Hydrogeology Concepts and Considerations for RCW 90.94 Streamflow Restoration in WRIA 14

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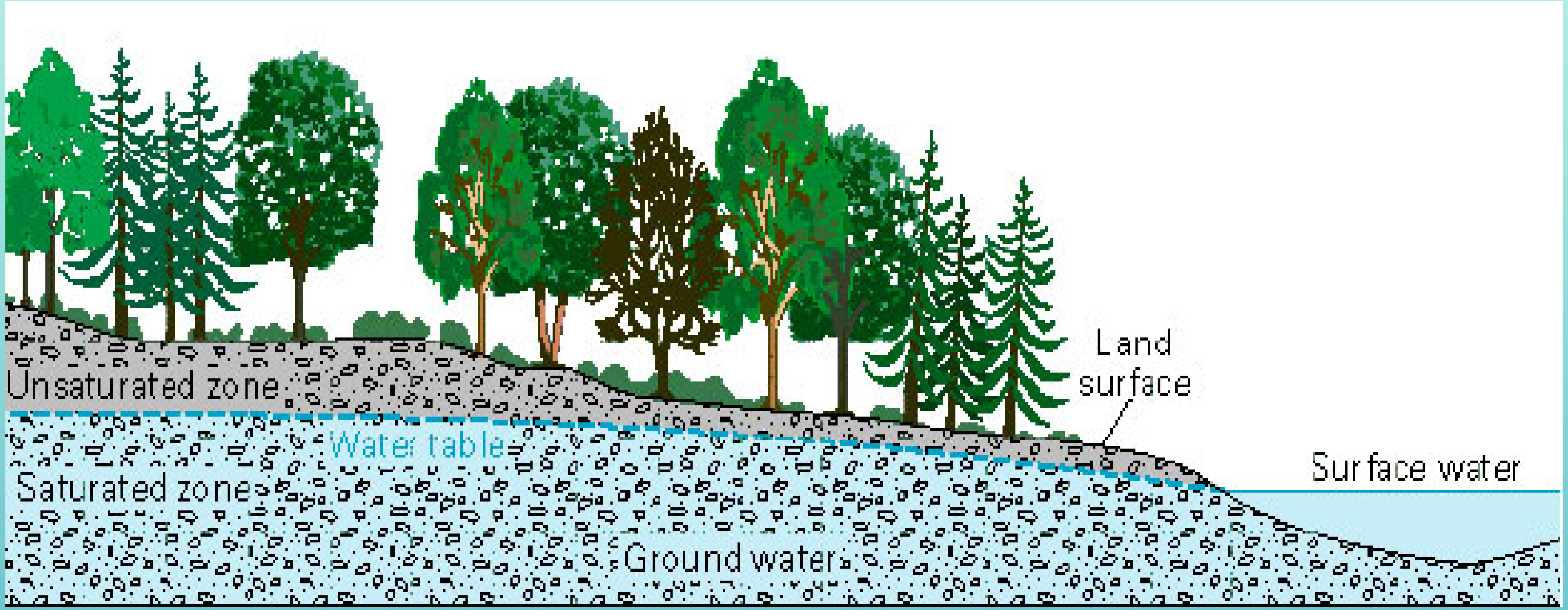
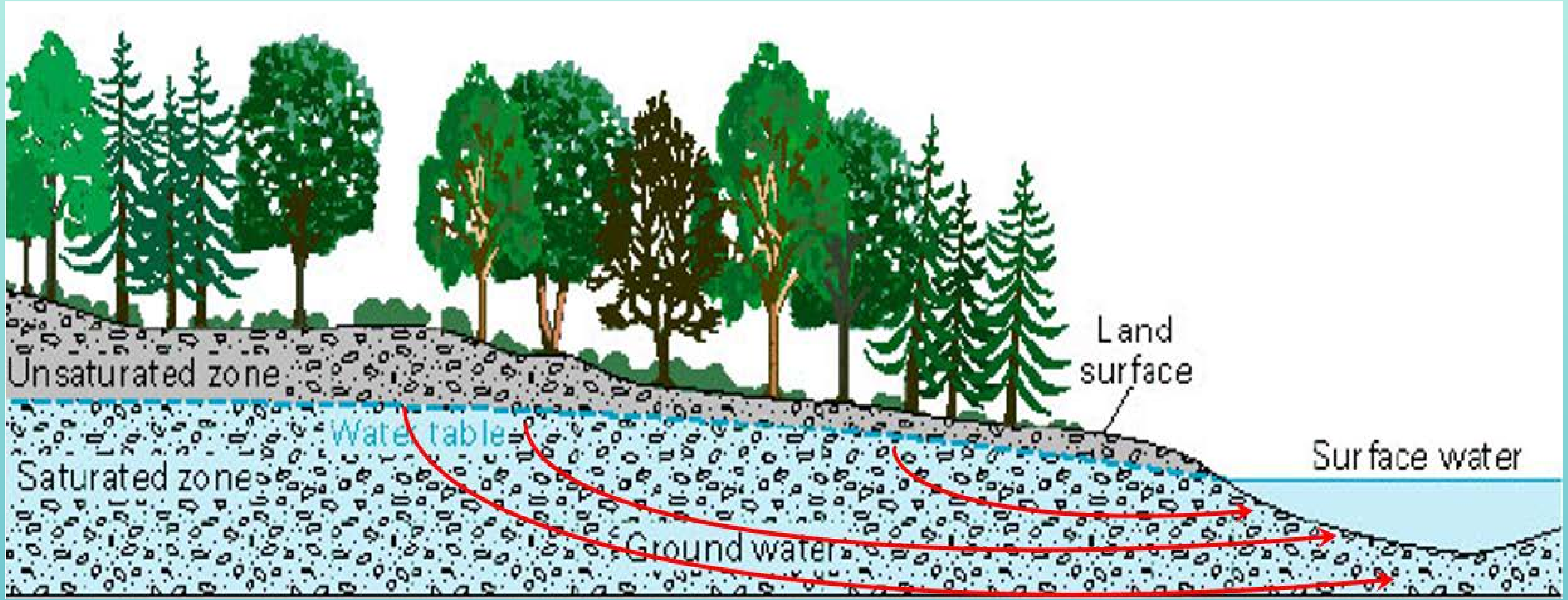
DEPARTMENT OF ECOLOGY State of Washington

- 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

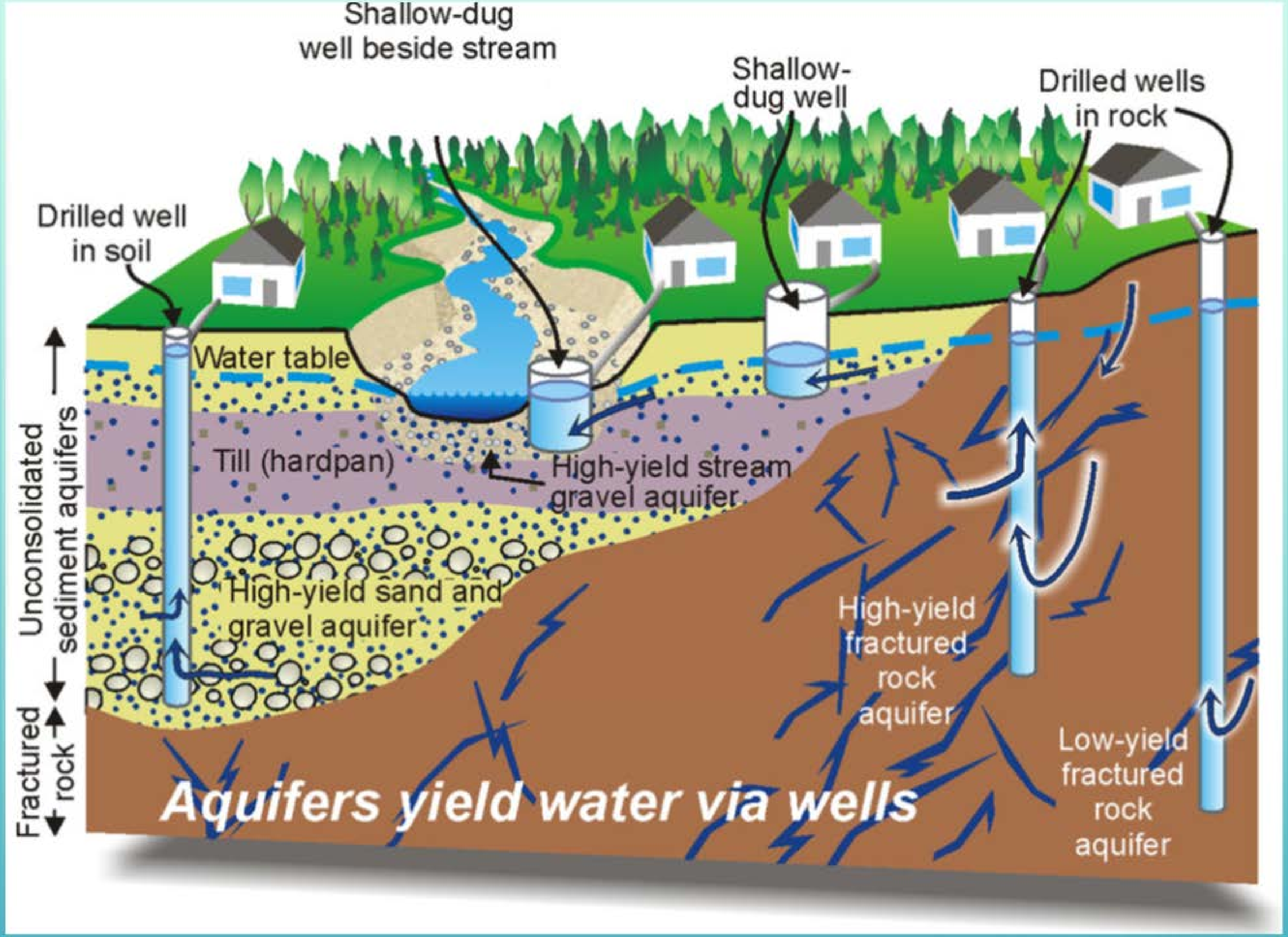


USGS Water Science School

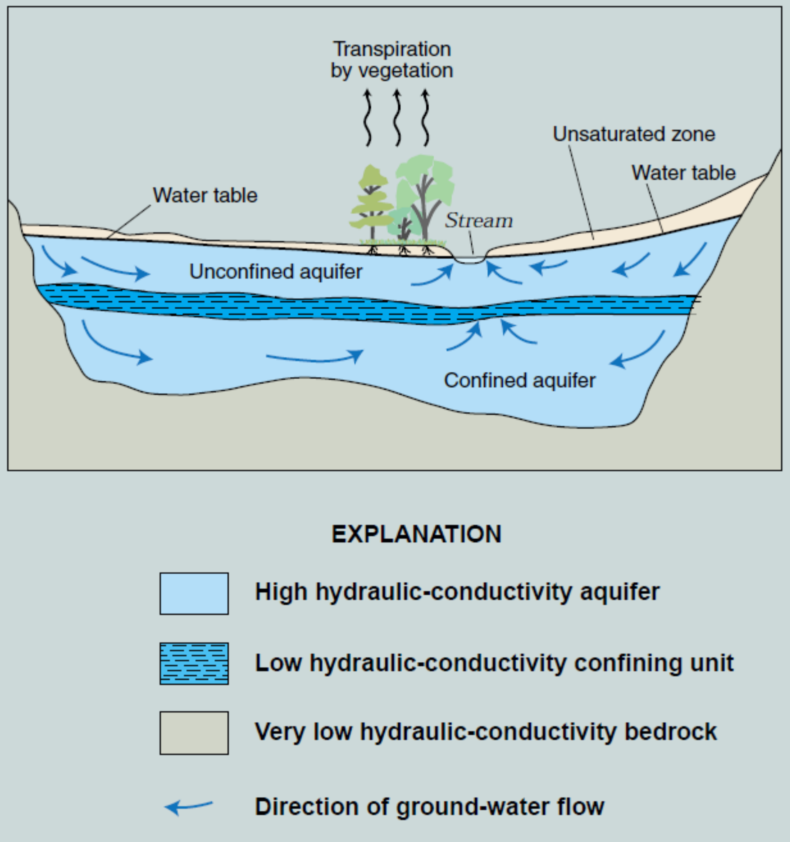
Aquifer -- saturated geologic material permeable enough to yield economical quantities of water

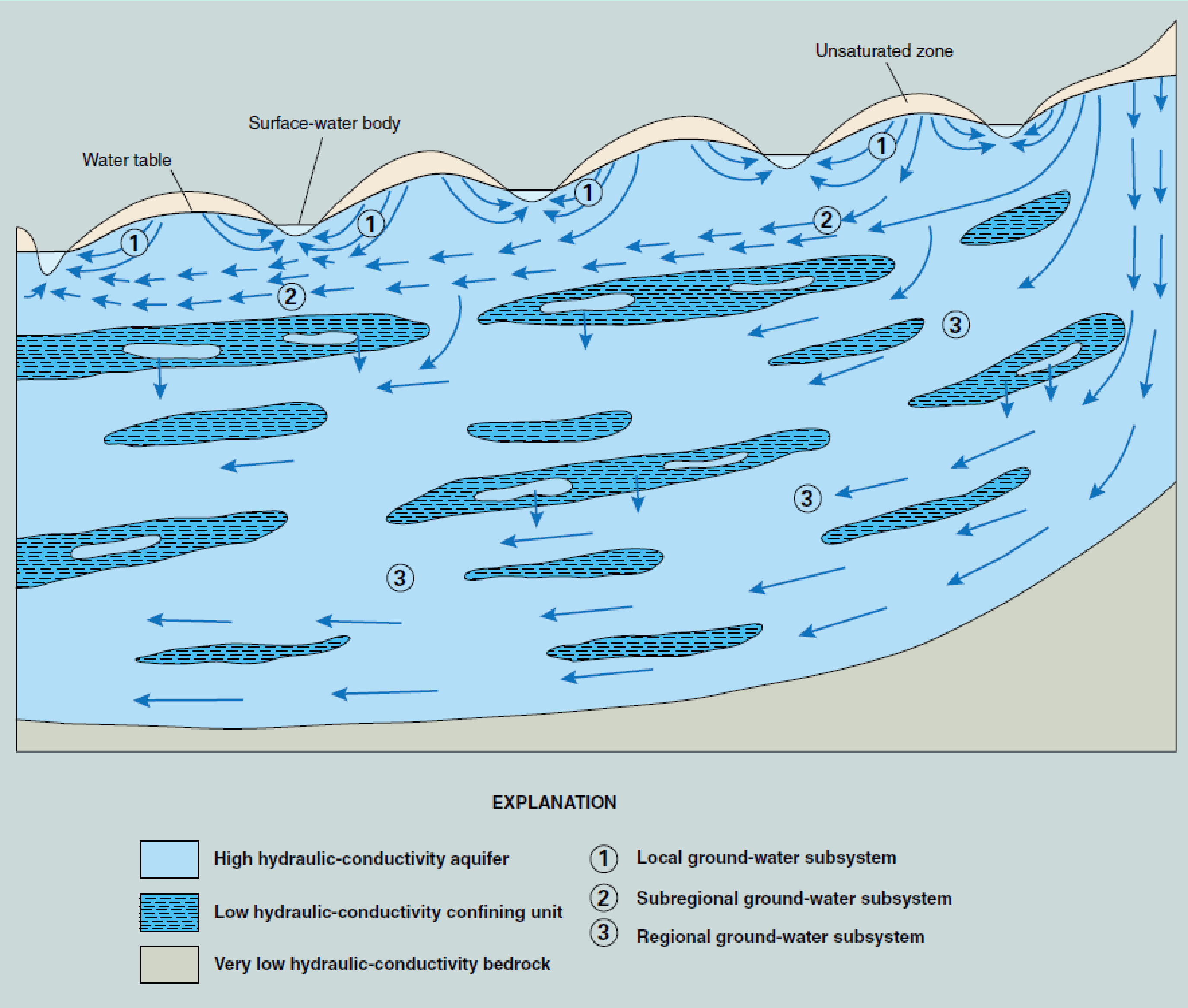
Aquitard -- saturated geologic material with low permeability; well yields low; also called “confining layer”

