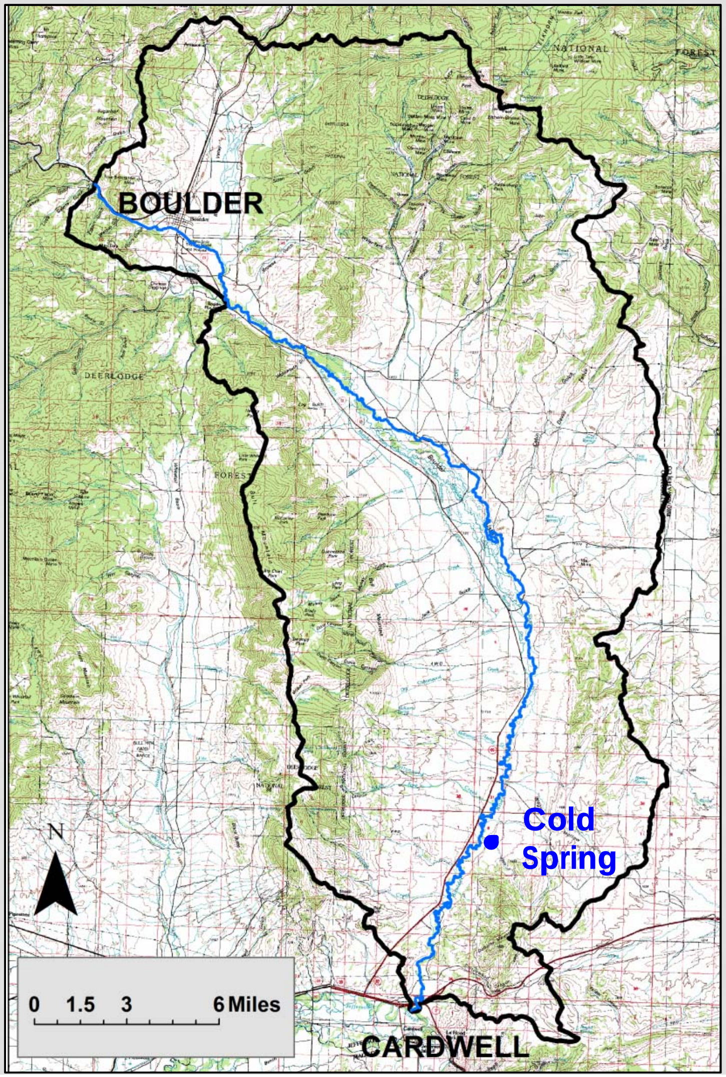
Investigation of the Source of Water for Cold Spring – Boulder River Valley, Montana



