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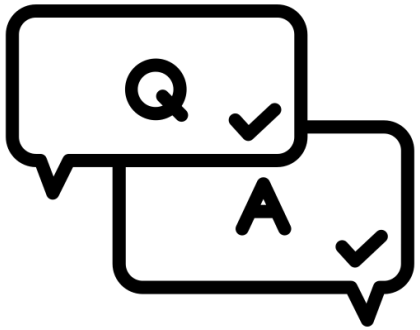
When Fire Meets Water: Understanding VOC Intrusion in Burned Water Distribution Systems

Amy Metz

Oregon State University

September 4, 2025

Webinar Housekeeping



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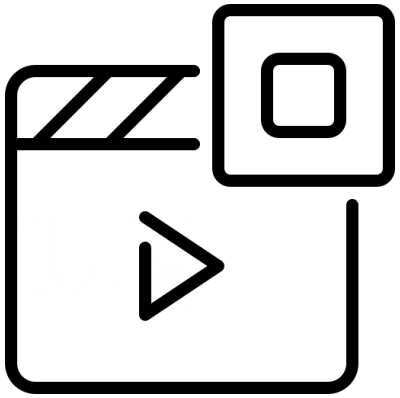

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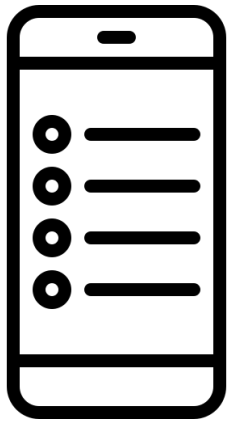

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When Fire Meets Water:

Understanding VOC Intrusion in Burned Water Distribution Systems

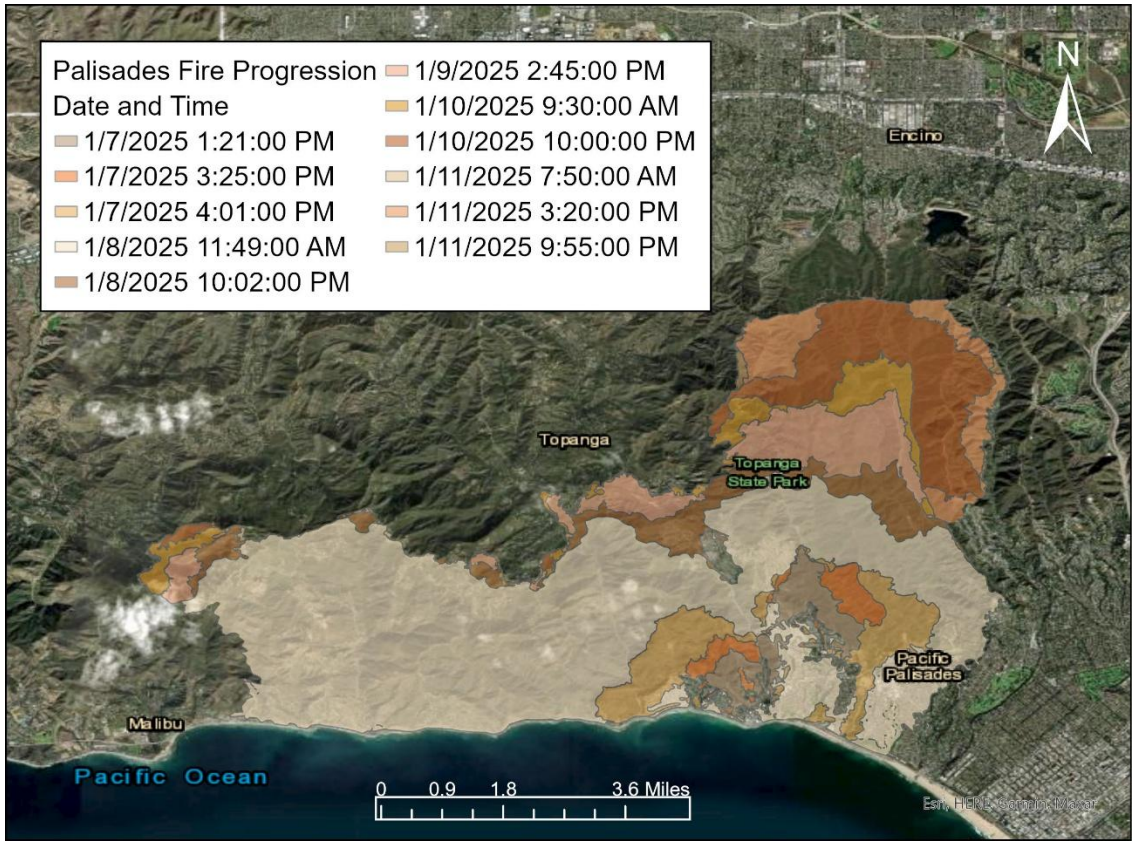
AMY METZ

SEPTEMBER 4, 2025

Image credit: Josh Edelson/AFP via Getty Images

Oregon State University

SFPE Foundation



Wildfire operates on a temporal and spatial level.

- Dependent of regional characteristics
- Has ecological and community impacts
- Is a natural part of ecosystems it occurs in


Image credit: Gaylon Wampler / Getty Images

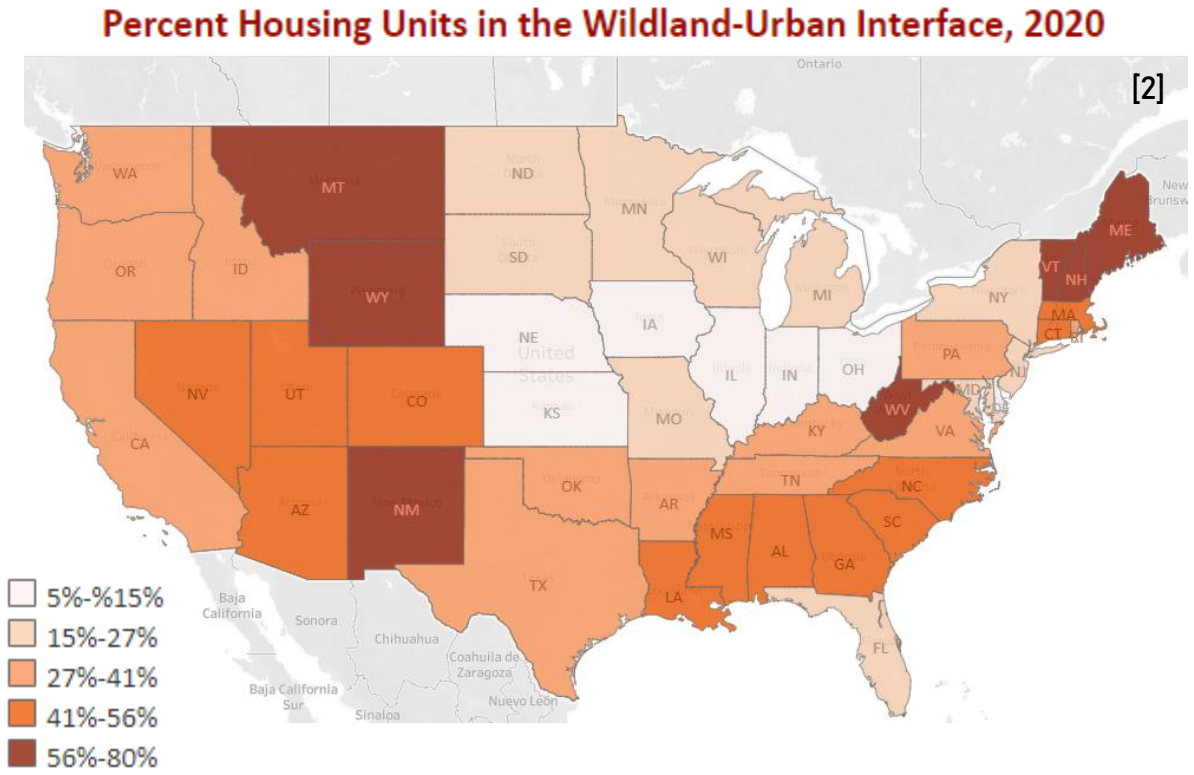
Fires in the Wildland Urban Interface (WUI)

Fires in the Wildland-Urban Interface

Wildland Urban Interface (WUI):

