Post-fire Impacts to Drinking Water Treatment

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Agenda

- Case Study: High Park Fire in northern Colorado
- Utility Response
- Overview of three AWWA-WRF Wildfire projects
  - Post-fire Monitoring of a Water Intake
  - Leaching of Wildfire-Affected Sediments
  - Laboratory Heating of Soil and Litter
- Summary and Recommendations

Water Research Foundation℠

Watershed Response	Treatment Implication
Increased particle loads	• Infrastructure problems • Coagulation, filtration, & disinfection challenges
Elevated nutrient levels	• Algal blooms • Algal organic matter
Altered dissolved organic matter	• Coagulation challenges • DBP formation & speciation

Goal: *connect post-fire water quality changes directly to impacts on treatment process performance and finished water quality*

Case Study- High Park Wildfire

- The High Park wildfire burned the Cache la Poudre (CLP) watershed in northern Colorado

- Burned from June 9th- July 1st, 2012
  - 87,000 acres at mixed severities
  - Burned ~10% of total watershed

- The CLP River provides water to several northern Colorado communities

Photo Credit: Michael Menefee

Watershed Response

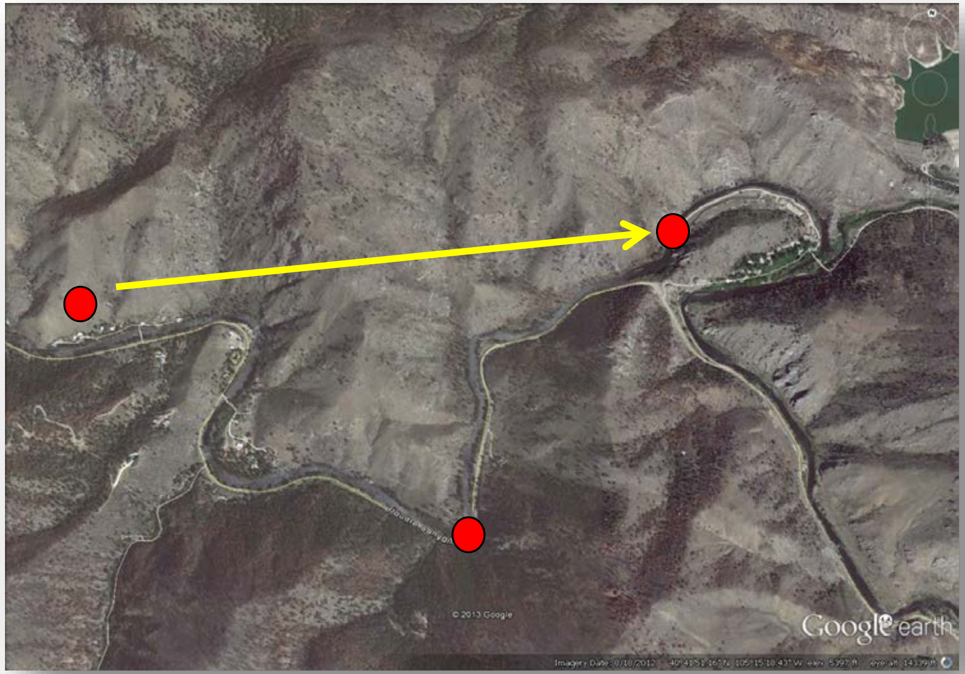
- Extensive loss of vegetation
- Moderate to high soil burn severity
- Hydrology shifted from subsurface to surface flow
- Even small, previously dry tributaries experienced very high, “flashy” flows

Fort Collins Utility Response

- Shut down CLP River water supply
- Used alternate water source (Horsetooth Reservoir) for over 100 days
- CLP River water was slowly blended back into drinking water source
- When turbidity exceeded 100 NTU the river intake was shut off again
- Rapidly designed and constructed a pre-sedimentation basin

Fort Collins Utility Response

- Installed early warning system
- Provides ~ 1 hour warning of highly turbid water
- Allows operators to shut down pipeline and avoid large sediment loads