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



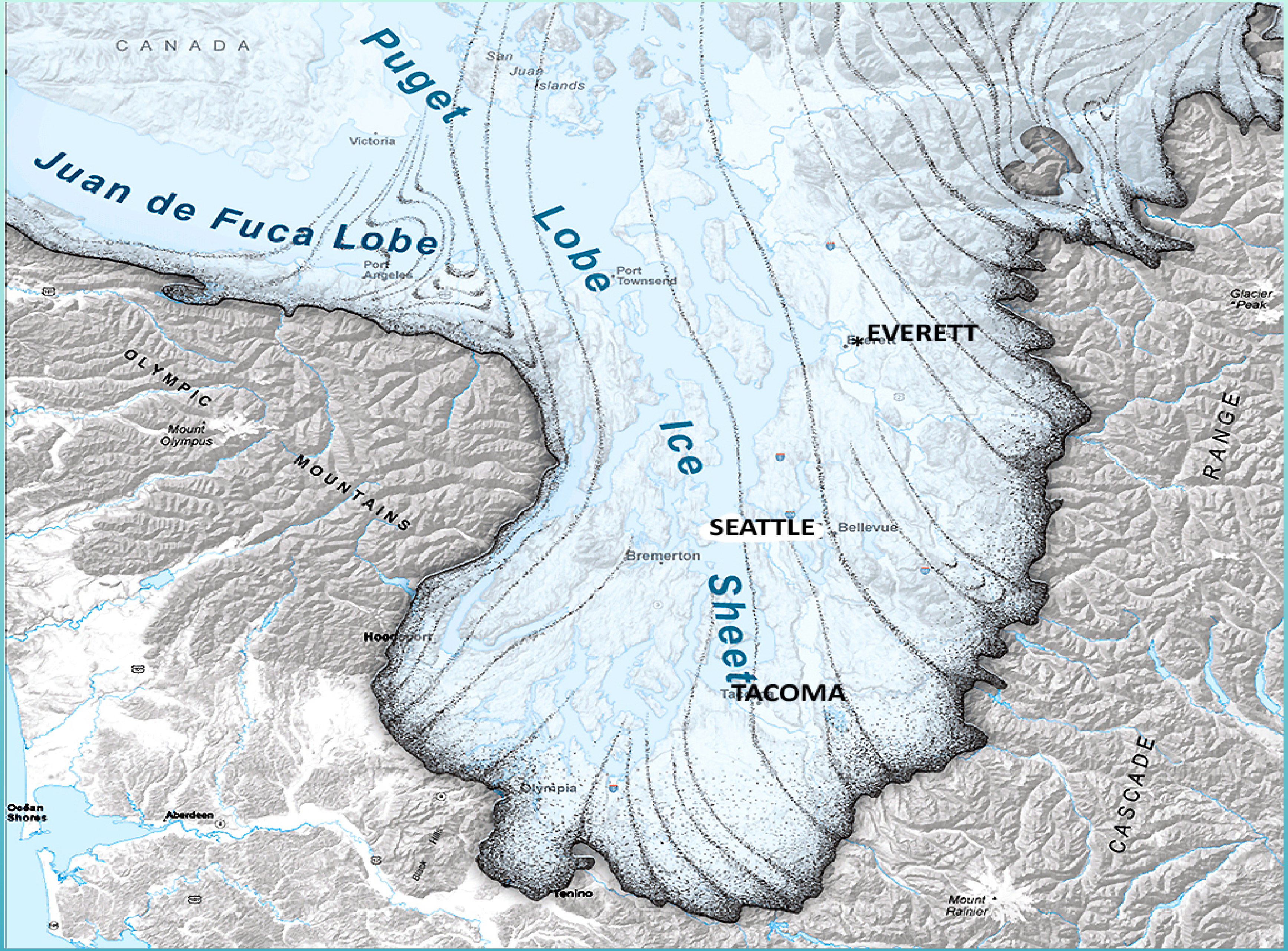
Canadian Geoscience Education Network
https://www.cgenarchive.org/bowen-island-underground.html





USGS Circular 1186

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



Washington Department of Natural Resources

Pierce County Geology

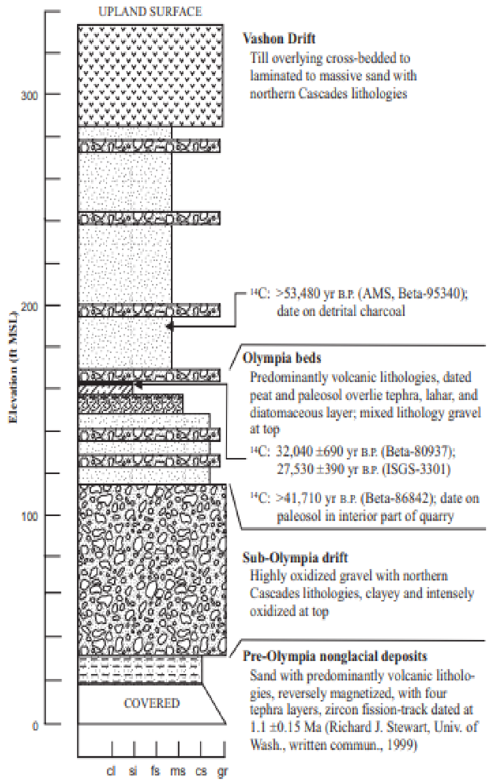
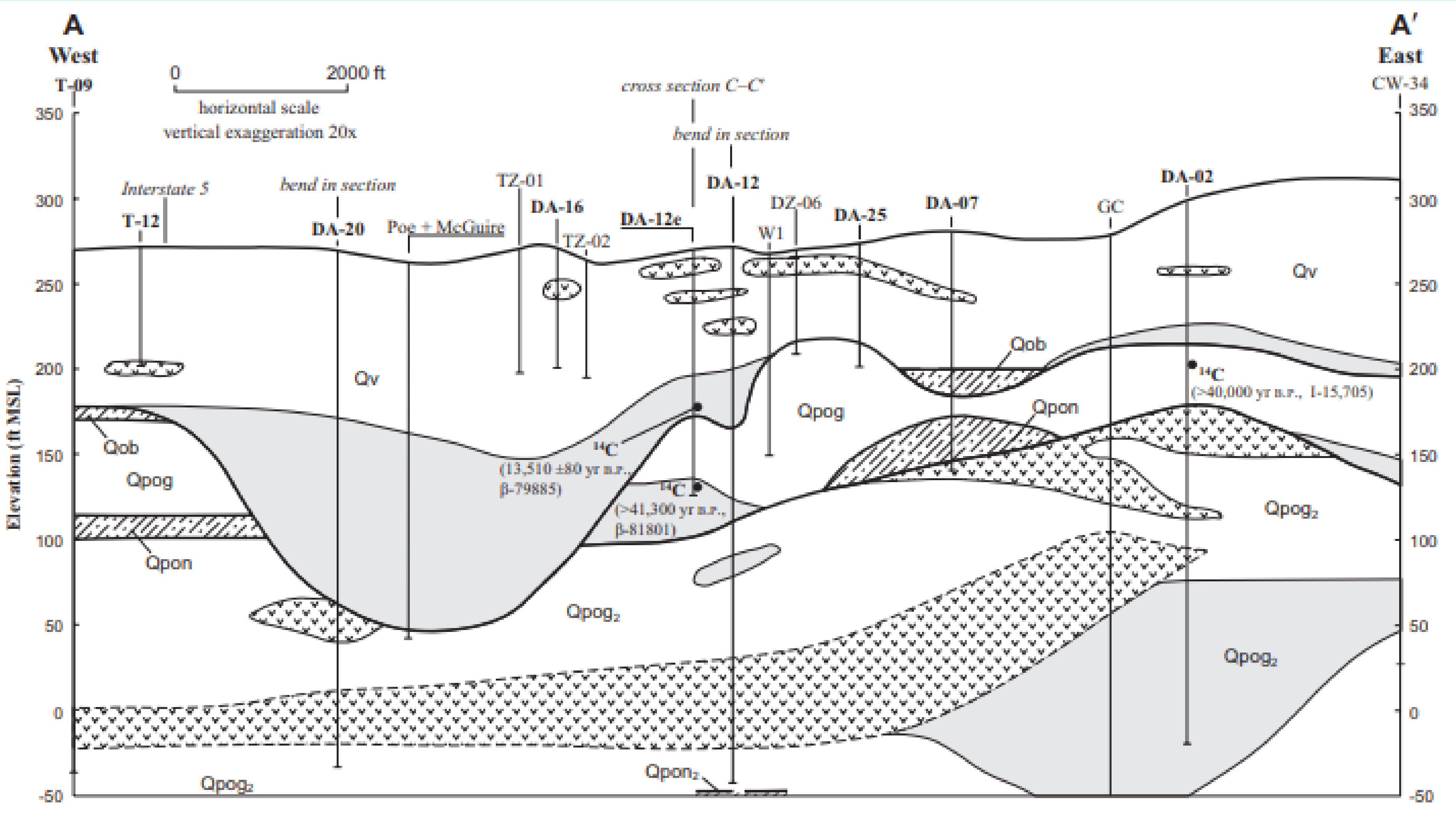
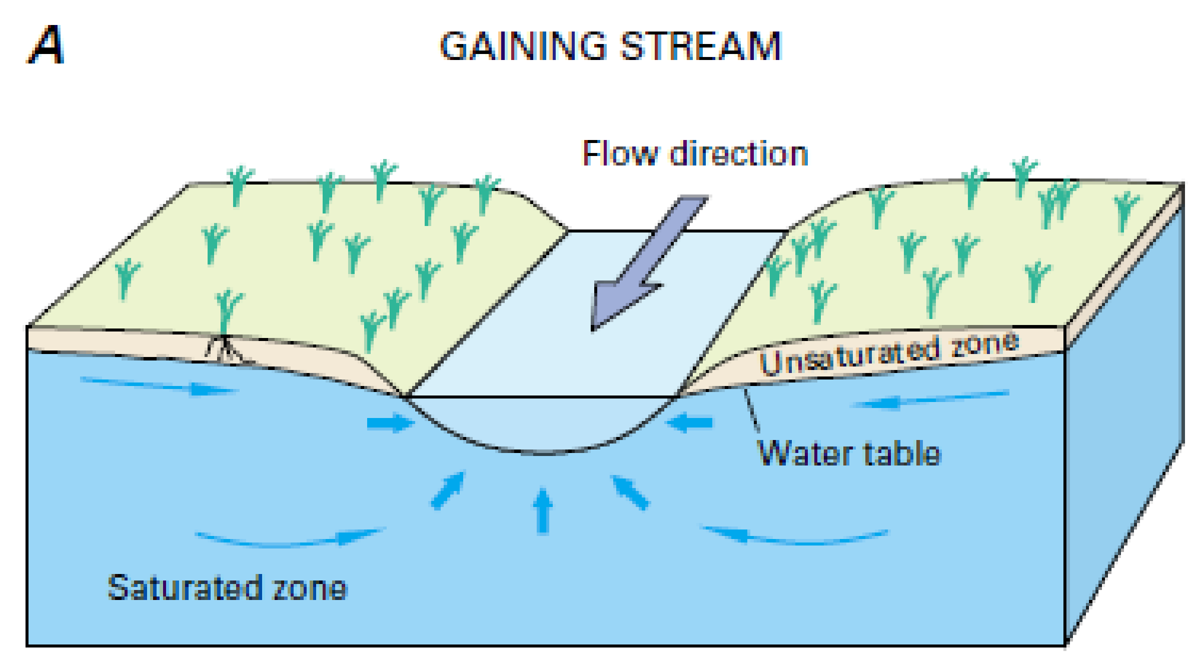


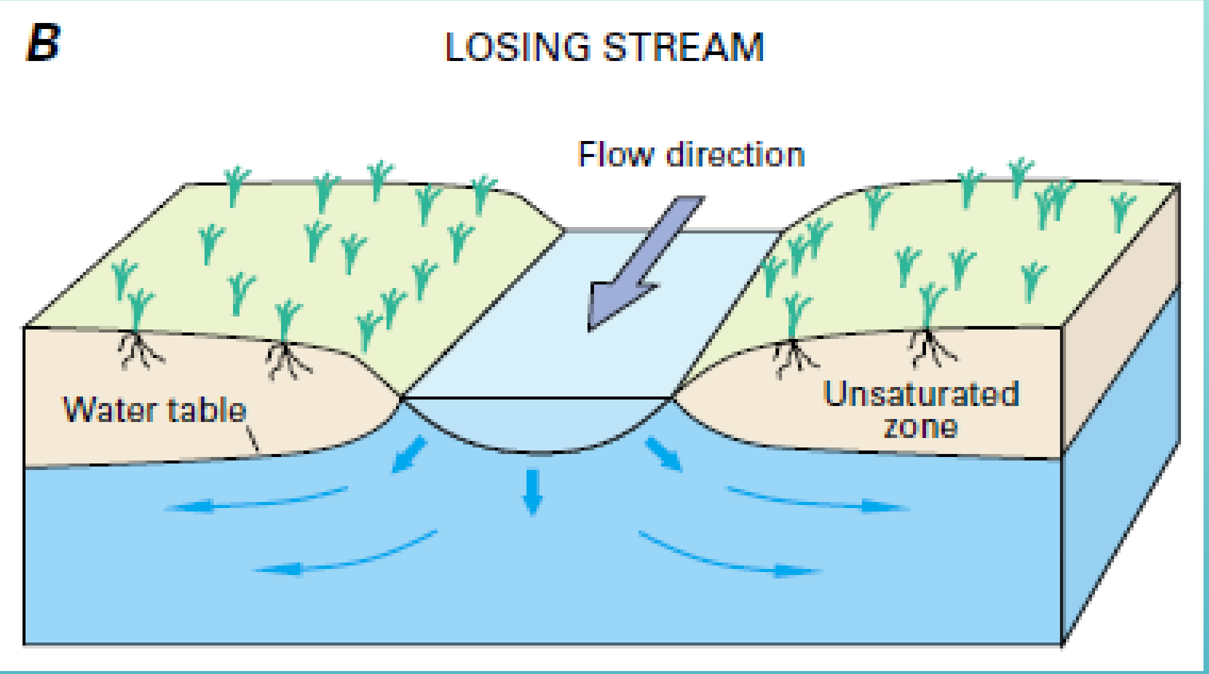
Figure 6. Woodworth quarry composite measured section, Poverty Bay 7.5-minute quadrangle, lat 47.2729 N, long 122.3728 W.



