

# Chemical composition of stream water in mixed alpine & subalpine watersheds at the Fraser Experimental Forest, Colorado

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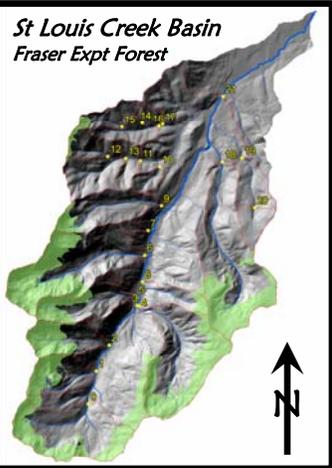
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## Overview

In high-elevation watersheds, variability in streamwater chemistry, nutrients and carbon responds to complex spatial patterns in vegetation, soil and the physical environment. High-elevation watersheds are sensitive indicators of changing climatic conditions and atmospheric inputs to alpine and treeline ecosystems. Greater understanding of interactions between terrain features and watershed processes will lead to better monitoring of ecosystem change in complex mountainous terrain.

At the Fraser Experimental Forest in central Colorado, we analyzed streamwater in 19 headwater tributaries of the Fraser River and locations along the river's main stem. We also developed terrain models and hydrological distance surfaces to characterize upland and riverine geomorphic variability in order to develop basin-wide characterizations of factors that regulate biogeochemical and hydrologic processes. This method accounts for non-linear relationships between spatially-explicit physical features of a watershed and point estimates of parameters such as the extent of exposed rock or steep slopes and Normalized Difference Vegetation Index (NDVI) and generates a representation of the landscape relationships that contribute to watershed biogeochemical fluxes.



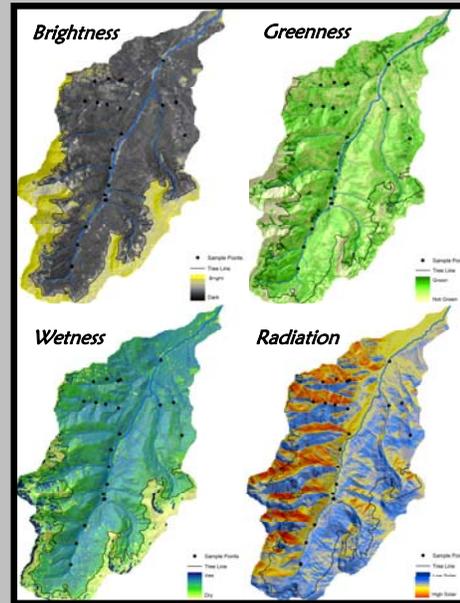
## Study Area Description

The 19 tributaries of St Louis Creek cover <10 to nearly 1000 ha with an average area of 315 ha. Individual tributaries span as much as 1000 m in elevation with an average of 624 m of relief. Treeline averages 3482 m elevation and ranges from 3242 to 3654 m. The individual tributaries are nested within the 8500 ha basin gauged by USGS St Louis Creek Station 09026500 located at 39°54'36" N, 105°52'40" W and 2735 m elevation (USGS 2008).

The proportion of each study basin located above treeline ranges from 0 to 56%. The smallest basins did not extend above treeline, but there was no consistent relation between basin size and alpine cover. For example, several smaller basins situated near the upper portion of the St Louis Creek basin (e.g. Lunch, Gordon, and Mine Cks) had among the highest alpine cover. Exposed rock covers as much as 70% and averages 44% of the alpine area. Valley bottom covers about 2.5% of the basins on average.

## Streamwater Analysis

Streamwater was sampled monthly during 2005 and 2006. Concentrations of major cations and anion were quantified by ion chromatography. ANC was measured by Gran titration to a 3.2 endpoint and pH and EC were measured using glass electrodes. Dissolved organic carbon and TDN were determined by high-temperature combustion catalytic oxidation



## Terrain Analysis

Brightness, greenness, and wetness analyses are a product of the Tassef Cap Transformation based on PCA-like techniques. This procedure reduces the spectral dimensionality of the 7 Landsat TM bands into 3 bands that explain ~98% of the spectral variability.

