Objective

- Use stable isotopes to identify if river is a significant source of water to City spring
- Characterize isotopic signature of groundwater, river water, spring water
- Identify difference or similarities, interpret

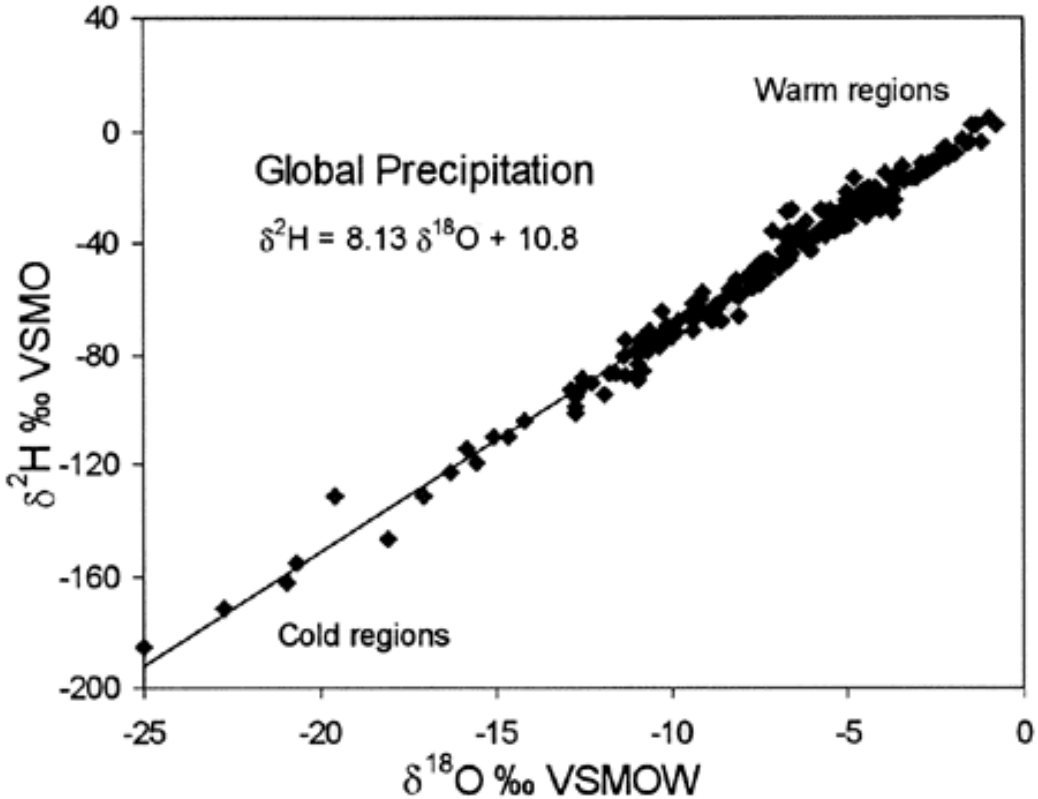
General Approach

1. Collect samples
2. Analyze for routine chemistry and stable isotopes that occur in water (D/H; $^{18}O/^{16}O$)
3. Graph with meteoric water line
4. Evaluate/interpret; use in conjunction with hydrogeologic data

