Damage Assessment and Restoration Activities for Water Systems After Wildfires

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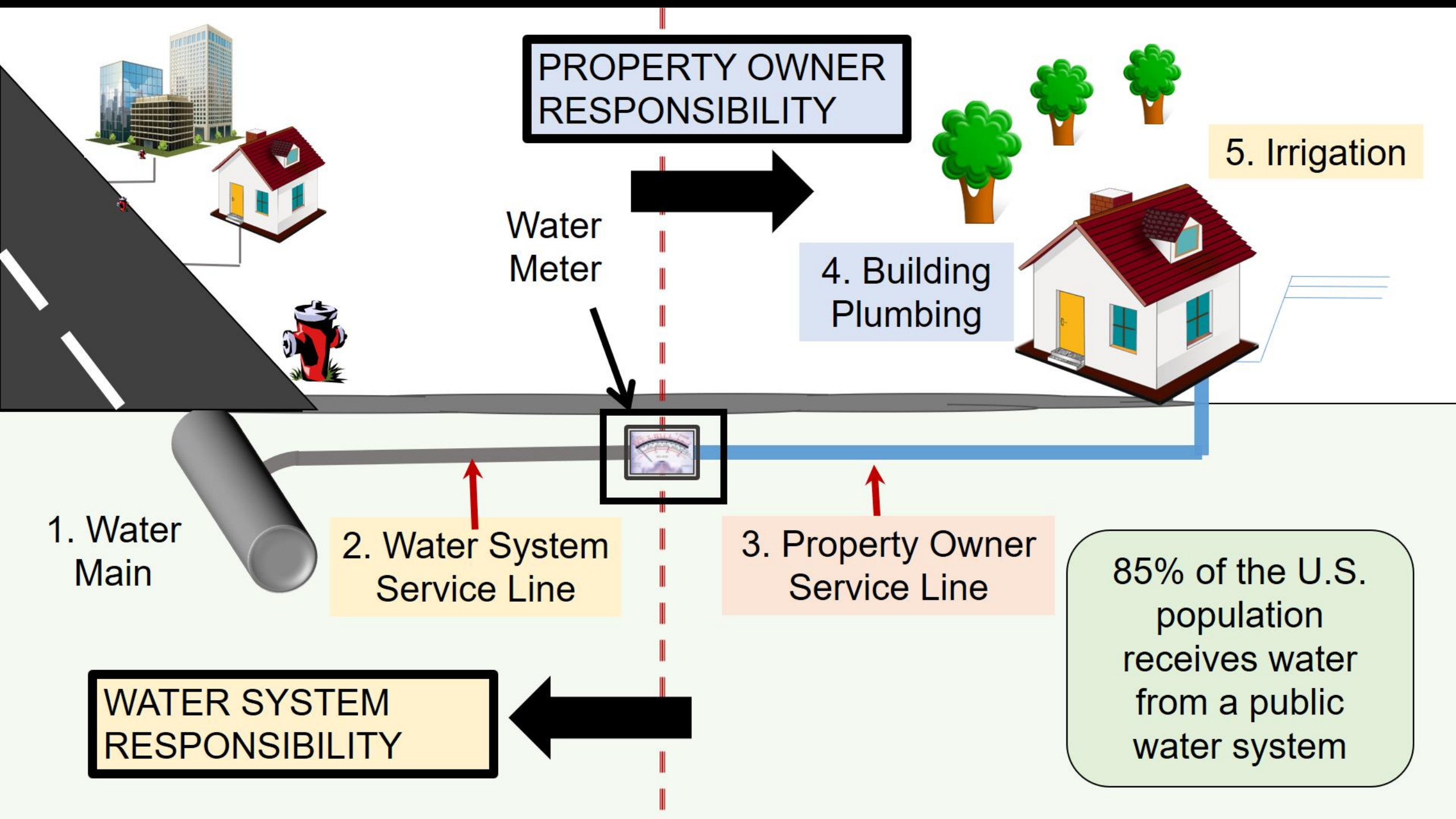
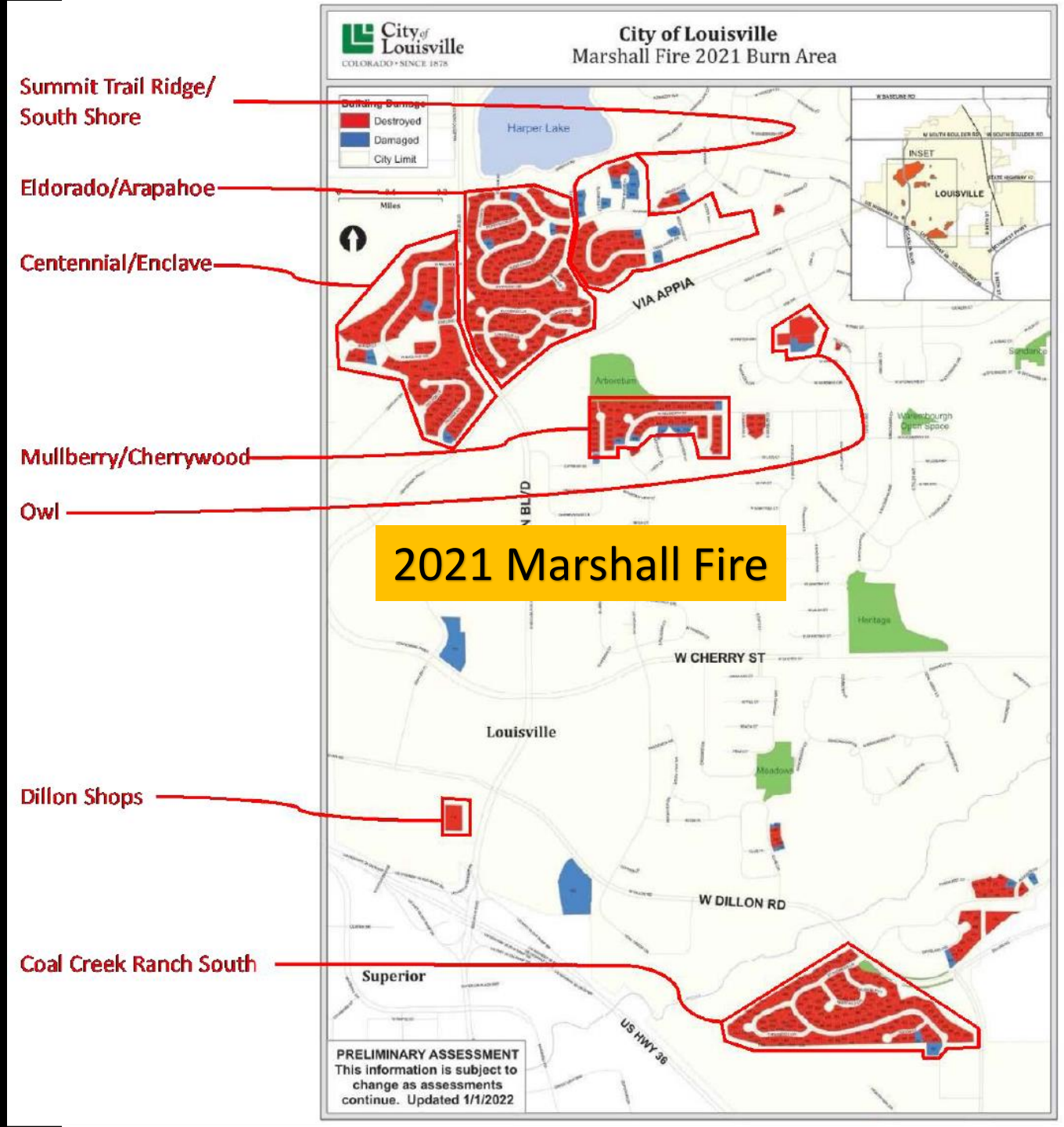
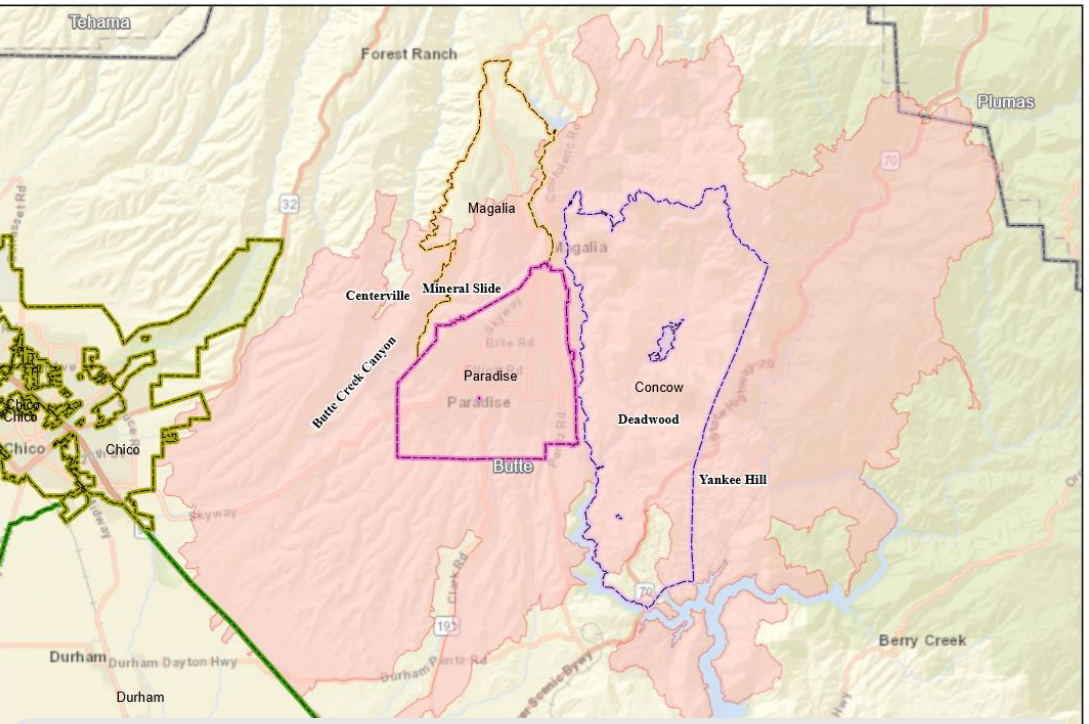
PURDUE
UNIVERSITY