Research Approach

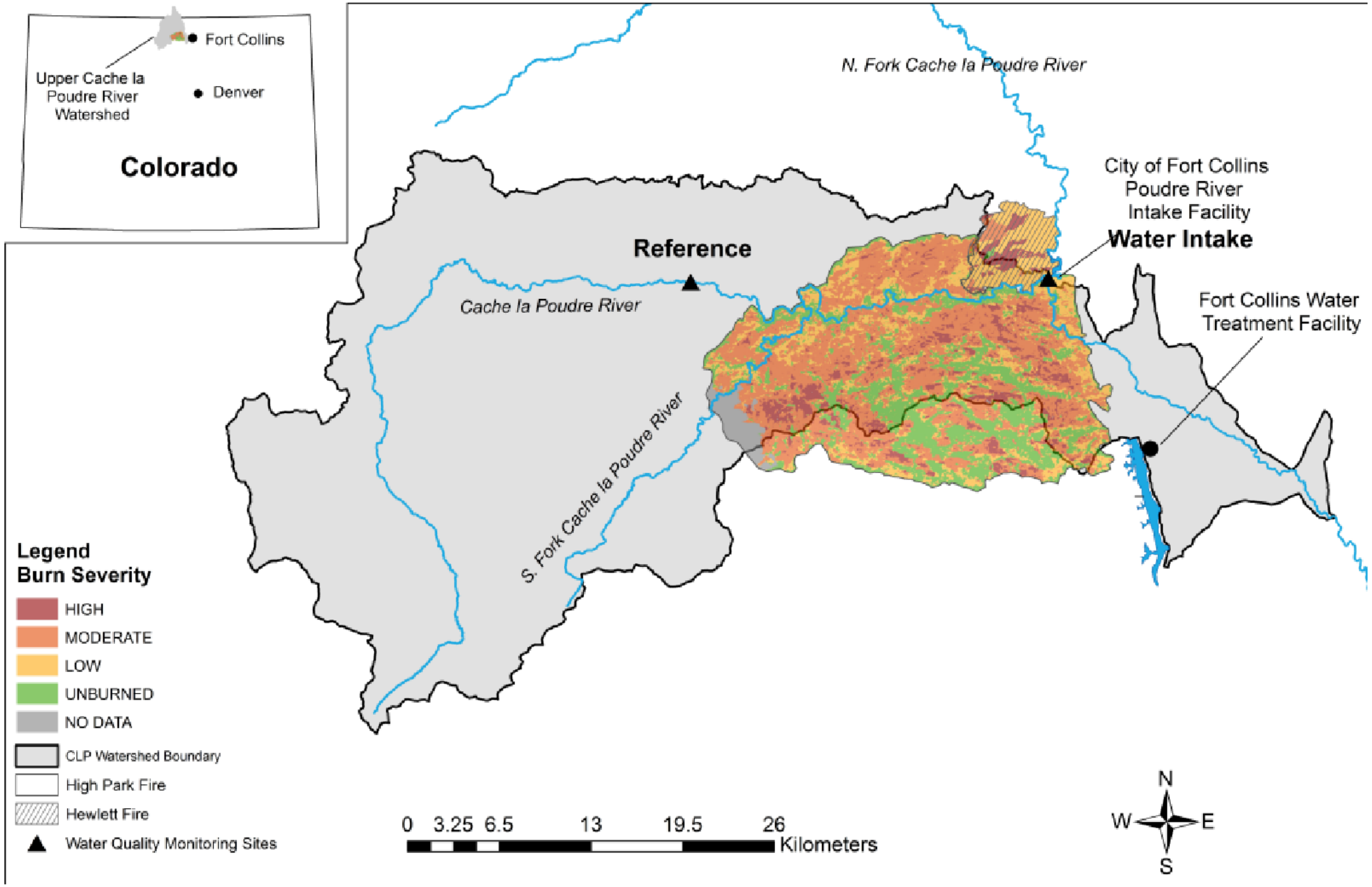
Bench-scale Treatability Evaluation

1. Post-fire monitoring of a drinking water intake

2. Leaching of wildfire-affected sediments

3. Controlled laboratory heating and leaching of soil and litter

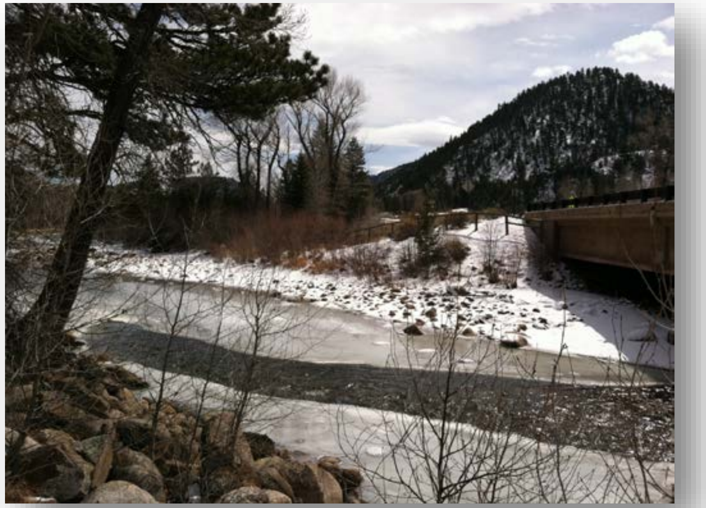
Study 1. Post-fire Monitoring



- Monitored bi-weekly during baseflow and snowmelt
- Post-rainstorm samples collected from intake

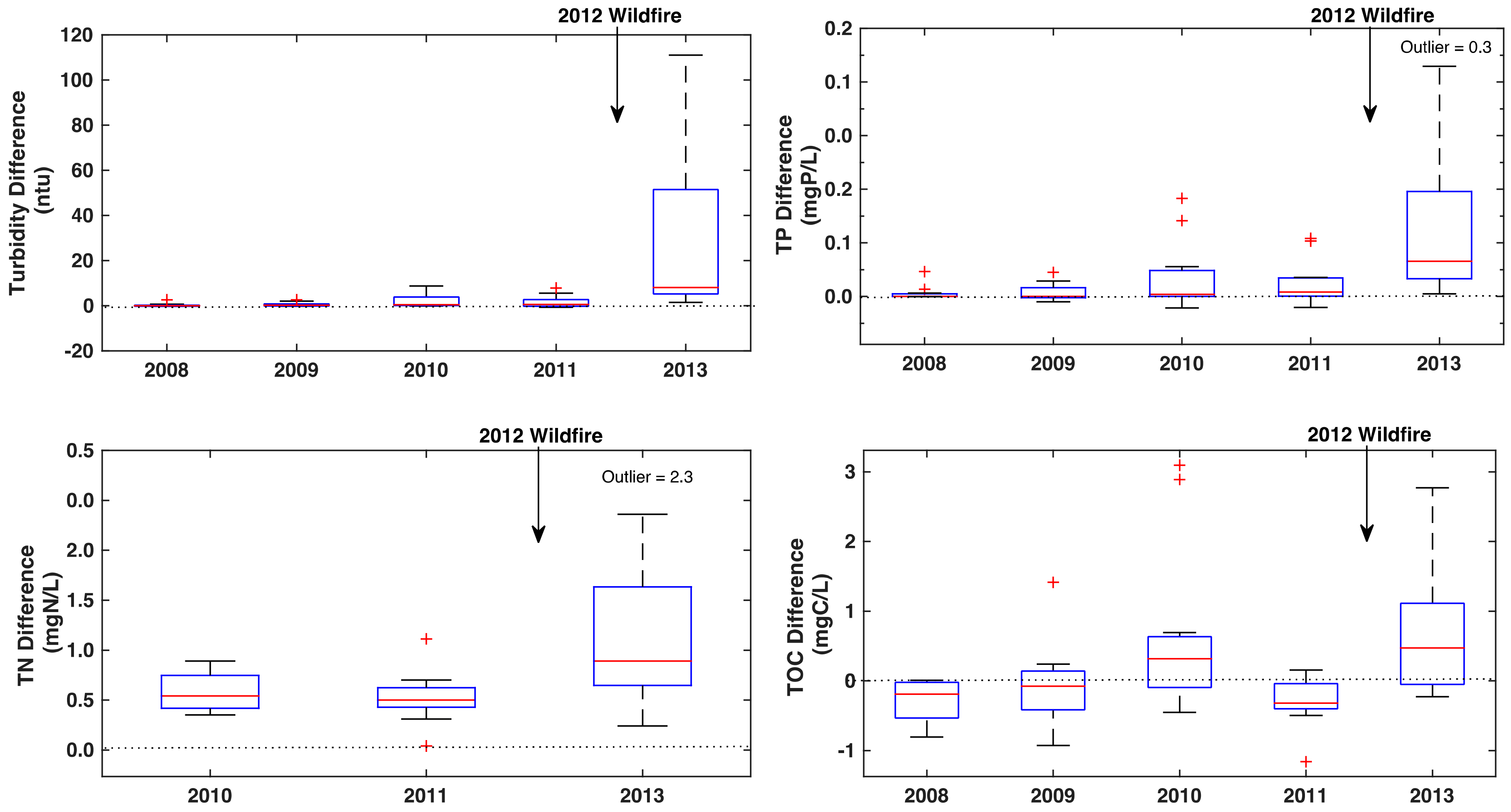
Water Intake

Reference Site



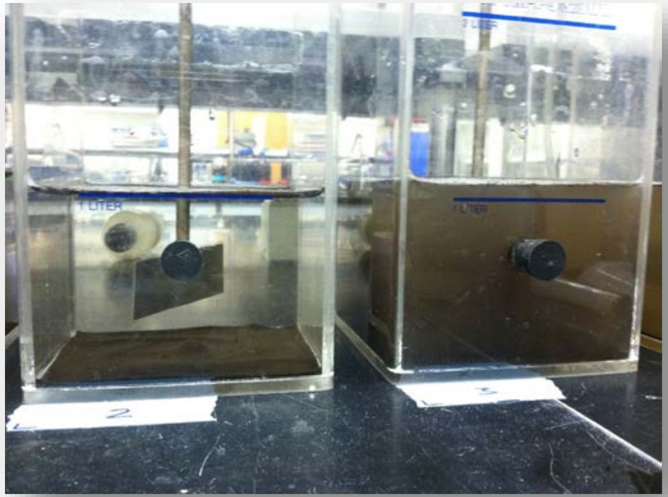
Pre- and Post-fire Water Quality

Hohner et al., 2016, Water Research

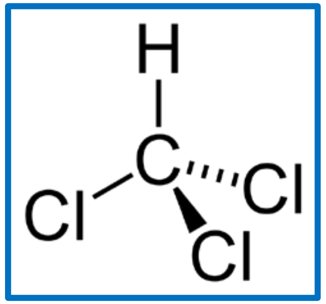


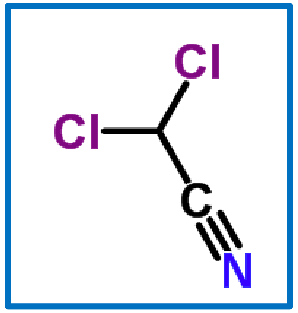
- Paired differences in water quality (intake – reference site)
- Dashed line (difference = 0)
- *Post-rainstorm samples were not included