Background information

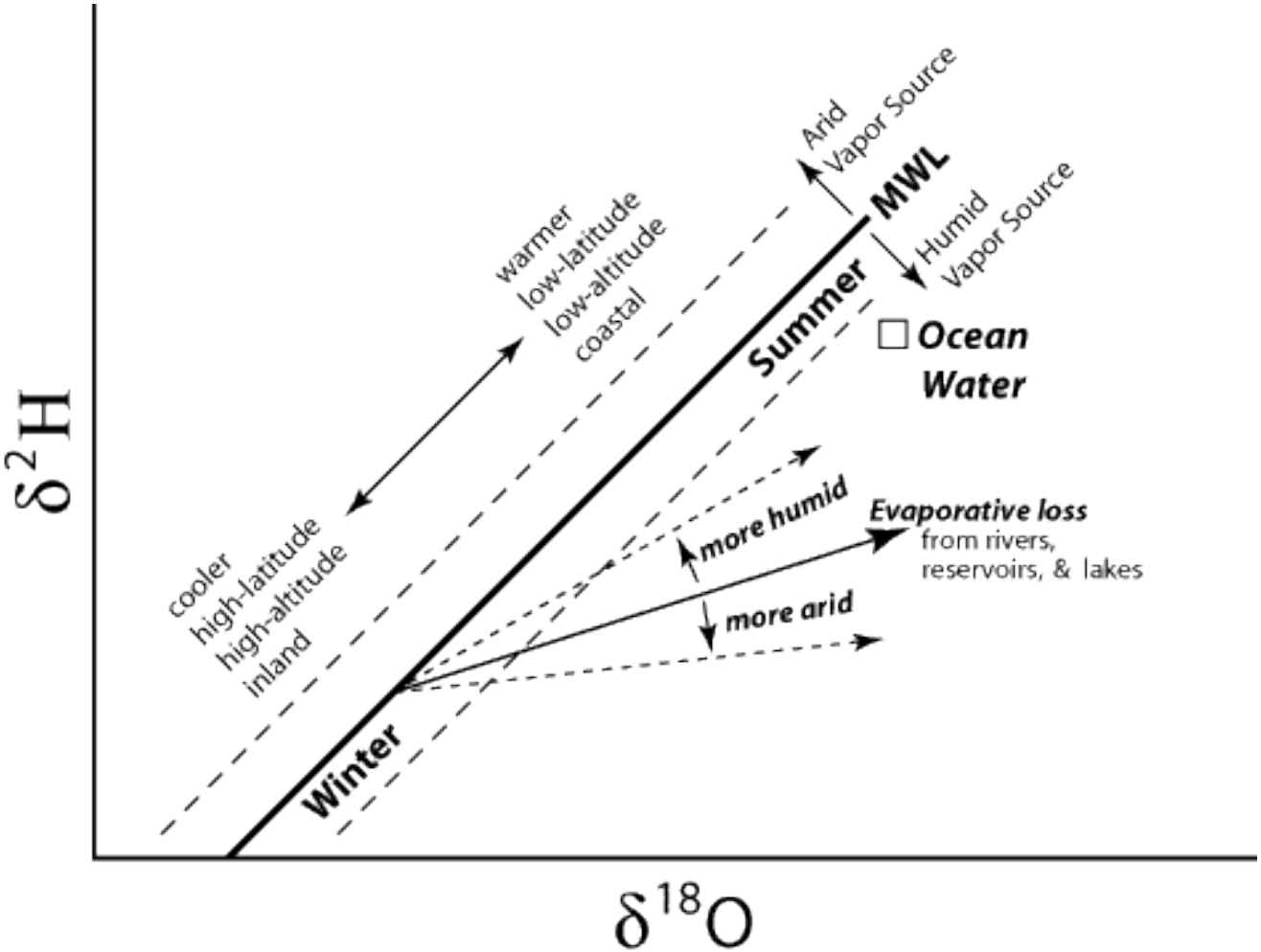
Craig's global meteoric water line, GMWL (1961) for ppt at IAEA global network stations

- All ppt plots approximately along GMWL
- Compared to standard mean ocean water, SMOW, reported permil (0/00)
- Different signature because heavier ^{18}O condenses out first, lighter ^{16}O tends to stay in vapor phase longer
- Signatures get lighter along rainout trajectory
- Light isotopic signatures are more negative (lower left corner) and characteristic of colder ppt
- Heavy isotopic signatures are more less negative (upper right corner) and characteristic of warmer ppt
- Local meteoric water lines may have *slightly* different slope and/or y-intercept; not noticeable on global scale
- Snoqualmie River carries water from higher elevation , and thus higher elev ppt