WA DNR Report of Investigations 33

Groundwater – Surface Water Relationships





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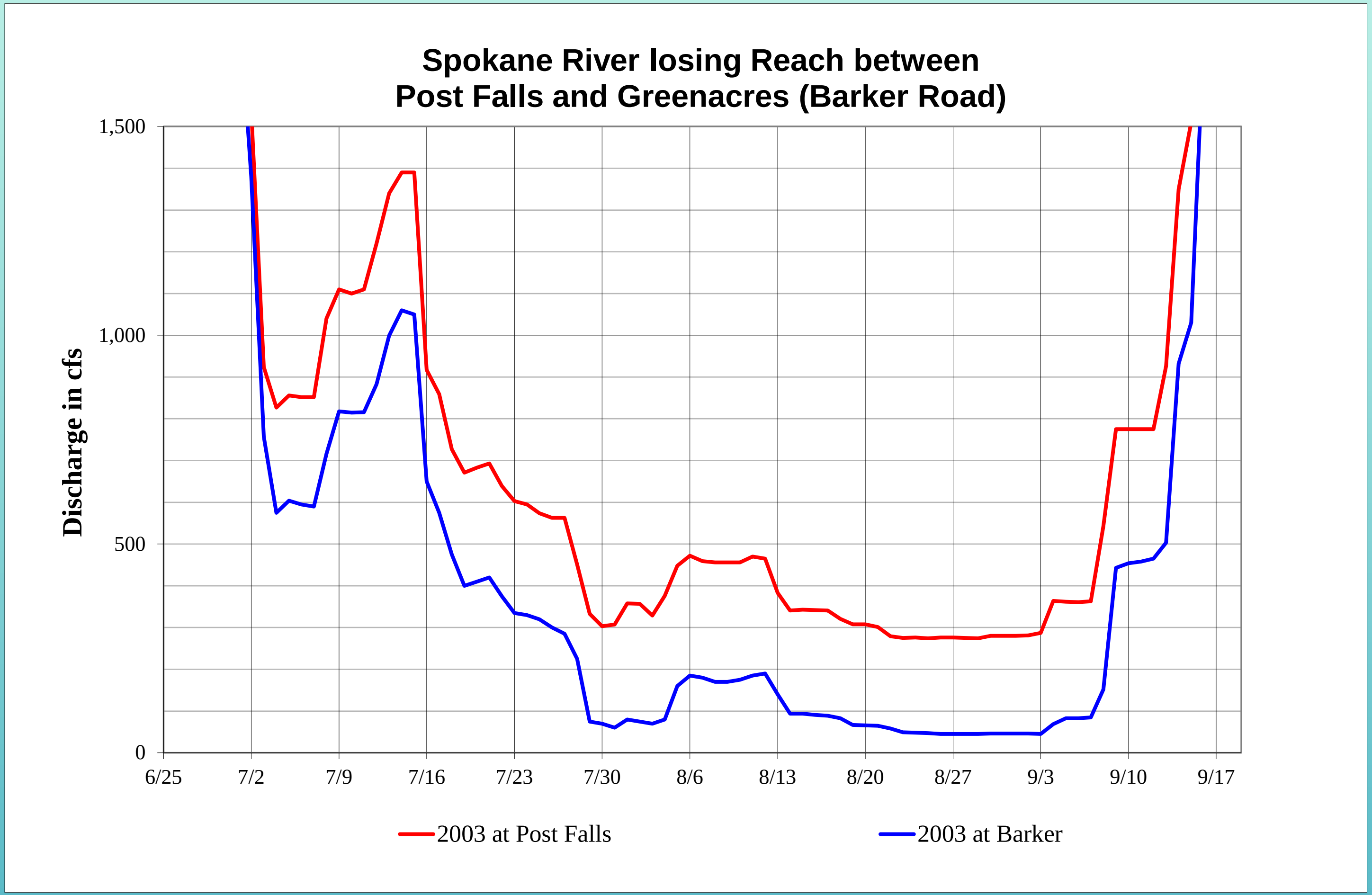
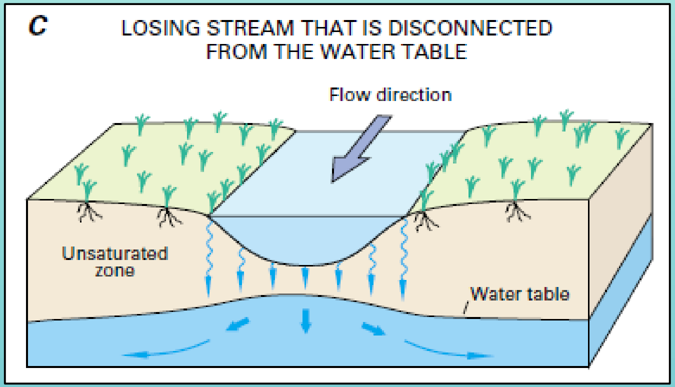


Spokane River is a losing reach…



USGS Circular 1186

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

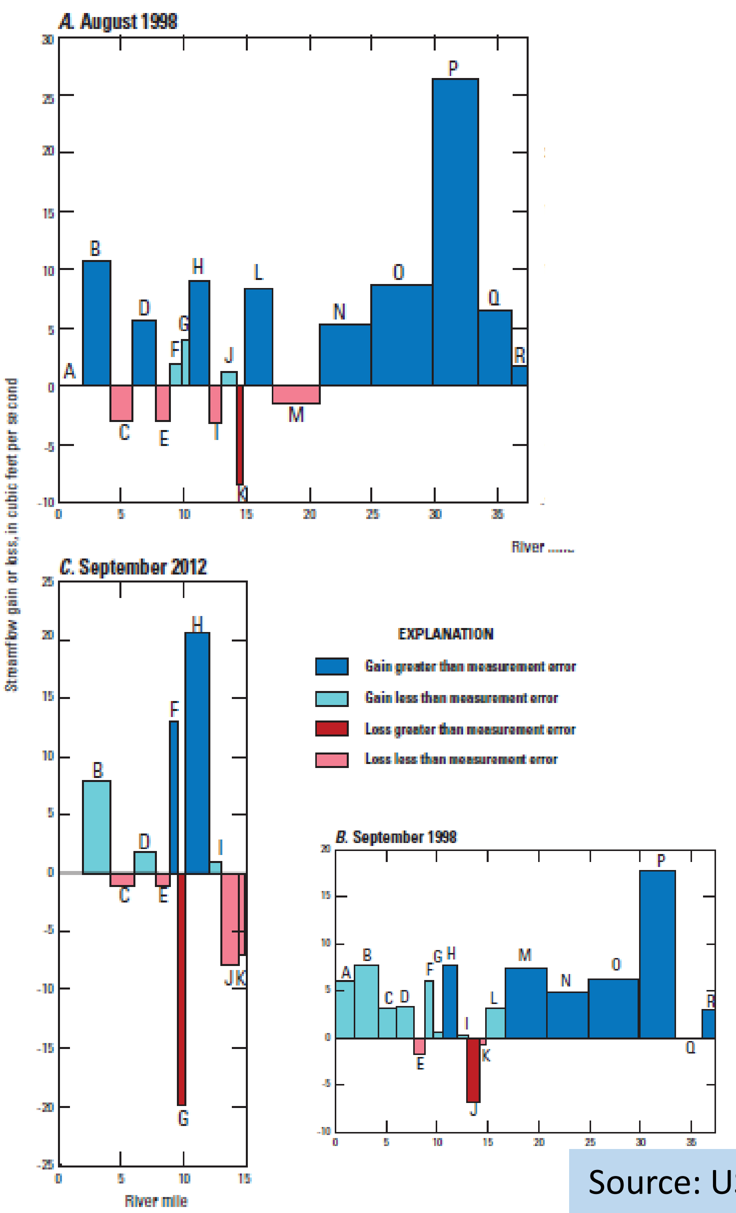


Figure 10. Seepage gains and losses measured during the seepage runs in August 1998 (*A*), September 1998 (*B*), and September 2012 (*C*), South Fork Nooksack River Basin, northwestern Washington.

Source: USGS SIR 2014–5221

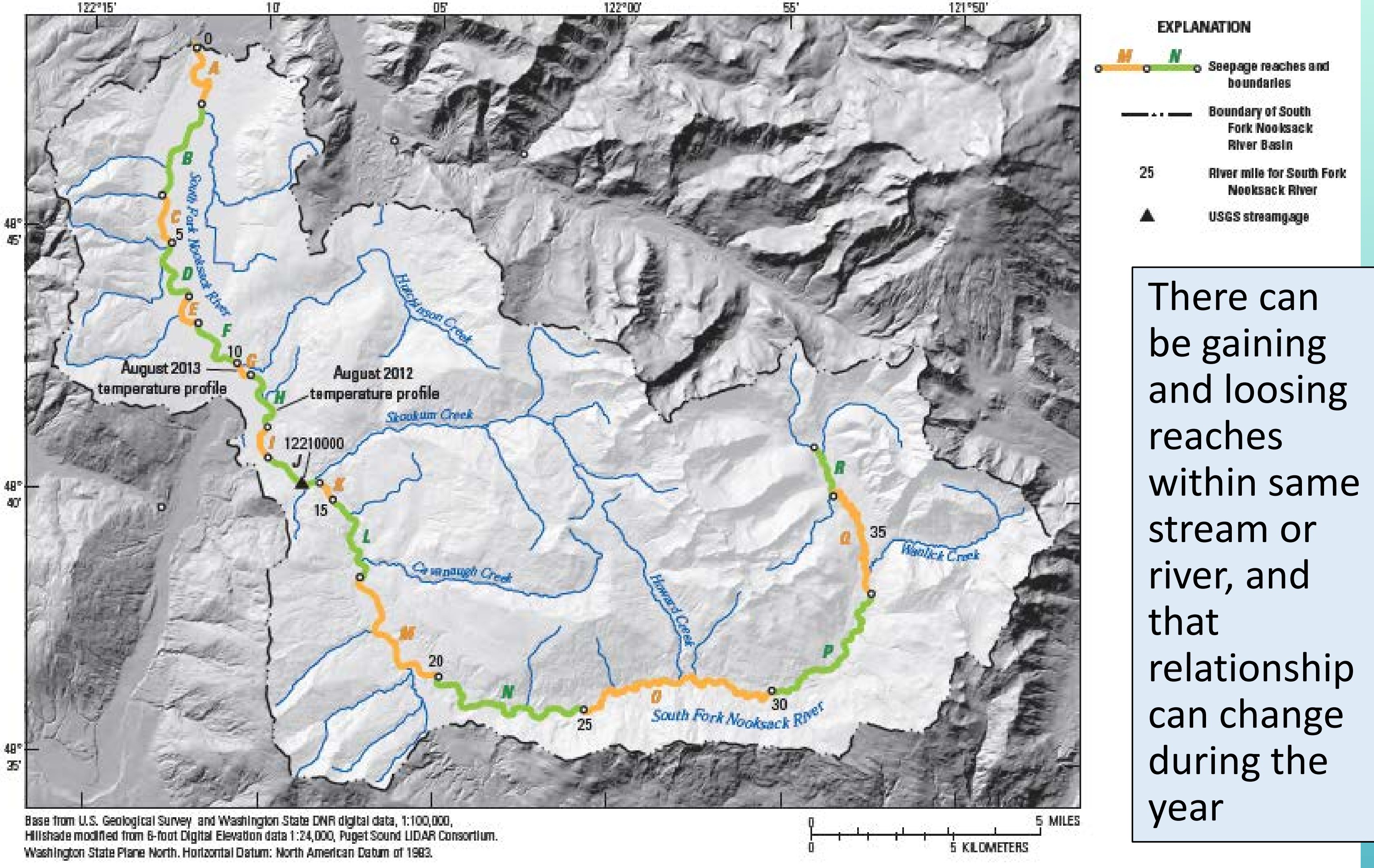
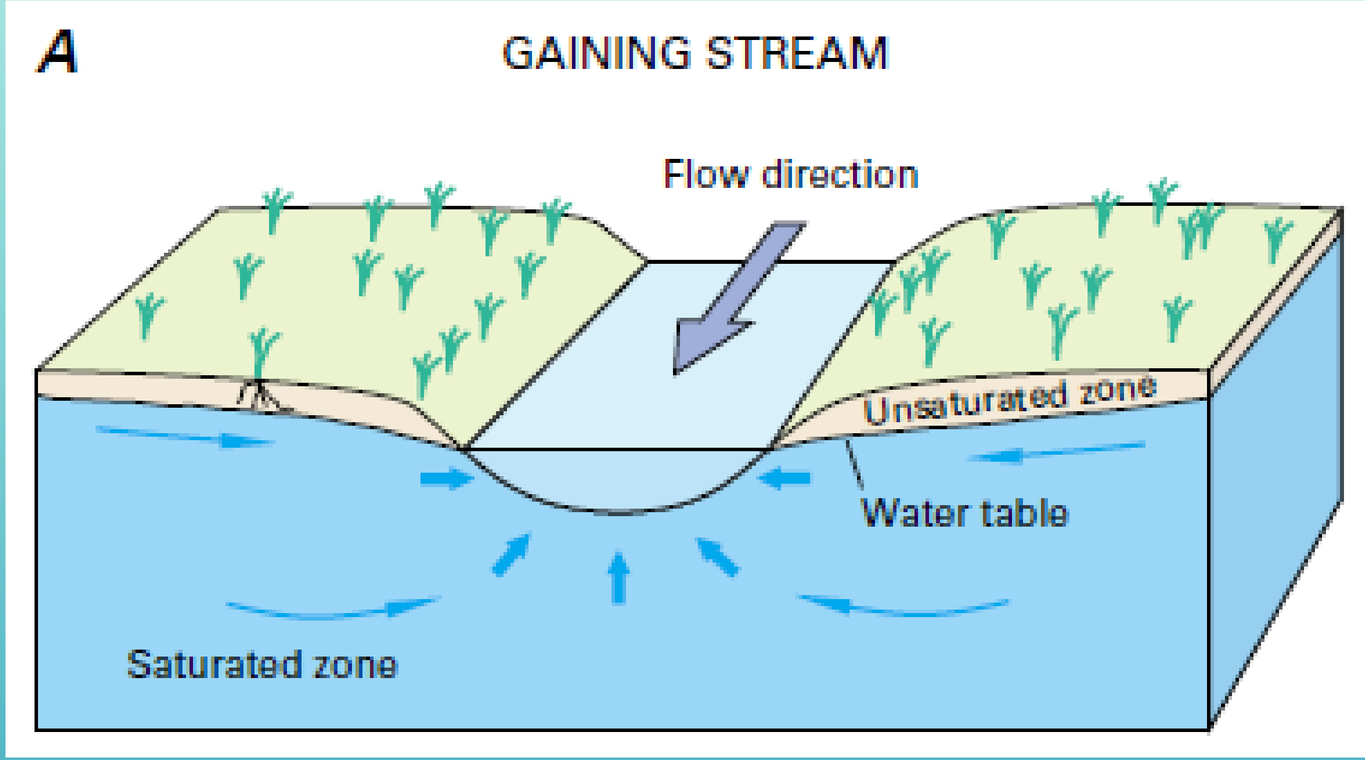


Figure 9. Seepage reaches (A–R) during seepage runs in August and September 1998 and September 2012, South Fork Nooksack River Basin, northwestern Washington.

