A δ18O and δ2H stable water isotope analysis of subalpine forest water sources under seasonal and hydrological stress in the Canadian Rocky Mountains

L.E. Langs[1,2], R.M. Petrone[1], J.W. Pomeroy[2]

[1]Department of Geography and Environmental Management, University of Waterloo, ON

[2]Centre for Hydrology Coldwater Lab Canmore, University of Saskatchewan, SK

I. Introduction

Fresh water supplies in mountainous regions are at risk as snow and ice stores continue to decline under rising global temperatures [6]. Alpine forests are of particular importance due to their hydrological and ecological connectivity within alpine watersheds [7]. In many recent studies, the need to understand the hydrological resilience of alpine watersheds has been highlighted [1]. In the 1970's numerous forestry management projects were conducted within the Kananaskis valley to investigate changes to runoff [5]. Although the results published were debated [1][3], these projects heavily influenced forestry regulations. Climate, resource management and water security uncertainty is the driving force for better understanding our mountain freshwater supplies.

2. Objectives

I. Determine subalpine forest water source waters during pre-, mid- and end- of the growing season

II. Partition relative source water contributions of xylem water within fir and spruce using the Bayesian mixing model MixSIAR

III. Evaluate which source waters are most important for subalpine tree T

3. Study Site & Methods

A mixed coniferous forest [**Table 1**] located at Fortress Mountain, Kananaskis, Alberta. Site elevation is 2100m asl, situated on a slight southern facing hill slope. Ground vegetation is comprised of low lying shrub and moss species. Isotope sampling was conducted at two sites, Powerline and Tower [**Figure 1**], with one area used for precipitation isotope collection. At each site, soil water isotopes were collected from the base of each sampled tree in 2017. Trees some each site were sampled (4 from each, 8 over all). Tree and soil water isotopes were collected three time throughout the season. Pre- growing season, middle and end. Groundwater and snow water isotopes also collected when available. Isotopes processed by azeotropic distillation at UWaterloo Environment Isotope Laboratory.

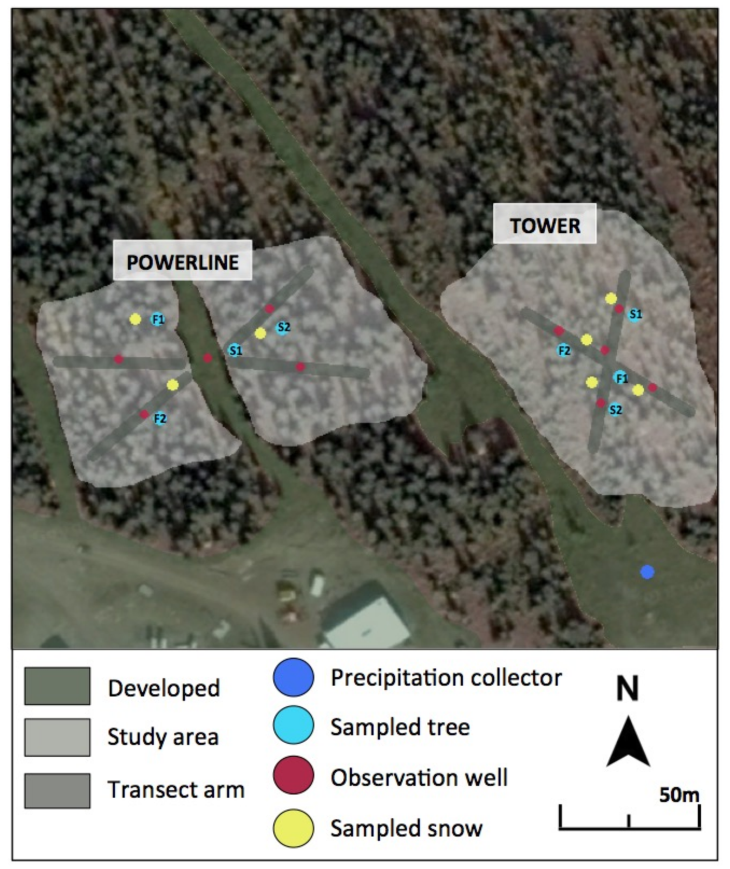
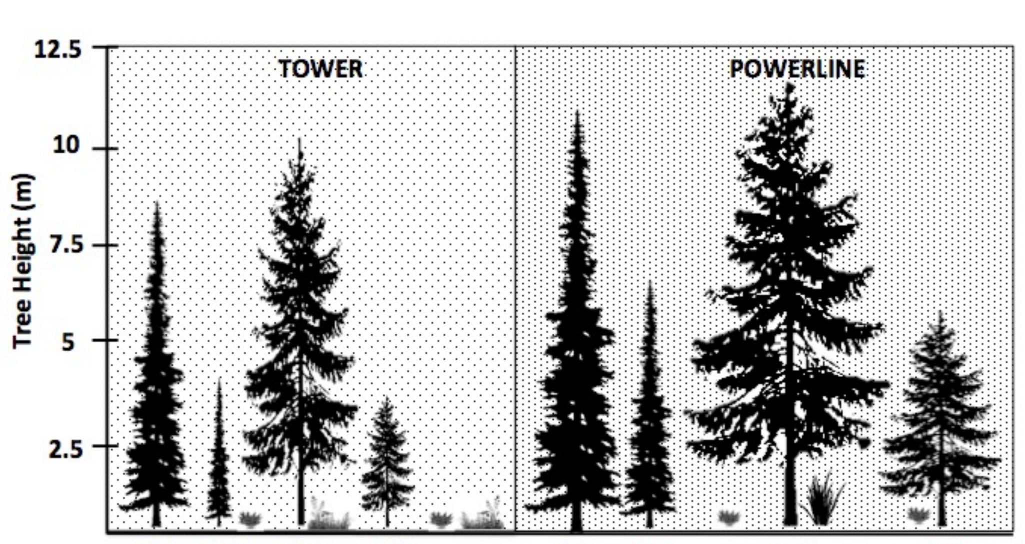