- Where human development meets or intermixes with undeveloped wildland
- Fastest growing land use type in the US

Fires in the Wildland-Urban Interface



Wildland Urban Interface (WUI):

- Where human development meets or intermixes with undeveloped wildland
- Fastest growing land use type in the US
- 32% of all US housing is in the WUI

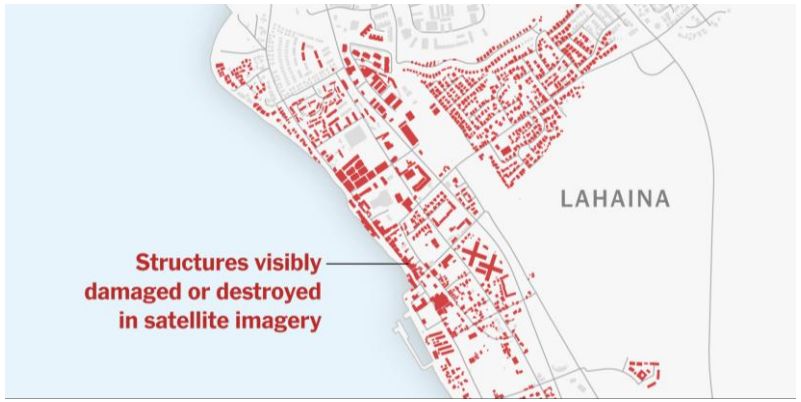
USDA Forest Service Northern Research Station, "Understanding the Wildland-Urban Interface (1990-2020) StoryMap." USDA Fore Service, 2023, [Online]. Available: https://www.fs.usda.gov/research/nrs/products/dataandtools/interactivemaps/understanding-wildland-urban-interface-1990-2020-storymap.

WUI Wildfire Events

Challenges of Wildfire to Urban Fire Scenarios

- Unfamiliar firefighting environments
- Extreme fire weather
- Water system design

Wildfire Events



Structures Destroyed

Leaks at Destroyed Structures

Firefighting Demands

Water System Impacts

NEWS

Water quality could be impacted for a decade from Oregon wildfire fallout for 200k people

Bill Poehler
Salem Statesman Journal
Sept. 25, 2020, 3:24 p.m. PT

After Deadly Wildfire, a New Problem for Santa Rosa: Contaminated Water

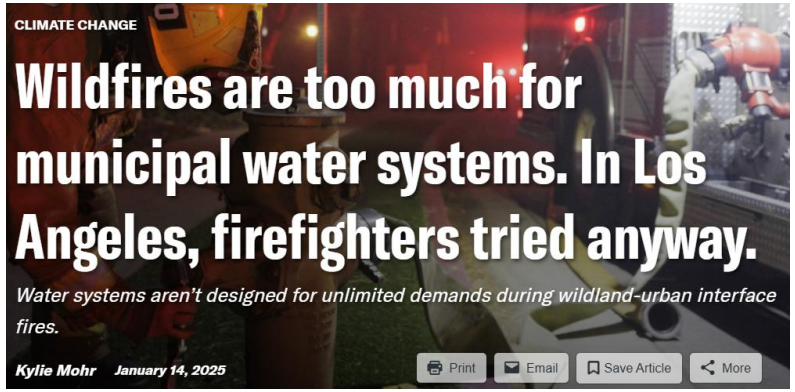
The Northern California city suffered one of the deadliest fires in state history. In the aftermath, it now confronts a costly pollution problem likely caused when melted plastic pipes released chemicals into the water supply.

A surprising byproduct of wildfires: Contaminated drinking water

By Daniel Wolfe and Aaron Steckelberg

41 / 41
New

Updated Jan. 12 at 9:02 a.m.
Originally published July 29, 2024



Amid the fires, LA is warning some residents the tap water isn't safe. Here's why

JANUARY 11, 2025 · 5:45 AM ET

HEARD ON WEEKEND EDITION SUNDAY

Pien Huang

Water System Impacts

What are VOCs?

- Carbon-based chemicals
- Can occur naturally or be man-made
- Evaporate easily at ambient temperatures

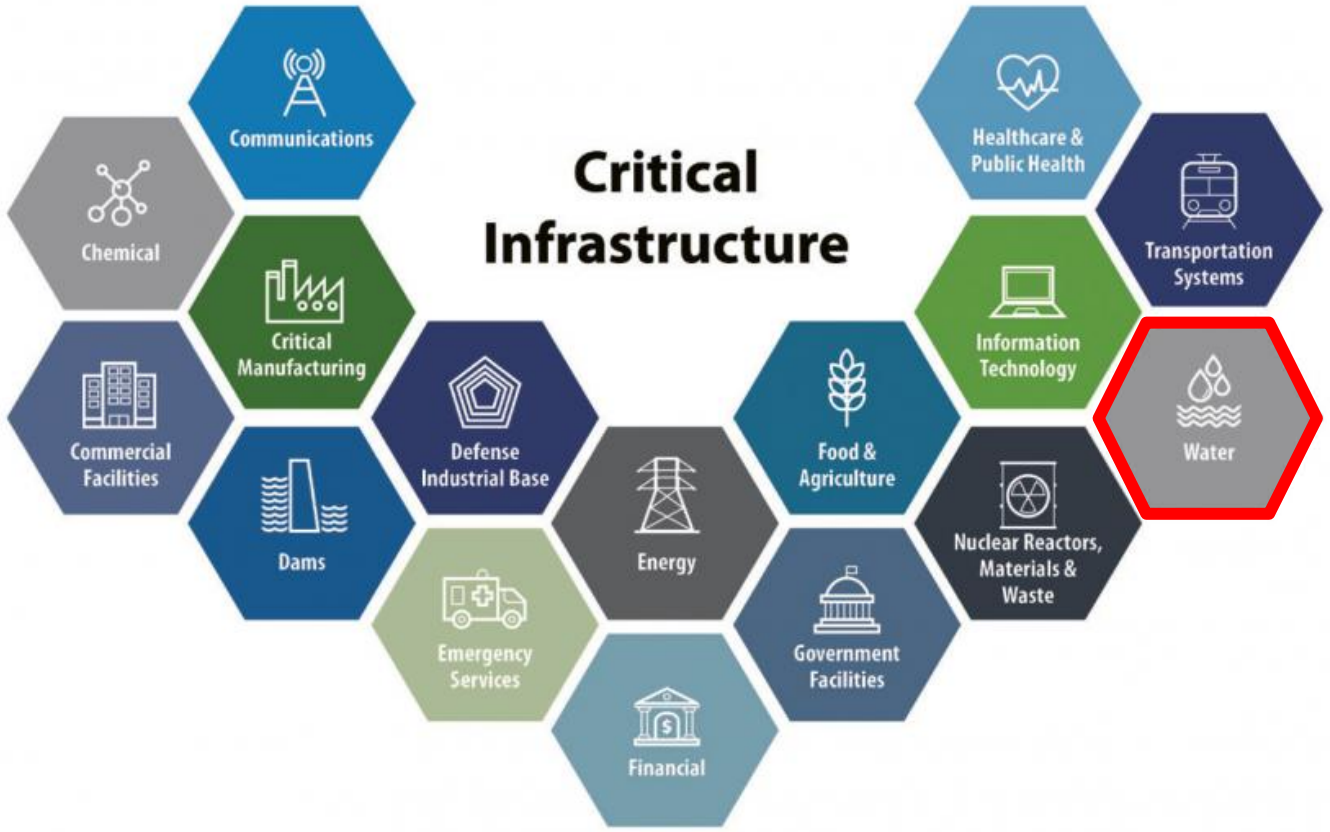
How are VOCs regulated?

