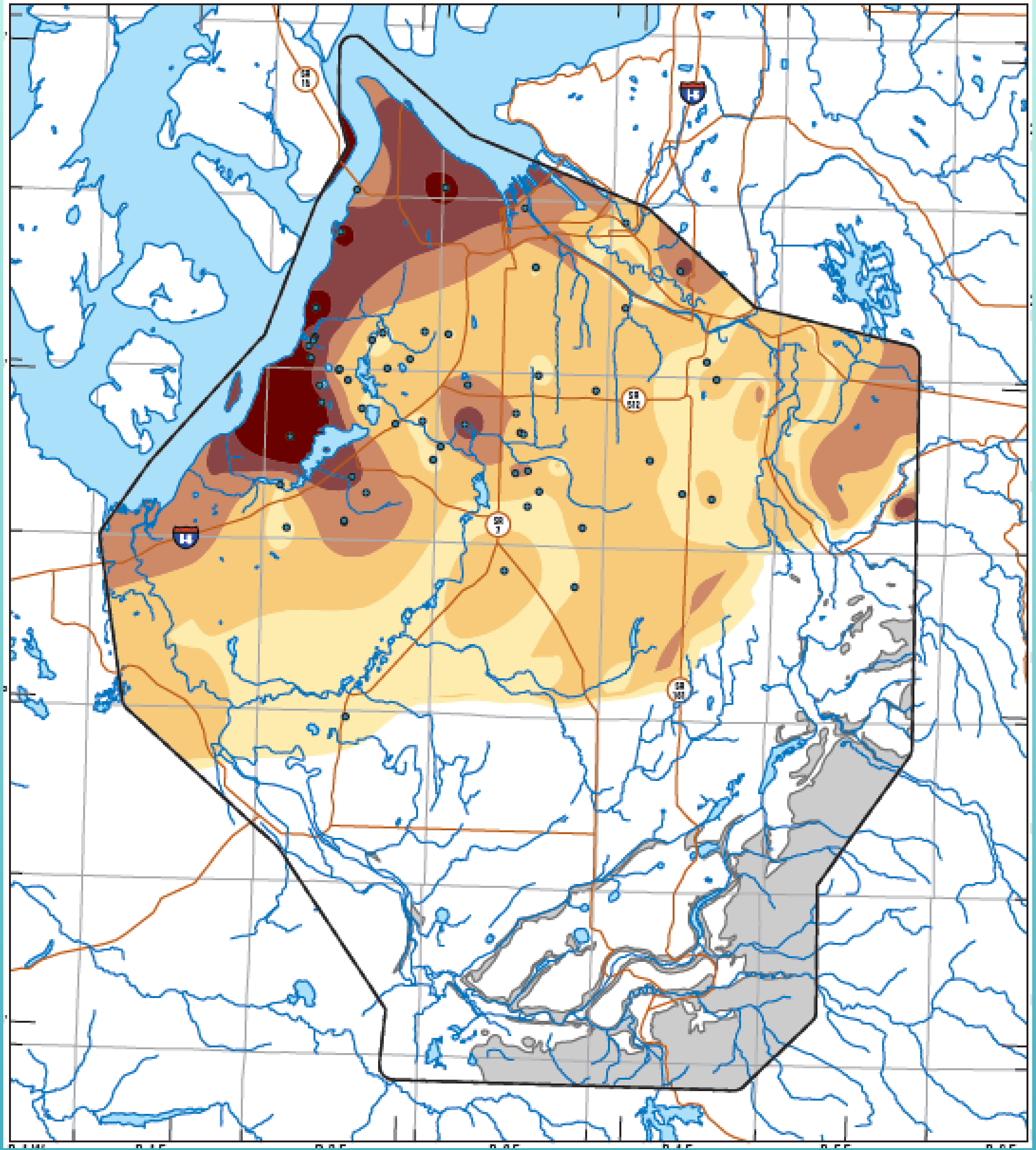
USGS SIR 2010-5055

Unit: E aquifer



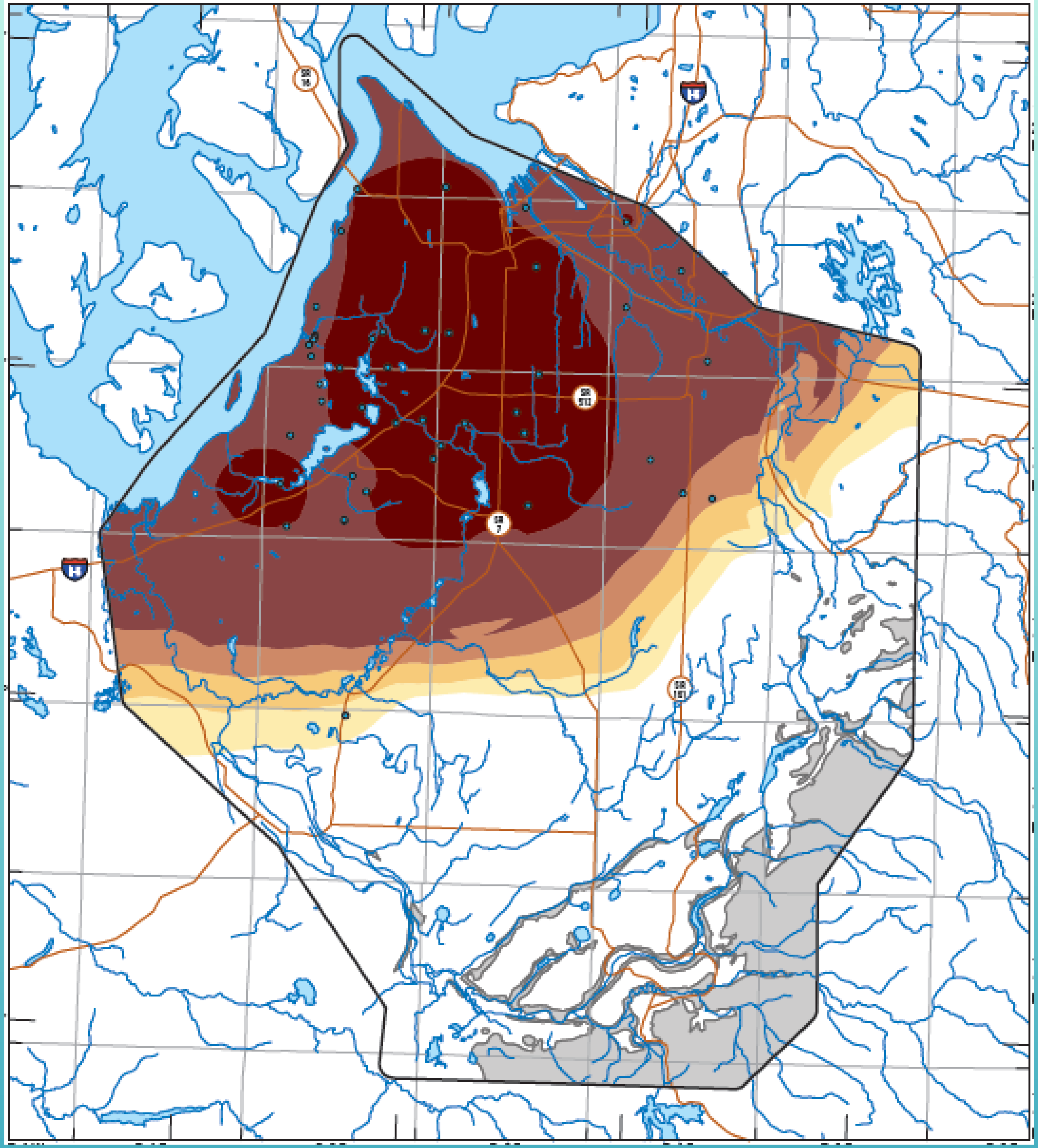
USGS SIR 2010-5055

Unit: F confining unit



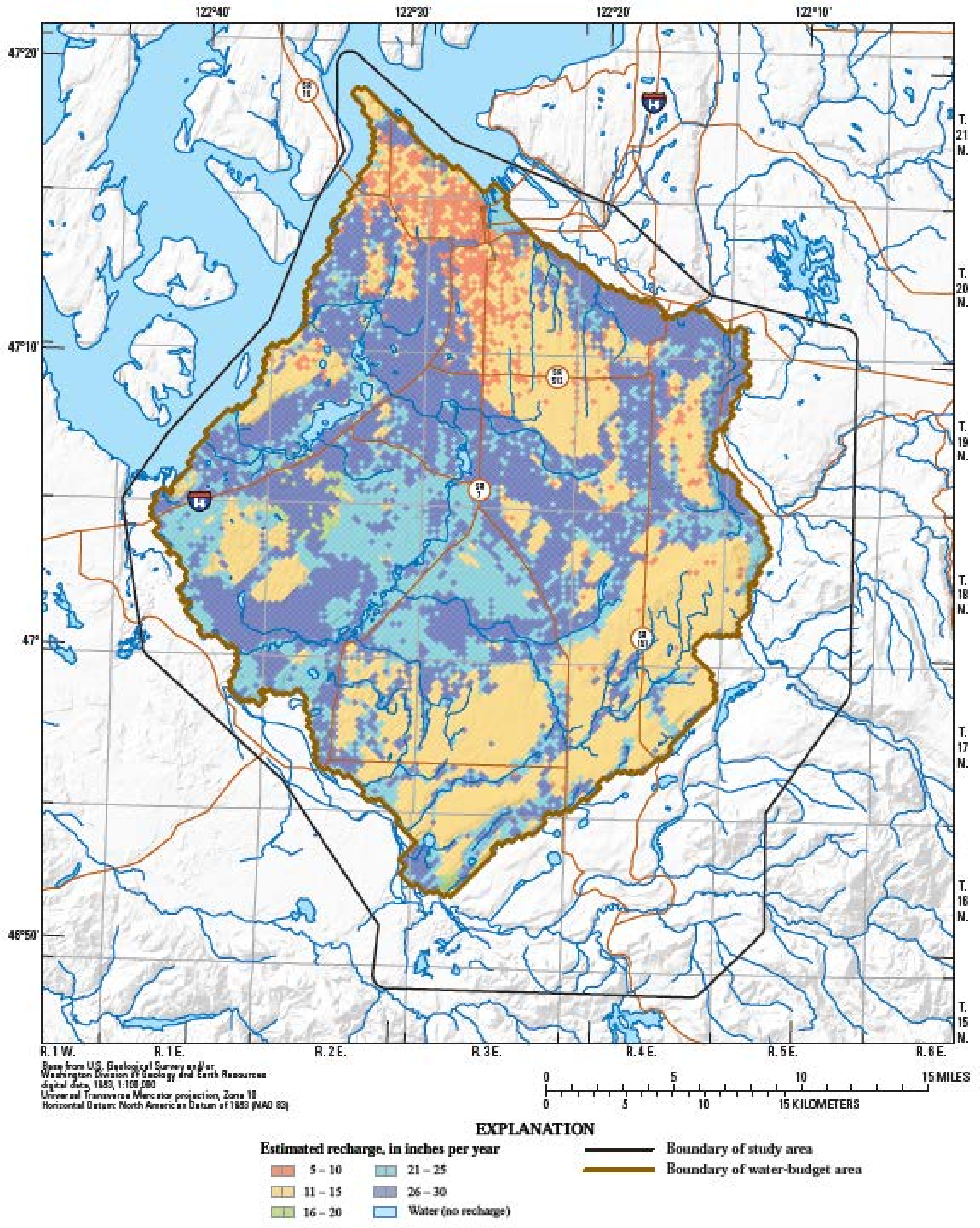
USGS SIR 2010-5055

Unit: G undifferentiated deposits



USGS SIR 2010-5055

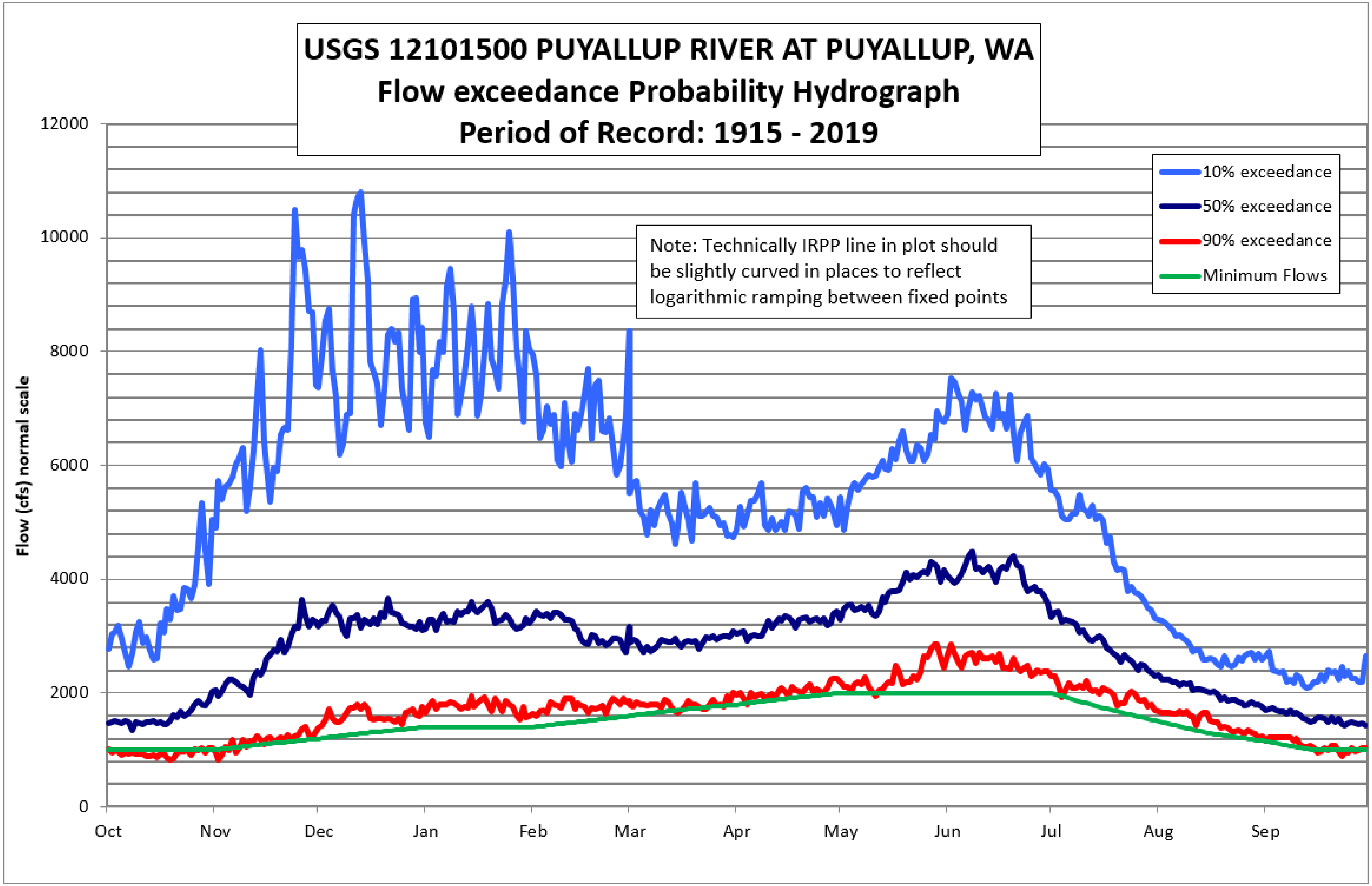
Grid with 1,000 by 1,000 feet cells for Chambers–Clover Creek watershed groundwater-flow system numerical simulation (Johnson, et al., 2011)



USGS SIR 2010-5055

Model Simulation	Recharge (precipitation and return flows)	Withdrawal amount (public and residential)	Withdrawal location
Simulation 1 Steady-State	Decrease precipitation recharge by 20 percent	No change	No change
Simulation 2 Steady-State	Increase return flows by 15 percent	Increase public and residential withdrawals by 15 percent	No change
Simulation 3 Steady-State	Increase return flows by 15 percent	Increase public and residential withdrawals by 15 percent	Deepen all public and residential withdrawals
Simulation 4 Steady-State	Increase return flows by 15 percent	Increase public and residential withdrawals by 15 percent	Deepen only group A public withdrawals
Simulation 5 Transient	Increase monthly return flows by 15 percent	Increase monthly public and residential withdrawals by 15 percent	No change
Simulation 6 Transient	Increase monthly return flows by 15 percent	Increase monthly public and residential withdrawals by 15 percent	Deepen only group A public withdrawals during summer months