MBMG Groundwater Investigation Program
Boulder River Project

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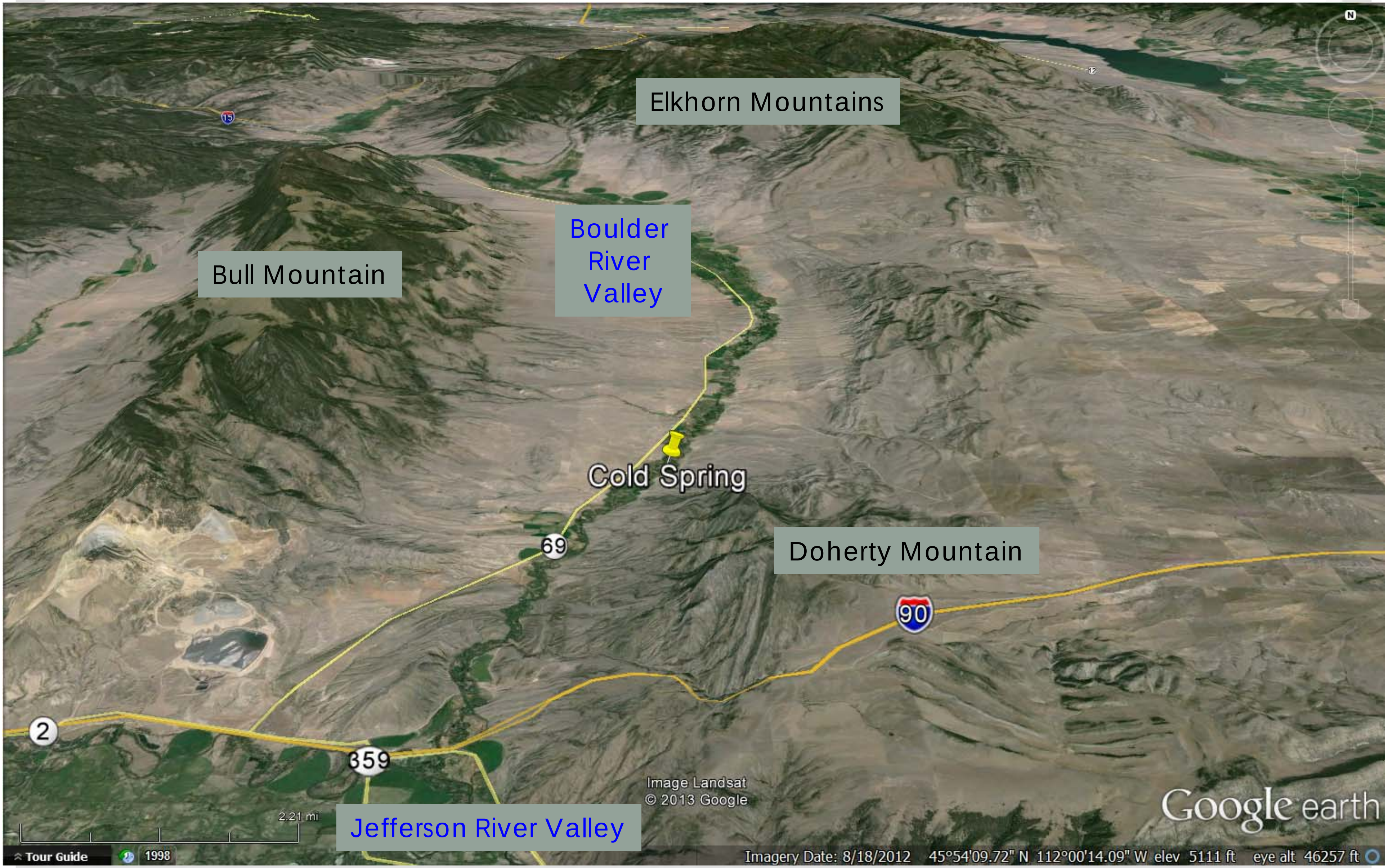
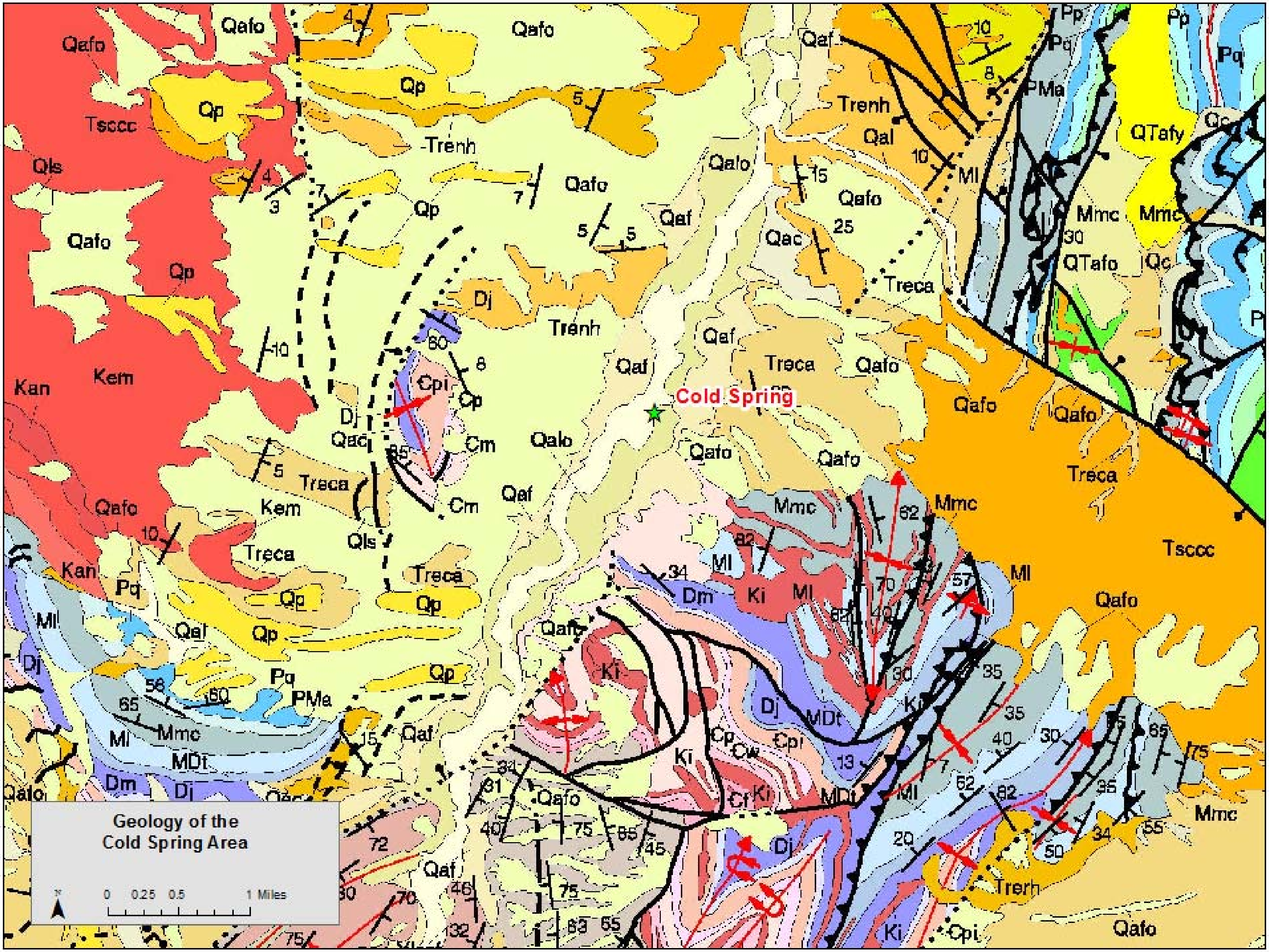
Montana AWRA Annual Conference October 3, 2013