From http://web.sahra.arizona.edu/programs/isotopes/images/diagram9.gif

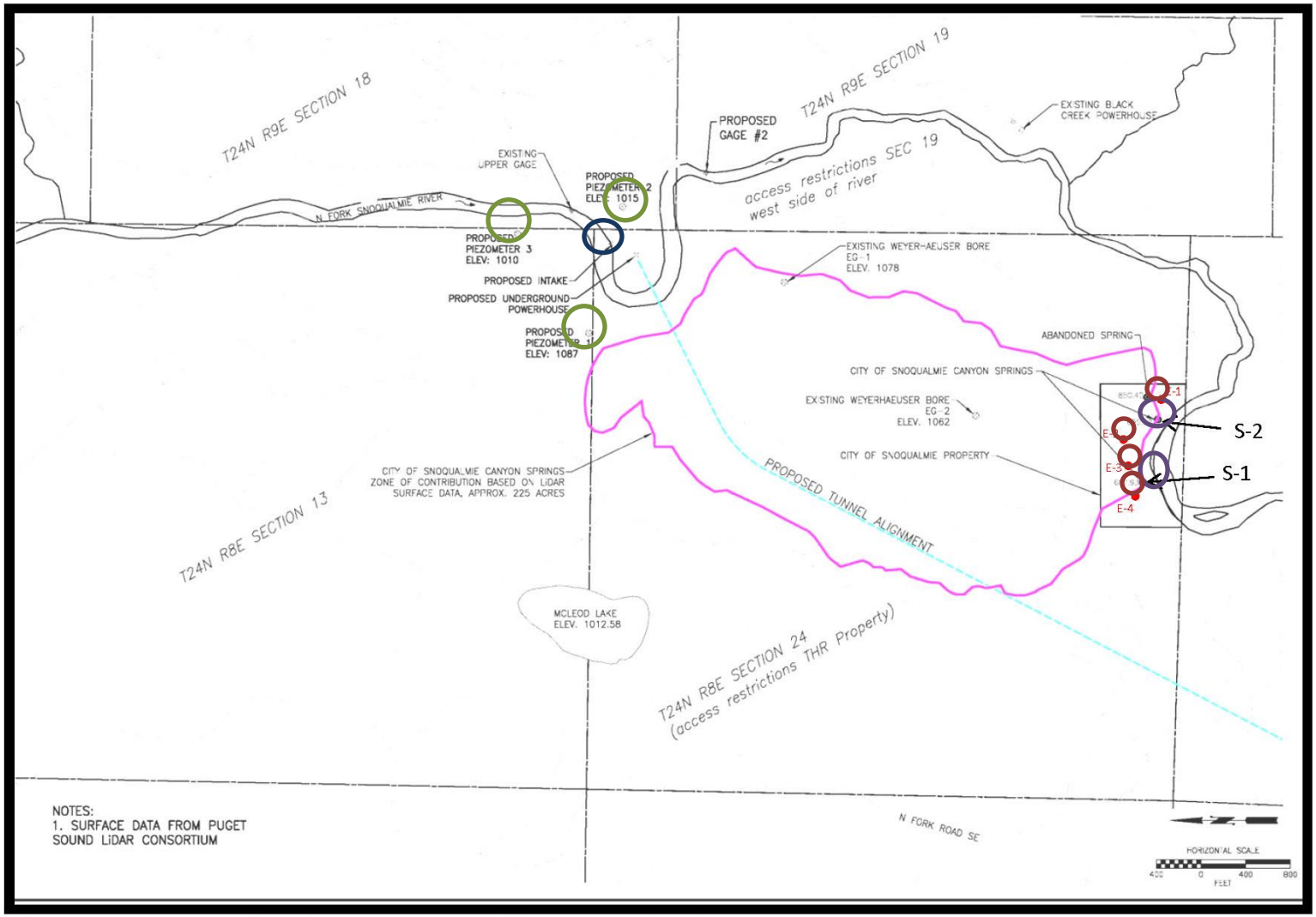
Variations in LMWL



http://web.sahra.arizona.edu/programs/isotopes/images/diagram7.gif

Site map with sample locations

Piezometer River Seep City Spring



Summary of Sampling

Location	November 2014	February 2015	April 2015
Piezometers	x		x
Springs	x	x	x
River	x	x	x
Seeps		x	x

