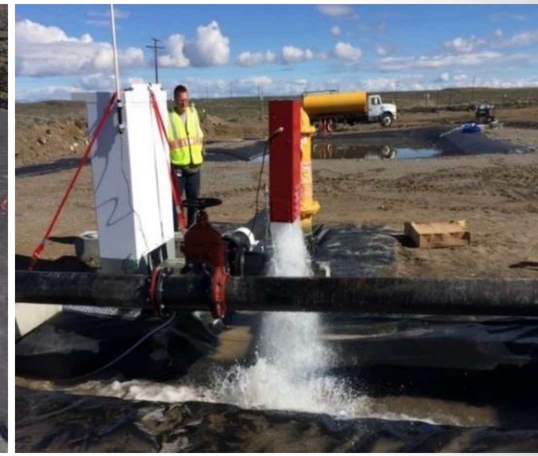
USEPA Office of Research and Development

# Homeland Security Research Program



# Science to support water infrastructure decontamination following a contamination incident

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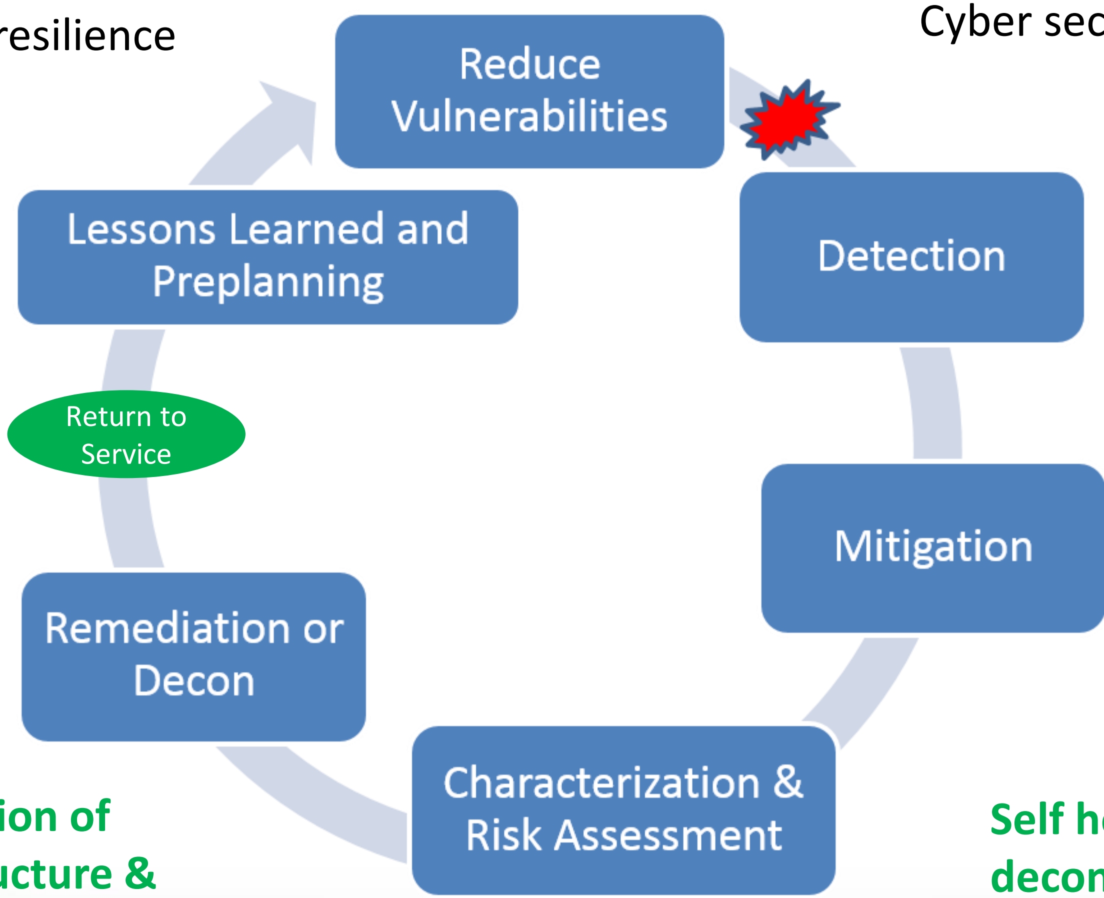
# Presentation Outline

- EPA Homeland Security Research Overview
- Water Security Test Bed Research
  - Decontamination of distribution system infrastructure with physical scouring (pigging)
  - Decontamination of home plumbing
- Summary