USGS SIR 2010-5055

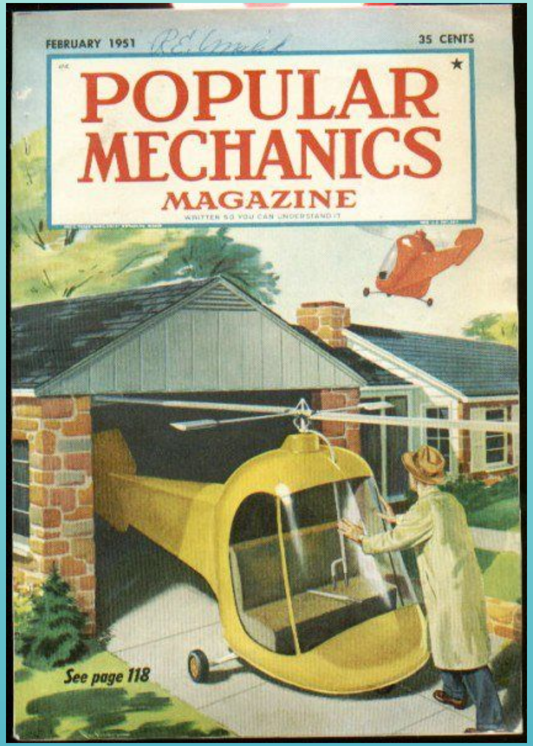


USGS 12101500 PUYALLUP RIVER AT PUYALLUP, WA
Flow exceedance Probability Hydrograph
Period of Record: 1915 - 2019
Note: Technically IRPP line in plot should be slightly curved in places to reflect logarithmic ramping between fixed points
10% exceedance
50% exceedance
90% exceedance
Minimum Flows
Flow (cfs) normal scale
12000
10000
8000
6000
4000
2000
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)

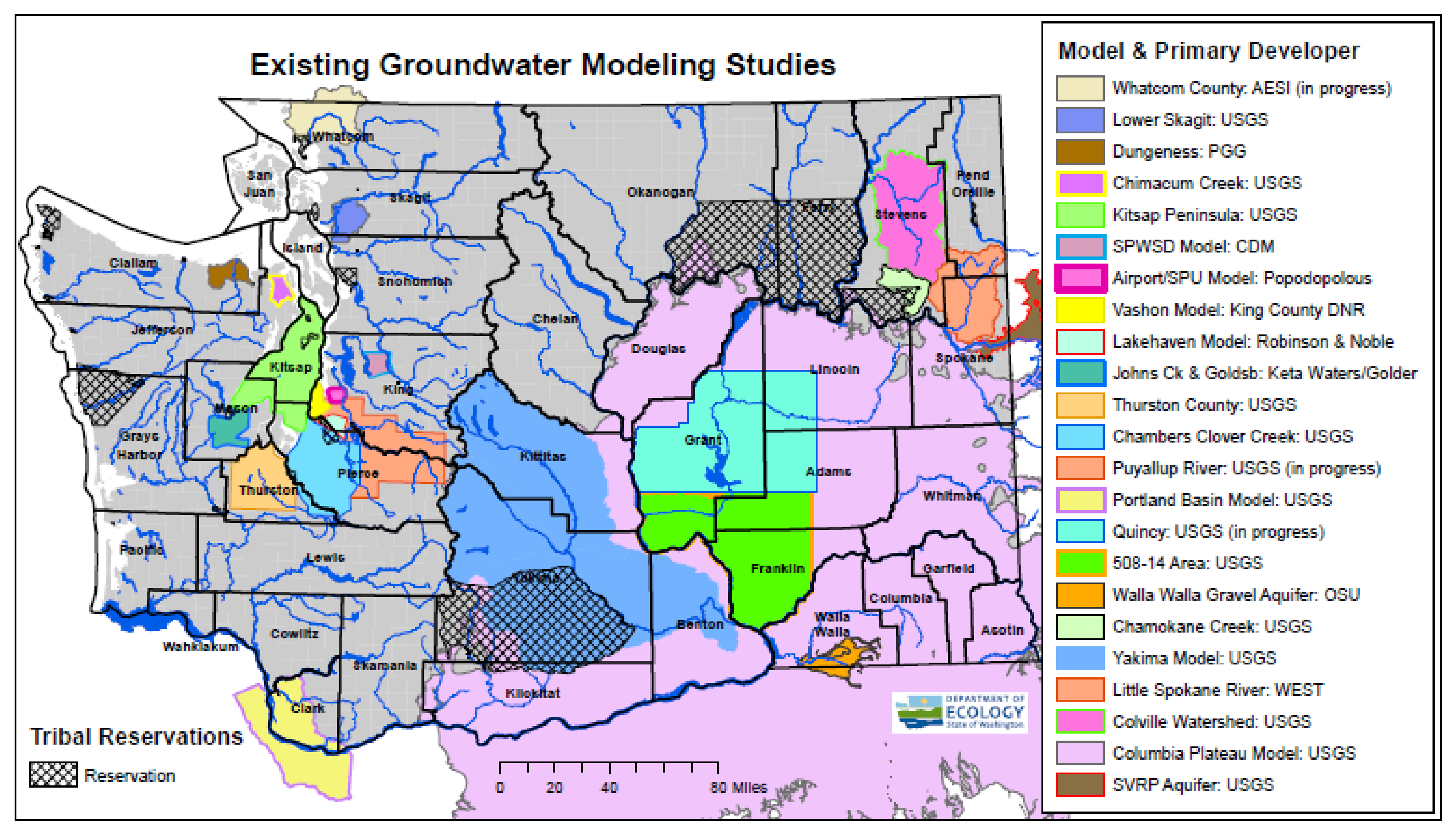
1. Assuming all houses discharge wastewater via septic systems
2. From Appendix A of the Washington Irrigation Guide (WAIG) (U.S. Department of Agriculture, 1997)

