Post-Wildfire Distribution System Water Quality Impacts and Potential Responses

Andrew Whelton, Ph.D., awhelton@purdue.edu

A special thanks to the many people who made this possible

PURDUE UNIVERSITY | Center for Plumbing Safety

www.PlumbingSafety.org

Home | About Us | Current Projects | COVID-19 Response | Resources | Opinions | News | Intranet

PURDUE / ENGINEERING / PLUMBING SAFETY / RESOURCES

Resources

- Plumbing 101
- Flushing Plans
- Plumbing Demonstrations - Camp Fire
- Video / Audio

Response and Recovery to Wildfire Caused Drinking Water Contamination

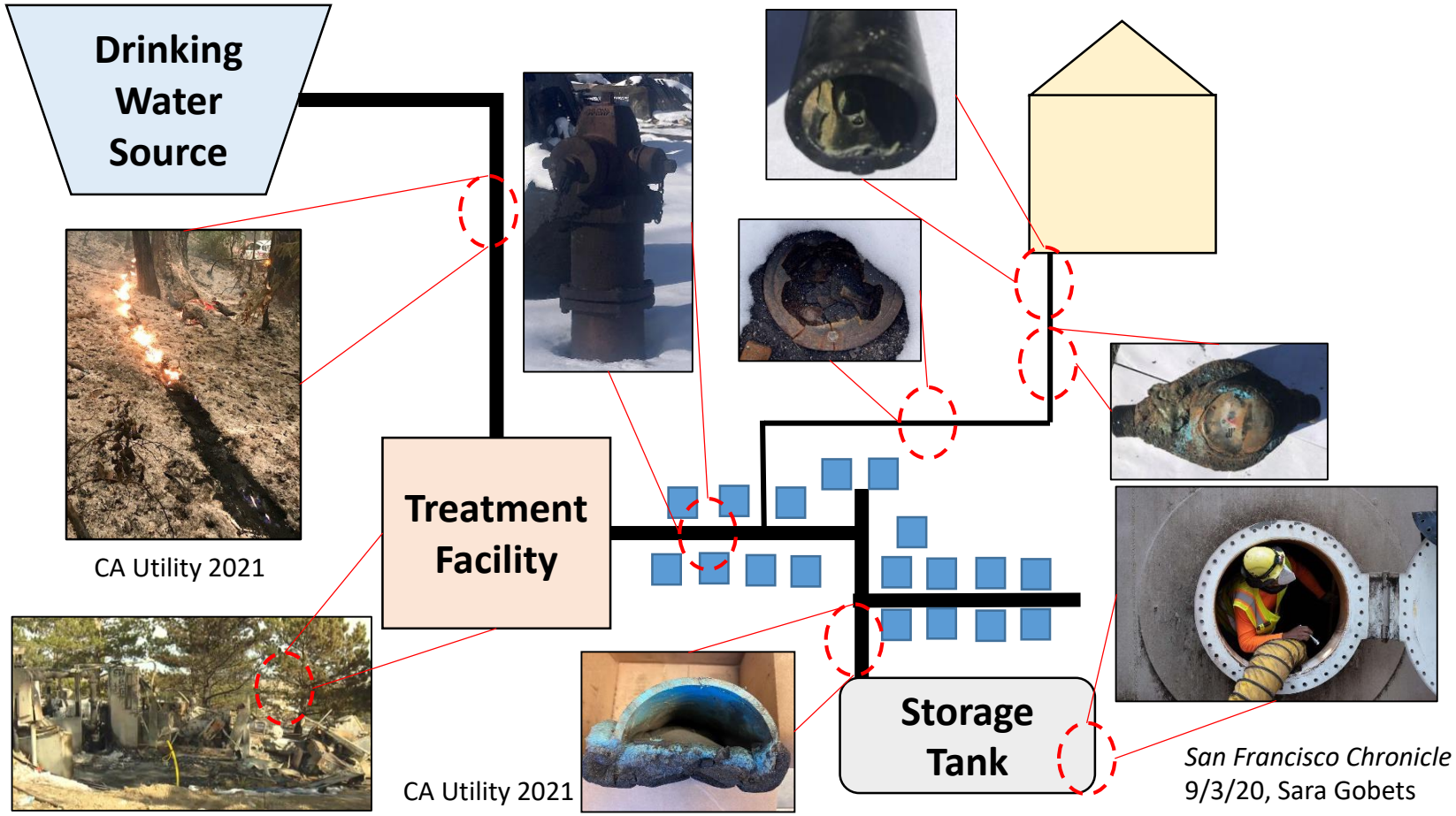
Wildfires can damage buried drinking water systems as well as private drinking water wells and building plumbing, making them unsafe to use. Since 2017, a growing number of wildfires have prompted chemical drinking water contamination in the United States. Levels found in some water systems have exceeded hazardous waste limits and posed an immediate health risk. To help households and building owners understand key wildfire drinking water contamination public safety issues, resources were compiled below. These resources will also be of interest to public health officials, water providers, municipalities, emergency management, insurance companies, nonprofit agencies, elected officials, and consultants.

- Questions can be directed to Dr. Andrew Whelton at awhelton@purdue.edu.

List of chemicals to test for post-fire (Version May 2022)
Videos for emergency operations and water quality officials
Post-fire water testing best practices
Homeowner and well testing best practices
FEMA Hazard Mitigation Assurance Policy Memo
And more…

Public drinking water systems and their assets are vulnerable to fire.