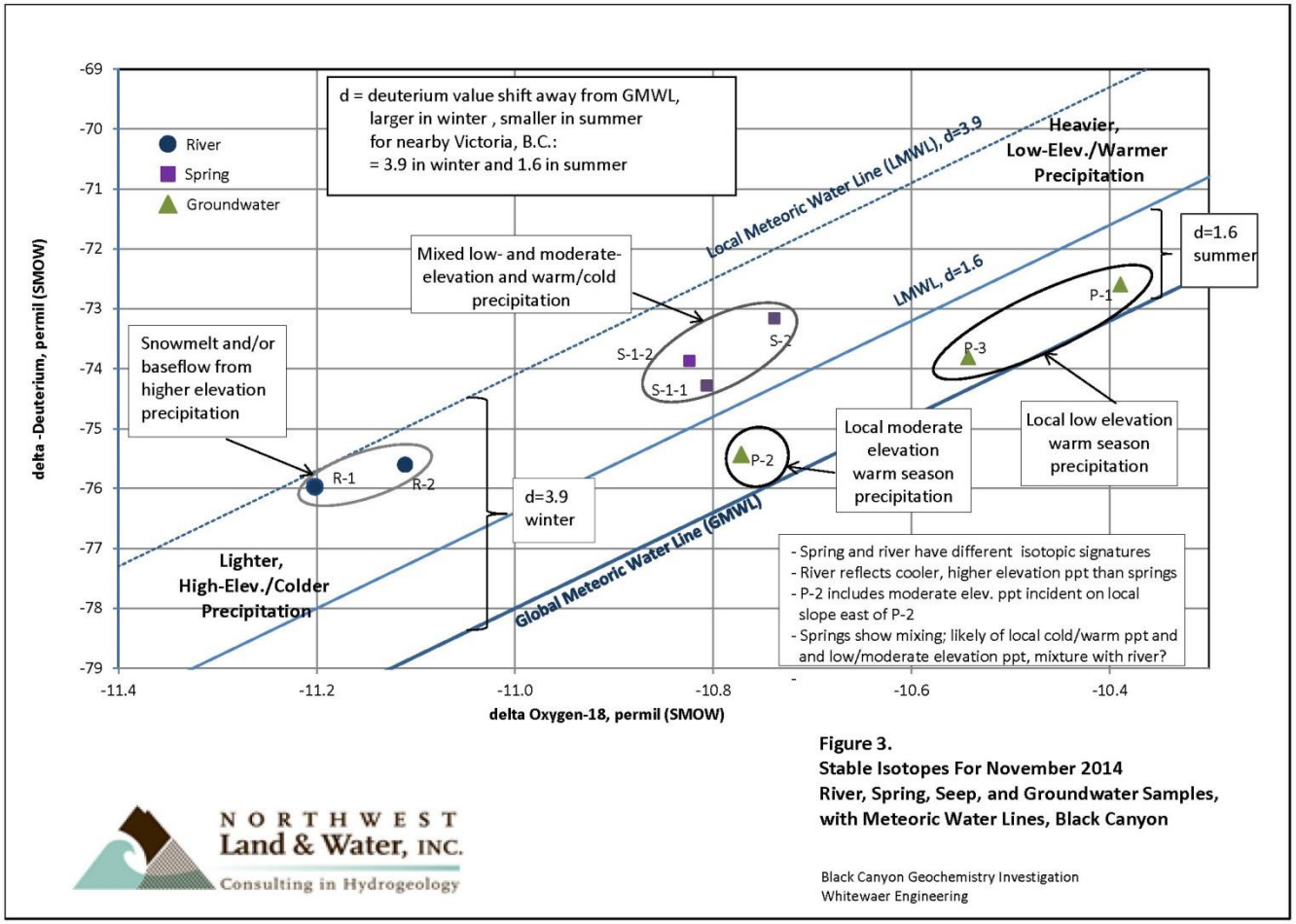
Relevant sub-surface data

Piezometer	Surface Elevation, ft	Depth, ft	Bottom Elevation, ft	Depth to Bedrock, ft	Top Of Bedrock Elev, ft	Adjacent River Elev, ft	Comments
P-1	1,087	45.0	1,042.0	33	1054	~965	Local ppt
P-2	1,011	246.5	764.5	220	791	~965	Dry and till above WLE (831-845)*
P-3	1,017	66.0	951.0	Not encountered	na	~977	silty-clayey gravel from 984 to the well bottom (951 ft)

*Elevation at springs is approximately 688 and 696 ft for S1 and S2, respectively

November sampling

- Variation reflects LMWL
- Nov river reflects cold season
- Piezos reflect warm season
- P2 is lighter than P1 and P3, but still warm season
- Springs a mixture?
- Questions remain



February sampling

- Variation reflects LMWL
- Seeps and springs reflect cold season
- River not as cold as expected. Only local liquid ppt available for the river?
- Springs and seeps are similar
- Suggests that springs are distinct from River
- Questions remain

