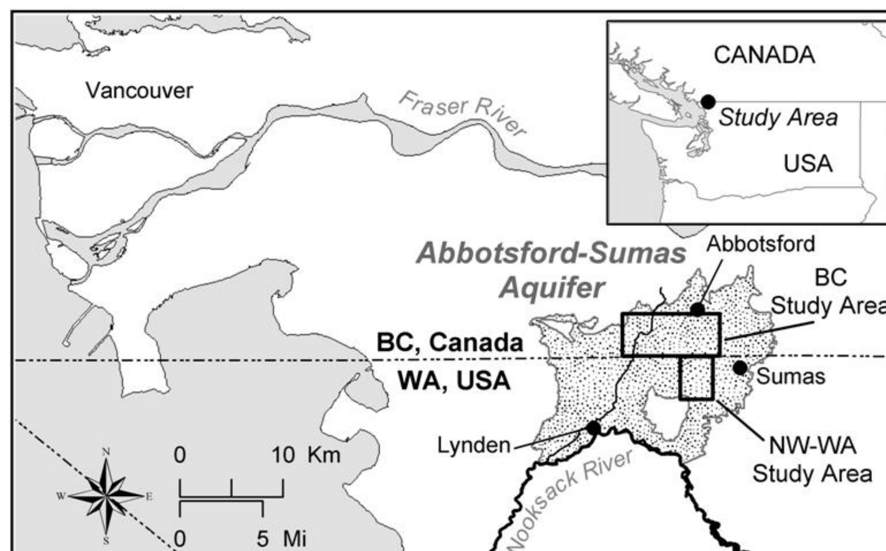
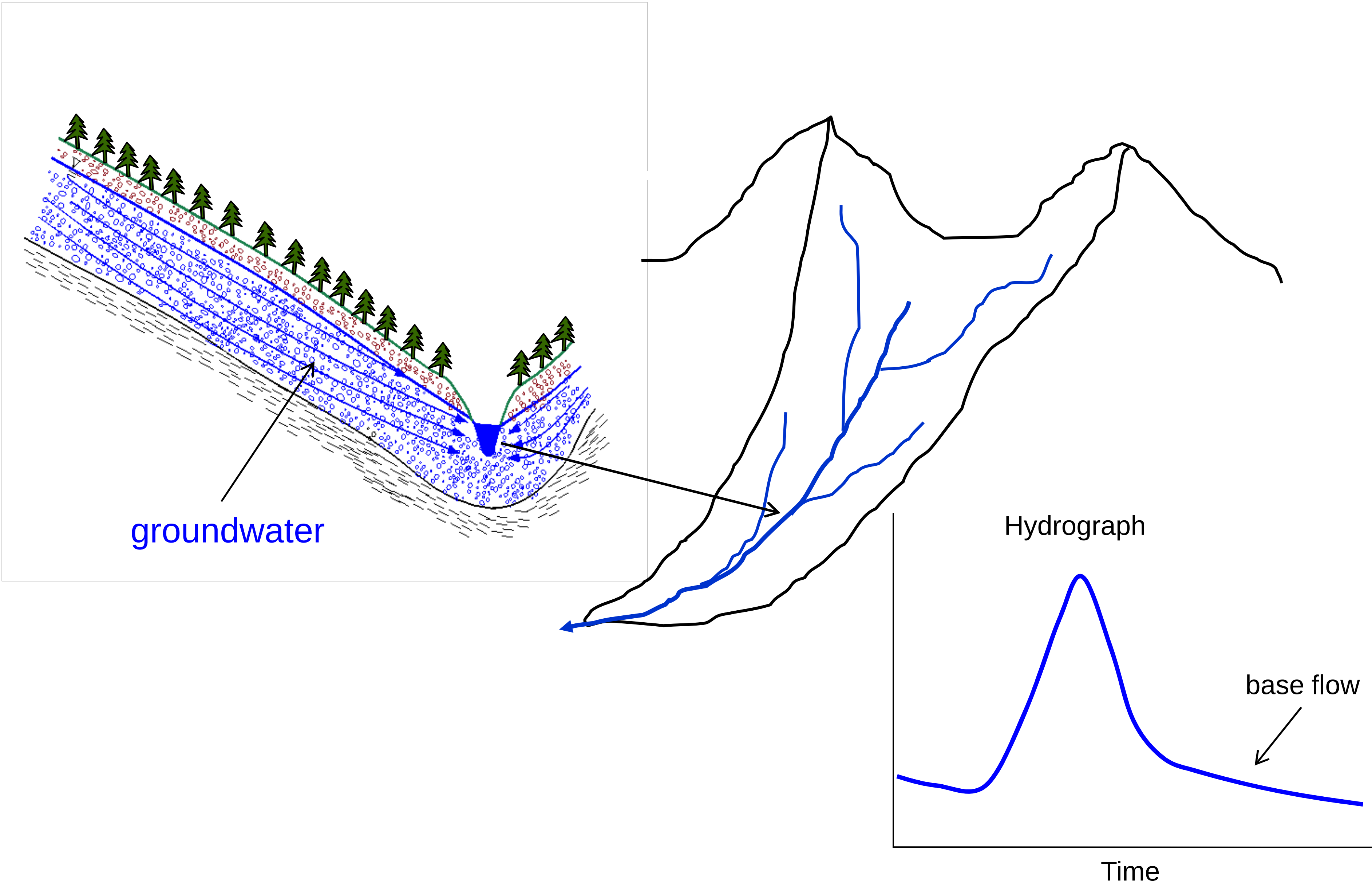
Lecture 21: Groundwater: Hydraulic Conductivity

Key Questions

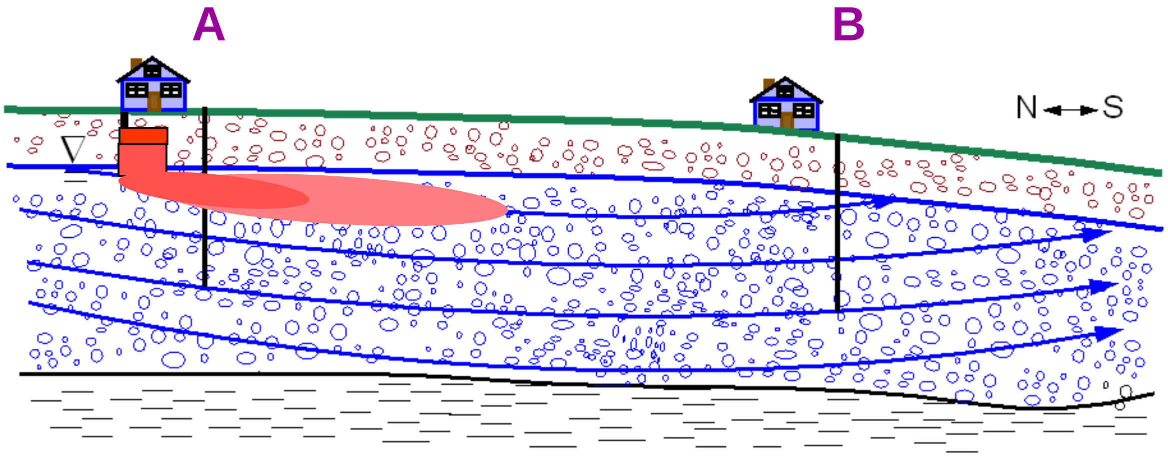
1. What causes groundwater to move?
2. What is the <u>hydraulic conductivity</u>?
3. What is Darcy's Law?
4. How is groundwater velocity estimated?
5. What makes good aquifers in the Puget Lowlands?
6. What is a cone of depression?



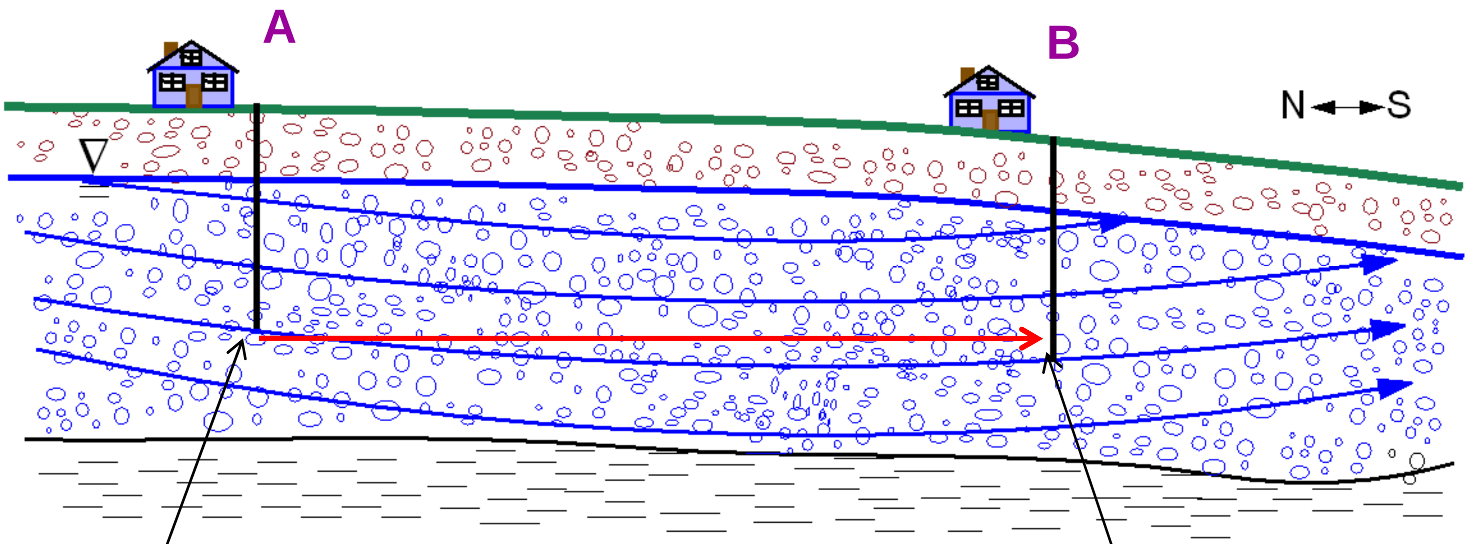
Groundwater supports streamflow in between rain events (baseflow)



Groundwater movement controls the transport of contaminants



A hydraulic gradient causes water to move

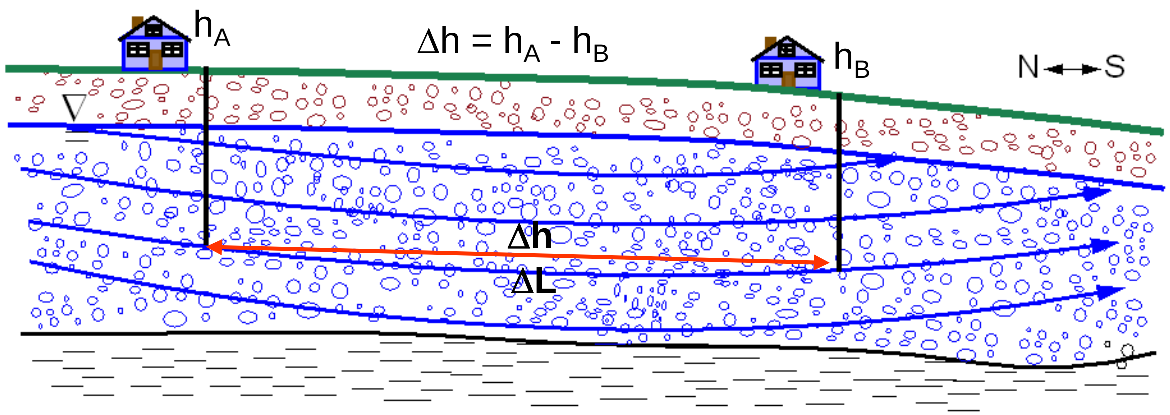


water has hydraulic head (pressure and gravitational energy) at location A

water has hydraulic head (pressure and gravitational energy) at location B

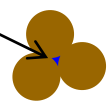
The hydraulic gradient is the change in total head divided the distance over which the change occurs.

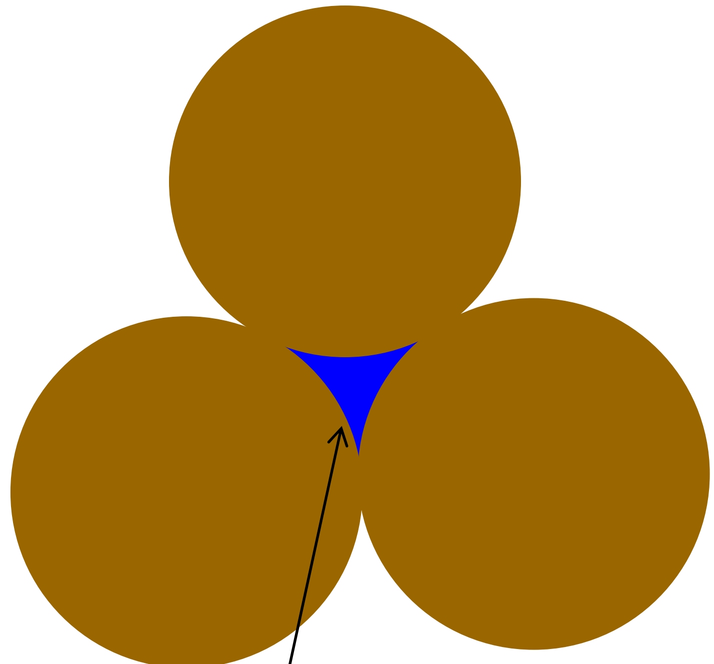
hydraulic gradient = $\Delta h / \Delta L$



The hydraulic conductivity of the sediment will resist the water flow

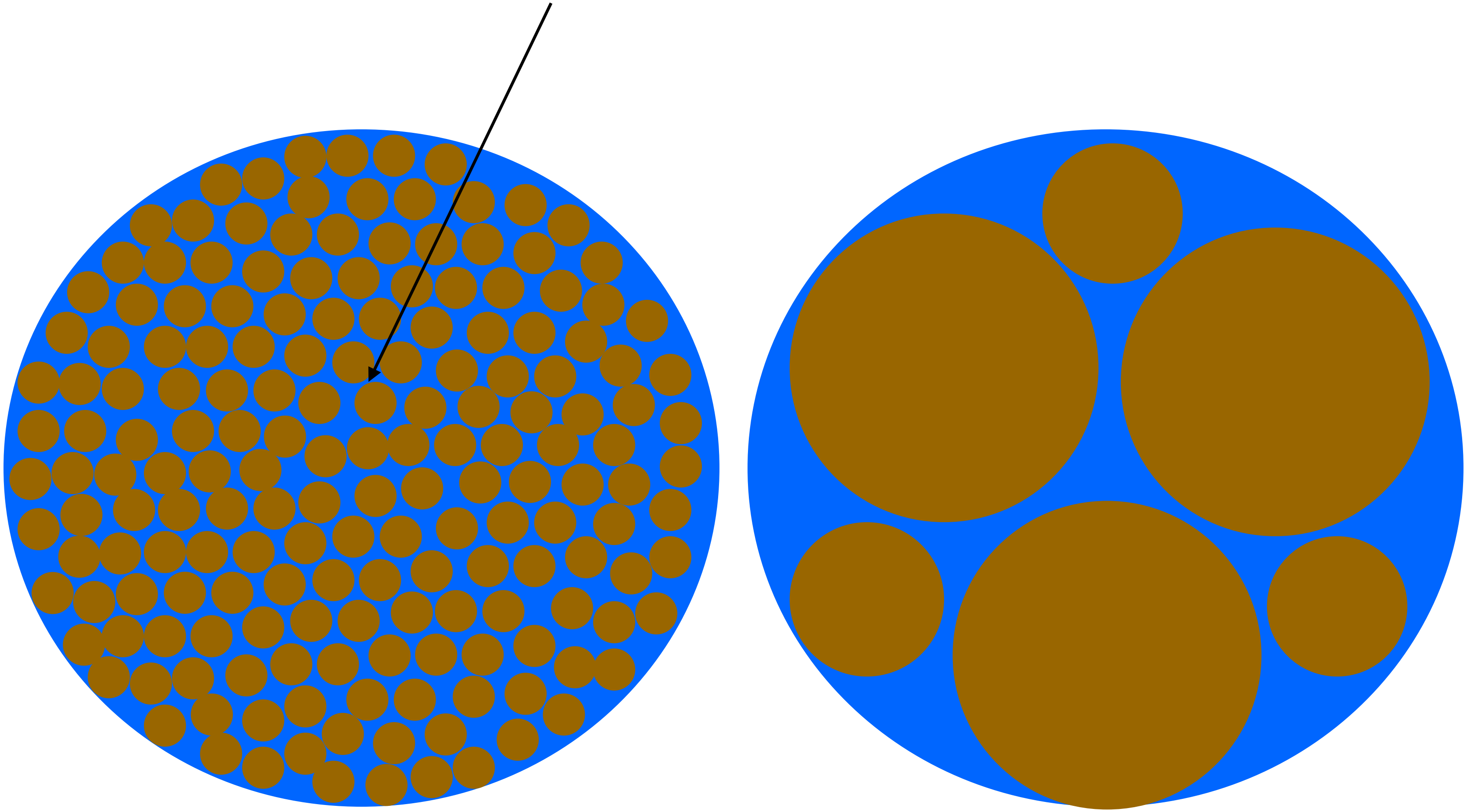
small area available for flow,
low hydraulic condcutivty





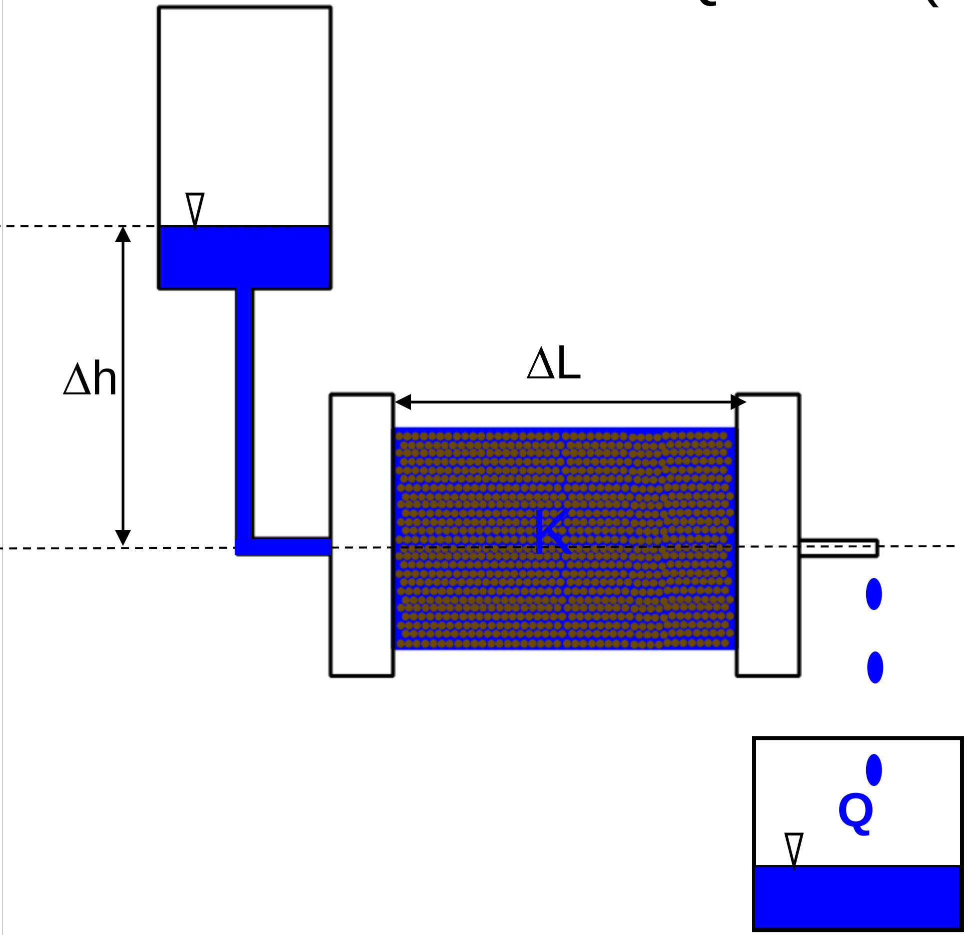
large grains, large area available for flow, large hydraulic conductivity

