

# *Mt. Shasta Springs 2009 Summary Report*



*Prepared For:*



*Prepared By:*



*With Assistance From:*



**Mt. Shasta Spring Water Summary**  
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## Section 1- Overview and General Conclusions

This spring and groundwater study was initiated by California Trout to assist county and community governments to make sound policies regarding the water resources of the greater Mount Shasta area. Much of the water resources in the area depend on springs that are sourced from glaciers, snow pack and rainfall that originates on Mount Shasta.

Water samples have been collected from approximately twenty-two springs since fall of 2007. These water samples have been analyzed for a full suite of general water quality and geochemical parameters. A subset of these samples were also analyzed for oxygen, hydrogen and deuterium isotopes. The intent of the sampling was to determine where the water originates on the mountain, as well as if any of the springs may be related. This information will assist in determining how and if these springs may be impacted due to development and/or climate change. To further support the study, nine springs have also been monitored for flow, to determine if seasonal/yearly fluctuations in flow are occurring. Figure 1- Spring Location Map, illustrates the relative location of all springs included in this study.

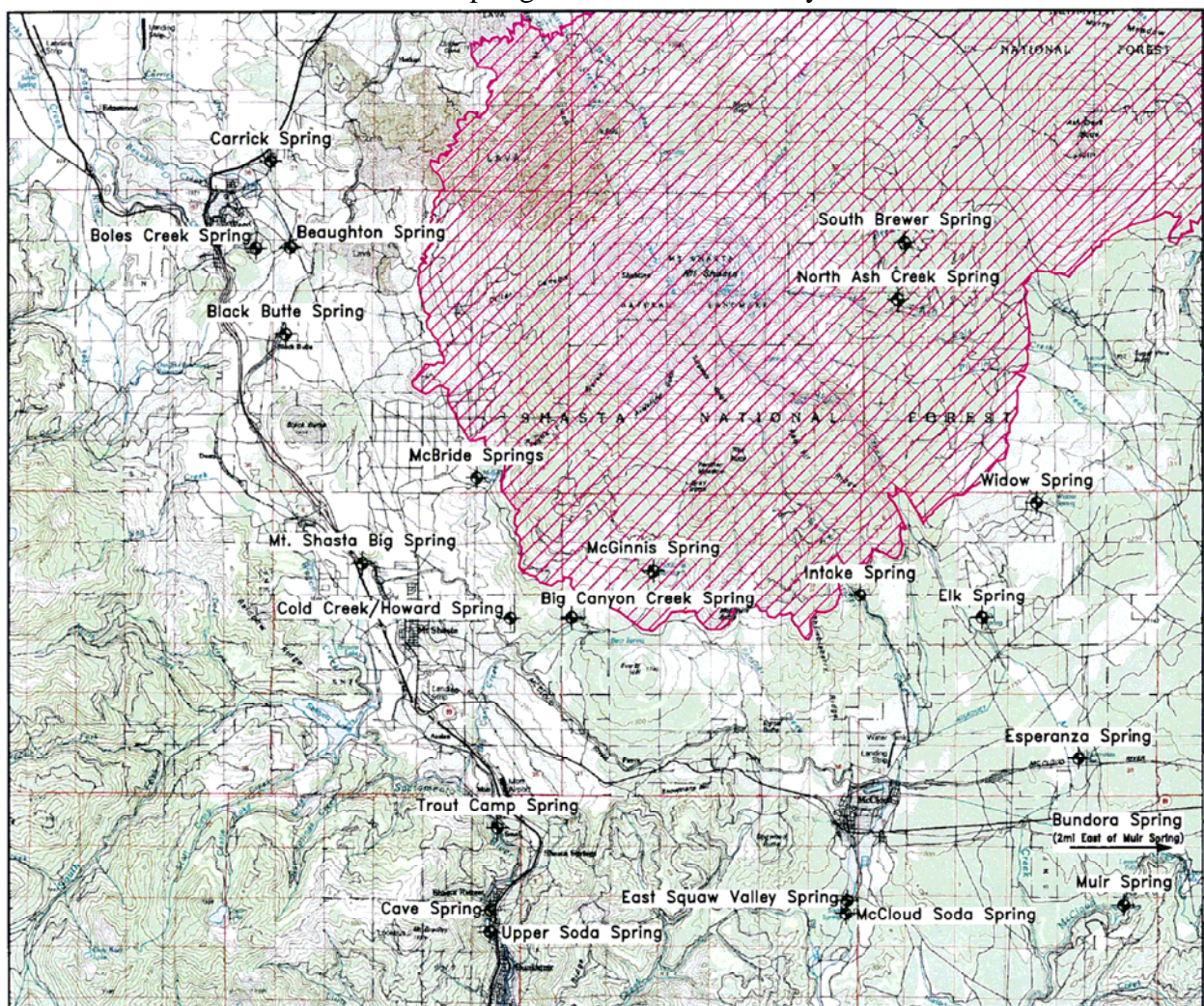


Figure 1- Spring Location Map

### **1.1-Data Analysis**

The spring water samples were analyzed by University of California –Davis (UCD). The geochemical data from that analysis was imported into AquaChem. AquaChem is a data analysis software package that provides comprehensive statistical and graphical analysis of water quality data. This software allows for a complete analysis of large data sets and the ability to look for and identify trends and correlations between samples.

AquaTerra Consulting collected all the samples from the springs and The Source Group, Inc (SGI), a consulting firm that specializes in hydrogeology conducted the preliminary data analysis of the geochemical data in AquaChem. Cynthia McClain, an undergraduate from UCD, analyzed the isotope data collected. The oxygen and hydrogen isotope data was used to determine the approximate elevation above which that precipitation ultimately sourced the spring flow. A small subset was analyzed for tritium isotope data to determine the approximate spring water age.

### **1.2-General Analysis Results**

#### *General Isotope Data*

The hydrogen and oxygen isotopes indicate that all of the 22 springs sampled are sourced on Mount Shasta at elevations above approximately 5,200 feet, with an average elevation of 6,536 feet. Eighteen of these 22 springs are sourced above 6,000 feet and ten are sourced above 7,000 feet, see Table 2. The area on Mount Shasta above 5,200 feet is depicted on Figure 1, showing the recharge area for these 22 springs. It should be noted that much of this recharge area falls within the boundaries of the Mt. Shasta Wilderness.

Age dating based on tritium isotope analysis was conducted on five springs in the study set. The results of the age dating indicates that the approximate elapsed time since the water left the atmosphere as precipitation on Mt. Shasta varied from 14 to greater than 50 years. See Table 1, Age Data.

<b>Sample ID</b>	<b>Age using EA (yr)</b>
Carrick Spring	>50
Mt Shasta Big Springs	>50
Muir Springs	13.9
Shasta E. Spring	44.4
Shasta N. Spring	26.6

**Table 1- Age Data**

**Table 2- Spring Elevations and Recharge Elevations**

Study Spring Designation #	Spring Name	Elevation (ft - MSL)	Calculated Recharge Elevation Based on Isotope Data Analysis (ft - MSL)	Elevation Difference (ft)
CM 1	Muire	2983	6039	3056
CM 2	Mt. Shasta Big Spring	3567	8170	4603
CM 3	McBride	4969	7408	2439
CM 4	East Squaw Valley Spring	3104	5654	2550
CM 5	McCloud Soda Spring	2992	5714	2722
CM 6	Widow	4675	5676	1001
CM 7	Bundora	3616	5166	1550
CM 8	Black Butte	3612	7334	3722
CM 9	Trout Camp	2753	6279	3526
CM 10	South Brewer	6732	7760	1028
CM 11	Carrick Spring	3531	8464	4933
CM 12	Boles Creek Spring	3563	8682	5119
CM 13	Beaughton	3438	8142	4704
CM 14	Cold Creek/Howard	4167	7291	3124
CM 15	Big Canyon Creek Spring	4971	7294	2323
CM 16	McGinnis	3711	6508	2797
CM 17	Esperanza	3437	5054	1617
CM 18	North Ash Creek	6500	7454	954
CM 19	Elk	3713	6179	2466
CM 20	Intake	4607	6435	1828
CM 21	Upper Soda Spring	3746	3656	-90
CM 22	Cave Spring	2415	3436	1021

*General Water Quality Data Analysis Results*

Statistical analysis of the general water quality data indicates a remarkable similarity in the general chemical composition of all 22 springs, with the exception of the significant differences present in the water quality of the soda springs sampled. The two Soda springs, McCloud and Upper Soda are substantially enriched with sodium, magnesium, calcium and chloride in comparison to all the other springs. Generally, the other springs have a low mineral content, which is reflective of a relatively short travel and storage time within the volcanic rocks of Mt. Shasta. The precipitation that falls within the recharge area on Mt. Shasta, enters the aquifer system through direct percolation of rainwater, percolation of snow pack melt or glacier melt water. Once the precipitation becomes part of the groundwater, it moves down slope through the volcanic rocks picking up mineral content along the way. This groundwater emerges as spring flow, base flow of rivers or is pumped by private or municipal wells. Description of the nature



of groundwater movement through Mt. Shasta to issue as the springs in this study, have been published by others as follows:

*Springs issue from the porous top and bottom parts of lava flows and from joints in the lava; other springs issue from the rims of depressions between adjacent shields; still others occur in fault zones cutting the lavas; and some springs issue from tubes in basaltic flows<sup>1</sup>.*

From another study:

*Many springs issue from fracture joints in lava and lava tubes around the mountain; the main groundwater movement is generally away from the slopes of Mount Shasta.<sup>2</sup>*

The source of the remarkable similarity of the water quality of these 22 springs is the nature of the volcanic rocks that make up the bulk of Mt. Shasta and thus the aquifers through which the water moves once it percolates into the system. The geology of Mt. Shasta has been mapped and studied by others providing clear insight into the chemical composition of the mountain.

*The greatest proportion of Mt. Shasta's volcanic rock are pyroxene andesites. These andesites occur in similar proportions both as lava flows and block and ash flows. Growth of Mt. Shasta by the accumulation of both lava flows and blocky pyroclastic and debris flows have given it the principal features characteristic of the great stratocone volcanoes. Basalts and basaltic andesites occur only on the flanks of the stratocone below altitudes of about 7,000 feet<sup>3</sup>.*

The andesites, basalts and dacites that are described above, are composed primarily of silicon dioxide. The andesites that make up the majority of the rocks have been chemically analyzed and contain an average of 62 percent Silica, combined with six additional minerals. Regardless of the type of rock (andesite, basalt or dacite), laboratory analysis of the composition of these rocks indicates that there are relatively small variations in the relative proportion of these minerals. See Table 3 below.

