PFAS: Fate & Transport, Site Characterization and Remediation

Ginny Yingling, Hydrogeologist
Minnesota Dept. of Health
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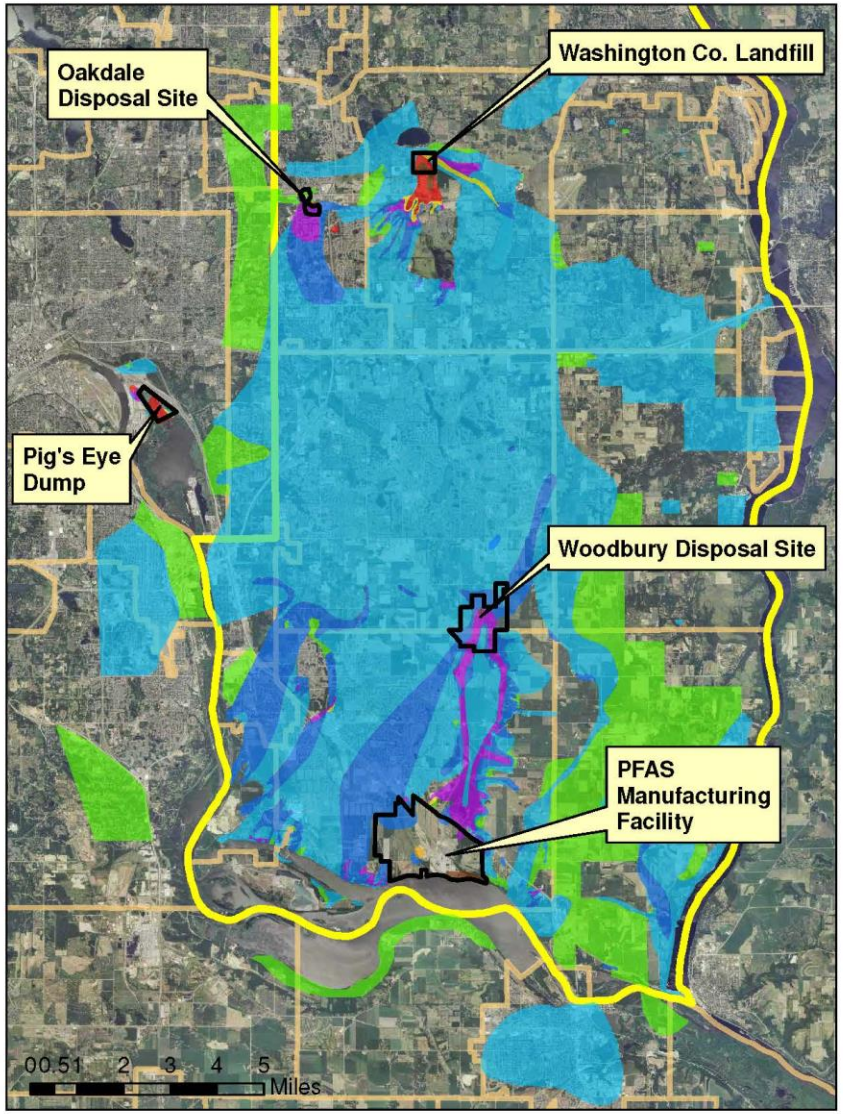
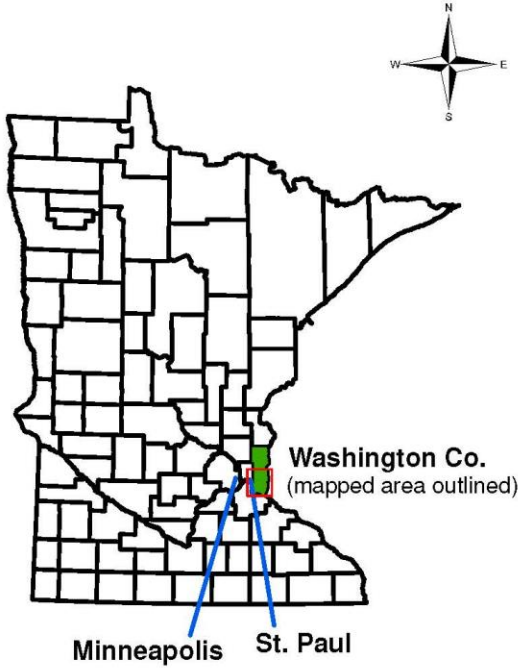
East Metro PFAS contamination