PROPERTY OWNER RESPONSIBILITY
Water Meter
5. Irrigation
4. Building Plumbing
1. Water Main
2. Water System Service Line
3. Property Owner Service Line
WATER SYSTEM RESPONSIBILITY
85% of the U.S. population receives water from a public water system

Wildfires cause widespread or partial structure damage across communities



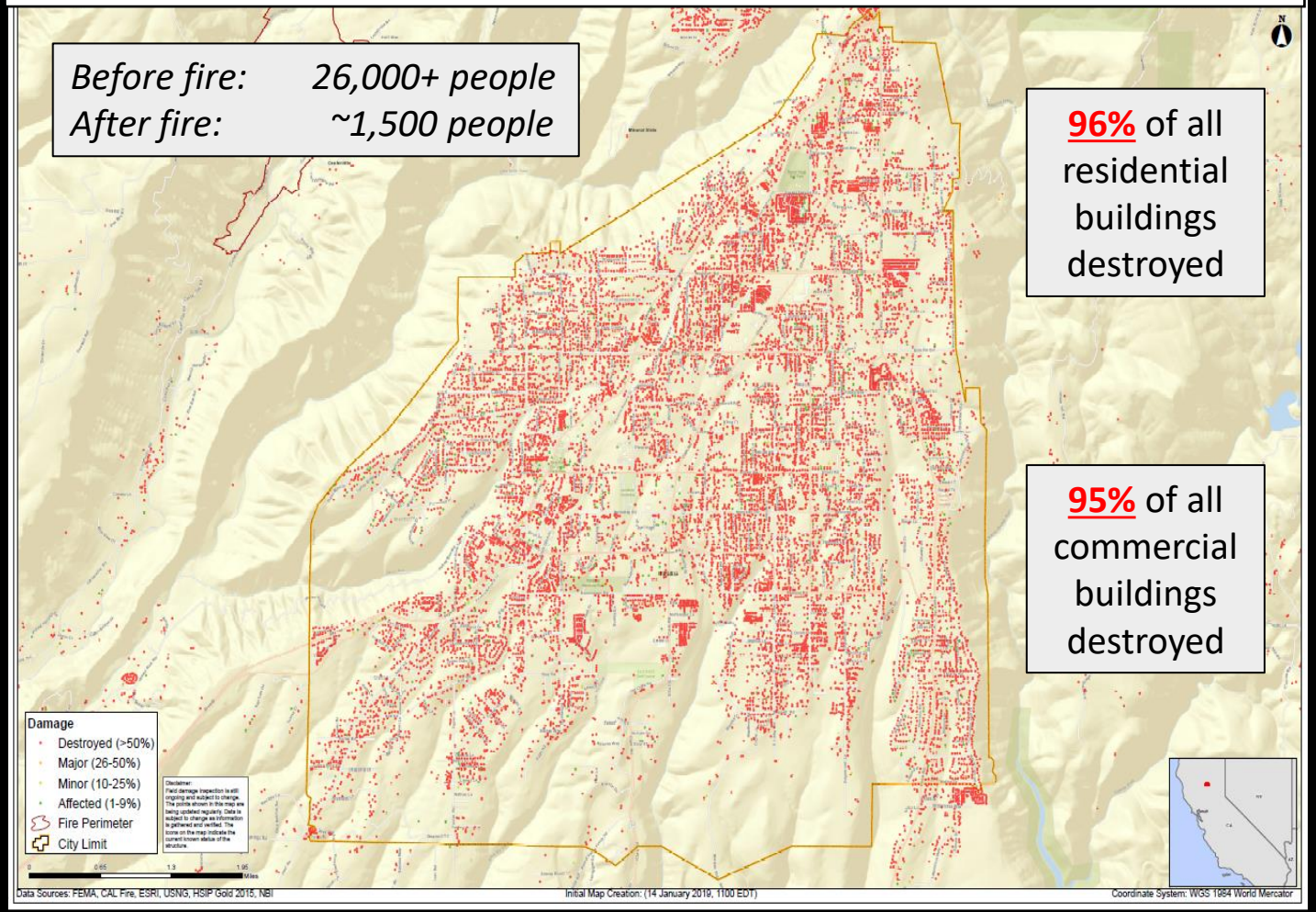
2018 Camp Fire



153,336 acres
86 fatalities

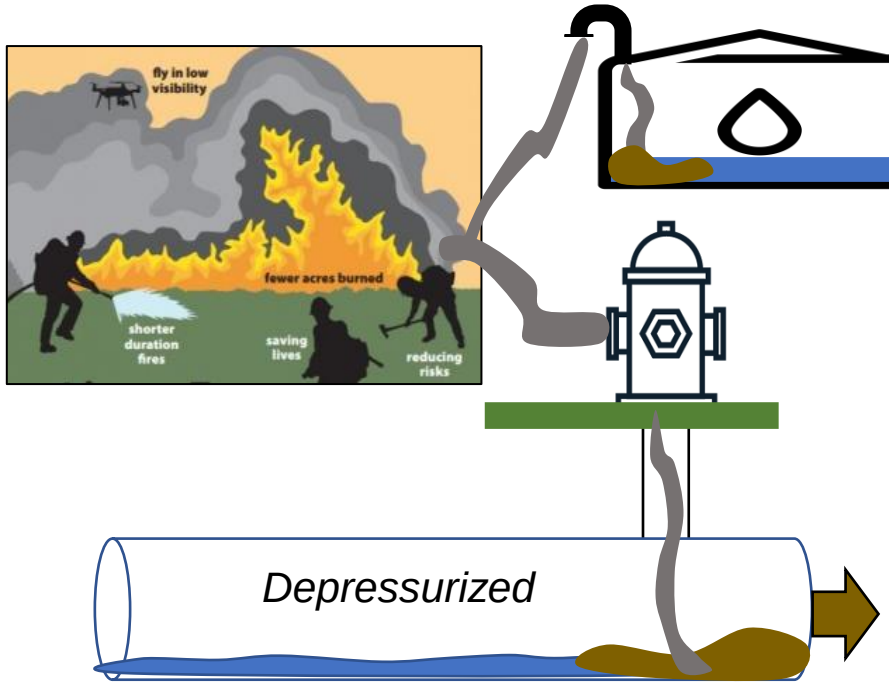
~13,972 residences destroyed
14,793 structures destroyed
3 firefighters injured

Town of Paradise Limits

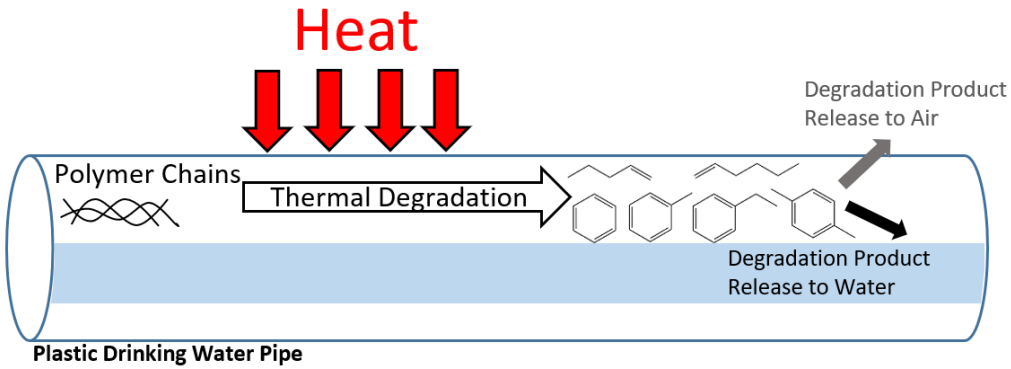


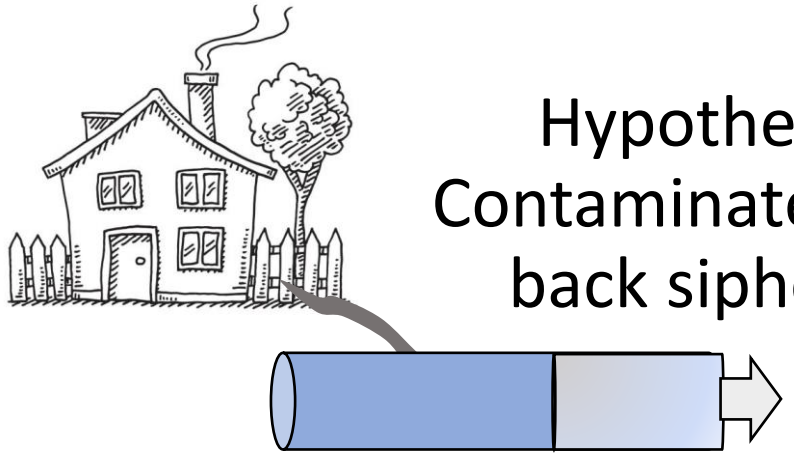
3 Ways water distribution systems become contaminated after a wildfire