**Table 3- Chemical Composition of Rock on Mt. Shasta**

Lithology	Basalt	Andesites								Dacites						
Location	Cinder Dome	Avalanche Gulch	Clear Creek	Bassin Creek	Lava Park	Near Cinderlake	Whitney Creek	McBride Springs	Northwest Flank	South of Konwakiton Glacier	Misery Hill	Southwest of North Gate	North Rim Shastina	South Rim Shastina	Black Butte	Summit
Cone Complex	Sargents Ridge	Misery Hill			Shastina					Sargents Ridge	Misery Hill		Shastina			Hotlum
SiO <sub>2</sub>	52.03	61	62.3	63.6	61.17	61.2	62.74	62.74	63	63.6	63.7	64.2	63.6	63.6	65.67	64.9
Al <sub>2</sub> O <sub>3</sub>	16.51	17.3	16.9	16.5	16.58	16.53	16.54	16.53	16.8	16.7	18	17.5	17.1	17.5	17.52	16.7
Fe <sub>2</sub> O <sub>3</sub>	3.41	1.5	1.4	1	1.37	1.21	1.62	1.71	1.4	2	2.7	1.5	1.6	1.5	1.14	1.5
Fe O	4.51	2.4	2.4	3.7	3.18	3.42	2.35	2.14	2.6	2.2	1.2	2.8	2	2.2	2.05	2.8
Mg O	9.59	3.9	2.9	4.1	4.03	3.65	3.32	3.24	3.7	2.8	2.6	2.8	3.3	2.8	1.96	3.1
Ca O	9.48	6.2	5.3	5.6	6.73	6.48	6.13	6.2	5.7	4.7	5	5.2	5.3	5.4	5.38	5.3
Na <sub>2</sub> O	2.97	4	4.2	4.1	4.21	4.08	4.12	4.08	4	4.3	4.1	4.1	3.9	4.2	4.52	4.1
K <sub>2</sub> O	0.41	0.78	1.4	1.4	1.05	1.16	1.2	1.18	1.2	1.9	1.3	1.5	0.95	1.1	1.12	1.6
H <sub>2</sub> O <sup>+</sup>	0.3	0.29	0.73	0.47	0.49	1.01	0.67	1.02	0.43	0.89	0.56	0.5	0.44	0.55	0	0.34
H <sub>2</sub> O <sup>-</sup>	0.09	0.19	0.14	0.11	0.14	0.15	0.26	0.29	0.18	0.31	0.41	0.25	0.48	0.15	0.03	0.12
Ti O <sub>2</sub>	0.66	0.75	0.6	0.63	0.69	0.71	0.58	0.56	0.6	0.58	0.62	0.47	0.49	0.49	0.42	0.57
P <sub>2</sub> O <sub>5</sub>	0.12	0.17	0.15	0.14	0.21	0.24	0.17	0.16	0.18	0.14	0.11	..14	0.14	0.12	0.11	0.13
Mn O	0.14	0.06	0.06	0.07	0.08	0.08	0.07	0.07	0.06	0.06	0.05	0.06	0.04	0.05	0.06	0.07
C O <sub>2</sub>		0.01	0.01	0.01					0.01	0.02	0.01	0.02	0.01	0.01		0.01
Sum	100.22	98.55	98.49	101.43	99.93	99.92	99.77	99.92	99.86	100.2	100.36	100.9	99.35	99.67	99.98	101.24

Source: Christiansen, R.L., Johnson, F.L., Conyac, M.D., Resource Appraisal of the Mt. Shasta Wildemess Study Area, Siskiyou County, California. USDI, USGS 53pp.

Due to the close similarity in the total mineral makeup of the different rock types on Mt. Shasta, the spring water that exits the lower flanks of the mountain is generally similar in composition as well, regardless of it's location or drainage. This was substantiated through the statistical analysis of the general water quality data in AquaChem.

The only distinction found in the water quality data, is the condition of increasing mineral content with increasing travel distance from the recharge area to the site of discharge as a spring. Spring water was grouped into four subsets based on the difference in elevation between the recharge area and elevation of the spring itself. Figures 2 provide graphical representation of mineral data for all springs with recharge changes greater than 4000 feet (greater total travel distance and travel time within the aquifer). Figure 2 presents a Schoeller diagram, plotting the concentrations of various cation and anions in milliequivalents, showing 4000 foot plus springs in red and all other springs in black. This figure clearly shows that for minerals of sodium, calcium, magnesium, chloride, sulfate and alkalinity, the springs with greater than 4000-foot travel distances, represent the highest mineral content. This is consistent with the isotope data analysis, that these springs are sourced farthest from the discharge points (See Table 2, which is based on Figure 3). This conclusion is not surprising, however it is the only distinction made through manipulation of the data. This is consistent with the findings within the Nathenson study of slightly thermal springs of Mt. Shasta, which indicates that water from "springs high on Mt. Shasta generally circulate to shallow depths, but that some springs at lower elevations have long circulation paths from higher elevations".



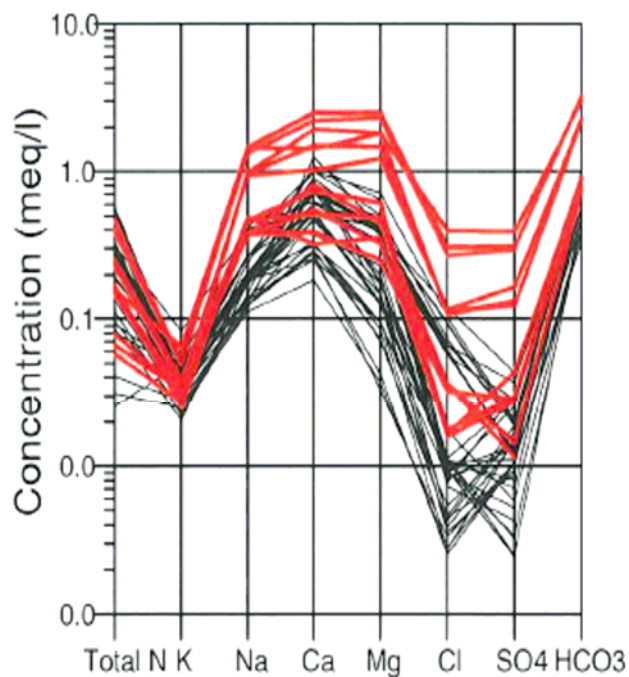


Figure 2- Cation and Anions of Water Samples (Red travel greater than 4000')

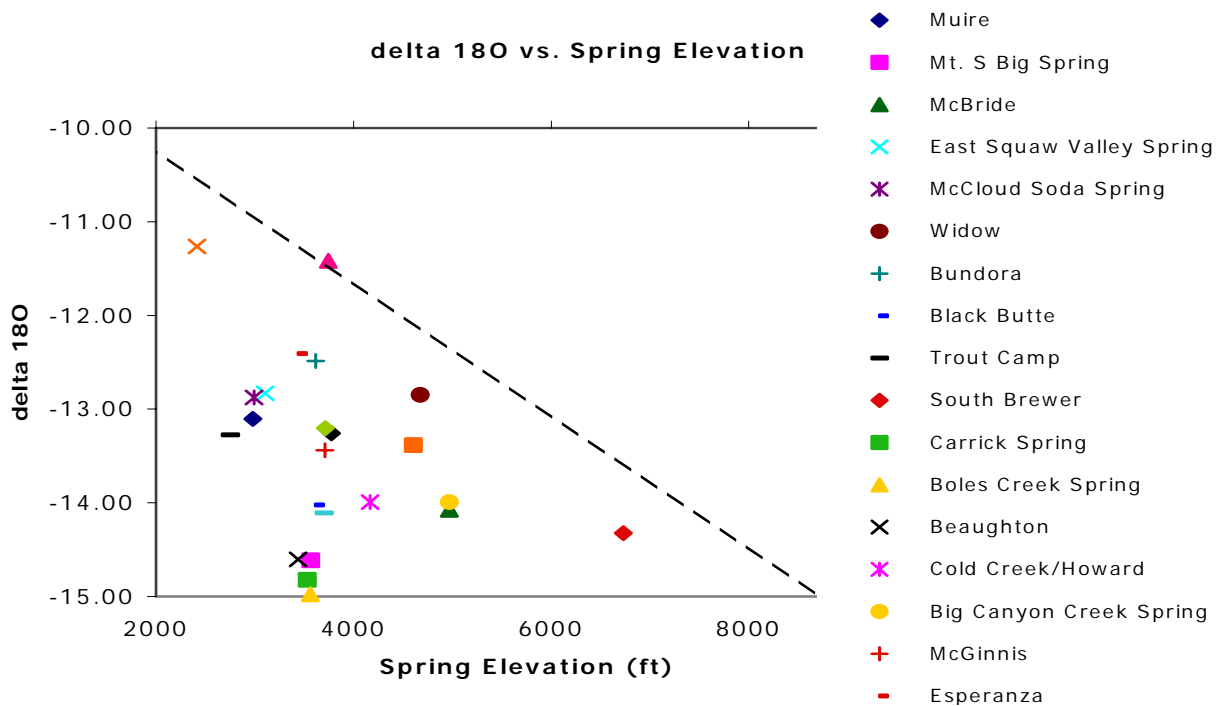


Figure 3- Oxygen Isotope Data to determine Recharge Elevations

The data was also analyzed in relation to which watershed they enter; the Shasta, the Upper Sacramento and the McCloud. The main difference is that the water entering the Shasta Watershed versus the other two watersheds, is the higher mineral content. This is consistent with the longer travel time, since many of these springs are discharged at lower valley elevations. The other notable differences, is in the McCloud watershed there is a reduction in sulfate equivalents. This may be an indication of a shorter travel time or a condition unique to the southeast side of the mountain. The other results worth mentioning is the springs within the Upper Sacramento watershed showed much lower mineral content, which is simply indicative of the short travel distance. The various graphs generated from AquaChem, illustrating these differences based on discharge-recharge elevation differences are located in Appendix A.

### **1.3-General Source Vulnerability Considerations**

The isotope data indicates that these springs are all sourced fairly high on Mt. Shasta, at elevations above 5,200 feet, with the majority sourcing well above 6,000 feet. Aside from the forest service roads, the Everitt Memorial Highway and the Sierra Club Cabin, the only other development within the identified spring recharge area is the Mt. Shasta Ski Park, located at 5,800 feet on the southern flank of Mt. Shasta. Most of the recharge area is contained within the boundaries of the Mt. Shasta Wilderness Area. As a result of the predominately highly protected nature of the recharge area of these springs, source vulnerability from a water quality perspective appears to be fairly low.

In light of the forecasted climate change, questions about source supply for these springs become highlighted when overall source vulnerability is considered. Substantial changes to the annual snow pack on Mt. Shasta due to global warming effects is logically expected to result in changes in the sourcing patterns for these springs, which ultimately could result in significant changes to total spring flows and the timing of spring flows.

The forecasted fate of the glaciers and annual snow pack of Mt. Shasta has been studied and modeled by others recently and published in 2006 (Howat et. al). In this published paper, it was concluded that the Whitney and Hotlum glaciers have been, and continue to be in a growth phase. Both a predictive snow pack and glacier growth/recession model for Mt. Shasta was conducted in the Howat study, which was extended through 2100 based on data collected on the Whitney and Hotlum glaciers. In the glacier study, two predictive models were used to generate precipitation and temperature forecasts. The first model used trends of historical measured climate data for Mt. Shasta and the second model used regional climate model RegCM2.5 predictions for precipitation and temperature. Both models predicted a continuing increase in total precipitation on Mt. Shasta through 2100 (Howat et. al.). However, the predictive model results diverge with respect to snow pack and glacier growth as a result of climate change. The model results using the climate trend (using local data) indicate the glaciers and annual snowpack on Mt. Shasta are said to continue to grow into 2100, gaining up to 140% of their current volume. However, the model results using the regional climate model, specific to temperature predictions, forecasts “the loss of most of Mt. Shasta’s glacier volume over the next 50 years with near total loss by the end of the century.”

Summarizing, the models agree that precipitation on Mt. Shasta will be increasing through 2100 due to climate changes. Then the models predict either snow pack and glaciers will continue to grow or they will significantly diminish. Although the modeling conducted in the glacier study does give us some answers, it primarily provides a focus for additional questions to be asked, to fully assess the vulnerability of Mt. Shasta's springs to climate change.

- If the increased temperatures result in loss of snow pack and glacier volume, yet precipitation on the mountain increases, how will this change the sourcing to the springs of major interest, and how will it ultimately impact the watersheds of the three river system sourced on the slopes of Mt. Shasta?
- Type of precip affects run-off vs perc....and when it comes out...How much of the increased total precipitation is able to percolate within the recharge areas of the springs such that substantial declines in the spring flow are not the result?