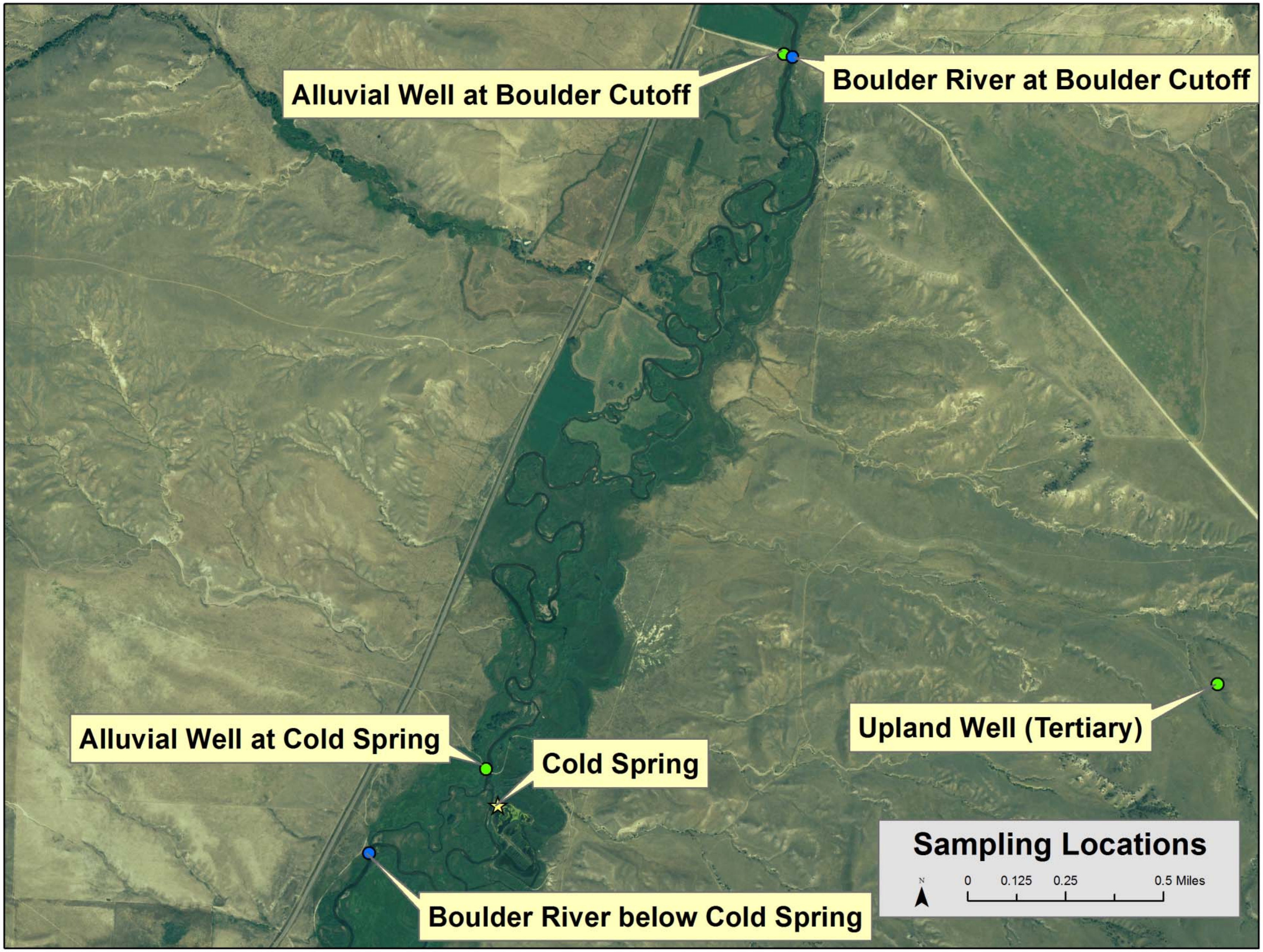
MBMG



2x vertical exaggeration



Geology from Vuke and others, in preperation


Alluvial Well at Boulder Cutoff
Boulder River at Boulder Cutoff
Alluvial Well at Cold Spring
Cold Spring
Upland Well (Tertiary)
Boulder River below Cold Spring
Sampling Locations
N
0
0.125
0.25
0.5 Miles

Sampled spring from a piezometer tip submerged about 2 feet into a sand boil

Sampling Parameters

- Field Parameters
  - SC
  - pH
  - Temperature
  - Flow or depth to water

- Analytical Parameters
  - Major Cations/Anions
  - Trace Elements
  - Tritium
  - Radon
  - δD and $\delta^{18}O$
  - $\delta^{13}C$ and DIC
  - $^{87}Sr/^{86}Sr$

Field Parameters

Site Name	Date	Time	Q (cfs)	SC (µS/cm)	T (^oC)	pH
Boulder River at Boulder Cutoff	4/11/2013	15:25	81	223	8.5	7.81
Boulder Cutoff Well	4/11/2013	17:20	---	818	8.1	7.49
Carey Upland	4/12/2013	14:45	---	799	10.1	7.79
Cold Spring	4/11/2013	11:45	39	393	12.1	7.69
Cold Spring Well	4/12/2013	11:57	---	530	10.6	7.15
Boulder River below Cold Spring	4/11/2013	14:05	125	277	9.9	7.80

Using simple mixing the water quality below Cold Spring appears to be a simple binary mixture of the Boulder River at Boulder Cutoff and Cold Spring water.