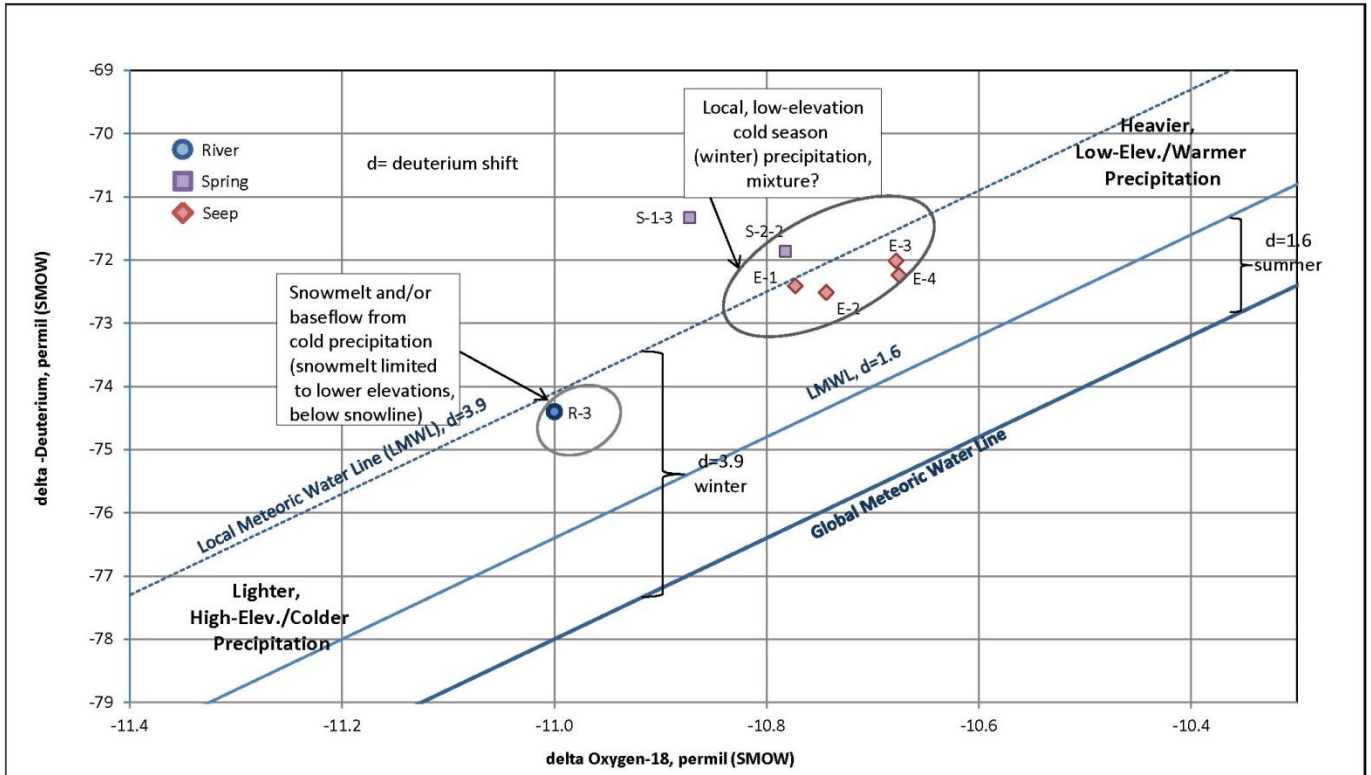


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Figure 4.
Stable Isotopes For February 2015 River, Spring, and Seep Samples, with Meteoric Water Lines, Black Canyon

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April sampling

- P2 similar to springs and seeps
- P2, seeps, and springs reflect cold season
- River very light; likely spring snowmelt
- P-3 distinctly heavier than P-2
- Suggests that springs and seeps discharge groundwater recharged from same source as that which recharges P-2
- River recharge to groundwater can't be excluded, nor can it be significant