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

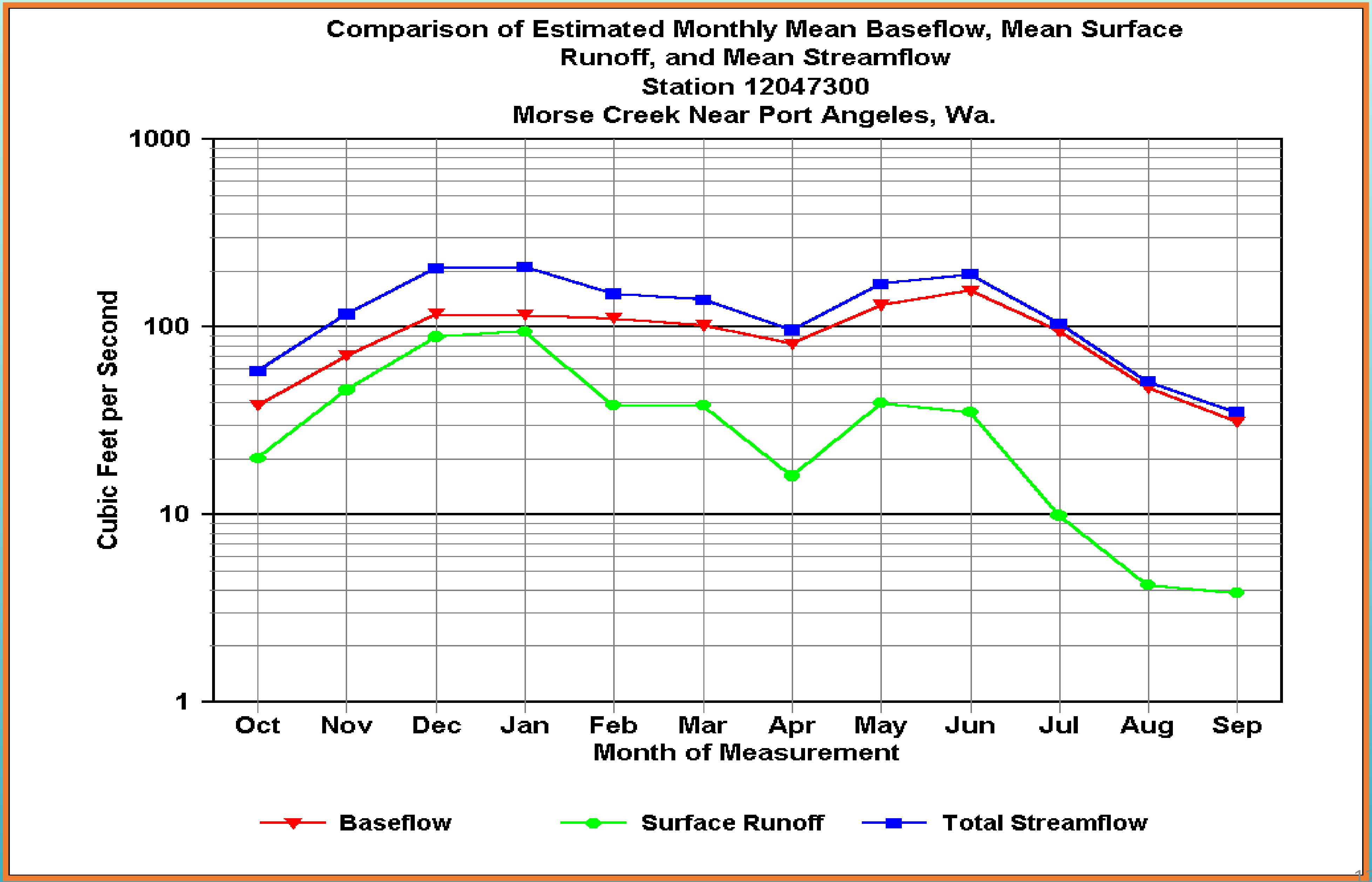
Baseflow: component of streamflow derived from groundwater inflow or discharge.



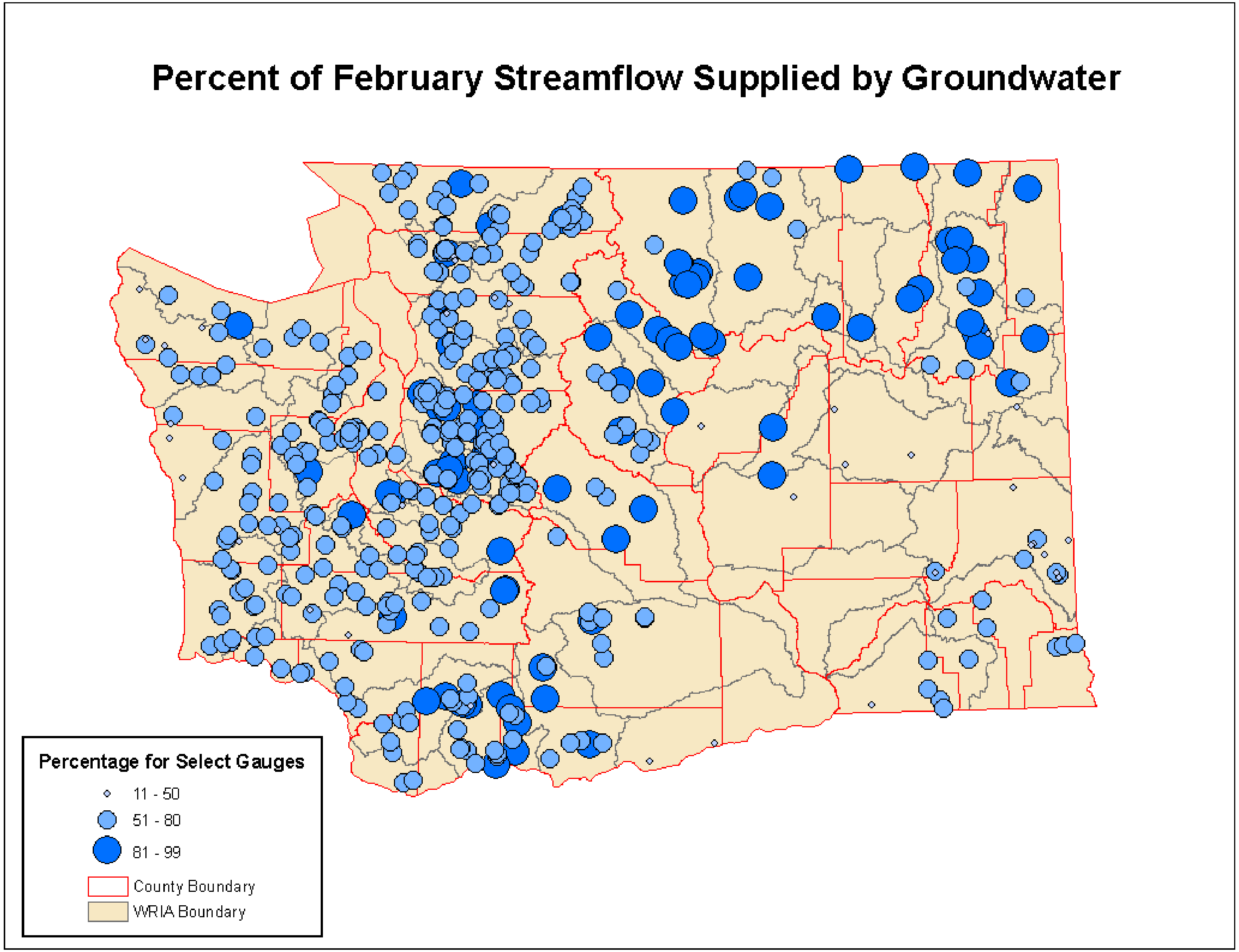
USGS Circular 1186

Baseflow is important for both water quantity and temperature.

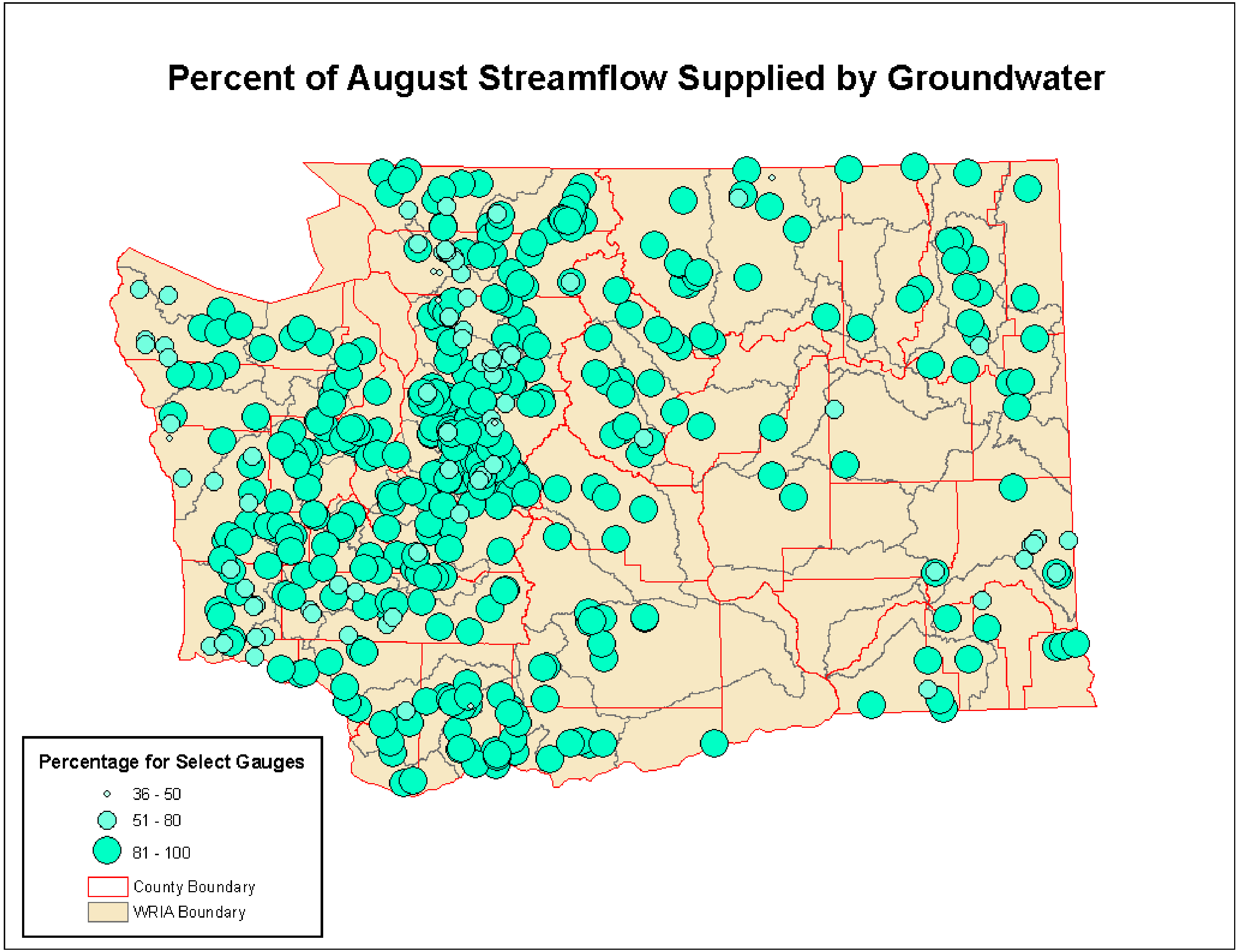
Note: vertical axis presented in **log scale**