- PFAS manufactured since 1940s
- Waste disposal: on-site and landfills
- 2004 – PFOS & PFOA detected in Oakdale city wells
- Subsequent investigations:
  - > 150 mi^2 contaminated GW & SW
  - 4 major aquifers
  - 13 communities
  - 8 municipal systems (140,000+ pop.)
  - > 4,000 private wells (1,300+ advisories)
  - 1 (more?) illicit dumpsites & AFFF
  - Municipal WWTP sludge in a landfill



Location of Legacy PFAS Sites in Washington Co., Minnesota



DEPARTMENT OF HEALTH

July 11, 2018

Minnesota Experience Parallels the Larger PFAS Story

Specific: Legacy & AFFF Sites

- Drinking water impacts initial focus (identifying and addressing)
- Limited analytical methods
- Limited risk assessment information
- Guidance values mainly for water
- Limited knowledge of PFAS sources, uses, and distribution
- Learning about fate & transport
- Limited understanding of ambient PFAS
- Limited treatment and remediation options

General: PFAS in the Wider Environment

- Ambient environmental sampling
- Locating additional sites
- Identifying & prioritizing potential PFAS sources
- Improved analytical methods
- Evolving risk assessment and increased knowledge of exposure pathways
- Guidance values for additional media
- Regulatory approaches to limit further releases
- Policy approaches to assist communities and utilities

Minnesota Water Guidance

- MDH health-based guidance values evolve as new research becomes available
- Protects the most vulnerable - developing fetuses & breast-fed infants born to mothers exposed 10+ yrs.
  - Provides even greater protection for the general population
  - More than protective for cancer and other less sensitive endpoints
- MDH also evaluates the additive effect of mixtures of similar chemicals (like PFAAs):

Health Risk Index (HI) = Σ $PFAA_{conc}$ / $PFAA_{value}$

HI > 1 is considered an exceedance

	Long-chain			Short-chain	
	PFOA	PFOS	PFHxS	PFBA	PFBS
2002	7	1			
2006	1	0.6		1	
2007	0.5	0.3		7	
2009	0.3	0.3		7	7
2013	0.3	0.3	0.3	7	7
2016	0.07	0.07	0.07	7	7
2017	0.035	0.027	0.027	7	2
2019	0.035	0.015	0.047	7	2

Values in ppb Blue = HRL; Red = HBV; Green = Surrogate

PFOA & PFOS Guidelines and Standards (ppb)