- US EPA's National Primary Drinking Water Regulations
- Some have set maximum contaminant levels (MCLs)
- MCLs based on long-term risks to human health

Water System Impacts

Critical Infrastructure:

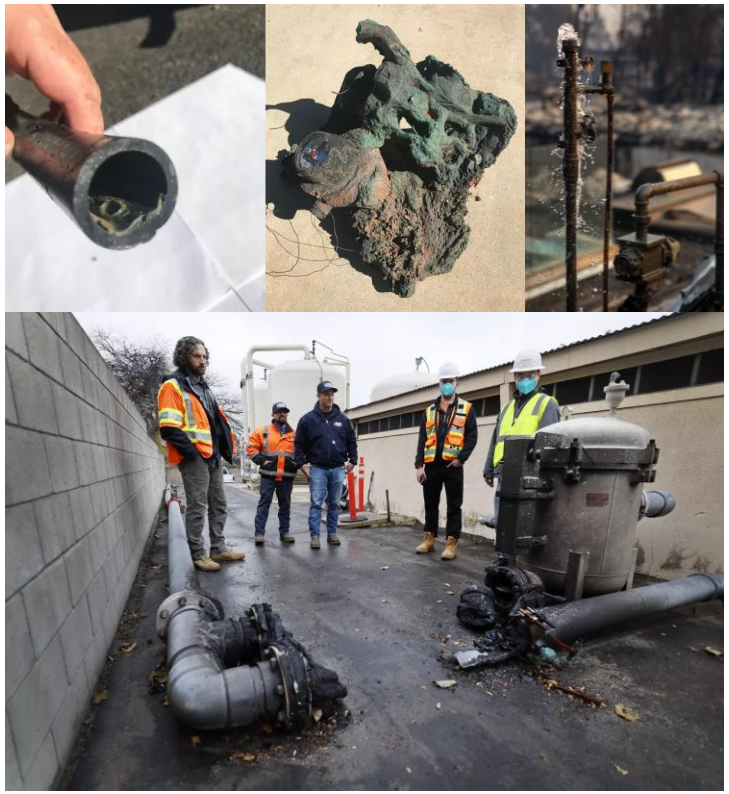
the systems, facilities, assets, and networks—both physical and virtual—that are essential for a society's functioning, security, and economic stability



Current State of Research: The Source of Water System VOC Contamination Following Wildfire

Post-Wildfire VOC Contamination

Physical Infrastructure Damage



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Depressurization

Why fire hydrants and water supply failed during Los Angeles wildfires

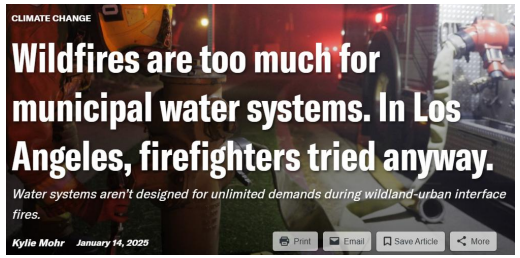
The LA wildfires continue to burn, with Santa Ana winds set to intensify and a range of challenges hampering rescue efforts.

As Inferno Grew, Lahaina's Water System Collapsed

Firefighters who rushed to contain the Maui wildfire found that hydrants were running dry, forcing crews to embark instead on a perilous rescue mission.

Q Why did some fire hydrants run out of water when we needed them most?

A Takeaway: When fire hydrants have low water pressure, it is likely because many people are using water at the same time to protect property, damaged pipes are leaking water, and/or electric power service is interrupted.



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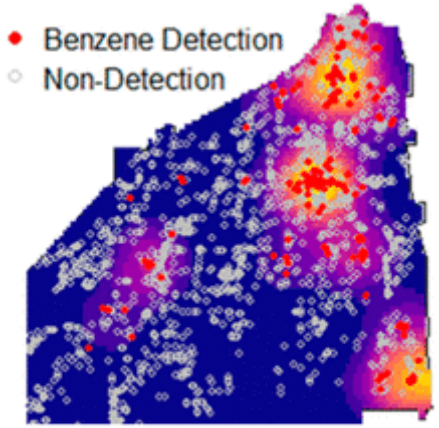
VOC Contamination



Paradise, CA, USA

[4]

Post-Wildfire VOC Contamination

Community Impacts of VOCs:

- Recovery delayed
- Do not drink, do not boil orders
- Costly system repairs

Post-Fire Analysis

- California and Colorado
- 12 different VOCs and SVOCs present
- 1000x MCL for benzene
- Present in both polymer and metal pipes

[4]- [7]

VOC Contamination Mechanisms

1. Degradation of pipe materials in water system due to exposure to elevated temperatures

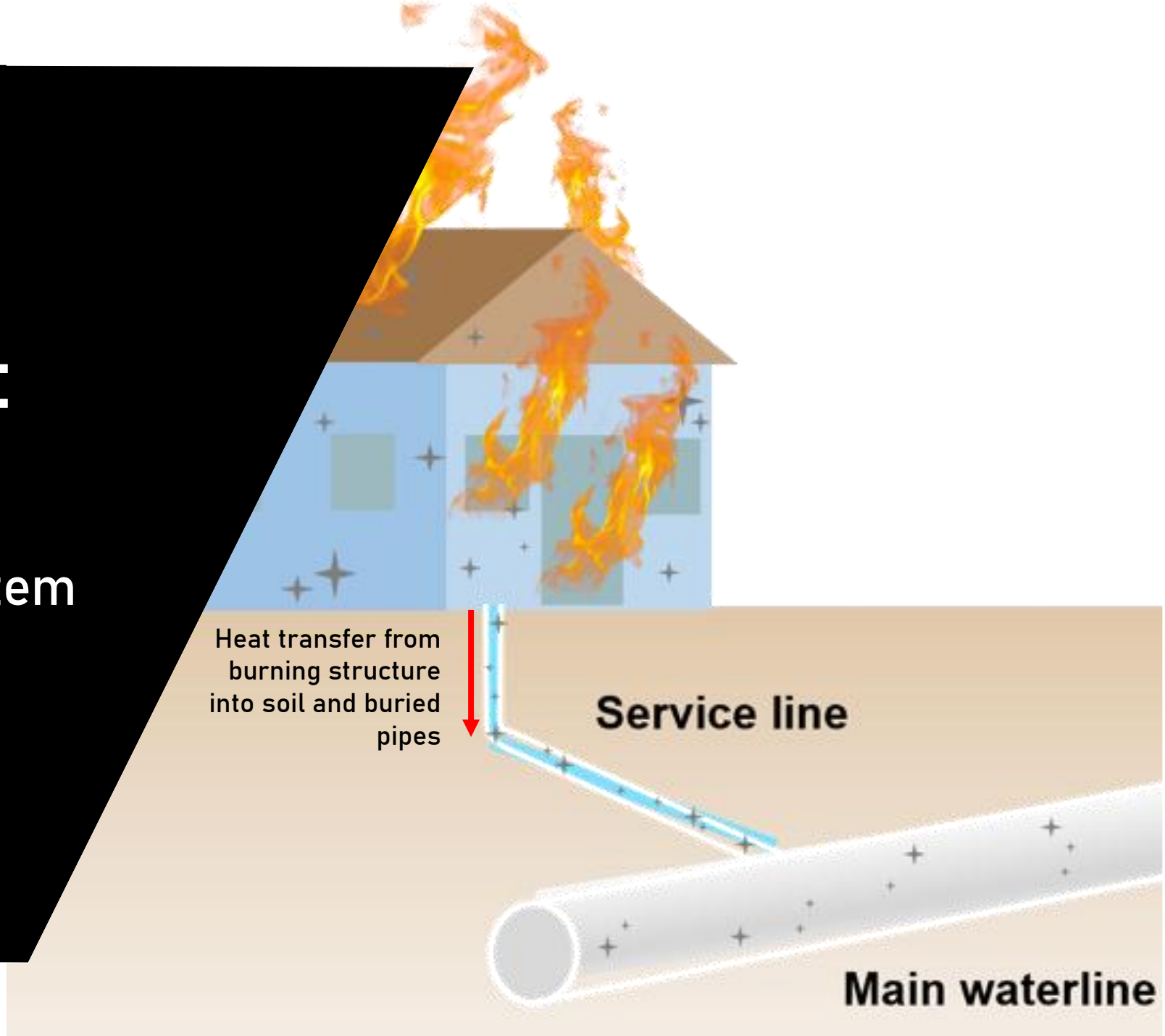
2. Localized depressurization introducing contaminated combustion gases and/or particulate matter into the system

3. Back siphoning of contaminated water from damaged building plumbing

How is current research addressing these contamination mechanisms?

