# High Elevation Wildfire Aggravates Water Quality Concerns in the Cache le Poudre Watershed

Fire on The Mountain
Sustaining CO Watersheds
Avon, Colorado
6 Oct 2021


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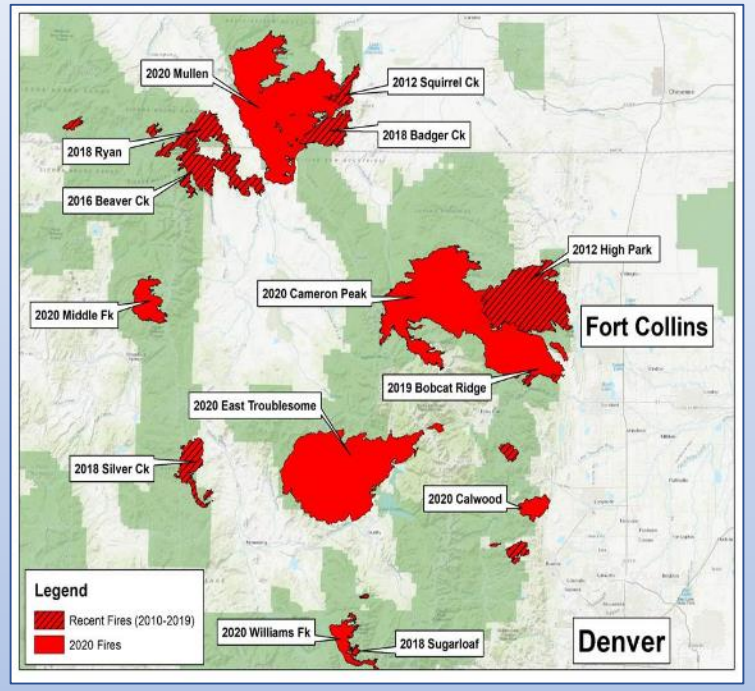
# Fires are Burning at Higher Elevations than Ever, Creating New Dangers

Hayley Smith, LA Times, SEPT. 14, 2021

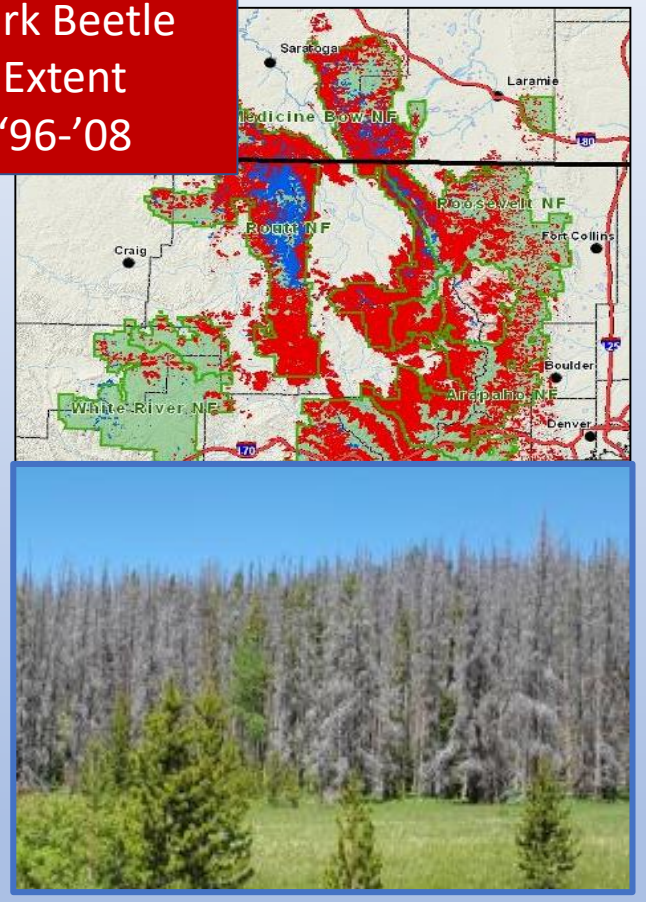



"Forest fires of the western United States have advanced upslope over the past few decades, scorching territories previously too wet to burn."

Alizadeh et al. 2021, PNAS

| High Elevation / Subalpine Forests | Fire Return Interval |
|---|---|
| Spruce-Fir | 150-300+ yrs |
| Lodgepole Pine | 90-300+ yrs |
| **Low Elevation / Montane Forests** | |
| Ponderosa Pine | 10- 50 yrs |

Bark Beetle Extent '96-'08




| | Lodgepole | Spruce Fir | Mixed Conifer | Ponderosa | Grass Shrub | Rock Alpine | Other |
|---|---|---|---|---|---|---|---|
| Mean | 76.4 | 8.2 | 0.1 | 1.2 | 5.3 | 7.3 | 1.5 |
| Min | 13.5 | 0.3 | 0.0 | 0.0 | 0.7 | 0.0 | 0.2 |
| Max | 97.0 | 57.5 | 0.3 | 7.5 | 16.5 | 47.8 | 6.2 |

***Gray Phase Fires***

| | Acres |
|---|---|
| 2010-2019 | 150,000 |
| 2020 | >600,000 |

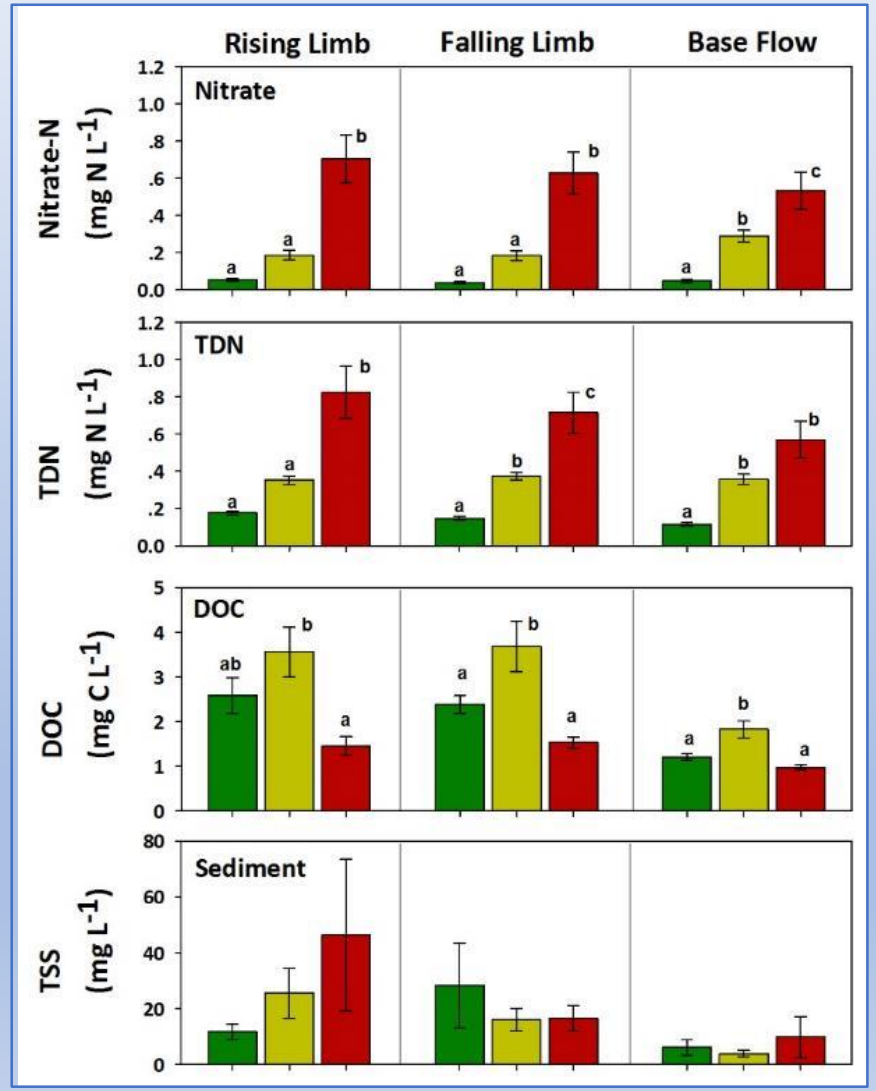
# Watershed Responses & Long-term Effects