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

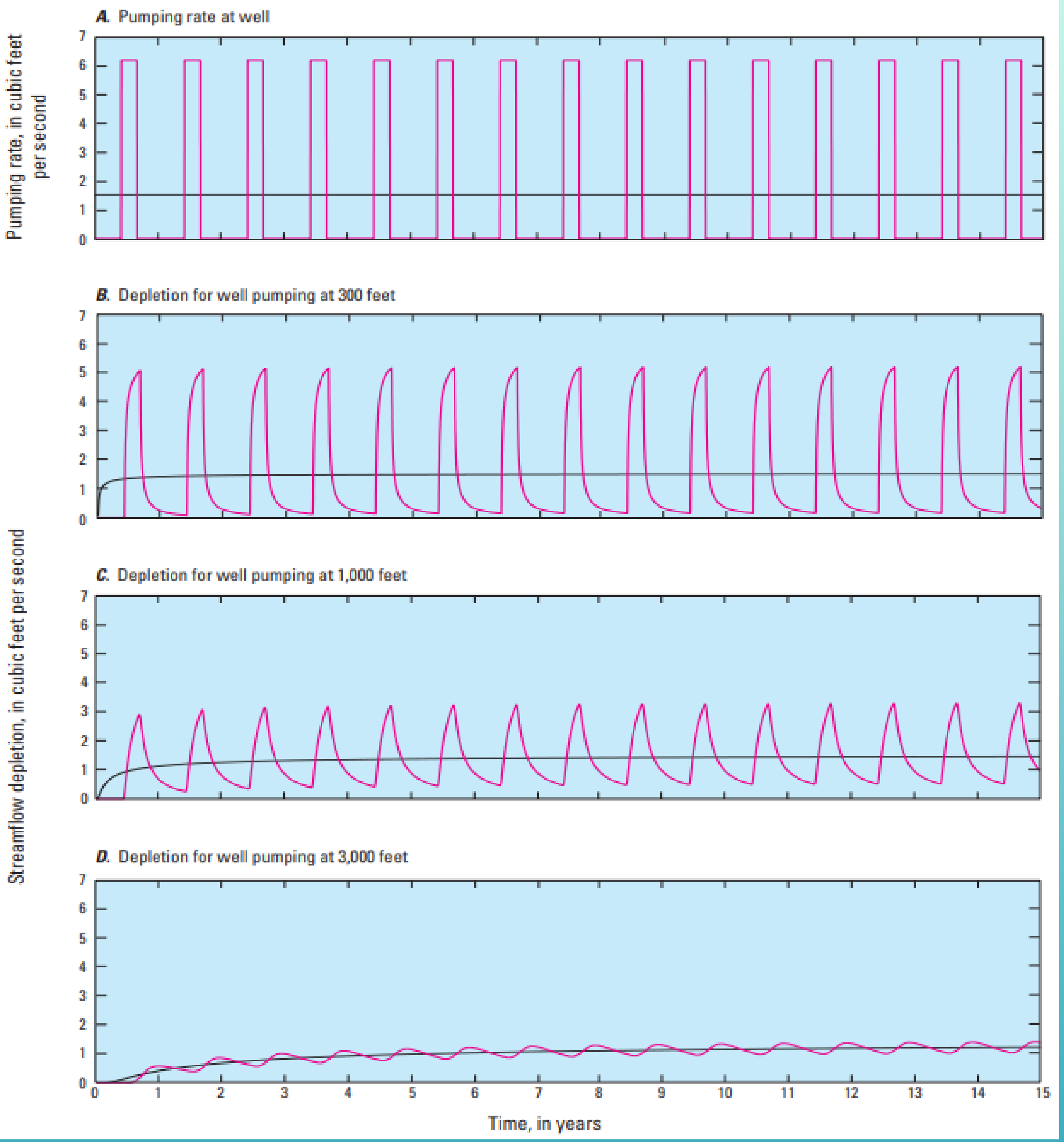
Conceptual groundwater models provide overall hydrogeologic understanding.