Hypothesis 1. Biomass and structure combustion



Hypothesis 2. Plastic thermal degradation

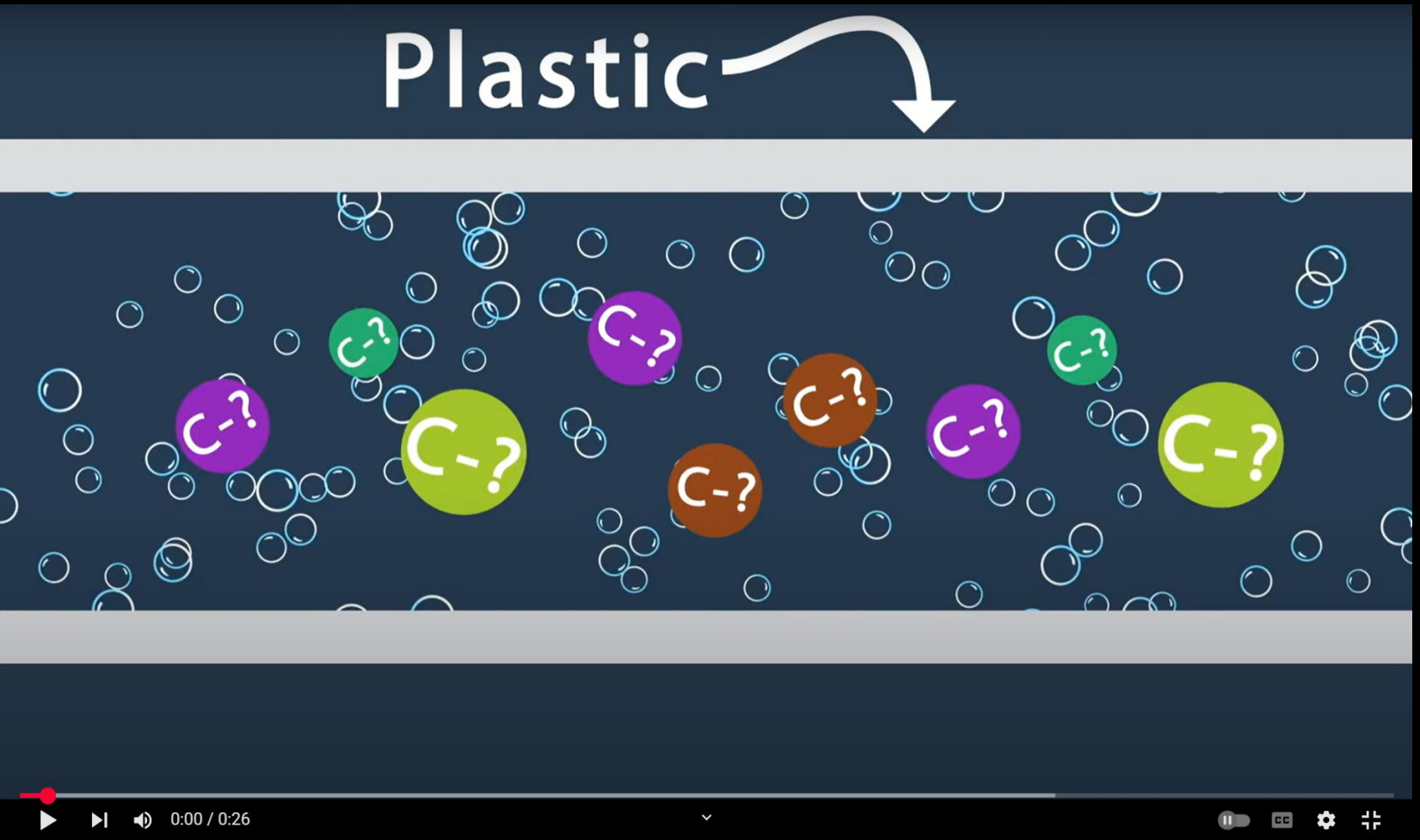




Hypothesis 3. Contaminated water back siphonage

Secondary Sources: Infrastructure desorption

Where can it be? Pipes, tank coatings, gaskets, water meters, valves, etc.



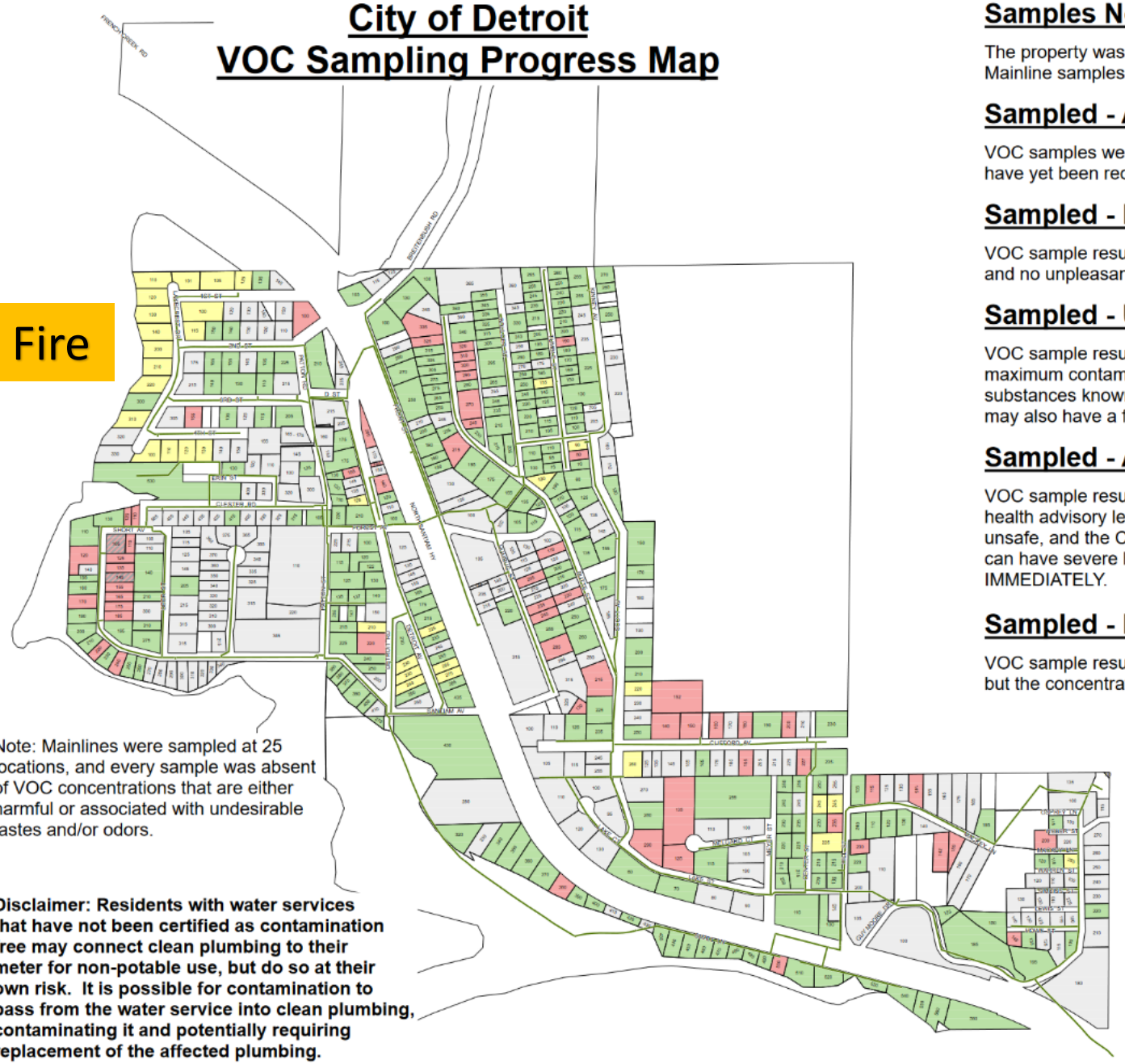
https://youtu.be/ythX2fP3-S4

To assess VOC contamination, you must stagnate before taking a sample (i.e., 72 hr)

City of Detroit
VOC Sampling Progress Map

2020 Santiam Fire

80% structures destroyed



Note: Mainlines were sampled at 25 locations, and every sample was absent of VOC concentrations that are either harmful or associated with undesirable tastes and/or odors.

Disclaimer: Residents with water services that have not been certified as contamination free may connect clean plumbing to their meter for non-potable use, but do so at their own risk. It is possible for contamination to pass from the water service into clean plumbing, contaminating it and potentially requiring replacement of the affected plumbing.