# Program Design: A Systems Approach to Incidents

Increasing resilience

Cyber security for water systems




**On-line monitoring of contaminants / Sensor and software testing**

**Contaminant fate and transport**

**Self help decontamination and risk reduction measures**

Sampling and analysis for water and waste water

**Decontamination of water infrastructure & water treatment**

**Wastewater treatment**

# Water Security Test Bed

***Water Security Test Bed:***

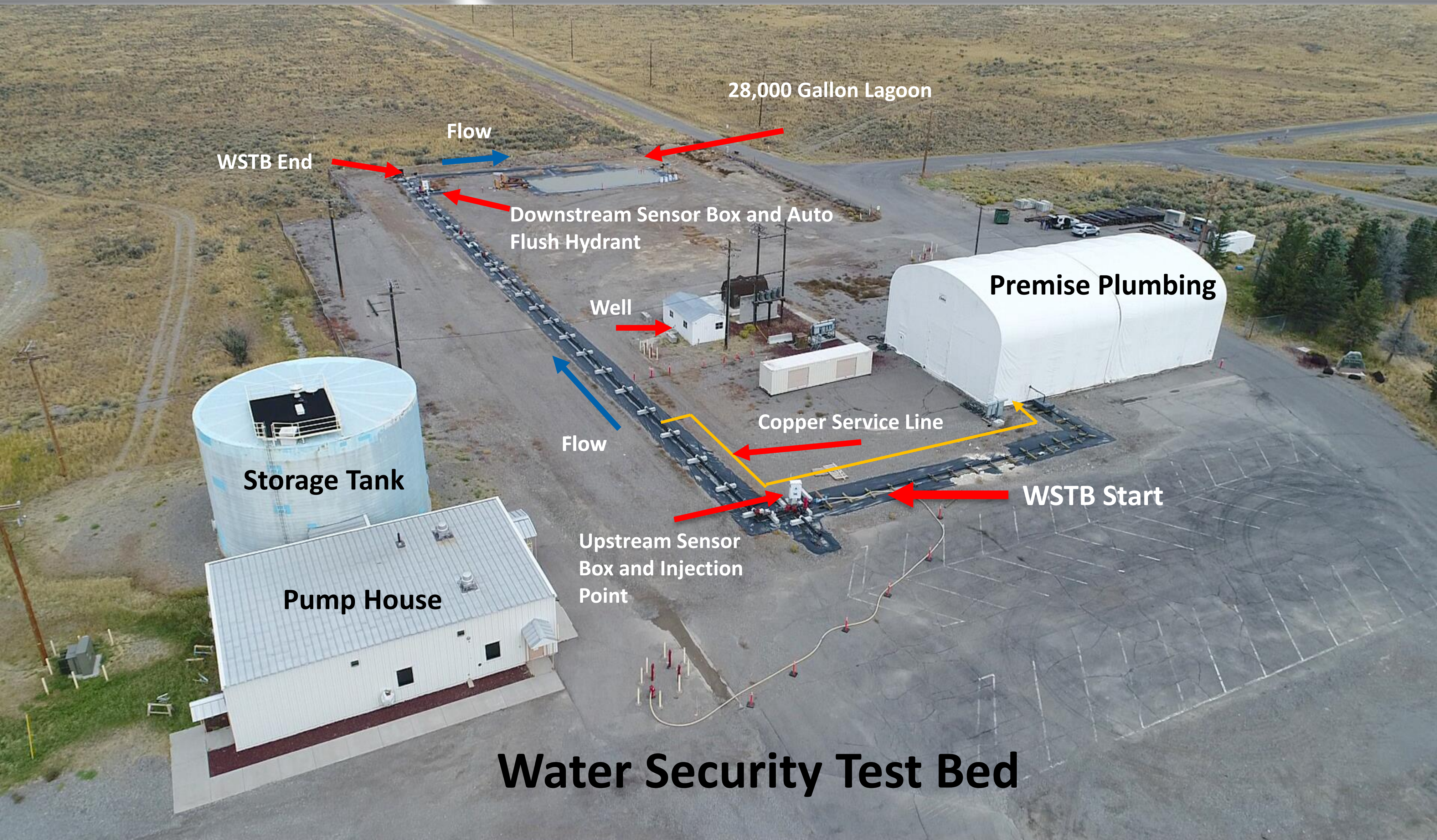
- Simulates intentional and inadvertent distribution system contamination (chem, bio, rad) and disruptions (cyber-attacks)
- Supports diverse applied research
- Located at Idaho National Lab (INL) (near Idaho Falls, Idaho)

**Water Security Test Bed Video:** https://youtu.be/olCs_kbegBA

***Phase I of the test bed is a once through system:***

- ~445' of 8" cement mortar lined, ductile iron pipe (water main)
- 6 × 1" service connections/sample ports, 2 hydrants
- 15' pipe material coupon section for sampling the interior of the pipe surface
- Above ground system, underlined by secondary containment
- 28,000 gallon lagoon/high rate groundwater pump/storage tank
- ~200 ' of 1" Cu service line to building, with home appliance and removable plumbing pipe coupons

# Why have we invested in this capability?



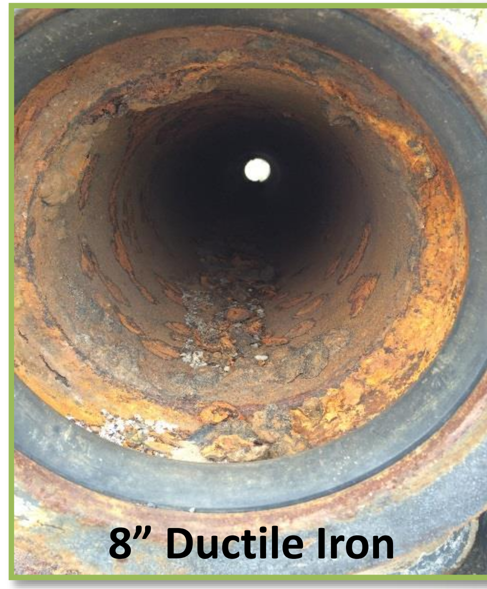

Water Security Test Bed

# Operational Pictures

*Injection Point*

*Triggered Flushing*


***Chlorine and TOC Sensors with Cellular Modem***



**8” Ductile Iron**

***4” Cast Iron***

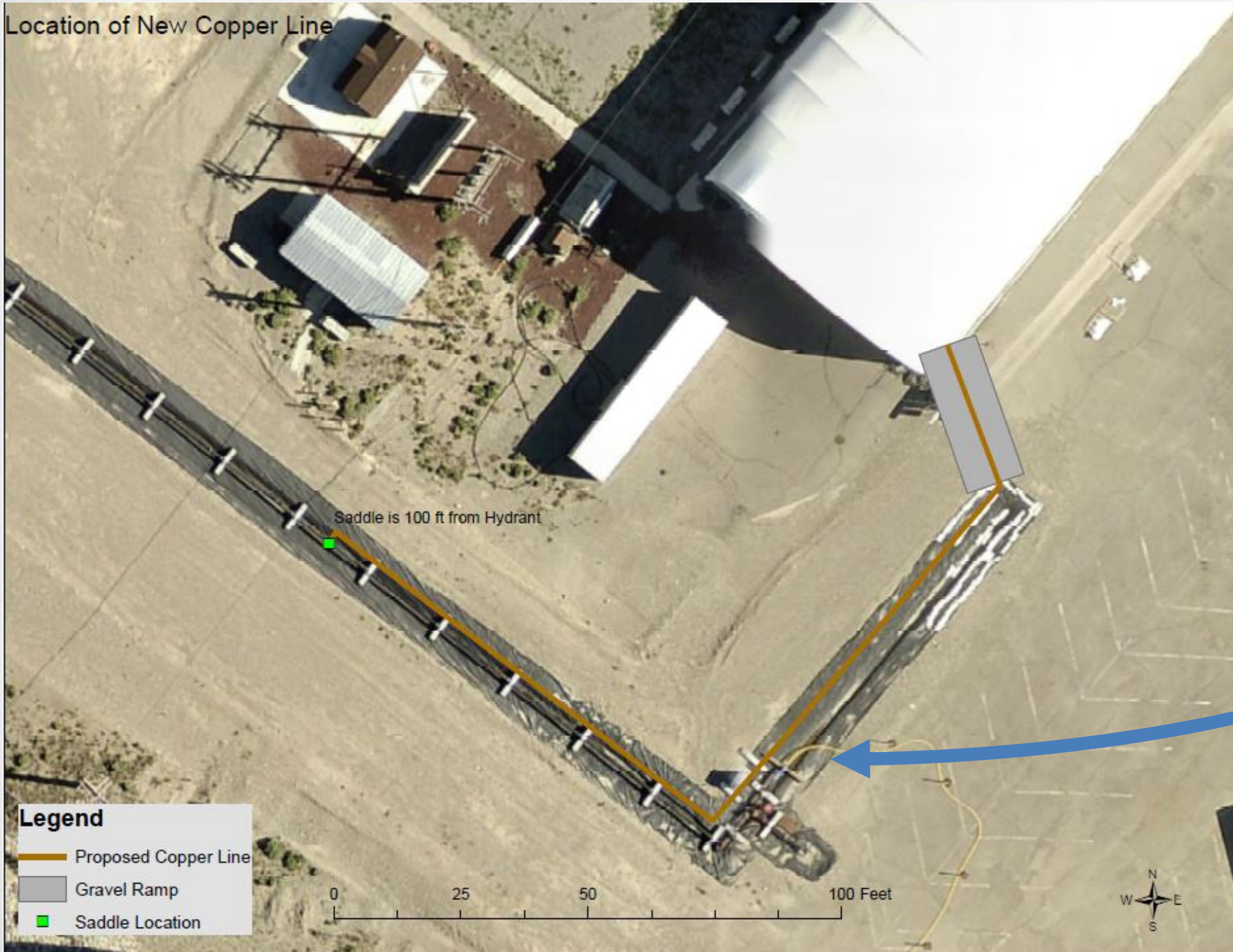
# Removable Coupons and Pipe Available for Decontamination Experiments