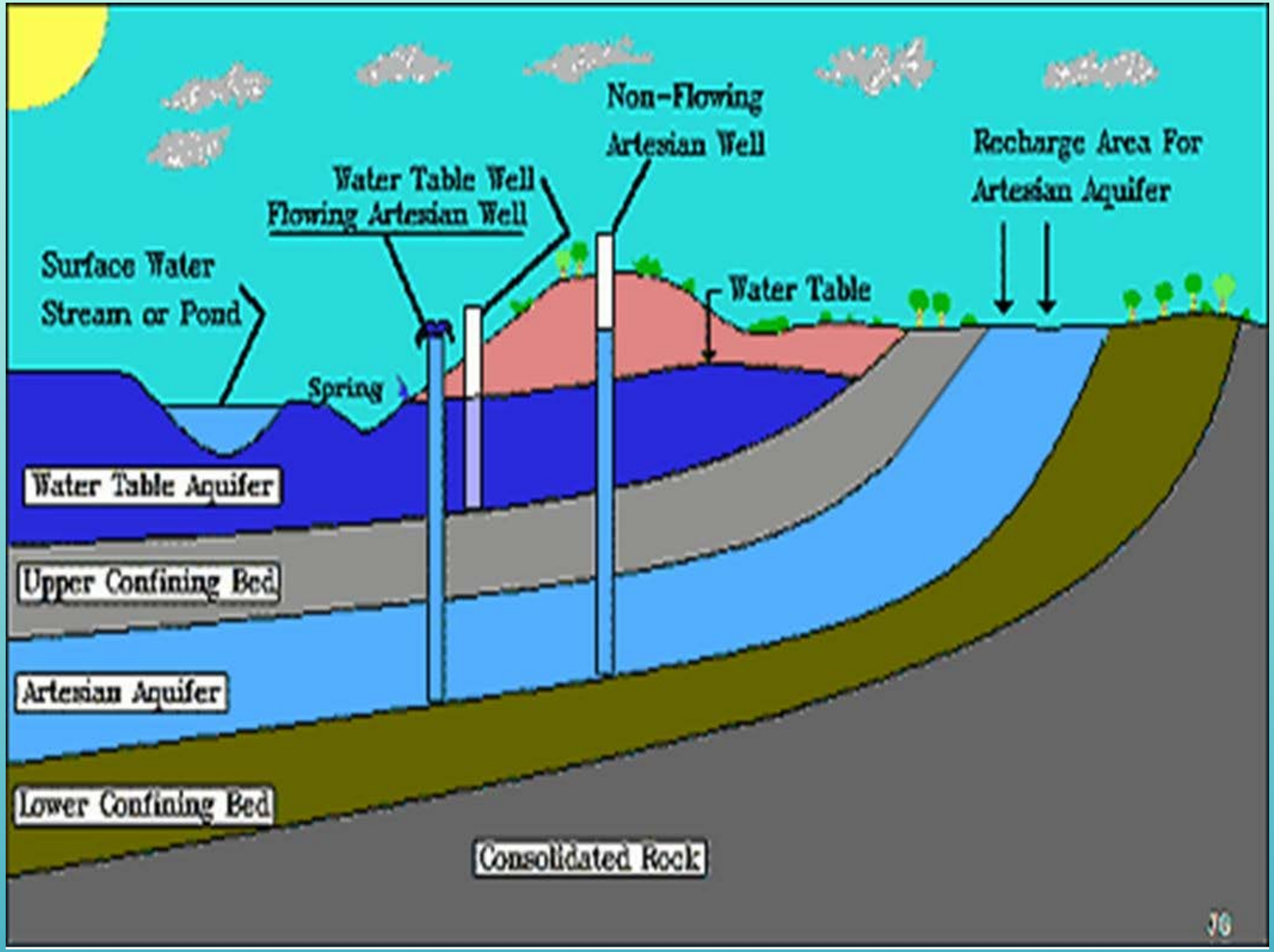


Baseflow maintains summer streamflow throughout most of Washington



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

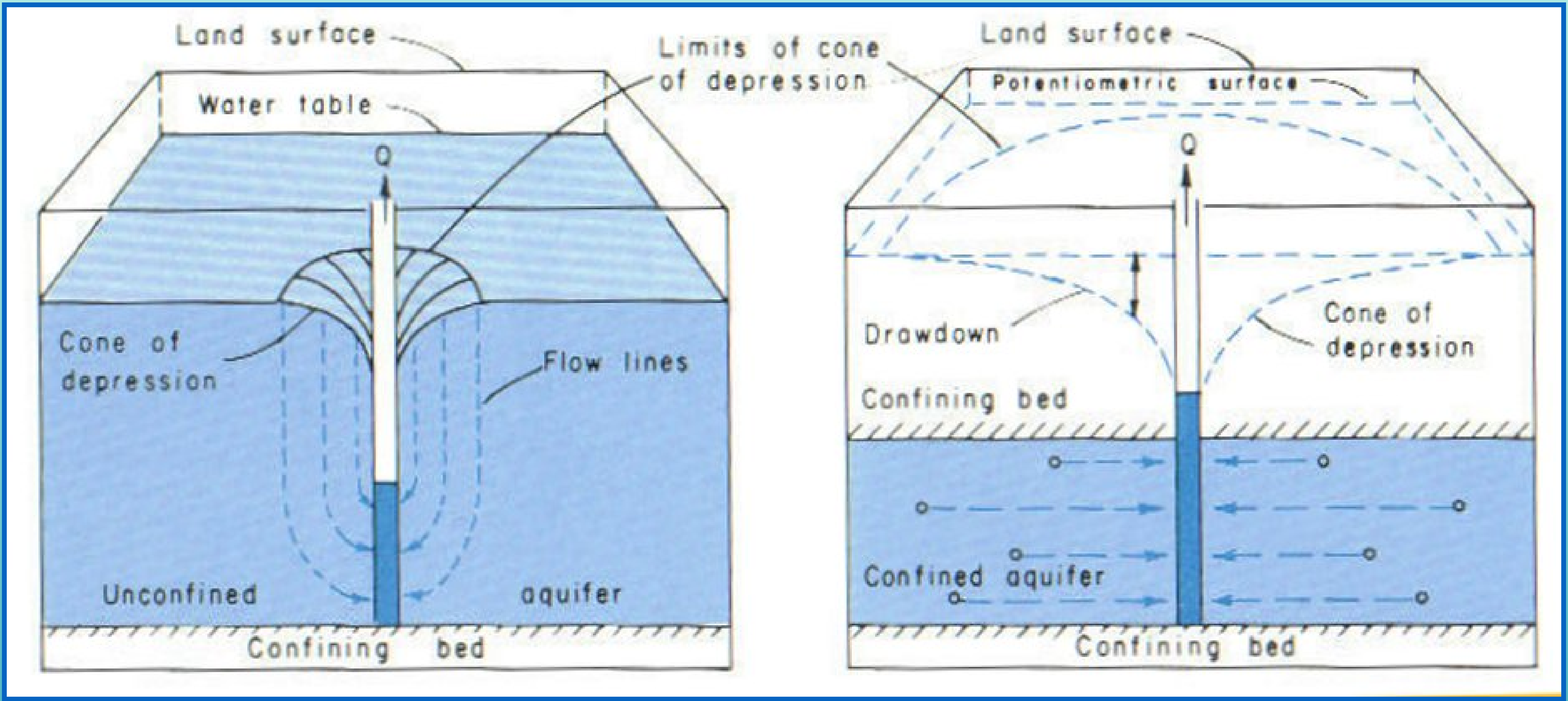




http://www.dennisalbert.com/AAADrilling/Aquafier.htm

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

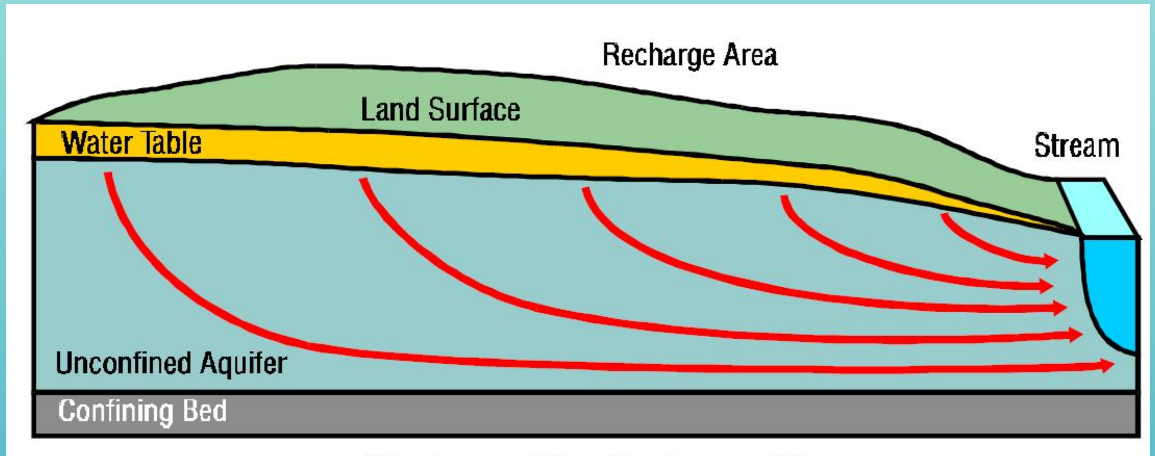
Pumping groundwater from a well (conservation of mass) always causes…

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

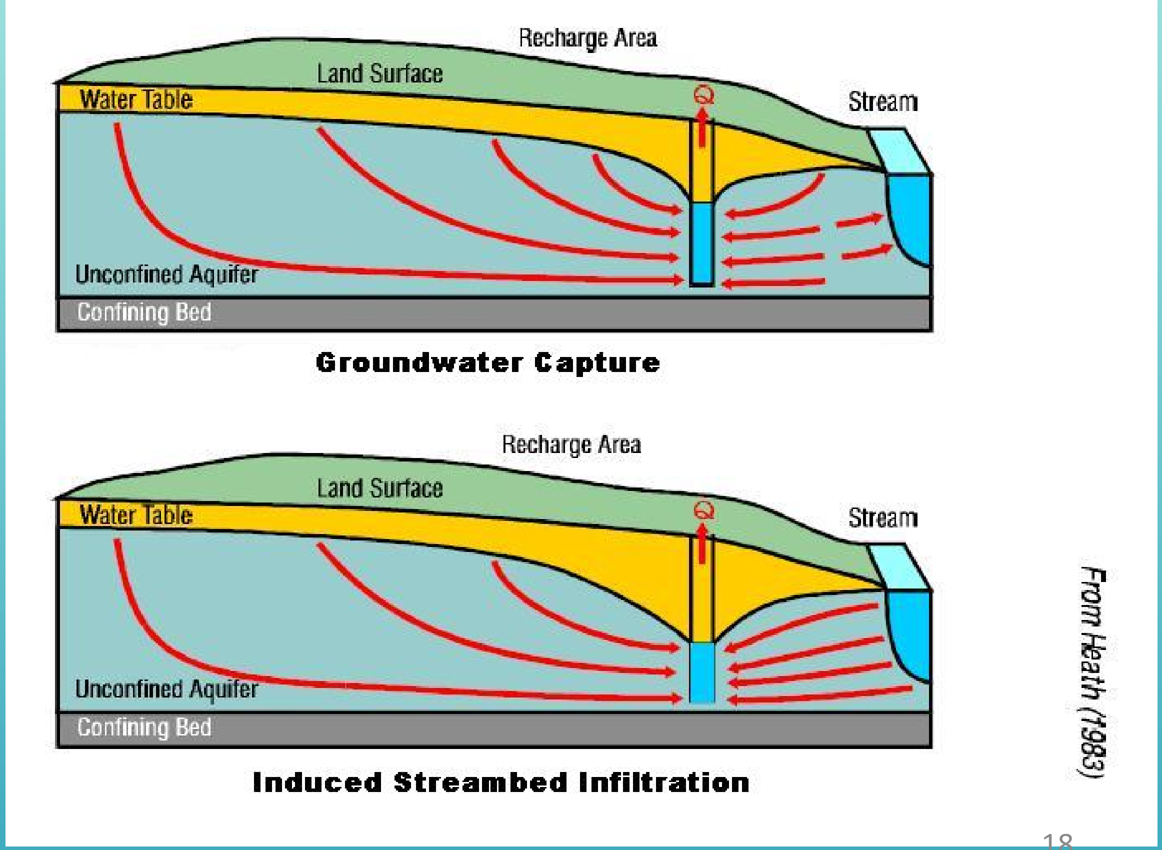
(2) diversion to the pumping well of groundwater that was moving slowly to its natural, possibly distant, area of discharge.

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)

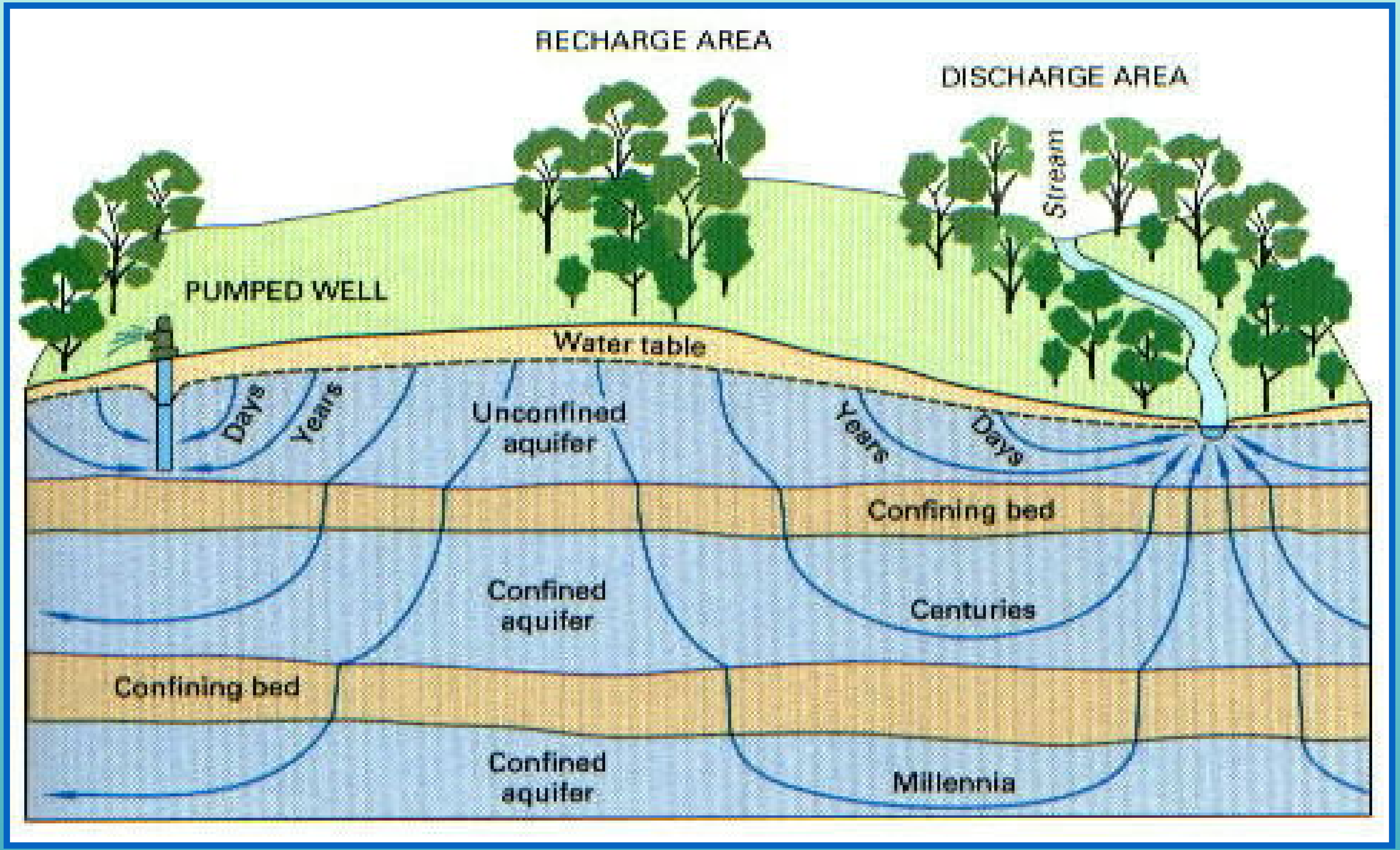


From Heath (1983)

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.

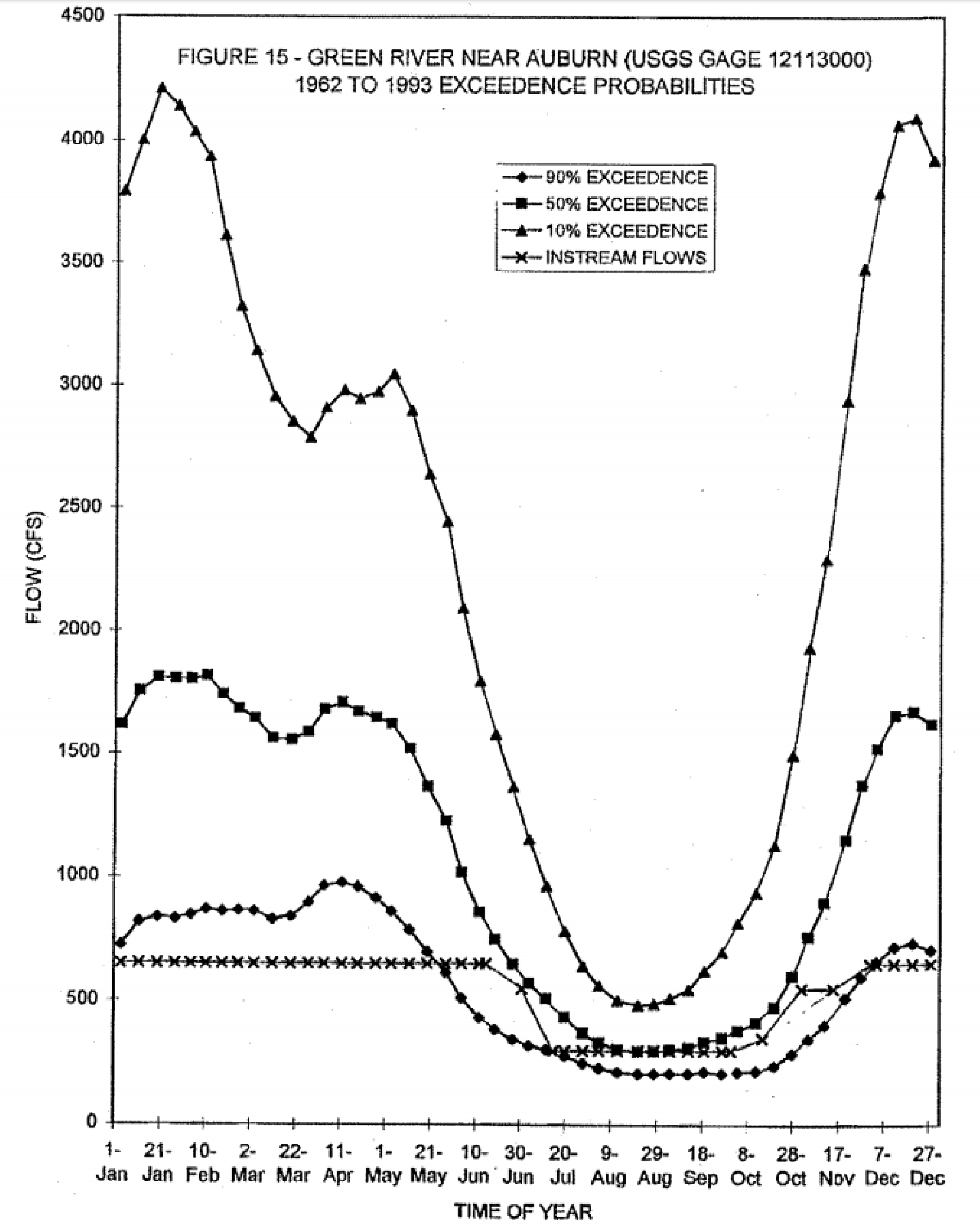
Groundwater travel time is not an indication of the speed at which pumping effects propagate