Samples Not Required

The property was not damaged in the fire, so no VOC samples were required. Mainline samples cleared the property as not contaminated with VOCs.

Sampled - Awaiting Results

VOC samples were required at this property and have been taken, but no results have yet been recieved.

Sampled - Not Contaminated

VOC sample results did not contain dangerous concentrations of any compounds, and no unpleasant taste or odor is anticipated.

Sampled - Unsafe Contamination

VOC sample results included concentrations of regulated substances above the maximum contamination level (MCL) and/or concentrations of unregulated substances known to be unsafe. This water is unsafe for contact/consumption, and may also have a foul taste or odor.

Sampled - Acute Health Risk

VOC sample results included concentrations of regulated substances above the health advisory level (HAL) for 1 and 10 day exposure. This water is extremely unsafe, and the City will disconnect your water for your safety. Short term use can have severe health effects. If your water service is on, CONTACT THE CITY IMMEDIATELY.

Sampled - Poor Taste and/or Odor

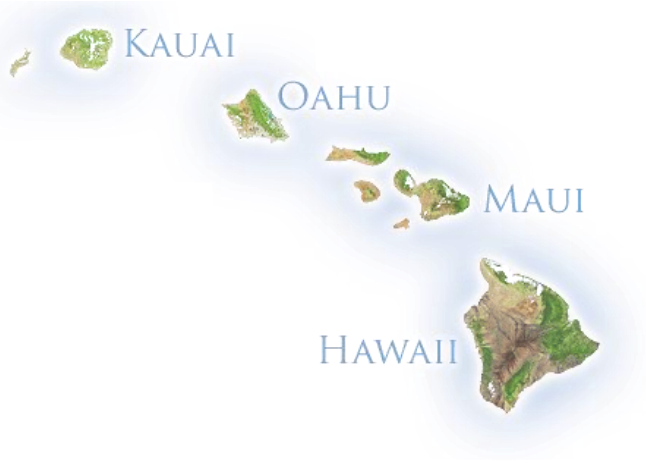
VOC sample results did not contain dangerous concentrations of any compounds, but the concentrations present will produce unpleasant odor and/or taste in the water.

Legend

- Taxlots

Sampling Status

- Samples Not Required
- Sampled - Awaiting Results
- Sampled - Not Contaminated
- Sampled - Unsafe Contamination
- Sampled - Acute Health Risk
- Sampled - Poor Taste and/or Odor
- Distribution System - Not Contaminated



Hurricane Dora, 60-80 mph gusts onshore

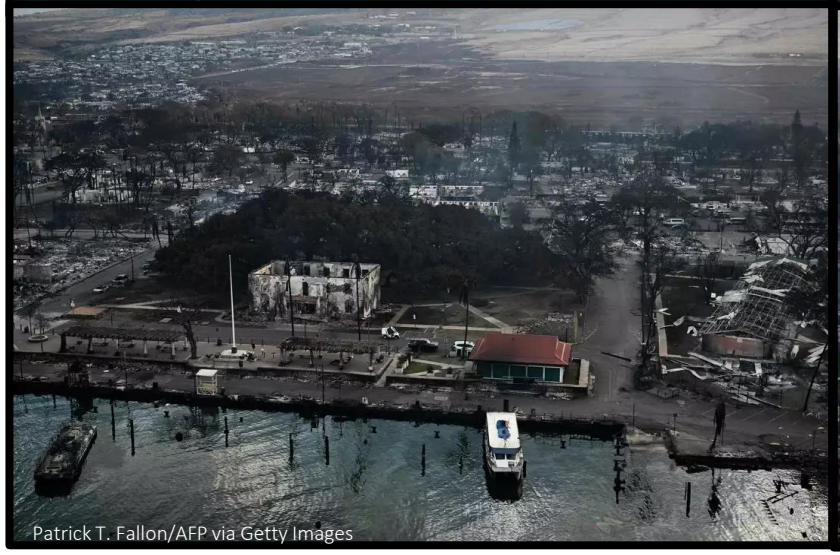
Olinda Fire: 1,081 ac, 2 structures

Kula Fire: 202 ac, 544 structures

Lahaina Fire: 2,170 ac, 2,207 structures

Puelho Fire: 5,300 ac, 0 structures

Deadliest wildfire incident in modern U.S. history



Maui Wildfires August 8, 2023

Lahaina Sys. Pop. 20,065
Elev. 1 ft.
28% White alone
Median income: $80,035
Median-value home: $0.72M
Seat of Hawaiian Kingdom

County Seat

Kula Sys. Pop. 7,686
Elev. 1,000-3,600 ft.
54% White alone
Median income: $86,938
Median-value home: $1.1M

University of Hawai'i private property drinking water results were more expansive and indicated more MCLs were sometimes exceeded

Chemicals exceeded a drinking water exposure limit for at least 1 sample, maximum concentration in ppb	
Trichloromethane* (MCL 80 ppb TTHMs)	195
1,2,3-Trichloropropane (MCL 0.6 ppb)	11.2
1,2-Dibromoethane (MCL 0.04 ppb)	10.3
Carbon tetrachloride* (MCL 5 ppb)	10.0
1,2-Dichloropropane* (MCL 5 ppb)	10.0
Vinyl chloride* (MCL 2 ppb)	9.80
Methylene chloride* (MCL 5 ppb)	9.72
1,1-Dichloroethane* (MCL 5 ppb)	9.73
1,2-Dibromo-3-chloropropane (MCL 0.04 ppb)	9.62
1,2-Dichloroethane* (MCL 5 ppb)	9.50
Benzene* (MCL 5 ppb)	8.56

Percentage of water samples where a chemical was detected greater than 50% of the time, maximum concentration in ppb		
Acetone*	84%	178
Trichloromethane*	80%	195
Bromodichloromethane*	71%	19.3
Dibromochloromethane*	68%	23.0
Bromoform*	68%	33.9
1,2-Dichlorobenzene*	67%	10
Methylene chloride*	63%	9.72
Bromomethane	57%	10.4
1,3-Dichlorobenzene	56%	9.79
Iodomethane*	56%	8.50
Toluene*	56%	7.99
1,2,4-Trichlorobenzene*	55%	8.73
m-/p-Xylene*	54%	9.30

The top 5 chemicals detected at the highest concentrations found, in ppb	
Methyl ethyl ketone (MEK)*	293
Tetrahydrofuran*	217
Trichloromethane*	195
Acetone*	178
Bromoform*	33.9
Other notable chemicals detected for at least 1 sample, maximum concentration in ppb	
Bromoform* (MCL 80 ppb TTHMs)	33.9
Dibromochloromethane* (MCL 100 ppb)	23.0
cis-1,2-Dichloroethene* (MCL 70 ppb)	18.0
Bromomethane (MCL 80 ppb TTHMs)	10.4
1,1,2,2-Tetrachloroethane (HA 2,500 ppb)	10.3
1,1,2-Trichloroethane* (MCL 200 ppb)	9.48
trans-1,3-Dichloropropene (1,3-D) (RSL, 60 ppb)	9.39

Data as of December 2023

Asterix (*) indicates the chemical was found in wildfire damaged drinking water systems outside Hawai'i prior to the 2023 wildfires in Maui.