$$C_m = \frac{C_1 Q_1 + C_2 Q_2}{Q_1 + Q_2}$$

Predicted SC = 275 - 282 µS/cm

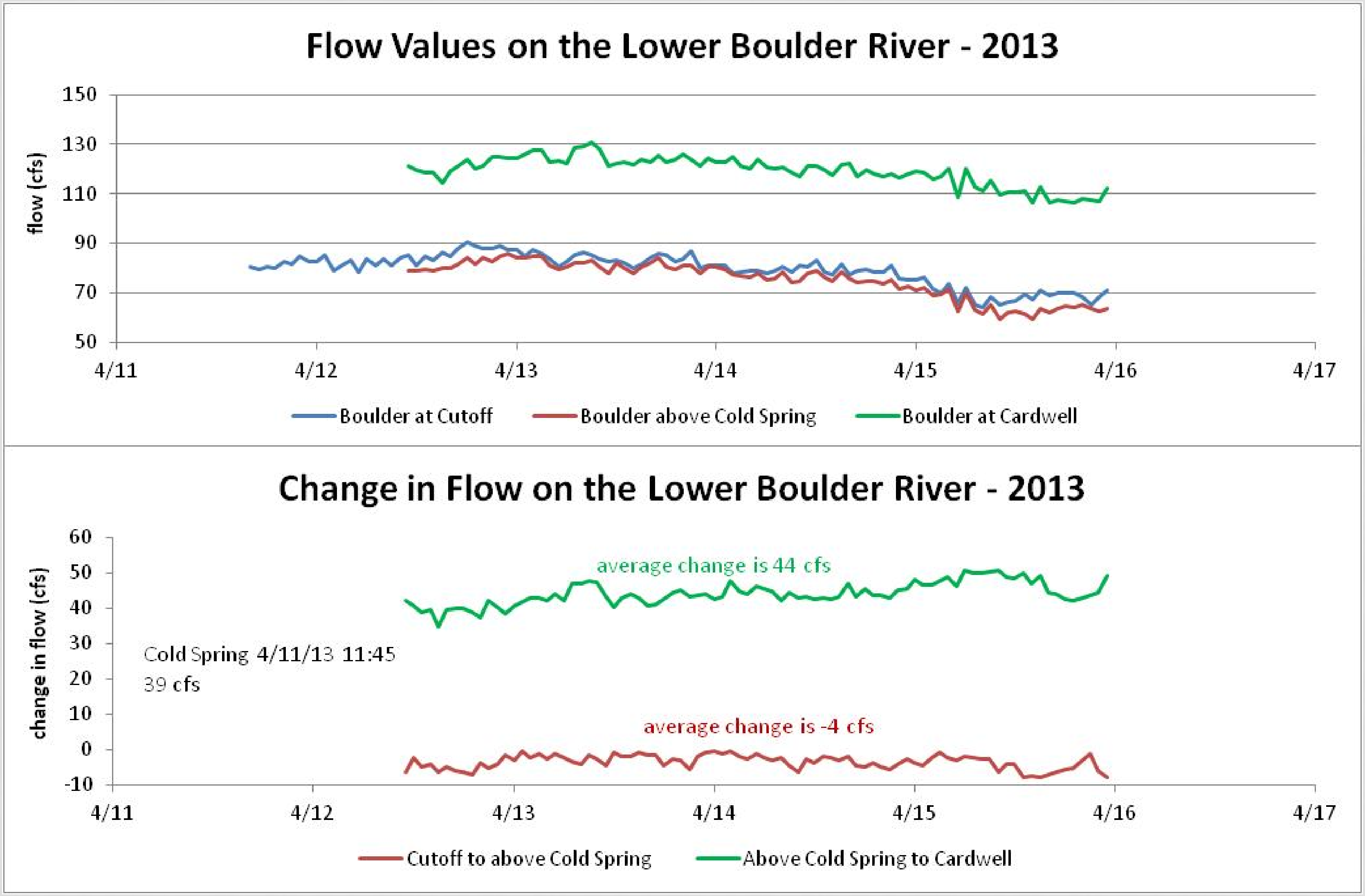
Measured SC = 277 µS/cm

Predicted Temp = 9.6 – 9.8^{o}C

Measured Temp = 9.9^{o}C

(range based on ±5% for flow values) (Cardwell Max Air Temp 4/11/13 = 8.9^{o}C)

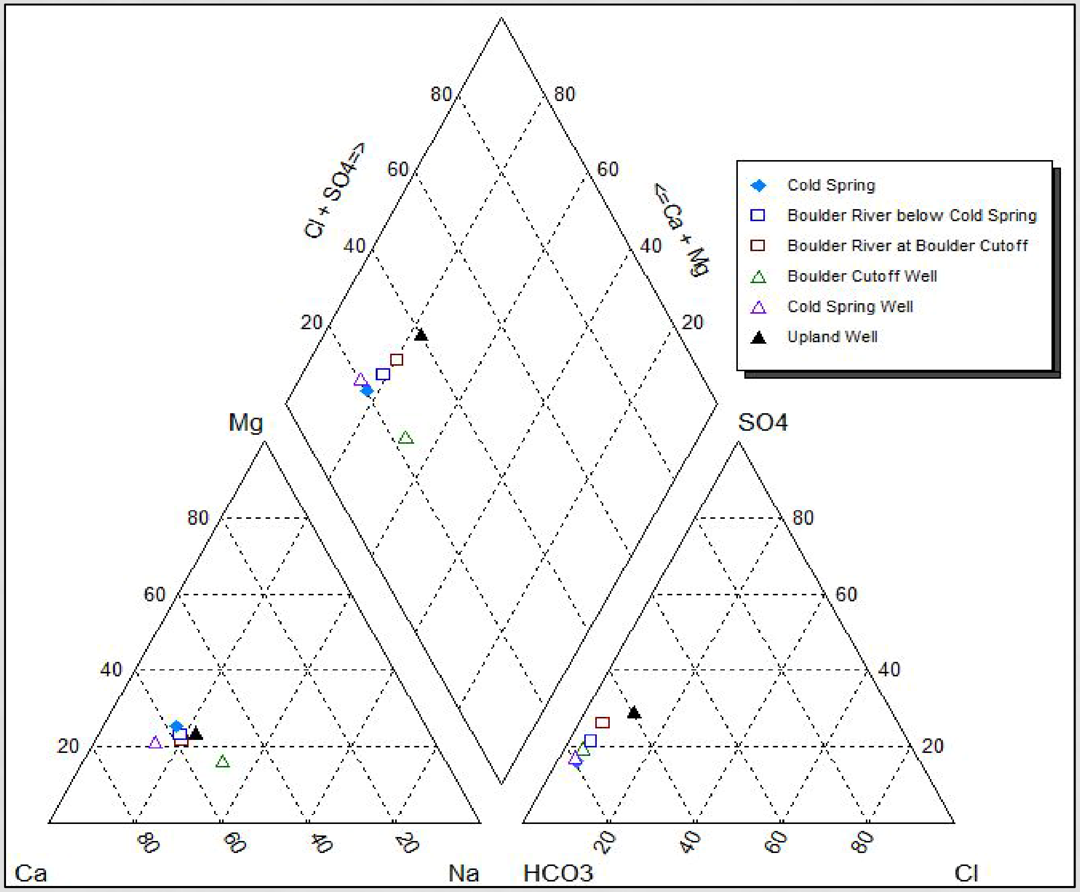
There is no noticeable influence from the higher SC shallow alluvium and Tertiary waters between cutoff and Cold Spring.