## Track Burn Severity

***Low Severity***
Vegetation remains 'green.' OM layers not fully consumed. Soil structure, roots unchanged

***Moderate Severity***
Most (50-80%) ground cover, OM consumed. Foliage may remain in tree canopies.

***High Severity***
Consumption of nearly all pre-fire ground cover & surface organic matter.




Rhoades et al. 2019

## 2002 Hayman Fire

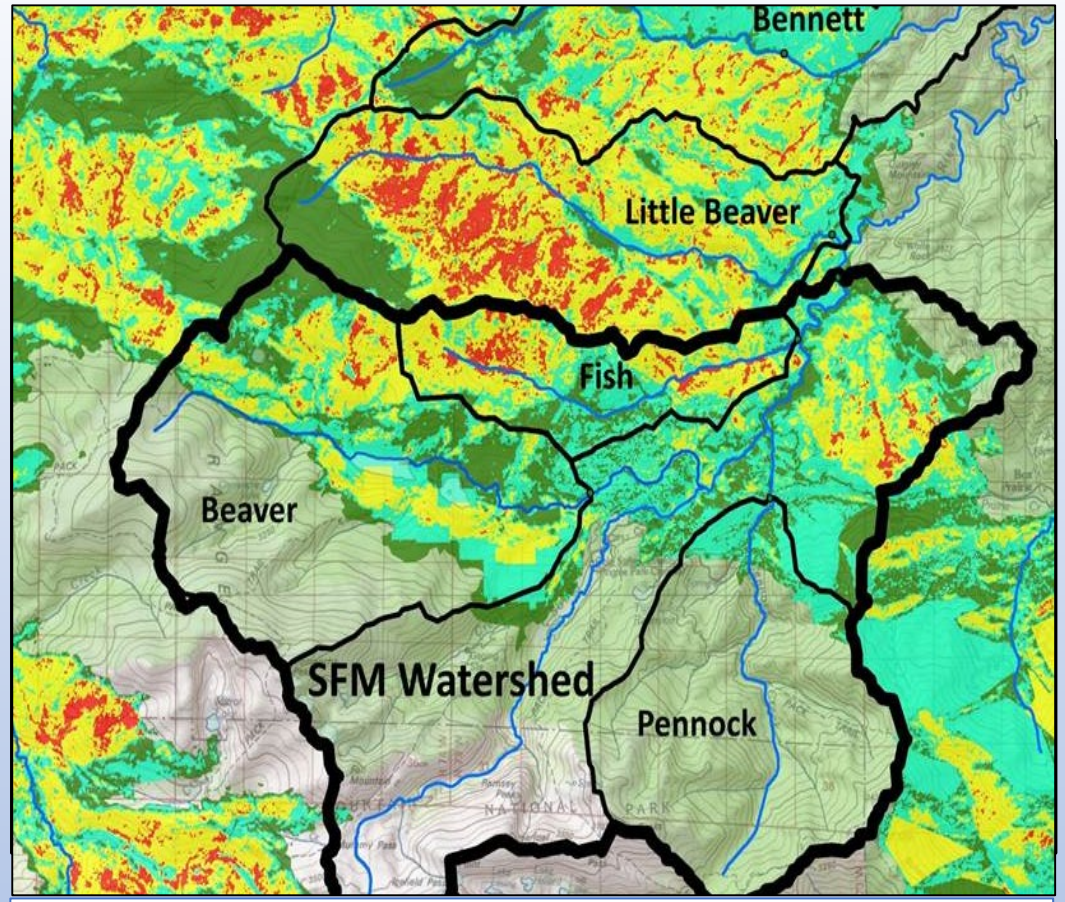
*14-15 yr post-fire

Nitrate & TDN 5-10X above background in Extensive & elevated in Moderate

Lasting changes in nutrient retention
(>95% pre- vs 48% post-fire)

DOC highest for moderate burns

Sediment losses are minor




| | High | Moderate | Low | Unburned | Acres |
|---|---|---|---|---|---|
| | ---------- % ---------- | | | | |
| **Cameron Peak** | 6 | 31 | 44 | 20 | 208,759 |
| **E. Troublesome** | 5 | 44 | 39 | 12 | 189,191 |
| **Mullen** | 24 | 41 | 22 | 13 | 176,878 |
| **Grizzly** | 12 | 43 | 33 | 12 | 32,438 |
| **Williams Fork** | 27 | 39 | 17 | 16 | 14,736 |
| **High Park (2012)** | 7 | 40 | 37 | 16 | 87,487 |
| **Hayman (2002)** | 35 | 16 | 34 | 15 | 138,114 |

# Severity at Watershed-Scale

| Watershed | Area | | Burn | Hi | Mod | Lo | No | Hi+Mod |
|---|---|---|---|---|---|---|---|---|
| | ($km^2$) | (acres) | (%) | % | | | | |
| Sheep | 7 | 1,766 | 100 | 14 | 57 | 29 | 0 | 71 |
| Little Beaver | 47 | 11,561 | 86 | 17 | 51 | 18 | 14 | 68 |
| Black Hollow | 17 | 4,294 | 88 | 12 | 51 | 24 | 12 | 63 |
| Fish | 13 | 3,242 | 86 | 11 | 46 | 29 | 14 | 57 |
| Tunnel* | 7 | 1,672 | 89 | 12 | 32 | 46 | 11 | 43 |
| Bennett | 37 | 9,209 | 70 | 4 | 33 | 32 | 30 | 38 |
| Sevenmile* | 19 | 4,789 | 70 | 2 | 25 | 44 | 30 | 26 |
| Roaring* | 15 | 3,751 | 57 | 2 | 27 | 28 | 43 | 29 |
| N. Joe Wright | 9 | 2,243 | 41 | 13 | 11 | 17 | 59 | 24 |
| Beaver | 57 | 14,003 | 43 | 1 | 18 | 25 | 57 | 19 |
| Fall | 13 | 3,176 | 23 | 8 | 7 | 8 | 77 | 15 |
| S. Fk. Poudre* | 183 | 45,197 | 33 | 2 | 13 | 19 | 67 | 14 |
| S. Lone Pine | 22 | 5,501 | 24 | 0 | 13 | 10 | 76 | 14 |
| Pennock | 47 | 11,519 | 16 | 0 | 1 | 15 | 84 | 2 |
| Deadman | 37 | 9,172 | 0 | 0 | 0 | 0 | 100 | 0 |
| N. Fk. Poudre | 19 | 4,604 | 0 | 0 | 0 | 0 | 100 | 0 |