USGS 2009



CA Utility 2021

CA Utility 2021

San Francisco Chronicle
9/3/20, Sara Gobets

Fires can physically and chemically damage infrastructure

The Marshall Fire, December 30, 2021

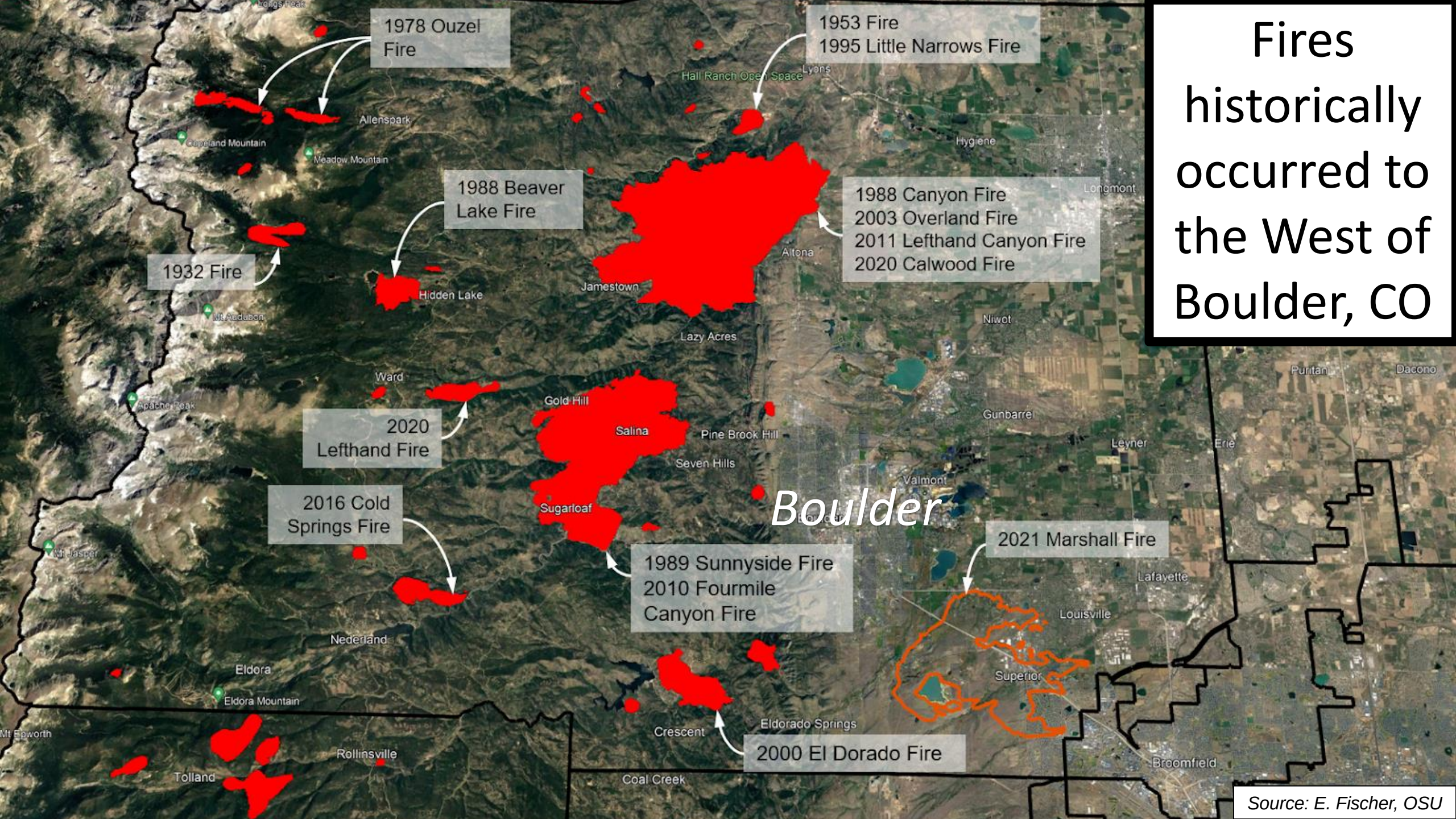
Most destructive in Colorado history in terms of the number of homes and businesses destroyed (>1000 buildings).

>$1 Billion in damage per NOAA, 6,000+ ac, 40,000+ evacuated

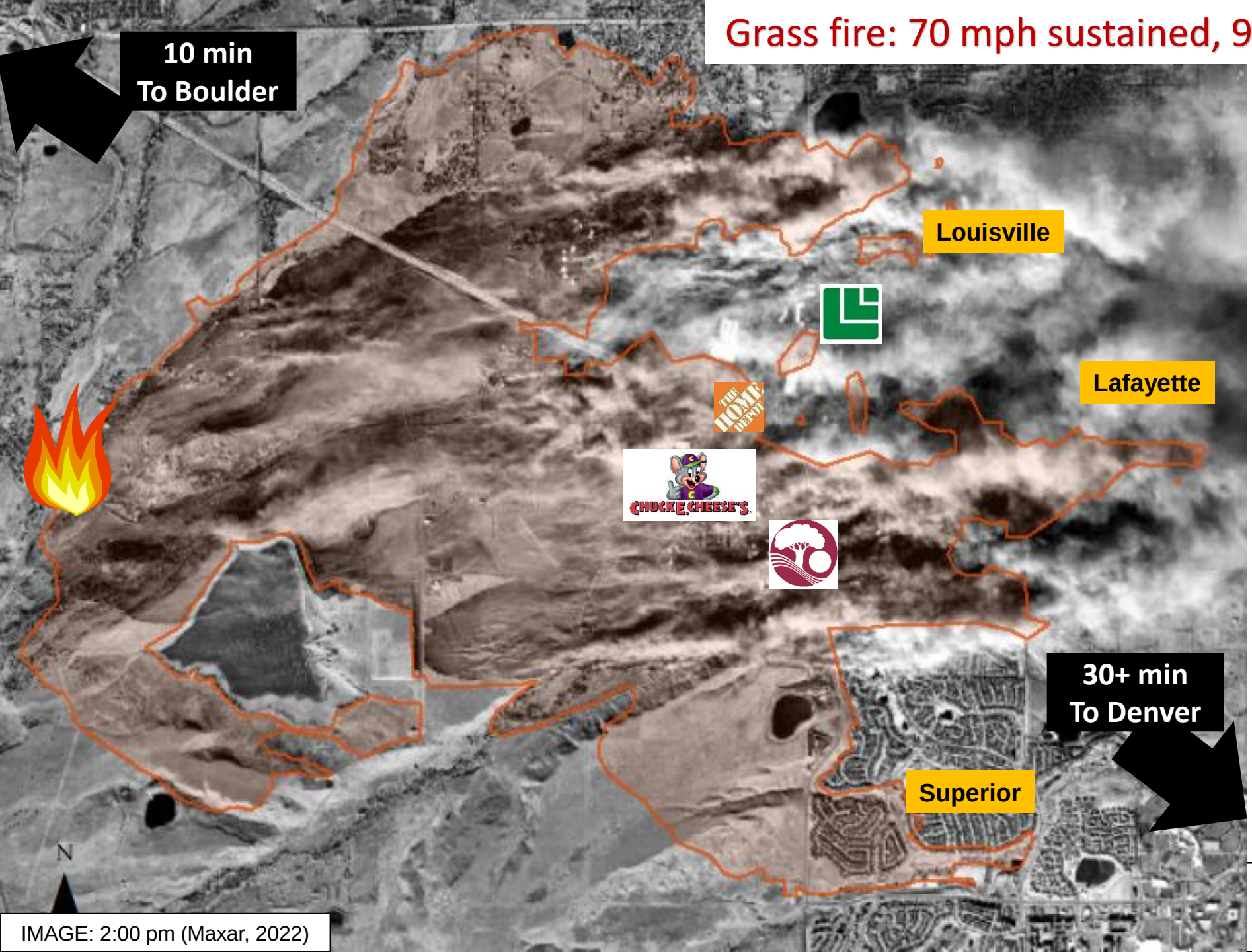
>100 mph winds

- 553 destroyed in Louisville, 45 damaged
- 332 destroyed in Superior, 60 damaged
- 106 destroyed in unincorporated Boulder County, 22 damage