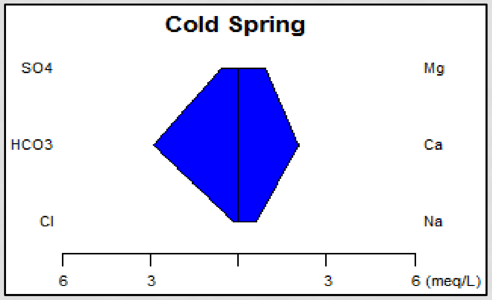


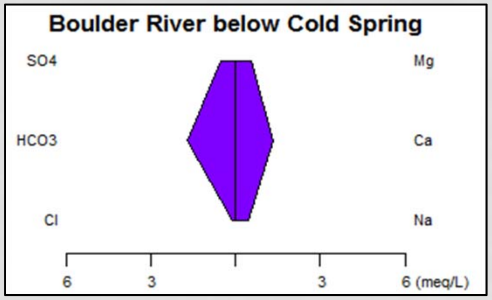
- The total average change in flow between Cutoff and Cardwell is 40 cfs.
- Cold Spring discharged 39 cfs at the main outlet on 4/11/13.

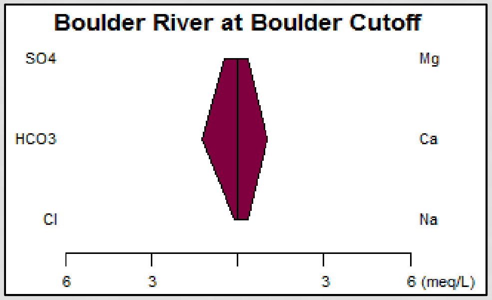
Cold Spring supplies virtually all of the groundwater discharge to the Boulder River along its lower reach between Boulder Cutoff and Cardwell.

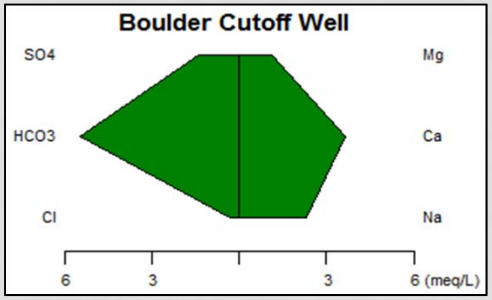
Major Ion Chemistry (April 11 & 12, 2013)

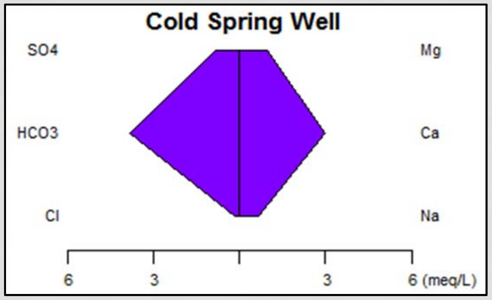


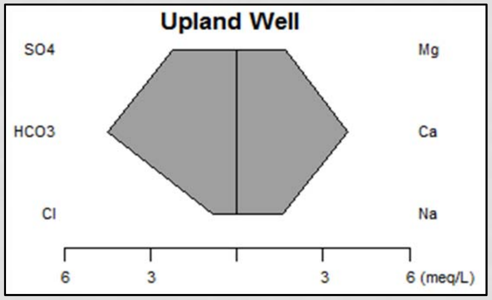












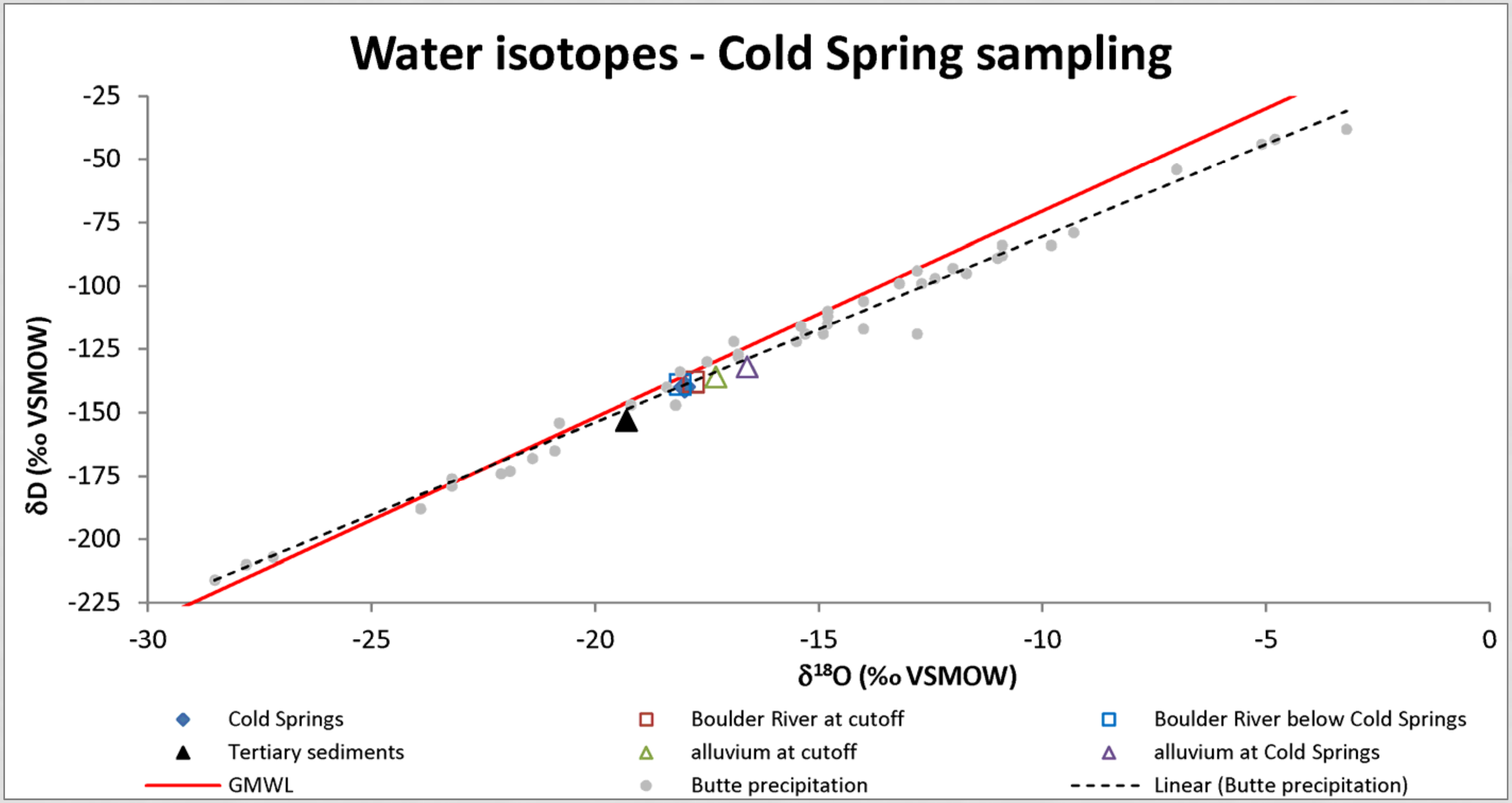
Site	Tritium Units	Radon pCi/L	δD	$\delta^{18}O$	DIC mg/L	$\delta^{13}C$	$^{87}Sr/^{86}Sr$
Boulder River at Boulder Cutoff	6	31	-138	-17.8	7.9	-6.4	0.708486
Boulder Cutoff Well	6	724	-136	-17.3	39.2	-12.5	0.708012
Upland Well	ND (3)	3003	-153	-19.3	12.5	-8.2	0.708288
Cold Spring	8	34	-140	-18.0	18.6	-8.1	0.709481
Cold Spring Well	7	630	-132	-16.6	44.8	-14.0	0.708314
Boulder River below Cold Spring	8	24	-139	-18.1	17.7	-6.8	0.708803