12 burned & 4 unburned; * pre and post-fire data

# Project & Talk Overview

**Overall Objectives**

Examine the influence of the Cameron Peak fire on watersheds, water quality, aquatic ecosystems and water supply and storage and estimate downstream delivery of key constituents to water treatment utilities.

Expands on City of Fort Collins, Coalition for Poudre River Watershed, RMRS monitoring and citizen science.

**Year 1 Activities**

1) Characterize ash chemistry across the fire and major forest types.

   Ash, char and mineral soil

2) Track post-fire water quality responses in headwater catchments burned by the Cameron Peak fire and the CLP.

   Weekly, bi-monthly and storm event sampling.

Go to **www.menti.com** and use the code **5269 7556**

# What are your most serious post-fire water quality concerns?

| | |
|---|---|
| 1st | Ash |
| 2nd | Sediment |
| 3rd | Nutrients |
| 4th | Carbon |
| 5th | Metal |
| 6th | Other |
| 7th | None |

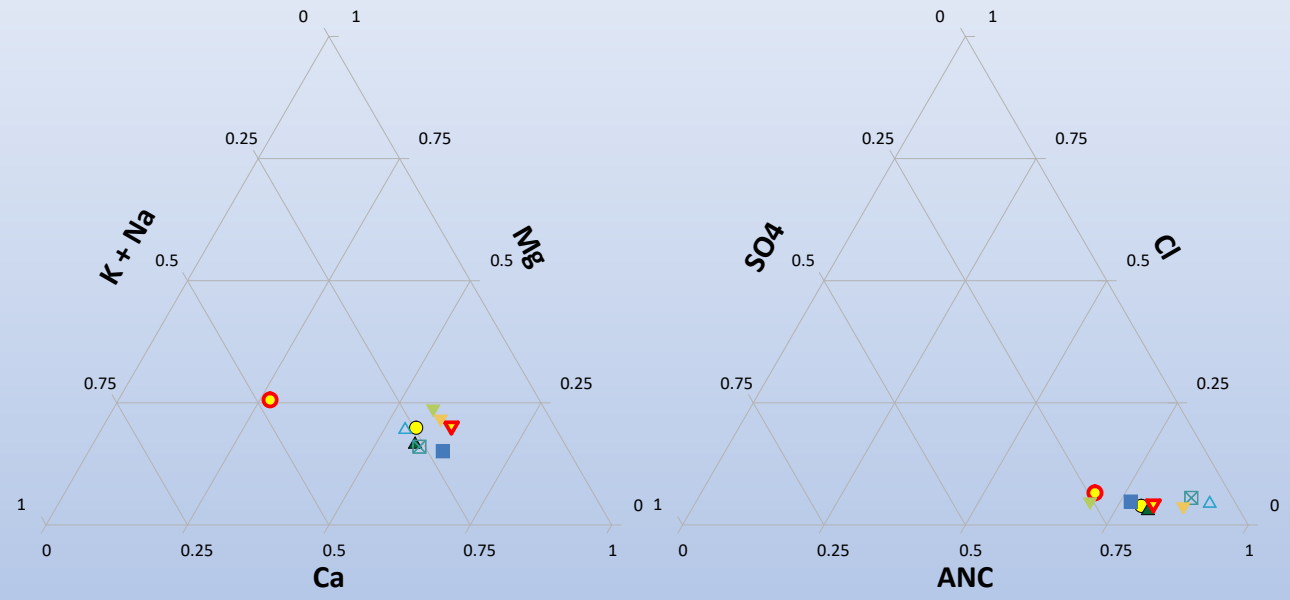
# Ash Chemistry – *Varies with Depth, Ecosystem Type*

| | | pH | | ANC | | Ca | | K | | $NH_4$ | | $NO_3$ | | $PO_4$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Max | Mean | Max | Mean | Max | Mean | Max | Mean | Max | Mean | Max | Mean | Max |
| | | | | $\mu eq\ L^{-1}$ | | mg $L^{-1}$ | | | | | | | | | |
| Ash | Subalpine | 8.1 | 8.6 | 1713.0 | 2701.9 | 30.5 | 51.1 | 11.9 | 33.7 | 0.9 | 2.4 | 0.7 | 2.1 | 4.0 | 5.4 |
| | Montane | 8.1 | 8.3 | 2736.9 | 4823.2 | 38.1 | 63.2 | 33.2 | 58.1 | 0.6 | 2.2 | 0.3 | 1.0 | 5.5 | 7.7 |
| | Riparian | 8.4 | 8.9 | 3210.1 | 4756.2 | 31.3 | 54.8 | 47.8 | 88.8 | 1.2 | 2.6 | 1.8 | 3.6 | 4.3 | 11.0 |
| Char | Subalpine | 7.5 | 8.2 | 2224.0 | 3359.1 | 36.8 | 49.6 | 15.2 | 48.7 | 1.8 | 2.8 | 1.7 | 2.5 | 5.4 | 8.3 |
| O Horizon | Montane | 7.9 | 8.4 | 2425.8 | 3175.6 | 38.1 | 52.3 | 35.9 | 57.1 | 1.3 | 2.8 | 1.7 | 2.1 | 8.1 | 13.7 |
| | Riparian | 8.1 | 8.4 | 3830.9 | 5054.3 | 55.1 | 86.3 | 43.0 | 62.5 | 2.6 | 7.9 | 4.7 | 15.7 | 8.0 | 12.0 |
| A Horizon | Subalpine | 6.4 | 7.1 | 1252.0 | 2031.3 | 22.7 | 42.9 | 5.5 | 9.4 | 1.7 | 2.6 | 0.3 | 0.8 | 0.2 | 0.5 |
| | Montane | 7.2 | 7.4 | 3941.8 | 5549.2 | 73.2 | 100.3 | 28.2 | 46.5 | 1.1 | 1.6 | 0.8 | 1.0 | 0.9 | 1.3 |
| | Riparian | 7.4 | 8.1 | 3614.0 | 4521.9 | 66.7 | 90.4 | 36.4 | 70.0 | 3.1 | 9.2 | 0.7 | 1.0 | 1.9 | 5.0 |

| | Ca | K | $NH_4$ | $NO_3$ | $PO_4$ |
|---|---|---|---|---|---|
| | mg $L^{-1}$ | | | | |
| **Ash** | 33.3 | 31.0 | 0.9 | 1.0 | 4.6 |
| **Char OM** | 43.3 | 31.4 | 1.9 | 2.7 | 7.2 |
| **A Horizon** | 54.2 | 23.3 | 2.0 | 0.6 | 1.0 |
| **Unburn O Horizon** | 17.6 | 13.3 | 3.4 | 1.0 | 4.9 |
| **Unburn A Horizon** | 9.1 | 5.9 | 0.3 | 1.4 | 1.4 |
| **Char / O Horz** | 2.5 | 2.4 | 0.5 | 2.8 | 1.5 |
| **Burn vs Unburn A Horiz** | 5.9 | 4.0 | 6.2 | 0.4 | 0.7 |