- Chemical contamination found in 2 of 6 public water systems


1978 Ouzel Fire
1953 Fire
1995 Little Narrows Fire
1988 Beaver Lake Fire
1988 Canyon Fire
2003 Overland Fire
2011 Lefthand Canyon Fire
2020 Calwood Fire
1932 Fire
2020 Lefthand Fire
2016 Cold Springs Fire
1989 Sunnyside Fire
2010 Fourmile Canyon Fire
2021 Marshall Fire
2000 El Dorado Fire
Boulder
Fires historically occurred to the West of Boulder, CO
Source: E. Fischer, OSU

Grass fire: 70 mph sustained, 90 to 102 mph wind gusts



December 30, 2021

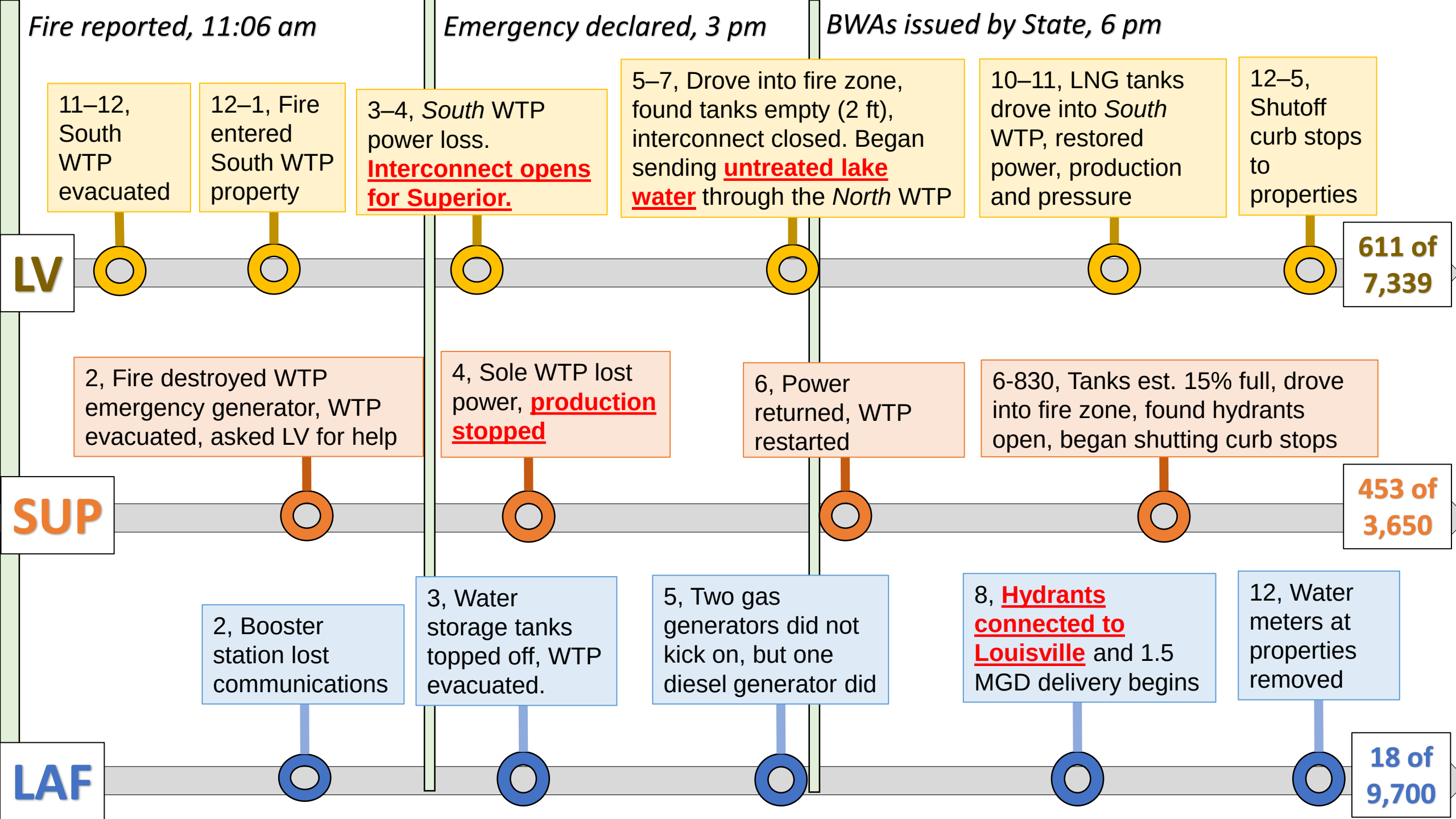
11:06 am, Fire in Boulder Co.
12:10 pm, Fire in Superior
12:50 pm, Fire in Louisville
1:00 pm, 1,000 acres

40,000+ evacuation ordered

The 3 largest communities
Lafayette: 30,411
Louisville: 21,266
Superior: 13,094

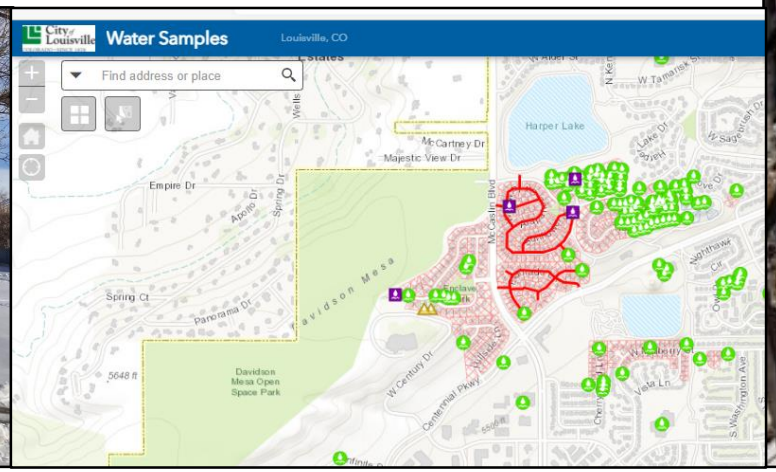
Source: Fischer & Wham et al. GEER report. The 2021 Marshall Fire, Boulder County, CO.