**Brightness:** Soil moisture dynamics (75% of variability)

**Greenness:** Vegetation vigor without soil reflectance influences (15% of variability).

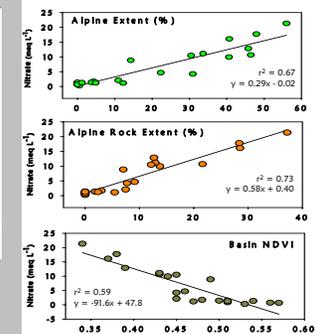
**Wetness:** Soil/ canopy moisture relationships (8% of variability).

**Radiation:** A unitless index of potential solar influence (0= high radiation to 1= high shade) from a raster algorithm and 10m DEM.

**NDVI:** Normalized Difference Vegetation Index analysis is a ratio

	pH	EC	Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>	K <sup>+</sup>	ANC	SO <sub>4</sub> <sup>2-</sup>	NO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>
<b>Metamorphic Bedrock</b>										
Upper Fool	7.4	35.0	176.9	70.4	103.9	18.9	280.6	33.9	1.3	4.0
East St Louis	7.5	38.4	215.2	79.6	90.2	17.0	288.3	46.8	4.2	4.3
Range	7.5	45.7	302.2	78.4	91.8	15.5	304.4	69.1	12.9	4.1
Lower Fool	7.6	54.9	327.1	118.9	120.9	23.4	469.3	45.1	0.3	5.0
<b>Mixed Parent Material</b>										
Byers	7.8	71.2	514.6	119.1	59.2	31.9	555.0	95.0	8.8	4.7
Mine	7.8	80.2	521.1	239.6	48.3	22.4	624.4	114.2	10.7	3.6
Wyssen	7.9	90.9	591.7	226.2	75.7	39.2	796.6	58.7	1.2	8.8
Laxen	7.8	79.7	600.6	147.0	75.7	18.0	725.9	39.0	1.1	5.1
Short	7.9	96.6	615.5	263.7	93.4	35.2	837.6	68.1	0.7	6.4
Iron	7.8	88.2	650.4	134.9	52.9	37.0	577.3	209.3	17.7	4.2
Lunch	7.8	94.5	655.6	163.0	55.9	28.2	623.5	220.5	16.1	4.1
Alder	7.9	106.0	678.6	273.0	114.0	50.1	917.9	94.9	0.8	8.0
West St Louis	7.9	99.7	692.1	196.3	80.8	32.0	889.3	59.2	1.4	6.3
Gordon	7.9	113.1	792.6	258.8	56.0	24.6	791.0	248.0	21.3	3.6
<b>Sedimentary Bedrock</b>										
Monk	8.0	145.4	1023.0	263.8	135.9	53.1	1305.5	101.1	0.7	9.7
Main Deadhorse	8.1	134.7	1076.6	220.5	63.6	33.7	1264.3	56.9	1.7	5.5
South Deadhorse	8.1	137.1	1121.0	227.1	67.0	25.2	1310.9	38.8	2.1	4.0
North Deadhorse	8.1	167.1	1370.9	294.5	104.3	28.6	1614.5	66.7	1.4	5.9
<b>Main Stem Stations</b>										
Upper St Louis	7.5	49.8	340.0	91.1	78.2	12.8	346.2	94.3	9.9	5.6
St Louis abv Range	7.7	70.8	472.9	163.6	76.7	18.7	518.3	126.3	10.5	4.3
St Louis abv Diversion	7.6	67.0	463.5	145.3	76.3	19.2	473.5	120.2	11.1	4.2
St Louis @ USGS gauge	7.9	90.6	615.6	194.3	104.8	28.6	732.9	105.7	4.7	6.0
<b>Overall Mean</b>	7.8	89.9	659.0	171.3	86.8	25.2	780.6	75.8	4.7	4.9
<b>SD</b>	(0.3)	(44.2)	(398.3)	(79.0)	(24.4)	(10.0)	(455.1)	(56.1)	(6.0)	(2.7)