USGS Circular 1139

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

or



WRIA 14 Hydrogeology

Some Significant WRIA 14 Hydrogeology Studies

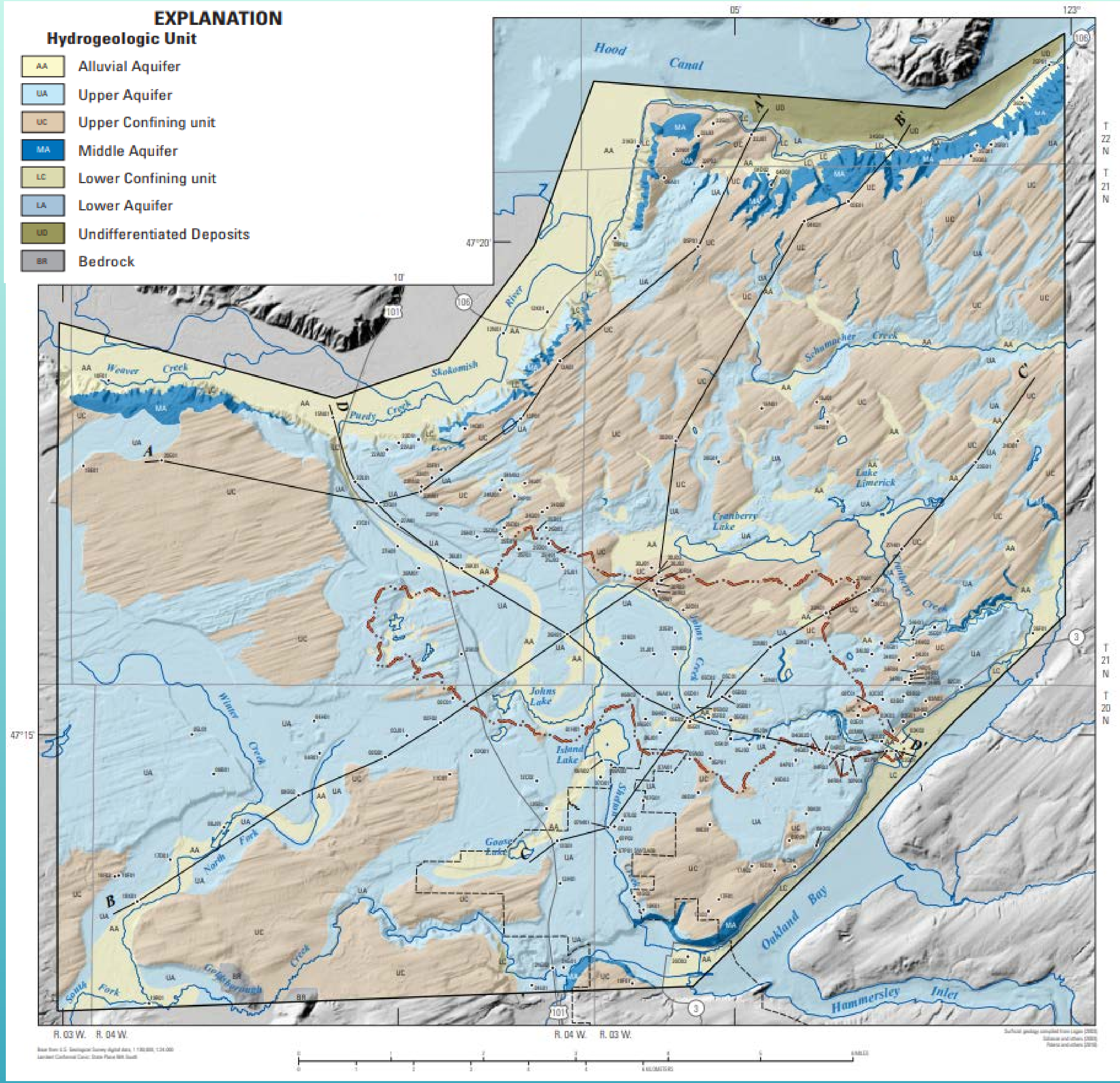
2005 WRIA 14/Kennedy-Goldsborough Watershed Phase II Hydrogeologic Investigation
For WRIA 14 Planning Unit by Northwest Land & Water, Inc.

2011 USGS hydrogeologic framework of the Johns Creek subbasin and vicinity (SIR 2011-5169)
Initial investigation, but there have been more detailed analyses since.

2015 Johns Creek/Goldsborough Creek & vicinity groundwater modeling
Conducted by Golder Associates on behalf of Ecology, and Keta Waters on behalf of Squaxin Island Tribe.

On-going USGS Mason County Hydrogeologic Characterization
Over 2-year period groundwater-levels monitored at ~60 wells and synoptic stream baseflow measurements collected at 20 locations. Data collection largely complete and information now being integrated into hydrogeologic characterization report.

WRIA 14's geology is composed of thick sequence of unconsolidated Quaternary glacial and interglacial deposits overlying Tertiary igneous and sedimentary bedrock



SIR 2011-5169

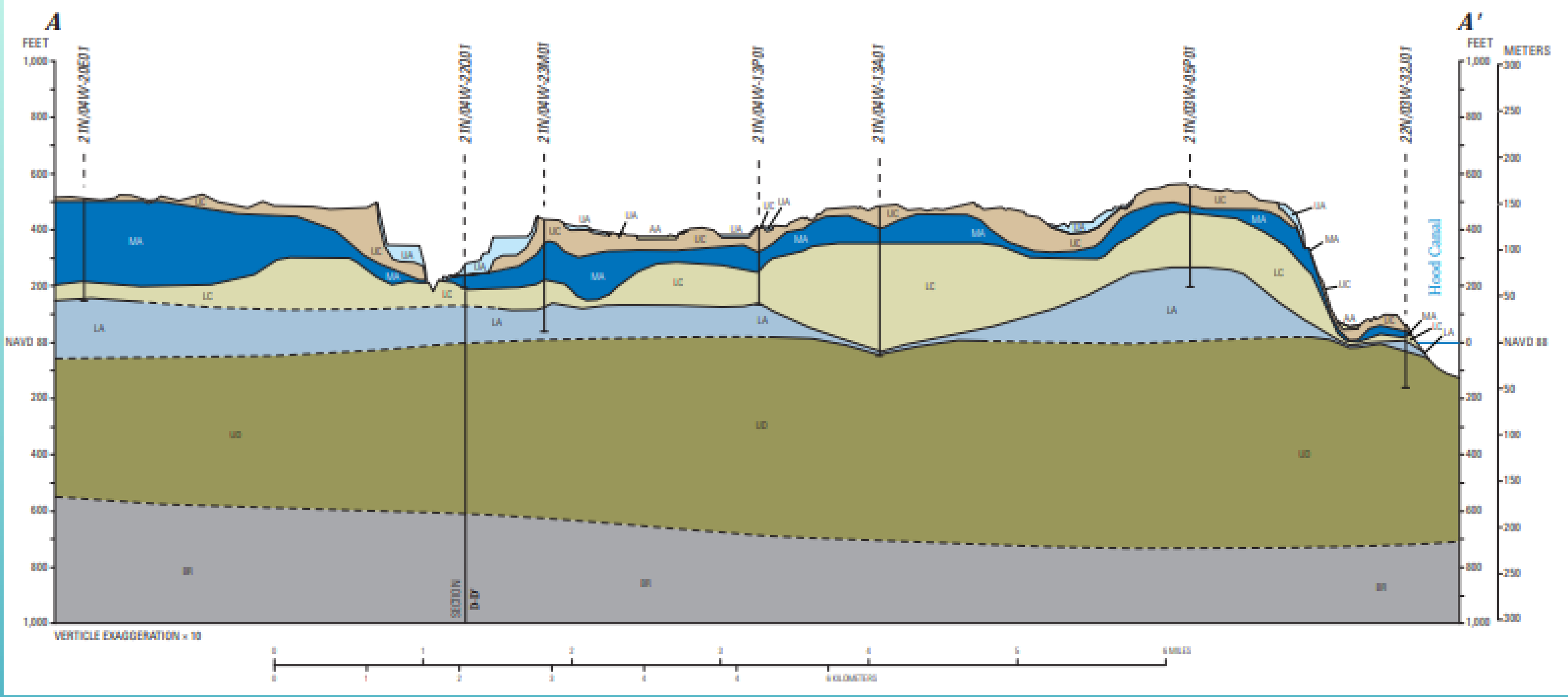
Table 1. Hydrogeologic units defined in this study and correlation with geologic and hydrogeologic units defined by previous investigations.

Period	Epoch	Hydrogeologic units defined in this study	Lithology	Geologic units in Logan (2003)	Geologic units in Schasse and others (2003); Polenz and others (2010)	Hydrogeologic units in Northwest Land and Water (2005)
Quaternary	Holocene	AA – Alluvial Aquifer recent alluvial deposits	Gravel, sand, and silt; clay and peat	Qa	Qa, [1]Qp, Qf, Qa(m), [1]Qaf, [1]Qmw, [1]Qls, Qm, Qoa, Qb, af, ml	Not delineated
	Pleistocene	UA – Upper Aquifer recessional outwash deposits	Sand and gravel; lenses of clay, silt, and fine sand	Qgo, Qapo, Qgd	Qgd, Qgic, Qgog, Qgo, Qgos, [1]Qgik, Qge, [1]Qmw, Qgol, [1]Qgof, [1]Qaf, [1]Qp	Unit A
		UC – Upper Confining unit glacial till deposits	Unsorted and compacted clay, silt, sand, and gravel; lenses of sand and gravel	Qgt	Qgt, Qgta, [1]Qp, Qgol, Qml	Units B and C
		MA – Middle Aquifer advance outwash deposits	Sand, gravel, and silt; occasional lenses of clay	Qga	Qga, Qpo, Qpg(o), [1]Qgik [1]Qgof, [1]Qmw, [1]Qls, Qapd	Unit D
		LC – Lower Confining unit glaciolacustrine and interglacial sediments	Clay and silt; some till; occasional peat and wood	Qc(k)	Qpu(op), Qpf, [1]Qgik, [1]Qls	Unit E
		LA – Lower Aquifer outwash, till, and glaciolacustrine deposits	Sand and gravel, silt and clay; some till	Qgp	Qpgo, Qpg, Qpd, Qpt	Unit F
		UD – Undifferentiated Deposits undifferentiated glacial and interglacial sediments	Alternating layers of clay and silt, sand and gravel		[2]Qu	
Tertiary	Eocene	Br – Bedrock igneous and sedimentary rocks	Volcanic and sedimentary rock	Ev(c)	[2]Ev(c)	Bedrock

[1] Thin (less than 10 feet) and (or) discontinuous geologic units (Polenz and others, 2010) in association with aquifer and confining hydrogeologic units at land surface.

[2] Geologic units delineated only in Schasse and others (2003); no equivalent geologic units delineated in Polenz and others (2010).