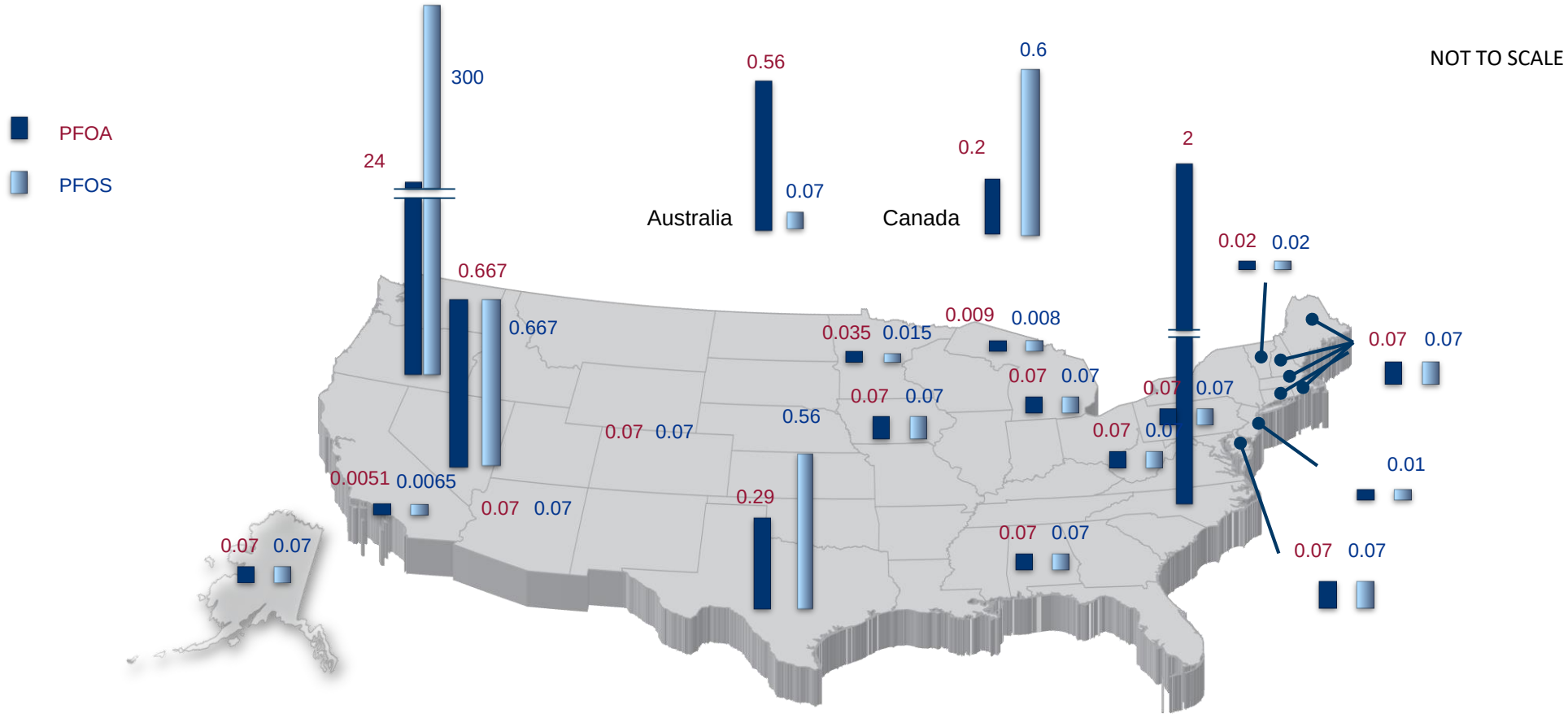


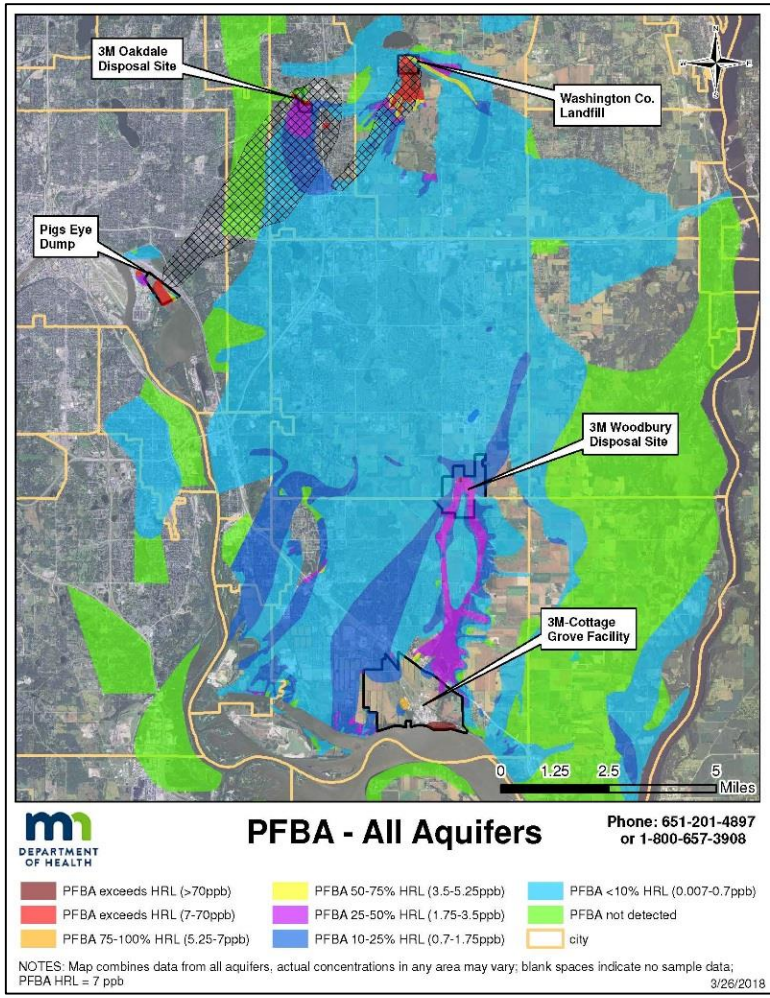
Figure by W. DiGuiseppi, Jacobs - used with permission. Data current as of October 2019

Initial Response Activities (2002-2006)

- Focused on extent and magnitude in drinking water
- Water guidance development (2002)
- Developed analytical method (2003)
  - PFOS & PFOA only
  - High detection limits (1 ug/L)
- Source investigations and plume delineation begin
  - Sampling public and private wells
  - Appeared to be relatively limited affected area
- 3M agrees to address water in affected areas
  - GAC treatment plant in Oakdale
  - Extend city water in Lake Elmo