Tritium: Upland Well – pre-1953 water (ND)
The Rest – Modern (6-8 TU)

Cold Spring water is not from a long flow path.

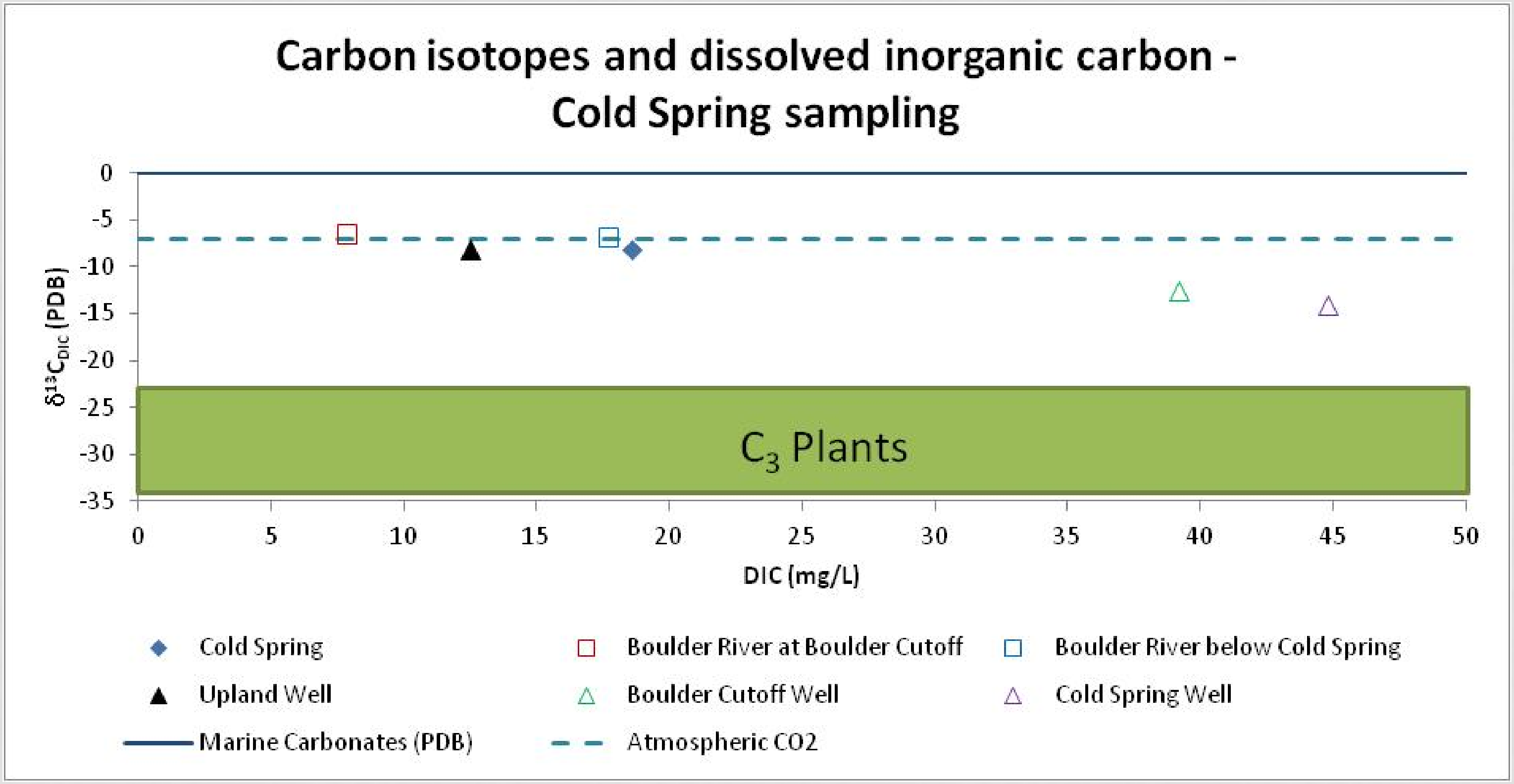
Radon:		
	Cold Spring and the river	Low (24-34 pCi/L)
	Shallow Alluvial Wells	Medium (630 & 724 pCi/L)
	Upland Well	High (3003 pCi/L)

Cold spring water has either been in the ground for a very short time or the water's flow path near the spring is through a low radon aquifer (e.g. limestone).