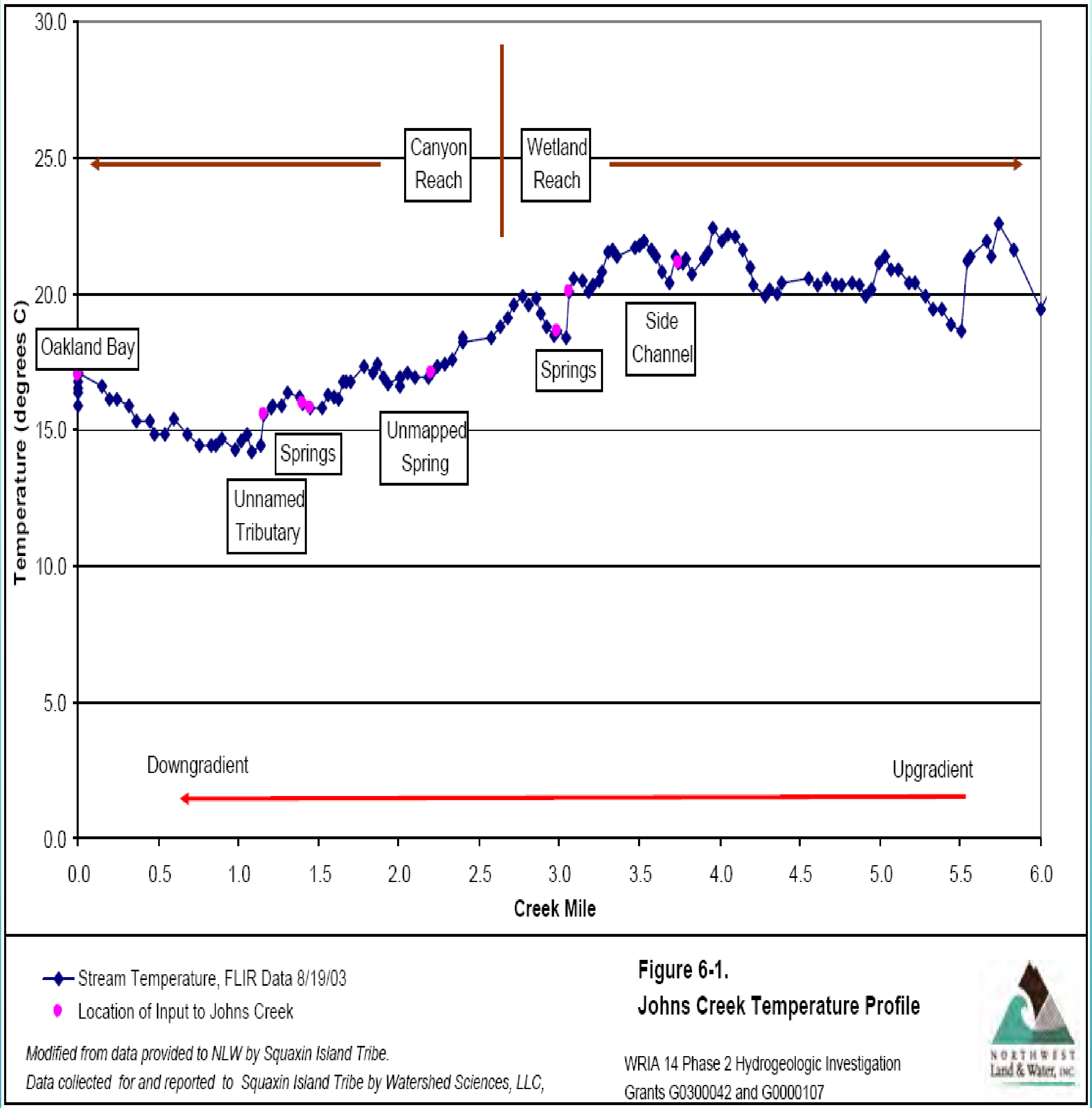
From USGS SIR 2011-5169

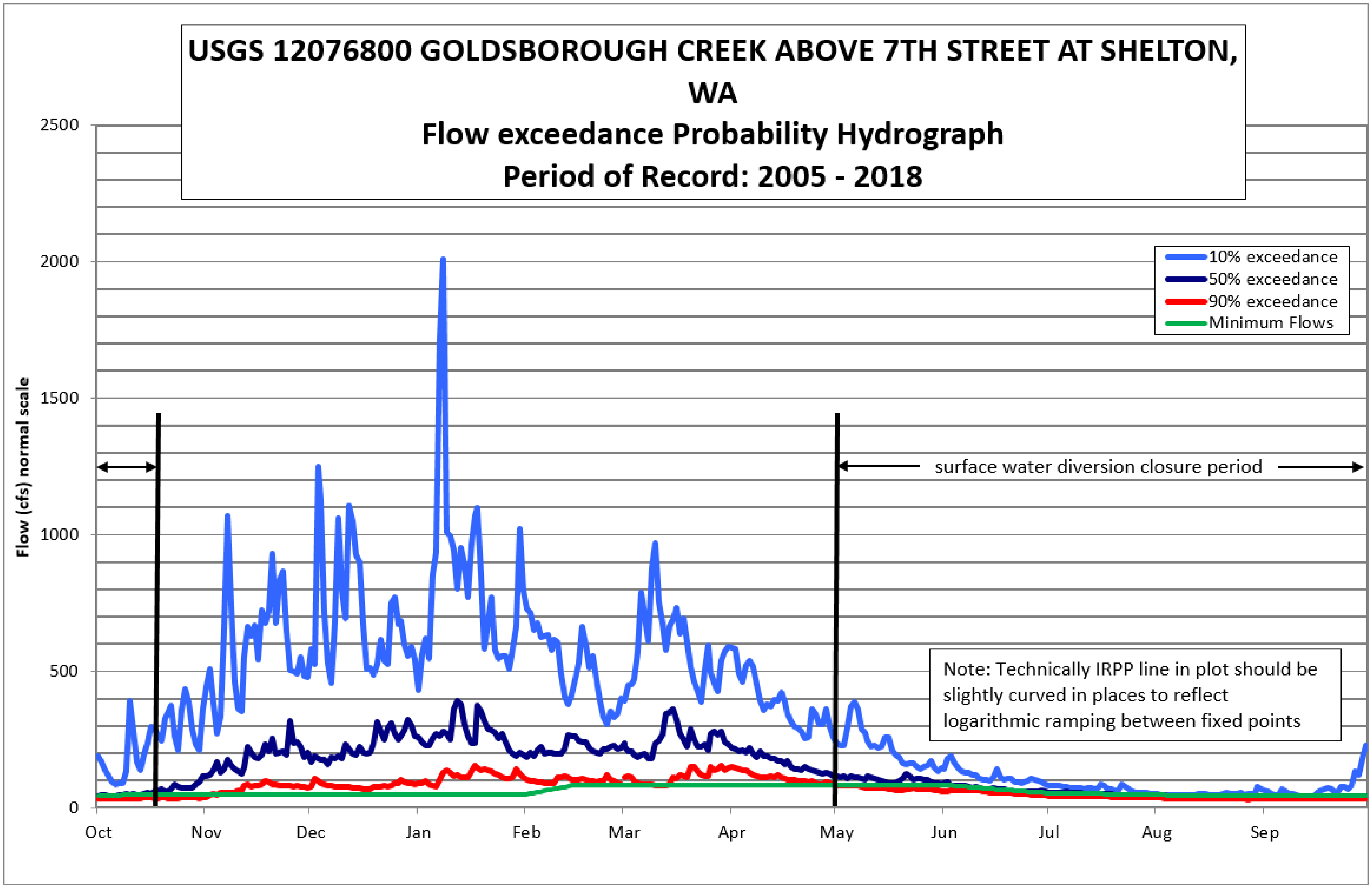


From USGS SIR 2011-5169

Temperature Data

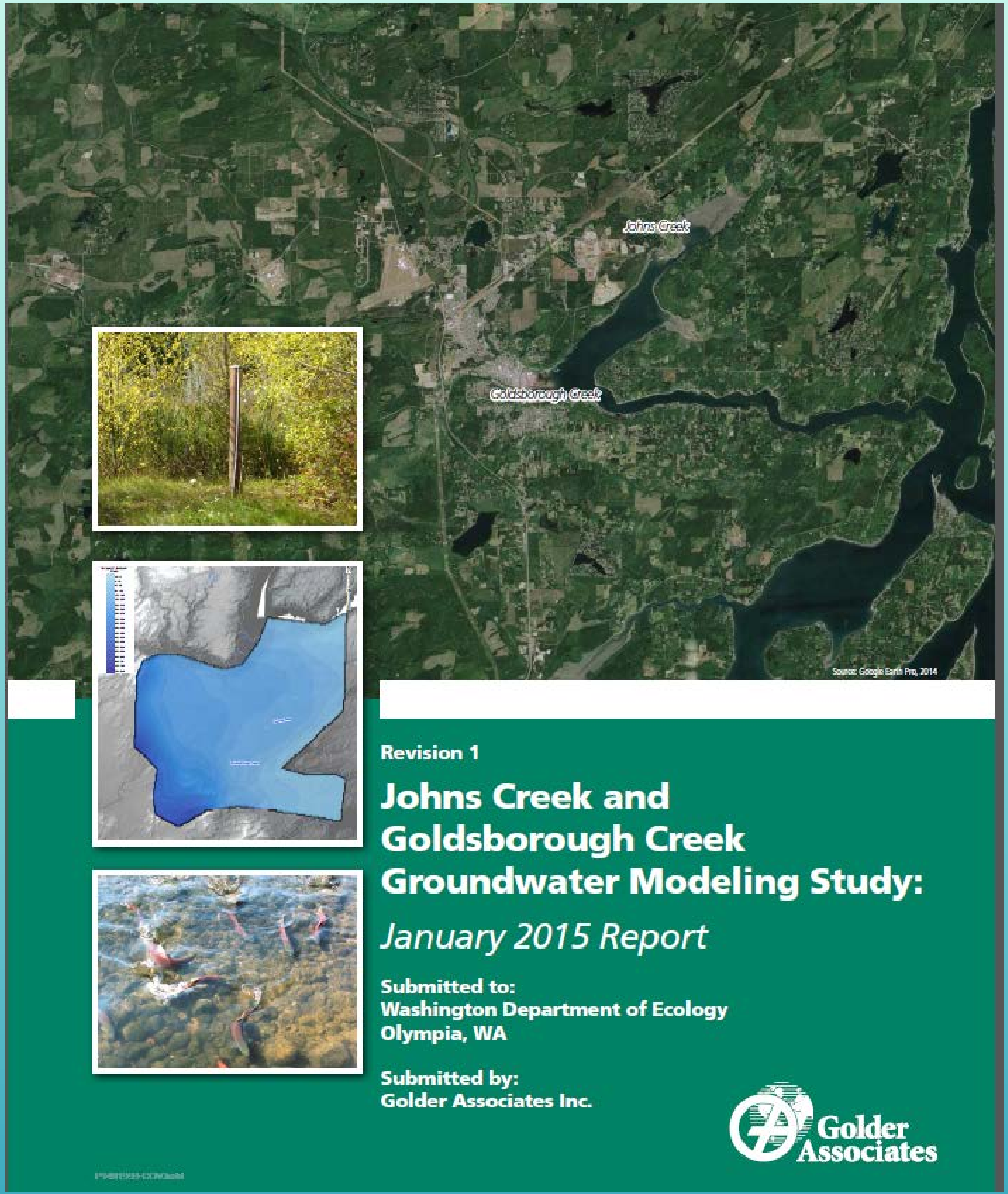
- Forward Looking Infrared (FLIR) temperature study was conducted for the Squaxin Island Tribe (Watershed Sciences, 2004).
- Stream temperatures measured from helicopter flying along length of the Johns Creek thalweg.
- Abrupt temperature drops occurred at spring locations where groundwater discharges upward through creek bed.



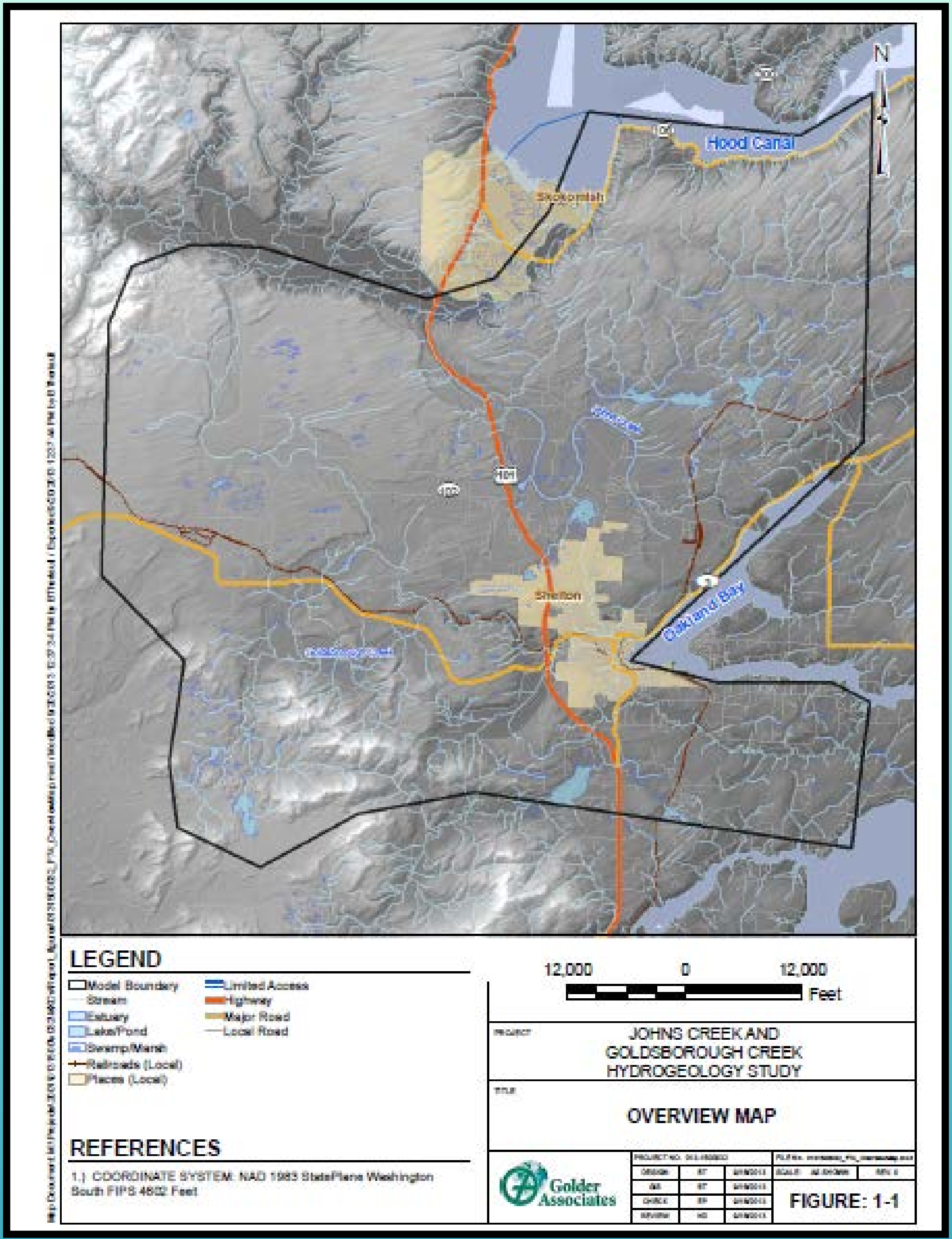


USGS 12076800 GOLDSBOROUGH CREEK ABOVE 7TH STREET AT SHELTON, WA
Flow exceedance Probability Hydrograph
Period of Record: 2005 - 2018
Flow (cfs) normal scale
2500
2000
1500
1000
500
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
10% exceedance
50% exceedance
90% exceedance
Minimum Flows
surface water diversion closure period
Note: Technically IRPP line in plot should be slightly curved in places to reflect logarithmic ramping between fixed points

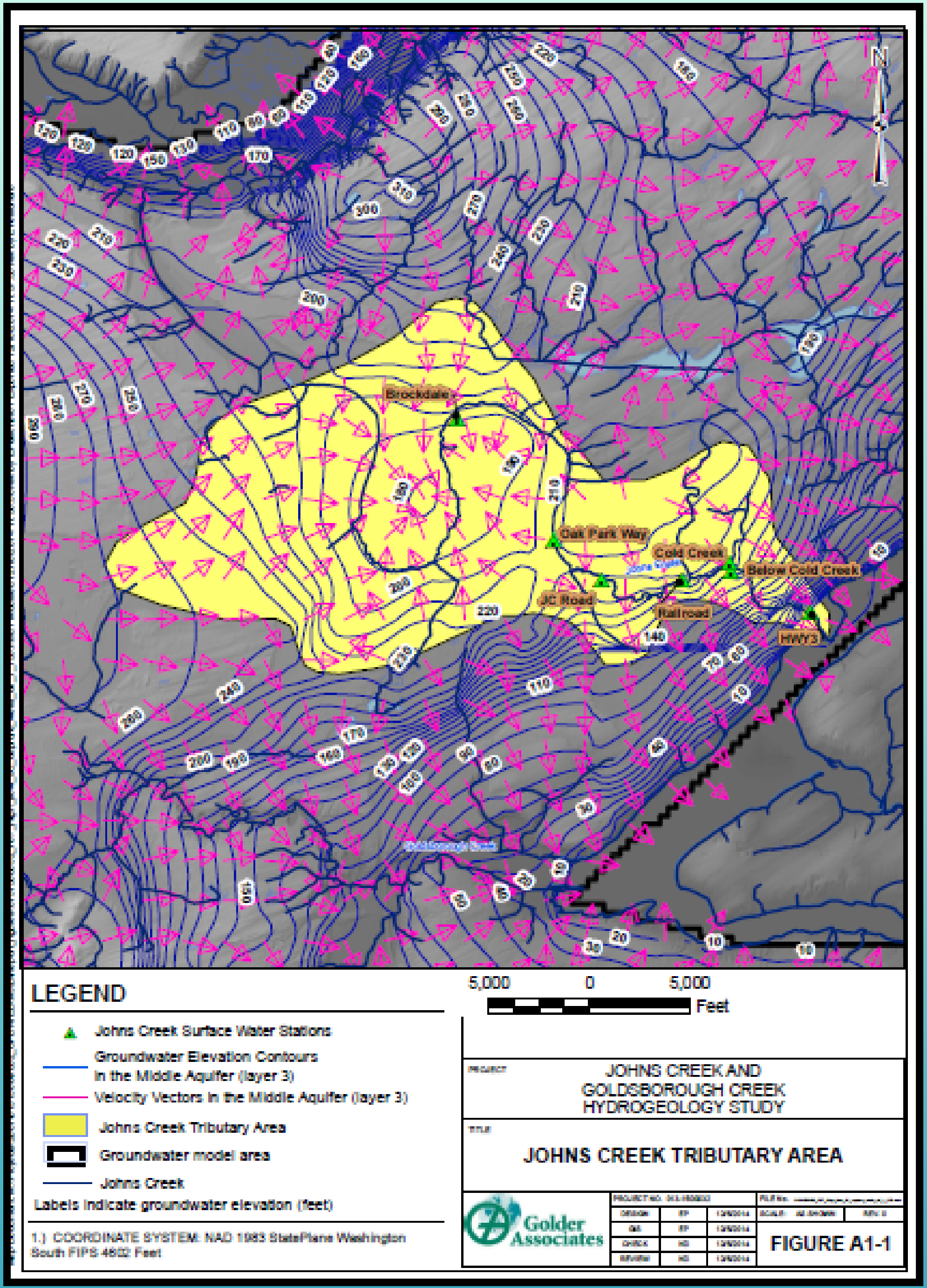
2015 Johns Creek/Goldsborough Creek & vicinity groundwater modeling study conducted by Golder Associates on behalf of Ecology, and Keta Waters on behalf of Squaxin Island Tribe.