As part of this study, limited flow monitoring has also been done, to identify if any of the spring flows fluctuate from season to season or watershed to watershed. Even though a distinct difference in the geochemical constituents is not notable (other than the travel distance and increase in mineral content), there is a difference in spring flow trends. The smaller springs (especially those at higher elevation) on the south side of the mountain do show fluctuation in flow throughout the year. Bear (referred to Big Canyon in the samples), Panther, Esperanza, Cold Creek, Black Butte and Trout Camp Springs all seem to fluctuate at varying degrees. It was noted during field observations that Bear, Panther and Esperanza have all been dry during some point of the year. However, it should be noted that continuous flow monitoring was not performed and measurements were only documented once per month. An interesting difference between the springs on the north side of the mountain that were monitored (Beaughton, Boles and Carrick springs) is that their flow does not seem to fluctuate (based on the monthly monitoring visits). This could be contributed to different things, but most obvious is that springs on the north side seem to be sourced much higher on the mountain and that there are substantial glaciers on the north side that mostly serve as the source of this water. The other possible consideration could be weather patterns (precipitation and temperature) may vary considerably on the south side versus the north side of the mountain. This variation could mean weather patterns could cause increased precipitation to be concentrated on the north side, causing glaciers on that side to grow, but the south side could see reduced snow pack, resulting in reduced discharge from these springs. Accordingly other questions to consider in the vulnerability considerations are:

- How does the climate model relate to snow pack and glaciers on the southern slopes of Mt. Shasta?
- Where do weather patterns on the mountain tend to distribute precipitation and what are the differences in temperature trends?



#### **1.4-Future Work**

This is a bulleted list of possible project directions for 2010:

- Continued analyses of the complete dataset using AquaChem software, which will include all the data acquired to date and enhanced with additional data from previous spring sampling studies (Nathenson and Blodgett) will be performed. With this complete dataset the spring water data will be evaluated more specifically looking for trends or characteristics of individual springs that may be extracted from the data and correlated to known conditions on the mountain and/or the general area as it relates to questions about source vulnerability.
- Initial contact with Slawek Tulaczyk has also been made and the data set has been sent to him for review. He is the lead scientist from UC Santa Cruz on a quantitative model regarding the glaciers and would like to analyze snow pack forecasting in relation to climate change on Mt Shasta. It would be helpful to correlate the springs data and the model results to determine vulnerability of the spring sources.
- With the help of a hydrogeology graduate student create a specific hydrogen/oxygen isotope line for Mt. Shasta. Currently a regional line (Rose line) is used to determine recharge elevations of spring water. Since the mountain may create it's own weather patterns, it may be useful to gather snow samples from Mt. Shasta at different elevations to determine the isotope composition specific to this locale.
- Create and maintain records of weather patterns on the mountain. Use precipitation and temperature records at different elevations to forecast how snowpack and temperature may affect spring discharges in the future.
- Further outreach to local communities to obtain whatever spring monitoring data they have from the domestic water supplies. It would be helpful to age the spring water that local communities use for municipal supply to help in forecasting supply into the future.
- Outreach to land owners that have springs on their property, to increase the amount of spring data we have and create a base line for flow data.
- Currently, flow measurements on a handful of springs are only preformed monthly, it is recommended to install flow measurement devices that continuously log flow fluctuations to get a better feel for when flows stop and start.

## **Section 2- Springs Summary**

This section will outline some basic details for each spring that has been visited and provide any information that has been collected.

### **2.1-McCloud Springs**

As stated above the springs that contribute to the McCloud watershed that were sampled as part of this study, all seem to have reduced sulfate equivalent, which may be an indication of a shorter travel time. This coincides with the tritium isotope results obtained on Muir Falls on the McCloud River, which has been dated at approximately 14 years. This is a significant spring in the McCloud basin and coupled with the dating results, it could indicate that the aquifer of this spring (and potentially McCloud Big Springs) is a very large one, with limited storage. Some of the other springs do not have year round flow or seem to fluctuate, indicating more relation to seasonal snow pack melting.

Most of the springs in the McCloud drainage are considered non-thermal springs, with low dissolved constituents, limited water-rock interaction and inferred low residence time (McClain, 2008). Low residence times are most obvious in Intake, Widow, Bundora, and Esperanza springs, which all have local recharge areas. Due to this they could all be considered more vulnerable to precipitation fluctuations. McCloud Soda Springs shows high dissolved constituents, low discharge rates, longer residence time, and slightly elevated temperatures, making it the only “slightly-thermal mineral spring” in the McCloud basin.

#### **McCloud Big Springs**

The Big Springs on the McCloud River is said to contribute approximately 200 cubic feet per second (Nathanson), which is a considerable percentage of the total flow of the McCloud River. It discharges directly into the McCloud River, emanating from a deeply eroded escarpment on the Hearst Property. The only access to the spring is via boat. An isotope sample was taken of this spring, however the UCD laboratory did not report the results. It may be reasonable to expect that McCloud Big Springs and Muir Falls are potentially sourced from the same aquifer.

#### **Muir Falls**

Muir falls also discharges directly into the McCloud River, located at an elevation of approximately 2,983 feet. It's a large spring, that discharges along a wide area of riverbank, at river surface, see photo below (spring in the foreground and river in background). The calculated recharge elevations based on isotope data analysis is 6039 feet.



**Figure 4- Muir Falls photo**

#### Widow Spring

Widow spring is a small spring located within the Mt. Shasta Forest subdivision owned by the homeowners association. Widow spring is located at an elevation of approximately 4,675-feet, with a calculated recharge elevation of about 5,676-feet; this is considered to be a fairly local recharge area. According to the Nathenson report, springs with local recharge areas could have a greater potential of flow fluctuation, as they mostly depend on snow pack melting for their source. However, since monitoring began on this spring, flow has been consistently around 0.5 cubic feet per second.

#### Esperanza Spring

Esperanza is another small spring in the McCloud watershed, which flows into a small meadow wetland area in the flats. It is located on Forest Service land at an elevation of 3,437- feet. From the isotope data, the recharge elevation was calculated to be around 5,054- feet, which is one of the lowest recharges of any of the springs that were monitored. During monitoring it was noted that this spring tends to stop flowing in the fall/winter months, which is indicative of its source being from lower elevation snowfields.





**Figure 5- Esperanza Spring Photo**

### *Bundora Spring*

Bundora is a small spring on the banks of the Upper McCloud River, above Lakin Dam. This spring is located at 3,616-feet, with a calculated recharge elevation of 5,166-feet, which would be considered one of the lowest recharge elevations of any of the springs in this study. Due to the local recharge and low residence times, it is suspected this spring would be more affected by precipitation/climate changes on the mountain.

### *McCloud Soda Springs*

McCloud Soda Springs, also known as Warm Castle Spring, is located at an elevation of 2,992-feet with a calculated recharge elevation of 5,714-feet. The main identifying characteristic is that it has very high concentrations of dissolved constituents, mainly calcium bicarbonate anions. This is likely due to deep contact with marine metasedimentary rocks (McClain) on the south side of the mountain. This spring bubbles up through several spring boxes located near a beaver pond off of Squaw Valley Creek.



### Elk Springs

There are two discharges that are considered to be Elk Springs, Upper and Lower Elk. Both of these springs are utilized by the Community of McCloud for drinking water and have structures over them for protection and collection. Upper Elk (see photos below) was sampled and analyzed for hydrogen and oxygen isotopes as part of this study. It's located at an elevation of 3,713-feet, with a calculated recharge area above 6,179-feet. Flow is most likely monitored by the McCloud Community Services District, however data was unavailable at the writing of this report.



**Figure 6- Upper Elk Spring Photo**

### Intake Spring

Intake spring is also a source of drinking water for the Community of McCloud. There is a structure over the spring for protection and collection, which was upgraded fairly recently. Intake is located at 4,607-feet, with a calculated recharge elevation of 6,435-feet. This is considered to have a fairly local recharge area and a shorter residence time, potentially indicating more vulnerability to climate changes. The Community Service District monitors this spring for flow, however this data was not obtained.

## **2.2- Upper Sacramento Springs**

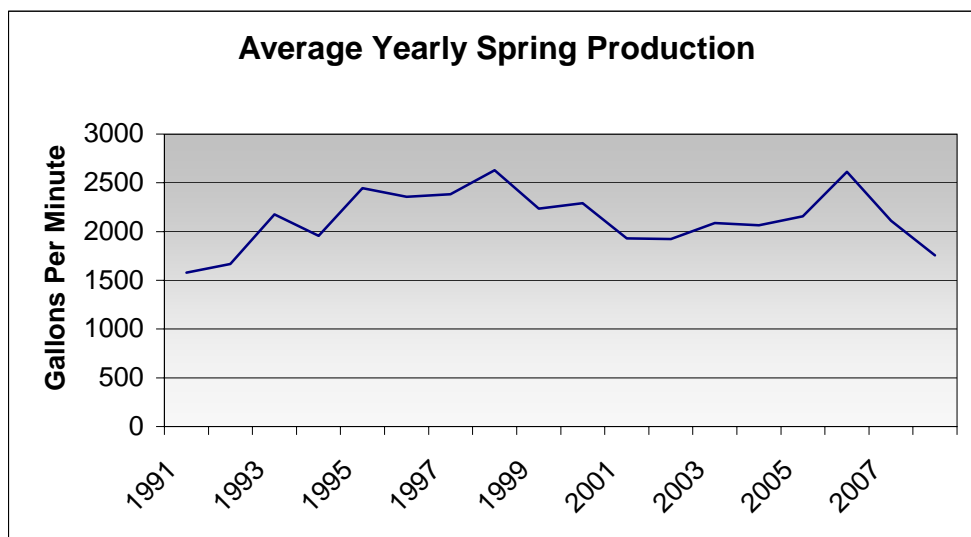
The springs that discharge into the Upper Sacramento watershed are mostly classified as “non-thermal springs”, having low dissolved mineral constituents and low residence time. There are a few exceptions to this generalization; one exception is Mt. Shasta Big Springs, which has been dated to be older than 50 years, indicating, high recharge elevations and longer recharge paths. There are also a few “slightly-thermal mineral springs” located in Dunsmuir, which have slightly elevated temperatures and high dissolved mineral content. Cities of Mt. Shasta and Dunsmuir depend upon spring water as their potable community water source and some data on spring production and water use has been obtained and included in this section.

### **Mt. Shasta Big Springs**

Mt. Shasta Big Springs is located in the Mt. Shasta City Park and is considered to be the “headwaters” of the Upper Sacramento River. With a discharge elevation of 3,567- feet and a calculated recharge elevation of 8,170-feet, it has one of the largest elevation differences of the springs sampled. It is considered to be a “non-thermal” spring according to Nathenson, however the elevation difference is substantial and similar to Shasta River Watershed springs that are consider to be “slightly thermal”. The tritium sampling of this spring indicated the water to be greater than 50 years old.

### **Cold Springs**

Cold Spring, also known as Howard Spring, is the water source for the City of Mt. Shasta. Cold Spring is located at an elevation of about 4,167- feet, with a calculated recharge elevation of approximately 7,291- feet. The City of Mt. Shasta monitors the flow and usage rates of this spring and made the data available for this study. The average yearly spring production does fluctuate from year to year, with its lowest monthly production of 1,317 gallon per minute (2.9 cfs), occurring in March 1992. The lowest yearly production average occurred in 1991, as shown in Figure 7. It was also noted that maximum spring production generally occurs in the summer months, however this does vary from year to year, as seen in Figure 8 and Figure 9, where in 2006 production peaked in June (with usage peaking in July) and in 2008 production was fairly consistent throughout the year and summer usage surpassed spring production.