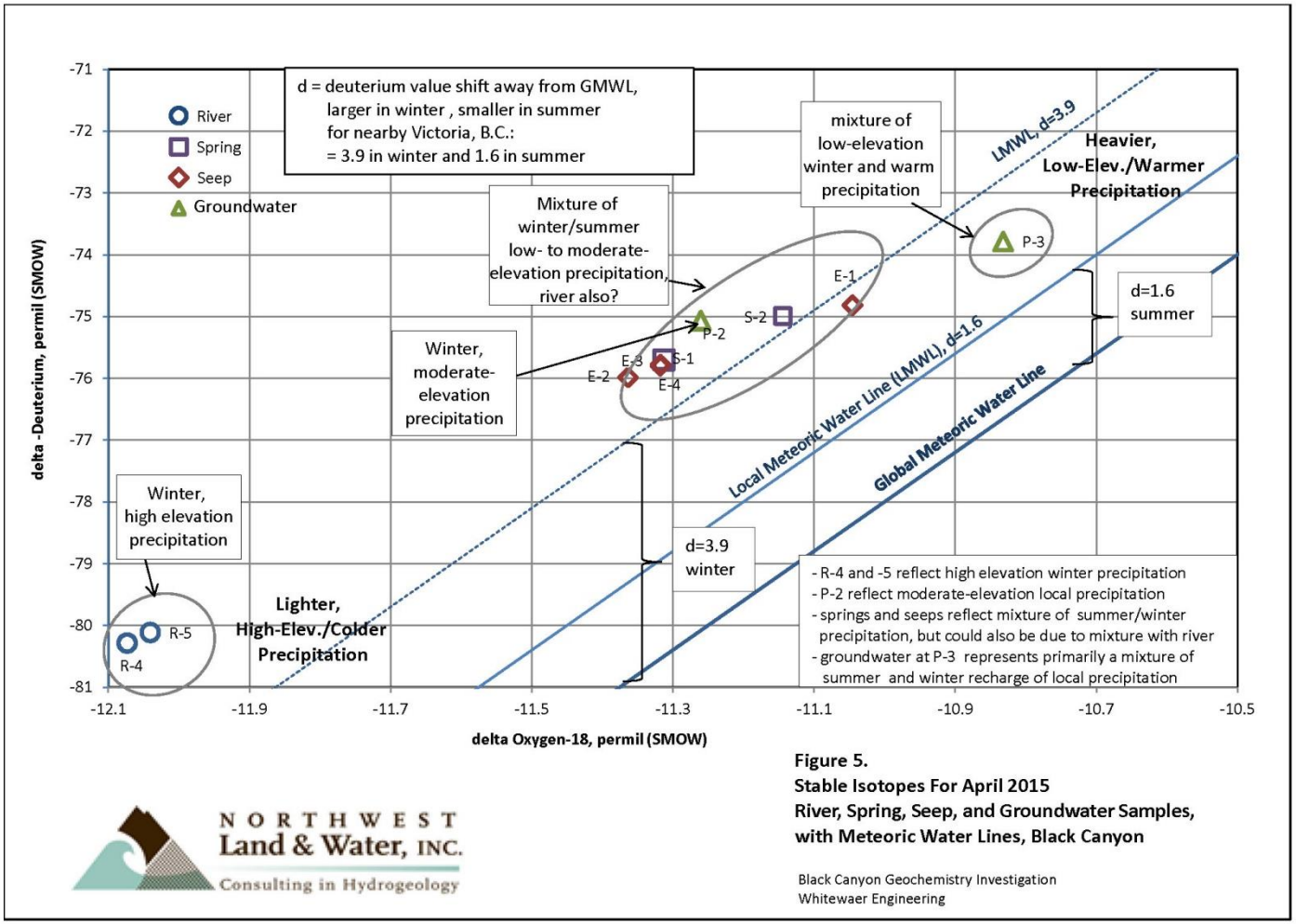

Figure 5.
Stable Isotopes For April 2015
River, Spring, Seep, and Groundwater Samples, with Meteoric Water Lines, Black Canyon