Cold Spring water is most similar to river water, and all samples appear meteoric.

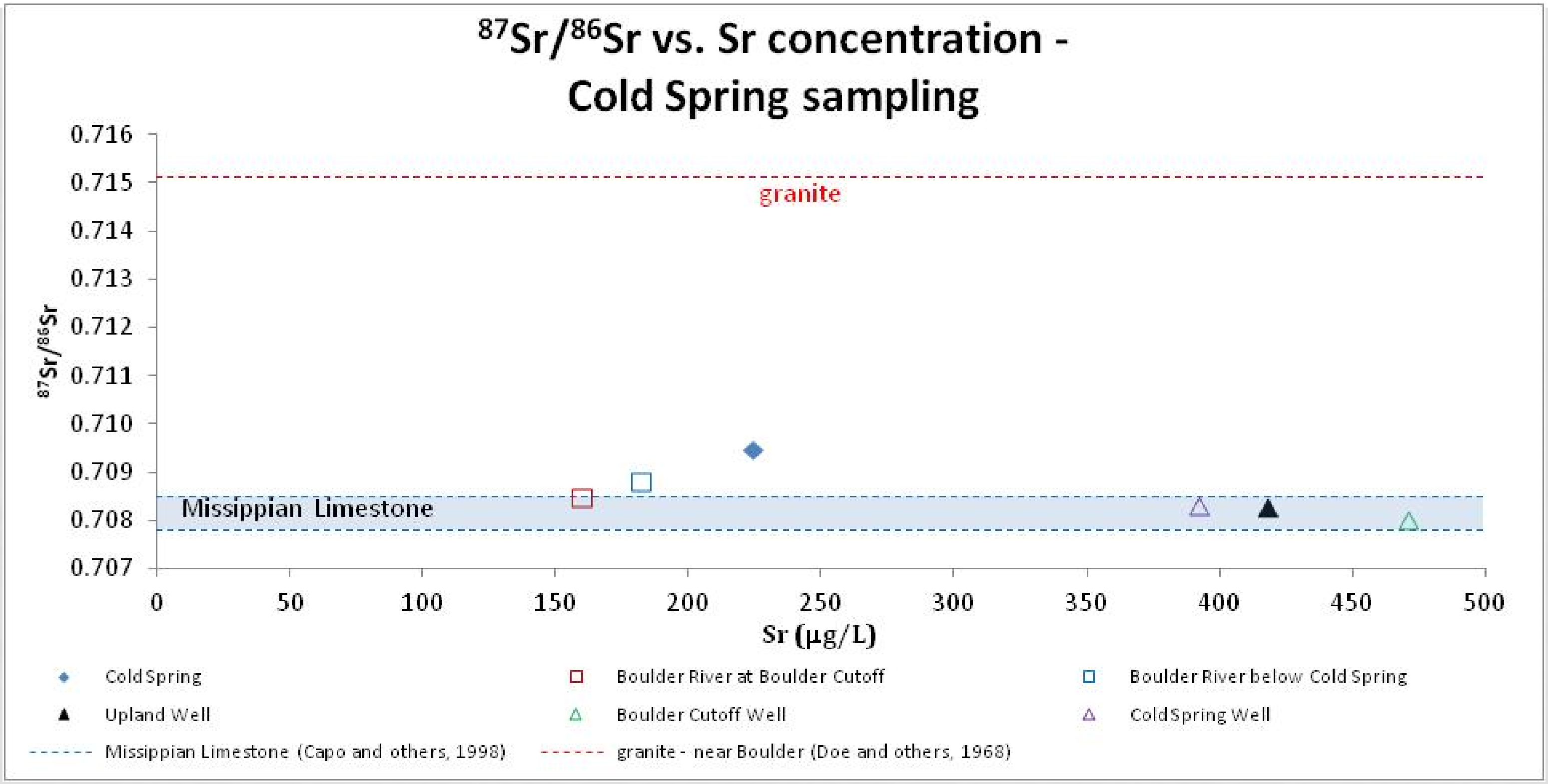
(Butte Precipitation data from Gammons and others, 2006; GMWL from Rozanski and others, 1993)



•For the river, spring, and the Upland well water DIC appears to be atmospheric (not from marine carbonates).

•Shallow alluvial waters are enriched in DIC and depleted in ^{13}C, likely indicating interaction with decaying C_3 plants.

(Atmospheric and C3 plant data from Faure, 1991)



•Cold Spring has a higher $^{87}Sr/^{86}Sr$ ratio. This may indicate extended contact with granitic materials.

•Boulder River below Cold Spring appears to result from simple binary mixing between the Boulder River at Boulder Cutoff and Cold Spring.

•Other samples have $^{87}Sr/^{86}Sr$ ratios consistent with reported values for Mississippian Limestone (based on global average seawater $^{87}Sr/^{86}Sr$).

(Mississippian Limestone values from Capo and others, 1998; Granite near Boulder from Doe and others, 1968)

Possible sources

- Requirements:
  - It is coming out of the ground
  - Major ion chemistry
  - Modern meteoric water (^{3}H - post-1953; δD and $\delta^{18}O$)
  - Low Radon aquifer or very short sub-surface flow path
  - Atmospheric carbon (not in marine limestone for a long time)
  - Elevated $^{87}Sr/^{86}Sr$ ratio suggests prolonged contact with granite

- Doherty Mountain (see my abstract)
  - No – Given the potential area that would drain to Cold Spring (~8 mi^2) recharge would have to be 334” per year to get 39 cfs. This is an 11” precipitation area.