June 2022


Fire reported, 11:06 am
Emergency declared, 3 pm
BWAs issued by State, 6 pm
11–12, South WTP evacuated
12–1, Fire entered South WTP property
3–4, South WTP power loss. Interconnect opens for Superior.
5–7, Drove into fire zone, found tanks empty (2 ft), interconnect closed. Began sending untreated lake water through the North WTP
10–11, LNG tanks drove into South WTP, restored power, production and pressure
12–5, Shutoff curb stops to properties
LV
611 of 7,339
2, Fire destroyed WTP emergency generator, WTP evacuated, asked LV for help
4, Sole WTP lost power, production stopped
6, Power returned, WTP restarted
6-830, Tanks est. 15% full, drove into fire zone, found hydrants open, began shutting curb stops
SUP
453 of 3,650
2, Booster station lost communications
3, Water storage tanks topped off, WTP evacuated.
5, Two gas generators did not kick on, but one diesel generator did
8, Hydrants connected to Louisville and 1.5 MGD delivery begins
12, Water meters at properties removed
LAF
18 of 9,700

Lessons from the 2021 Marshall Fire

1. Internal leadership and commitment
2. Worker safety, power, and water pressure
3. Damage containment
4. Rapid neighbor/mutual aide support
5. Rapid water contamination support
6. Communications



Lessons Learned from the 2017 Tubbs Fire and 2018 Camp Fire

AWWA WATER SCIENCE

Wildfire caused widespread drinking water distribution network contamination

Download FREE here:
https://doi.org/10.1002/aws2.1183

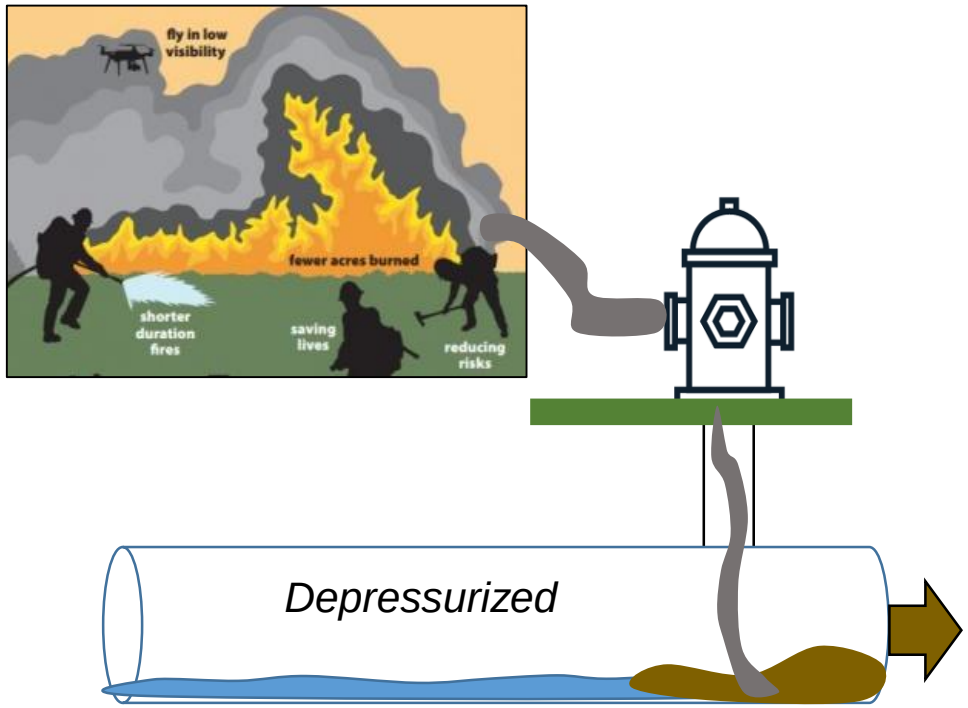
VOCs and SVOCs present, levels can exceed hazardous waste limits (40,000 ppb benzene, etc.)

Do Not Use water order should be issued

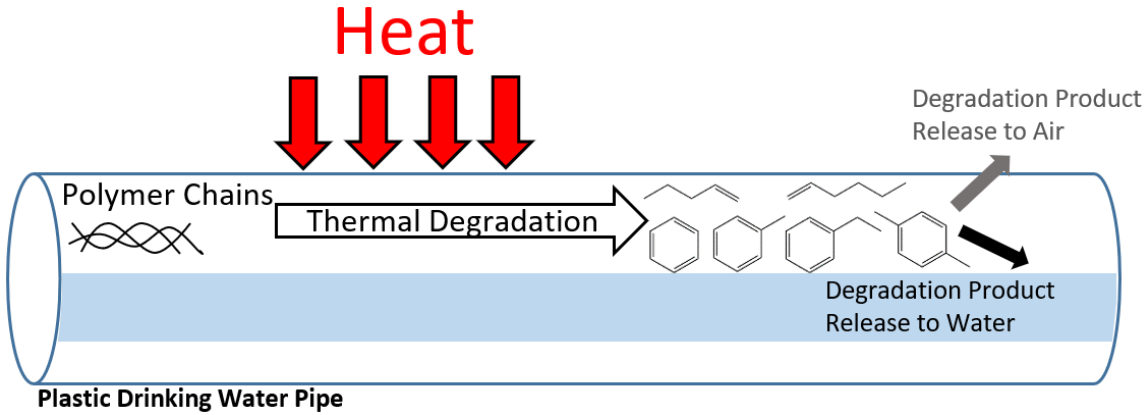
Protect homeowners and their plumbing

Potential PRIMARY Sources

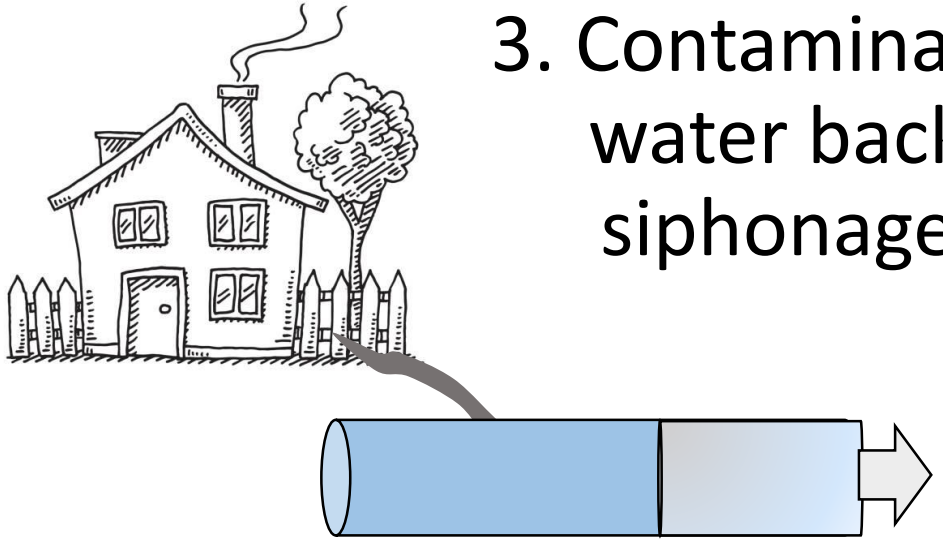
1. Forest biomass or structure combustion