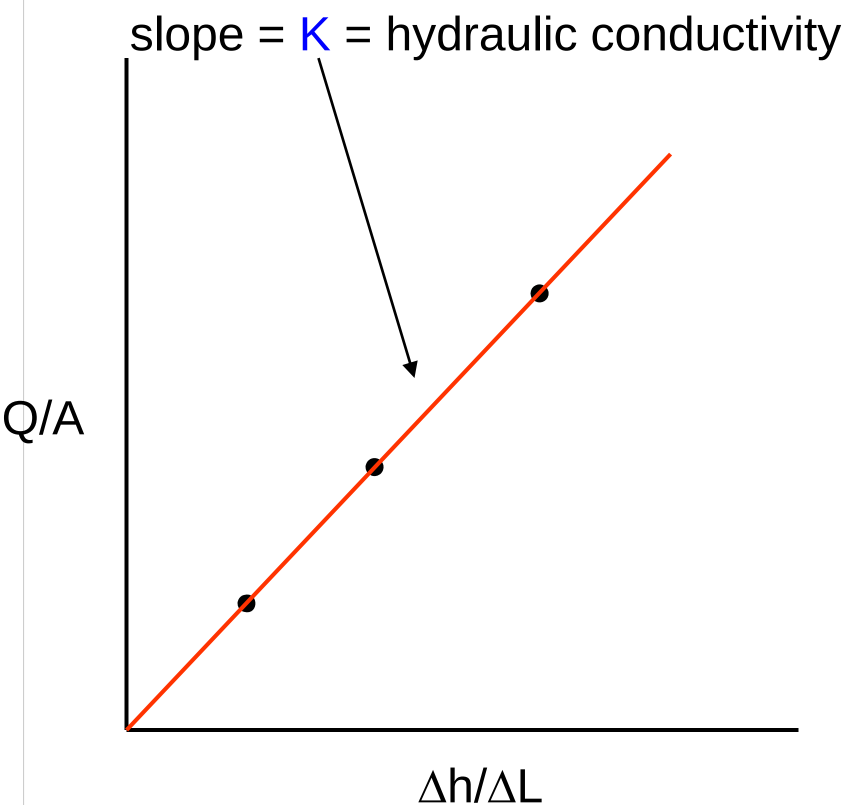
Smaller grains, means smaller pores (area available for flow), and more frictional resistance, and hence lower hydraulic conductivity



Darcy's Law

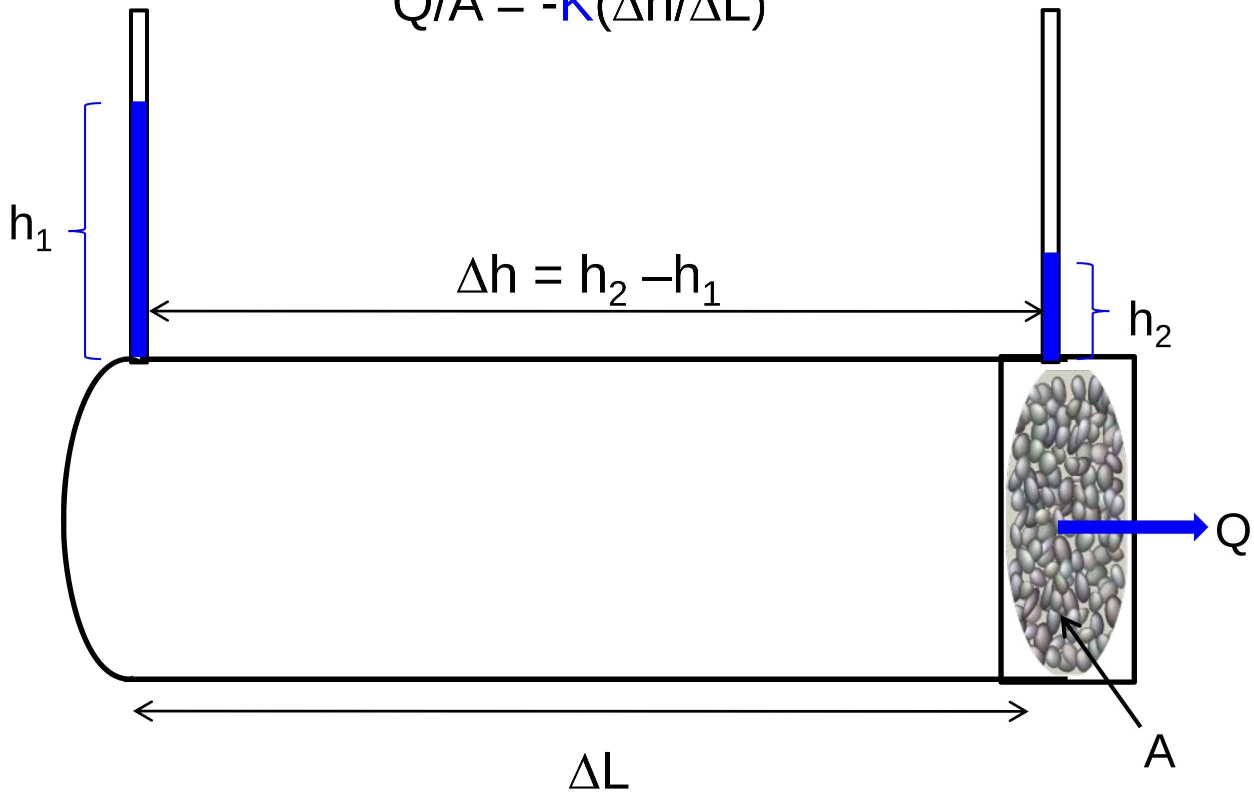
$$Q/A = -K(\Delta h/\Delta L)$$



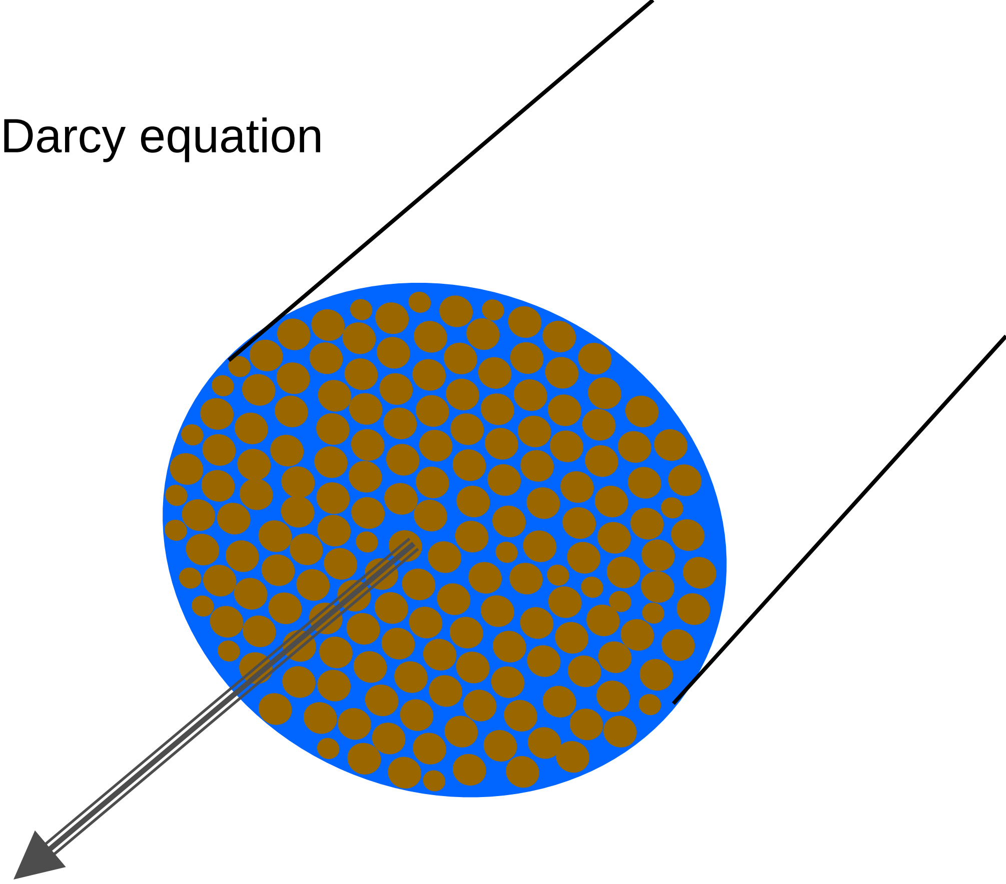


Darcy's Law states that the amount of water (Q) flowing through porous media depends on the energy driving the water flow ($\Delta h/\Delta L$) and the hydraulic conductivity (K) of the porous media

$$Q/A = -K(\Delta h/\Delta L)$$

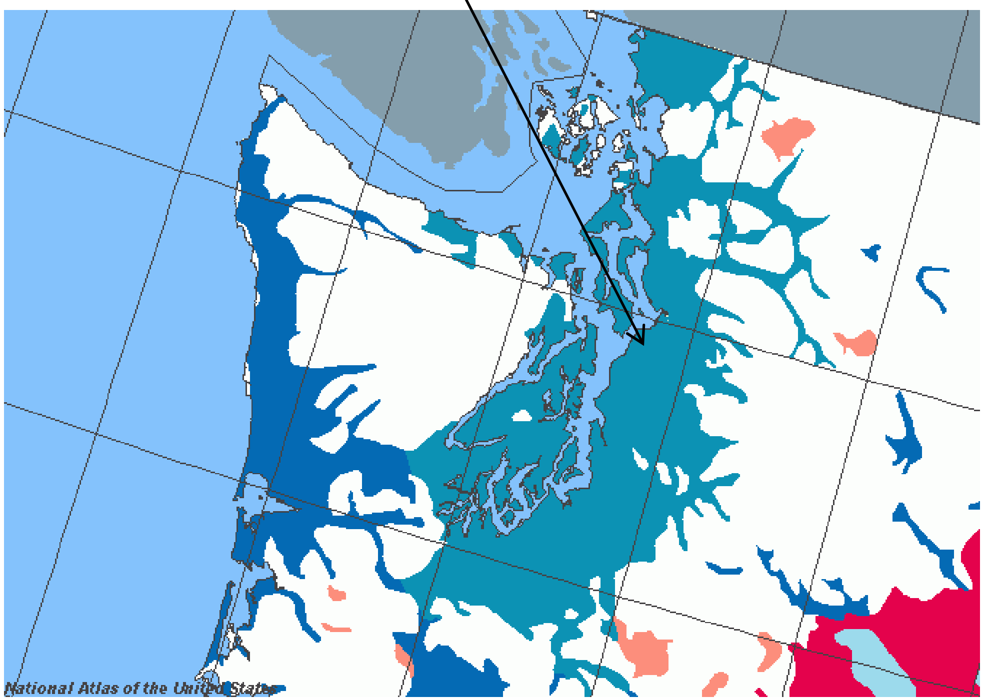


The average velocity of the water is the Darcy equation divided by the porosity of the sediment.



average pore water velocity $v = -K/n(\Delta h/\Delta L)$

Most aquifers in the Puget Lowlands are unconsolidated glacial deposits



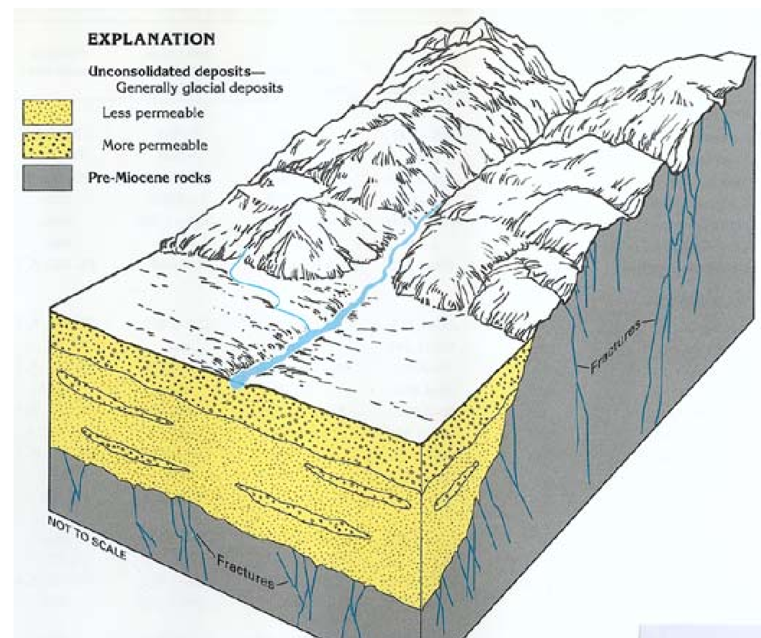
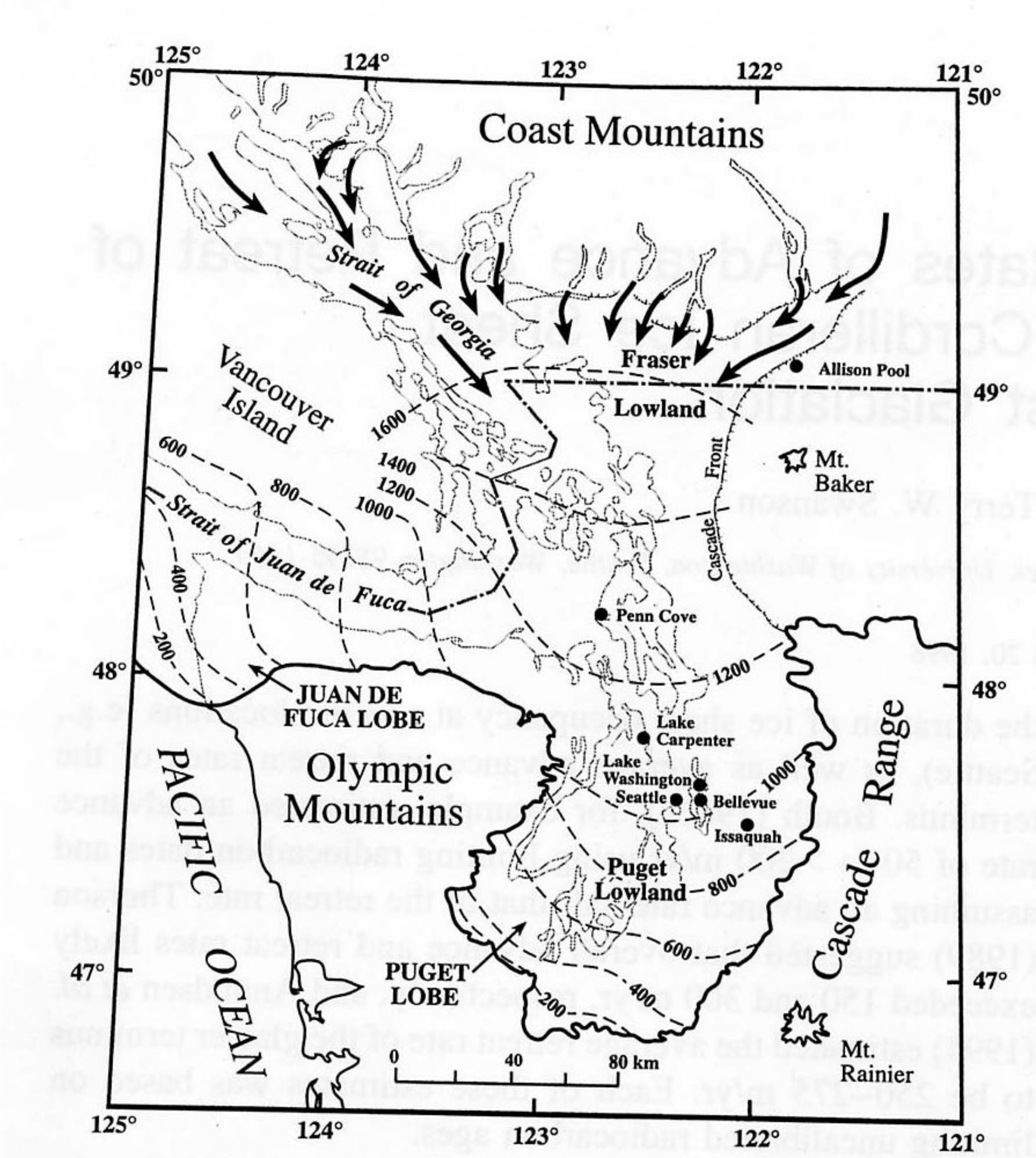
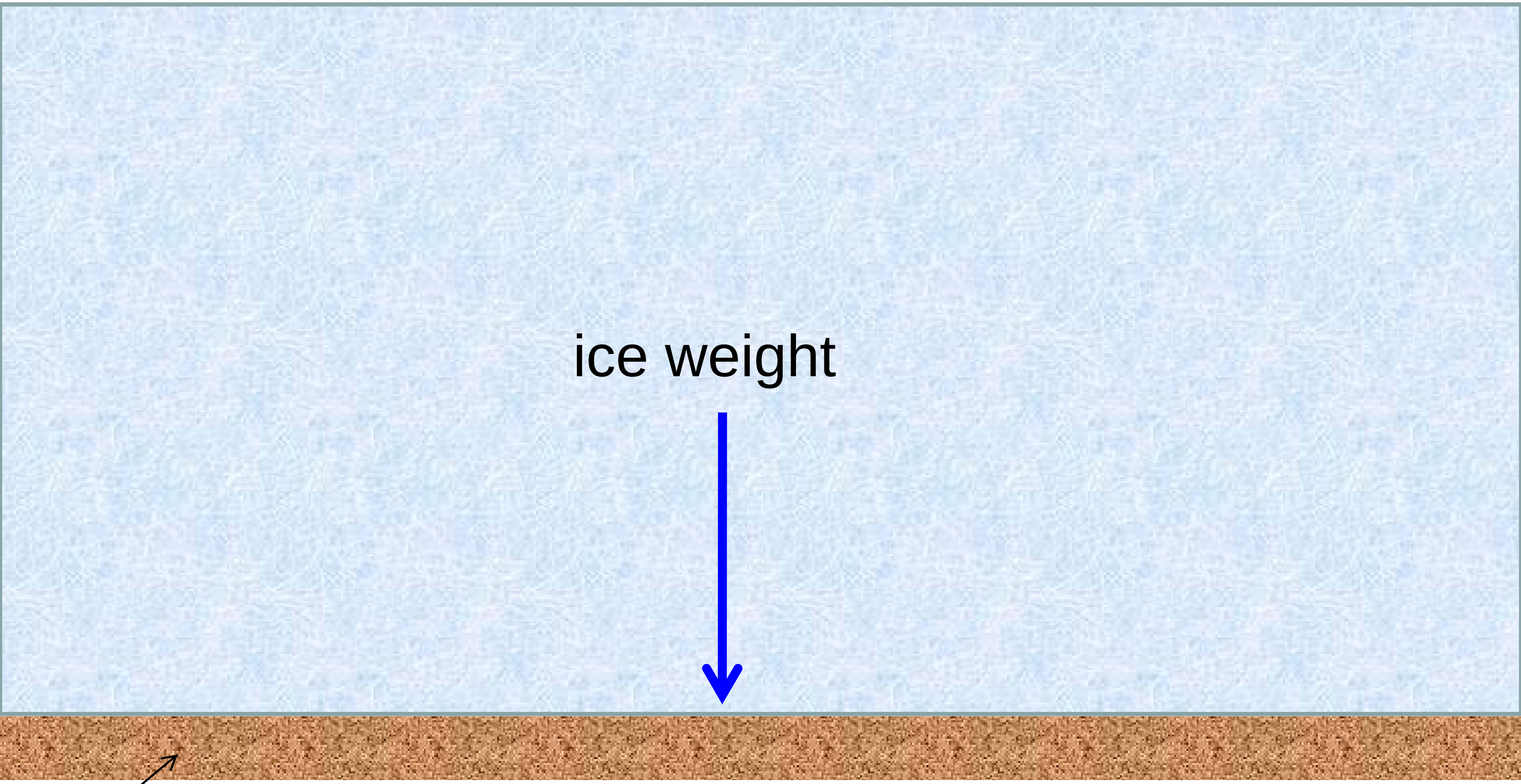