**Figure 7- Average Yearly Cold Springs Production**



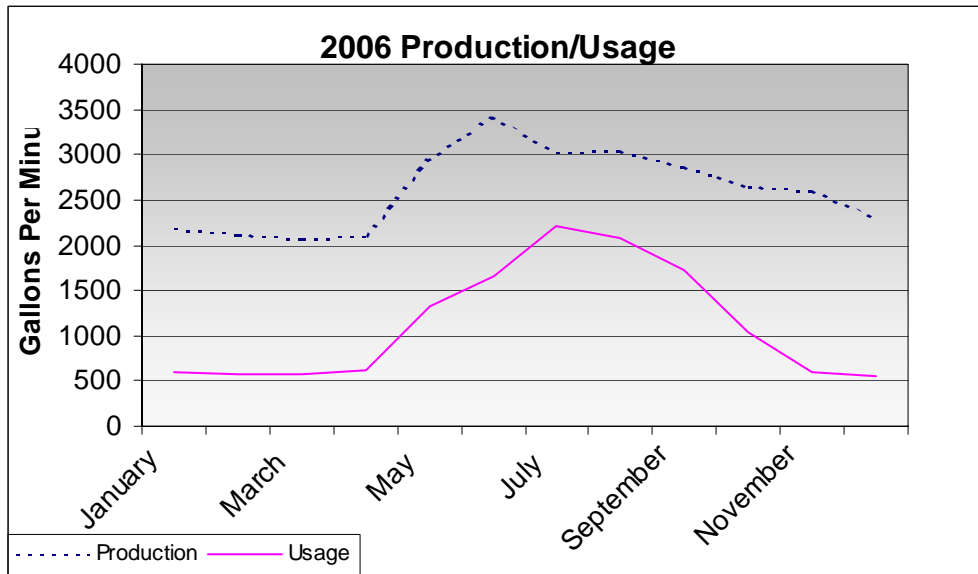


Figure 8- 2006 Cold Spring Production/Usage

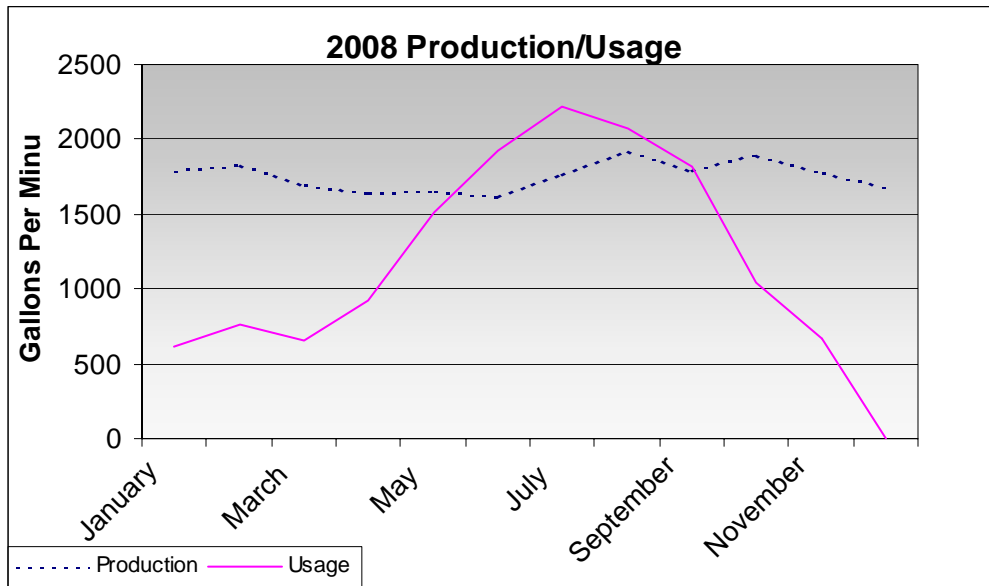


Figure 9- 2008 Cold Spring Production/Usage

### Bear Springs

Bear Springs (identified as Big Canyon Spring in the data) is a small spring located along Bear Spring Road above the City of Mt. Shasta. It emerges from a spring box several hundred yards above the road and there is currently a water diversion on the creek for potable water use by a small water district. Bear Spring is located on the south side of the mountain at 4,971-feet, with a calculated recharge elevation of 7,294- feet. During monitoring activities it has been noted that

its flow has been fluctuating seasonally, usually dry in the spring and flowing in summer months and then drying again in the fall. The discharge and recharge elevations of this spring are very similar to Cold Creek Spring, which is the main water source for the City of Mt. Shasta.

#### Trout Camp Spring

Trout Camp Spring is one of the lowest springs in the study; at an elevation of 2753-feet and a calculated recharge elevation of 6,279-feet. Trout Camp has slightly elevated levels of chloride and nitrogen, which is considerably higher than concentrations that would be found in precipitation, which could indicate rock water interactions or water gas interaction (McClain). It is considered to be a “non-thermal” spring, with fairly local recharge. There has been slight fluctuation in flows over the monitoring period, but the flow is usually between 1 to 1.5 cubic feet per second.

#### Upper Soda Springs

Upper Soda Spring is located at 3,746- feet, and is considered to be a “slightly thermal mineral spring” (Nathenson), with high amounts of dissolved constituents. It is defined as having local recharge, elevated temperatures, extensive water-rock interaction with marine metasedimentary rocks and long residence time.

### **2.3- Shasta Springs**

The springs that discharge into the Shasta River Watershed are mostly considered “slightly thermal”. As stated above, they have more dissolved mineral content and high recharge elevations. The water from most of the Shasta River springs is utilized for either potable water by the City of Weed, by Roseburg, or for agricultural irrigation.

#### Beaughan/Beaughton Spring

Located behind Weed High School at an elevation of 3,438-feet, it is one of the “non-thermal” springs of the Shasta watershed. With a calculated recharge elevation of 8,142-feet, it is among the highest recharge areas of all the springs monitored as part of this study. It also has elevated phosphate levels compared to the rest of the non-thermal springs. This could be interpreted to mean a longer residence time and deeper flow paths, where water is reacting with soluble phosphate in underlying marine shales. The water from this spring is highly utilized, with a consistent flow of around eight cubic feet per second. However, it should be noted this is after an initial diversion by Crystal Geyser and the City of Weed of around 4 cfs total (direct communication with Arne Hultgren of Roseburg). There are numerous agricultural diversions from Beaughan Creek with decreed rights totaling 10.3 cfs. The list of adjudications is included in Appendix B.

#### Black Butte Spring

Black Butte Spring is also considered to be a “non-thermal” spring in the Shasta watershed. It is a small spring located above the railroad grade in South Weed, historically used as a water source for the railroad. There are numerous little spring discharges that emerge from a knoll and come together to form Black Butte Creek. The spring flow seems to maintain a consistent discharge of around 0.5 cfs (when measured at a culvert after it comes together); however there may be other places where the spring enters the creek downstream of where a measurement was

obtained. The spring is located at an elevation of 3612-feet and a calculated recharge elevation of 7334-feet, having one of the larger differences between discharge and recharge elevations.

### *Boles Spring*

The Boles spring that was sampled as part of this report is also referred to as Kellog Spring. The water that discharges from this spring flows into Boles Creek, which is a fairly small spring with a consistent flow of around 1.6 cfs. Kellog Spring is located behind Weed High School, at an elevation of around 3563-feet with a recharge elevation of approximately 8682-feet. This spring is considered to be among the “slightly-thermal” springs of the Shasta watershed; with the highest recharge elevation and discharge- recharge difference of all the springs analyzed. There is another spring located adjacent to Interstate 5, named South Boles Spring, which appears to have substantially more production and also flows into Boles Creek. Together the two springs are highly utilized by Roseburg, the City of Weed, Crystal Geyser, as well as numerous agricultural diversions; totaling 17.68 cfs in adjudicated water rights. The decree schedule is included in Appendix B.

### *Carrick Spring*

Carrick Spring is a “slightly thermal” spring located in Carrick Park, off of Highway 97. With a discharge elevation of 3,531-feet and a recharge elevation of 8,464-feet, it has one of the second largest differences between discharge and recharge elevations. The spring water has elevated mineral concentrations, indicating a long residence time, which coincides with tritium sampling results that the water is greater than 50 years old. The flow stays fairly consistent at around 8.5 cfs, split between three channels, two of which are for agricultural diversions. The waters of Carrick spring are utilized mostly for agriculture, with an adjudication totaling 11.72 cfs. The list of diversions in the Shasta River Adjudication is included in Appendix B.



**Figure 10- Carrick Creek**

## 2.4- References

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McCord, B.M., Hydrogeochemistry and isotopic analyses of the fractured volcanic aquifer system of Mt. Shasta, Siskiyou County, California. M.S. Thesis, Department of Geology, California State University, Northridge, 110p.

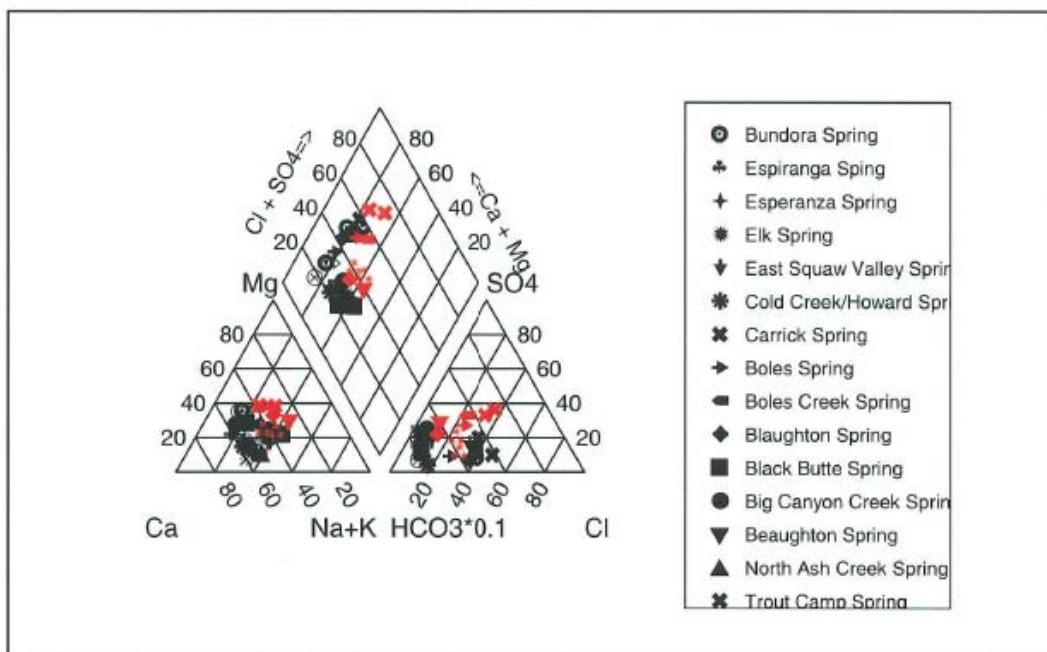
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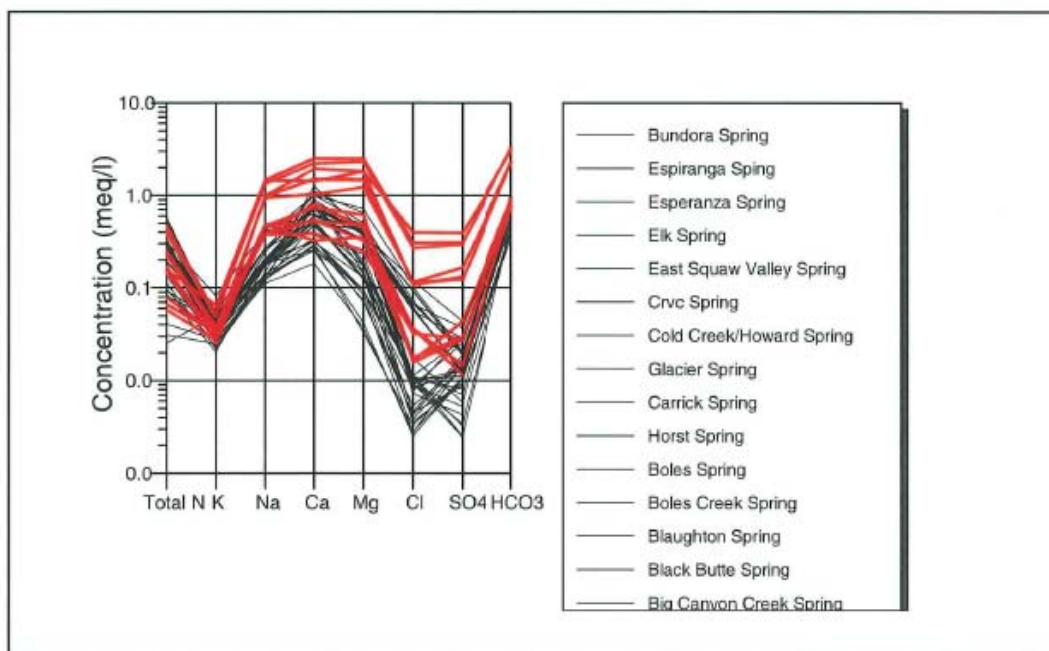