Treatability Evaluation



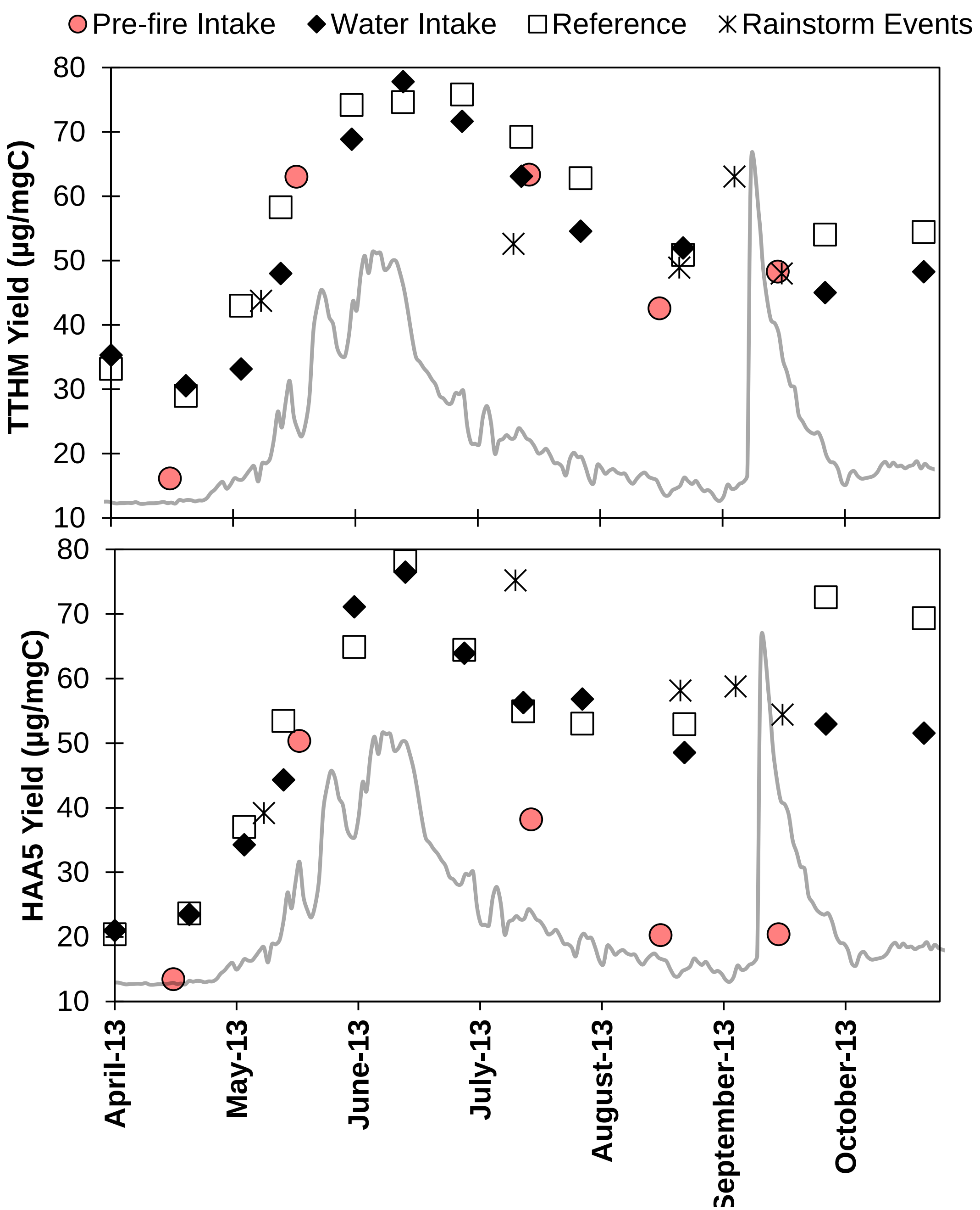
- Conventional treatment with aluminum sulfate
- Coagulant dose selected based on optimal DOC removal
- Raw and treated water samples were chlorinated and analyzed for disinfection byproduct formation (DBPs)
  - Carbonaceous DBPs
    - Total trihalomethanes (TTHMs)
    - Five haloacetic acids (HAA5s)
  - Nitrogenous DBPs
    - Haloacetonitriles (HANs)
    - Chloropicrin





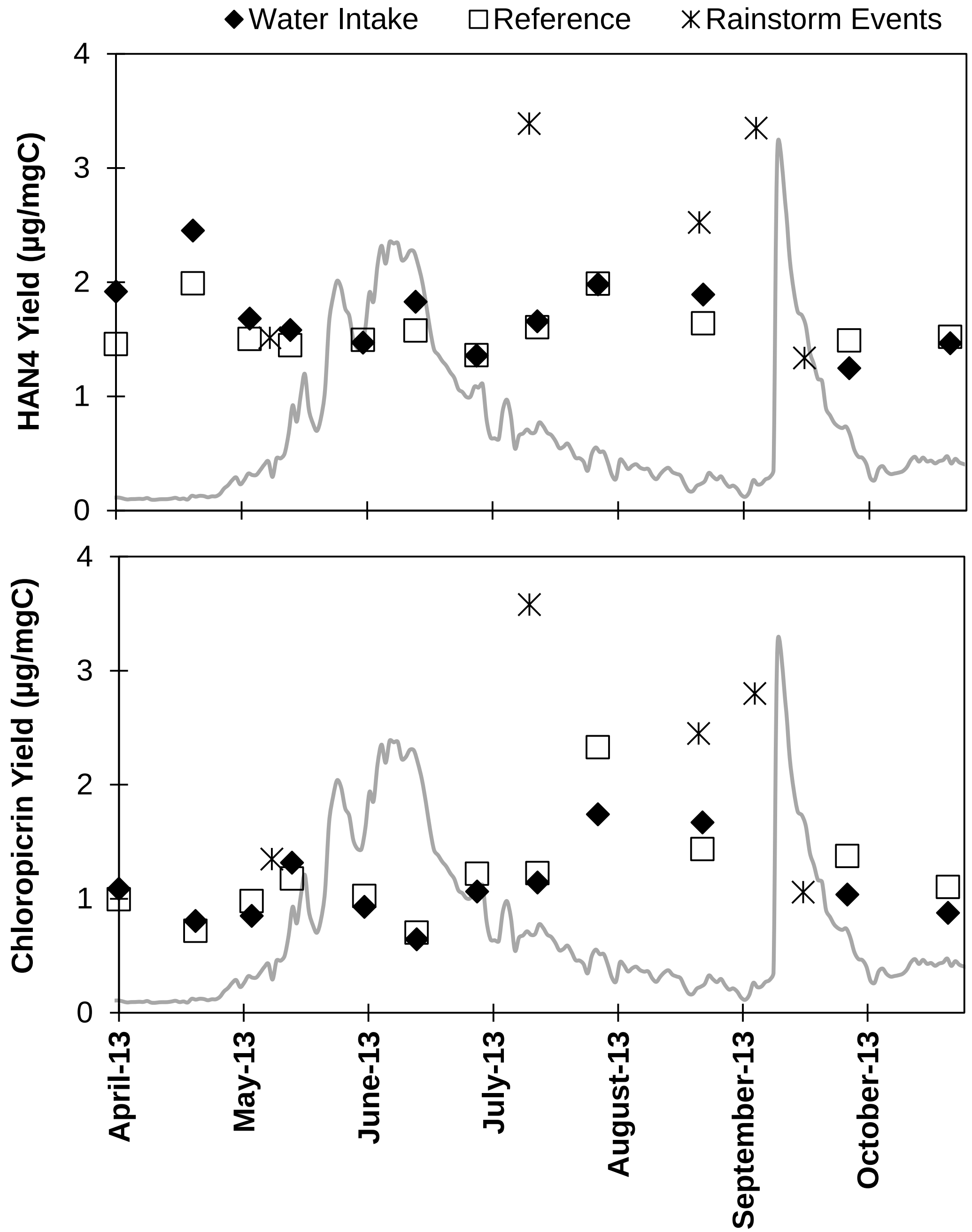
Watershed Monitoring: Raw Water C-DBPs

- TTHM formation (µg/L) was significantly higher at the water intake
- C-DBP yields peaked with snowmelt
- C-DBP yields were not significantly different following the wildfire
- Post-rainstorm C-DBP yields were similar to baseflow & snowmelt samples