East Metro PFAS Investigations Expands: 2006 - 2016

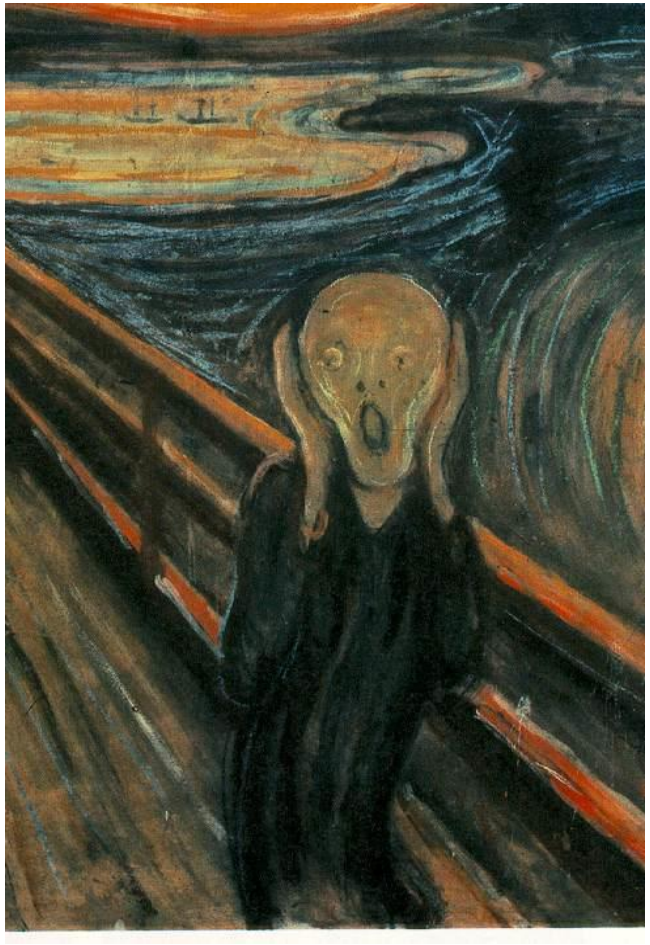
- Expanded analyte list (PFBA, PFPeA, PFHxA, PFBS, PFHxS)
- Lower detection limits
- Lowered guidance values for PFOS and PFOA
- Surrogate values: PFOA for PFBA (2006), PFOS for PFHxS (2013)
- Area with PFAS detections greatly expanded
  - >> model predictions
- Studies to address public concerns:
  - Home water treatment study (GAC, RO, IX)
  - Health outcome reports (e.g. cancer incidence, birth outcomes)
  - Garden produce study
  - Biomonitoring study begun (funded by legislature)



PFAS – A Communication Challenge

- **Widely present in the environment**
  - Detected in drinking water and biota
- **Evolving understanding of fate & transport**
  - ID'ing new pathways and affected areas create sense the problem is "getting worse"
- **Evolving analytical capabilities**
  - Expanding analyte lists & lowered detection limits = "more detections" and sense the problem is "getting worse"
- **Evolving risk assessment**
  - Changing guidance values = public confusion and sense the problem is "getting worse"

Risk Communication



East Metro Remedial Actions: 2006 - 2013

2007 3M Consent Order

- 3M site investigations & remedial actions (three sites)
- Partial funding of state cleanup at Washington Co. landfill
- On-going funding of public/private well sampling & treatment where state values are exceeded
- ~250 private wells in Lake Elmo & Cottage Grove (GAC or city water connections)
- Funding for statewide PFAS investigations
  - Shallow groundwater
  - AFFF training sites
  - Fish
  - WWTPs
  - Landfills