## **Appendix A**

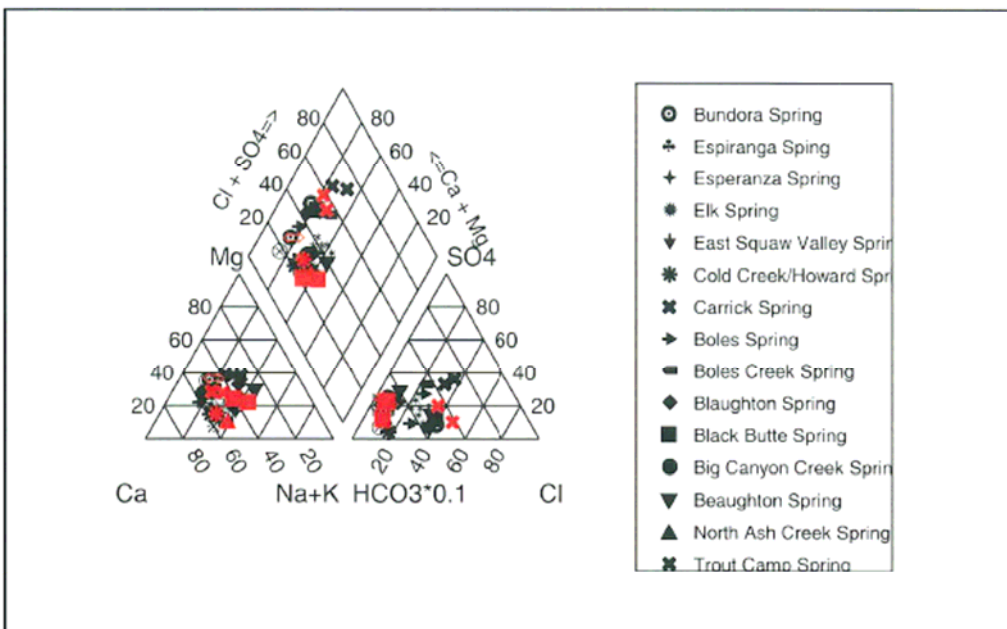
**Figure 2A**  
**Elevation Difference 4000 Feet +**



**Figure 2B**



**Figure 3A**  
**Elevation Difference 3000 Feet +**



**Figure 3B**

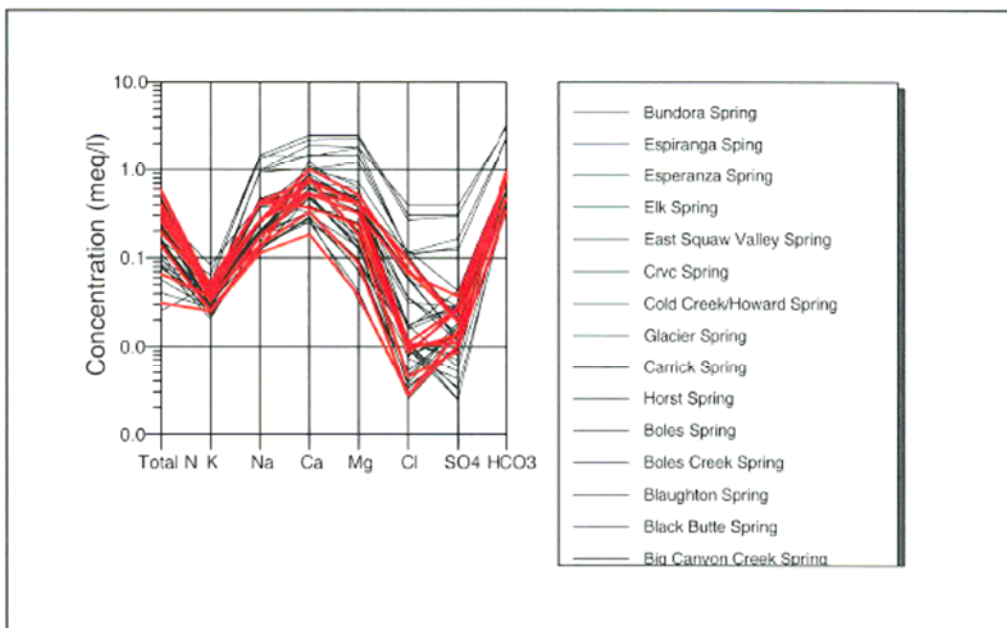


Figure 4A

Elevation Difference 2000 Feet +

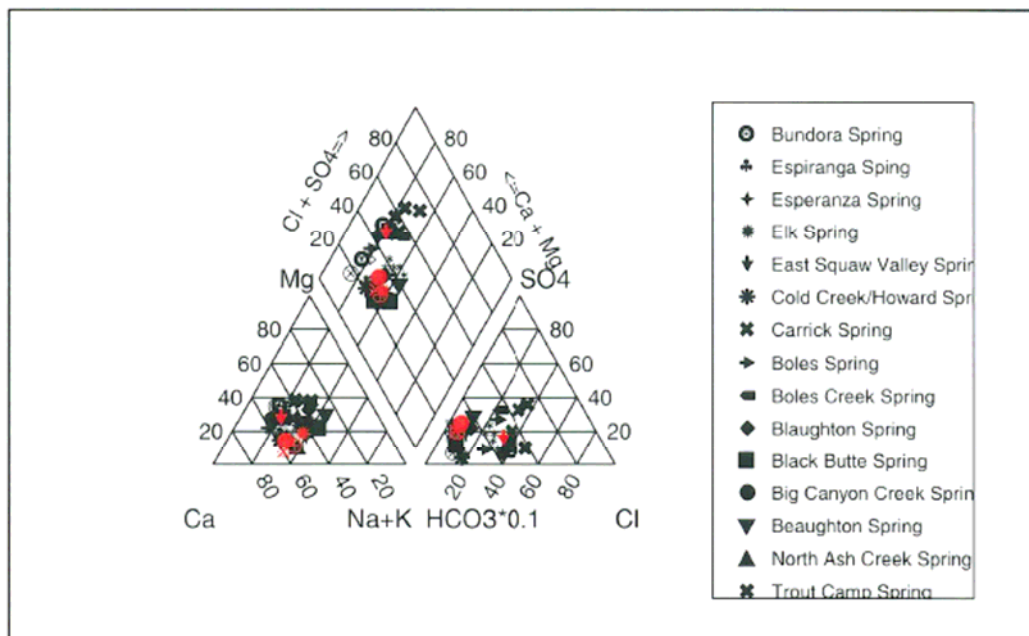
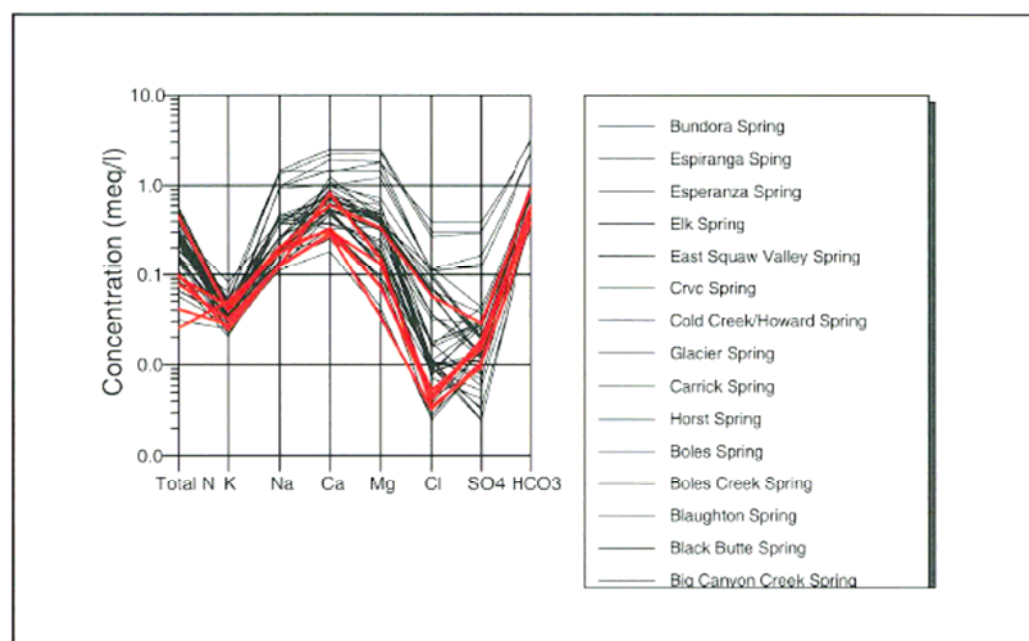