FIGURE 1– Study site map, Fortress Mountain, Kananaskis, AB

Sampled Isotope Trees



Site	Tree Species	Sample Code	DBH (cm)	Height (m)
Tower	*Abies lasioscarpa*	T-F1	6.7	4.27
	Abies lasioscarpa	T-F2	18.7	8.76
	Picea engelmannii	T-S1	6.3	4.13
	Picea engelmannii	T-S2	30.5	10.64
Powerline	*Abies lasioscarpa*	C-F1	10.3	6.68
	Abies lasioscarpa	C-F2	18.6	10.43
	Picea engelmannii	C-S1	7.9	5.88
	Picea engelmannii	C-S2	28.6	12.22

TABLE 1– Data shown for Tower and Cutline sites for the 5.64m radius portion of a completed forest inventory survey. Data collected in August 2015 at Fortress Mountain, Kananaskis, Alberta

4. Results & Discussion

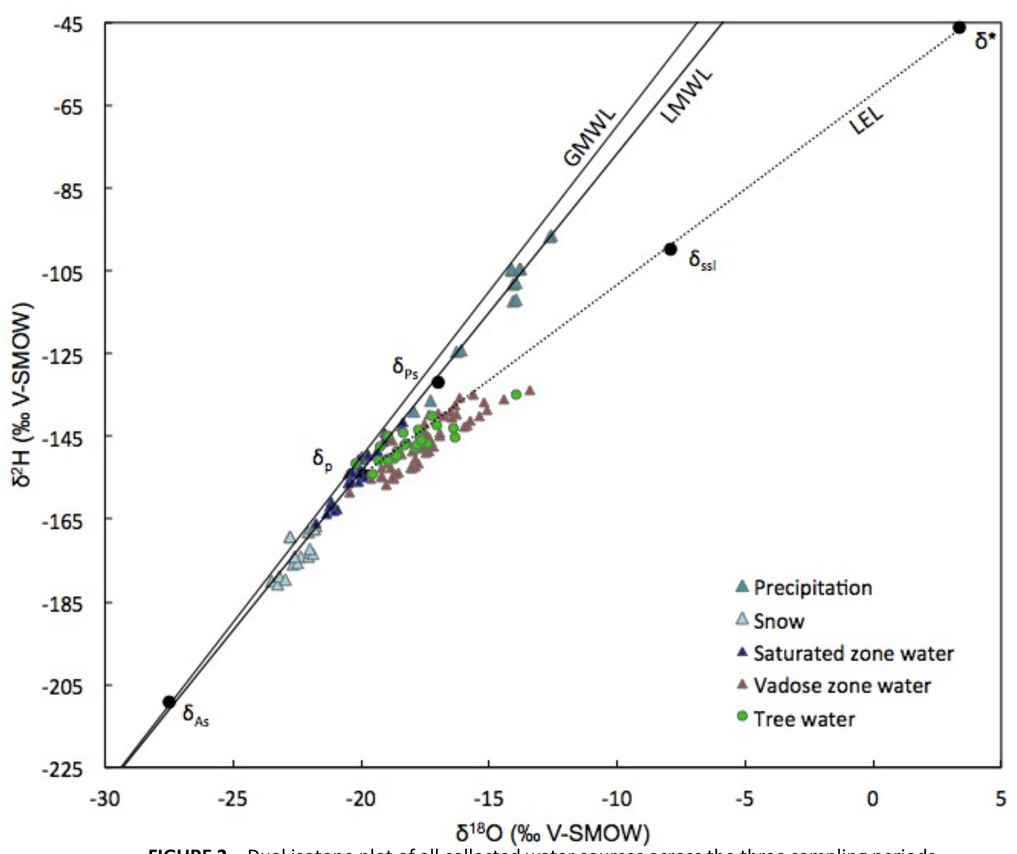


FIGURE 2 – Dual isotope plot of all collected water sources across the three sampling periods

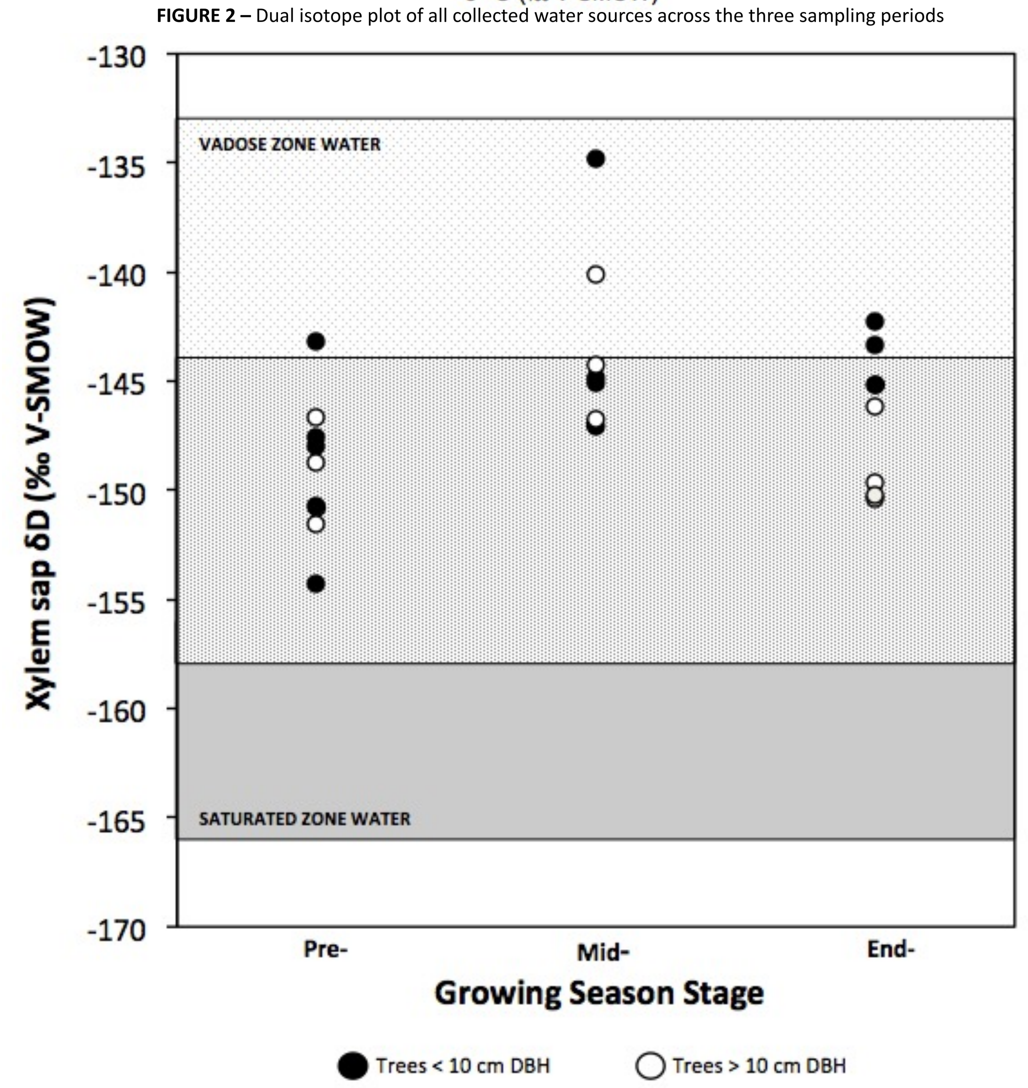
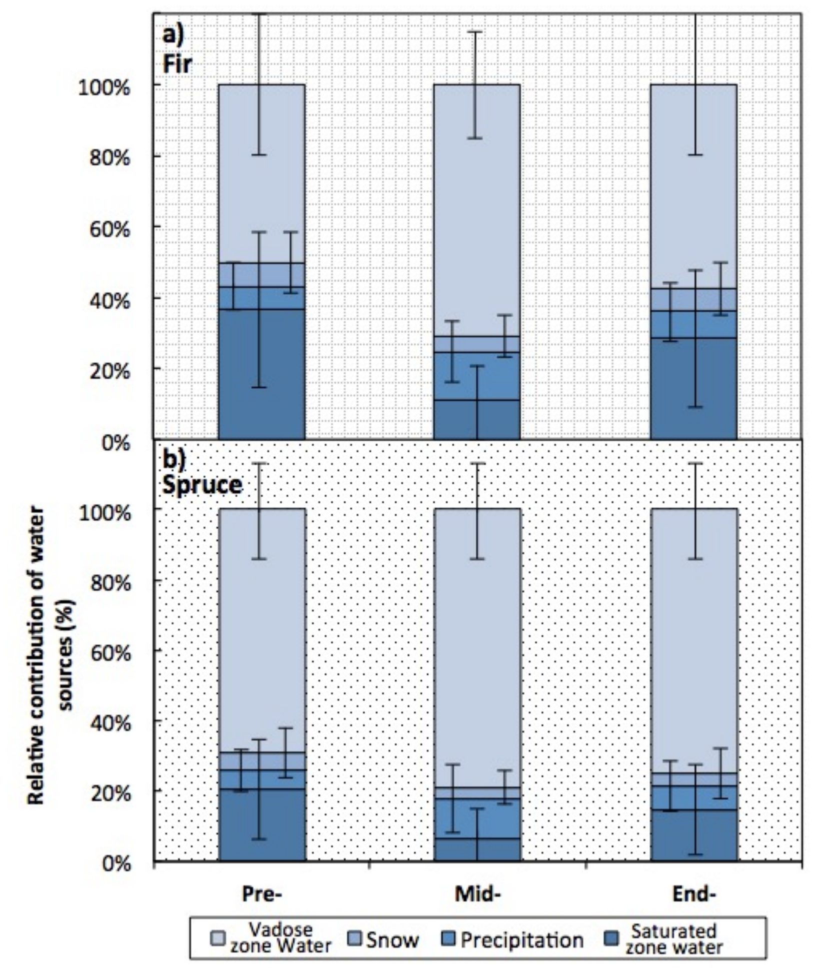