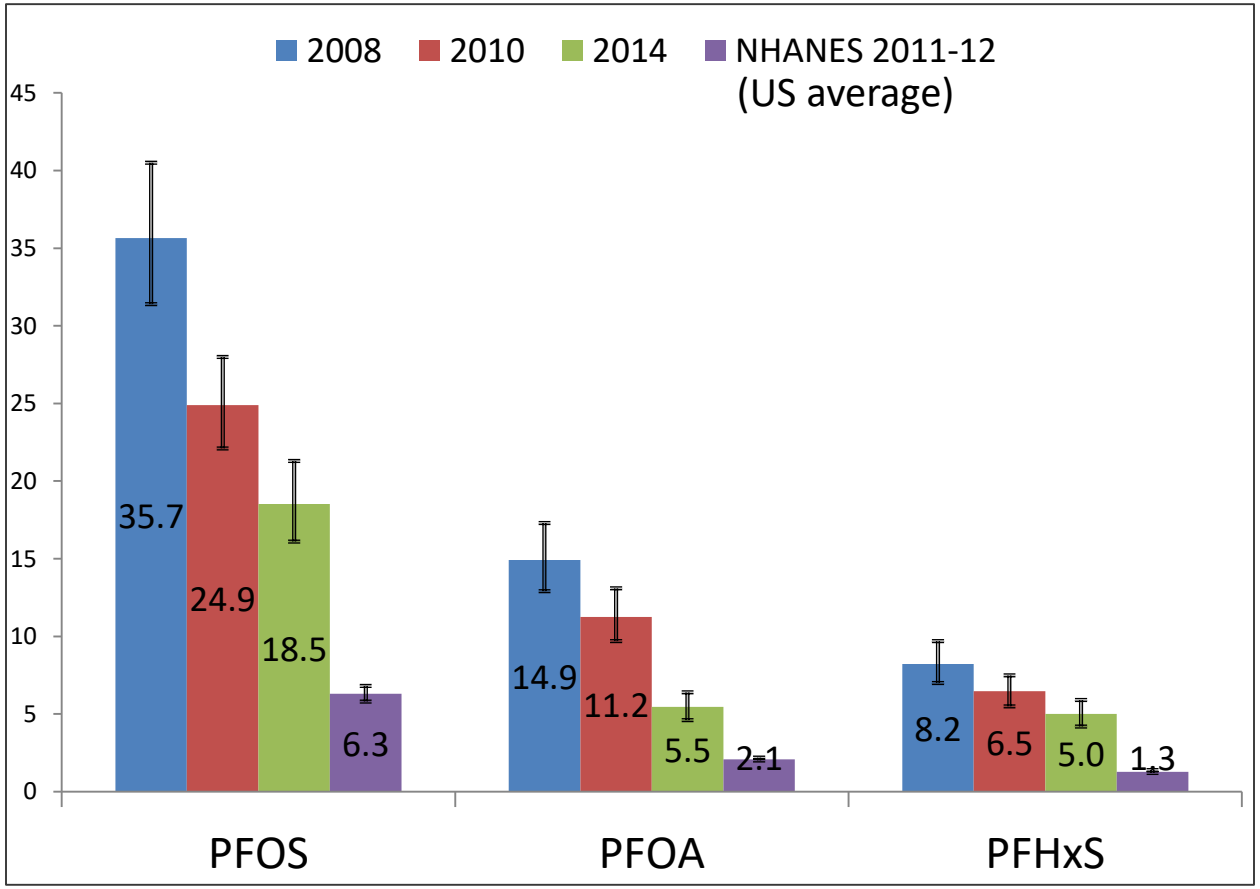
2.5 million m^3 excavated/dredged and contained

Bonus – oxidation of precursors!

Biomonitoring

- Exposed adults in affected East Metro communities:
  - 3 rounds: 2008, 2010, 2014
  - 196 initial participants (164 completed all 3 rounds)
- PFOS, PFOA, and PFHxS detected in 100%
- PFAS serum levels decreased for residents drinking treated water, but…
- Average concentrations > national average
- Conclusion: removing drinking water pathway key to reducing exposure