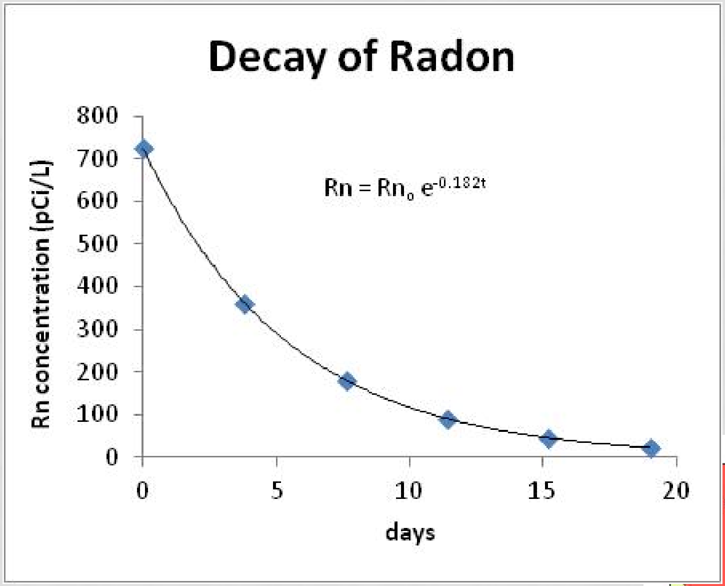
- Rapid Rerouted River Water
  - No – There is not enough water missing from the river (loss from Cutoff to Cold Spring ~4 cfs).

- Discharge of Regional flow in Madison
  - No – Water is modern and this would be inconsistent with Sr and C isotopes.

Possible sources (cont.)

- Alluvial Water
  - Works physically
    - Potentiometric Surface
    - Bedrock Canyon
  - Most similar in terms of major ions
  - Spring has lower DIC, higher $\delta^{13}C$, and higher $^{87}Sr/^{86}Sr$ ratio than shallow alluvial wells.
  - Spring has much lower Radon.

- A possible explanation:
  - Boulder River generally looses water from about 4 miles below Boulder
  - The water flows preferentially through clean higher permeability zones
    - Few decaying plants so low DIC, and atmospheric $\delta^{13}C$
    - Prolonged interaction with granitic clasts, causing the $^{87}Sr/^{86}Sr$ ratio to increase.
  - Toward the end of the flow path, the water enters a fractured low radon aquifer (e.g. limestone).
    - Fracture flow causes discharge to occur at a point rather than over a longer reach.



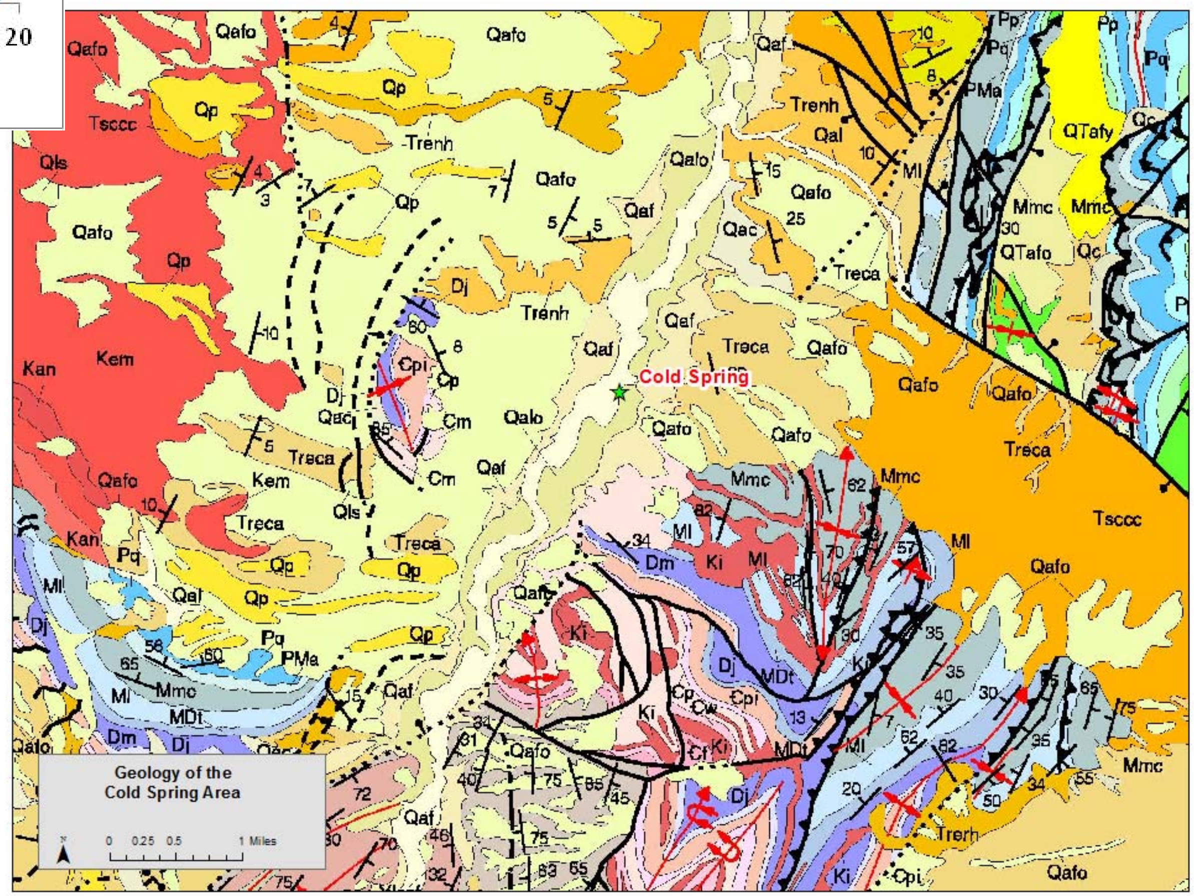
The half life of Radon is 3.8 days, so water isolated from a radon source would go from shallow alluvial levels (630-724 pCi/L) to spring values (34 pCi/L) in 16-17 days.

It is geologically possible that there would be shallow limestone at this site.

We now plan to:

•take another Rn sample.

•drill near the spring



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THANK YOU
QUESTIONS???