- Three dimensional, steady-state model simulates groundwater flow under saturated conditions
- Modeled area includes two watersheds and surrounding areas
- Model calibrated using water level and stream flow data



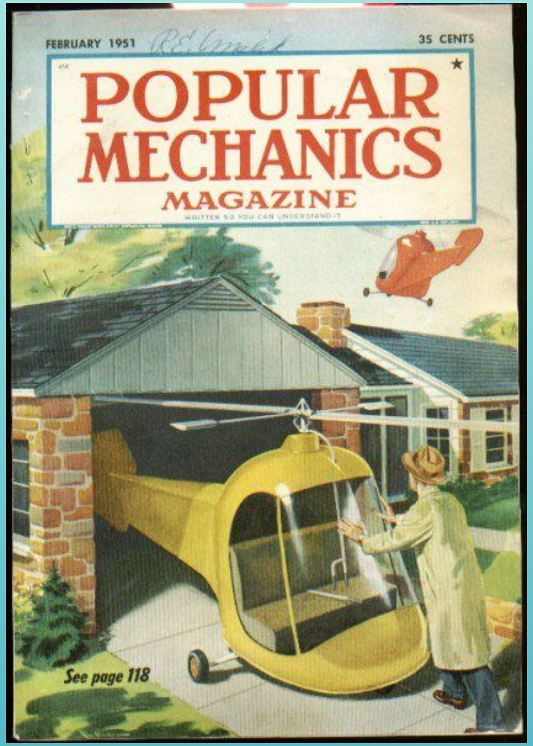
Once constructed, Golder Associates ran modeling scenarios on behalf of Ecology, while Keta Water ran model scenarios on behalf of Squaxin Island Tribe.



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)

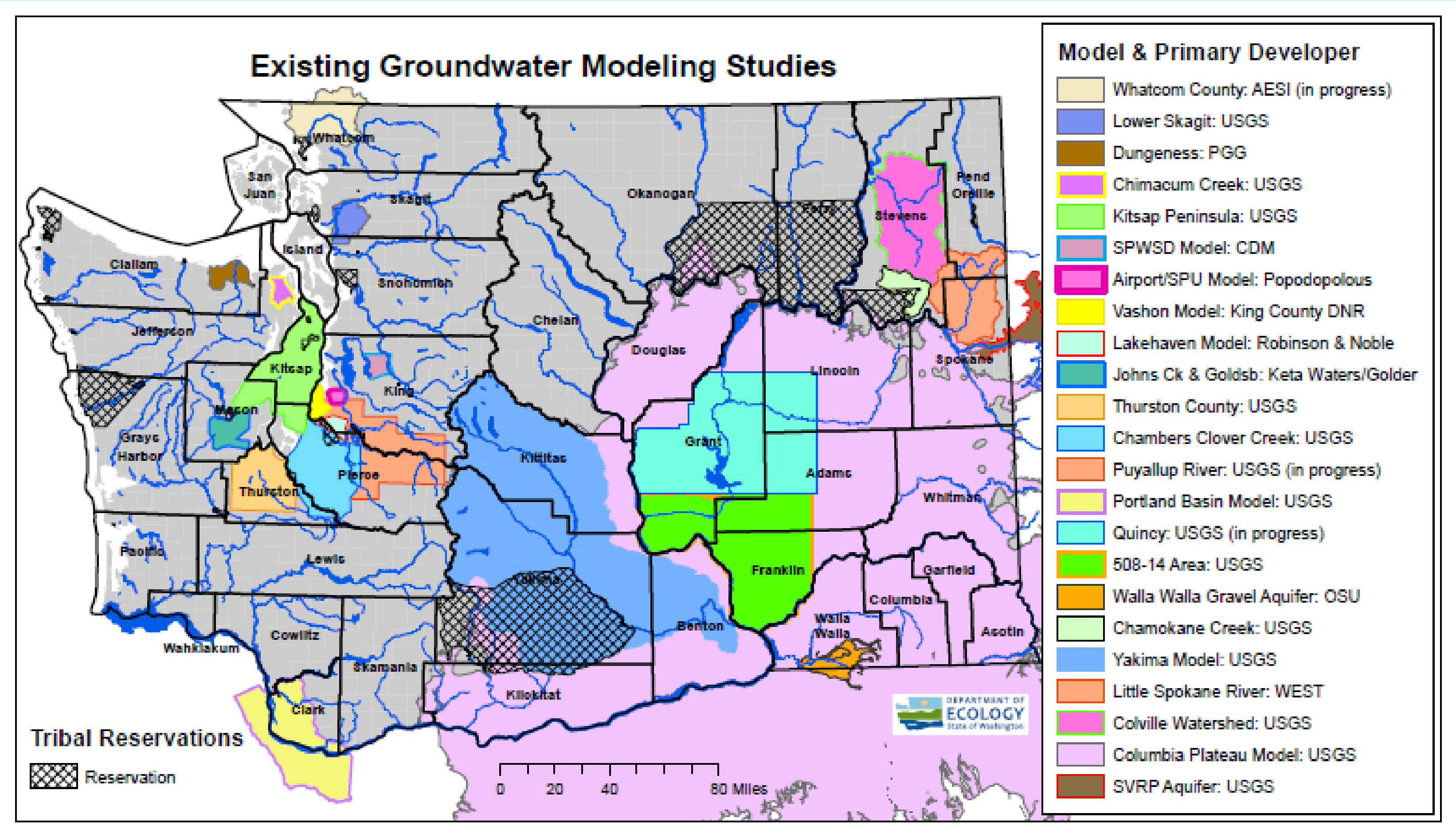
1. Assuming all houses discharge wastewater via septic systems
2. From Appendix A of the Washington Irrigation Guide (WAIG) (U.S. Department of Agriculture, 1997)

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

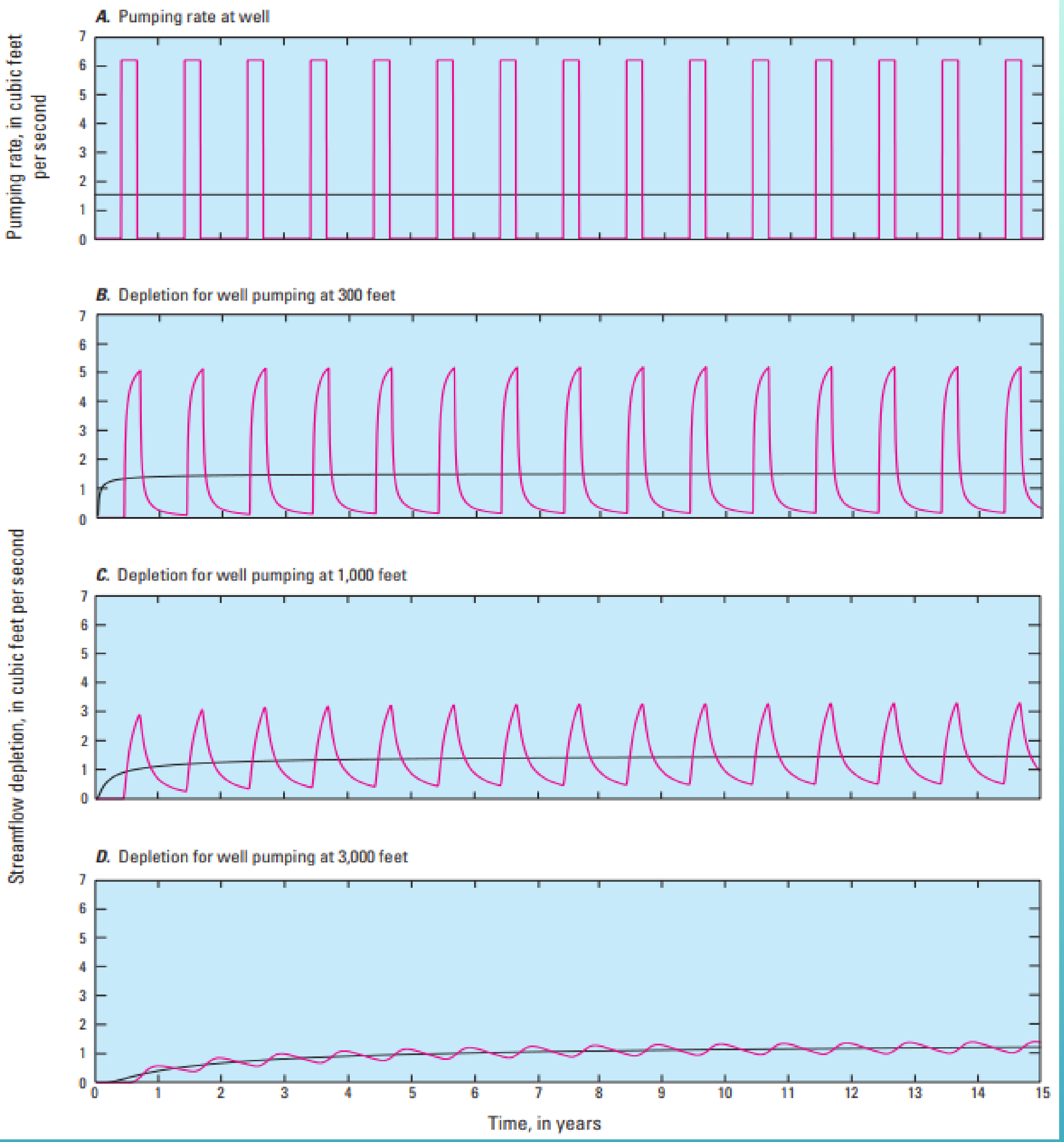
Conceptual groundwater models provide overall hydrogeologic understanding.

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.



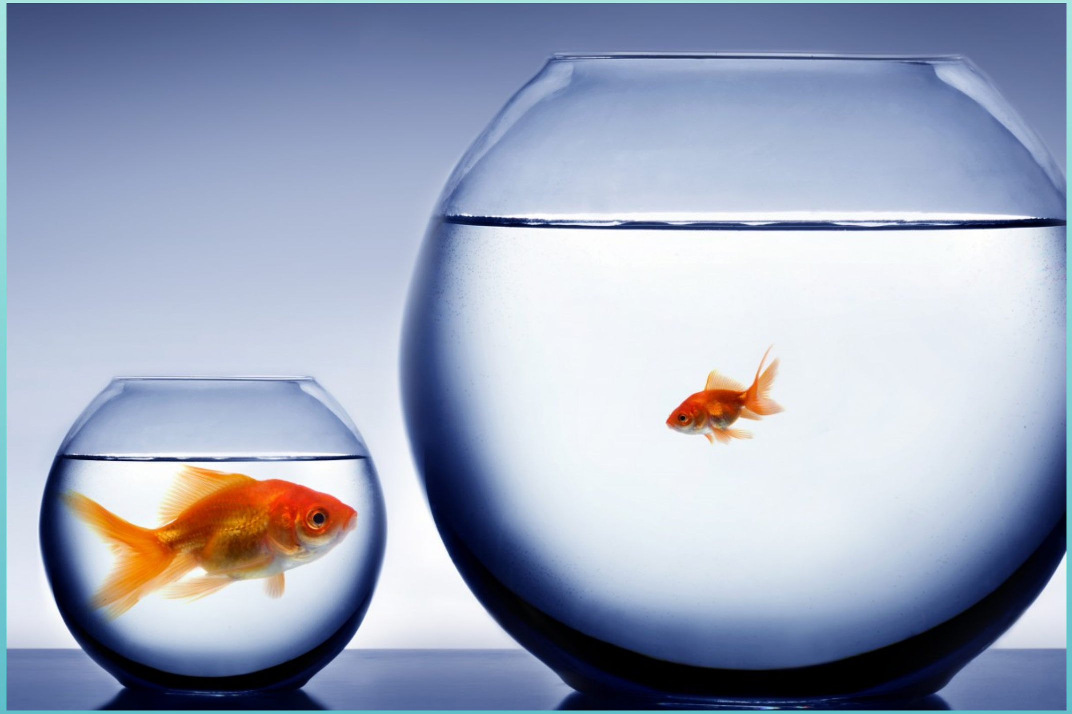
USGS Circular 1376

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.

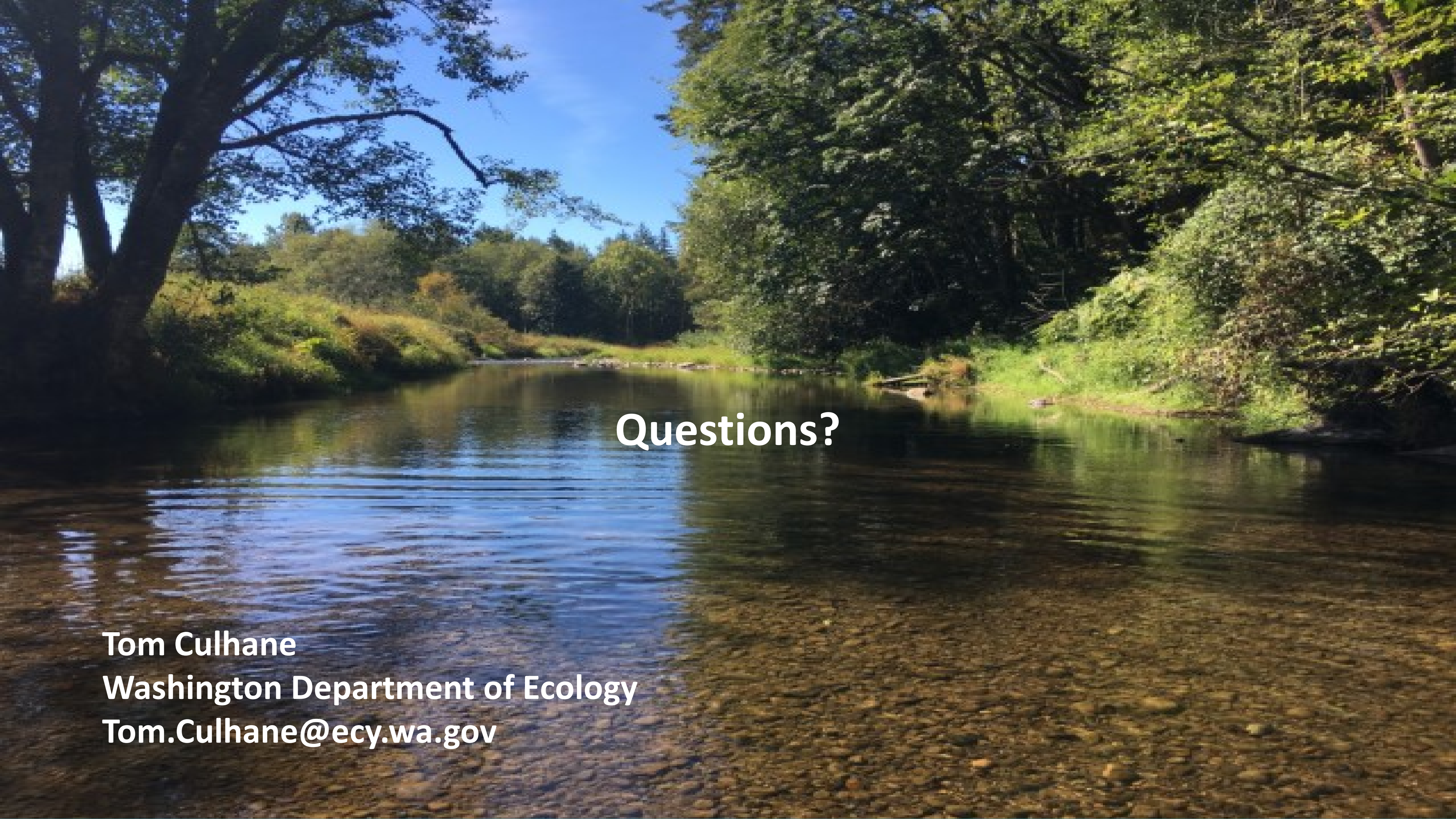
Significance of Scale

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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