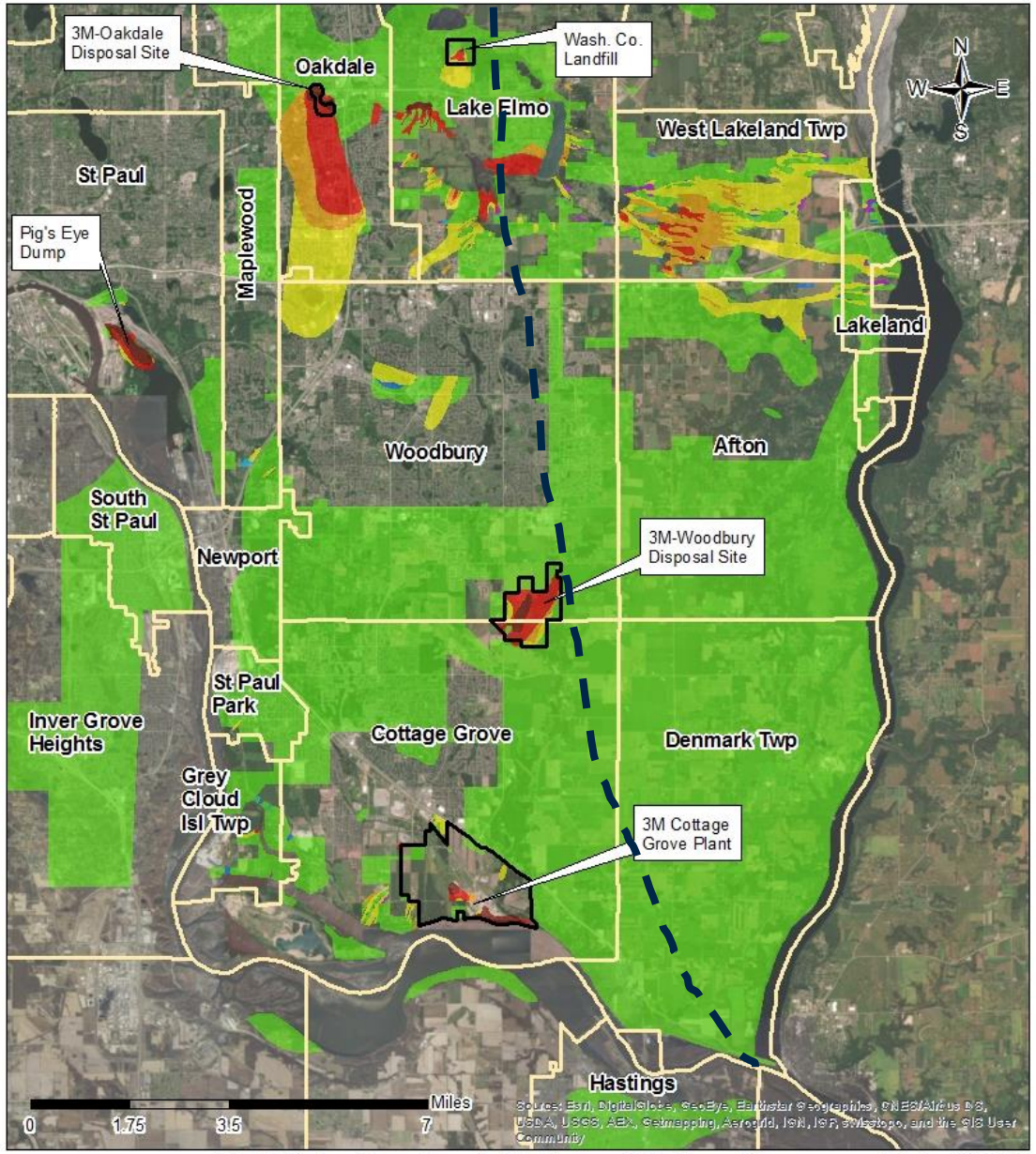
(Results in ug/L)



https://www.health.state.mn.us/communities/environment/biomonitoring/projects/pfas.html

East Metro PFAS Investigations Expand: 2016-2020

- 2016 EPA Lifetime Health Advisory Values
- Lower values for PFOS, PFOA, PFHxS (2016, 2017, 2019) ➡ Sampling areas grow again!
  - ~ 1,300 additional drinking water advisories
  - ~ 3,000 additional wells tested
- Lower detection limits
- Notice of Health Advisories – 4 additional municipal systems
  - GAC treatment or pumping management (wells shut off and/or blending to meet MDH values)
- 2018 3M Settlement
  - Natural resource damage assessment
  - Primary: clean drinking water (public and private) & evaluating the surface water pathway
  - Secondary: natural resource restoration