Contamination Mechanism #1:

Degradation of pipe materials in water system due to exposure to elevated temperatures



VOC Leaching from Degraded Pipe Materials

PEX

PVC

HDPE

Copper

Galv. Steel

Release VOCs when exposed to elevated temperatures [4] –[11]

Largely Inert [8], [9]

Supports contamination mechanism 1 by showing polymer pipe materials can degrade and release VOCs

VOC Leaching from Degraded Pipe Materials

PEX

- Temperature benzene is first leached: 150°C [5]

PVC

- Estimated temperature concentration of benzene leached will exceed federal MCL: 194°C [8]

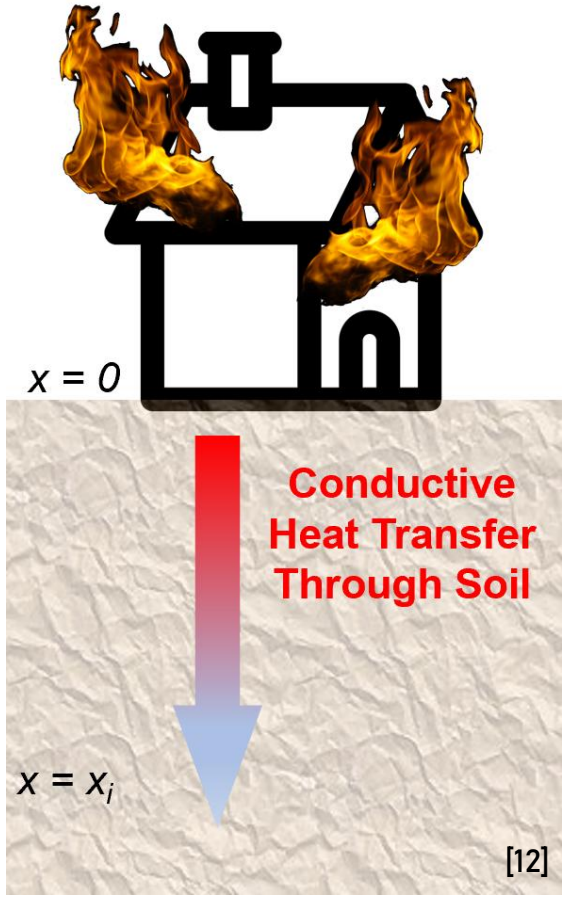
HDPE

- Temperature benzene is first leached: 150°C [5]
- Estimated temperature concentration of benzene leached will exceed federal MCL: 254°C [8]

VOC Leaching from Degraded Pipe Materials

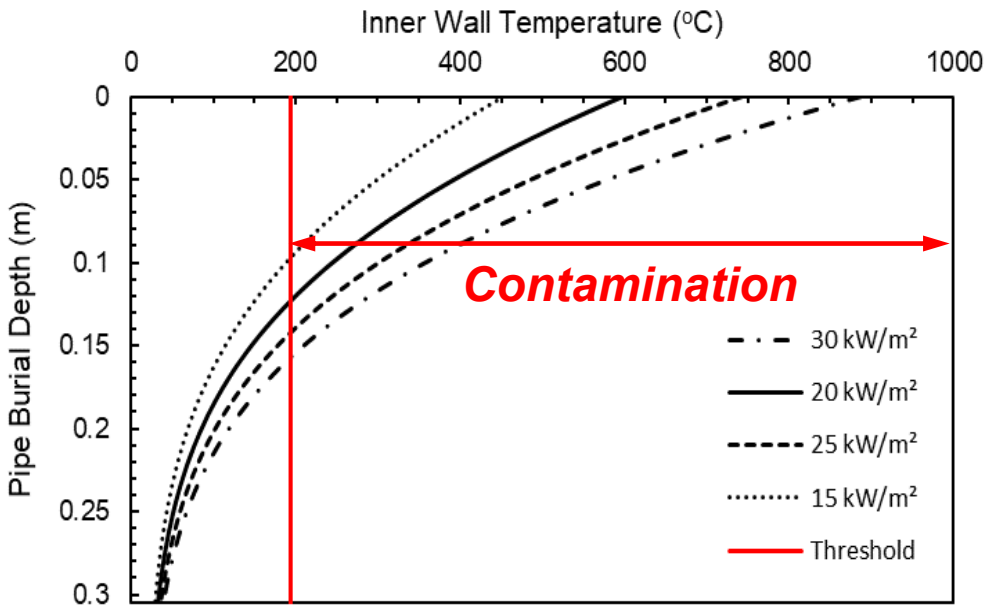
PVC critical temperature (194°C) [8]

HDPE critical temperature (254°C) [8]

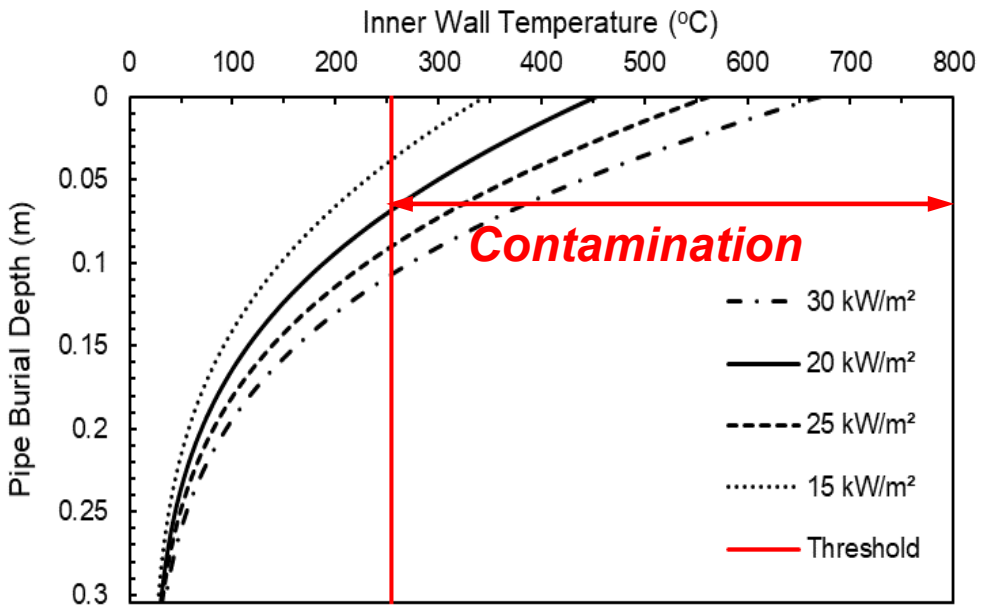


VOC Leaching from Degraded Pipe Materials

Two-hour exposure (PVC)



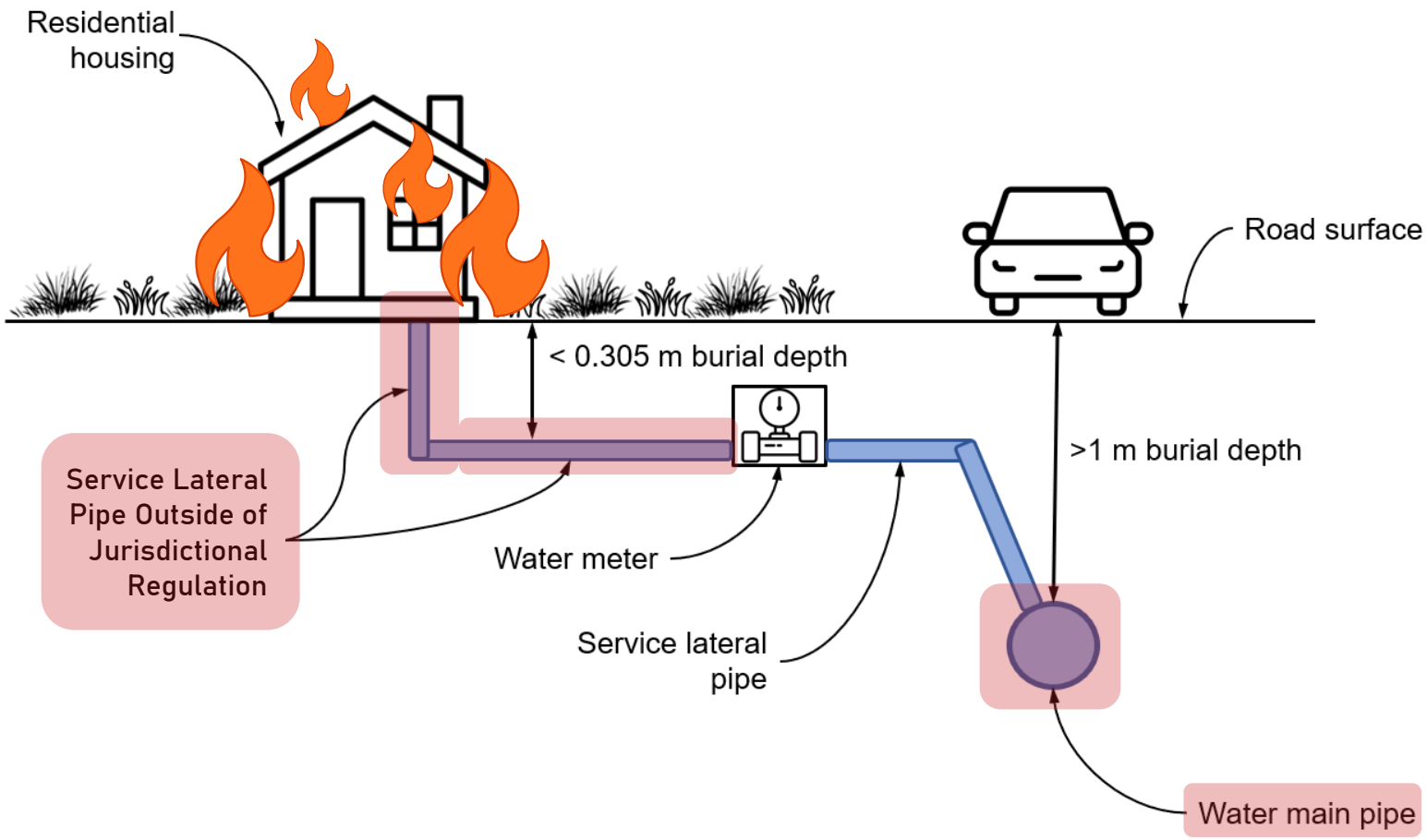
Two-hour exposure (HDPE)