Figure 85. The Puget Sound lowland is underlain by unconsolidated deposits that are as much as 3,000 feet thick near Seattle, Wash. The deposits become finer grained and more compacted as depth increases.

http://pubs.usgs.gov/ha/ha730/ch_h/H-text10.html

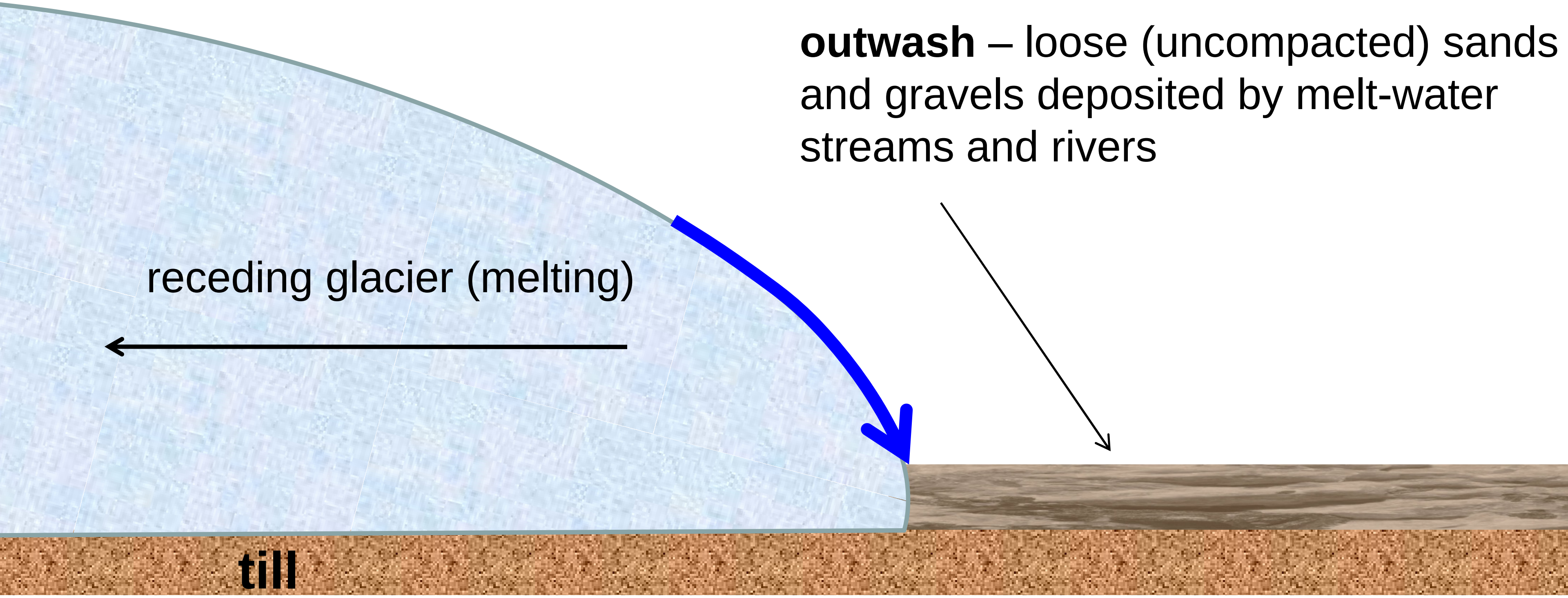
Glacial Deposits

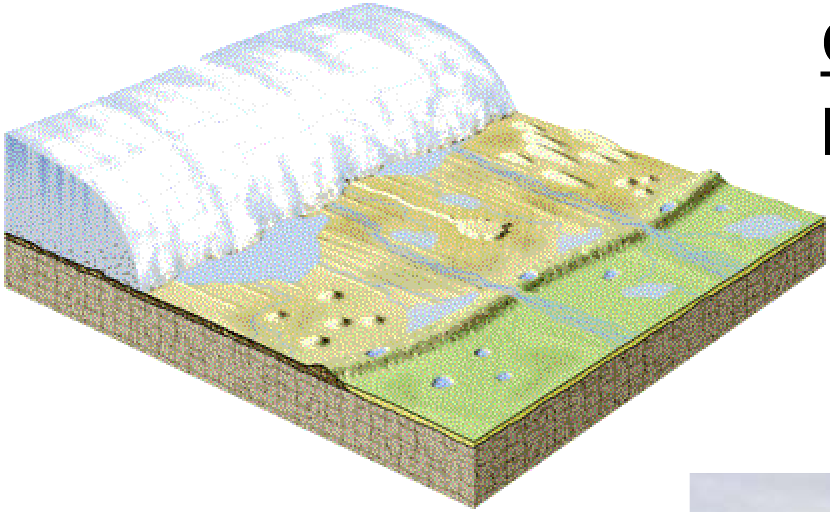




Till – deposited beneath a glacier, it is a well compacted mixture of grain sizes

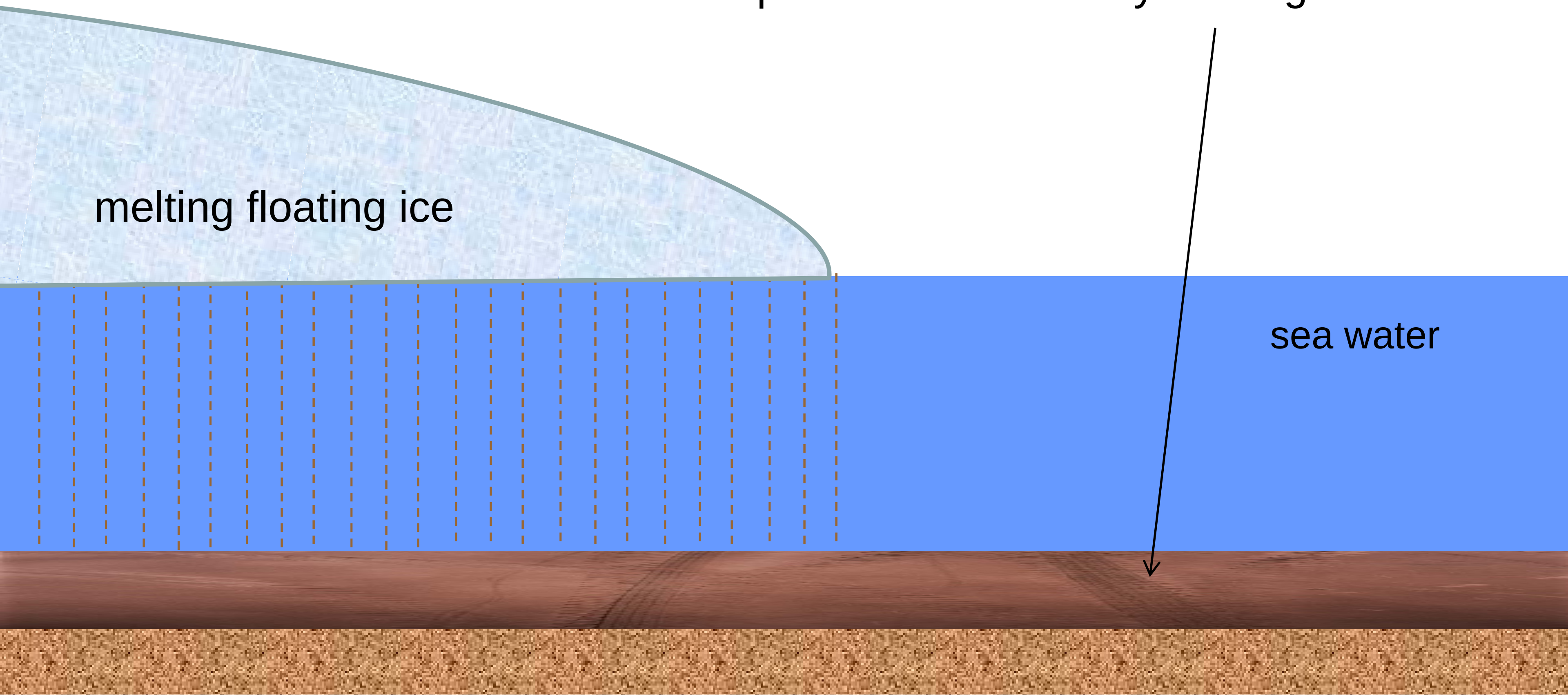
(till does NOT make good aquifers)


outwash – loose (uncompacted) sands and gravels deposited by melt-water streams and rivers
receding glacier (melting)
till

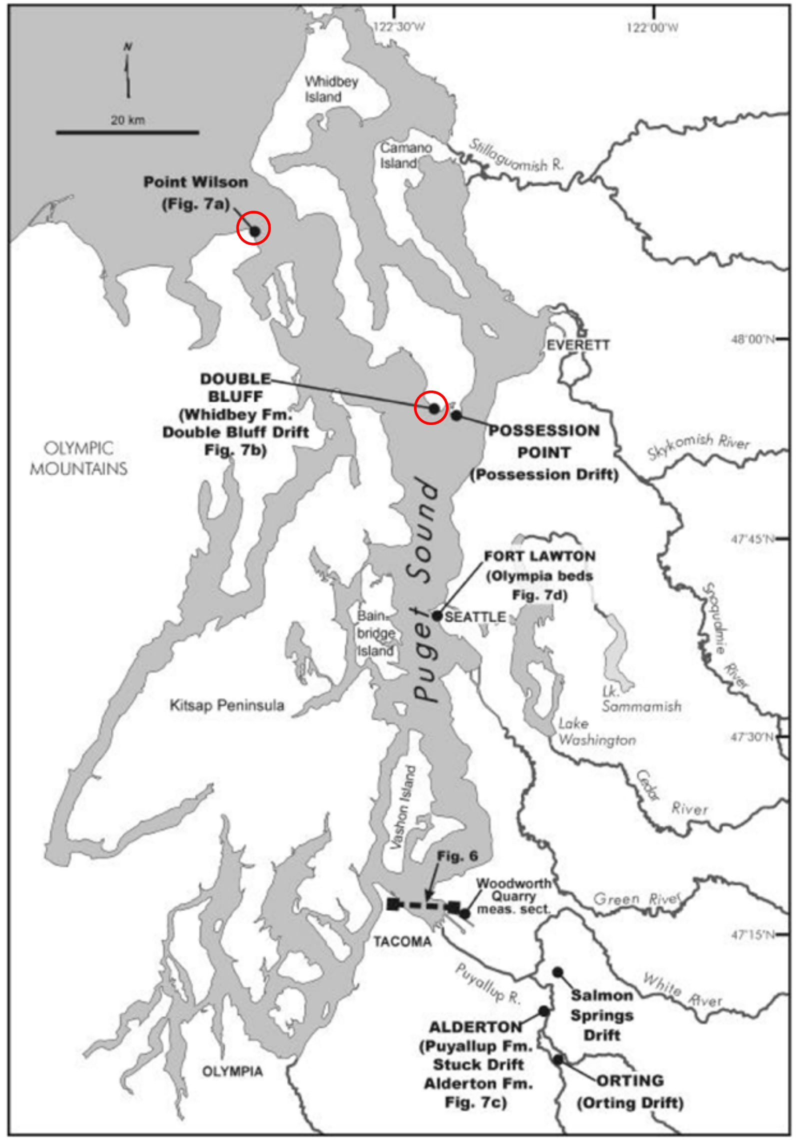


Glacial outwash makes the most productive aquifers

glaciomarine drift – clay rich sediment deposited in the sea by melting ice



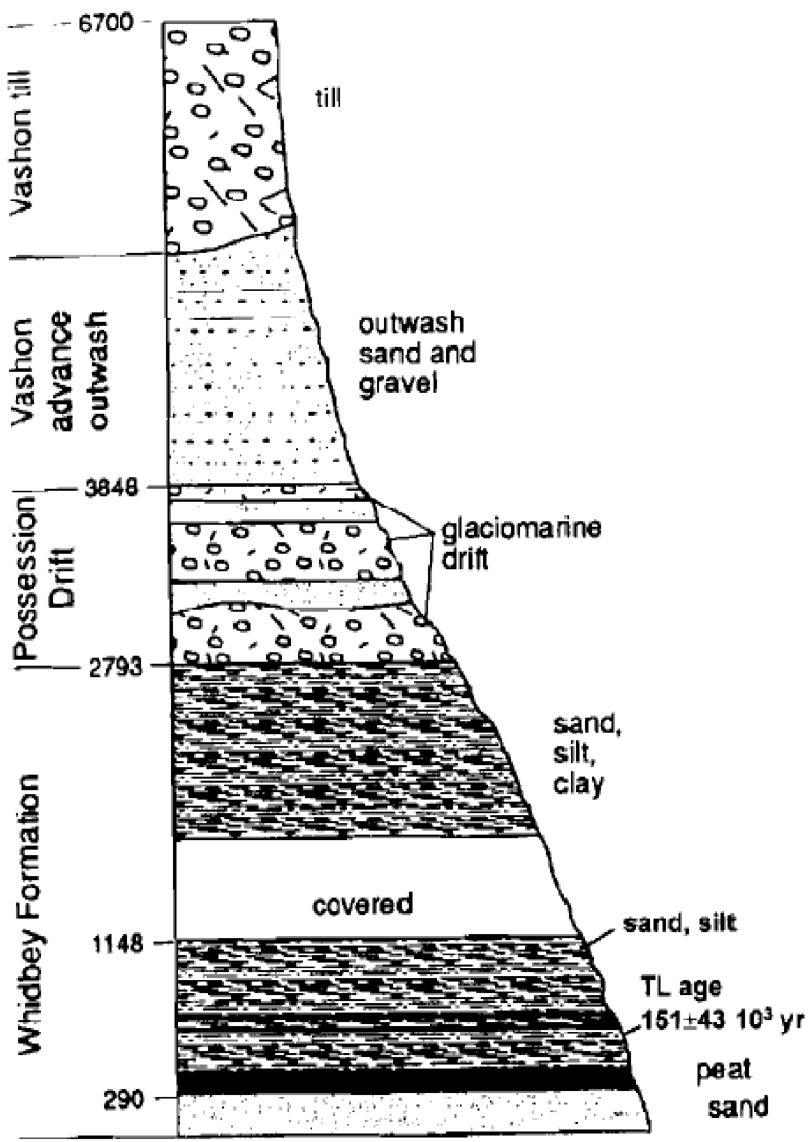
glaciomarine drift does NOT make good aquifers



THE CORDILLERAN ICE SHEET
by Derek B. Booth, Kathy Goetz Troost, John J. Clague, and Richard B. Waitt

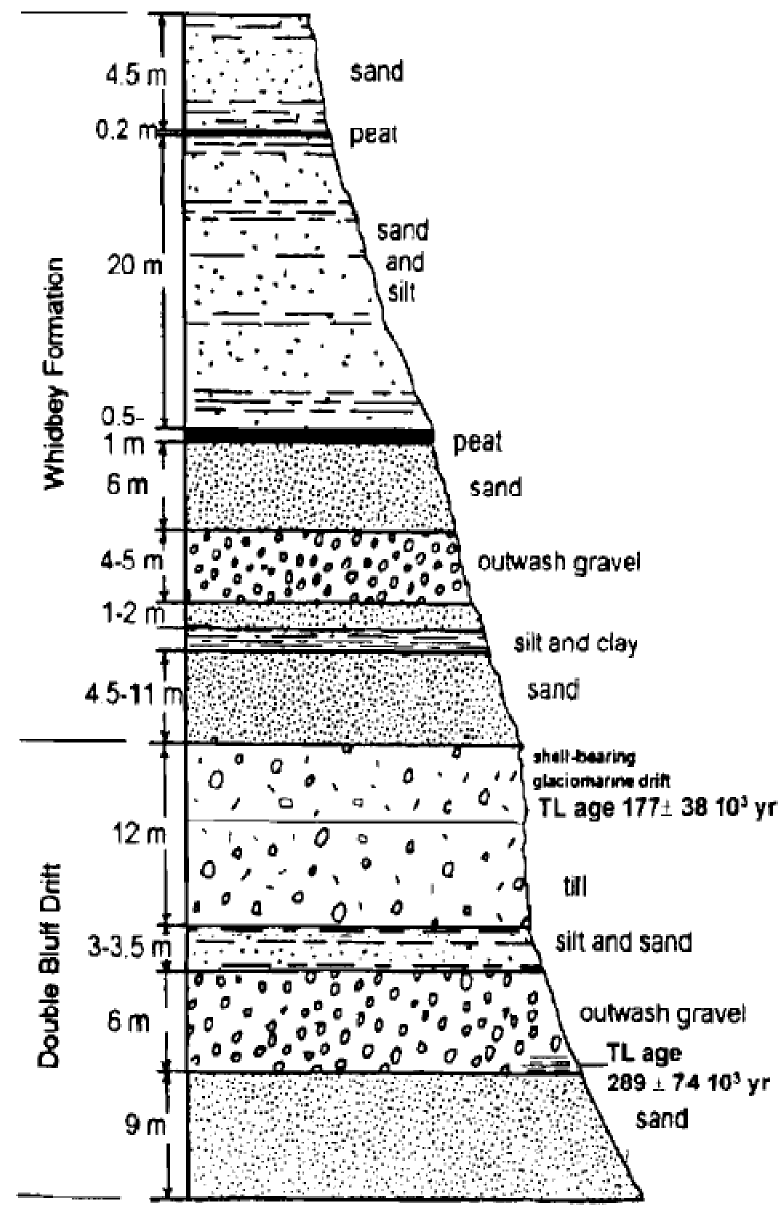
Preprint of Chapter 3 from *The Quaternary Period in the United States*
To be published by the International Union for Quaternary Research
August 2003