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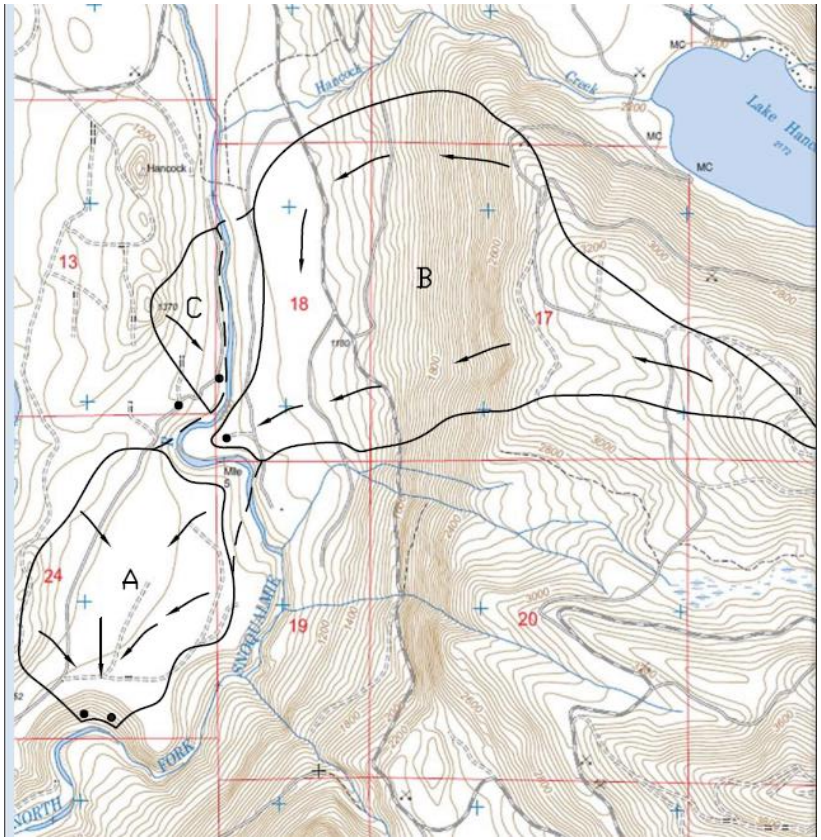
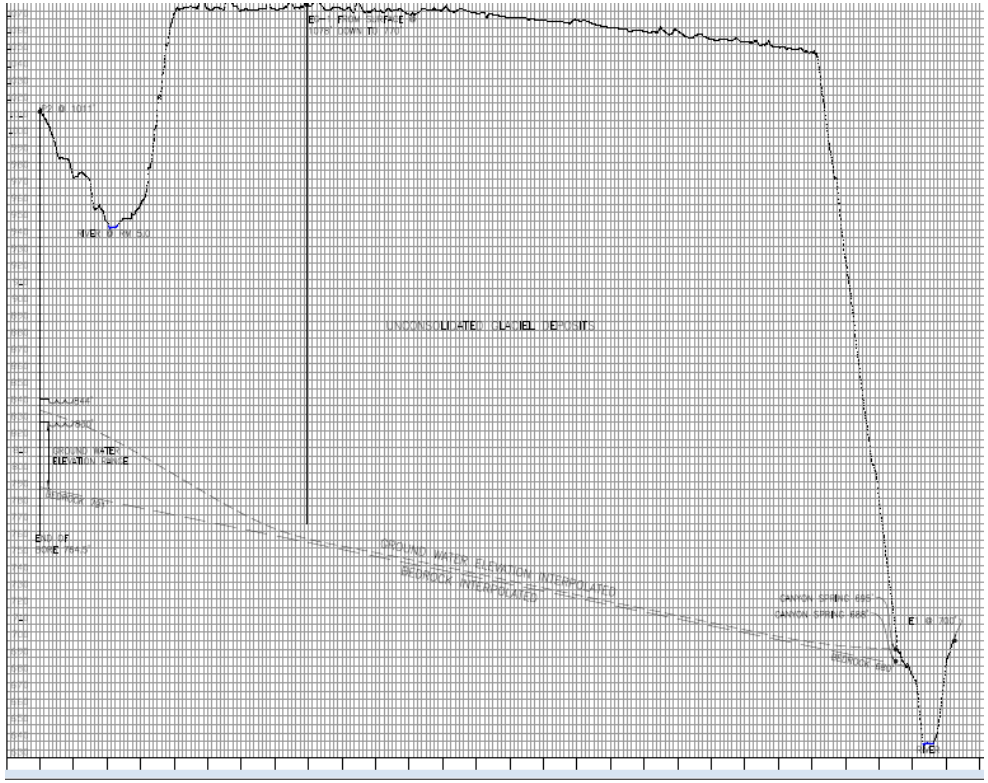
Relevant hydrogeologic information





- Recharge area for P2 is large and includes higher elevation than recharge areas for P1 and P3
- P1 isotopic signature is heaviest (area A), then P3 (area C), then P2 (area B)
- Areas C and A contribute to springs, mostly recharged from local precipitation

- X-section shows high permeability aquifer from P-2 to City springs
- Is elevation of springs controlling groundwater elevation at P2 because there is such a strong connection?