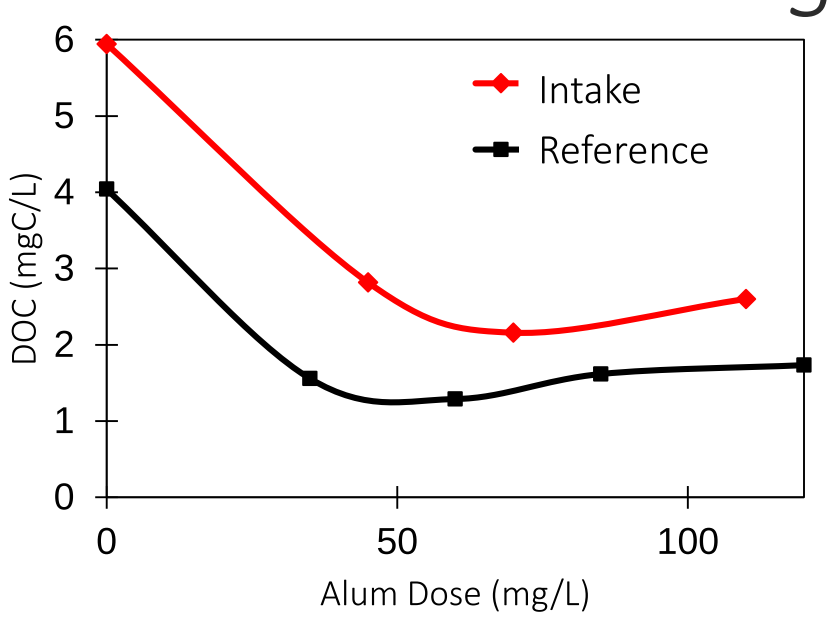


Watershed Monitoring: Raw Water N-DBPs

- HAN4 formation (µg/L) was significantly higher at the water intake
- N-DBP yields did not follow the same seasonal trend as C-DBPs
- N-DBP yields were similar for the water intake and reference site
- Post-rainstorm N-DBP formation and yields were elevated



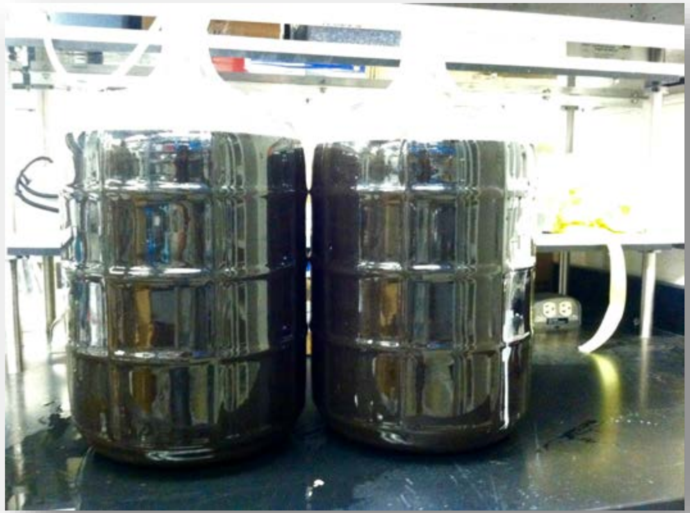
Watershed Monitoring: Treatment Response



- During baseflow and snowmelt significantly higher alum dose (10 mg/L) required for water intake
- Post-rainstorm samples presented treatment challenges, and even at high alum doses (>65 mg/L) showed minimal DOC removal (< 10%)
- Post-fire samples had high initial turbidity (>200 ntu) and high DOC
- Five post-rainstorm samples exceeded DBP MCLs

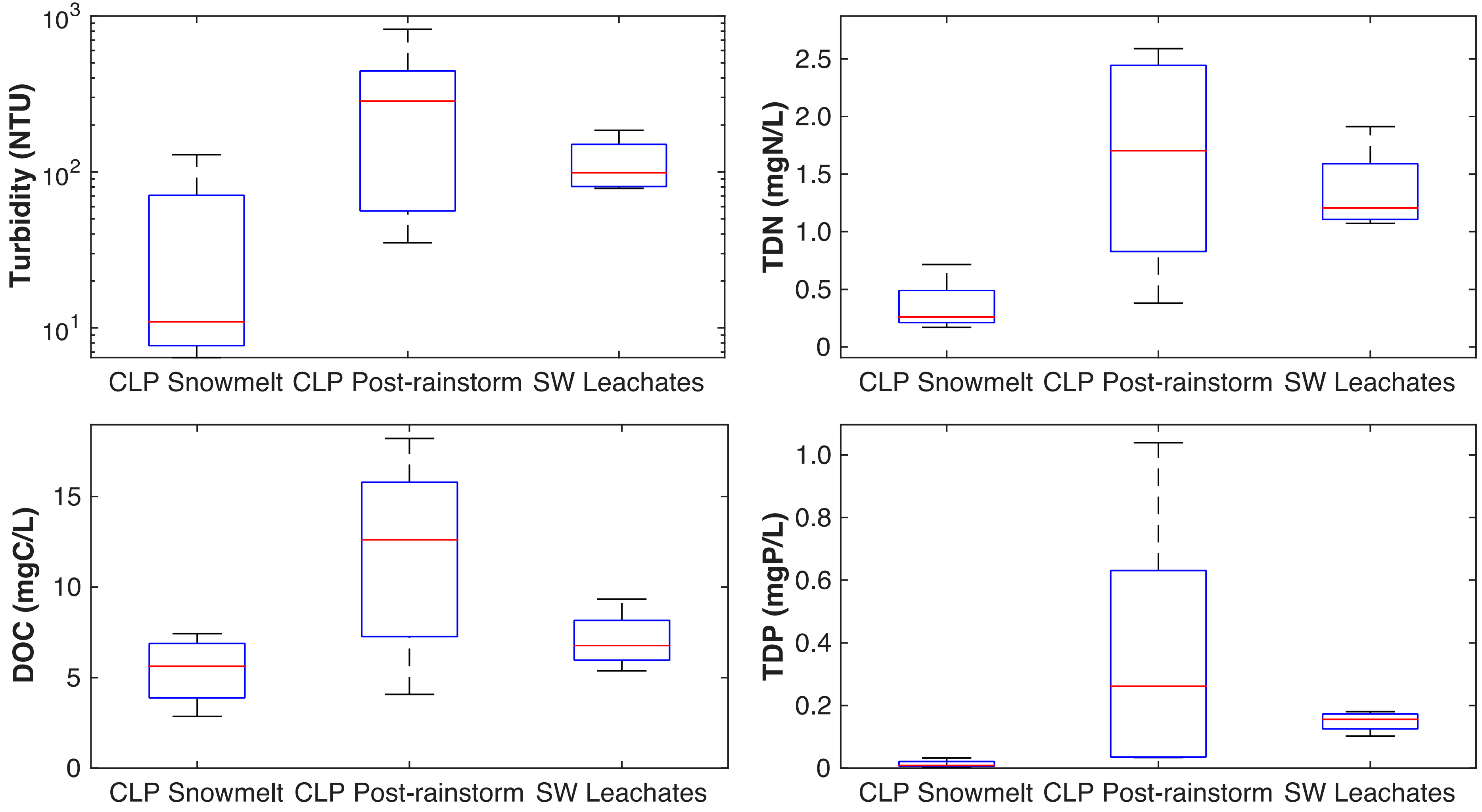
Study 2. Wildfire-affected Sediment Leaching