2. Plastic thermal degradation

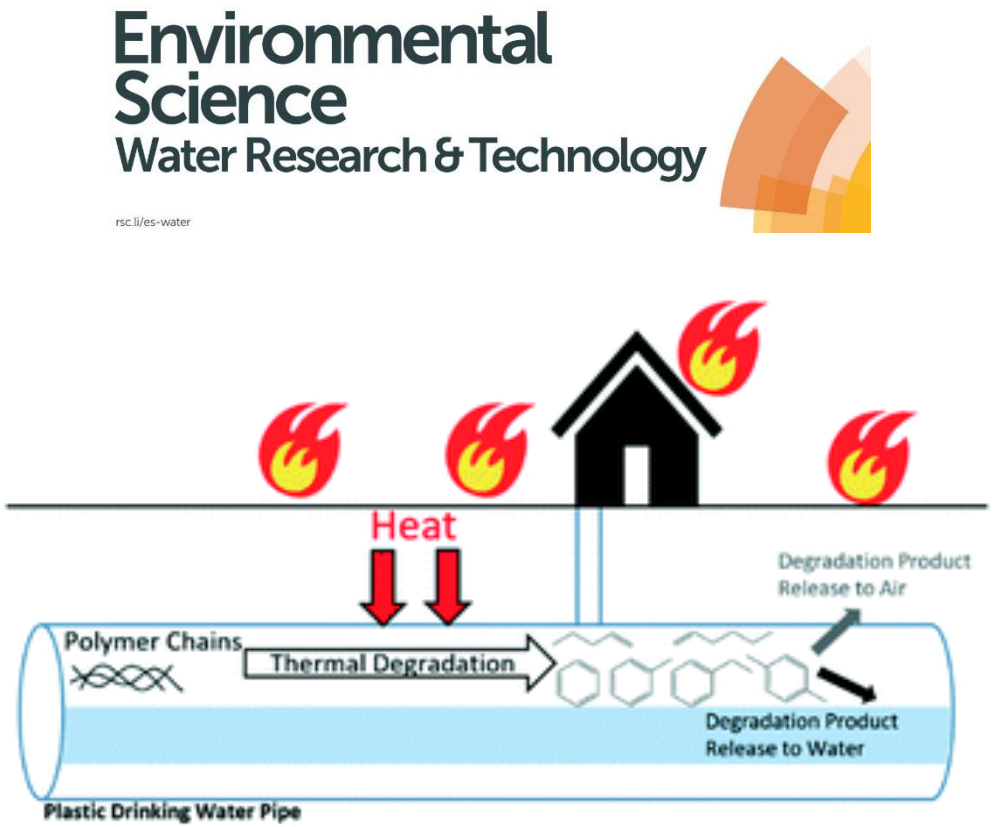


3. Contaminated water back siphonage



Secondary Sources: Infrastructure desorption

December 2020 Study: Thermally damaged plastic pipes can be a source of water contamination



Drinking water contamination from the thermal degradation of plastics: implications for wildfire and structure fire response, *AWWA Water Science*

Download FREE here:

https://doi.org/10.1039/D0EW00836B

Heating new HDPE, PEX, PVC, CPVC, and PP pipes < T_{deg} generated VOCs *and* SVOCs

Benzene generated by heating all pipes except PP

Once plastic cooled, chemicals leached into water

200-400˚C	Confirmation of BTEX Components in Water				Number of TICs in extract[a]	
Material	B	T	E	X	Water	*n*-Hexane
Cold water pipes						
PVC	✓	✓	–	–	4	41
HDPE	✓	✓	✓	✓	14	100
Hot and cold water pipes						
CPVC	✓	–	–	–	3	32
PEX-a1-a	✓	✓	✓	✓	19	123
PEX-a1-b	✓	✓	✓	✓	16	122
PEX-a2	✓	✓	✓	✓	22	117
PEX-b	✓	✓	✓	✓	18	127
PEX-c1-a	✓	✓	✓	✓	19	133
PEX-c1-b	✓	✓	✓	✓	17	134
PEX-c1-EVOH	✓	✓	✓	✓	20	109
PP	–	✓	–	–	6	95

Fires are often >200˚C, but ground temperature can be >100˚C for hrs

Chemistry:

Polymer chain scission

Aromatization

The role of additives

The role of temperature

The role of RH

The role of O_2

Partitioning after generation

*Building codes never considered damaged plastic water system materials becoming a 1˚ or 2˚ source of drinking water contamination. (est. 300,000 structure fires per year - **NFPA**)*

Organic Chemical Contaminants in Water System Infrastructure Following Wildfire, *ES&T Water*

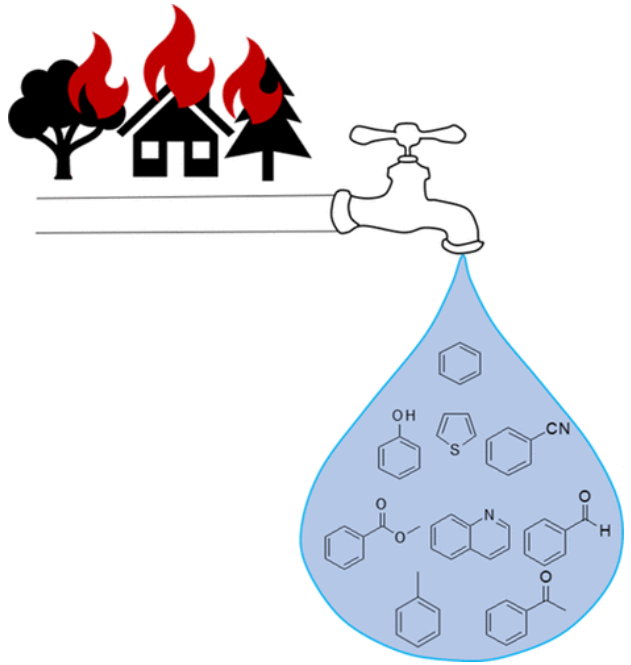
https://doi.org/10.1021/acsestwater.1c00401

Characterized target and nontarget VOCs and SVOCs in water from **1** contaminated service line after the Camp Fire.