Some households sought out their own water test kits, but….

VOC	Chemical Screened for by the Organization		Home Test Kit Name, Cost, and Minimum Detection Limit for Chemical in ppb		
	State of Hawai'ii	University of Hawai'i	Safe Home ULTIMATE Drinking Water Test Kit, $379	City Check Deluxe, $329	Extended City Water Test, $675
[X]Acetone		**Yes**	**50**	**10**	
[X,*,Δ]Benzene	**Yes**	**Yes**	**1**		**1**
Bromochloromethane		Yes	1		0.5
Bromodichloromethane		Yes	1	2	1
Bromoform		Yes	1	4	1
n-Butylbenzene		Yes			0.5
sec-Butylbenzene		Yes			0.5
tert-Butylbenzene		Yes			0.5
Carbon disulfide		Yes	5		
*Carbon tetrachloride	Yes	Yes	1	1	0.5
*Chlorobenzene	Yes	Yes	1	1	0.5
Chloromethane		Yes	1	2	0.5
4-Chlorotoluene		Yes		1	0.5
Dibromochloromethane		Yes	1	4	0.5
*1,2-Dichlorobenzene	Yes	Yes		1	
*1,4-Dichlorobenzene	Yes	Yes		1	0.5
1,1-Dichloroethane	Yes		1		0.5
*1,2-Dichloroethane	Yes	Yes	1	1	0.5
1,1-Dichloroethene	Yes	Yes			0.5
1,2-Dichloroethylene		Yes	Not Screened By Any Kit		
*1,2-Dichloropropane	Yes	Yes	1	2	0.5
[X]Ethanol					
[X,]*Ethylbenzene	Yes	Yes	1	1	0.5

Two Weeks After the 2023 Maui Wildfires

2024. *Environ. Sci: Wat. Res. Technol.* https://doi.org/10.1039/D4EW00216D

1) After the evacuation order was lifted, above/below ground smoldering continued
2) Interviewed households had received no government communication; All used drinking water before hearing it was unsafe to use.
3) Home drinking water tests revealed contamination utility tests did not; Consumers use pool test kids and bought at-home kits, but could not find all fire-related chemicals.
4) Agricultural water system damage was like residential systems. 50,000 ft of HDPE animal watering pipe destroyed at 1 property.
5) Public health recommendations provided.

PROJECT NO.
5106

Concept of Operations (CONOPS) Plan for Water Distribution System Testing and Recovery

EBMUD was the lead utility

Developed for utilities, by utilities

Draws from multi-state experiences

In response to:

- Failures to detect the full extent of chemical contamination and damage
- Lack of awareness of needed testing and sampling procedures
- Delayed customer notifications about health risks from contaminated drinking water
- Postponed actions to restore pressure and remove contaminated water from the system
- Struggles with communicating postfire drinking water safety issues to customers, elected leaders, and support organizations

Sponsor: EBMUD, CA
Susan Teefy, David Briggs, Michael Hartlaub

Advisory Committee

Kevin Morley, PhD AWWA

Benjamin Klayman, PhD, Medford Water Commission

Participating Professionals and Utilities

- **City of Santa Rosa, CA:** Joe Schiavone, Mark Shipman, Emma Walton
- **Paradise Irrigation District, CA:** Mickey Rich
- **SJWC, CA**: Sarah Richardson, Francois Rodigari, Suzanne DeLorenzo
- **LADWP, CA:** Marlyn Stasiak, John Kuo
- **Central Contra Costa Water District, CA**: Dave Huey, Andrea Flores
- **City of Napa, CA**: Joy Eldredge
- **Portland Water Bureau, OR:** Kimberly Gupta
- **City of Louisville, CO:** Kurt Kowar, Cory Peterson
- **Town of Superior, CO:** Alex Arinello
- [**Maui County, HI:** John Stufflebean]

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9. Post-fire chemical analysis
10. Water sampling considerations
11. Decision-making considerations using water sample results
12. Communication and general questions

Concept of Operations Plan (CONOPS) for Water Distribution Response and Recovery.

2024. Water Research Foundation. Denver, CO USA. Whelton et al.

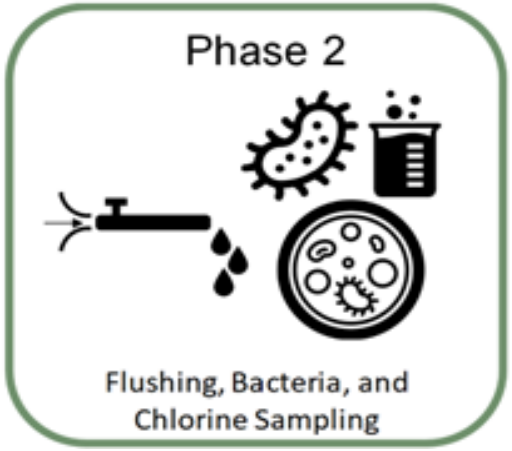
Appendices

A. Example return to service plan
B. CDC guidance about water advisories
C. Target chemicals for water sampling
D. Water sampling SOPs
E. Example FAQs
F. Guidance about drinking water testing reports for the general public

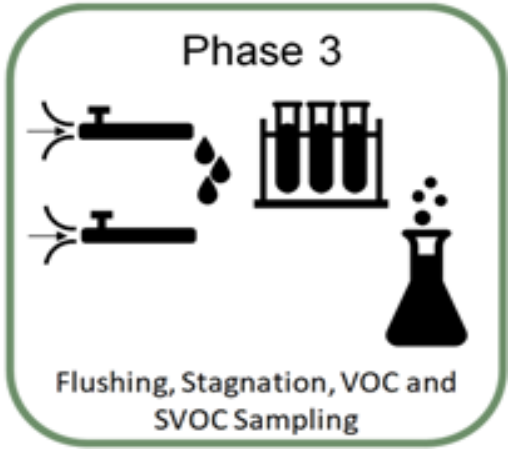
There are 3 main phases of water utility response decisions

Concept of Operations Plan (CONOPS) for Water Distribution Response and Recovery

Support firefighting
Isolate damage
Maintain pressure
Water use warnings



Personnel surge
Restore control, pressure
Repeated sampling
Laboratories



Personnel surge
Repeated sampling
Laboratories
Decon, remove, replace

Pressure, utility network and building plumbing: Leaking, destruction

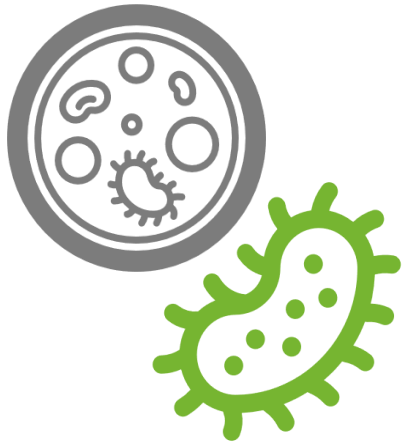
Power: Electric poles down, shutoff by provider, natural gas generators destroyed, lacking fuel