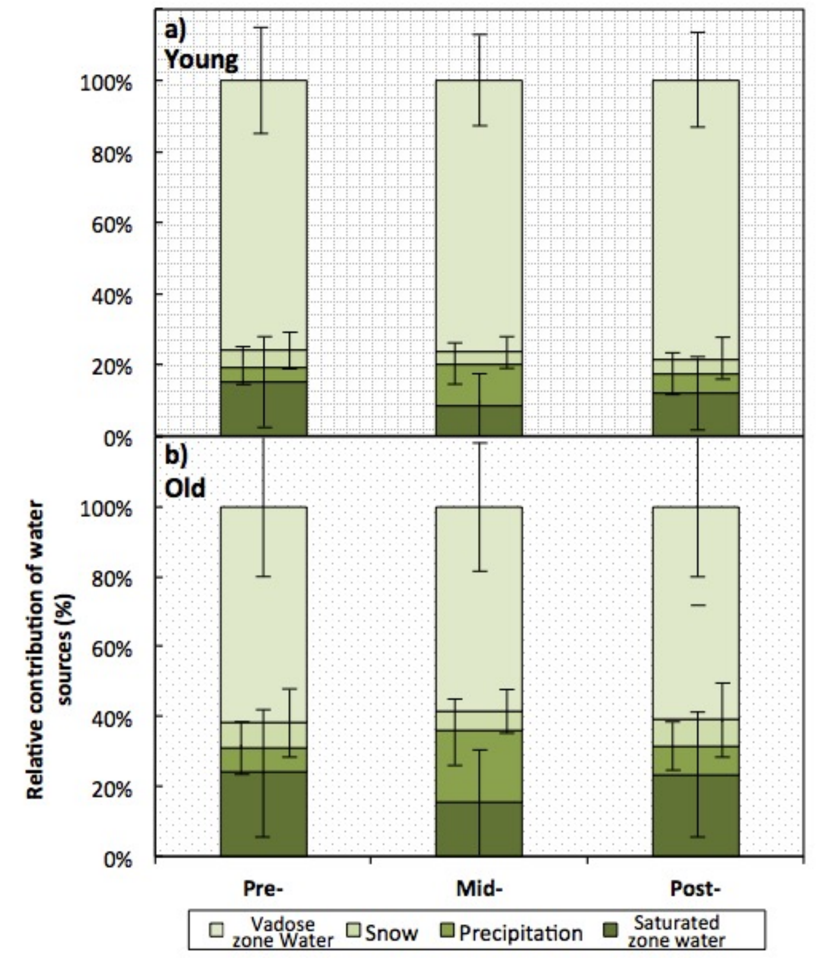
FIGURE 3 – ²H isotope plot plotted by tree size and sampling period showing seasonal progression