Point Wilson



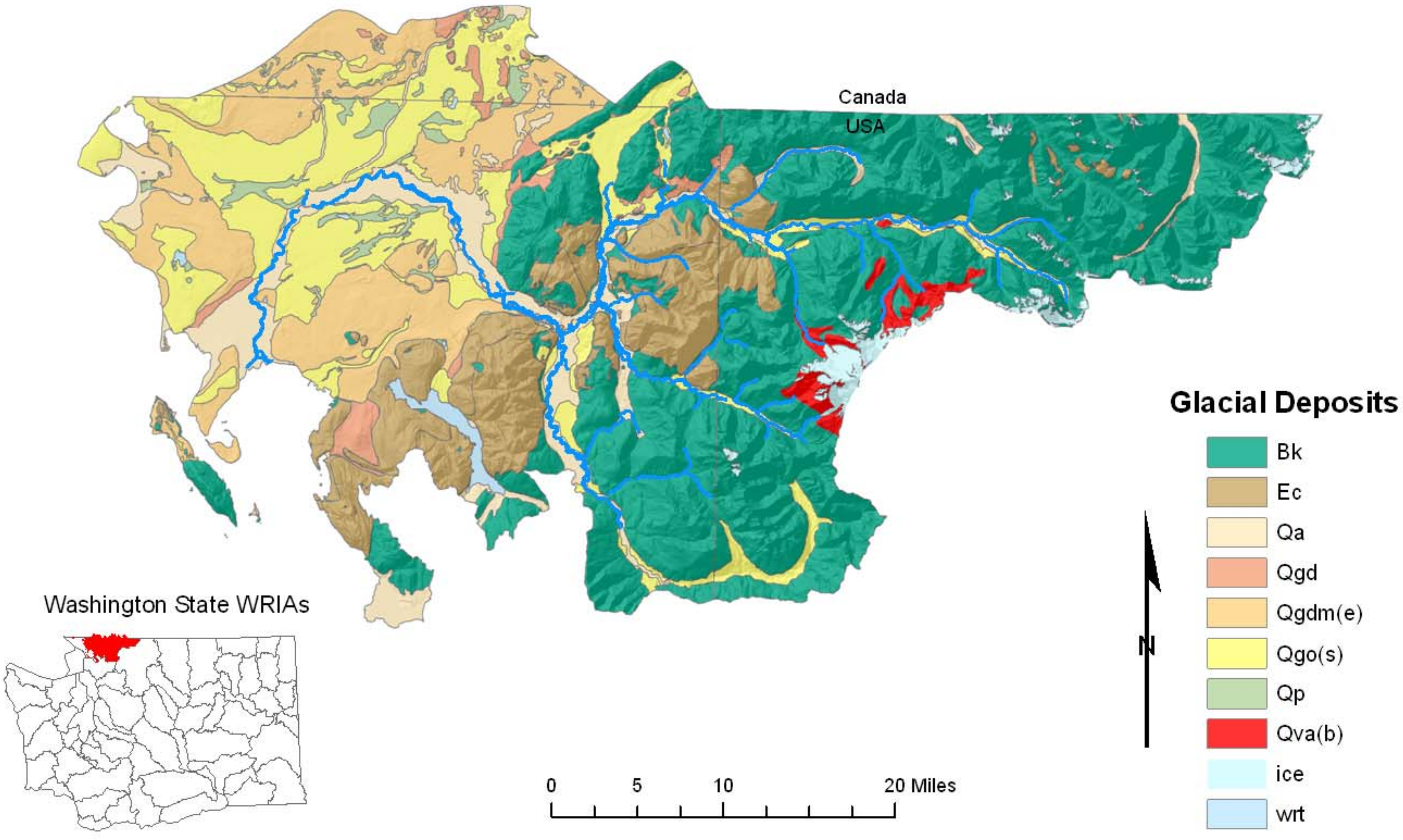
(a)

Double Bluff



(b)

Whatcom County Glacial Aquifers



Whatcom County Glacial Deposits

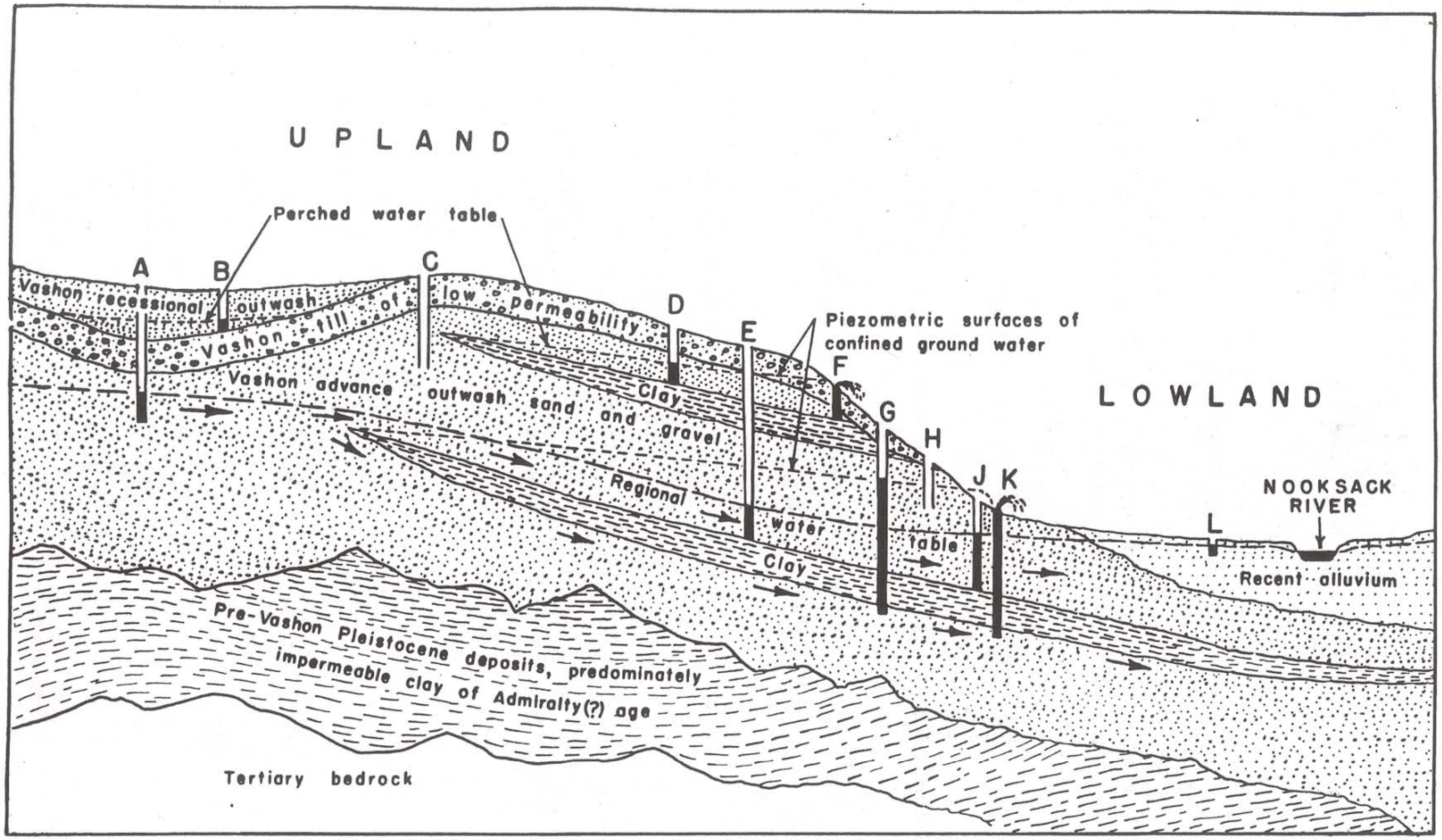
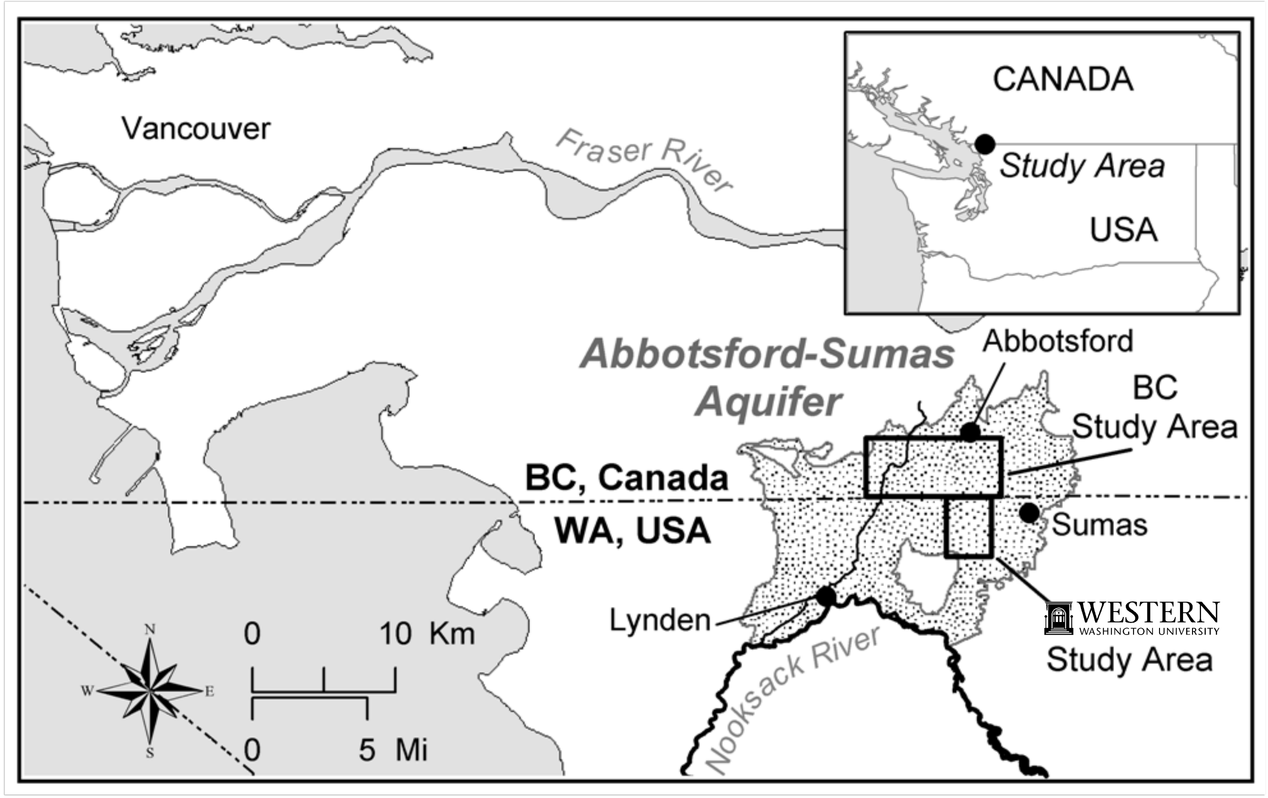


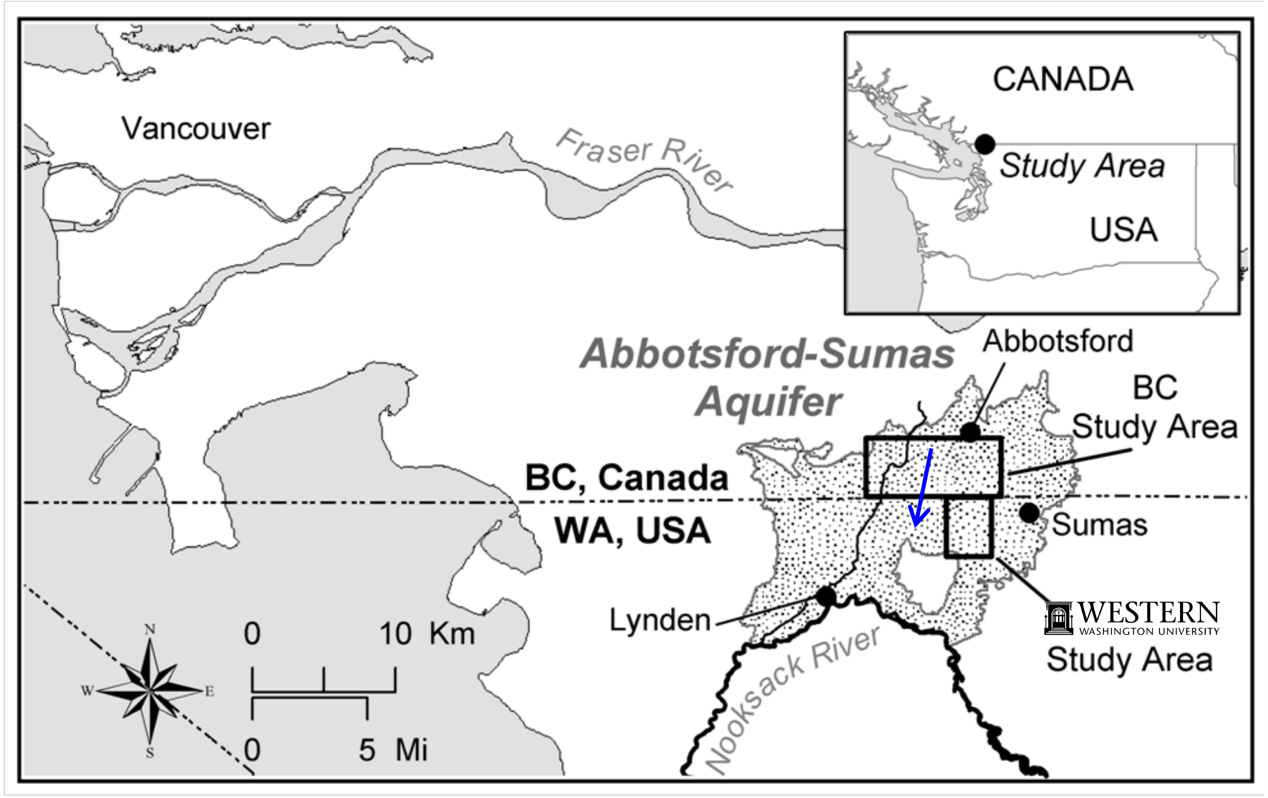
Figure 11. GENERAL CONDITIONS OF GROUND-WATER OCCURRENCE WITHIN THE LOWER NOOKSACK RIVER BASIN. Vertical scale exaggerated. Arrows indicate direction of ground-water movement.

Abbotsford-Sumas Aquifer

The aquifer covers approximately 200 km^2 and serves as a water supply for approximately 110,000 people in BC and WA.

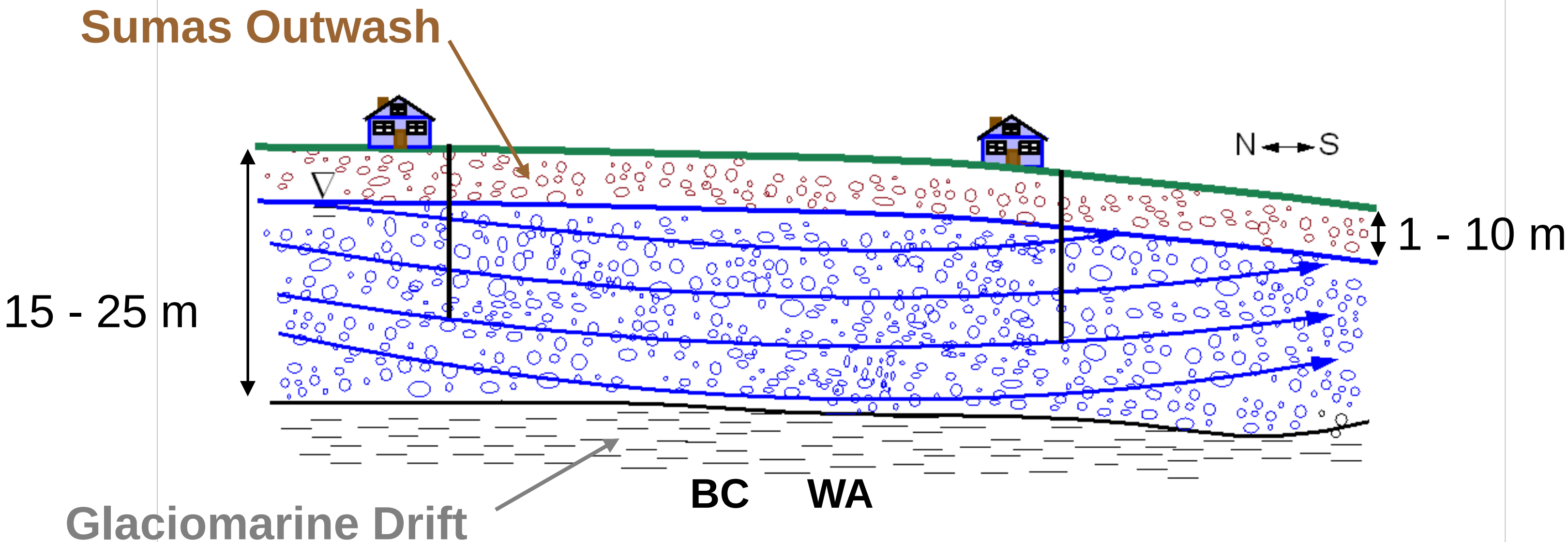


Ground Water Flow is from North-to-South

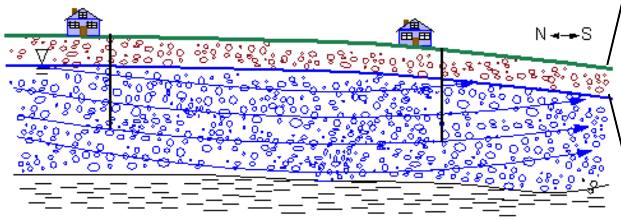


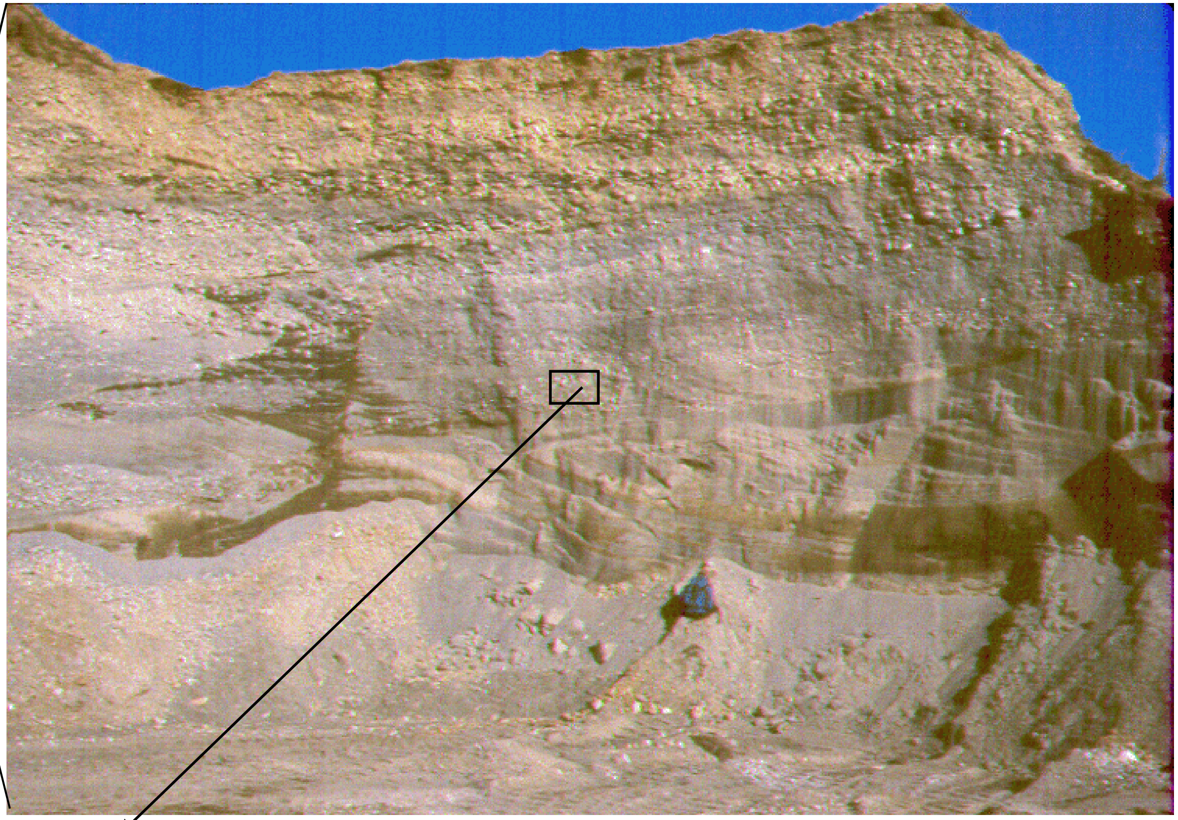
Abbotsford-Sumas Aquifer

The aquifer is unconfined and comprised of glacial outwash sands and gravels (Sumas Outwash) deposited about 10,000 years ago.