- **Source Water Leachates:**
  - Sediments added to source waters for two utilities
    - Fort Collins (baseline)
    - Denver Water (baseline)
- **LCT Leachates:**
  - Sediments added to low-carbon tap-water (LCT)

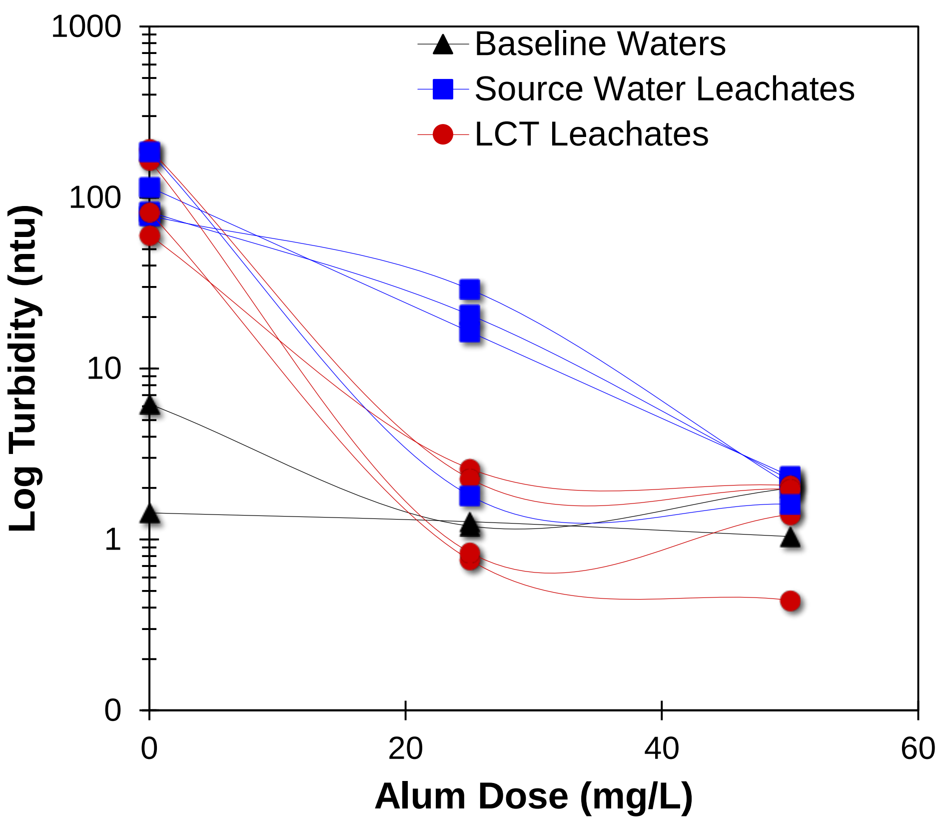


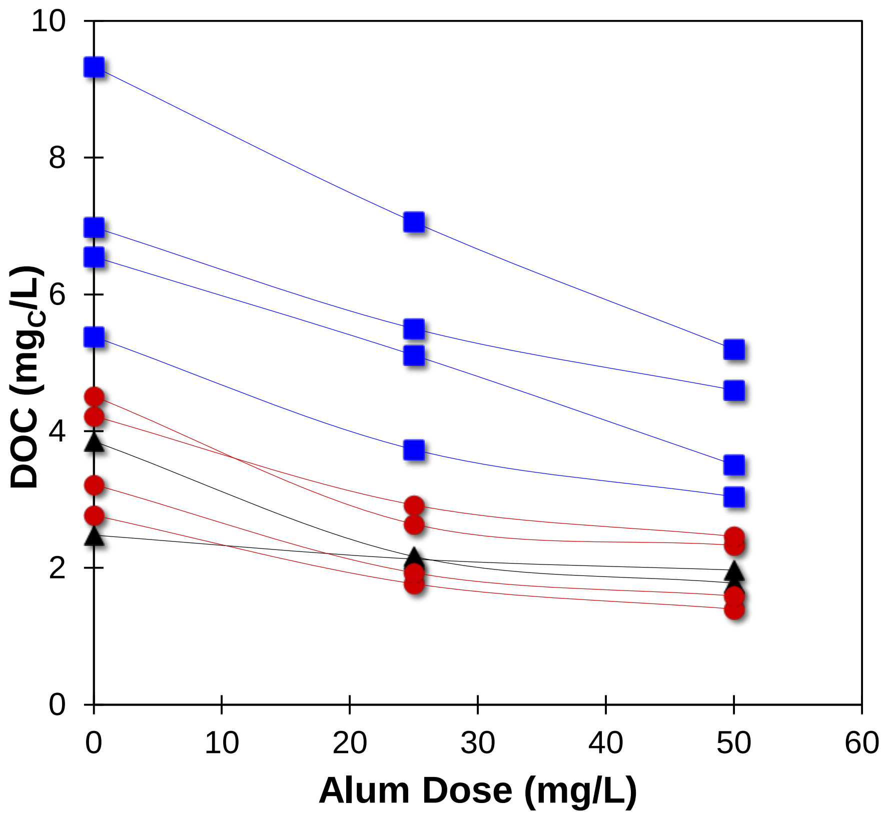
- **Treatment processes evaluation:**
  - Coagulation
  - Pre-oxidation/Coagulation
  - Powdered activated carbon (PAC) + Coagulation
  - Biofiltration/Coagulation
  - Ozonation/Coagulation/Biofiltration

CLP River Water and Sediment Leachate Comparison



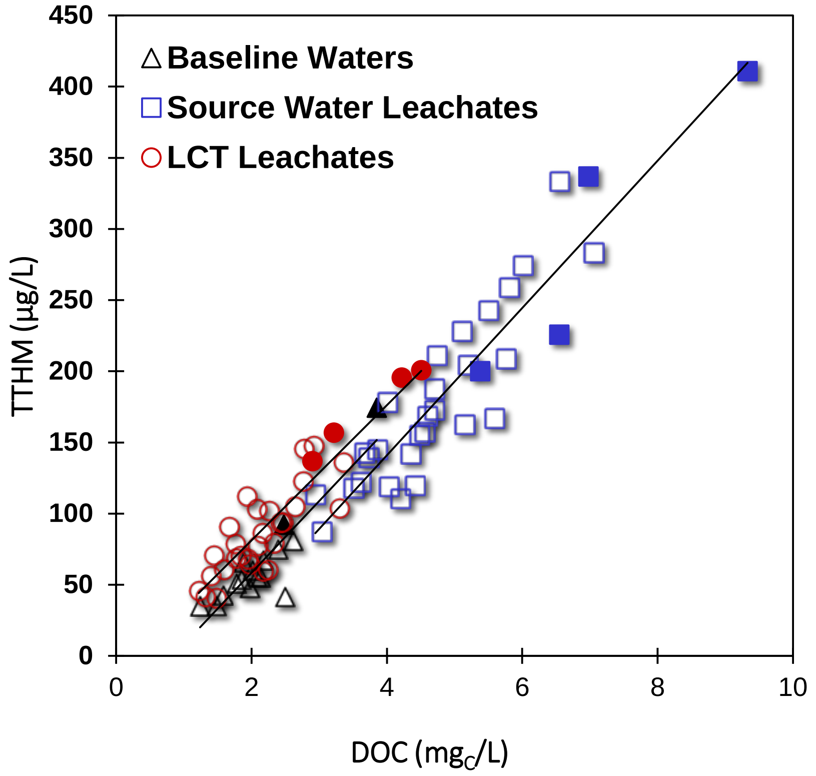
Sediment Leachates: Coagulation Response