PVC, PEX, and HDPE pipe **heating experiments** conducted

Results:

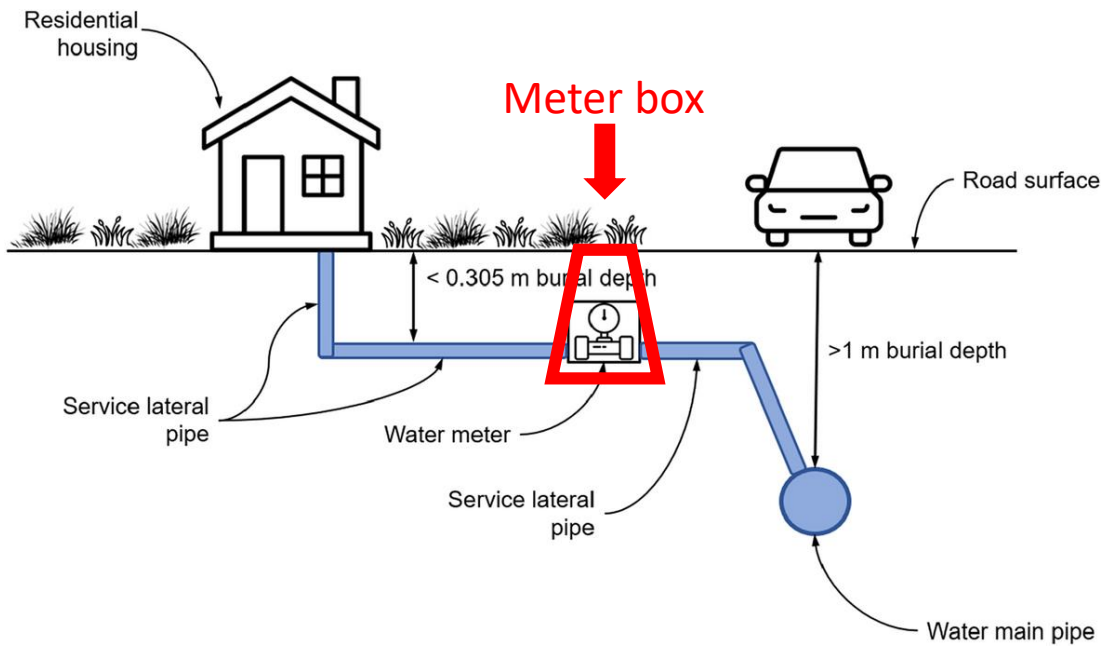
- PVC heating: 32 compounds
- HDPE/PEX heating: 28 compounds
- Service line: 55 compounds associated with uncontrolled burning of biomass and waste materials.



Findings support hypotheses that wildfires can contaminate drinking water systems both by thermal damage to plastic pipes and intrusion of smoke.

Simulation of Heat Transfer Through Soil for the Investigation of Wildfire Impacts on Buried Pipelines, *Fire Technology*

https://doi.org/10.1007/s10694-022-01232-3



Mathematical Modeling Results:

- The upper limit temperature for pressure service of the pipelines was exceeded at depths up to 0.45 m (1.5 ft).
- The upper limit temperature will be exceeded at least 50% of the time at depths up to 0.19 m (0.6 ft).

Buried depth will impact thermal vulnerability

Max. Benzene, ppb	Event / Location	Pop.	System	Year
221	Marshall Fire/ Colorado	20,319	City of Louisville	2021
5.1	Marshall Fire/ Colorado	300	East Boulder County Water District	2021
5.5	Echo Mountain Fire/ Oregon	120	Whispering Pines Mobile Home Park	2020
11.3	Echo Mountain Fire/ Oregon	362	Hiland WC -Echo Mountain	2020
1.1	Echo Mountain Fire/ Oregon	760	Panther Creek Water District	2020
76.4	Almeda Fire/ Oregon	6,850	City of Talent	2020
44.9	Lionshead Fire/ Oregon	205	Detroit Water System	2020
1.8	CZU Lightning Complex Fire/ California	1,650	Big Basin Water Company	2020
42	CZU Lightning Complex Fire/ California	21,145	San Lorenzo Valley Water District	2020
>2,217	Camp Fire/ California	26,032	Paradise Irrigation District	2018
38.3	Camp Fire/ California	924	Del Oro Water Co.-Magalia	2018
8.1	Camp Fire/ California	1,106	Del Oro Water Co.-Lime Saddle	2018
530	Camp Fire/ California	11,324	Del Oro Water Co.-Paradise Pines	2018
40,000	Tubbs Fire/ California	175,000	City of Santa Rosa	2017

Have there been more? Probably. Testing not always conducted correctly.

Is ***benzene*** THE indicator of contamination?

--No

Is ***BTEX*** THE indicator of contamination?

--No

Is ***VOC*** THE indicator of SVOC contamination?

--Probably not, untested theory

Oregon 2021: Methyl ethyl ketone (138 ppm) exceeded the USEPA 1-day drinking water health advisory in the absence of benzene

No shortcuts to chemical contamination decisions

THE Water Research FOUNDATION

<u>Goal:</u> To better understand the degree thermally damaged plastic materials contribute to VOC/SVOC drinking water contamination …and… propose response and recovery actions for utilities who face water distribution system contamination.

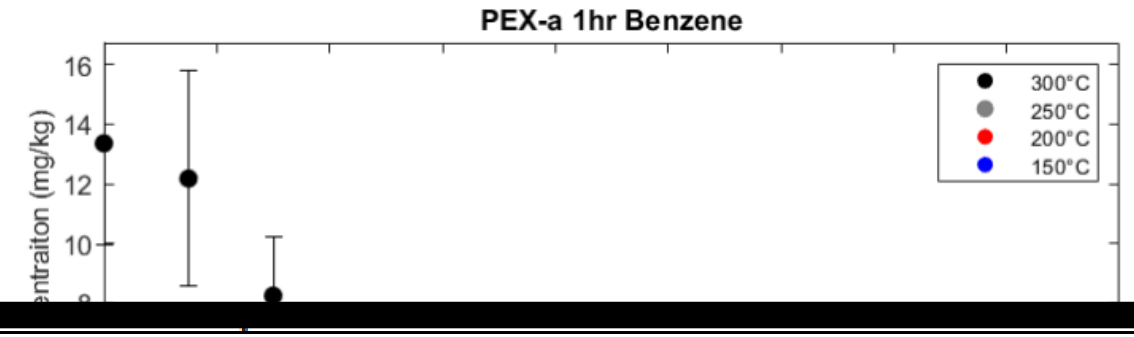
<u>(1) Gather and Compile Data:</u> Develop case studies, and select material for laboratory testing.

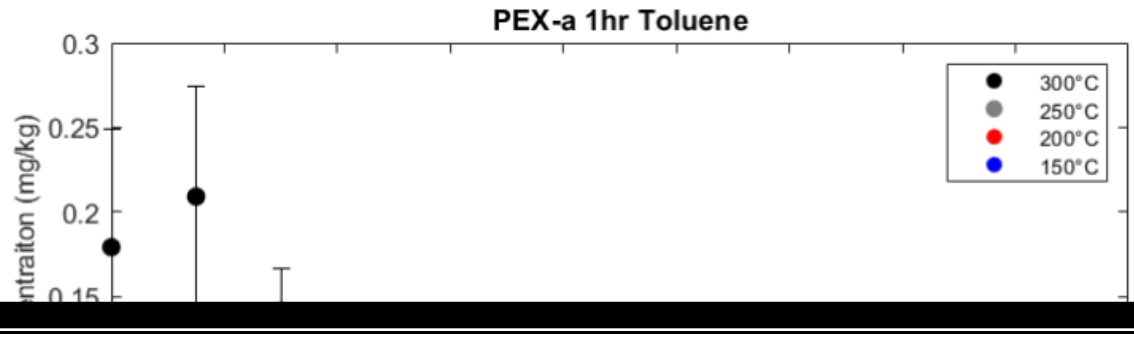
<u>(2) Characterize VOCs/SVOCs:</u> Assess the type and variability of VOC/SVOCs generated by thermal degradation of water infrastructure plastics in the presence of water with continuous flow capabilities. Explore the potential for a surrogate in detection of VOC/SVOC contamination.