PVC and HDPE pipes buried with 4" or less of soil cover exceeded their critical threshold temperature under simulated low-intensity wildfire exposures.

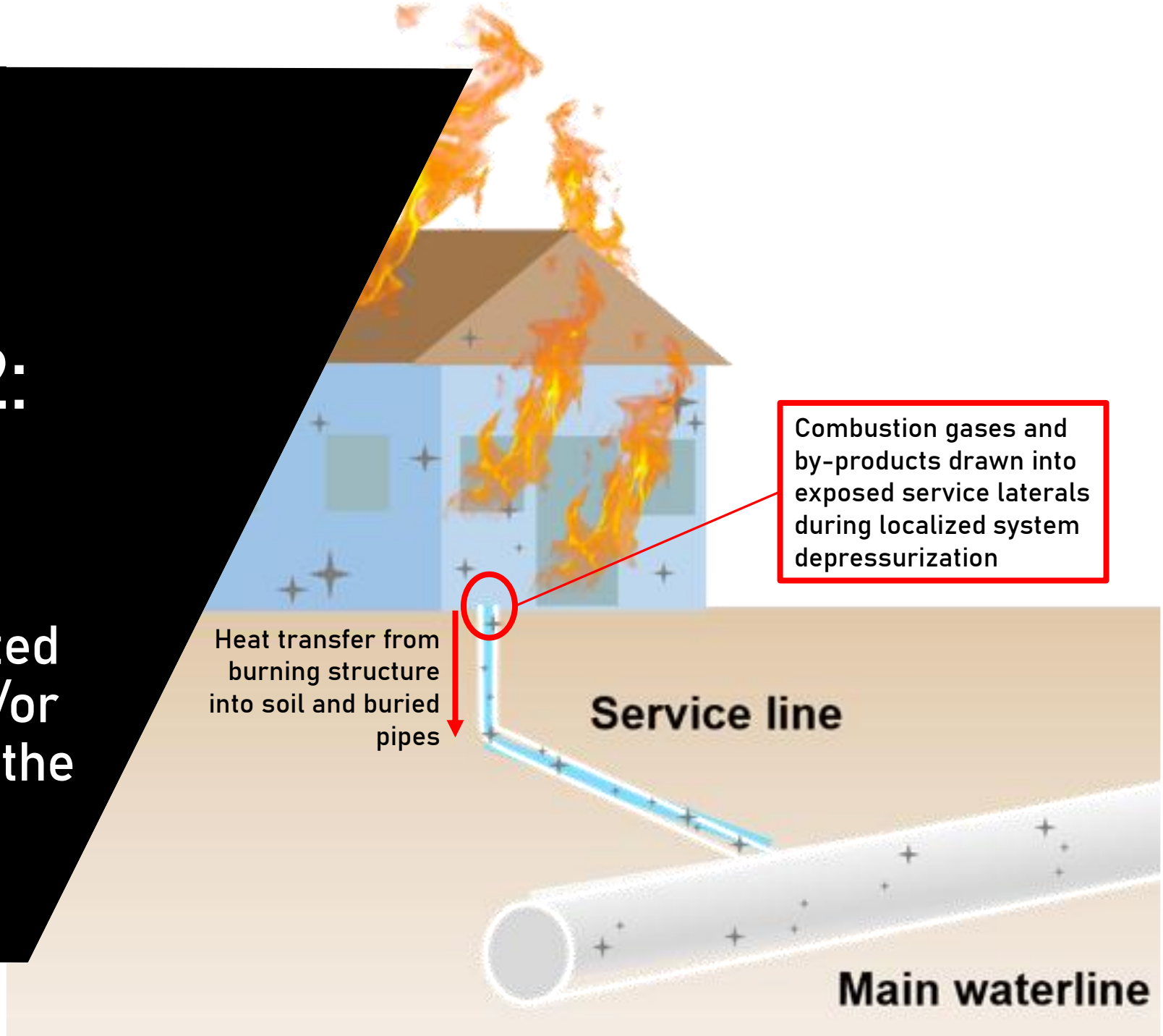
[12], [13]

VOC Leaching from Degraded Pipe Materials



Contamination Mechanism #2:

Localized depressurization introducing contaminated combustion gases and/or particulate matter into the system



VOCs Generated Combustion By-products

Demonstrates that there is the potential for combustion gases to introduce VOC to open service laterals when local depressurization occurs.

Burning structures release VOCs as materials burn [14], [15]

Concentrations of VOCs released generally increase with combustion time [14], [16]

VOCs from combustion gases can condense to liquid when gases cool [17]