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.



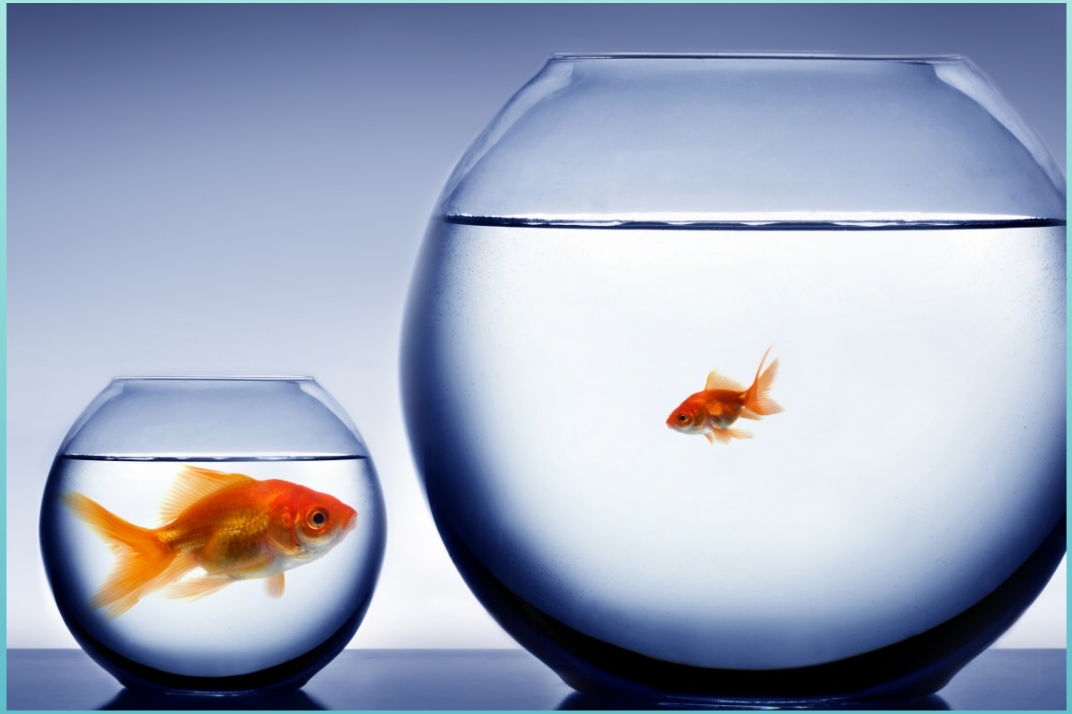
USGS Circular 1376

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.