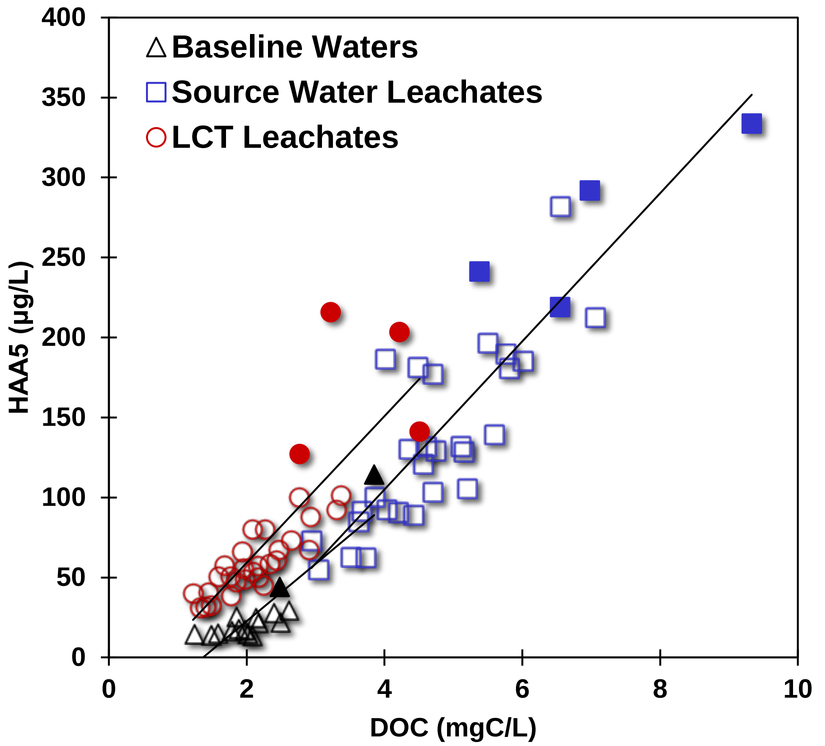




Hohner et al., 2017, Environmental Science: Water Research & Technology

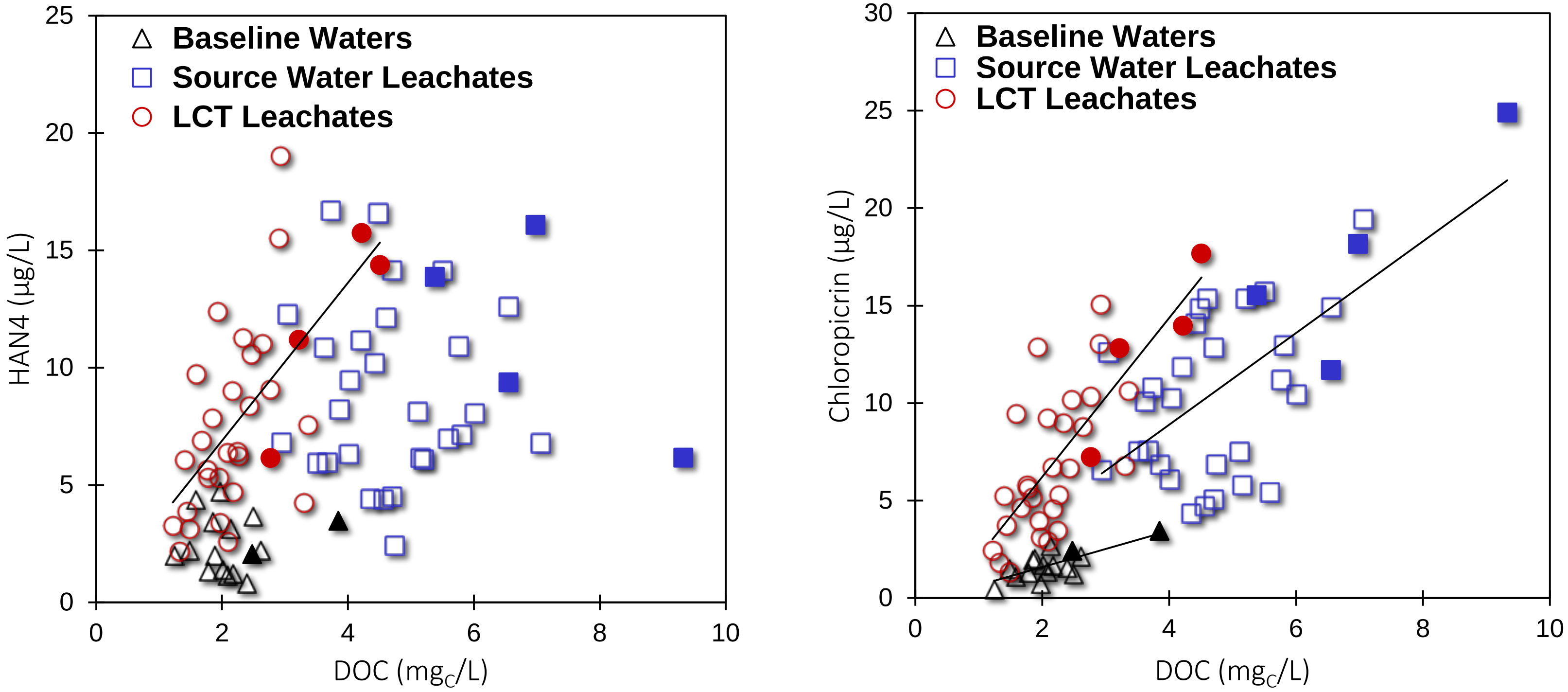
Sediment Leachates: C-DBP Formation





- Solid symbols represent raw samples and open symbols show treated samples
- Trends were significant for all sample groups ($p < 0.001$)
- Slopes for different sample groups were <u>not</u> significantly different ($p > 0.05$)

Sediment Leachates: N-DBP Formation



- HAN4 trend was significant ($p < 0.001$) for the LCT leachates
- Slopes for the different sample groups were significantly different ($p > 0.05$)
- Sediment leachates appear enriched in N-DBP precursors

1. DBP MCLs were used to assess treatability of the sediment leachates

$$TTHM\ MCL = 80\frac{\mu g}{L} \qquad HAA5\ MCL = 60\frac{\mu g}{L}$$

2. DBP Yields were used for comparison of samples with varying DOC

$$DBP\ Yield = \frac{DBP\ concentration\ \frac{\mu g}{L}}{DOC\ concentration\ \frac{mgC}{L}}$$

3. Required DOC threshold values for the point of chlorination were determined

$$DOC\ Threshold = \frac{DBP\ MCL\ \frac{\mu g}{L}}{DBP\ Yield\ \frac{\mu g}{mgC}}$$

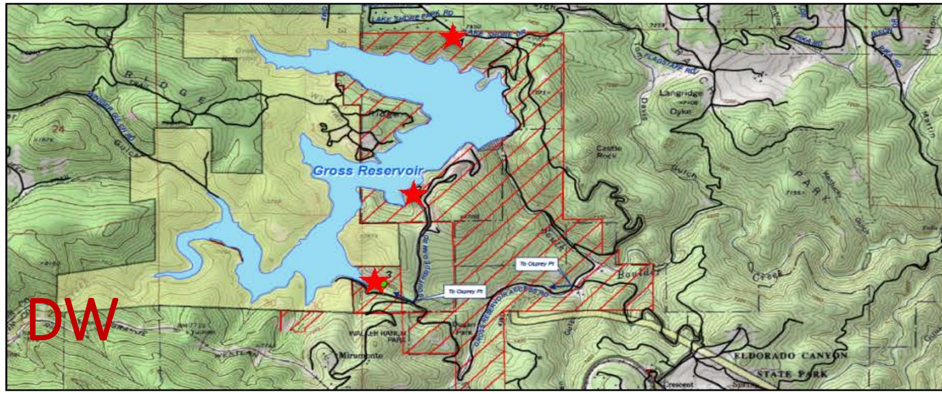
4. The more restrictive DOC threshold was chosen (TTHM or HAA5)- lower required treated water DOC concentration for meeting MCLs