# Fresh Ash Differs from Residual Ash, Soils, Water

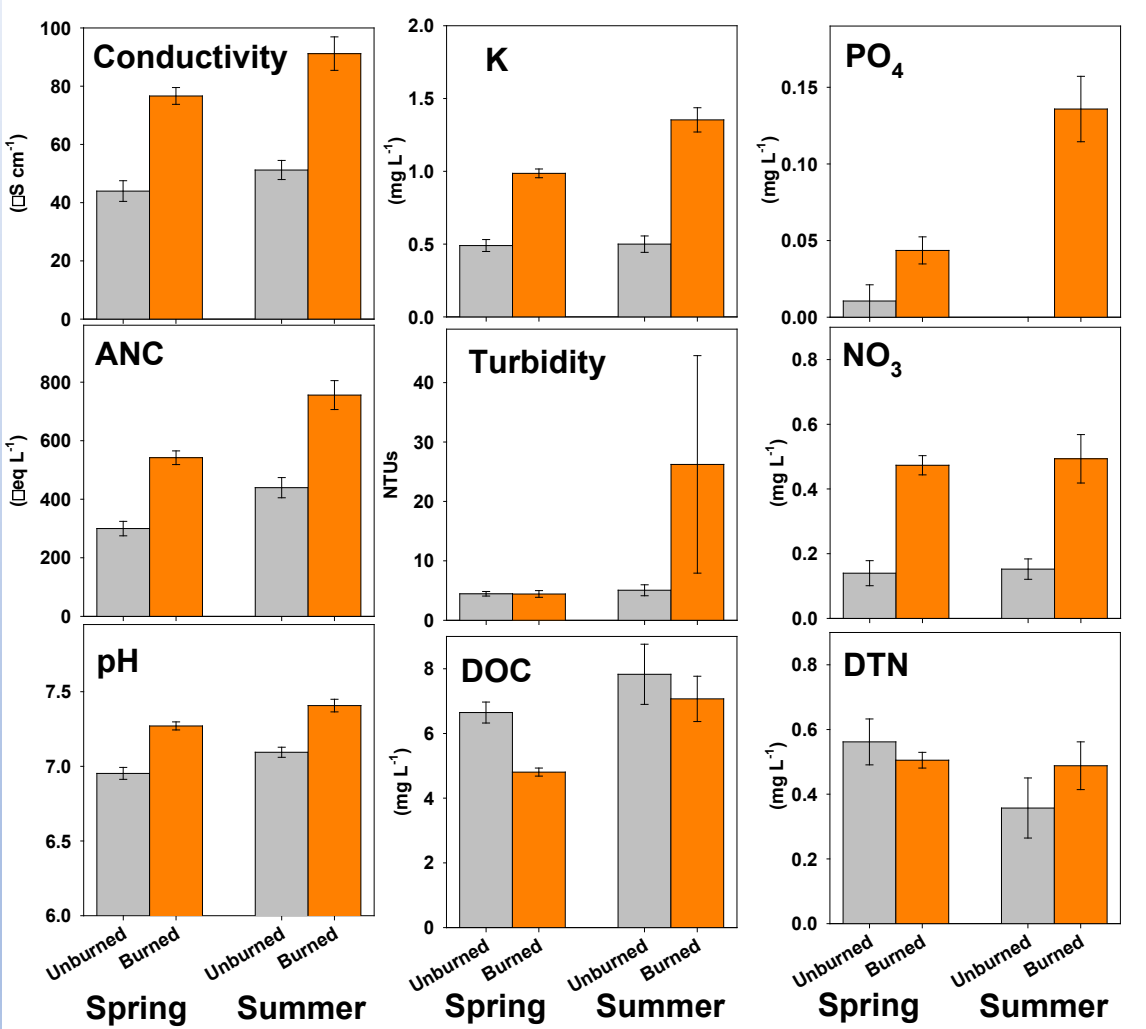
| | | Ash | | |
|---|---|---|---|---|
| | | 2020 Fresh | 2021 Residual | Δ |
| **K** | mg $L^{-1}$ | 490.5 | 28.5 | 17 |
| **Mg** | " | 87.1 | 7.6 | 12 |
| **Ca** | " | 192.5 | 32.4 | 6 |
| **$PO_4$** | " | 30.1 | 4.5 | 7 |
| **$NO_3$** | " | 13.1 | 1.0 | 13 |
| **$NH_4$** | " | 1.3 | 0.9 | 1 |
| **DTN** | " | 21.6 | 3.5 | 6 |
| **DOC** | " | 252.6 | 47.2 | 5 |
| **ANC** | μeq $L^{-1}$ | 19378.6 | 2423.0 | 8 |
| **Conductivity** | μS $cm^{-1}$ | 3147.1 | 328.7 | 10 |
| **pH** | | 8.5 | 8.2 | |




Fresh Ash has elevated K compared to residual ash
K is 50% in Fresh vs 20% in ash, soils, water

Large concentration differences before and after the first winter.
Fresh Ash: losses to wind and leaching into soils.
Residual Ash: material available for Year 1 surface runoff and losses to stream.