Telecommunications: Outages inhibit tank level, pressure, chemical feed, and pump status monitoring

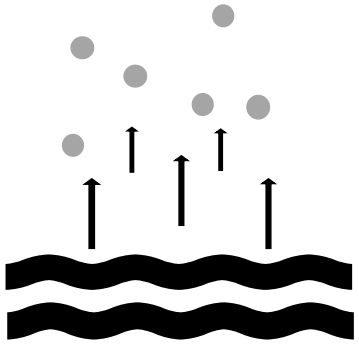
Personnel: Hazard situations, unable to respond due to staff availability

Contamination: Chemicals and microbiologicals drawn into the water system, immediate health risk

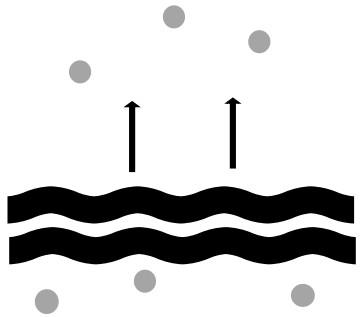
Drinking water system assets can experience extreme contamination



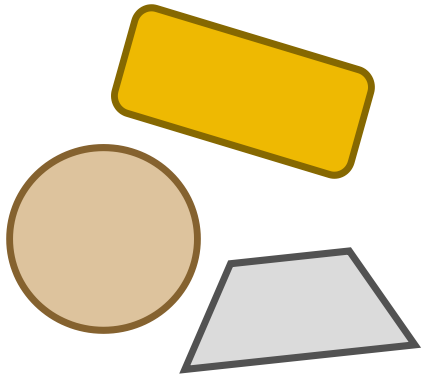
Microorganisms
(ex: *E. Coli*)



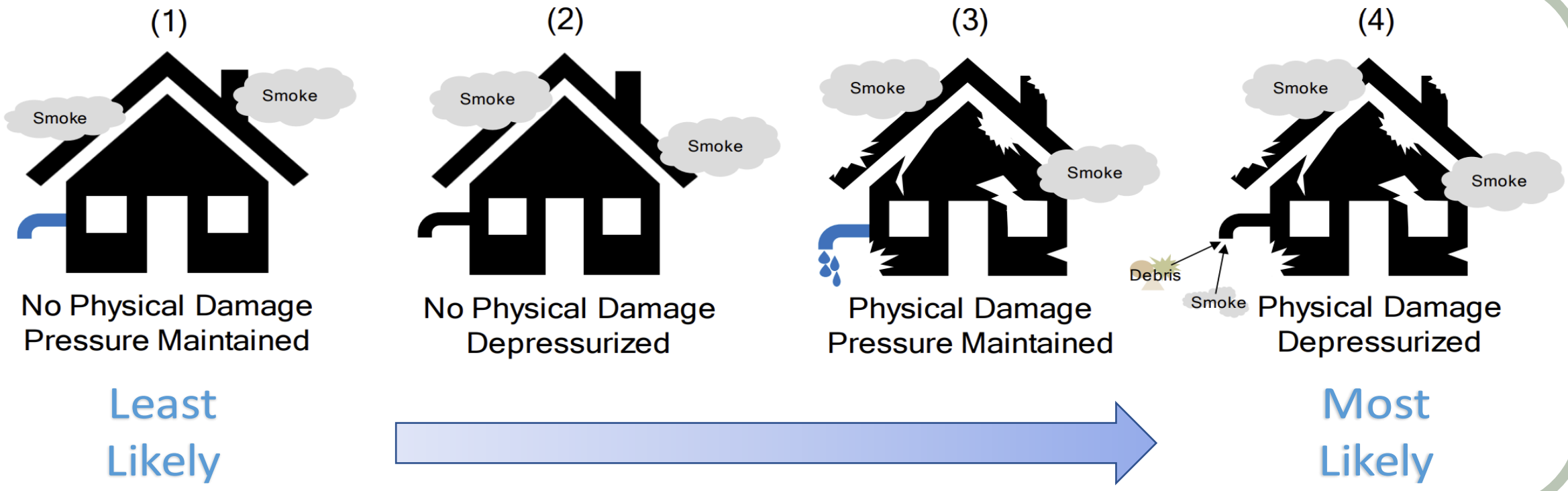
Volatile Organic
Compounds
(VOCs)



Semi-Volatile
Organic Compounds
(SVOCs)



Heavy Metals



Different scales of wildfire property damage will relate to the potential for contaminated drinking water. Water utilities should rate customer buildings to assess their potential for being a SOURCE of the contamination.

Exposure Routes

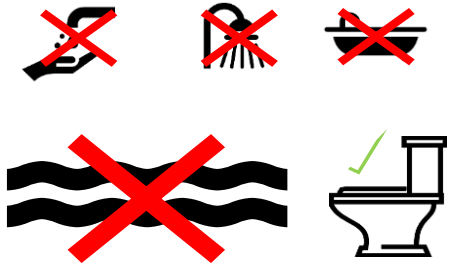
(i.e., Adults, children, infants, etc.)

Ingestion

Dermal contact

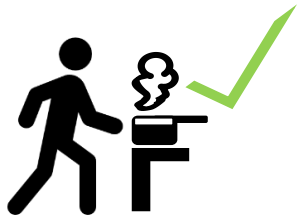
Inhalation

Water Use Warnings



Do Not Use (DNU)

Do Not Drink (DND)



Boil Water Order

Water utilities should issue a drinking warning to customers ASAP, if necessary, (i.e., Boil Water Advisory, Do Not Use Order). It must be protective of the specific health threats.

Overall Decision Flow Chart

No advisory v. Boil Advisory v. Do Not Use Advisory?

Wildfire

Test the water source of the zone

Below drinking water limits?

Yes

No

Evaluate potential damage and make necessary repairs or install necessary treatment

Multiple burned structures in a zone?

Yes

No

Path 2 – Burned structures zone with NO pressure loss

Do Not Use

Pressure loss?

Yes

No

Path 1 – Burned structures zone with pressure loss

Do Not Use

Hydraulically receives water from wildfire impacted zones?

Yes

No

Path 3 – Hydraulically impacted undamaged zone

BWA or Do Not Use

Pressure loss?

Yes

No

Path 4 – Boil water advisory

No Advisory

Maintain service

A Few Water Testing Thoughts Based on Experience

- Repressurize, measure disinfectant residual, then go after VOCs
- Use the recommended VOC Method (EPA 524.2) for *specific* chemicals at the minimum. Other methods may be fine as along as they are sensitive enough and inclusive of fire-related chemicals
- The total number of chemicals you screen for is irrelevant
- Not all labs screen for the same EPA Method 524.2 chemicals (Check)
- If you find chemicals that historically have been your DBPs, that doesn't mean what you find isn't from the fire (i.e., Lake Madrone, CA)
- Make data publicly available
- Make methods used publicly available
- Develop restoration of service plan….then seek external resources to support
- Including expert feedback as you create your plan (system detail level)

“Fire package” list of chemicals to screen

BOLD and RED exceeded health limit (list as of March 2024)

Blue symbol indicates it was sucked into plumbing during a structure study

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

How long can decontamination take?