Forty year old conveyance pipes (cement mortar lined ductile iron) servicing a decommissioned building was dug out of the ground at INL

8” ductile iron

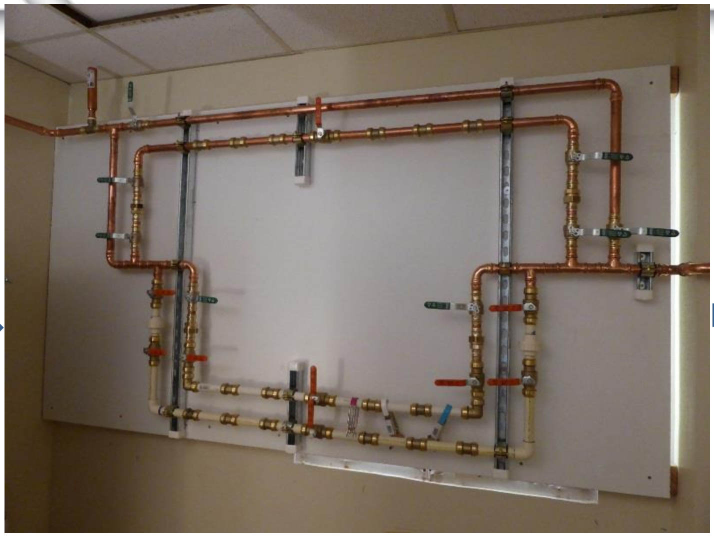
# 28,000 Gallon Lagoon, Tanker Truck and Treatment System

# Premise Plumbing Decontamination



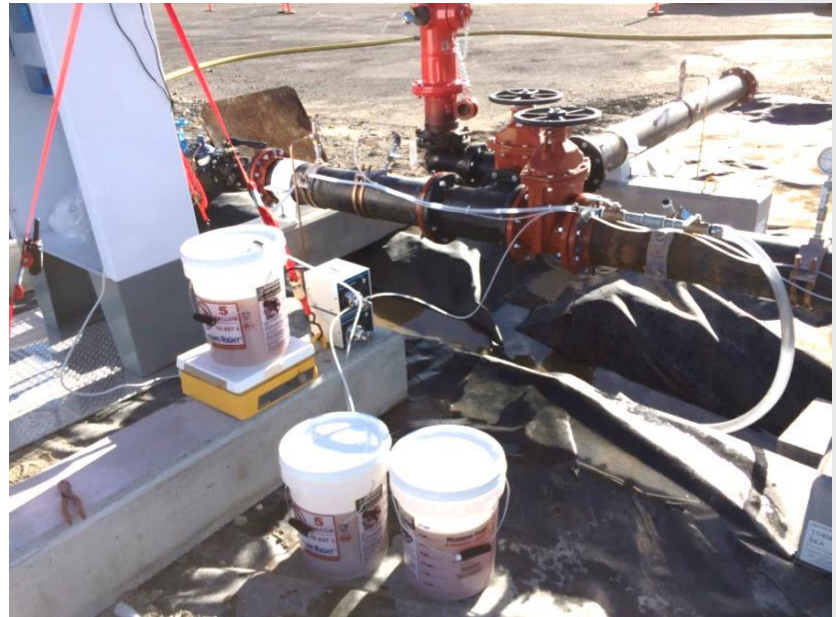

**1" Copper Service Line to Indoor Plumbing (~ 200')**

# WSTB Premise Plumbing

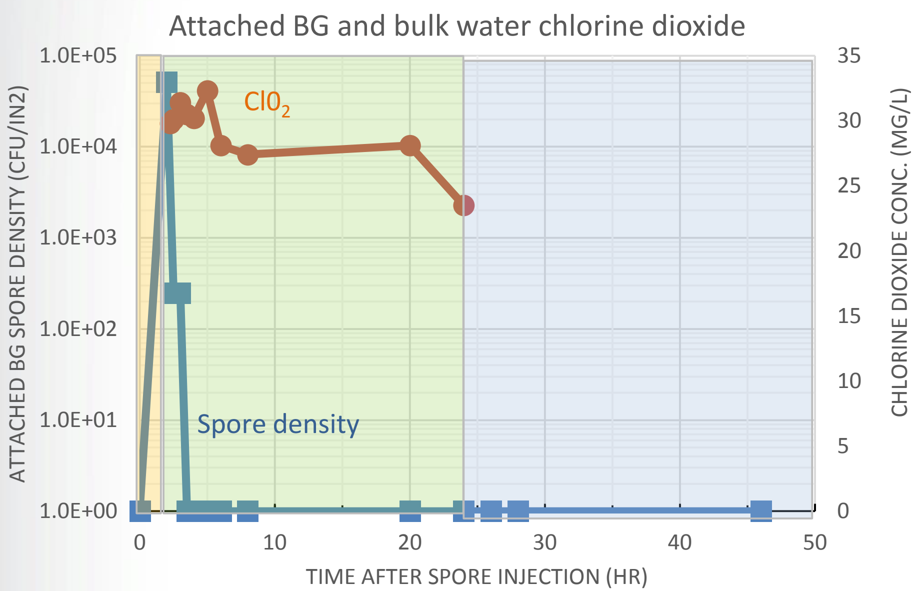



# Microbial Decontamination

- WSTB pipe was contaminated with *Bacillus globigii* (BG) spores
  - BG injected at $10^6$ cfu/ml in the bulk water phase
- Decontamination with chlorine dioxide
  - Target concentrations
    - 25 mg/L per pilot experiments
    - 100 mg/L in the field
  - Chlorine dioxide concentration difficult to maintain due to heat and pipe demand
  - Only 2-log reduction in spores compared to 5-log in the pilot scale experiments