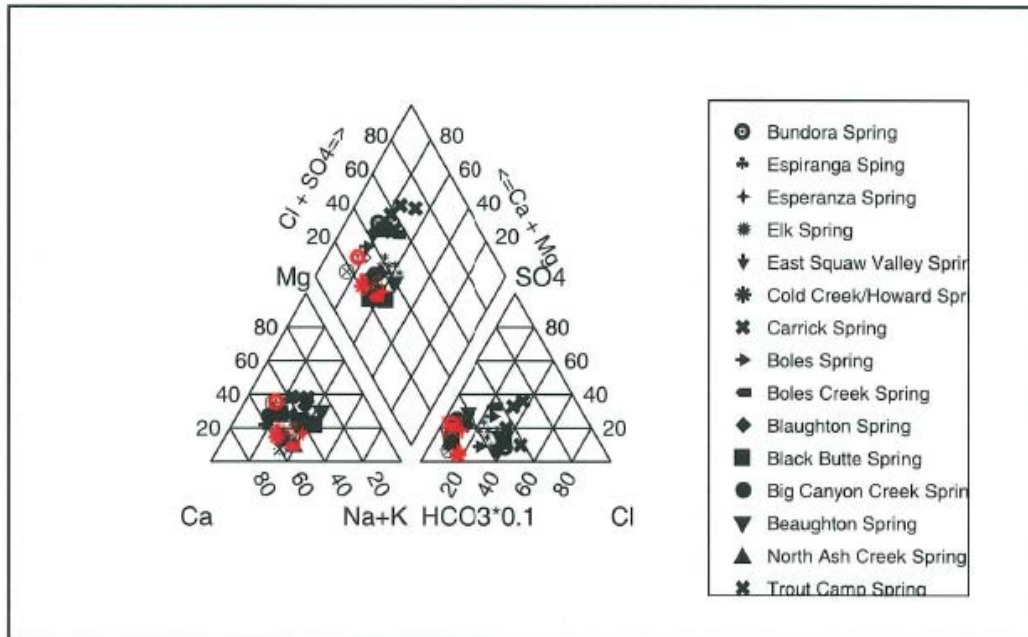
Figure 4B





**Figure 5A**

**Elevation Difference 1000 Feet +**



**Figure 5B**

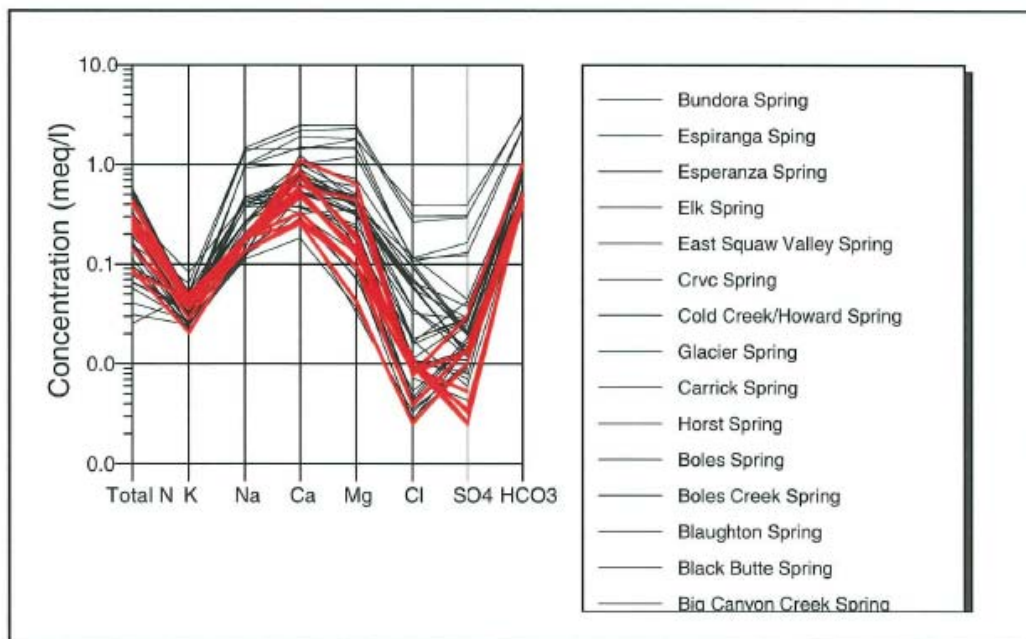


Figure 6A

Shasta Watershed

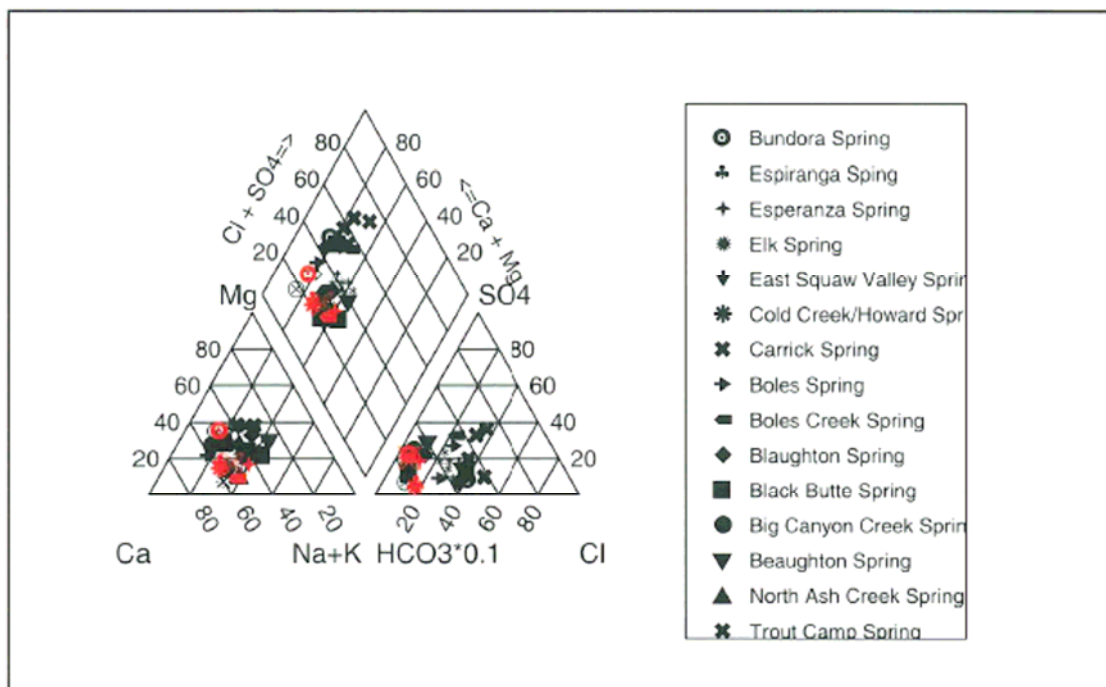


Figure 6B

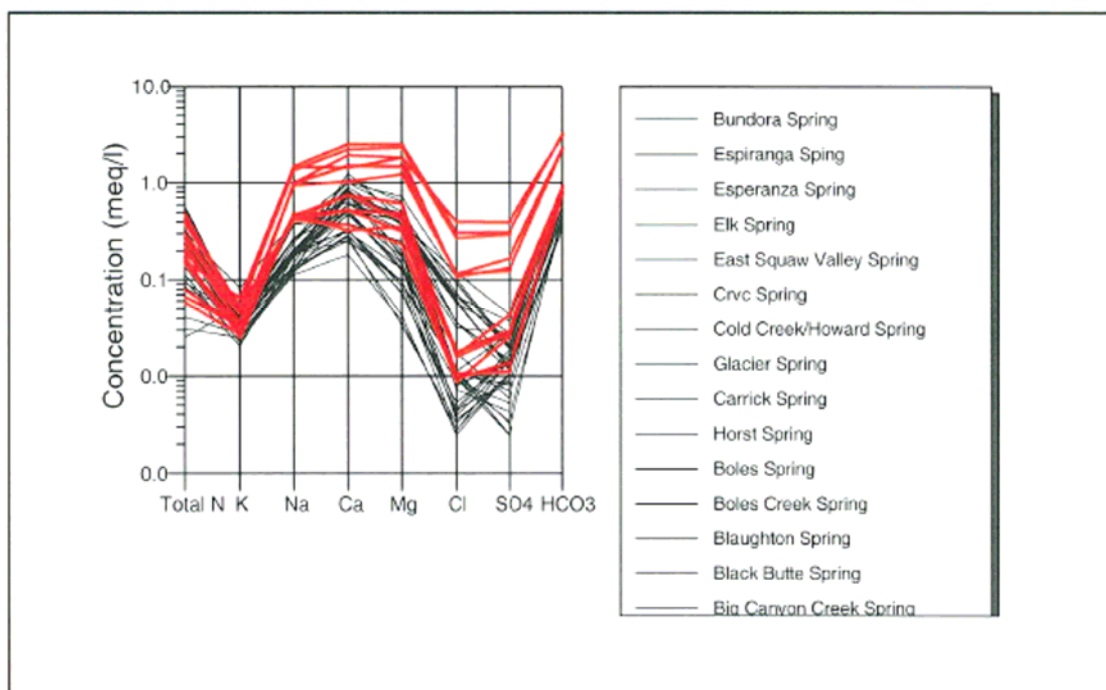


Figure 7A

Sacramento Water Shed

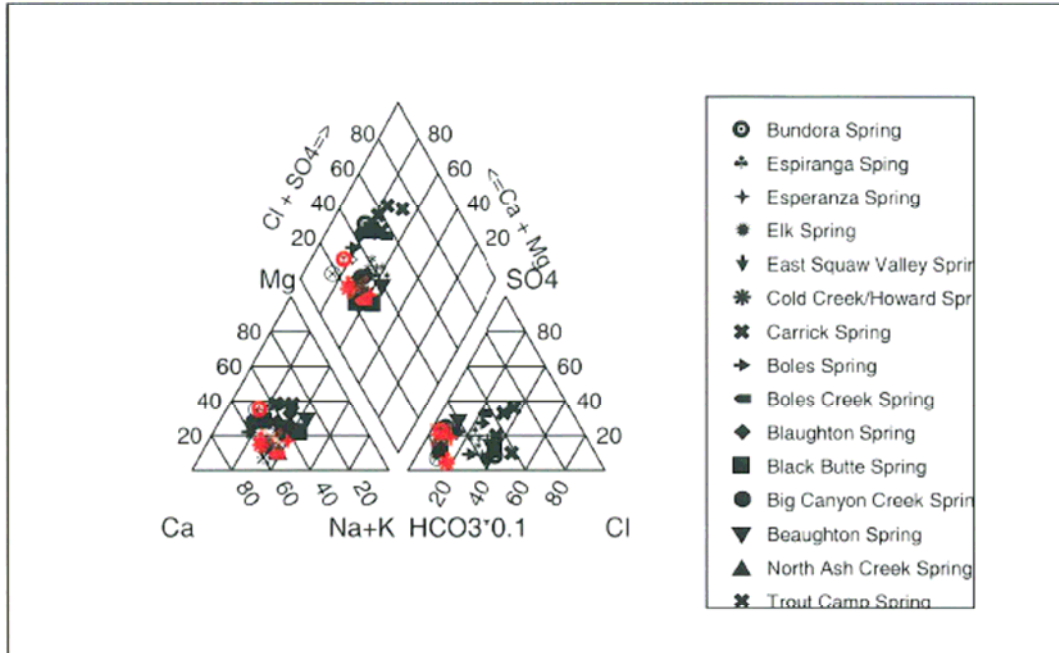


Figure 7B

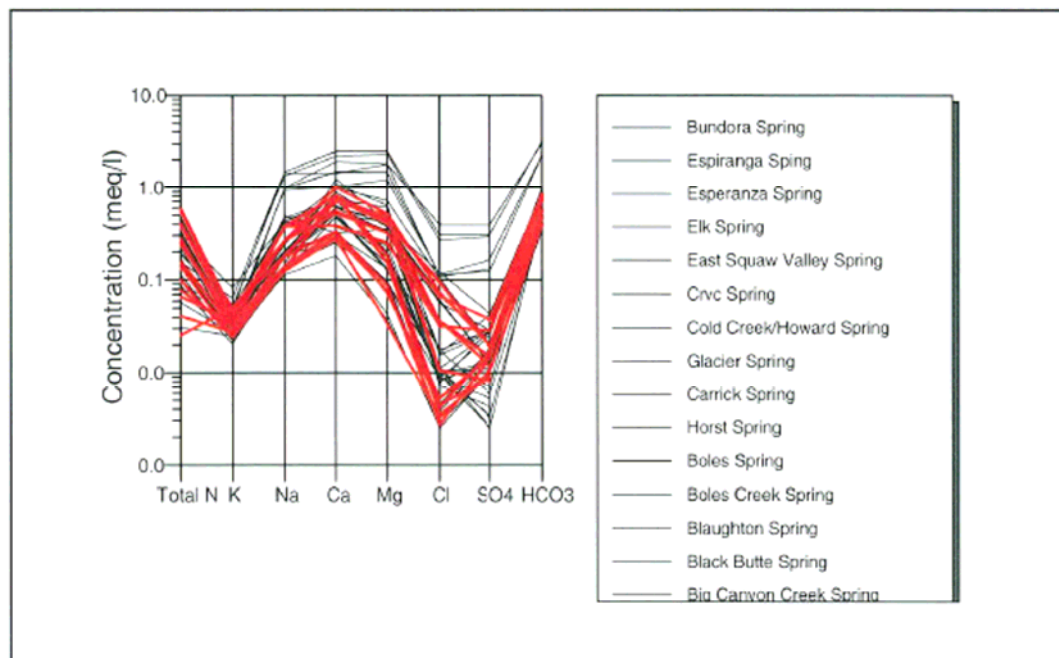


Figure 8A

McCloud Watershed

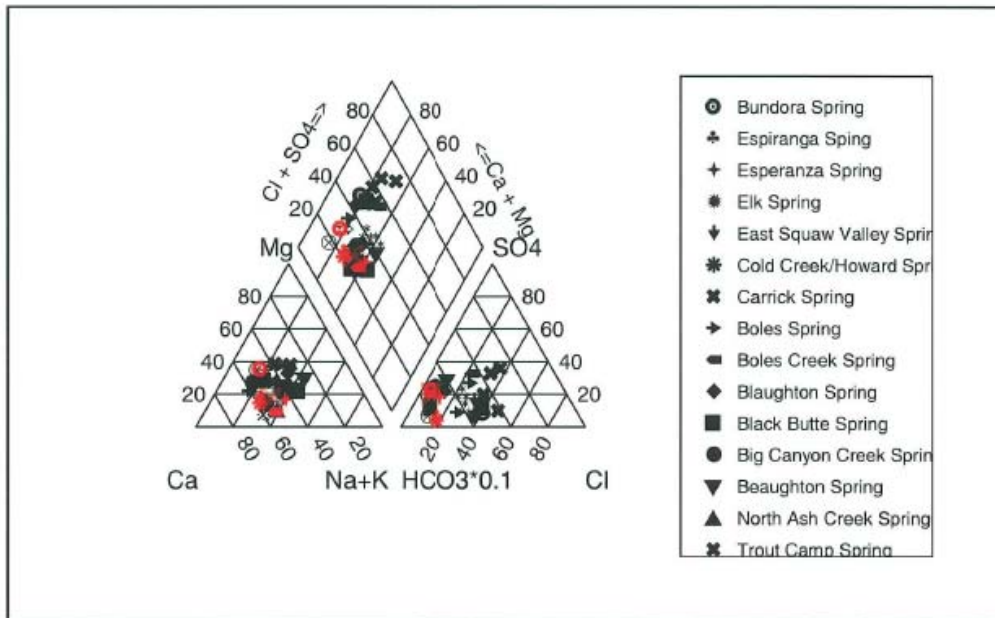
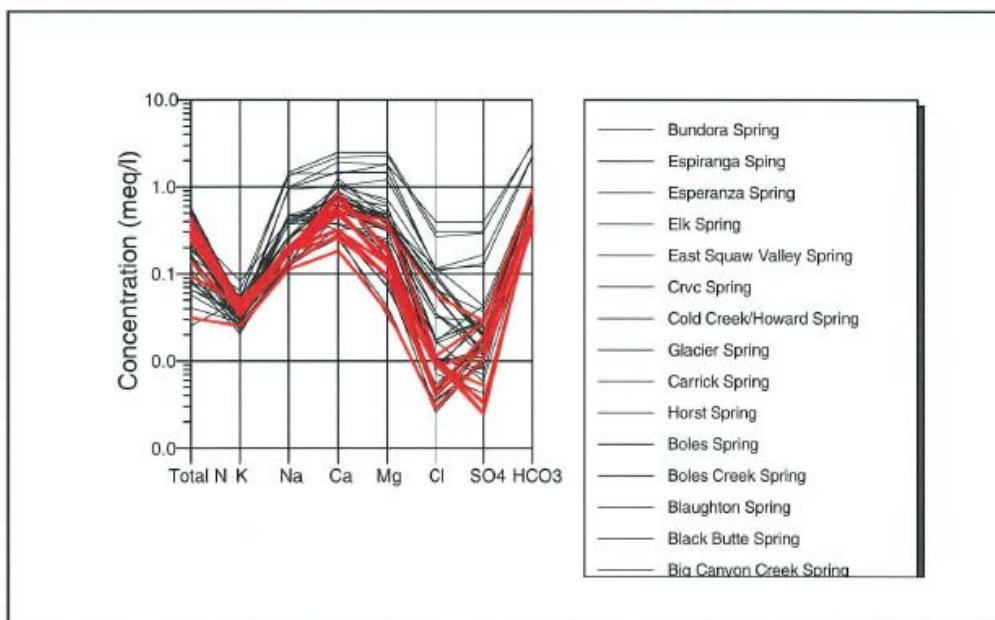


Figure 8B





## **Appendix B**

**BEAUGHAN CREEK 1/**  
(Table 3, Decree 7035)

DWR Tract	Present Owner	Decreed Owner	Diversion Number	Water Right Priority	CFS	Decree Parg. No.	Source
95-1 2/	Roseburg Lumber Co. (City of Weed Lease)	Long Bell Lumber Co. "	72a, 73 70	1 2	0.50 1.50	231 230	Little Beaughan Sprg. Beaughan Cr. or Sprg.
			Tract 95-1 subtotal		2.00		
95-2-1	Roseburg Lumber Co.	Long Bell Lumber Co. " "	72a, 73 72 70, 71, 74-78 3/	1 1 2	0.28 0.13 0.76	231 232 230	Little Beaughan Sprg. three unnamed springs Beaughan Cr. or Sprg.
			Tract 95-2-1 subtotal		1.18		
95-2-2	Baxter, J. H.	" " "	72a, 73 72 70, 71, 74-78 3/	1 1 2	0.22 0.04 0.64	231 232 230	Little Beaughan Sprg. three unnamed springs Beaughan Cr. or Sprg.
			Tract 95-2-2 subtotal		0.89		
93-1	Broadhead, William	Belcastro, J. "	83 83	2 3	0.16 0.39	13 13	Beaughan Creek Beaughan Creek
			Tract 93 subtotal		0.55		
4/							
84-1	Shufelberger A. & S.	Cavanaugh, R. E.	90	2	0.20	49	Beaughan Creek
84-3	Shufelberger A. & S.	"	90	2	0.20	49	Beaughan Creek
			Tract 84 subtotal		0.40		
5/							
119-1	Butteville Elem. School	Cavanaugh & C.P.R.R.	85	2	0.07	50	Beaughan Creek
119-2	McMahon, Robert	"	85	2	0.02	50	Beaughan Creek