MixSIAR – Water Source Use by Species

- Both species, spruce and fir, had different seasonal source water proportions but similar water use trends
- Pre- period largest water source was vadose zone water (50.1% fir, 69.3% spruce) saturated zone water was second highest proportion due to available snowmelt water. Fir used more saturated zone water, by 16%
- Mid- period saw increases in vadose water source use (71.0% fir, 79.2% spruce)
- End- period saw fir reducing vadose water use and increasing saturated zone use (57.6% and 28.5%). While spruce stayed with a higher vadose zone use (74.5%)
- Fir root deeper in mountainous environments, which is evident in the BMM results. Spruce tend to root shallower, relying more on the vadose zone

FIGURE 5 – Relative source water contribution to xylem water generate by MixSIAR BMM showing sources by species over the growing season



MixSIAR – Water Source Use by Age

- Young trees had a higher reliance on vadose zone water, where as older trees utilized more saturated zone water
- Young tree water sourcing stayed consistent throughout the season, with 76.0-78.6% of water use coming from the vadose zone. Secondary source was primarily saturated zone water
- Older trees used more saturated zone water, ranging from 15.3-24.1% throughout the season. Vadose zone use ranged from 58.7-61.8%
- Physiologically, these results make sense. Older more established trees have deeper rooting systems able to access deeper water sources. Young trees are less established drawing water heavily from the vadose zone

FIGURE 6 – Relative source water contribution to xylem water generate by MixSIAR BMM showing sources by age class over the growing season