# Tributary Water Quality Responses




**Post-fire higher for most analytes**

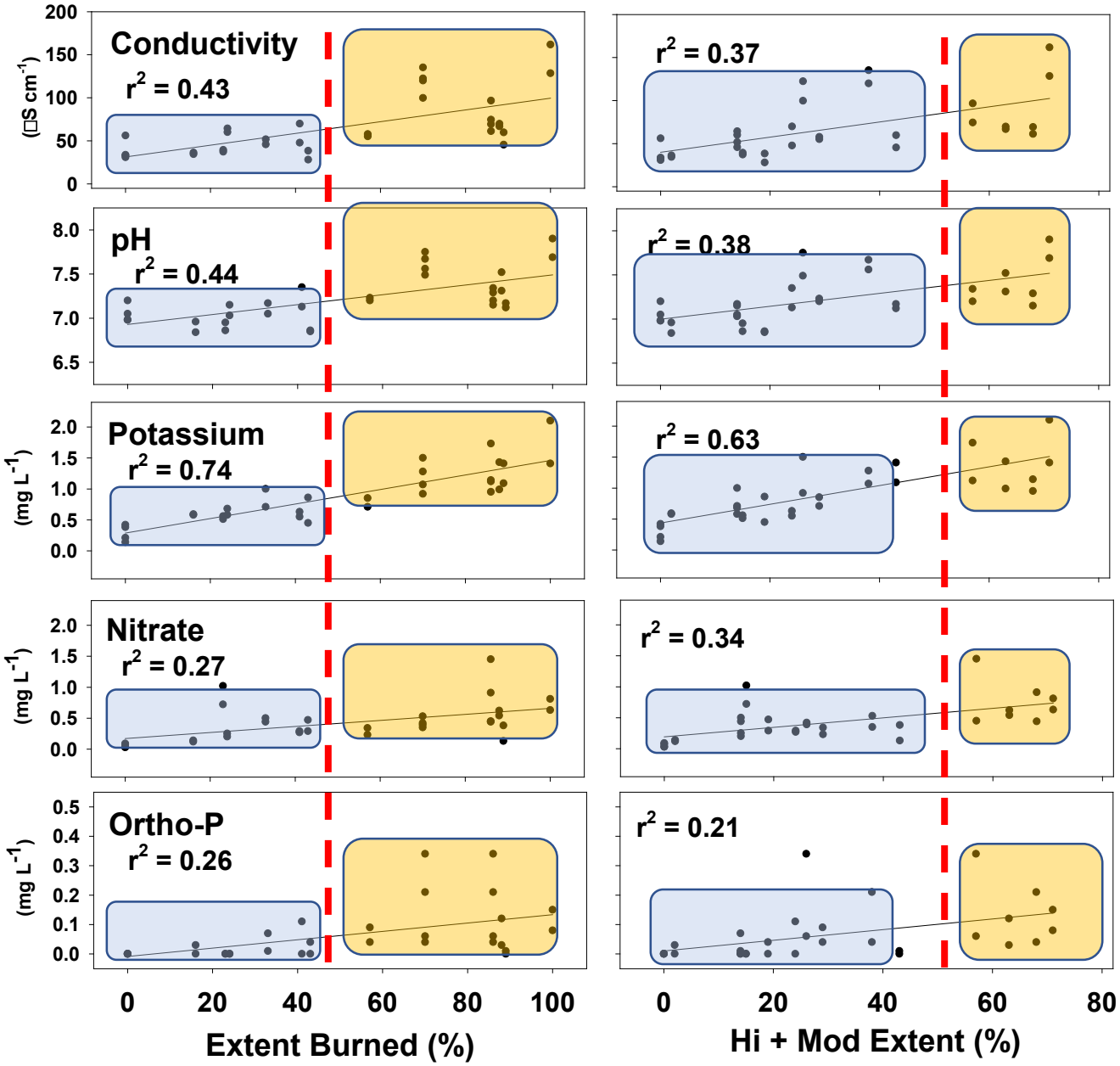
Cond, ANC, K, $NO_3$: 1.5 to 3-fold higher
$PO_4$, Turbidity: > 5-fold higher
pH: 0.4 unit pH higher

**Post-fire increased vs Pre-fire**

Cond, K, $NO_3$, $NH_4$, DTN, DOC: 2-fold increase
Turbidity: 10-fold increase
$PO_4$: 100-fold increase

*12 burned & 4 unburned catchments
4 pre- vs post-fire comparisons

# Extent Burned & Severity Determines Stream Chemistry




The overall extent of a watershed burned, and the extent burned at Hi + Mod severity impact water quality

**> 50% Burn Extent Threshold**

2X more than < 50% + Unburned

ANC, SC, Na, K, Mg, Ca, $NO_3$, SO4

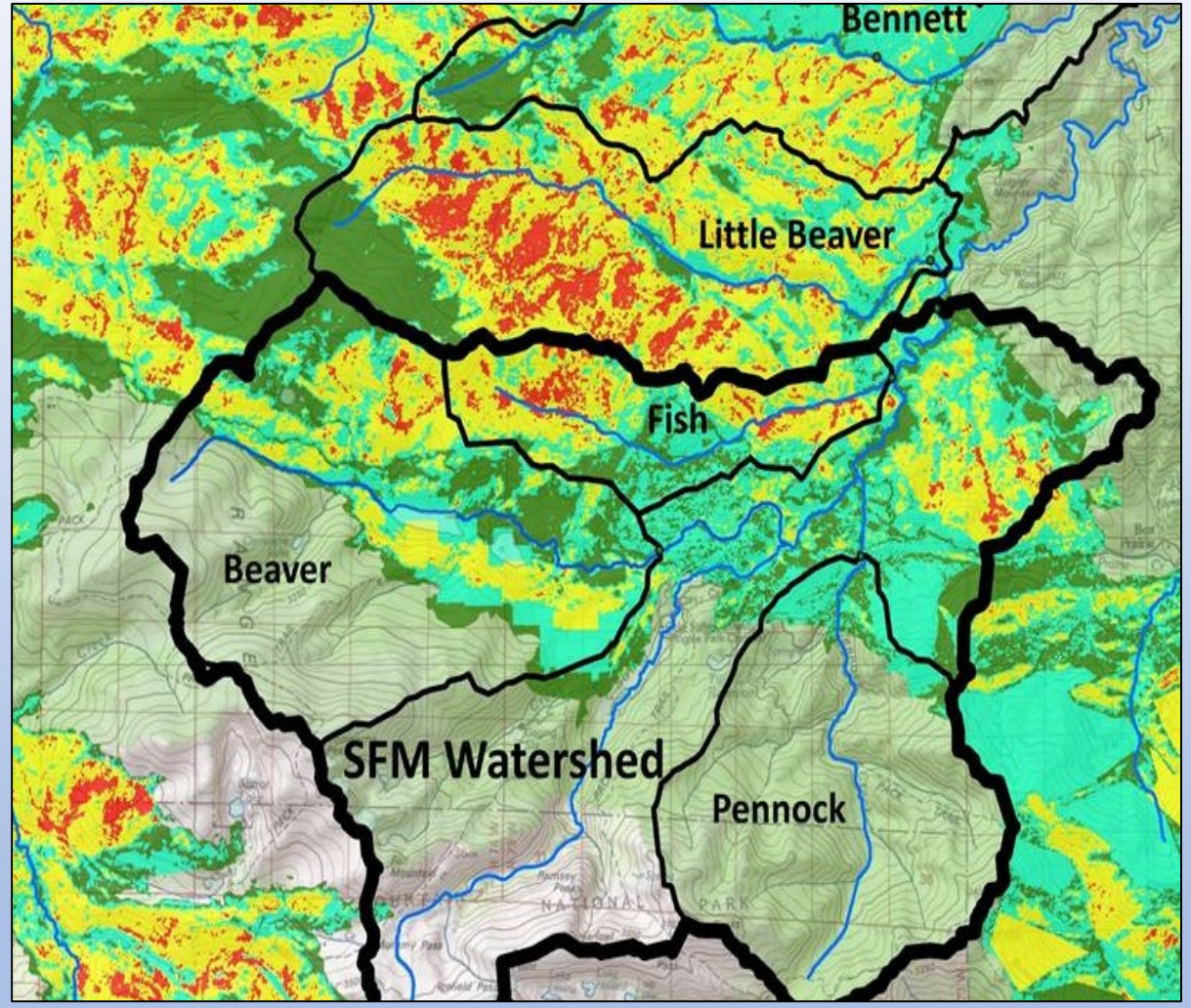
7X more $PO_4$; 6X more Turbidity

$NO_3$: Even watershed with lower extent burned were significantly higher than unburned