119-3	Dahlquist, D & C.	"	85	2	0.02	50	Beaughan Creek
119-4	Singleton, M.	"	85	2	0.02	50	Beaughan Creek
119-5	Wagner, P.	"	85	2	0.02	50	Beaughan Creek
			Tract 119 subtotal		0.15		
76 6/	Jackson, S. C.	Jackson, S. H.	84	2	2.62	171	Beaughan Creek.
83-1	Carr, Shelly	Koppel, Alice V.	84	2	0.39	212-215	Beaughan Creek
83-2-1	Lemos, Kenneth	"	84	2	0.14	212-215	Beaughan Creek.
83-2-2	Lemos, Amber	"	84	2	0.41	212-215	Beaughan Creek.
83-3	Mulvihill, Thomas	"	84	2	0.16	212-215	Beaughan Creek.
			Tract 83 subtotal		1.10		
94	Heller, Joseph Trust	Morris, C. " " "	79, 80 79, 80 81 80A	2 3 4 5	0.24 0.21 0.10 0.15	291 291 293 292	Beaughan Creek Beaughan Creek unnamed fork Beaughan Cr. unnamed fork Beaughan Cr.
			Tract 94 subtotal		0.70		
85-1 7/	Shufelberger A. & S.	Wholey & Lewis "	89 92	2 2	0.08 0.58	389 390	Beaughan Creek Beaughan Creek
			Tract 85-1 subtotal		0.66		
85-2	Shufelberger A. & S.	"	89	2	0.05	389	Beaughan Creek
			Tract 85 subtotal		0.71		
			GRAND TOTAL		10.30		
Notes:	1/ The water rights from Beaughan Creek are superior to the water rights from the Shasta River. See page 9, paragraphs 11 and 12 of Decree 7035.						
	2/ See Siskiyou County Official Records Book 477 Page 727 regarding lease agreement between Roseburg Lumber Co City of weed lease is for 0.03 cfs of Roseburg Lumber Co. Water Right.						
	3/ City of Weed currently uses Diversion 78 only.						
	4/ Tract 84-1 also has water rights from Boles Creek and the Shasta River. Tract 84-2 has water rights from Boles Creek.						
	5/ Currently used on decreed owner Cavanaugh lands only. See paragraph 50, Decree 7035.						
	6/ Tract 76 also has water rights from Carrick and Jackson Creeks.						

(Table 2, Decree 7035)