Tributaries	Watershed		Alpine		Alpine		Valley		NO <sub>3</sub> -N		DON		DOC	
	Area	Area	%	% of Alp	% of Basin	Bottom	%	mg/L	%	mg/L	%	mg/L		
Gordon	274.5	153.7	56.0	66.4	37.2	2.8	298.54	0.94	59.35	0.05	0.73			
Iron	781.6	374.6	47.9	59.2	28.4	4.1	243.11	0.86	68.54	0.12	1.16			
Mine	250.6	116.4	46.5	46.6	21.6	4.2	149.14	0.86	51.83	0.12	1.27			
Range	774.8	354.5	45.7	27.7	12.7	3.2	179.95	0.75	79.02	0.23	1.44			
Lunch	295.9	120.3	40.7	70.1	28.5	4.0	225.15	0.81	71.85	0.17	1.17			
East St Louis	941.3	290.9	30.9	25.0	7.7	3.1	58.83	0.50	93.22	0.46	1.72			
Byers	353.9	50.6	14.3	49.1	7.0	3.4	123.76	0.70	71.41	0.27	1.18			
Laxen	129.9	15.9	12.3	44.3	5.4	1.6	15.79	0.27	68.17	0.64	0.99			
South Deadhorse	125.6	13.7	10.9	68.2	7.5	2.2	29.38	0.45	58.12	0.52	0.57			
Wyssen	374.3	18.4	4.9	48.3	2.4	2.6	17.07	0.23	83.85	0.66	2.85			
Main Deadhorse	319.5	14.1	4.4	67.7	3.0	2.7	23.74	0.38	76.76	0.56	1.06			
West St Louis	488.9	18.4	3.8	48.3	1.8	2.7	17.80	0.23	81.20	0.72	1.71			
Upper Fool	129.4	1.6	1.2	0.00	0.0	1.5	17.95	0.14	122.25	0.83	2.31			
Lower Fool	307.3	1.6	0.5	0.0	0.0	2.8	3.62	0.07	115.08	0.92	2.56			
North Deadhorse	21.0	0.0	0.0	0.0	0.0	0.0	19.51	0.21	107.20	0.76	2.17			
Alder	27.5	0.0	0.0	0.0	0.0	0.0	11.72	0.16	93.94	0.79	1.76			
Monk	2.7	0.0	0.0	0.0	0.0	0.0	9.95	0.18	66.63	0.81	2.03			
Short	68.8	0.0	0.0	0.0	0.0	5.0	9.13	0.07	155.73	0.87	2.69			
<b>Main Stem Stations</b>														
Upper St Louis	639.6	259.6	40.6	33.9	13.8	3.9	139.13	0.61	111.54	0.37	2.32			
St Louis abv Range	2089.7	1141	30.45	40.0	12.9	4.2	146.75	0.70	92.30	0.28	2.36			
St Louis abv Diversion	3388.3	636.3	33.66	38.4	12.2	4.1	155.79	0.47	89.78	0.27	1.99			
St Louis @ USGS gauge	8507.2	1900	22.34	40.8	9.1	4.7	65.40	0.45	98.00	0.51	2.06			

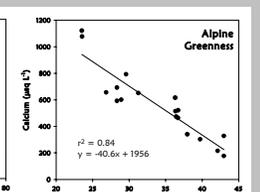
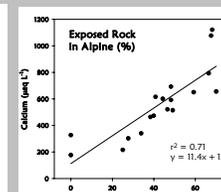
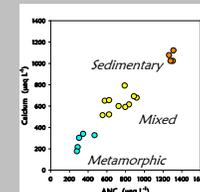


## Streamwater Nitrogen

- Nitrate concentrations in the 5 basins with > 40% alpine cover are 10X higher than the other 13 basins.
- Nitrate comprised 75 to 94% of the total dissolved nitrogen in the five high nitrate streams, but it was less than half of TDN in the others.
- Exposed rock represents 13 to 37% of the basin area of the five high nitrate streams compared to less than half that in the remaining basins.
- DON concentrations are 30% lower on average for the high nitrate streams.

## DOC

- In general, DOC concentrations were highest in basins with no or low alpine cover.
- The basin with the highest DOC (Short Ck) had the greatest extent of valley bottom (5%), though this terrain attribute was a poor predictor of DOC.



## Streamwater Chemistry

- The pH of St Louis Creek tributaries averages 7.8 and ranges from 7.4 to 8.1
- Streamwater calcium and ANC are regulated by basin bedrock with differences between basins containing sandstone and shale, those formed on metamorphic material and basins with mixed geology.
- The extent of exposed rock and the spectral greenness of the Alpine explain 71 and 84% of the variability of streamwater calcium, respectively and related similarly to ANC.