All sampling events

- Piezo variation reflects LMWL shifts with season, like Victoria
- November springs likely a mixture of winter and warm recharge, but can't anything from River)
- Springs and seeps are similar
- Seasonally, seeps and springs are distinct from River
- In conjunction with other hydrogeologic data, suggests that spring discharge is primarily local precipitation and IF there is recharge from the river it is not significant in volume

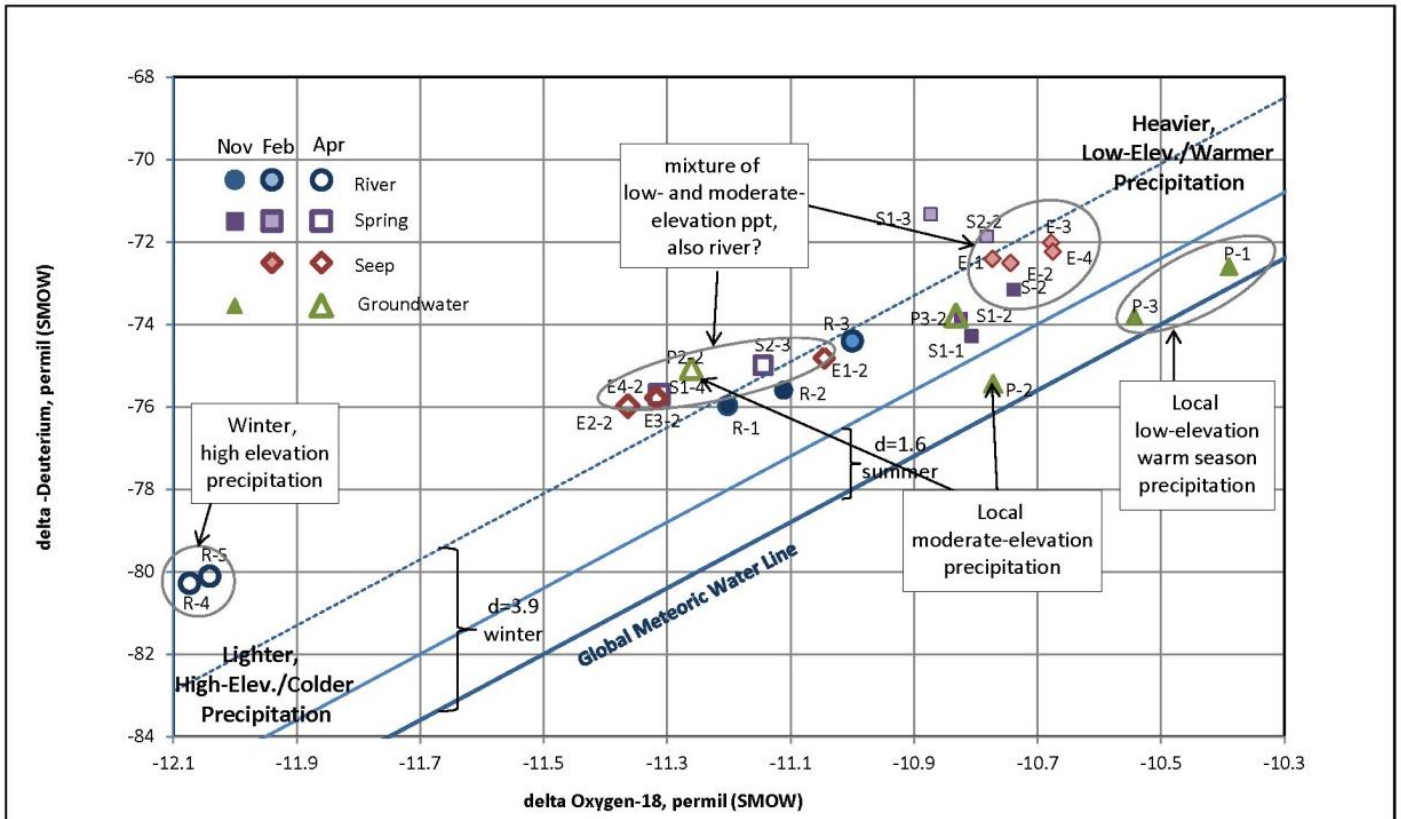


Figure 6.
Stable Isotopes For All Nov 2015, Feb & April 2015 River, Spring, Seep, and Groundwater Samples, with Meteoric Water Lines, Black Canyon

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