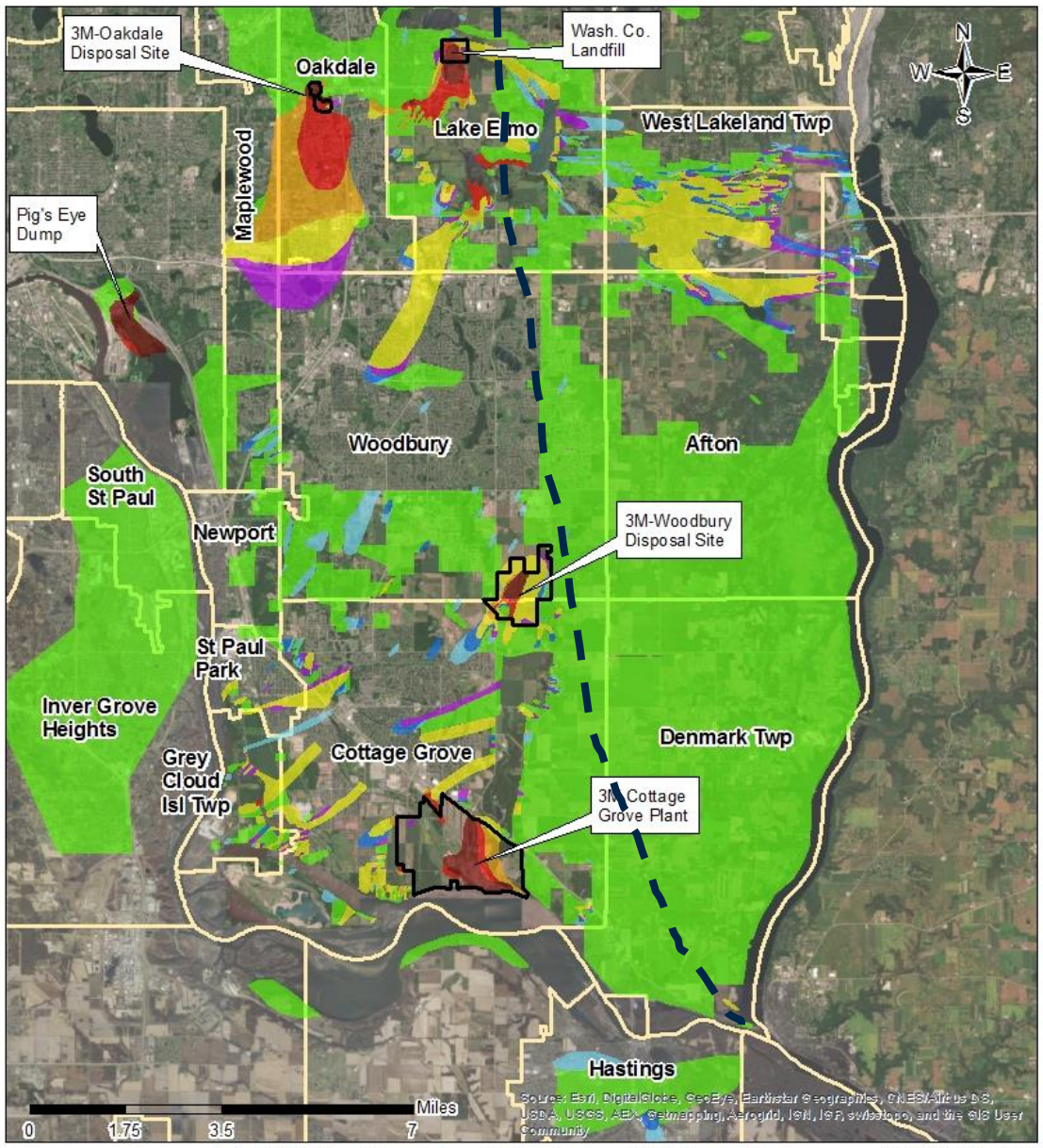
PFOS in the East Metro - All Aquifers

October 18, 2019

- PFOS greater than 50x HRL (>0.75 ppb)
- PFOS 10-50x HRL (0.15 - 0.75 ppb)
- PFOS 5-10x HRL (0.075 - 0.15 ppb)
- PFOS 1-5x HRL (0.015 - 0.075 ppb)
- PFOS 75-100% HRL (0.0112 - 0.015 ppb)
- PFOS 50-75% HRL (0.007 - 0.0112 ppb)
- PFOS less than 50% HRL (<0.007 ppb)
- PFOS not detected

Health Risk Limit (HRL) for PFOS is 0.015 parts per billion(ppb)

NOTE: This map shows data from all aquifers, concentrations in any given area may differ between wells; blank areas = no data



PFOA in the East Metro - All Aquifers

October 21, 2019

- PFOA greater than 50x HRL (>1.75ppb)
- PFOA 10-50x HRL (0.351-1.75ppb)
- PFOA 5-10x HRL (0.176-0.35ppb)
- PFOA 1-5x HRL (0.036-0.175ppb)
- PFOA 75-100% HRL (0.027-0035ppb)
- PFOA 50-75% HRL (0.0175-0.026ppb)
- PFOA less than 50% HRL (<0.0174ppb)
- PFOA not detected