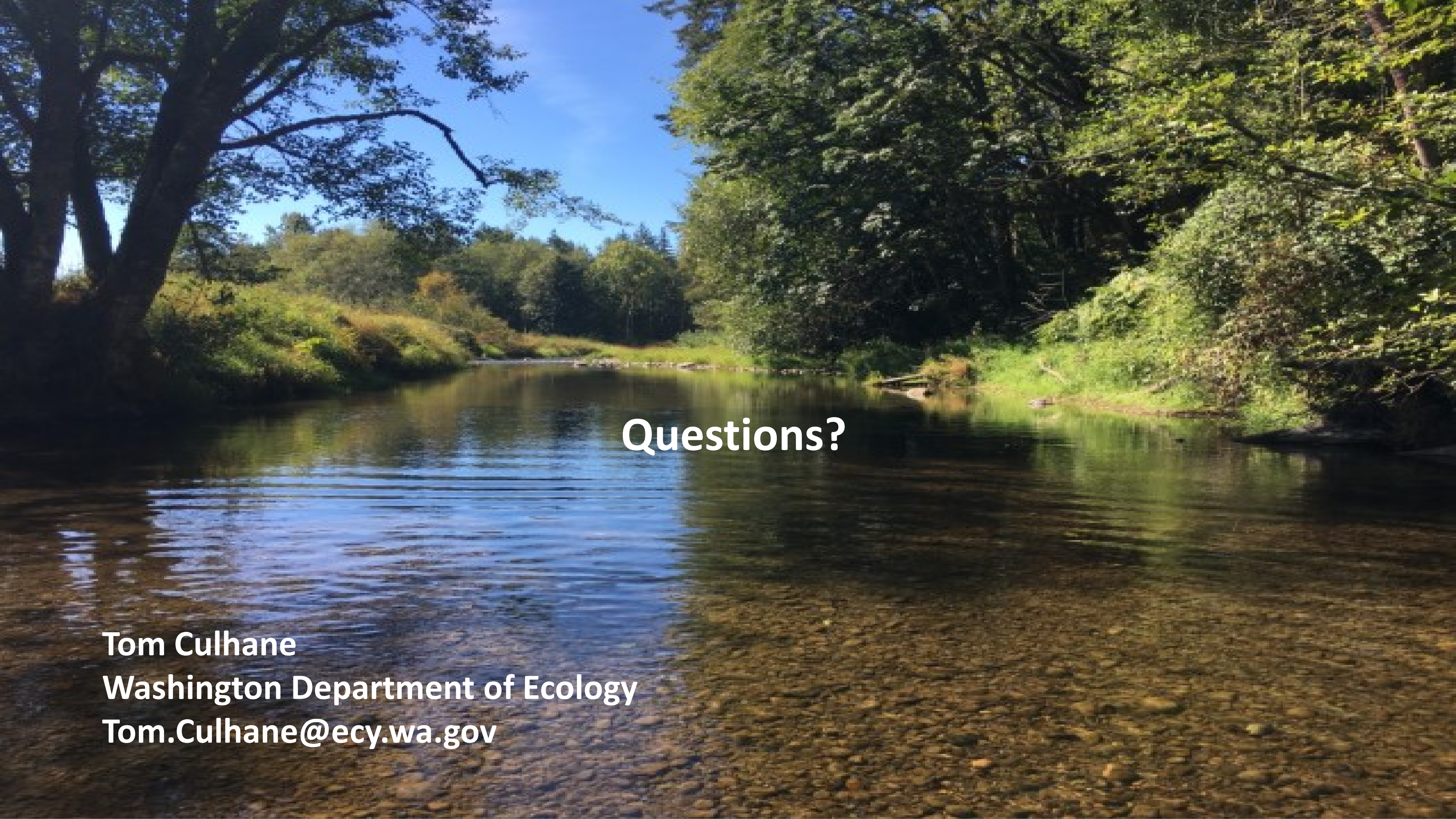
Significance of Scale

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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