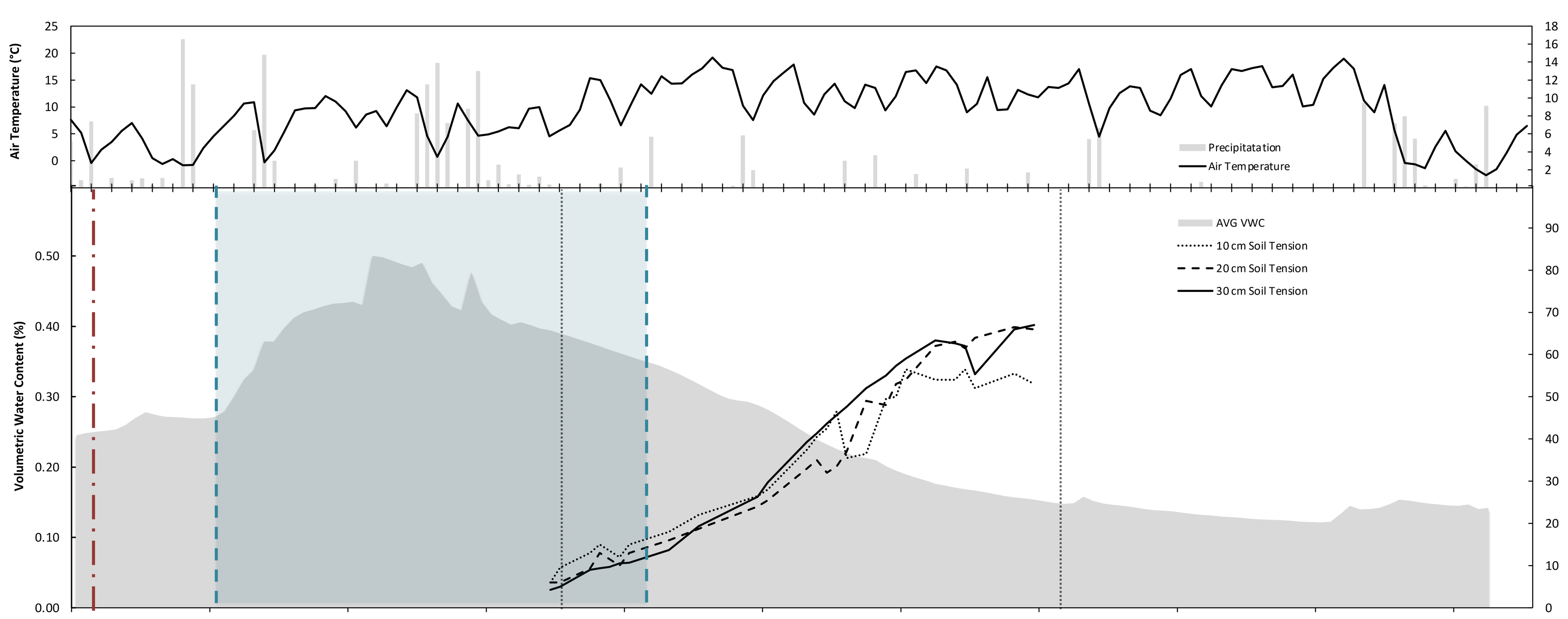


FIGURE 4 – Hydrometric data for 2017 at Fortress Mountain field site. Max SWE indicated by red line, snowmelt period in blue shading.

A simple figure [**Fig 3**] using collected isotope data showed seasonal source water spread over the growing season. This figure shows a shift to using vadose zone water (rain infiltration) in the middle of the season from using snowmelt water at the beginning. The hydrometric data [**Fig 4**] supports this trend, with snowmelt water availability from May 19 – early July.

5. Conclusions

- Results highlighted the importance of soil moisture reserves to the productivity of subalpine forests. This study was conducted during a summer of drought in the Canadian Rockies, and the water use behaviours observed helped shed light upon potential impacts to these forests under sustained or long term drought
- Successionally, these forests could be nudged off balance in their growth under climate change if moisture availability in the vadose zone is compromised under sustained drought. Older trees are able to utilize deeper source water and will have a higher survival rate compared to their younger counterparts who may experience increased levels of drought stress
- A stable water isotope approach and MixSIAR BMM application was valuable to understanding the source waters most important to these sensitive forests. A multi-year isotope study would further understanding of source water use temporally, and under varying seasonal hydrologic conditions

References

Harder, P., Pomeroy, J. Westbrook, C. (2015). Hydrological resilience of a Canadian Rockies headwaters basin subject to changing climate, extreme weather, and forest management. *Hydrological Processes* **[1]**; Jones, B.(2009). Alberta, Canada map. *Bruce Jones Inc,* Web Resource **[2]**; Pomeroy, J., Fang, X., Ellis, C.R. (2012). Sensitivity of snowmelt hydrology on mountain hillslopes to forest cover disturbance. *Centre for Hydrology*. **[3]**; Steinburg, S.L., van Bavel, C.H.M., McFarland, M.J. (1989). A gage to measure mass flow rate of sap in stems and trunks of woody plants. *Journal of the American Society for Horticultural Science*. 114, P.466-472. **[4]**; Swanson, R.H., Golding, D.L. (1982). Snowpack management on Marmot watershed to increase late season streamflow. Western Snow Conference: Reno, Nevada, 215-218 **[5]**; Bawden, A., Burn, D., Prowse, T. (2015). Recent changes in patterns of western Canadian river flow and association with climatic drivers. *Hydrology Research.* P.551-565. **[6]**. Markovich, K., Maxwell, R., Fogg, G. (2016). Hydrogeological response to climate change in alpine hillslopes. *Hydrogeological Processes.* 3138, P.3126-3138 **[7]**.