* 12 Burned & 4 Unburned catchments

Spring & Summer 2021

# Catchment Comparisons

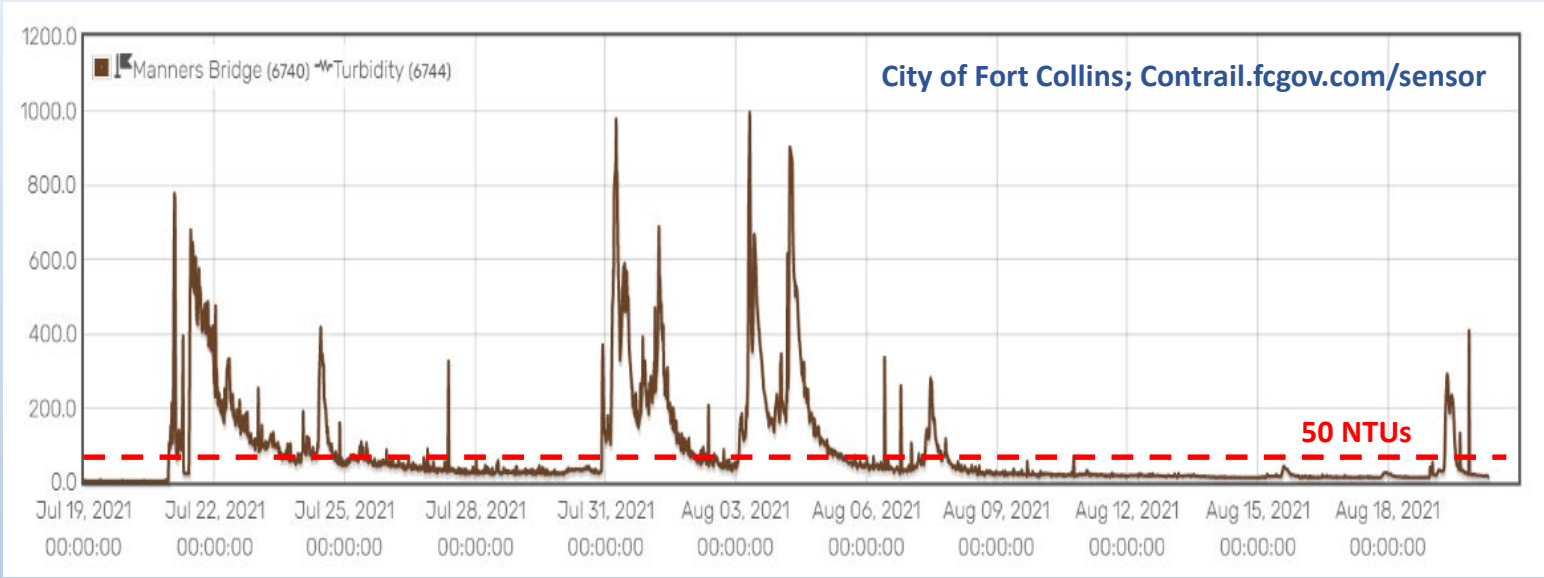



| | $NO_3$ | $PO_4$ | Burn | Hi + Mod |
|---|---|---|---|---|
| | mg $L^{-1}$ | | % | |
| **Fish** | 1.4 | 0.3 | 86 | 57 |
| **Little Beaver** | 0.9 | 0.2 | 86 | 68 |
| **Beaver** | 0.3 | 0.0 | 43 | 19 |
| **Bennett** | 0.4 | 0.2 | 70 | 38 |
| **S. Fk. Poudre** | 0.5 | 0.1 | 33 | 14 |
| **Pennock** | 0.1 | 0.0 | 16 | 0 |
| **Sheep** | 0.6 | 0.1 | 100 | 71 |
| **Black Hollow** | 0.6 | 0.1 | 88 | 63 |

**Larger Responses:** Extensive burning, burned headwaters, small catchments

**Smaller Responses:** Large catchments, unburned headwaters

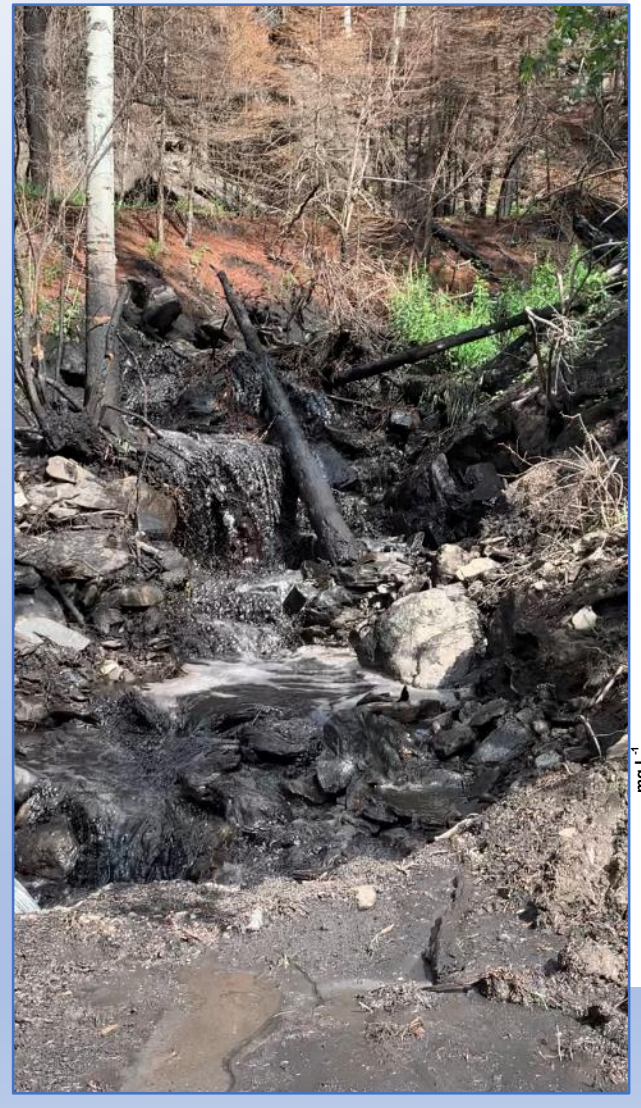
# Summer Monsoon Storms – *Major Watershed Changes*