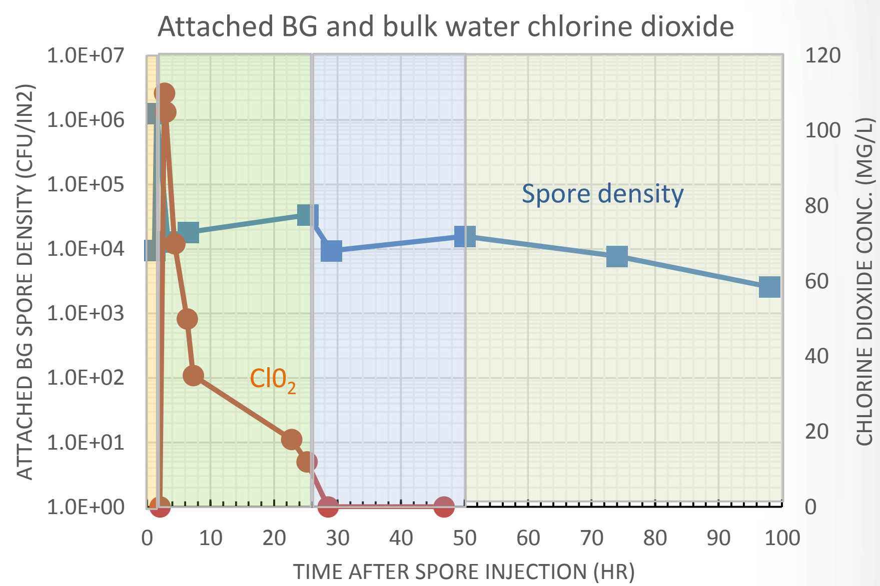


# *Bacillus globigii* Experiments




***Data from <u>Pilot Scale</u> Decontamination Loop at EPA's Test & Evaluation Facility***

- **No spores detected on cement-mortar after treatment with 25-30 mg/L $Cl0_2$**




***Data from <u>Full Scale WSTB</u> at INL***

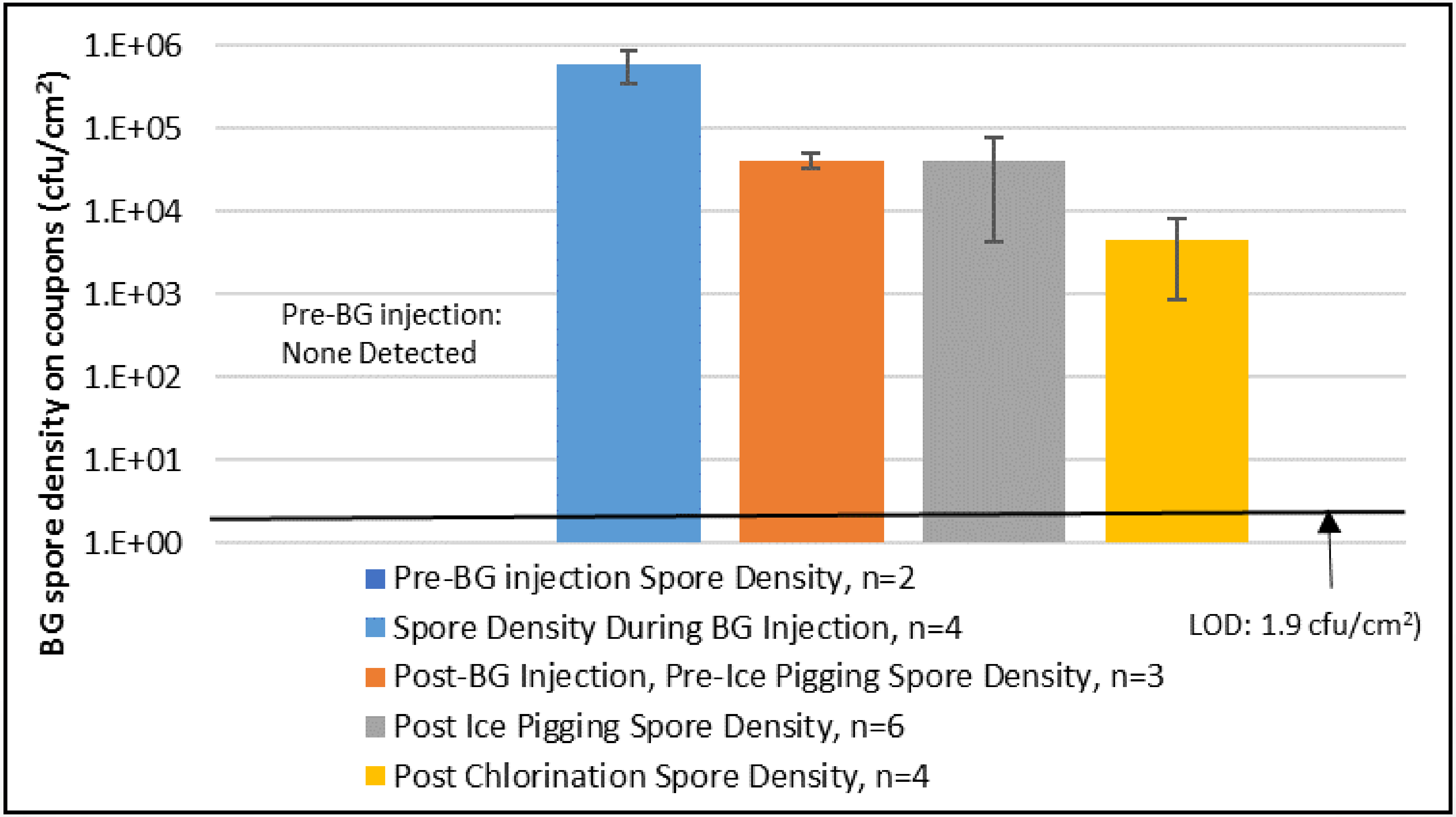
- **Spores persisted on cement-mortar in the presence of up to 100 mg/L $Cl0_2$**
- **Pipe demand, temperature fluctuation and dead end spaces impacted decontamination**
- **Spores found on surfaces even after WSTB was mothballed for winter**