Sample Name		DOC Threshold (mg_C/L)							Best Treatment Option
		Conventional Treatment	Enhanced Coagulation	PAC	Chlorine Dioxide	Pre-ozonation	Biofiltration	Pre-ozonation/ Biofiltration	
Baseline Waters	Fort Collins (FC)	2.6	2.8	2.3	2.6	2.7	2.6	3.0	Pre-ozonation/ Biofiltration
	Denver Water (DW)	3.1	3.3	2.8	4.8	3.0	2.7	3.3	Chlorine Dioxide
Average increase in DOC threshold			0.2	-0.3	0.8	0.0	-0.2	0.3	
Source Water Leachates	A- FC	2.0	2.0	1.8	1.8	2.4	1.4	2.2	Pre-ozonation
	B- DW	1.7	2.1	1.8	1.8	3.0	1.6	2.6	Pre-ozonation
	C- DW	2.1	2.8	2.1	2.1	2.8	2.4	2.1	Enhanced Coag & Pre-ozonation
	D- FC	1.8	2.4	1.3	2.0	2.4	1.8	2.3	Enhanced Coag & Pre-ozonation
LCT Leachates	A- LCT	2.0	2.3	1.8	2.1	2.6	1.6	2.4	Pre-ozonation
	B- LCT	1.6	2.1	2.0	2.0	1.7	1.7	2.1	Enhanced Coag & Pre-ozonation/Bio
	C- LCT	1.4	1.9	2.1	1.7	3.0	1.5	2.1	Pre-ozonation
	D- LCT	2.1	2.0	1.8	2.2	2.7	1.6	2.5	Pre-ozonation
Average Increase in DOC threshold			0.4	0.0	0.1	0.7	-0.1	0.5	Pre-ozonation

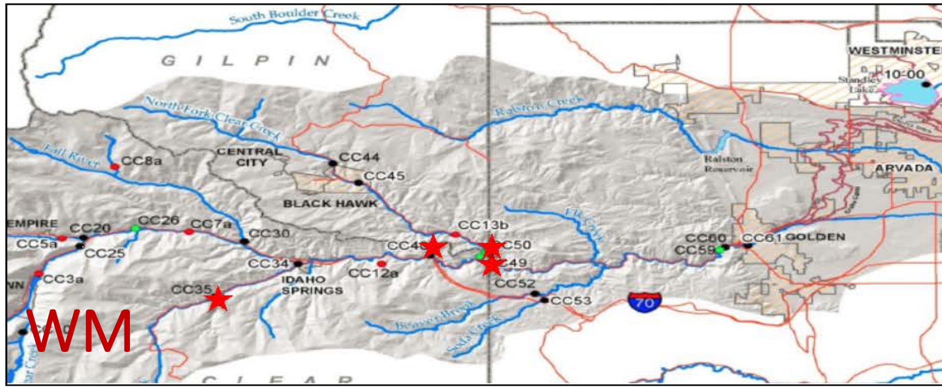
Study 3: Controlled Heating

- Objective: Understand the effects of a low-moderate severity wildfire on dissolved organic matter and treatability

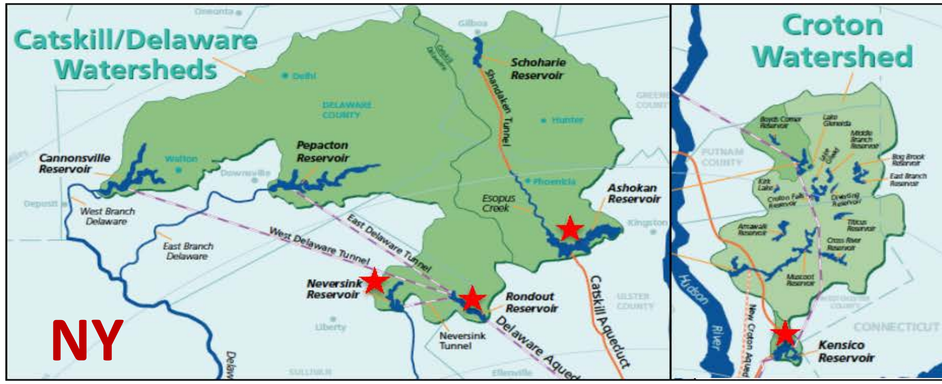
- Surface litter and soil samples were collected from three source watersheds