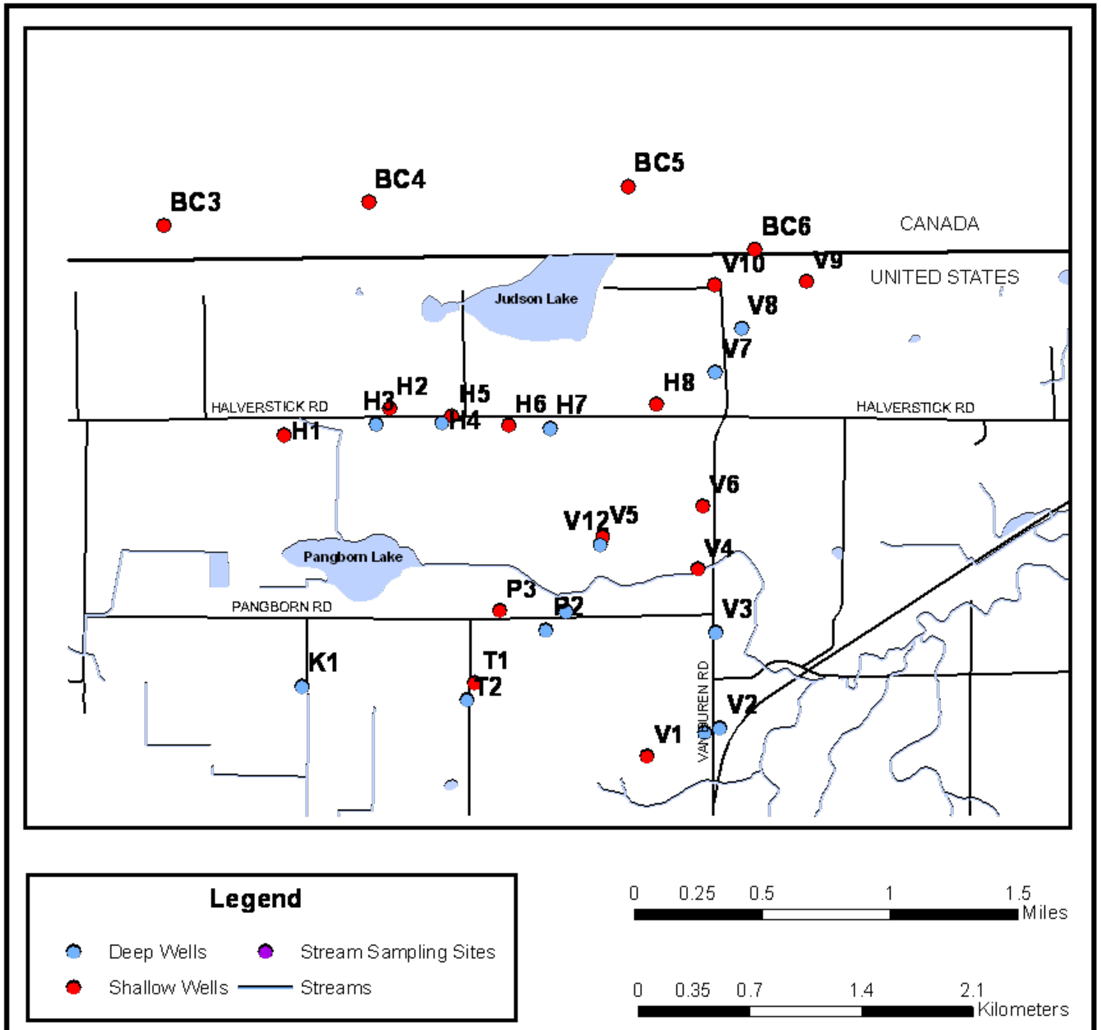
Sumas Outwash





gravel mine in Whatcom County

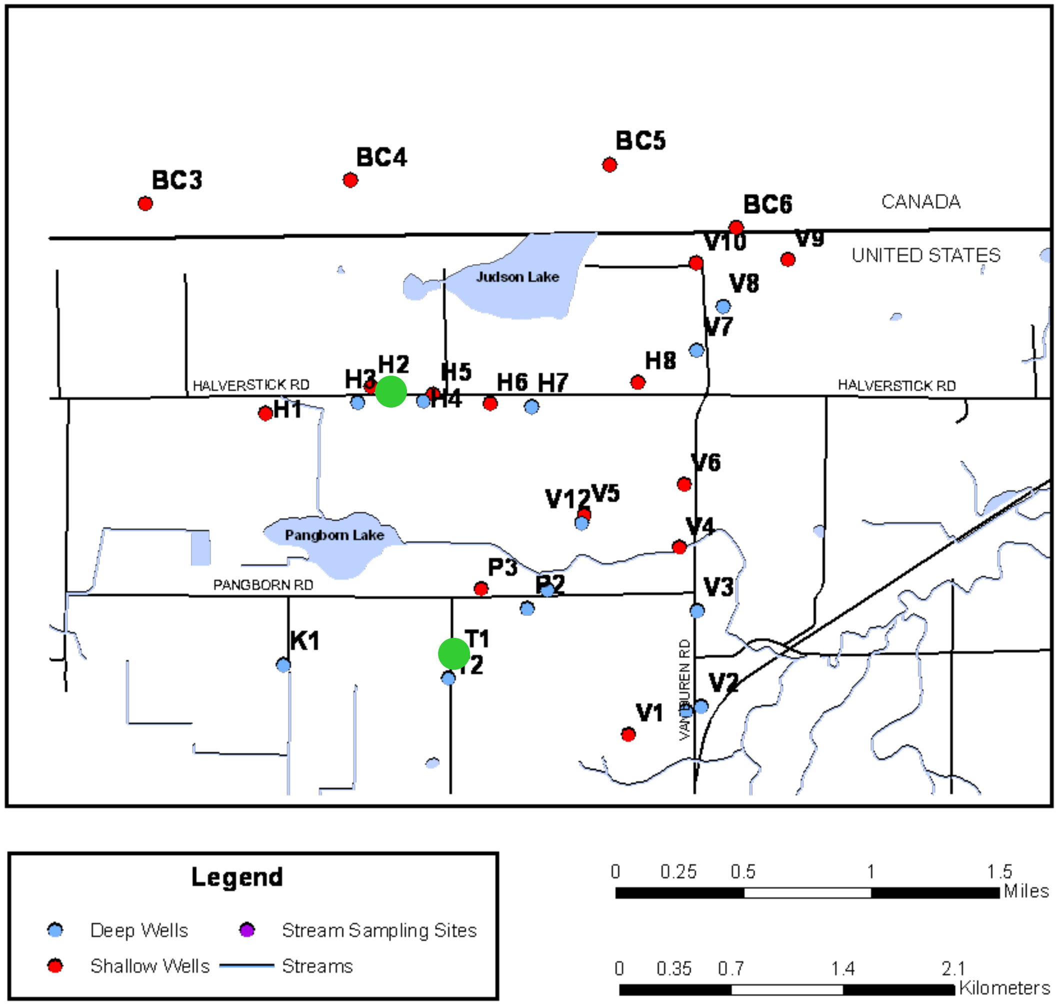
Well Sampling Sites



26 wells

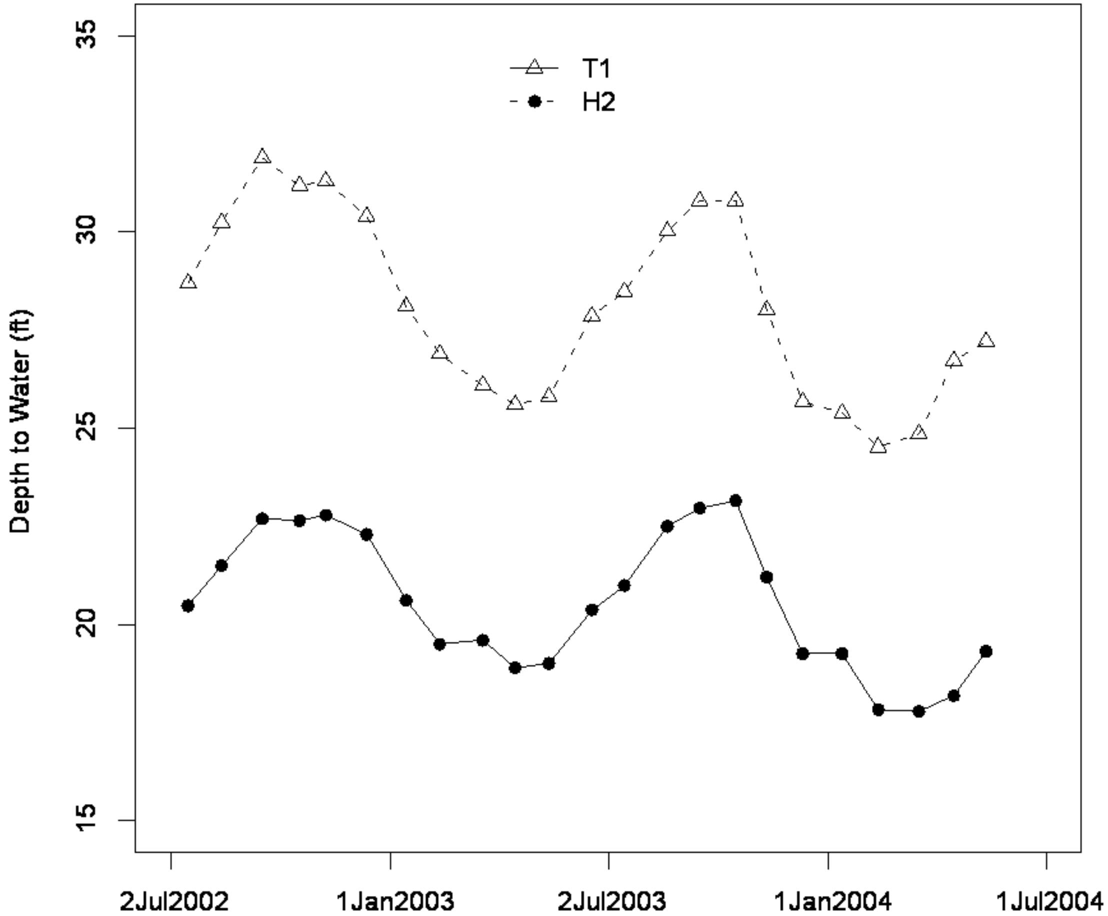
Water-level measurements

Well Sampling Sites

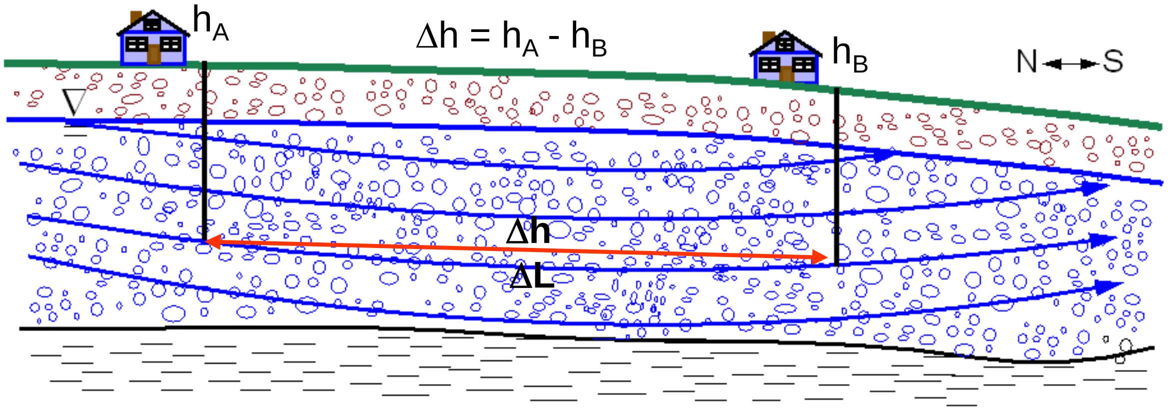


26 wells

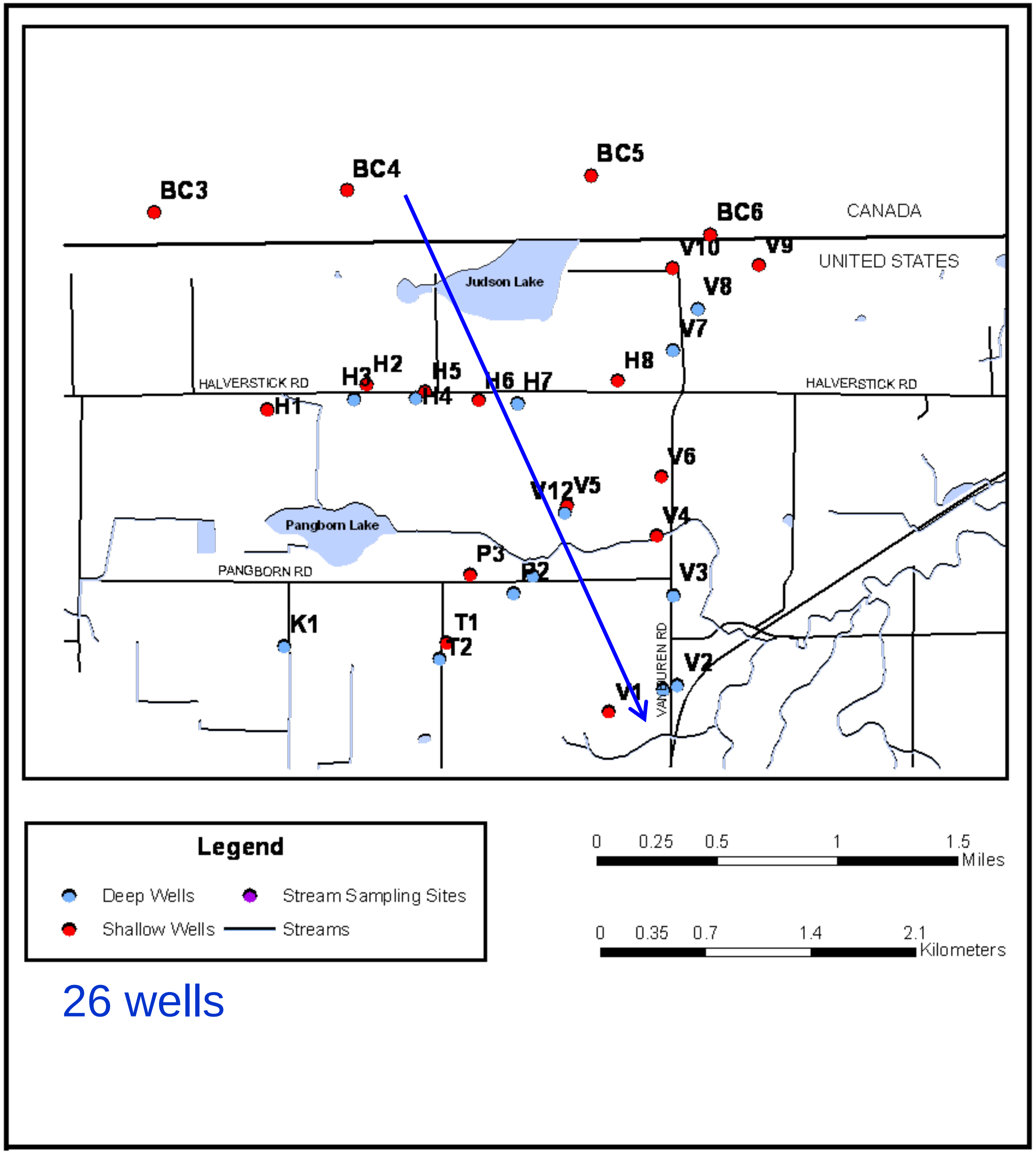
Water Table Hydrographs



hydraulic gradient = $\Delta h/\Delta L$



Well Sampling Sites



26 wells

Flow is in the southeast direction (155°) and is drive by a gradient of

$$\frac{\Delta h}{\Delta L} = - 0.0055$$

The average hydraulic gradient in the Abbotsford-Sumas aquifer is

$$\Delta h/\Delta L = -0.0055$$

The average hydraulic conductivity of the glacial sediments is

$K = 545$ ft/day or $K = 0.187$ cm/sec

The average porosity of the glacial sediments is

$$n = 0.30$$

The average pore-water velocity can be determined using

$$velocity = v = -K/n\ (\Delta h/\Delta L)$$

Using the aquifer parameters in the equation above yields

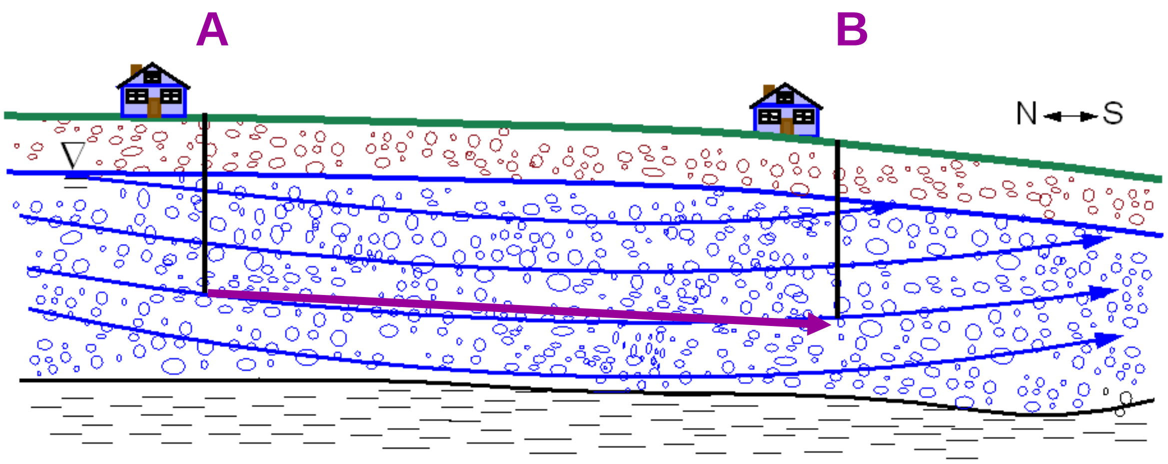
$$velocity = v = -545/0.30(-0.0055) = 10\ ft/day$$

which is very fast for groundwater

The average groundwater velocity is 10 ft/day

How long would it take water to travel from well A to well B

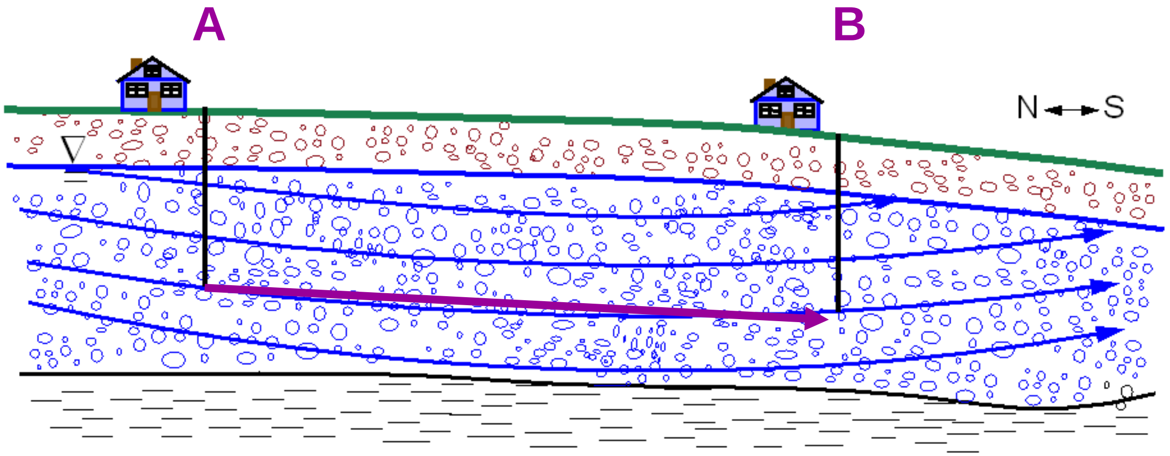
If the distance from A to B is 1000 ft



Time = distance ⁄ velocity

Time = 1000 ft ⁄ 10 ft/day

Time = 100 days

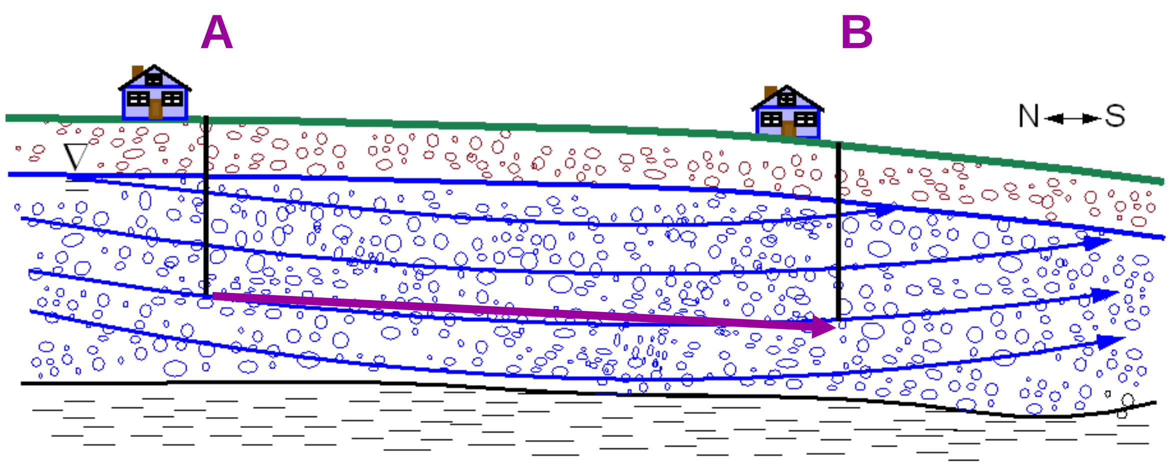


If the aquifer were a fine sand with a hydraulic conductivity of 5.45 ft/day……then the