# Decontamination Using Ice Pigging

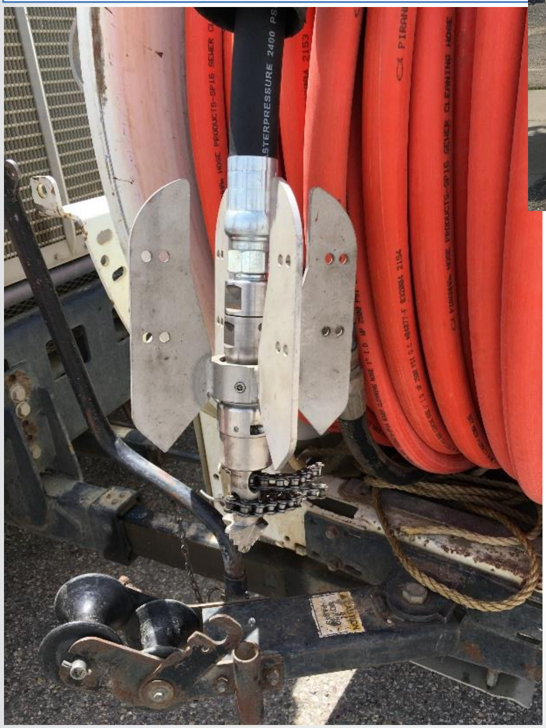


# Ice Pigging

# Ice Pigging Decontamination Data



# Decontamination with Pigging (KEG chain cutter)



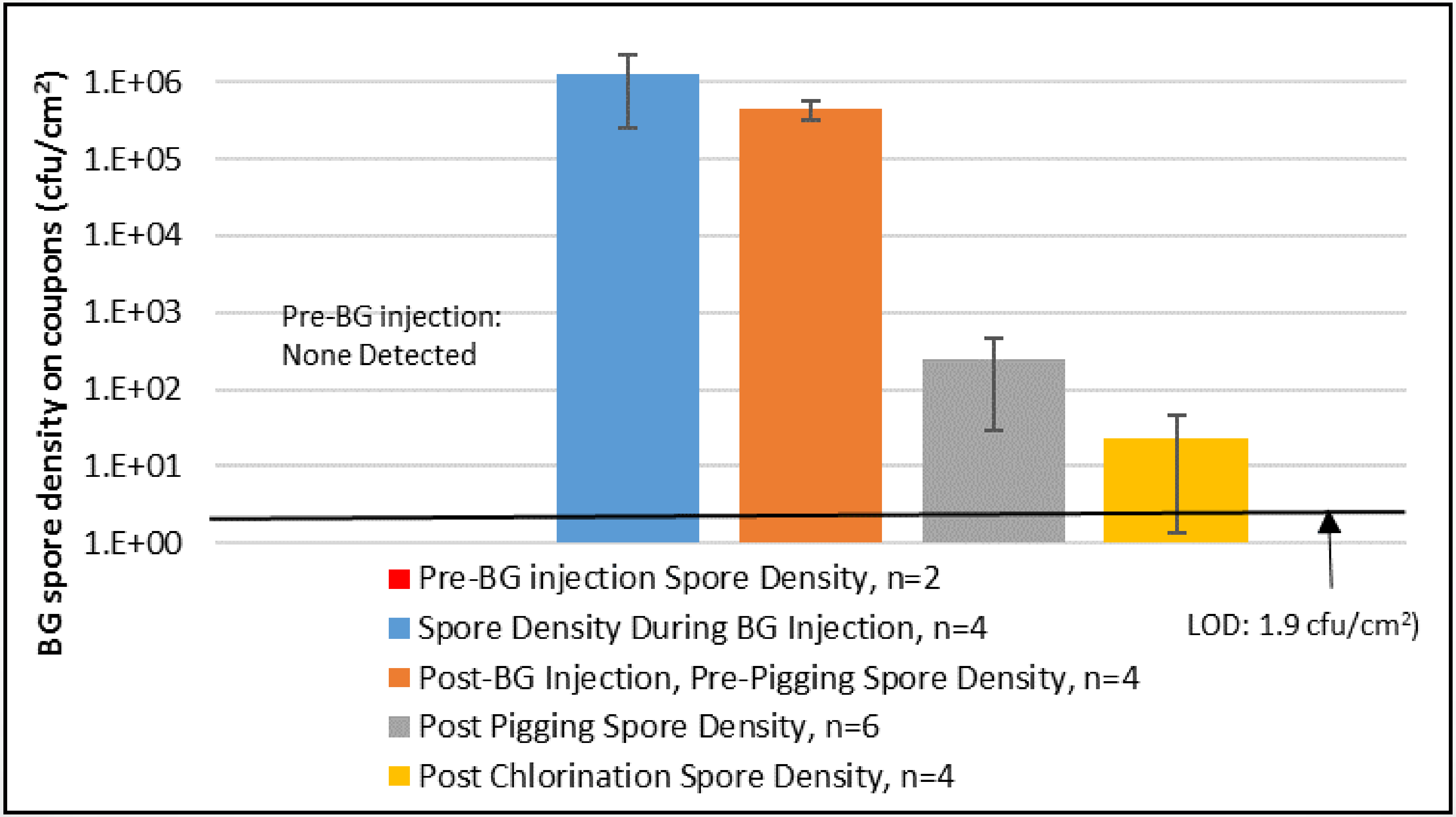
# Chain Cutter Pigging

# Pipe Interior Before and After Pigging

Before pigging:

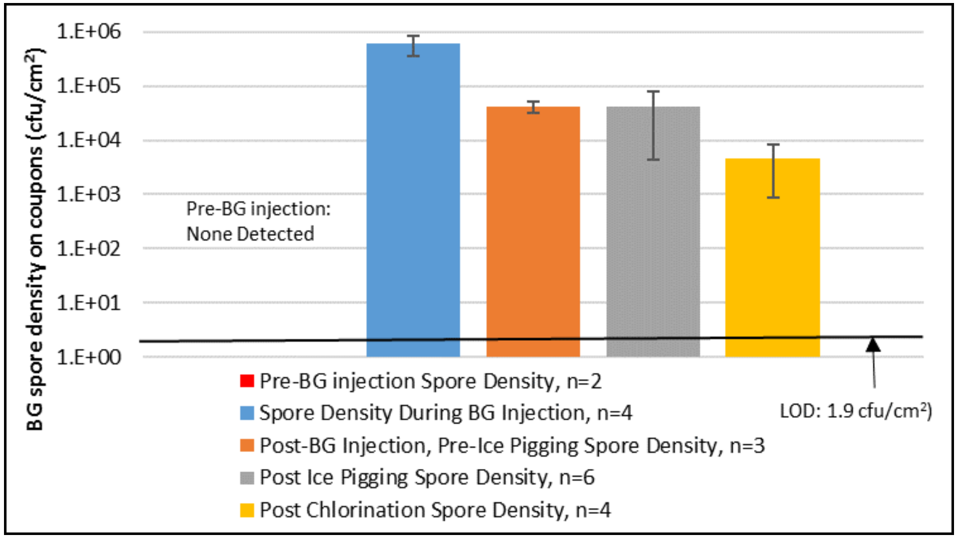
After pigging:

# BG Decon with Chain Cutter Pigging

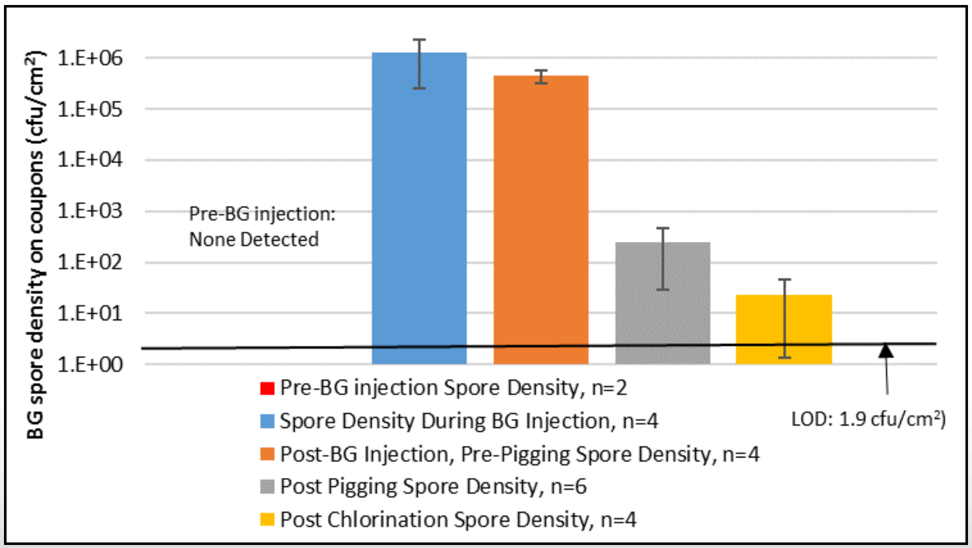


# *BG* Decon with Physical Scouring

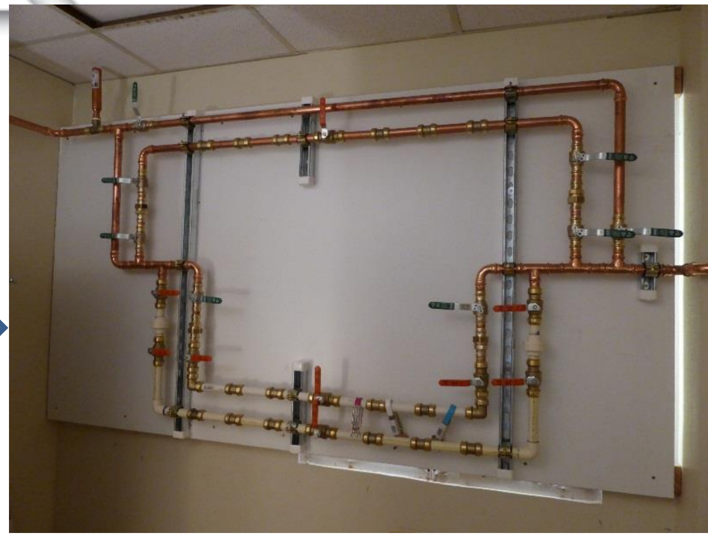
**Ice Pigging (450 ft pipe)**




**Chain Cutter Pigging (450 ft pipe)**

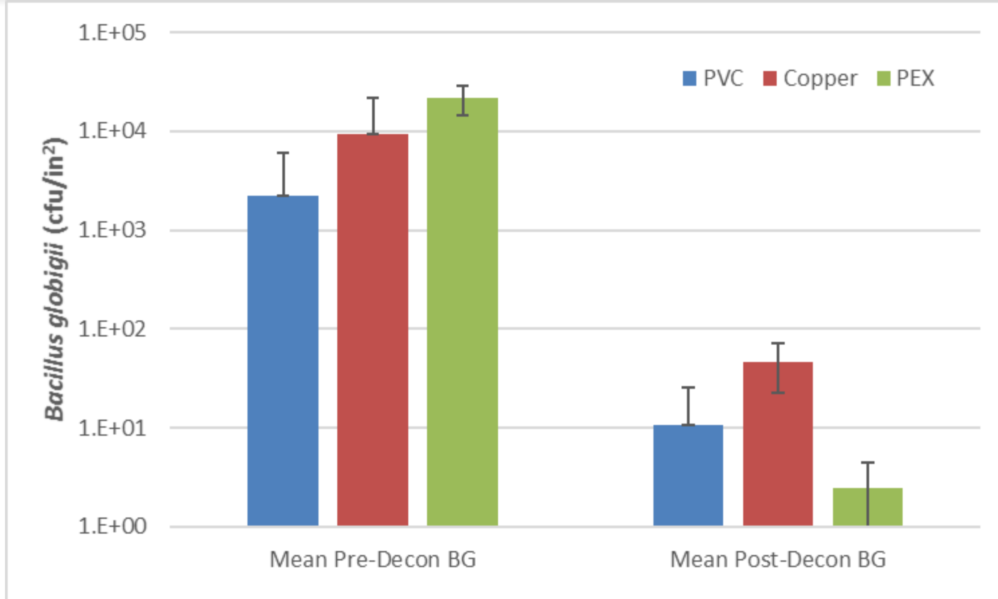


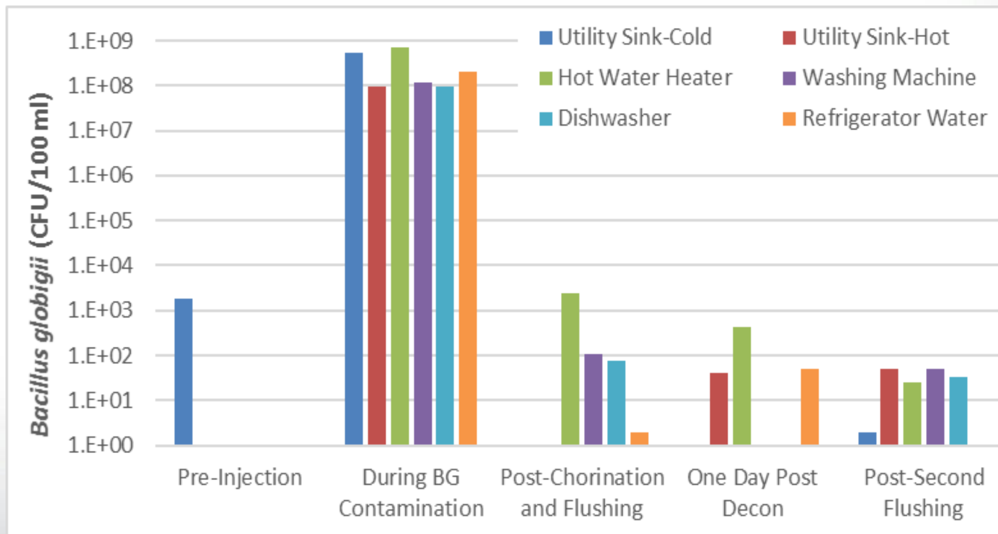
# Premise Plumbing Decon

# Plumbing Microbial Decontamination

- BG spores injected at $10^6$ cfu/ml
- Disinfection and Flushing:
  - Amended bleach added to plumbing and allowed to sit for 1 hour (1-part bleach:11.75-part water:1-part vinegar)
  - Cold water and refrigerator flushed for 20 min (hot water off)
  - Hot water heater drained, refilled, then hot water flushed for 75 min
  - The flushing process was repeated the next day



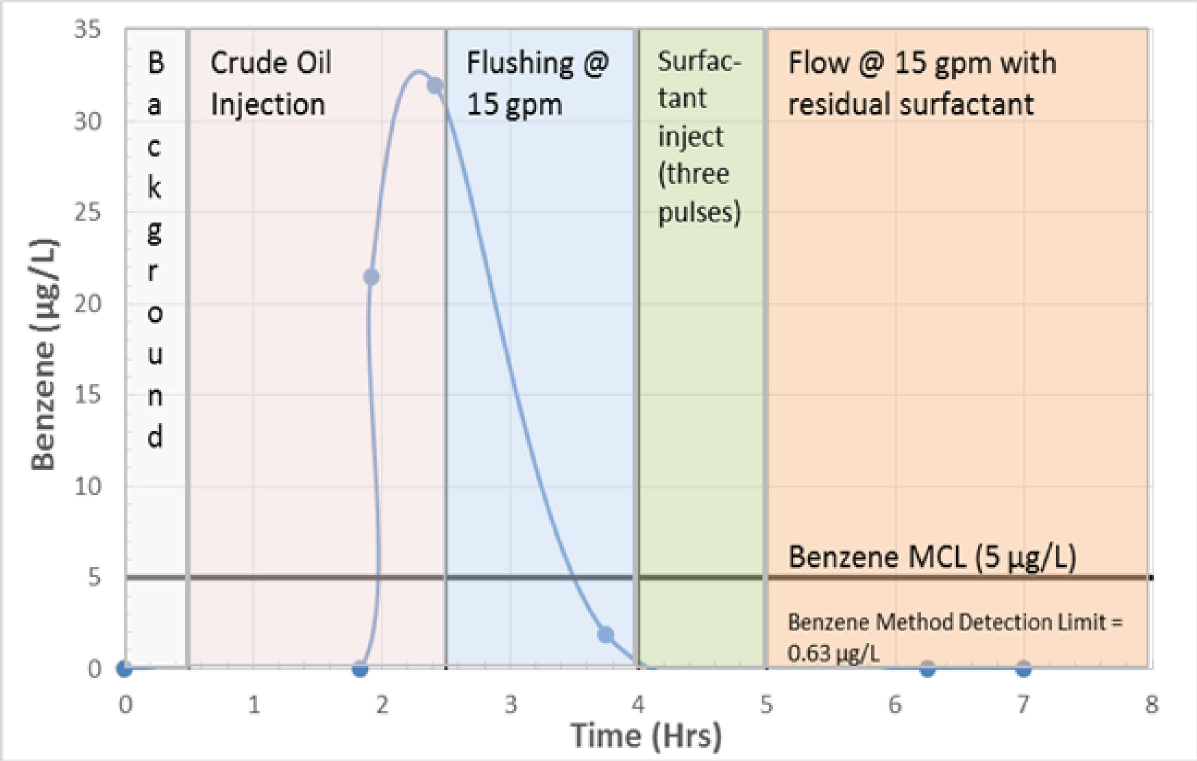



# Bakken Crude Oil Decontamination

## Response to Bakken Crude Oil Spills

- Examined flushing and adding a surfactant as decontamination methods
- Coupons and water samples were analyzed
  - **BTEX**- Benzene, Toluene, Ethyl Benzene, Xylene
  - **ORO**- Oil Range Organics
  - **GRO** -Gasoline Range Organics
  - **DRO** -Diesel Range Organics