Denver, Colorado



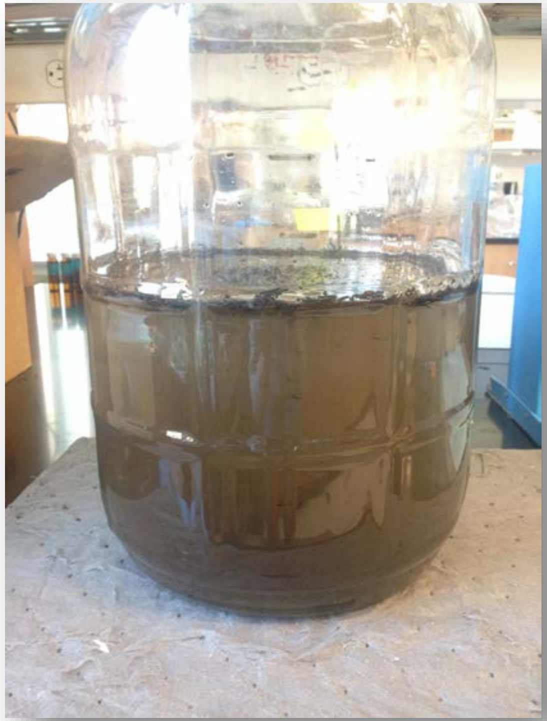
Westminster, Colorado



New York City, New York

Controlled Laboratory Heating

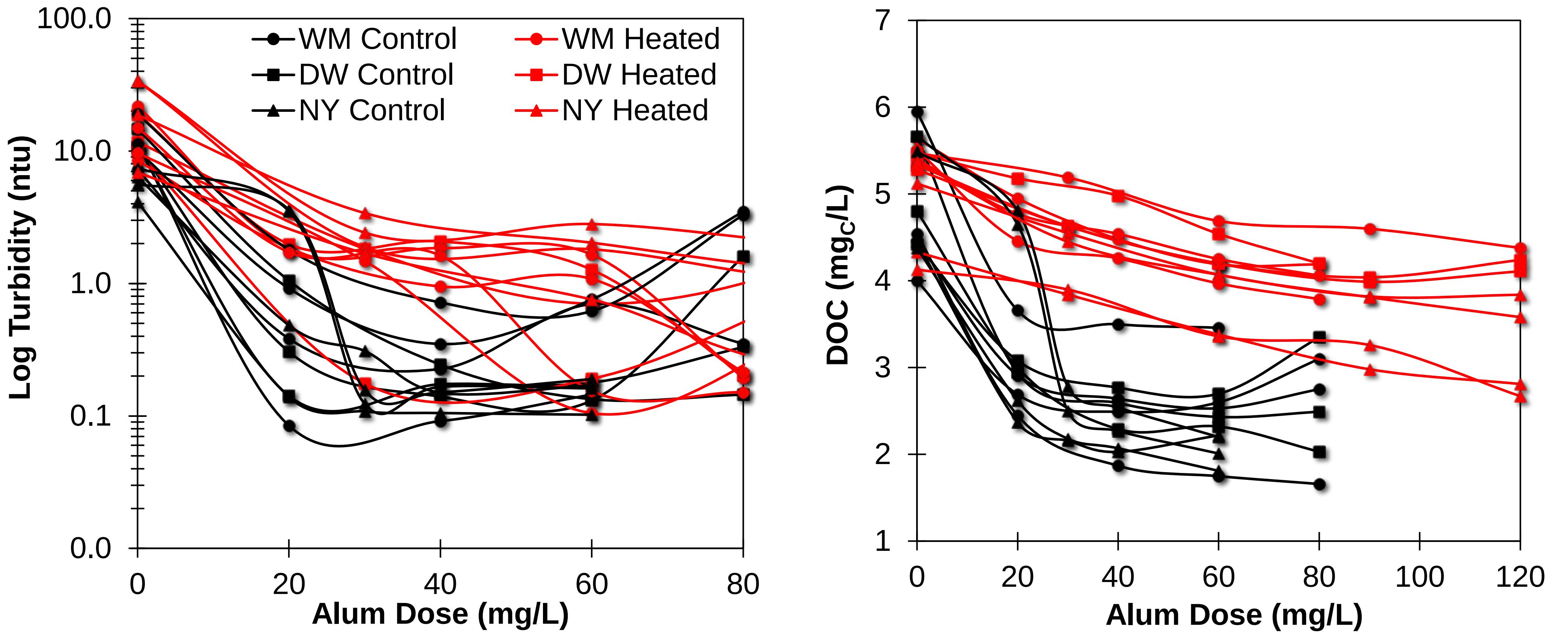
- Materials were heated in a furnace at 225°C for two hours
- Soil and litter were composited
- Unheated (control) and heated materials were leached for 24 hours in LCT water
- Leachates were diluted to a DOC concentration = 5.0 ± 1.0 mg_C/L



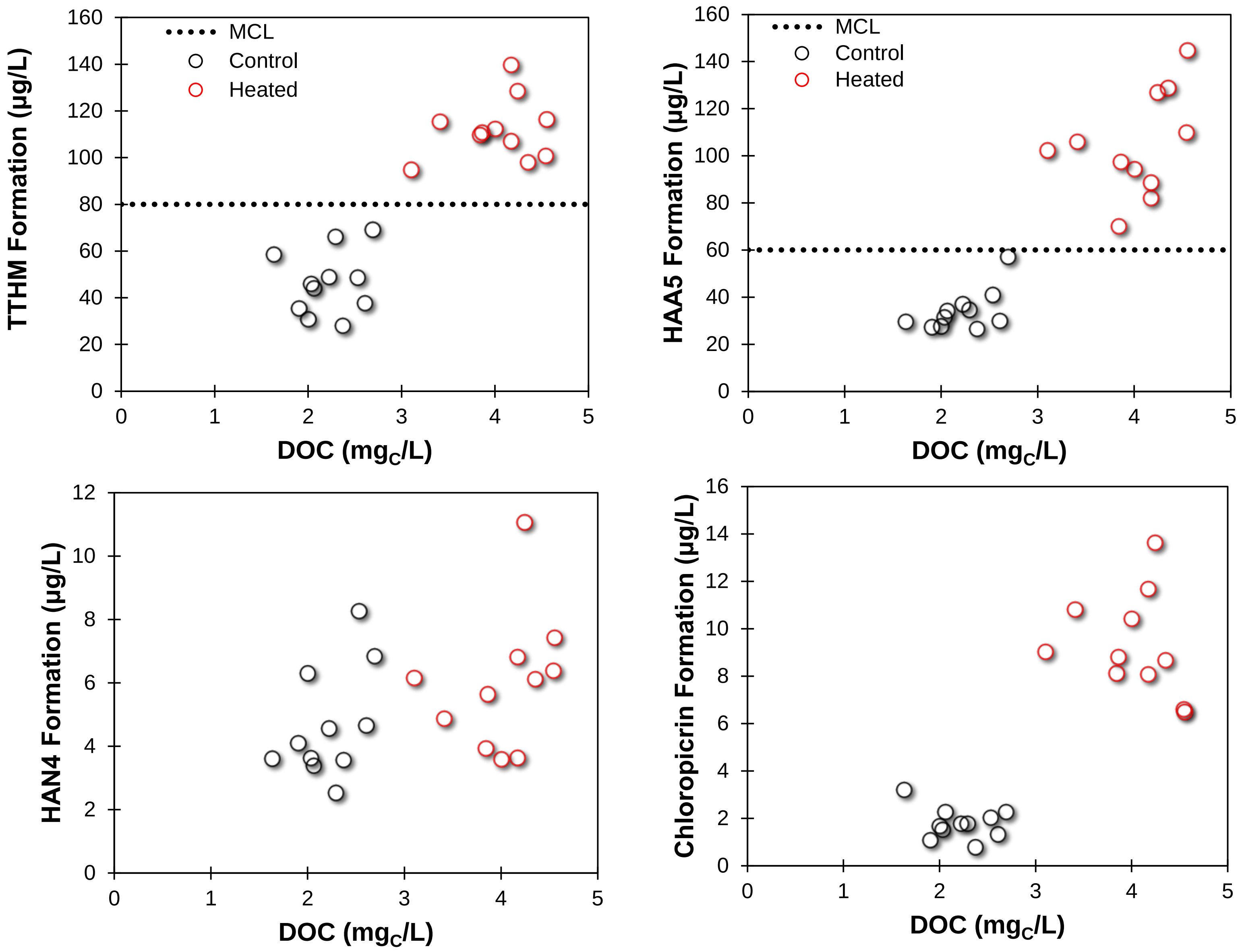
Controlled Heating: Dissolved Organic Matter (DOM)

- Heating altered the DOM character:
  - Nitrogen enriched: DOC:DON ↓
  - More aromatic: $SUVA_{254}$ ↑
  - Lower molecular weight compounds

Controlled Heating: Jar Test Response



Controlled Heating: Treated Water DBP Levels



Research Summary

- A small wildfire may impact water quality and treatment
- Post-rainstorm samples presented the greatest treatment challenges
- Additional treatment may be required to meet DBP MCLs
- Attention should be given to post-fire N-DBP precursors
- DOM character may be altered by wildfire heating

Recommendations

- Capital Investment Considerations
  - Expanding water storage capacity
  - Exploring additional supplies
  - Increasing monitoring
  - Constructing pre-sedimentation basins

- Treatment Operations
  - Increase coagulant dose to account for higher turbidity and DOM
  - Increased solids loading, greater costs, shorter filter runs
  - Difficulty meeting DBP regulations

- *Small, single source water treatment systems may be at greatest risk*

Acknowledgments

- Water Research Foundation
- Colorado Department of Public Health & Environment
- Hazen & Sawyer
- Water Utilities
  - Denver Water, NYC Department of Environmental Protection, City of Westminster, San Francisco Public Utilities Commission, Truckee Meadows Water Authority, Metropolitan Water District of Southern California, City of Fort Collins
- University of Colorado
  - Jeffrey Writer, Dorothy Noble, Kaelin Cawley, Jack Webster, Leigh Gilmore, Eli Townsend, Ariel Retuta, Garrett McKay, Andrew Moscovich, Wade Godman

Additional Resources

- Becket et al., 2018, Journal AWWA
- Hohner et al., 2016, Water Research
- Hohner et al., 2017, ESWRT
- WRF 4590 Report, 2018
- Writer et al., 2014, Journal AWWA
- **Contact:** Amanda Hohner, Washington State University, ahohner@wsu.edu

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Drinking water treatment response following a Colorado wildfire

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PAPER

WILLIAM C. BECKER, AMANDA HOHNER, FERNANDO ROSARIO-ORTIZ, AND JAMES DEWOLFE

Preparing for Wildfires and Extreme Weather: Plant Design and Operation Recommendations