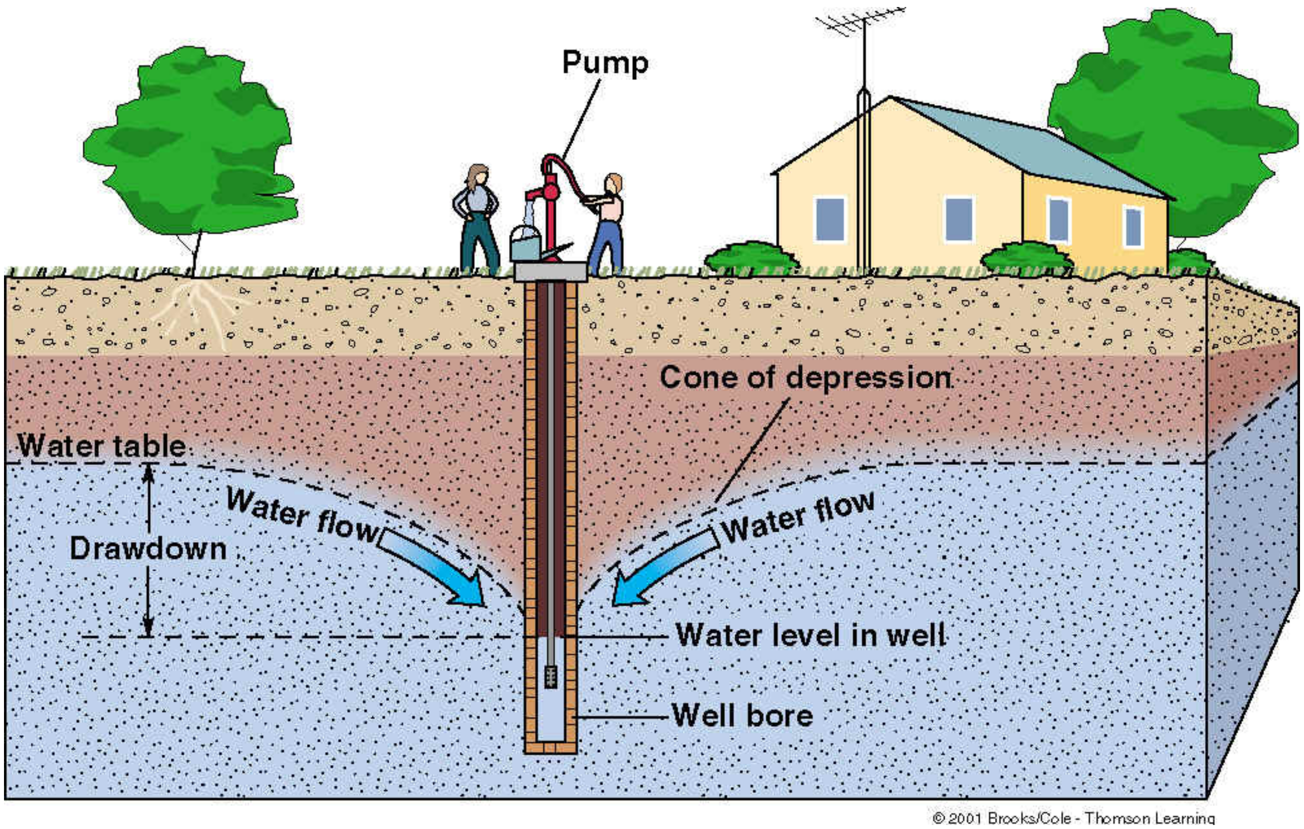
Velocity = 0.10 ft/day

Time = 1000 ft ⁄ 0.10 ft/day

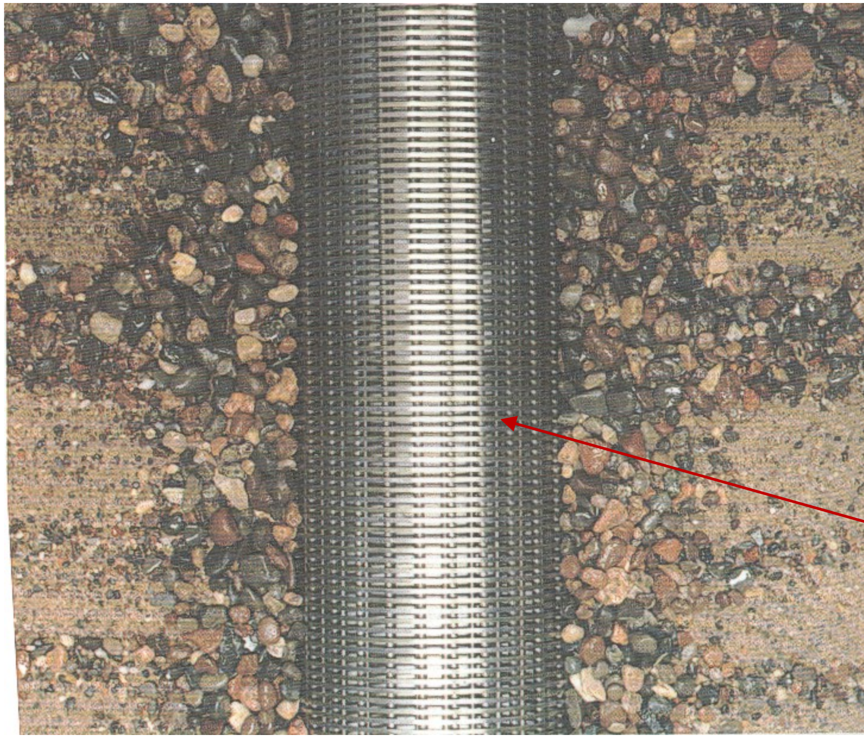
Time = 10,000 days or 27 years!!

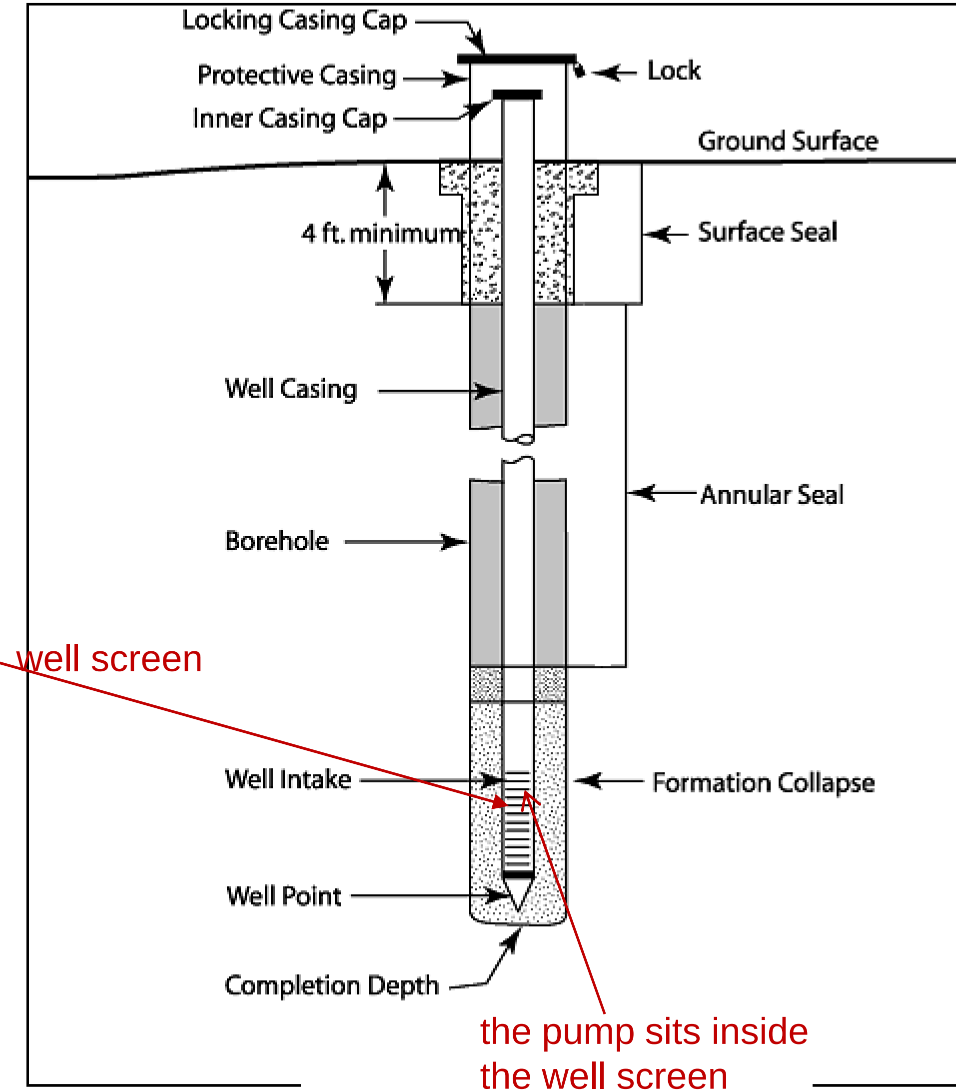


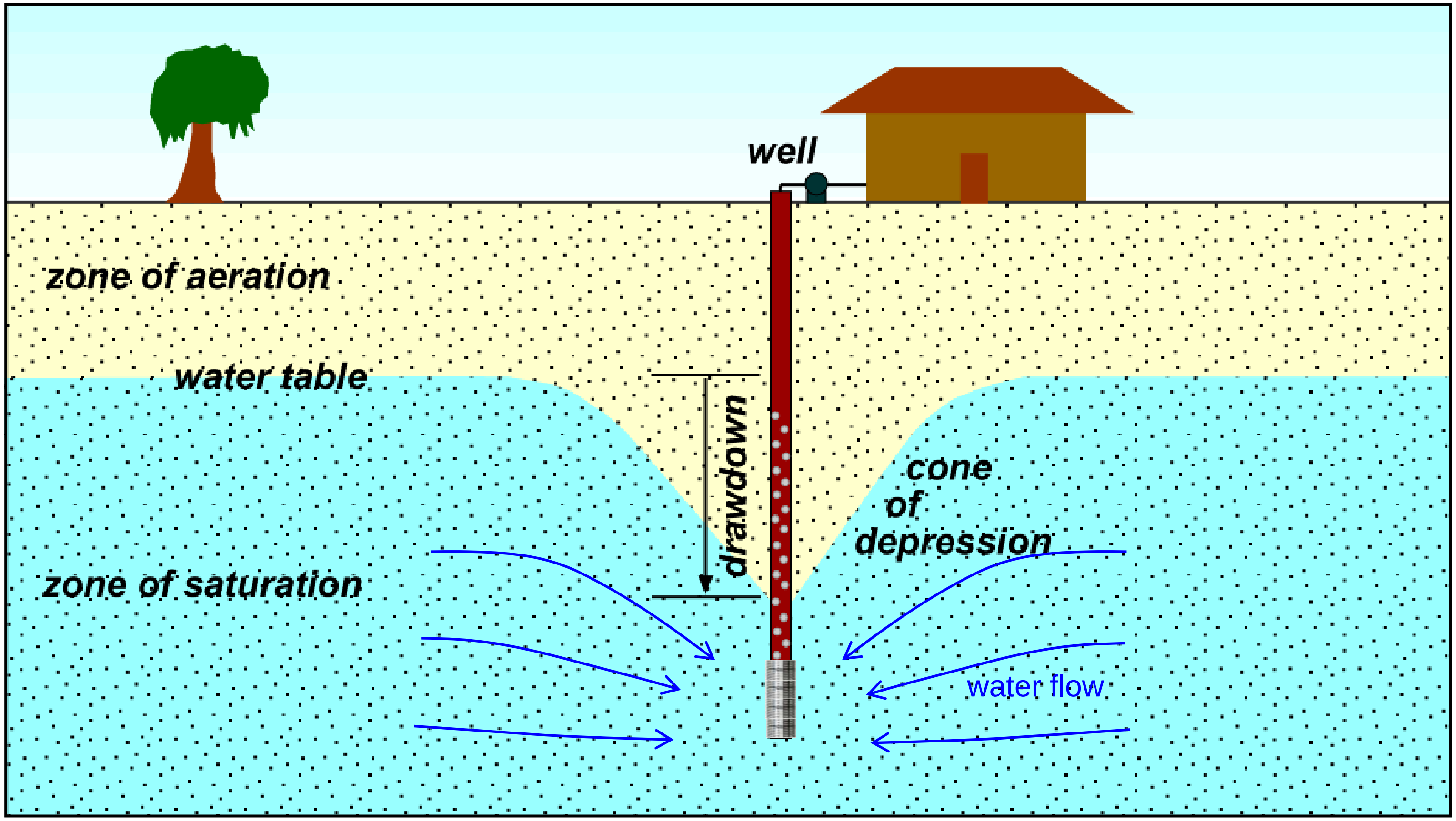
Pumping wells create a cone-of-depression in the water table

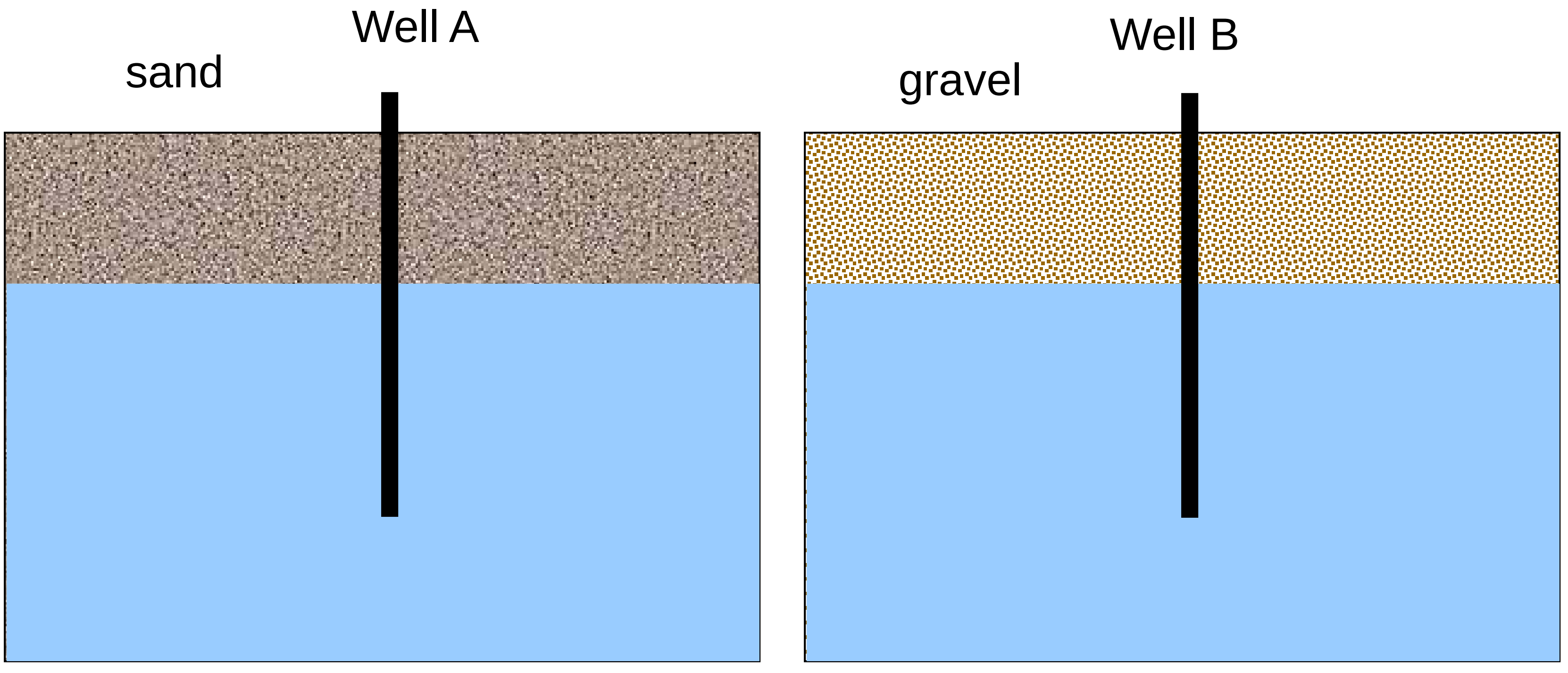


http://www.uwsp.edu/geo/faculty/ozsvath/images/cone_of_depression.htm

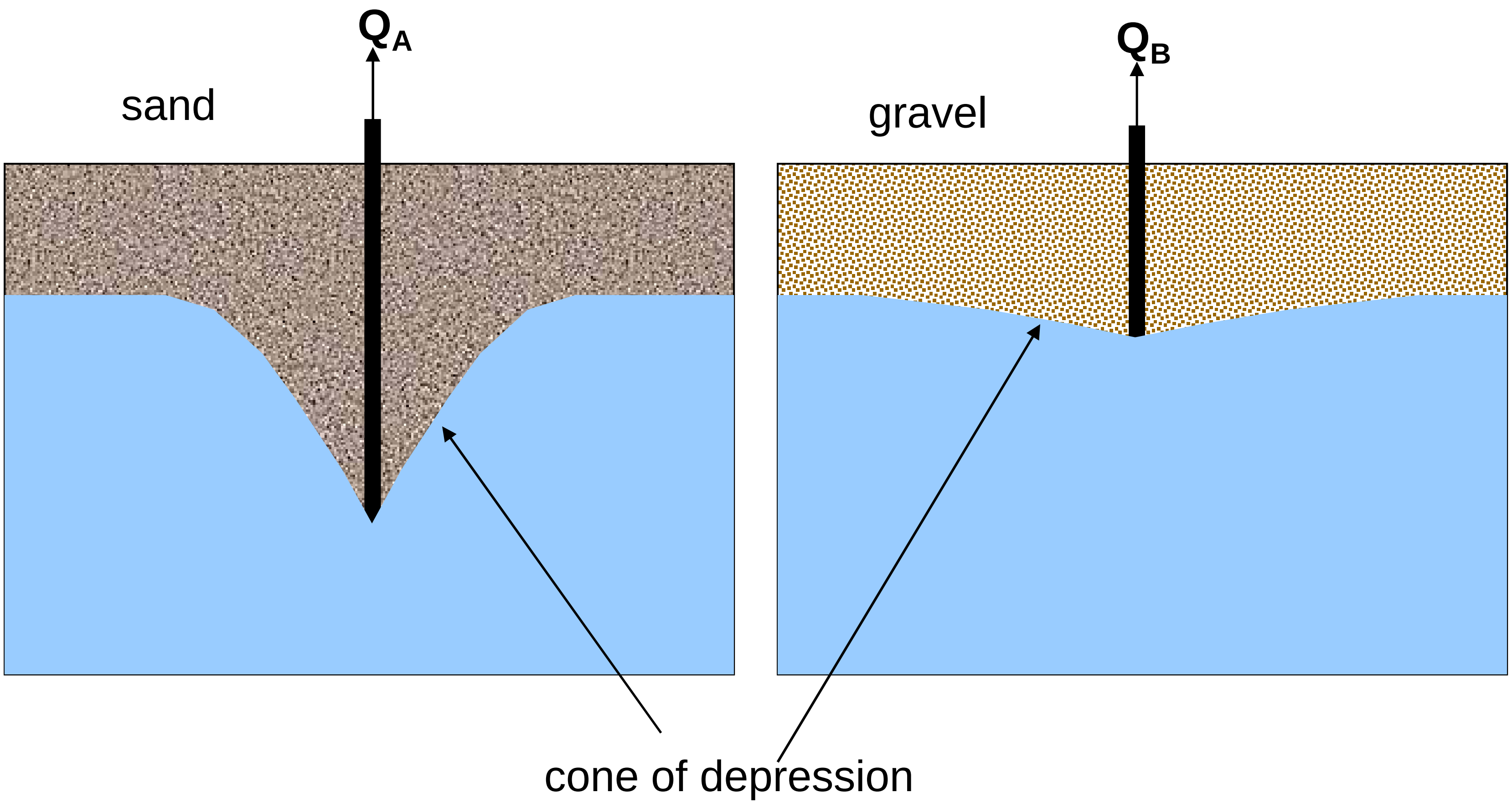



Locking Casing Cap
Lock
Protective Casing
Inner Casing Cap
Ground Surface
4 ft. minimum
Surface Seal
Well Casing
Annular Seal
Borehole
Well Intake
Formation Collapse
Well Point
Completion Depth
well screen
the pump sits inside the well screen