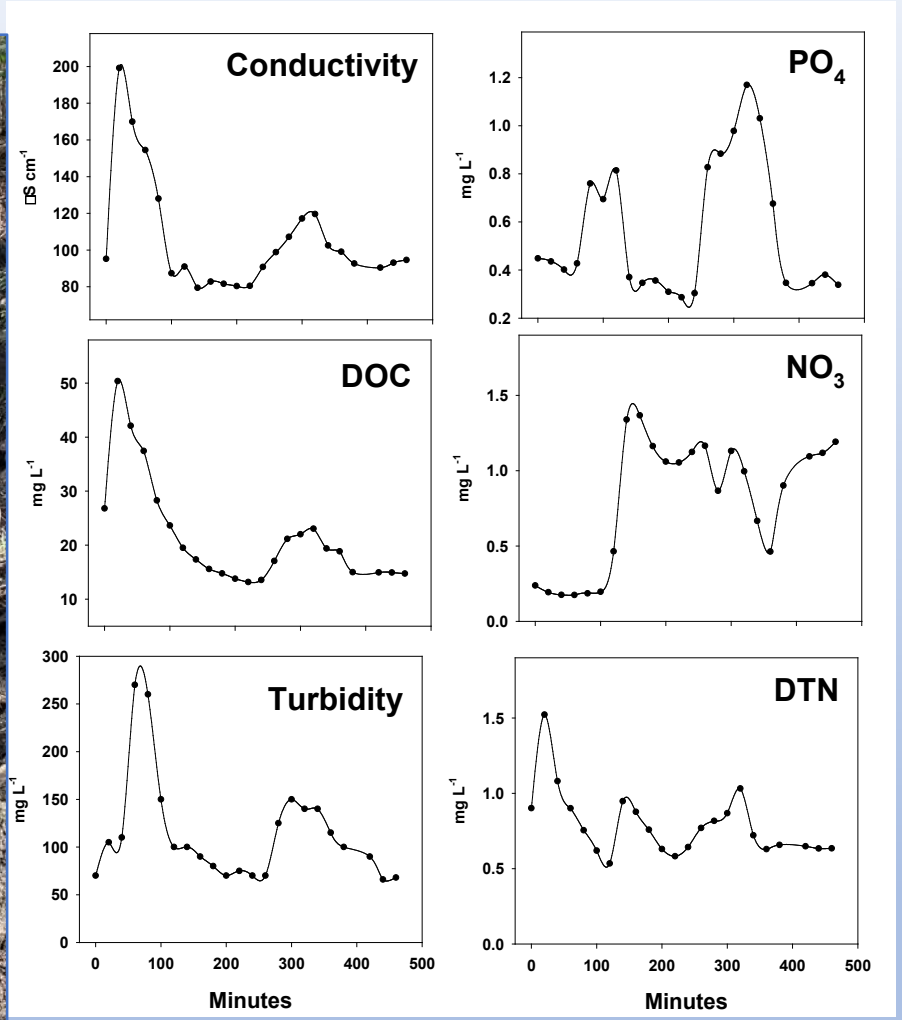



Fort Collins Utilities ceases taking water when turbidity exceeds 50 NTUs

| | Amount | Intensity ($I_{10}$) | Storm Duration | |
|---|---|---|---|---|
| | | | Downpour | Overall |
| | inches | in $hr^{-1}$ | minutes | |
| **Mean** | 0.4 | 0.8 | 16.7 | 133.1 |
| **Max** | 0.8 | 1.5 | 28.0 | 264.0 |

# Summer Storms - *Temporal Patterns in Stream Water*






| | Minutes to Peak | |
|---|---|---|
| | Mean | Max |
| Conductivity | 47 | 110 |
| Turbidity | 124 | 300 |
| DOC | 94 | 460 |
| DTN | 80 | 440 |
| $NH_4$ | 96 | 460 |
| $NO_3$ | 97 | 200 |
| $PO_4$ | 190 | 520 |