Introduction of VOCs through Local System Depressurization

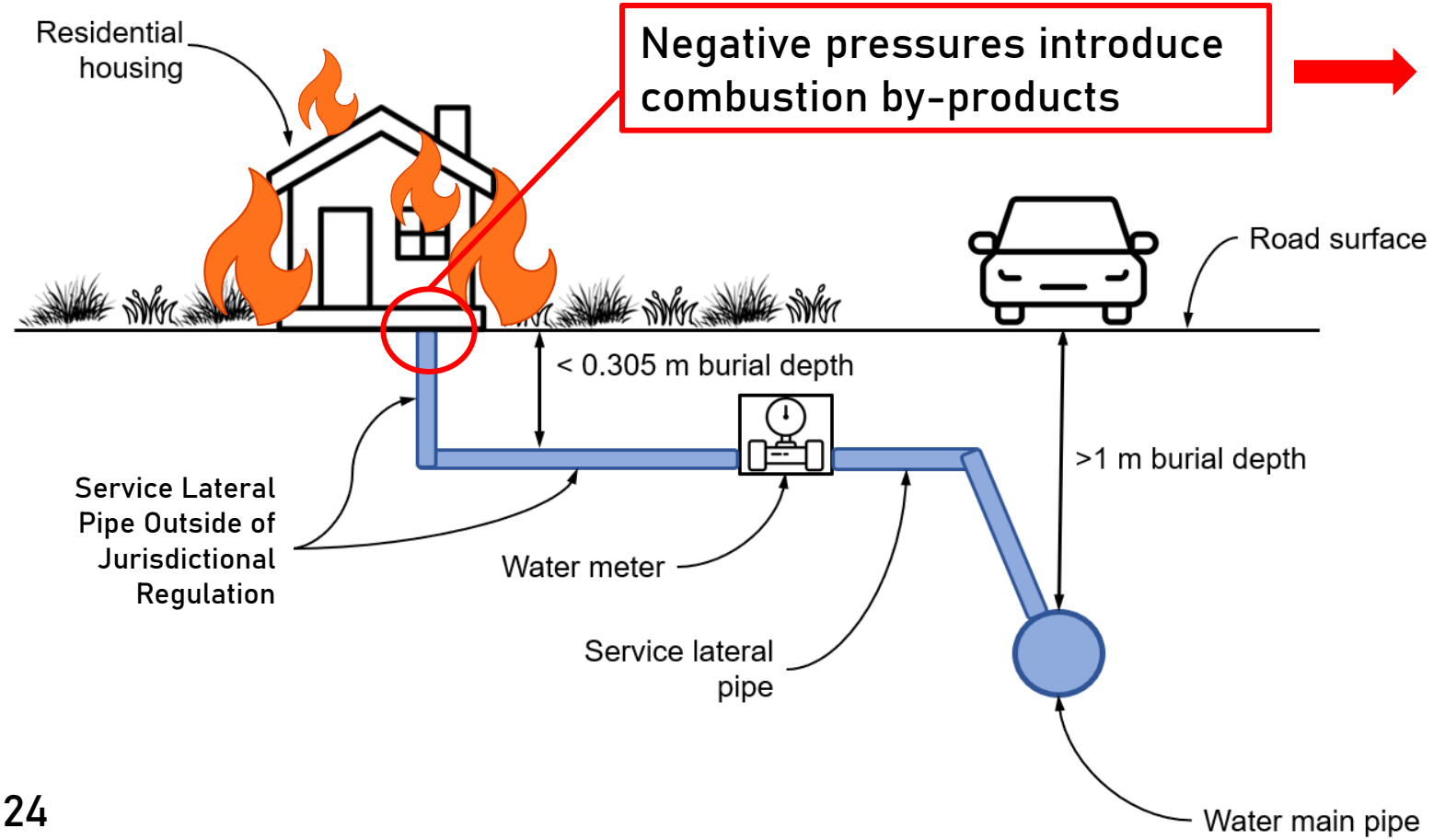
- Methodology developed to simulate localized depressurization of service laterals

- Looks to quantify:
  - VOCs generated from combustion of compartment of known fuel load
  - Impact of introduced combustion gases and condensate on service laterals

- On-going research

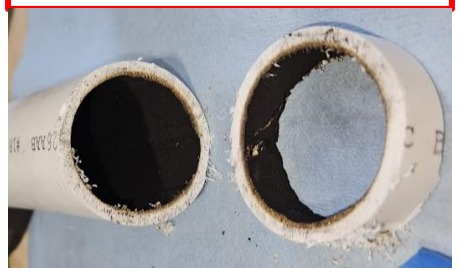
[18]-[20]

Introduction of VOCs through Local System Depressurization



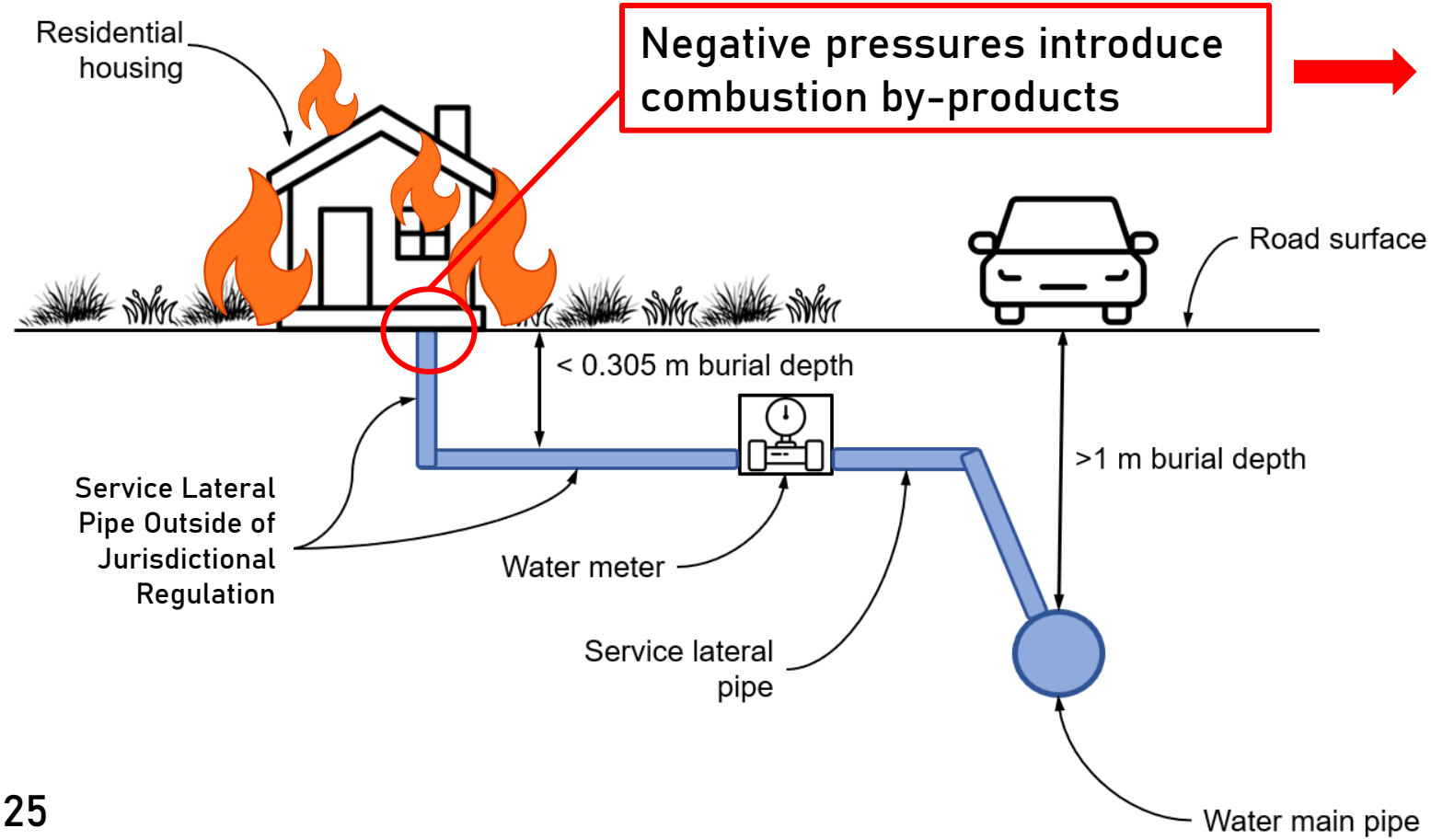
No visible damage on exterior

Adhesion of particulate matter and thermal degradation on the interior



[18]-[20]