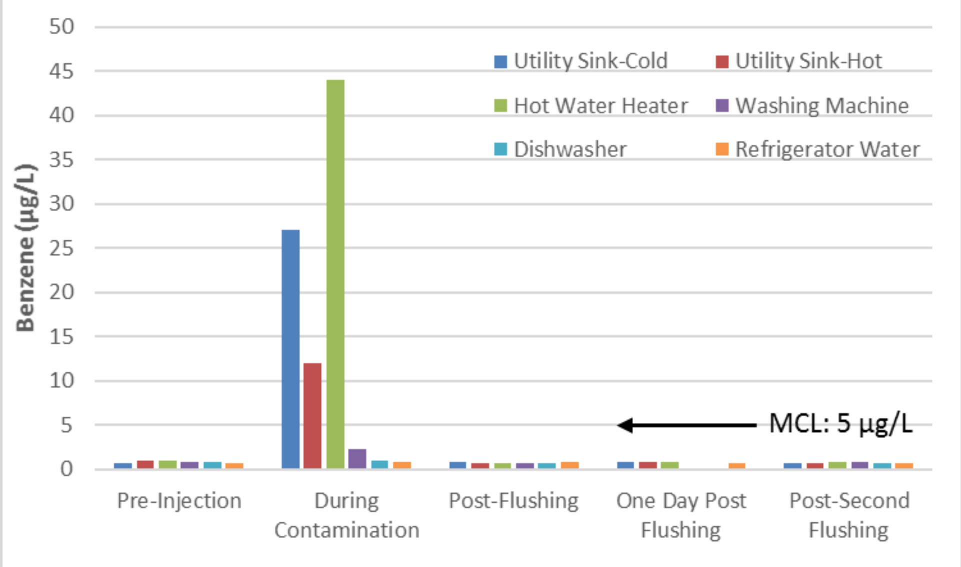
# Bakken Crude Oil Flushing Experiment

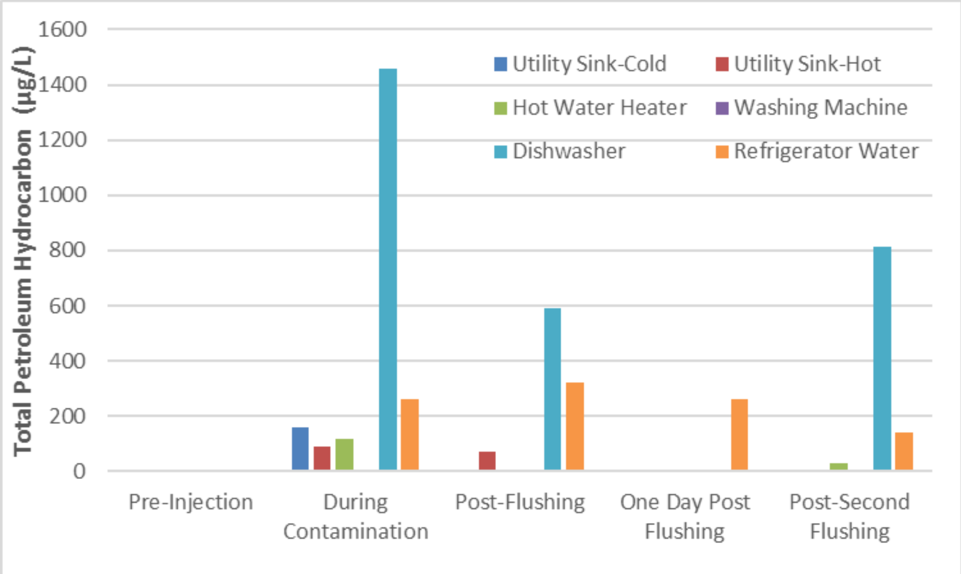



- Bakken Crude oil components (Benzene) were not detected on the coupon surfaces
- Flushing alone was effective to remove the soluble fraction of crude oil from the system
- Surfactant addition was unnecessary, and could be counterproductive as it did persist (surfactant may be needed for higher petroleum product loading)

# Plumbing Decontamination Data

- Bakken crude oil injected in the same manner as in the big pipe previously (water soluble fraction containing dissolved compounds)
- Flushing:
  - Cold water and refrigerator flushed for 20 min (hot water off)
  - Hot water heater drained, refilled, then hot water flushed for 75 min
  - The flushing process was repeated the next day



# WSTB Experiments Summary

## Full-Scale 8” Pipeline BG Spore Decontamination

- Only 2-log reduction in spore removal versus 5-log reduction in the pilot scale experiments with chlorine dioxide
- Temperature and disinfectant demand impeded performance at full scale
- Ice pigging was not as effective as expected
  - 1 to 2-Log removal at best
- Physical scouring preformed better than ice pigging
  - -4-log spore removal with pigging and chlorination on cement mortar
  - -Similar results on iron, but more spores left behind

## Plumbing and Appliance Decontamination (BG spores and Bakken oil)

- Flushing with acidified bleach solution not entirely successful at removing spores after 2 days
- Longer term/sequential flushing and sampling likely necessary to decontaminate premise plumbing
- Bakken crude was readily flushed, but some organics remained on appliances like the dishwasher and refrigerator

# WSTB Current and Future Experiments

## Accomplished

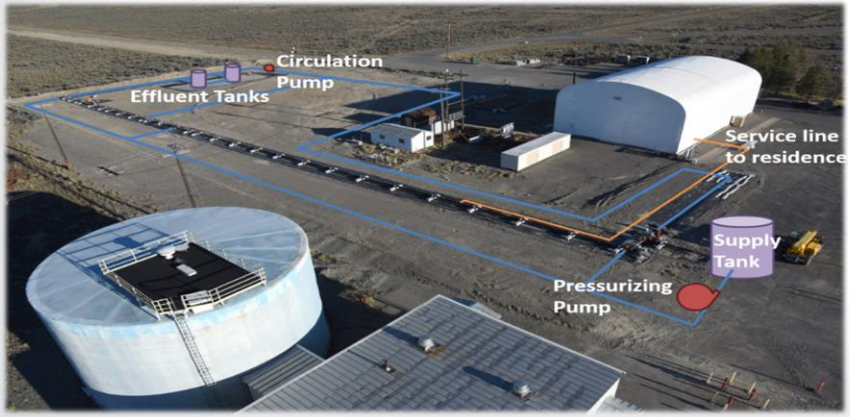
- Persistence of *Bg* spores
- Efficacy of Chlorine dioxide
- Physical scouring of pipes
- **Bakken crude oil flushing**
- **Premise plumbing decon**
- Wash water treatment
- PFAS water treatment

## Planned Experiments

- Additional PFAS treatment
- Detection/Decontamination of radionuclides
- Aerosolizing of biological agents via points of use
- Pipe lining technologies

## SME Recommended Future Opportunities

- Build a larger distribution grid (2 or more city blocks)
- Evaluate other contaminants especially other types of crude oil
- Evaluate detergent impacts on premise plumbing
- Integrate cyber-security activities



# Acknowledgements

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# Thank you

***"Priority Activity: Improve detection, response, and recovery to contamination incidents" –*** 2017 Roadmap to a Secure and Resilient Water and Wastewater Sector, Critical Infrastructure Partnership Advisory Council

**www.epa.gov/homeland-security-research**

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