* 7 storms; Fish Ck

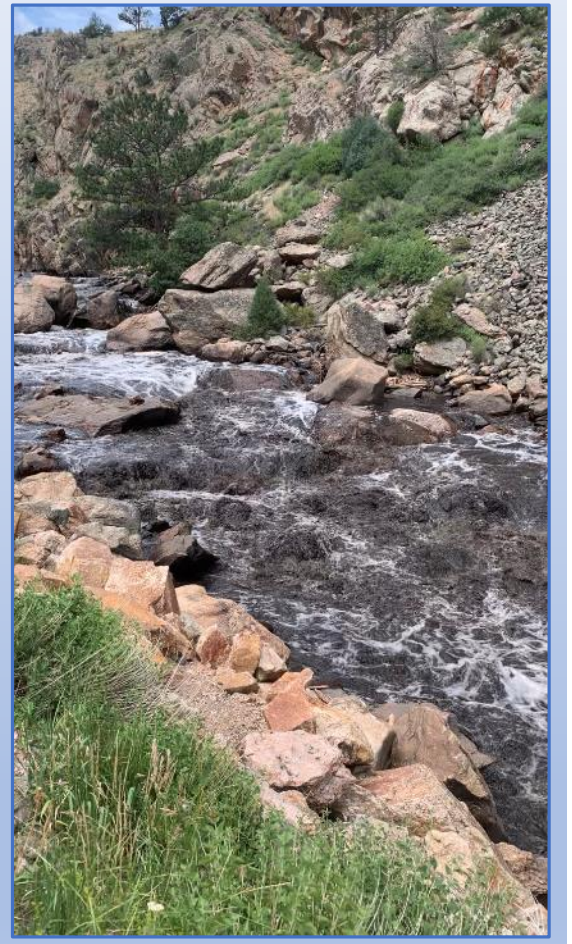
# Storm Events Mobilize Hillslope Ash

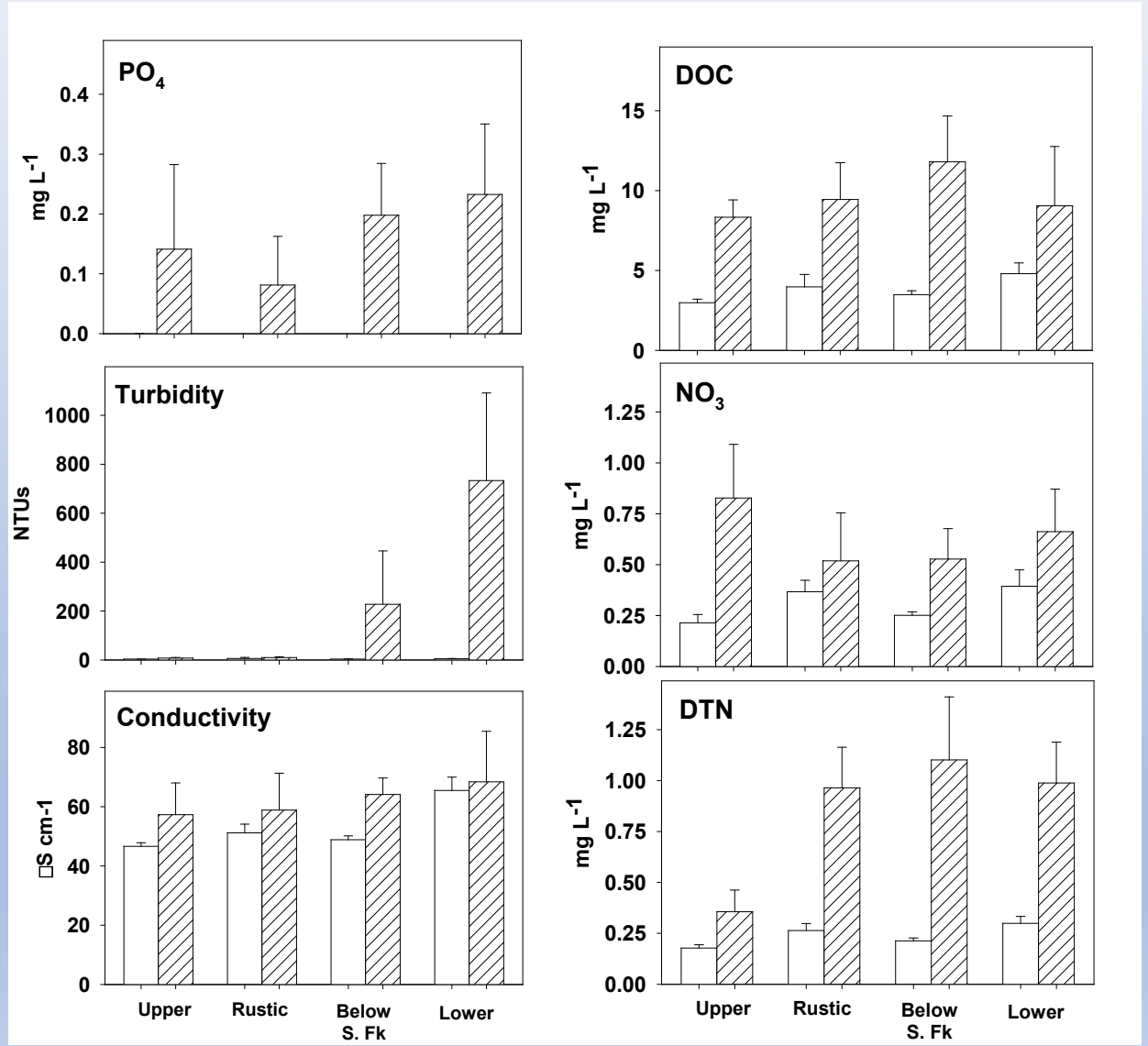
| | | Turbidity | Cond. | DOC | DTN | $NH_4$ | $NO_3$ | $PO_4$ |
|---|---|---|---|---|---|---|---|---|
| **Storm Events** | Mean | 1495.0 | 184.4 | 52.5 | 2.5 | 0.5 | 2.5 | 0.7 |
| Peak | Max | 1670.0 | 272.6 | 86.0 | 4.1 | 1.2 | 5.4 | 1.2 |
| **Non-Storm** | Mean | 7.4 | 82.9 | 7.3 | 0.7 | 0.0 | 0.9 | 0.2 |
| Monthly Mean | Max | 15.3 | 109.4 | 10.7 | 1.4 | 0.1 | 1.5 | 0.4 |
| **Storm vs Non** | Mean/Mean | 202 | 2 | 7 | 3 | 10 | 3 | 4 |
| X-fold increase | Max/Mean | 226 | 3 | 12 | 6 | 25 | 6 | 7 |

*Summary from 7 storms in July & August at Fish Crk ISCO

The first storms were largest with the biggest water quality responses.
The size and response both declined for latter storms.

# Monsoon Storms Effect CLP Water Quality



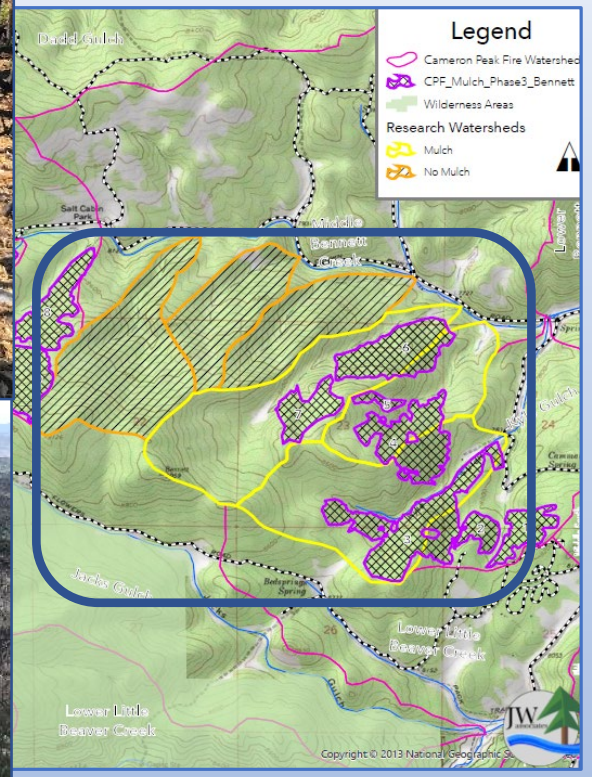



Responses extend & increase downstream

**Maximum Values**
Turbidity 1150 NTUs
DOC 21 mg/L
DTN 2.3 "
NO3 1.3 "
PO4 0.4 "

* 4 storms (7 & 8/21) vs. non-storm, post-fire

# Steps Toward Watershed Recovery




Mulch treatments to protect water quality, and speed recovery of soil productivity and vegetation.

Tree planting to rehabilitate highly impacted riparian vegetation and enhance watershed nutrient retention and improve water quality and aquatic habitat

# Preliminary Post-fire Responses

Ash is high in alkalinity, K, N and P, and these constituents are responsible for changes in downstream water quality in Yr 1.

Intense rain events have major effects on stream water quality that propagate down the main stem of the CLP.

Waters quality in burned tributaries is altered compared to pre-fire conditions and unburned streams.

Post-fire effects track the extent and patterns of burning in headwaters catchments

Stream waters quality responses help prioritize restoration activities and gauge restoration success

Go to **www.menti.com** and use the code **32 51 12 8**

# Has your municipality, agency or watershed group had to respond to changes in post-fire water quality? Yes/No? If so, how?

Press **ENTER** to pause scroll

# THANKS!

*Contact: charles.c.rhoades@usda.gov*

City of Fort Collins | City of Greeley | Coalition for the Poudre River Watershed | USDA Forest Service