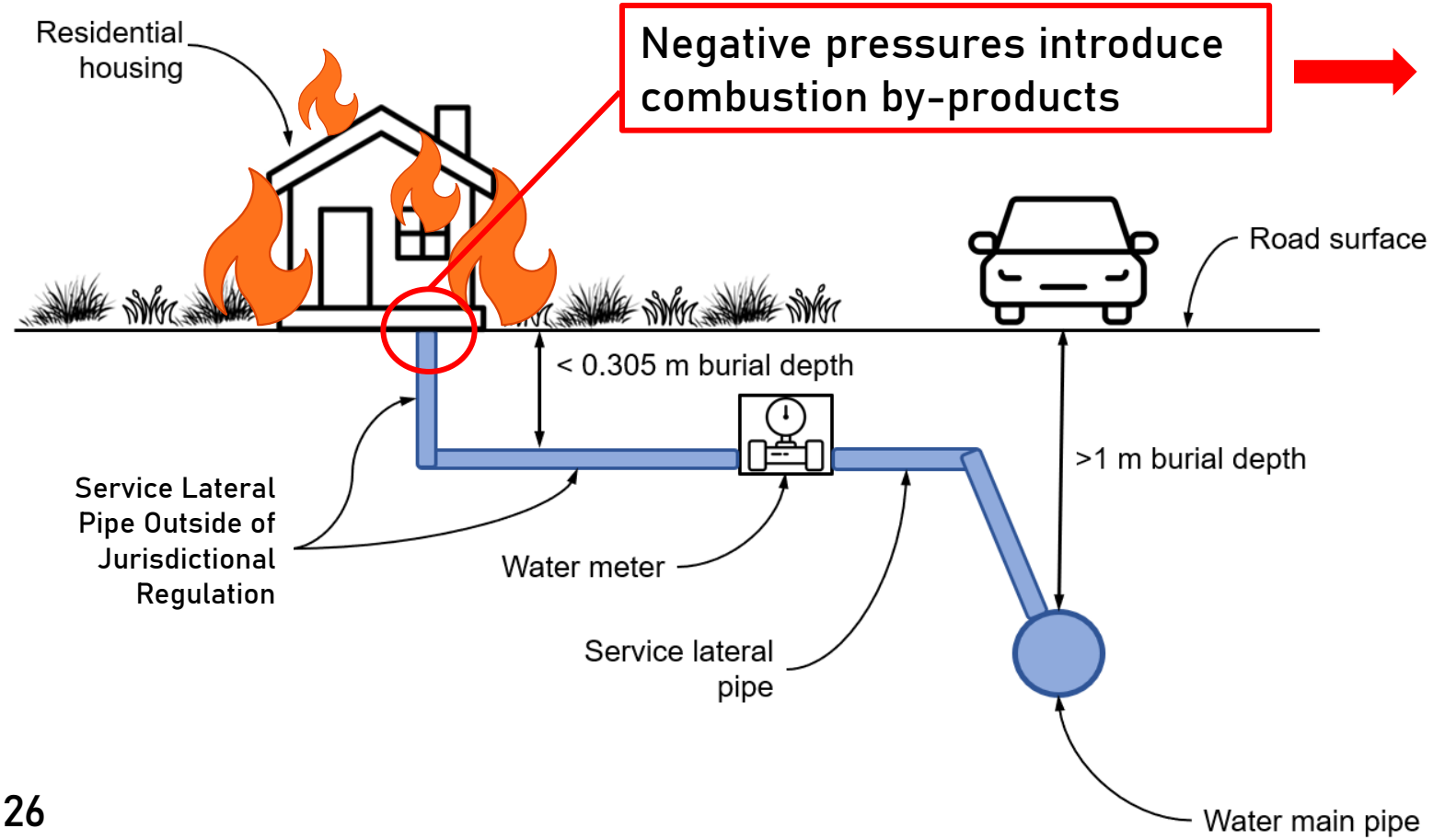
Introduction of VOCs through Local System Depressurization



Polymer Pipes (PVC, HDPE) more susceptible to VOC contamination under negative pressure conditions than metal (galv. steel)

[18]-[20]

Introduction of VOCs through Local System Depressurization



Negative pressures introduce combustion by-products

Flushing pipes after exposure reduced VOC concentrations leached but did not eliminate

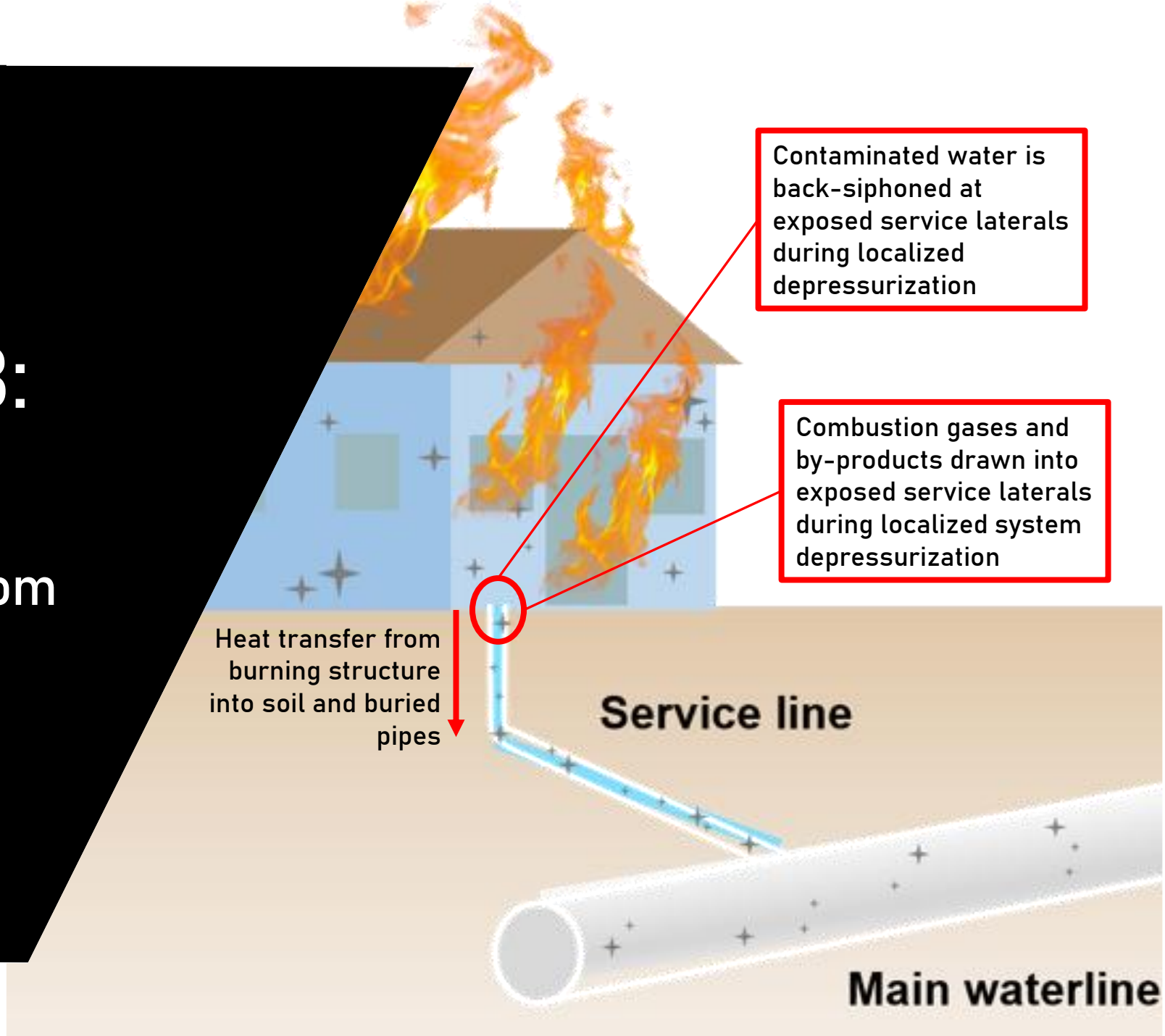
72 hr stagnation (potable water or open-to-air)