<u>(3) Investigate Decontamination Technologies:</u> Assess the effectiveness of asset decontamination.

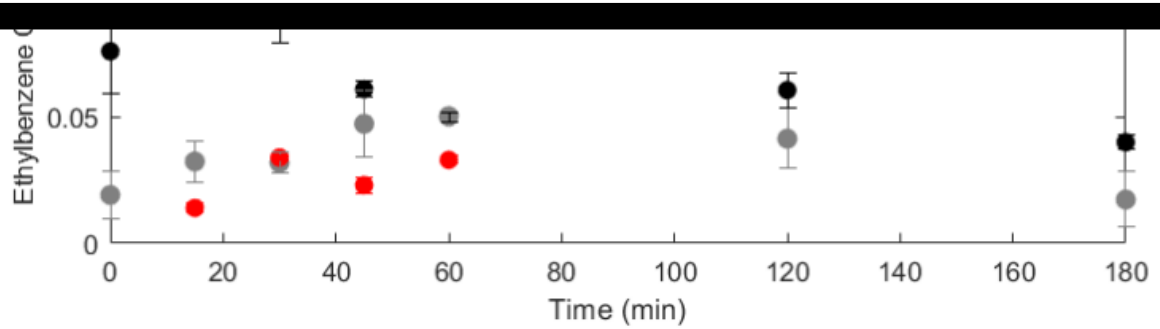
<u>(4) Response Plan:</u> A Concept of Operations (CONOPS) plan for responding to and recovering from drinking water chemical contamination events will be developed.

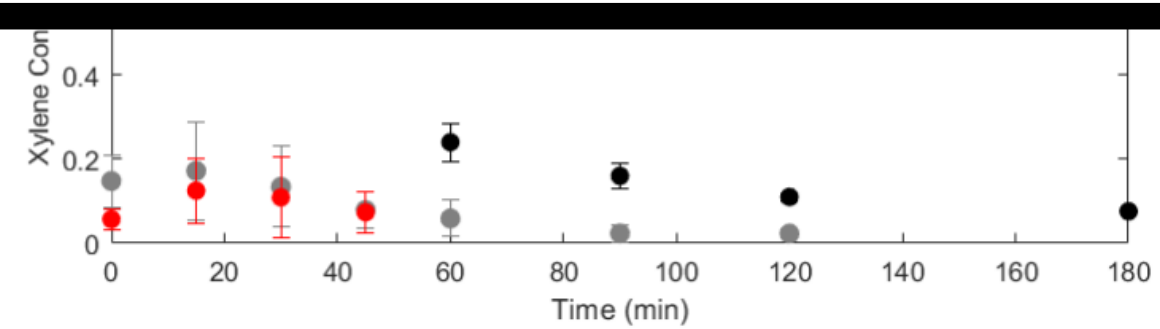
Actions part of Tasks 1-3	Status
Plastic degradation reactor setup and plastic pipe degradation experiments (VOC/SVOC)	[Ongoing]
Surrogate contamination indicator experiments (TOC, UV_{254}, VOC/SVOC)	[Ongoing]
Characterize damaged pipes and meter materials from the 2021 Marshall Fire (VOC/SVOC)	[Ongoing]





Degradation Temperature (°C)	Benzene Concentration (mg/kg)
150	0.059 ± 0.037
200	0.095 ± 0.019
250	0.616 ± 0.221
300	3.89 ± 1.242

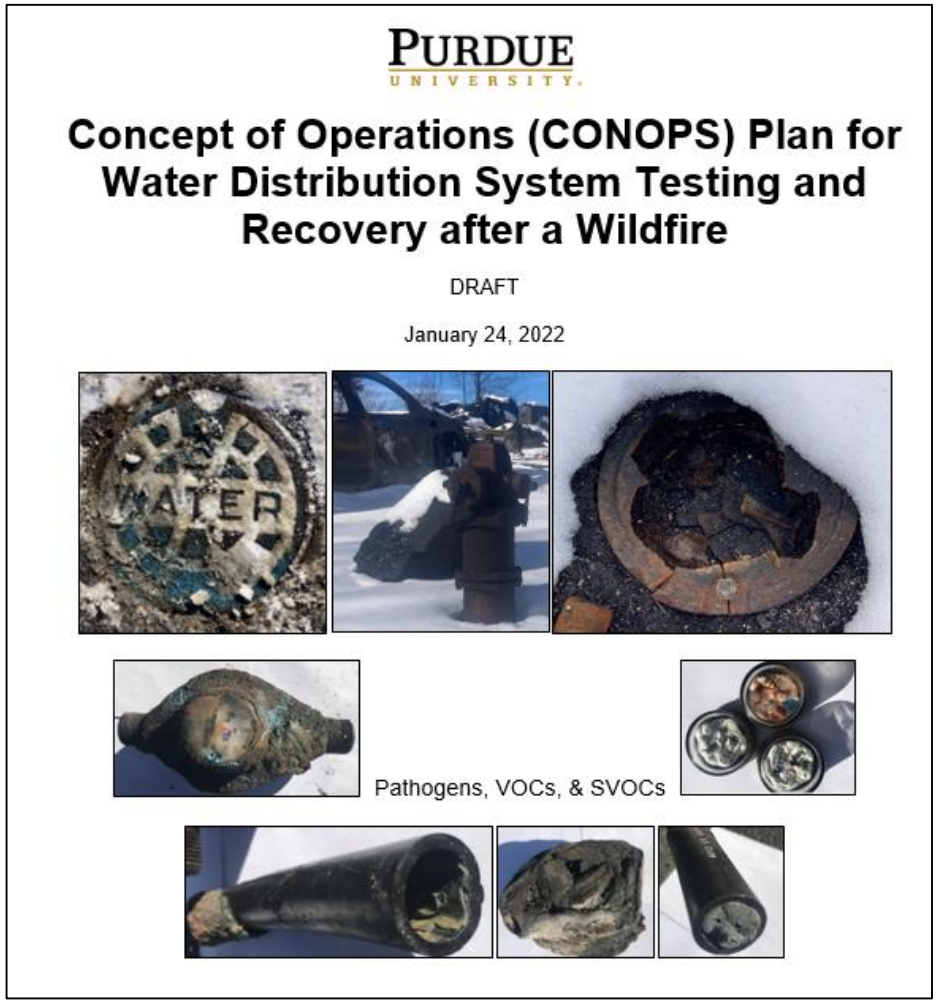




Task 4. CONOPS Plan

Identify roles, responsibilities, and activities associated with chemical testing and recovery of impacted drinking water distribution systems. This document contains a:

1. Describe conditions that may prompt wildfire drinking water distribution system contamination
2. Summarize organization roles and responsibilities
3. Identify chemicals of concern
4. Identify factors influencing water use conditions and testing decisions
5. Identify considerations for water sampling and decisions based on testing results
6. Provide SOPs for water sampling
7. Provide foundational materials from government agencies, utilities, leading researchers and nonprofit organizations



List of VOCs Detected in Previous Drinking Water Distribution System Water Samples after Wildfires Before the Marshall Fire

"Water testing package after fire"

Acetonitrile	Chlorodibromomethane	Ethyl-*tert*-butyl ether (ETBE)	1,2,4-Trichlorobenzene
Acetone	Chloromethane	Iodomethane	1,1,1-Trichloroethane
Acrolein	4-Chlorotoluene	Isopropylbenzene	1,1,2-Trichloroethane
Acrylonitrile	Dibromochloromethane	Methylene chloride	Trichloroethylene
Benzene	1,2-Dichlorobenzene	Methyl ethyl ketone (MEK)	Trichloromethane
Bromochloromethane	1,4-Dichlorobenzene	Methyl isobutyl ketone (MIBK)	1,2,4-Trimethylbenzene
Bromodichloromethane	1,1-Dichloroethane	Methyl-*tert*-butyl ether (MTBE)	1,3,5-Trimethylbenzene
Bromoform	1,2-Dichloroethane	Naphthalene	Vinyl chloride (VCM)
n-Butylbenzene	1,1-Dichloroethene	Styrene	*ortho*-Xylene
sec-Butylbenzene	*cis*-1,2-Dichloroethene	*tert*-Butyl alcohol (TBA)	*meta*-Xylene
tert-Butylbenzene	*trans*-1,2-Dichloroethylene	Tetrachloroethylene	*para*-Xylene
Carbon disulfide	1,2-Dichloropropane	Tetrahydrofuran (THF)	
Carbon tetrachloride	Ethanol	Toluene	**SVOCs too**
Chlorobenzene	Ethylbenzene	1,2,3-Trichlorobenzene	

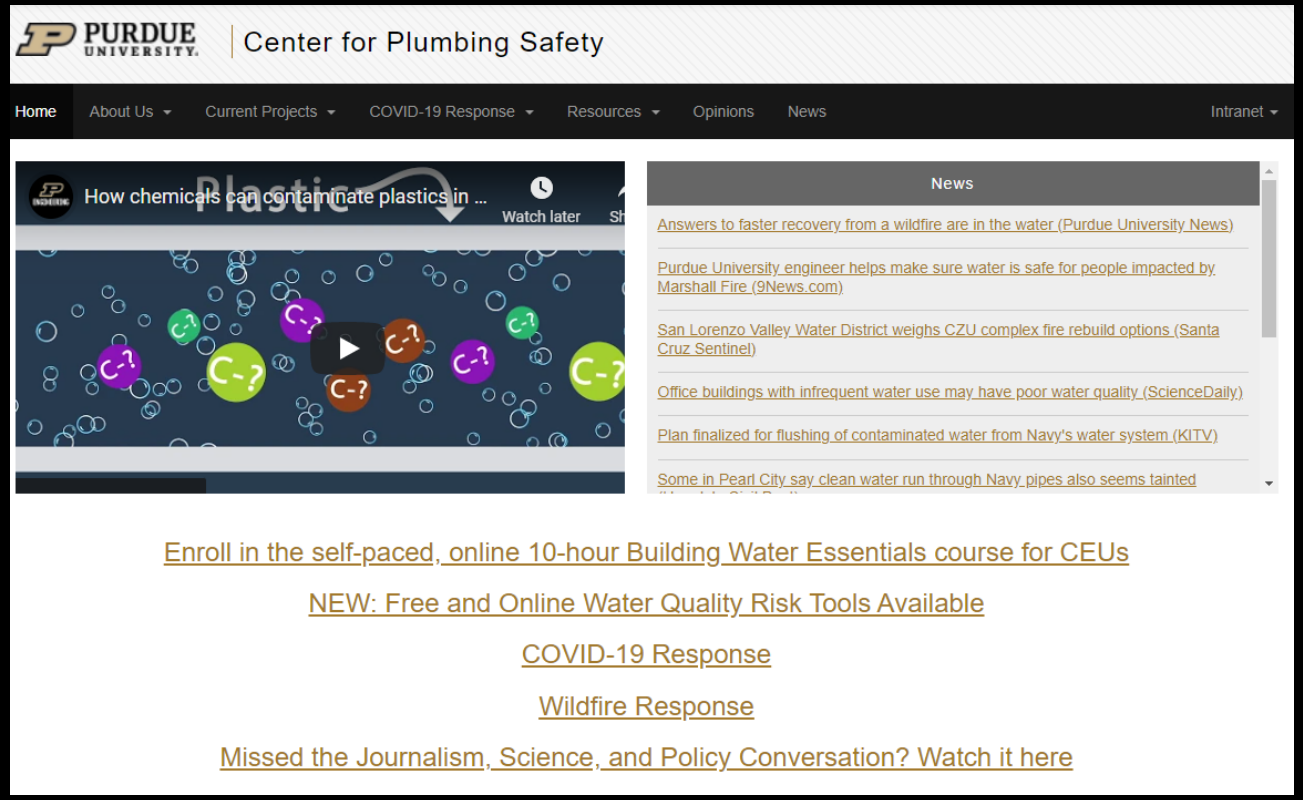
1. For initial response: Trained staff, practice, interconnections, maintaining power, water storage, pressure, rapid mutual aide, and knowing where and how to monitor and operate facilities without technology.

2. Sources of contamination are varied. Depressurization is likely a major factor. VOC and SVOC sources from plastic thermal degradation need to be further understood. The exact chemicals to test for have not been identified…we know what people *have* tested for and found. Through strategic rapid response and lab studies you can get there…

3. The Concept of Operations Plan (CONOPS) for guiding utility water contamination response and recovery is being prepared. In the mean time, rapid qualified expert input can expedite and hone decision making.

Thank you. More results coming…

Andrew Whelton, Ph.D. awhelton@purdue.edu



Funded by:

2214580 RAPID: Drinking Water System Contamination Response & Recovery Following the 2021 Colorado Fires

Post-Wildfire Distribution System Water Quality Impacts and Potential Responses, #5106

Learn more at:

www.CIPPSafety.org www.PlumbingSafety.org

Follow Us

@TheWheltonGroup