It depends. Flushing is your friend. Repressurize and remove contamination out as fast as possible to limit further damage.

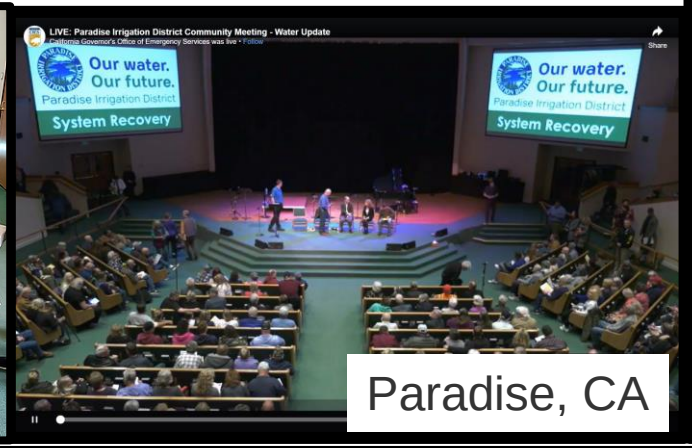
Table 1. Time in Days Needed PER SERVICE LINE to Decontaminate by Water Flushing, based on the concentration of benzene measured before flushing begins. Flushing is with 2.03 GPM of benzene-free (0.0 ppb) water.

Initial measurement concentration (C_2)	Goal A (never above 0.5 ppb)		Goal B (only exceed 0.5 ppb after 72 hours of stagnation)	
	Continuous	Intermittent (once/72 hrs)	Continuous	Intermittent (once/72 hrs)
100 ppb	286	312	195	240
50 ppb	246	270	156	198
20 ppb	195	213	104	141
10 ppb	155	171	66	99
5 ppb	116	129	33	60
2 ppb	64	74	8	20

NOTE: Benzene isn't the panacea

Other thoughts

- Underground smoldering for weeks
- Destroyed buildings: Remove water meters, do not just shut them off or you should expect cross-connections; Suspend water bills
- Public meetings
- If impacted utilities in the same area do not apply the necessary actions



Paradise, CA

Maui, HI

- **Immediate Actions (Cat B)**
  - Water Pickup/Fill Stations (Cat B)
  - Source Water Concerns
  - System Isolation/Stabilization
  - Public Relations and Outreach Information
    - Does Utility have Resources? PR Firm Sole Source (Cat B)
    - Immediate, Short Term, Long Term Return to Service Map ETA's for Public Information
  - Initial Testing Coordination/Reporting (VOC's) (Cat B)
  - Flushing
    - Environmental Concerns/Constraints
    - Test/Flush/Test (Traditional Incremental)
    - Test/Flush/Flush/Flush/Test (New ~Historical Data Driven)
  - Infrastructure Cleaning ~Reservoirs, WTP's, Tanks, etc. (Cat B)
  - Initiate Recovery Program Development (Cat B)
  - Damage Assessment/Mapping (Cat B)
  - Areas to Restore to Service ASAP
  - Regulatory/CALWARN/FEMA Coordination
  - Time/Expense Tracking (Cat Various)
- **Mid Term Actions (Cat B)**
  - Testing Protocols and Lab Capacity (VOC's, Chlorine, Bacteria)
  - Recovery Program Development RFP Assistance
  - System Impact Modeling (If Necessary)
  - FEMA Category B, First 30 Day Activities
  - Declaring Long Term No Service Areas to Inform Habitable Homes for Alternative Living Arrangements/Expenses
  - Upstream Utility Recovery – Power, Natural Gas, Comms
  - Downstream Utility Recovery – Sanitary Sewer,
    - Stormwater
- **Mid - Long Term Actions (Cat D)**
  - TBD
  - Recovery Program Structure
  - Return to Service Testing
  - Service Line Abandonment prior to Debris Removal
    - Highest Likely Source of Ongoing Contamination.
    - Debris Removal Activities will grab service lines and damage/destroy mainlines.
  - Insurance Policy Review vs FEMA Categories
  - Time/Expense Tracking Reporting (Cat Various)

From Kurt Kowar, City of Louisville DPW Director

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

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- Flushing Plans
- Plumbing Demonstrations - Camp Fire
- Video / Audio
- Presentations / Reports
- Peer-Reviewed Publications
- Water Quality Risk Tools
- Hawaii Response
- Wildfire Response
- Survey - Camp Fire
- FAQs - General Plumbing
- FAQs - Camp Fire Response

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.

Marshall Fire Homeowner Support

Letter to Homeowners Affected by the Marshall Fire in Unincorporated Boulder County (January 2022)

Resources for Households, Private Well Owners, and Public Health Officials

Here is a list of chemicals to test for (as of May 2022) to find chemical contamination in wildfire impacted drinking water systems:

- List of Chemicals in Wildfire Impacted Water Distribution Systems [May 2022]

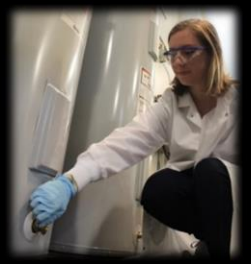
These 1 page information sheets provide households and public health officials considerations for water system, inspection, testing, and potential safe drinking water options when the plumbing is unsafe. These documents were developed based on firsthand experience investigating contamination after wildfire, building plumbing, sampling, decontamination, and advising local, county state, and federal agencies. Information in these documents is partly based on practices from several health departments who have responded to wildfire caused drinking water contamination disasters and also influenced by our firsthand experiences and testing.

- After a Wildfire: Water Safety Considerations for Private Wells [May 16, 2021, Prepared by the Center for Plumbing Safety]
- After a Wildfire: Water Safety Considerations Inside Buildings [May 16, 2021, Prepared by the Center for Plumbing Safety]
- ***Attention: Persons impacted by wildfire should seek specific advice from their local health department.***

Resources for Emergency Management, Water Utility, Public Health, and Elected Officials

This video helps prepare officials for water system damage scenarios. Wildfires can damage water distribution system infrastructure both physically –and– chemically. Some damage may not be visible. Hazardous waste scale drinking water chemical contamination can be caused. This presentation does not cover all situations, but instead provides an introduction for the viewer. More information and help can be obtained by contacting the Center for Plumbing Safety.

www.PlumbingSafety.org
www.CIPPSafety.org


- ✓ Post-fire chemicals to test for
- ✓ Brief videos for emergency managers and health officials
- ✓ Guidance for private well owners
- ✓ Guidance for building owners
- ✓ Government agency resources
- ✓ FEMA mitigation guidance
- ✓ Other training resources

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