VOC concentrations leached from pipe materials increased

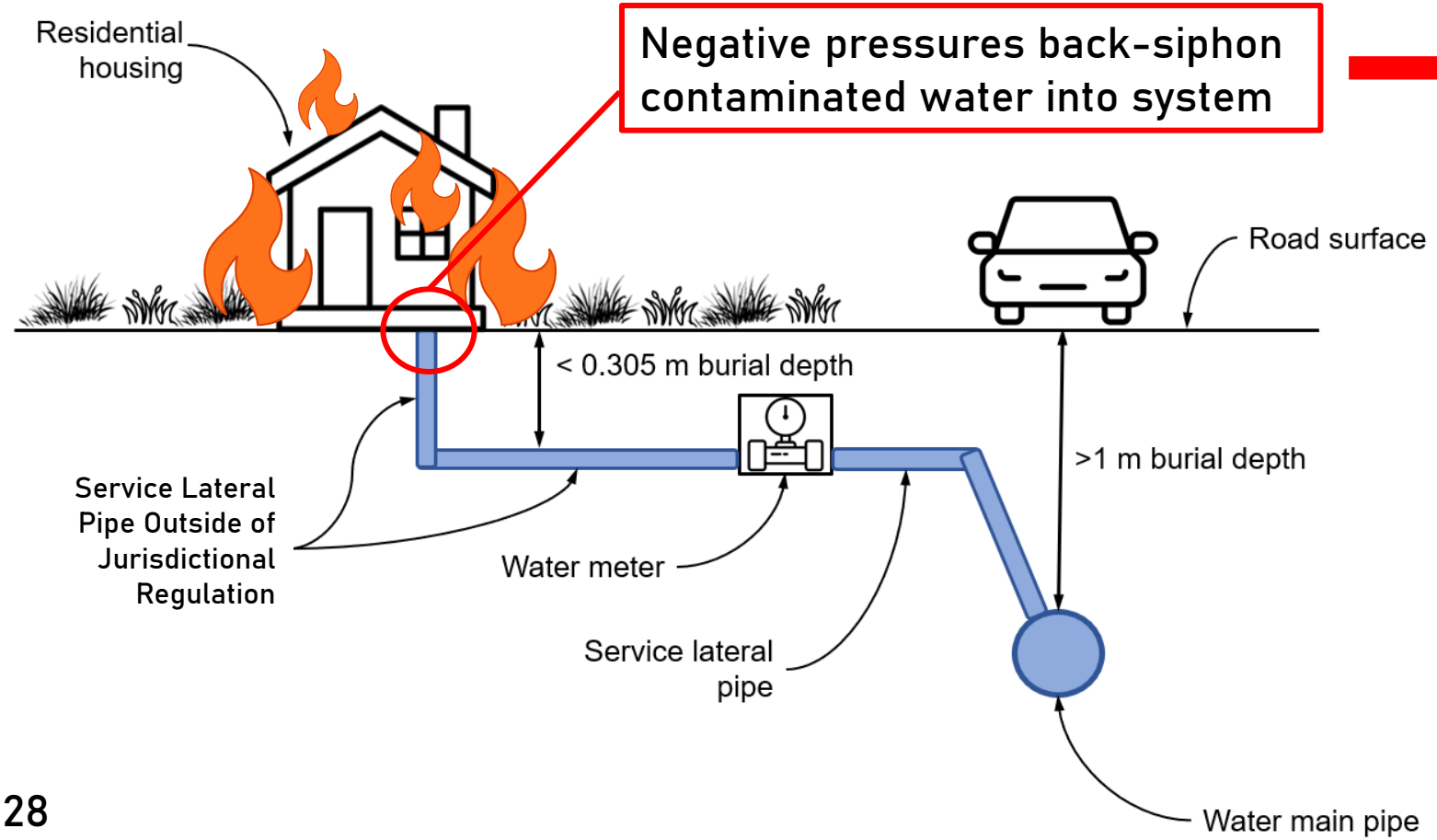
[18]-[20]

Contamination Mechanism #3:

Back siphoning of contaminated water from damaged building plumbing



Introduction of VOCs through Back-siphoning of Contaminated Water



Negative pressures back-siphon contaminated water into system

Pipe flushed after exposure to combustion by-products

72 hr stagnation with fire suppression runoff inside

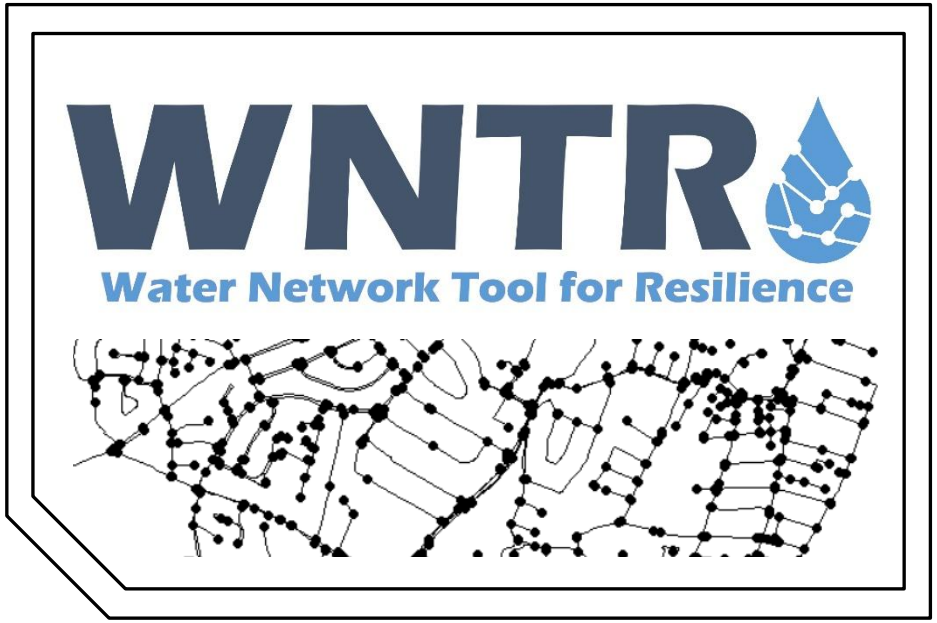
VOC leaching did not increase like it did for potable water and open-to-air stagnation conditions

[18]-[20]

Image Credit: AP Photo/Chris Pizzello

Current State of Research: Design of More Wildfire Resilient Water Systems

Design of More Wildfire Resilient Water Systems



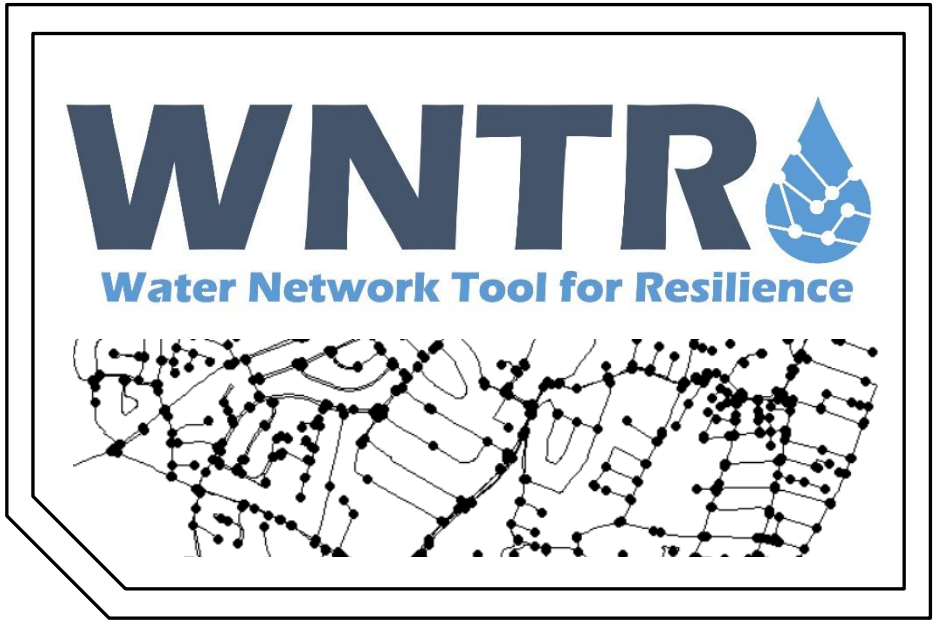
[21]

- Model demands wildfires place on water systems
  - Leaks at fire impacted structures
  - Firefighting

Leaks at Destroyed Structures

Firefighting Demands

Design of More Wildfire Resilient Water Systems



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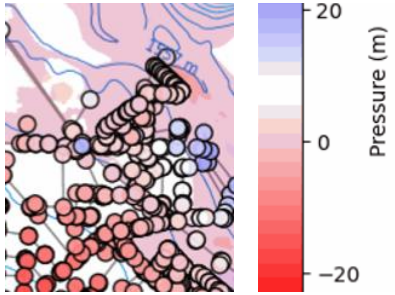

Depressurization vulnerability assessment

[22]

Wildfire operations planning

[23]

Evaluation of effectiveness of potential mitigation measures

Design of More Wildfire Resilient Water Systems

Concept of Operations (CONOPS) Plan for WDS Testing and Recovery [24]

- Developed to help communities recover
- Provides operational guidance
  - Addresses complex scenarios
  - Flexible

PROJECT NO.
5106

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

LA DWP Los Angeles Department of Water & Power
SAN JOSE WATER
EBMUD
CONTRA COSTA WATER DISTRICT

Image Credit: AP Photo/Chris Pizzello

Future Research

Image Credit: AP Photo/Chris Pizzello

Future Research - Experimental

- Contamination characterization
- Pressure system integrity
- Recovery protocols
- Fire suppression capacity

Image Credit: AP Photo/Chris Pizzello

Future Research - Numerical

- Contamination transport modeling
- Vulnerability assessment frameworks
- Recovery optimization modeling

Thank You!

metzamy@oregonstate.edu

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