DWR Tract	Present Owner	Decreed Owner	Diversion Number	Water Right Priority	CFS	Decree Parg. No.	Source	Map Number
12/ P186	Calif. State Div. of HWY Weed, City of	Kellogg, F. A. et al	37	6	0	186	unnamed spring	14
					0.15			
			Tract P186 Sub-total			0.15		
P188-1	Fernandes, L.A. & T.D.	Kellogg, F. A. et al	42	7	0.04	188	Kellogg Spring	14
P188-2	CG Roxane LLC	"	"	"	0.20			
P188-3	Weed, City of	"	"	"	0.01			
			Tract P188 Sub-total			0.25		
P189	Jones, R. J. & J. T. Trust	Kellogg, F. A. et al	42A	17	0.025	189	Kellogg Spring	14
P185-1	City of Weed	Kellogg, F. A. et al	35	26	0.16	185	S. Fork Boles Creek	14
P185-2	Newton, Albert H. Jr	"	"	26	0.24	185	S. Fork Boles Creek	14
			Tract P185 Sub-Total			0.40		
P191-1	Mazzei, Mary T. Trust	Kellogg, F. A. et al	2/	1	0.01	191	S. Fork Boles Creek	14
P191-2	Weed, City of	"	2/	1	0.02	191		
P191-3	Lowrey, Blake F.	"	2/	1	0.01	191		
P191-4	Weed, City of	"	2/	1	0.20	191		
P191-5	Newton, Albert H. Jr.	"	2/	1	0.06	191		
P191-6	Weed, City of	"	2/	1	0.34	191		
P191-7	Newton, Albert H. Jr.	"	2/	1	0.03	191		
P191-8	Weed, City of	"	2/	1	0.56	191	S. Fork Boles Creek	14
P191-9	Newton, Albert H. Jr.	"	2/	1	0.17	191		
			Tract 191 Sub-total			1.40		
P187-1	Weed, City of	Kellogg, F. A. et al	38	2	0.06	187	unnamed fork Boles Cr.	14
P187-2	Maas, P.A. & J.A. Trust	"	"	2	0.04	"		
			Tract P187 Sub-total			0.10		
P190	Maas, P.A. & J.A. Trust	Kellogg, F. A. et al	44	2	0.10	190	Middle Fork Boles Cr.	14
104	Fitzgerald, Don, Kathy	Rovito, F. & M.	45	2	1.05	323	Boles Creek	15
96-1 3/	Roseburg Lumber Co.	Long Bell Lum. Co.	36 4/	3	4.00	227	S. Fork Boles Creek	14
			51, 52	4	0.15	229	N. Fork Boles Creek	15
			Tract 96-1 subtotal			4.15		
96-2 3/	Weed Golf Course	Long Bell Lum. Co.	46	13	0.65	228	Boles Creek	15
106	5/	Long Bell Lum. Co.	46	8	0.5	228	Boles Creek	15
P373-378-1	Weed, City of	Sullivan, G.	47,48,49,51,52,53	4,5,10,20	0.009	373-378	Cr., N.F. Boles Creek, Sullivan	15, 16, 19
P373-378-2	Lorinczi, Ida B. Trust	"	"	4,5,10,20	0.008	373-378	"	15, 16, 19
P373-378-3	Weed S & D, Italy Amer.	"	"	4,5,10,20	0.005	373-378	"	15, 16, 19
P373-378-4	Gonzalez, Effraime A. & Ester	"	"	4,5,10,20	0.006	373-378	"	15, 16, 19
P373-378-5	Willis, P.W. & V.E. Trust	"	"	4,5,10,20	0.006	373-378	"	15, 16, 19
P373-378-6	Rural Housing I	"	"	4,5,10,20	0.06	373-378	"	15, 16, 19
P373-378-7	Martinez, Robert	"	"	4,5,10,20	0.008	373-378	"	15, 16, 19
P373-378-8	Minsart, Lillie	"	"	4,5,10,20	0.006	373-378	"	15, 16, 19
P373-378-9	Banos, E.J. & B.J. Trust	"	"	4,5,10,20	0.023	373-378	"	15, 16, 19
P373-378-10	Patton, Lory	"	"	4,5,10,20	0.005	373-378	"	15, 16, 19
P373-378-11	Siskiyow Devel. Co. Inc.	"	"	4,5,10,20	0.043	373-378	"	15, 16, 19
P373-378-12	Weed Family Hous. Pnt.	"	"	4,5,10,20	0.07	373-378	"	15, 16, 19
P373-378-13	Sisk. Child Care Coun.	"	"	4,5,10,20	0.013	373-378	"	15, 16, 19
P373-378-14	Weed Family Hous. Pnt.	"	"	4,5,10,20	0.026	373-378	"	15, 16, 19
P373-378-15	Duchi, B.A. & S.L.	"	"	4,5,10,20	0.035	373-378	"	15, 16, 19
P373-378-16	Duchi, B.A. & S.L.	"	"	4,5,10,20	0.027	373-378	"	15, 16, 19
P373-378-17	Rural Housing II	"	"	4,5,10,20	0.104	373-378	"	15, 16, 19
P373-378-18	Berg, M.R. & T.C.	"	"	4,5,10,20	0.207	373-378	"	15, 16, 19
P373-378-19	Berg, M.R. & T.C.	"	"	4,5,10,20	0.13	373-378	"	15, 16, 19
P373-378-20	Berg, M.R. & T.C.	"	"	4,5,10,20	0.131	373-378	"	15, 16, 19
P373-378-21	Clements, B.W. & L.M. Trust	"	"	4,5,10,20	0.000	373-378	"	15, 16, 19
P373-378-22	Melaine, George	"	"	4,5,10,20	0.02	373-378	"	15, 16, 19
P373-378-23	City of Weed	"	49	5	0.04	373-378	Sullivan Spring Channel	15, 16, 19
P373-378-24	City of Weed	"	48	20	0.60	373-378	Sullivan Spring	15, 16, 19
			Tract 105 subtotal			1.69		



							Shasta River WMSA	
							Boles Creek	
							Page 2 of 2	
BOLES CREEK								
(Table 2, Decree 7035)								
DWR Tract	Present Owner	Decreed Owner	Diversion Number	Water Right Priority	CFS	Decree Parg. No.	Source	
92-1-1-1	Smith, Richard	Chase, G. L. B.	63	9	0.594	56	Boles Creek	10
92-1-1-2	Andrighetto, Louie	"	63	9	0.396	56	Boles Creek	10
92-1-2	Acquistapace, E.M.	"	63	9	0.15	57	Boles Creek	10
	"	"	64	11	0.24	57	Boles Creek	10
92-2-1	Freeman, G & E.	"	64	9	0.03	57	Boles Creek	10
92-2-2 7/	Shivy, Greg & Sylvia	"	54	9	0.59	57	Boles Creek	10
Tract 92 subtotal					2.10			
91	Shufelberger, A & S	Chase, R. & E.	63	9	1.00	61	Boles Creek	10
84-1	Shufelberger, A & S	Cavanaugh, R. E.	63	9	0.45	44	Boles Creek	10
		"	64, 27 8/	11	1.00	43	8/	10
84-2	Andrighetto, Gary	"	63	9	0.15	44	Boles Creek	10
Tract 84 subtotal					1.60			
97	Oliver, John & Joyce	Salanti, G. et al	55	12	0.80	326	Boles Creek	16
			56	12	0.15	327	Two Springs	16
			59	12	0.15	330	Boles Creek	16
			57 8/	18	0.05	328	Behnke-Lukens Spring	18
			58	18	0.025	329	Behnke-Lukens Spring	18
Tract 97 subtotal					1.175			
98	Butcher, Fred	Davidson, C. & D.	55	14	0.20	67	Boles Creek	16
			58A	14	0.04	68	Behnke-Lukens Spring	18
			60	14	0.25	69	Boles Creek	10
			61	14	0.25	70	Boles Creek	18
Tract 98 subtotal					0.74			
10/								
117-1	Mich.-Calif. Lum. Co.	Central Pacific R.R.	39, 40	15	0.265	51	Black Butte Spring	13
117-2-1	McKinnis, M. S.	"	41	16	0.204	51	Black Butte Spring	14
117-2-2	James, P. W. & K.	"	41	16	0.031	51	Black Butte Spring	14
Tract 117 subtotal					0.500			
99	Berger, Marilyn	Scallise, Louis	62	19	0.10	332	Boles Creek	18
GRAND TOTAL					17.680	11/		
Notes: 1/ Boles Creek and Shasta River below Boles Creek are all one priority by agreement only.								
2/ Point of Diversion is movable. See paragraph 191.								
3/ 0.65 cfs was transferred from Tract 96 to Weed Golf Course. See letter from Bob Steel (Supervising Watermaster) to International Paper Company dated 8/5/82. Golf course currently uses gravity diversion located on right bank upstream of Diversion 55.								
4/ This diversion is called the Igerna Pipeline. Water is to be used for domestic, municipal, and industrial purposes within the City of Weed and for the manufacturing plant of Roseburg Lumber Company. This right is superior in priority to all rights by appropriation to the use of the water of Boles Creek and the Shasta River below the confluence of Boles Creek except those rights defined in paragraphs 185, 187, 190, 194, and 323.								
5/ This water right was abandoned. See letter from Bob Steel to International Paper Company dated 8/5/82. This right is superior in priority to all rights by appropriation to the use of the water of Boles Creek and the Shasta River below the confluence of Boles Creek except those rights defined in paragraphs 185, 186, 187, 188, 190, 191, 227, 229, 323, 375, 376, 377, and 378.								
6/ Water right for Tract 105-1 was abandoned by George Meline per letter dated 10/18/96.								
7/ Tract 92-2-2 also has water rights from the Shasta River.								
8/ This water right is in lieu of the amount of water allocated from the Shasta River as defined in paragraph 42 from Diversion #27. Diversion from Boles Creek in lieu of the Shasta River can occur between the period of August 25 through September 25 only. See paragraph 43 and Upper Shasta River field schedule.								
9/ This water right is to be used only in lieu of an equal amount of water from Boles Creek or from the two springs described in paragraph 327, or from both sources.								
10/ See Siskiyou County Superior Court Decree #34325 dated 2/1/84 regarding division of Tract 117 water right.								
11/ The sum of the individual water rights listed in Table 2, Decree 7035 is 17.905 cfs. The TOTAL as shown at the bottom of the Table is 17.63. Both numbers are in error. Table 2 lists priority 17 for Kellogg as 0.25 cfs. Paragraph 169 defines this right at 0.025 cfs. The corrected total is 17.680 cfs.								



Shasta River WMSA  
Carrick Creek  
Page 1 of 1

CARRICK CREEK (Table 5, Decree 7035)									
DWR Tract	Present Owner	Decreed Owner	Diversion Number	Priority	Water Right			Decree Parg. No.	Source
					Irr. Season	CFS	Winter		
79 3/	Goltz, Edward	Carrick, M. & C.	117	1	3/1-11/1	2.20	2.20	30	Carrick Creek
			120	1	3/1-11/1	0.12	0.00	31	unnamed spring
			126	1	3/1-11/1	0.15	0.013	32	unnamed spring
			Tract 79 subtotal			2.47	2.213		
68	Mills Ranch	Mills, F. H.	145, 146, 148	1	3/1-6/15	0.20	0.00	278	Carrick Creek
				6	3/1-6/15	0.90	0.00	278	Carrick Creek
			Tract 68 subtotal			1.10	0.00		
78 2/	Zwanziger, R.	Albee, A. C.	116	2	3/1-11/1	2.20	0.25	1	Carrick Creek
			133	2	3/1-11/1	0.014	0.00	2	unnamed spring
			134	2	3/1-11/1	0.015	0.00	3	unnamed spring
			Tract 78 subtotal			2.229	0.25		
76 1/	Jackson, S. C.	Jackson, S. H.	139	3	3/1-11/1	0.50	0.00	178	Carrick Creek
			140	3	3/1-11/1	0.10	0.00	179	Carrick Creek
			138	4	3/1-11/1	0.60	0.00	177	Carrick Creek
			141	11	3/1-11/1	0.10	0.00	180	unnamed spring
			Tract 76 subtotal			1.30	0.00		
81	Luiz, Leonerd	Stone, F. E.	118, 119, 121	5	3/1-11/1	0.59	0.00	370	Carrick Creek
			123	5	3/1-11/1	0.12	0.00	366	unnamed spring
			124	5	3/1-11/1	0.20	0.10	367	Stone Creek
			125	5	1/1-12/31	0.023	0.023	368	Stone Spring
			129	8	1/1-12/31	0.21	0.21	369	unnamed spring
Tract 81 subtotal			1.143	0.333					
82	Macintosh, Donald	Stone, W. O.	118	5	3/1-11/1	0.21	0.00	370	Carrick Creek
			129	8	3/1-11/1	0.66	0.20	371	unnamed spring
			130	13	1/1-12/31	0.025	0.025	372	Stone House Spring
Tract 82 subtotal			0.895	0.225					
80	Hoy, Betty Belle et al	Hoy & Mills	124	7	3/1-11/1	1.00	0.00	167	Stone Creek
			122, 127, 128	9	3/1-11/1	0.86	0.25	170	Carrick Creek
			126B	9	3/1-11/1	0.15	0.00	169	unnamed spring
			132	10	3/1-11/1	0.15	0.00	168	Hoy Creek
Tract 80 subtotal			2.16	0.25					
77	Hoy, Betty Belle et al	Mills, F. H.	126B	9	3/1-11/1	0.15	0.00	265	unnamed spring
			132	10	3/1-11/1	0.25	0.00	267	Hoy Creek
			126A	12	1/1-12/31	0.025	0.025	266	unnamed spring
			Tract 77 subtotal			0.425	0.025		
GRAND TOTAL					11.72	3.30			
Notes: 1/ Tract 76 also has water rights from Beaughan and Jackson Creeks. 2/ Tract 78 Diversion 116 has an additional water right of 14acft from the period between 11/1-3/1. 3/ Tract 79 Diversion 117 - 1.95cfs of 2.2cfs winter water right is for power purposes only and to be returned to the creek after being used for power.									