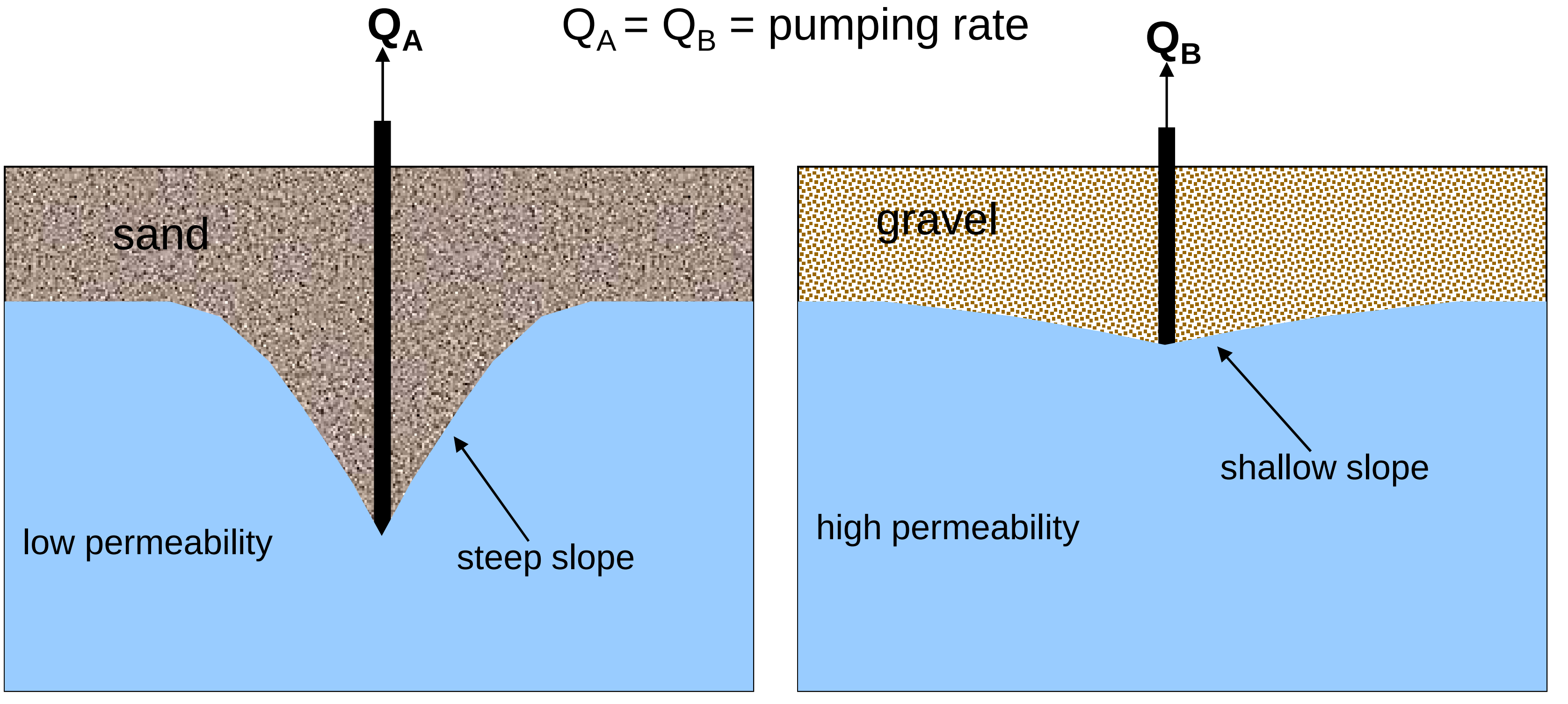

well
zone of aeration
water table
drawdown
cone
of
depression
zone of saturation
water flow


Well A
sand
Well B
gravel

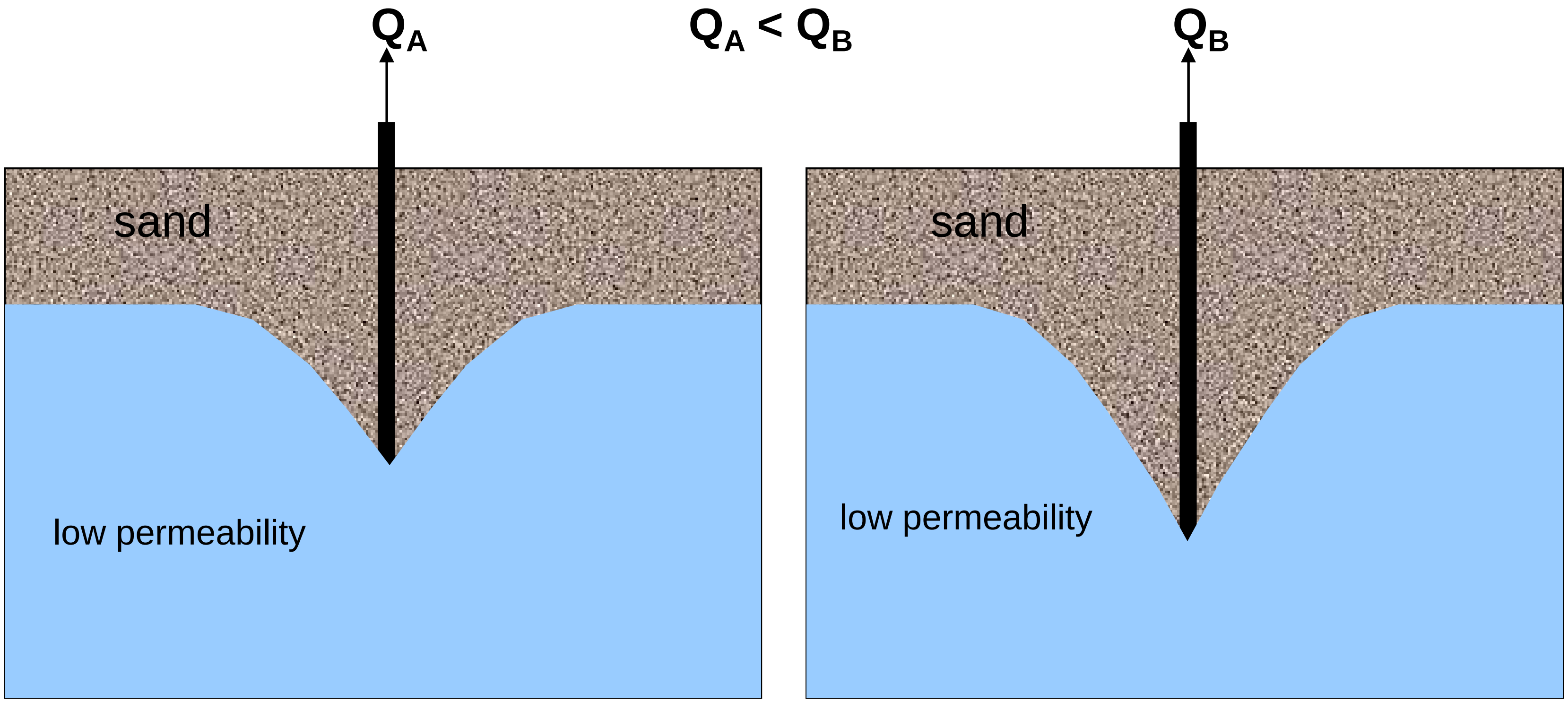
$Q_A = Q_B$ = pumping rate



$Q_A = Q_B$ = pumping rate

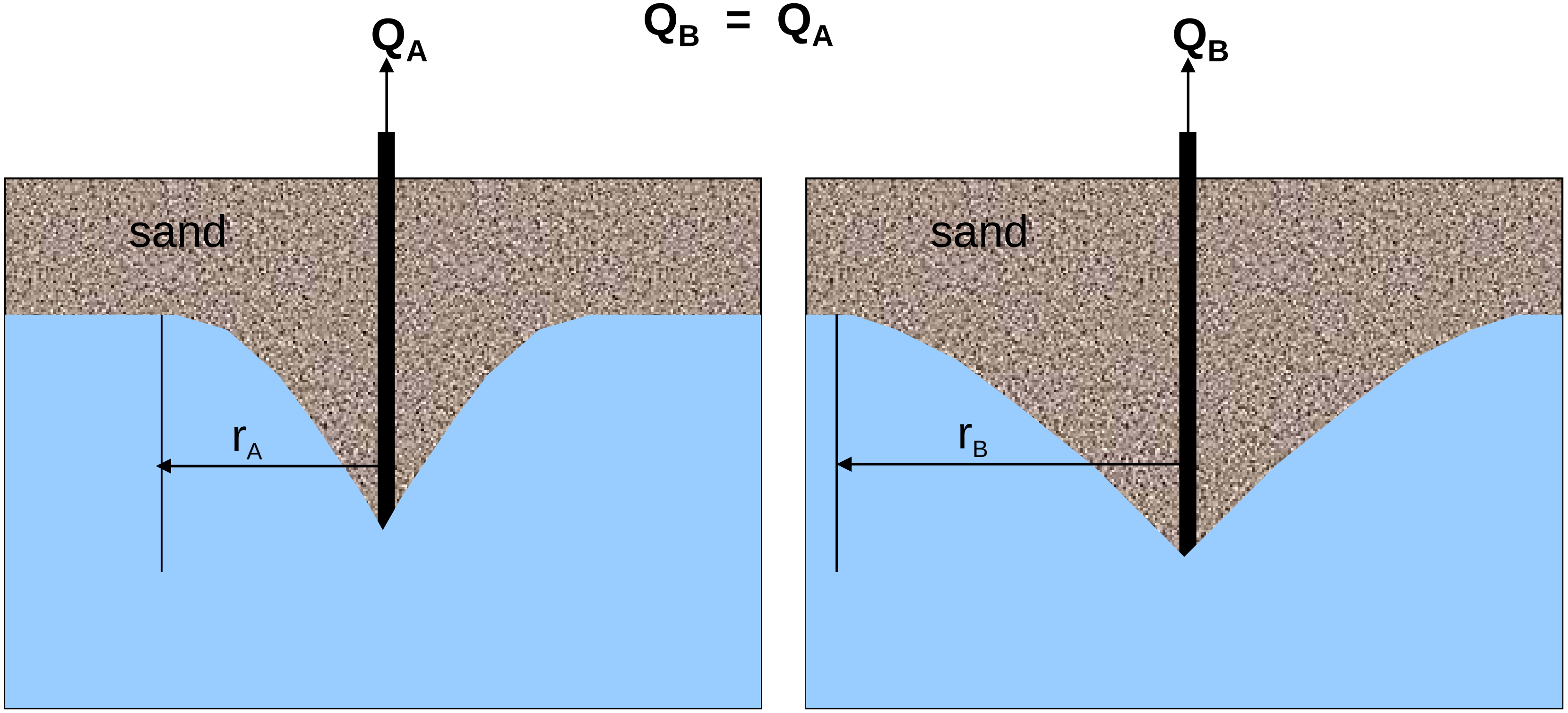


The <u>slope</u> of the cone of depression is determined by the <u>permeability</u>



The <u>depth</u> of the cone of depression is determined by the <u>pumping rate</u>

$Q_B = Q_A$



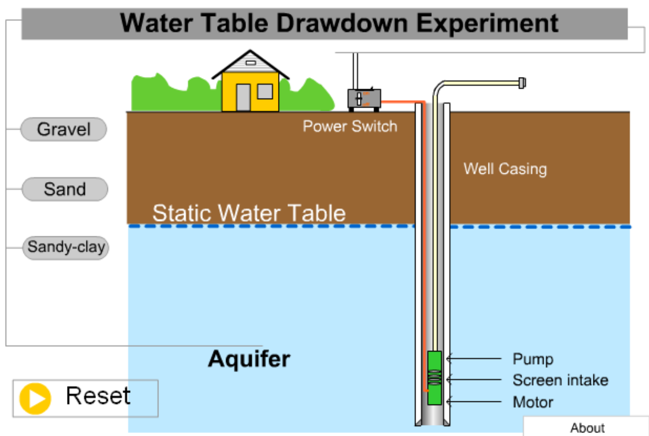
The <u>radius</u> of the cone of depression is determined by the <u>pumping duration</u>

$r_A < r_B$

greater is the drawdown. When the drawdown causes the water table to come down to the level of the intake screen of the pump the pump cannot pump any more water and must be turned off till the water table raises or the pump needs to be placed at a lower level. Sometimes this will require that the well be drilled deeper.

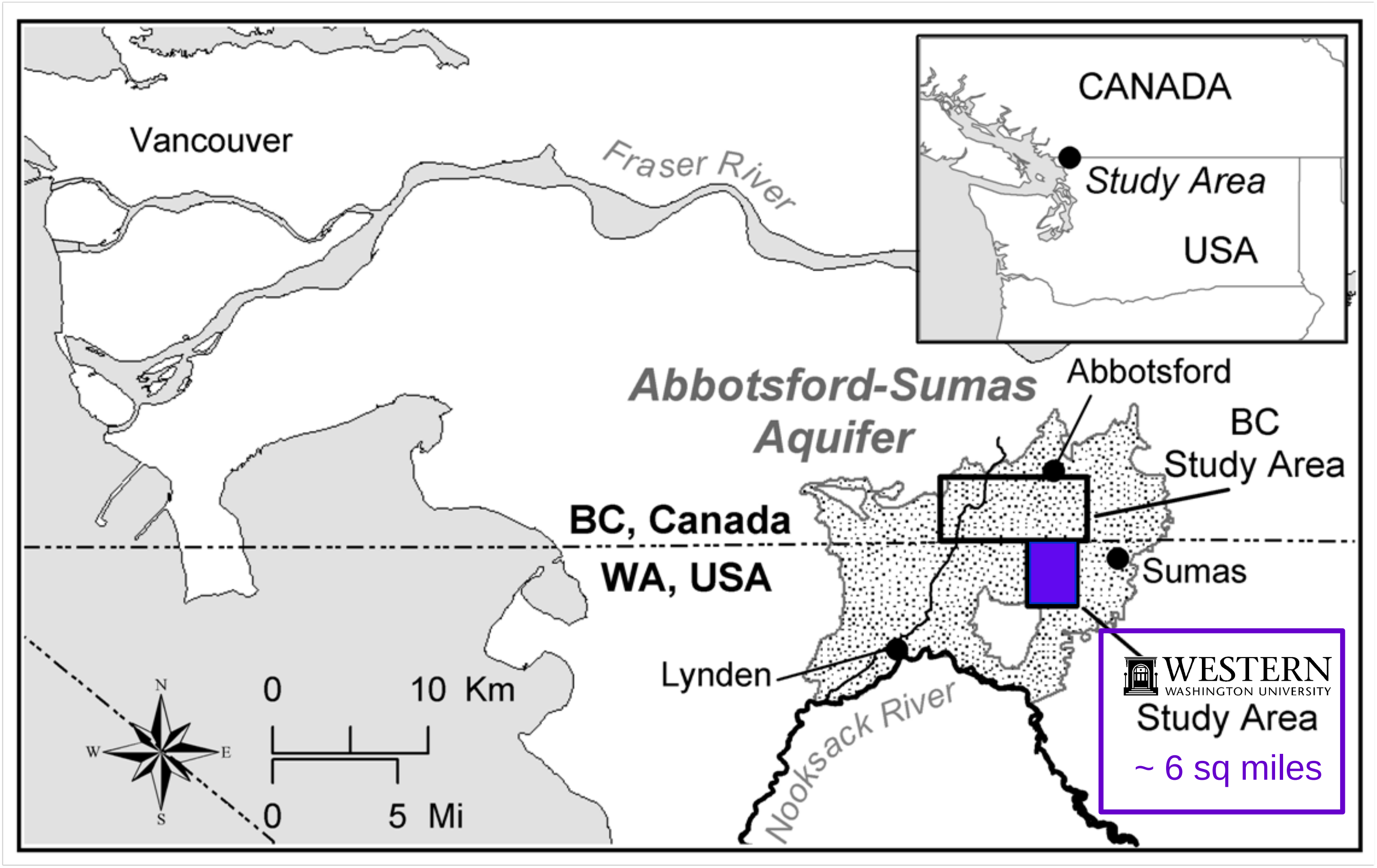
To conduct the experiment:

1. Select soil type
2. Turn on the pump

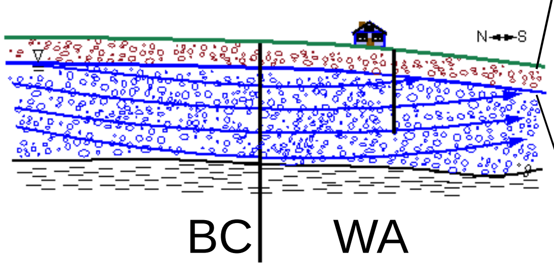


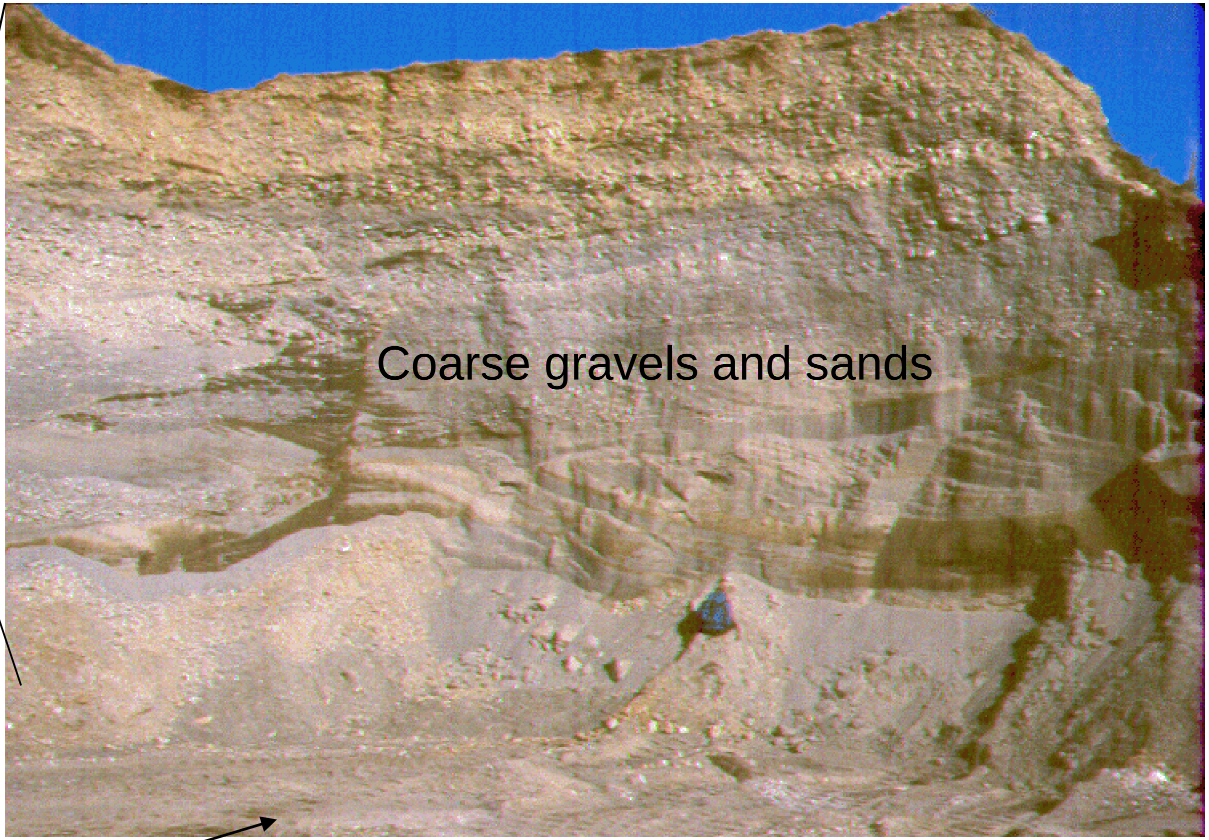
Rate this Resource

Study Area



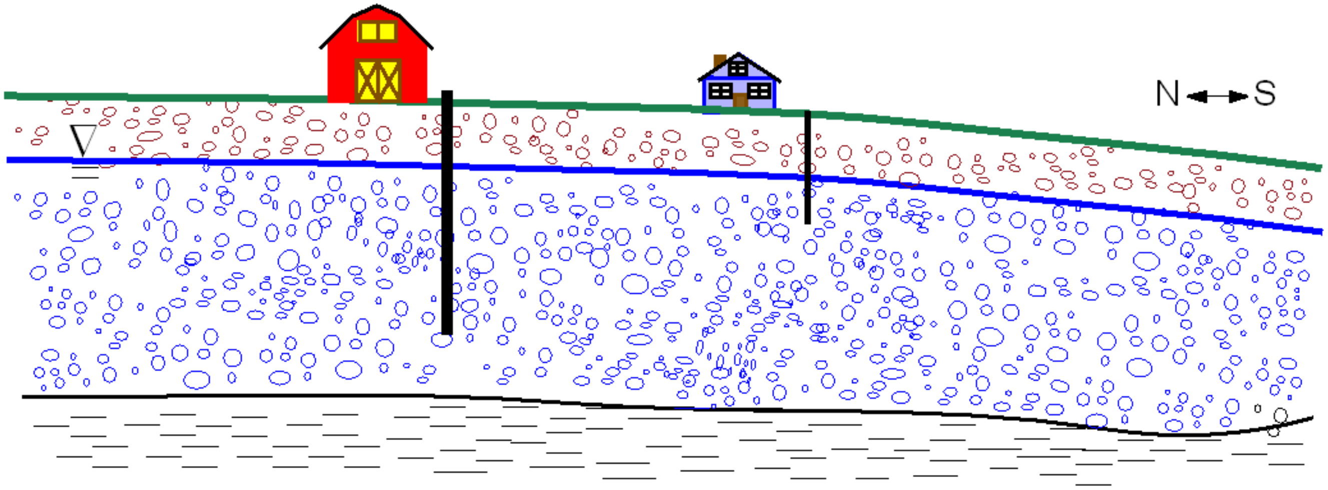
CANADA
Study Area
USA
Vancouver
Fraser River
Abbotsford-Sumas Aquifer
Abbotsford
BC Study Area
BC, Canada
WA, USA
Sumas
Lynden
Nooksack River
0 10 Km
0 5 Mi
N
W
E
S
WESTERN WASHINGTON UNIVERSITY
Study Area
~ 6 sq miles



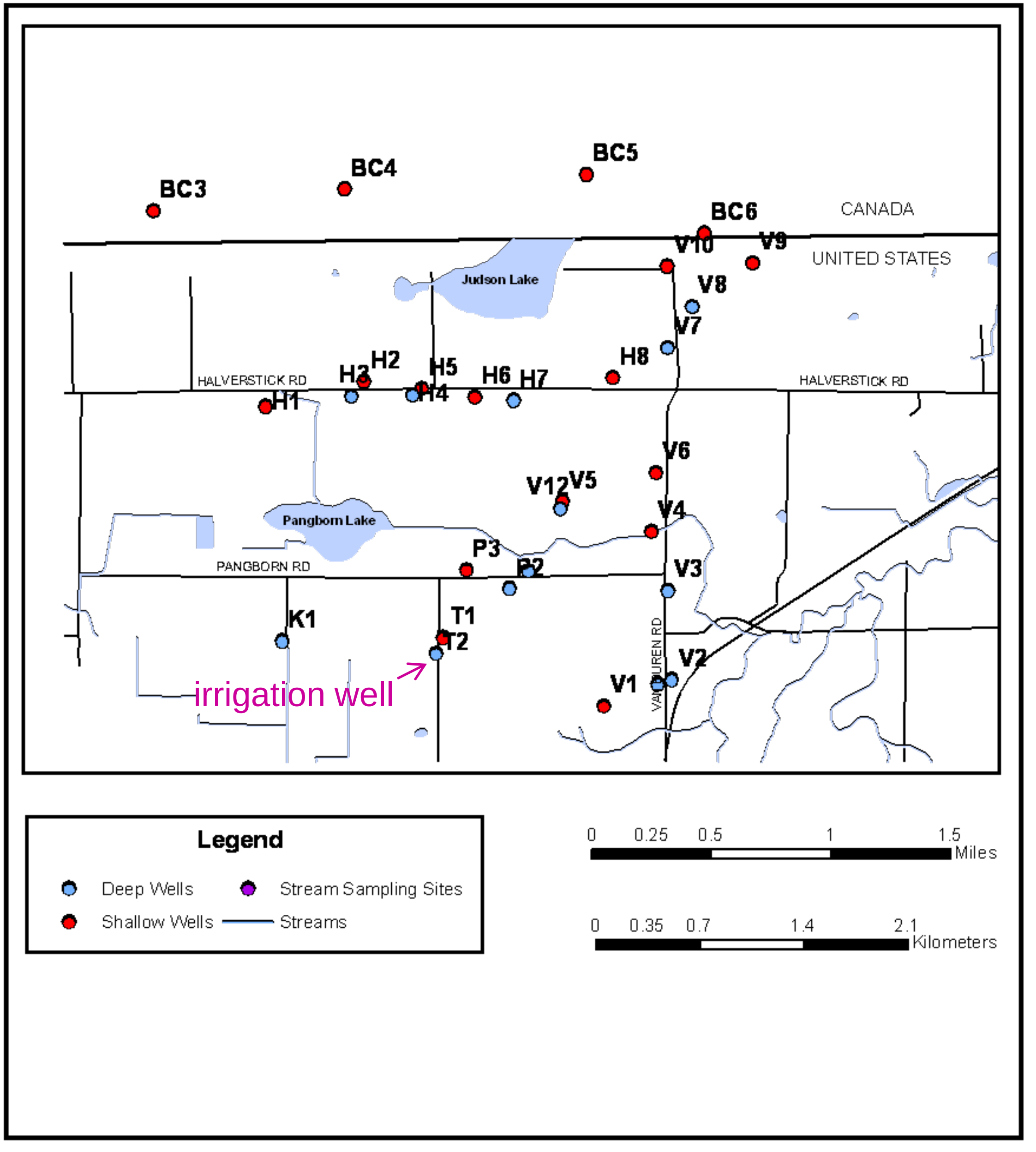


Water table is just below the ground surface

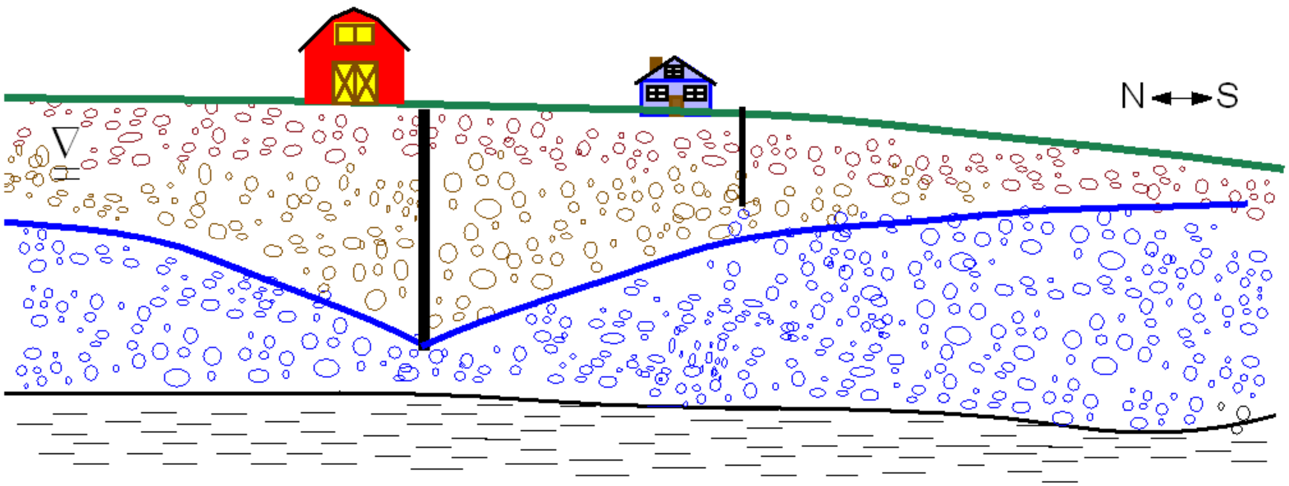
Pumping wells can influence neighboring wells



Irrigation Well

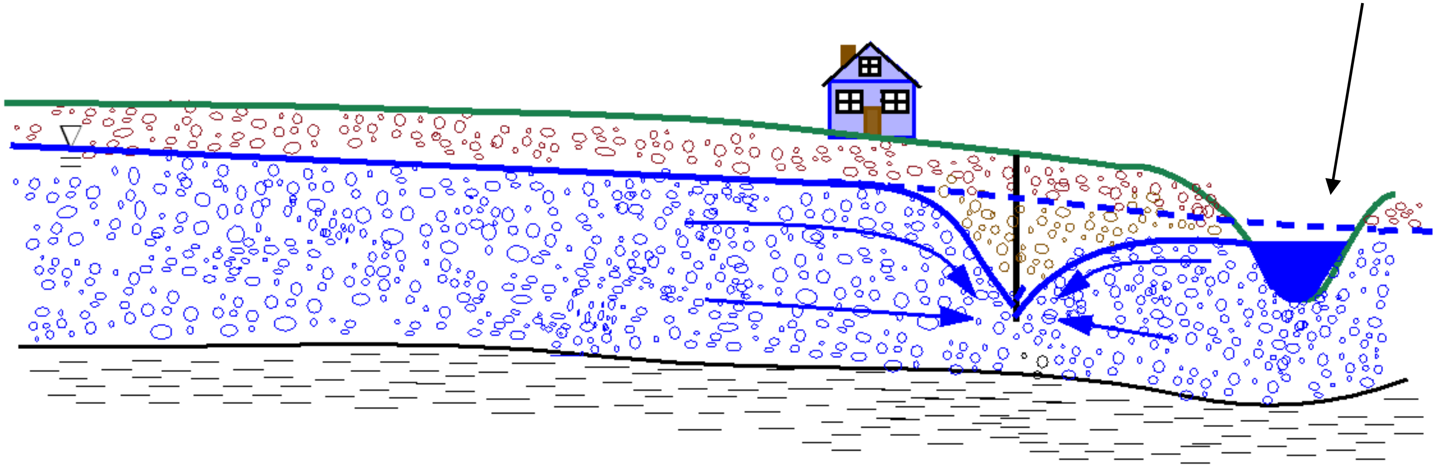


Over pumping of irrigation well lowers the water table below the domestic well (water rights)

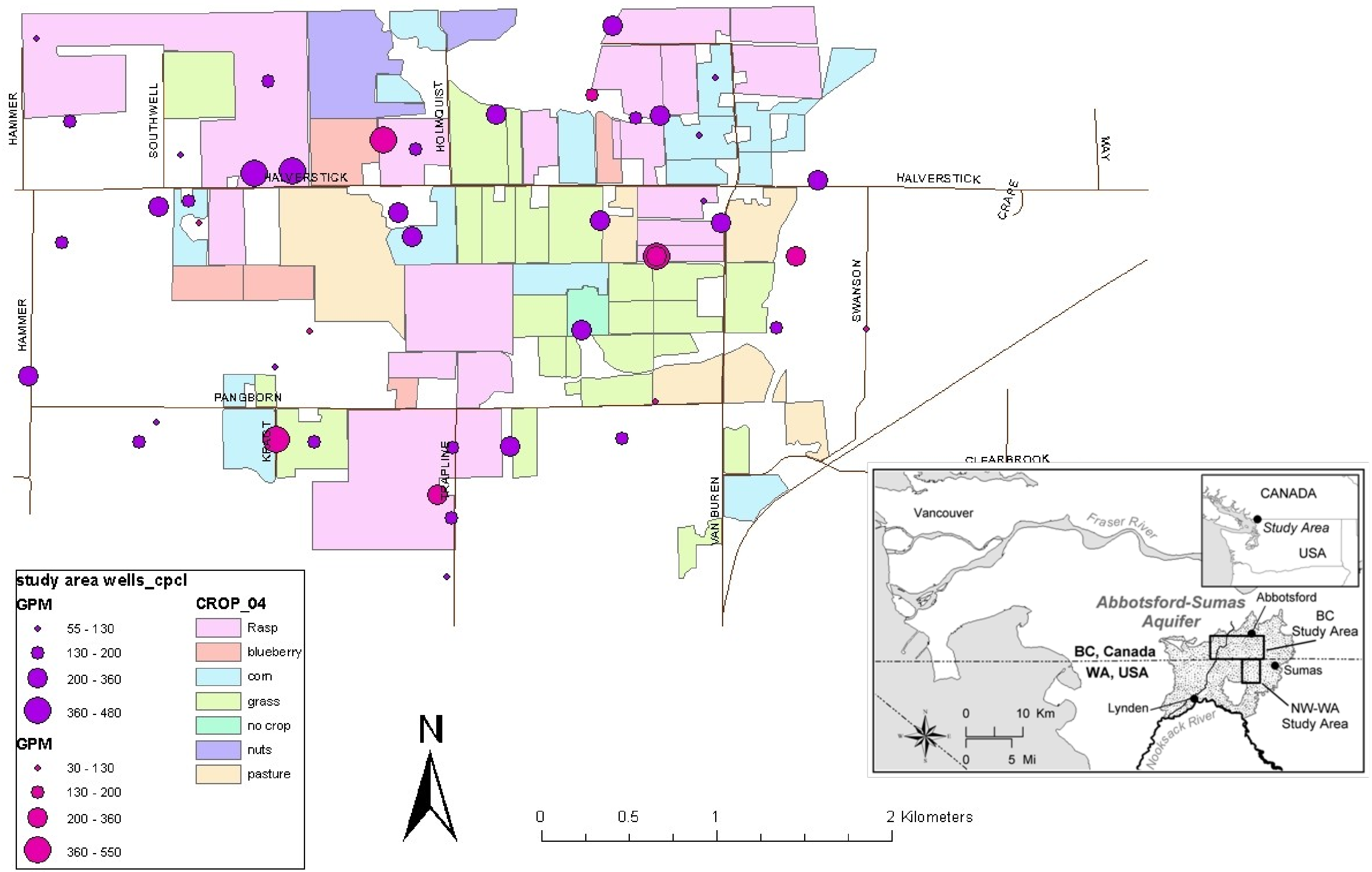


Groundwater surface water interactions

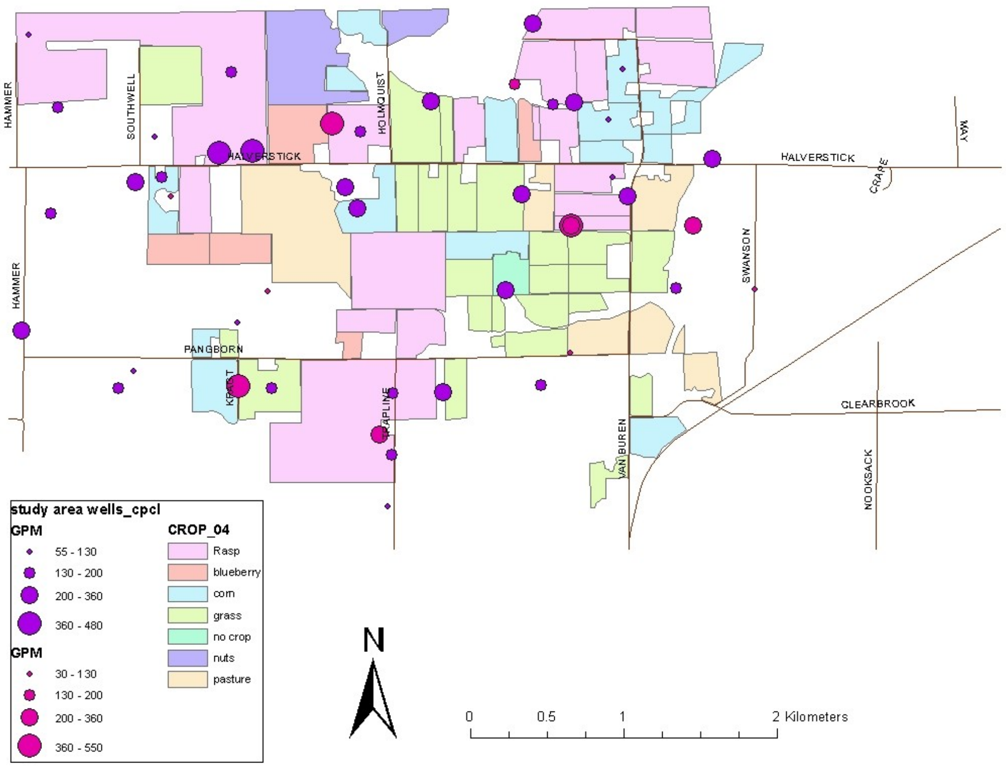
A pumping well can influence streamflow



Irrigation Wells in the study area



Sate law highly restricts the water rights of farmers



However, State law allows Exempt wells (low use wells). So, farmers could sell there land for subdivisions and many homes can drill a well without needing a water right. This is a problem.