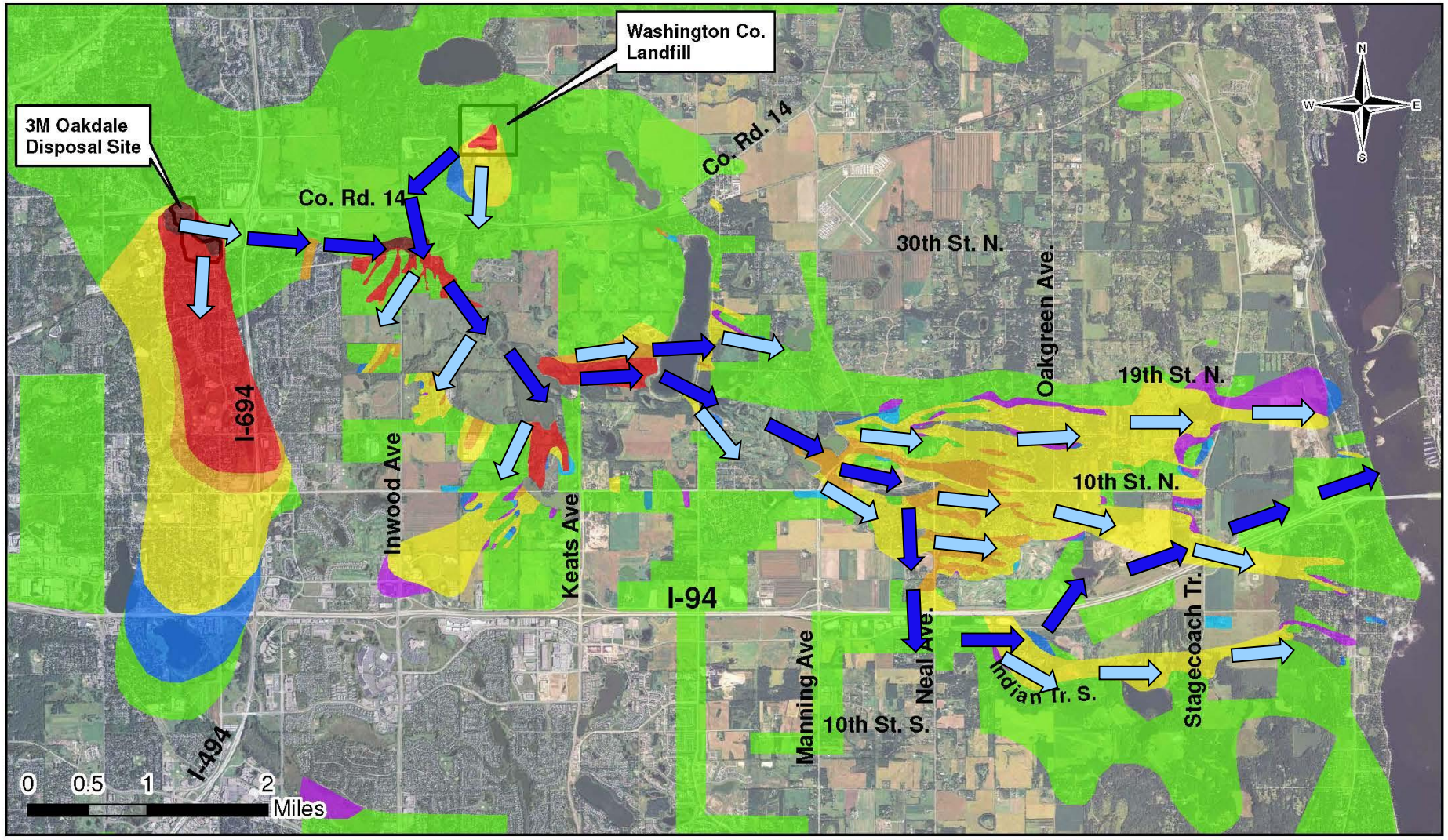
Health Risk Limit (HRL) for PFOA is 0.035 parts per billion (ppb)

NOTE: This map shows data from all aquifers, concentrations in any given area may differ between wells; blank areas = no data

Groundwater flow

Surface water or stormwater flow

- Surface water transport may move PFAS many miles away from source areas (See also: Awad et al., 2011 and Kwadijk et al., 2014).
- Infiltration along a surface water pathway may create discrete groundwater plumes isolated from the source.
- Groundwater discharge to surface water may contaminant water bodies distant from source areas.



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PFOS - All Aquifers

Phone: 651-201-4897
or 1-800-657-3908

- PFOS > 1.35 ppb (>50x HBV)
- PFOS 0.271-1.35ppb (10-50x HBV)
- PFOS 0.136-0.27ppb (5-10x HBV)
- PFOS 0.028-0.135ppb (1-5x HBV)
- PFOS 0.021-0.027 ppb (75-100% HBV)
- PFOS 0.0136-0.02ppb (50-75% HBV)
- PFOS 0.004-0.0135ppb (<50% HBV)
- PFOS not detected

MDH Health Based Value (HBV) for PFOS is 0.027 parts per billion (ppb; or 27 parts per trillion)

NOTES: Map combines data from all aquifers, actual concentrations in any area may vary; blank spaces indicate no sample data

1/7/2019

2018 NRDA Settlement: major components

- $850 million **Grant** to the State
  - $125 million for outside counsel
  - $4.5 million reimbursement for state costs under the 2007 Consent Order
- $720 million for long-term solutions in the east metro area for:
  - Clean and sustainable drinking water
    - Includes evaluation of surface water pathway
  - Restoration and enhancement of natural resources

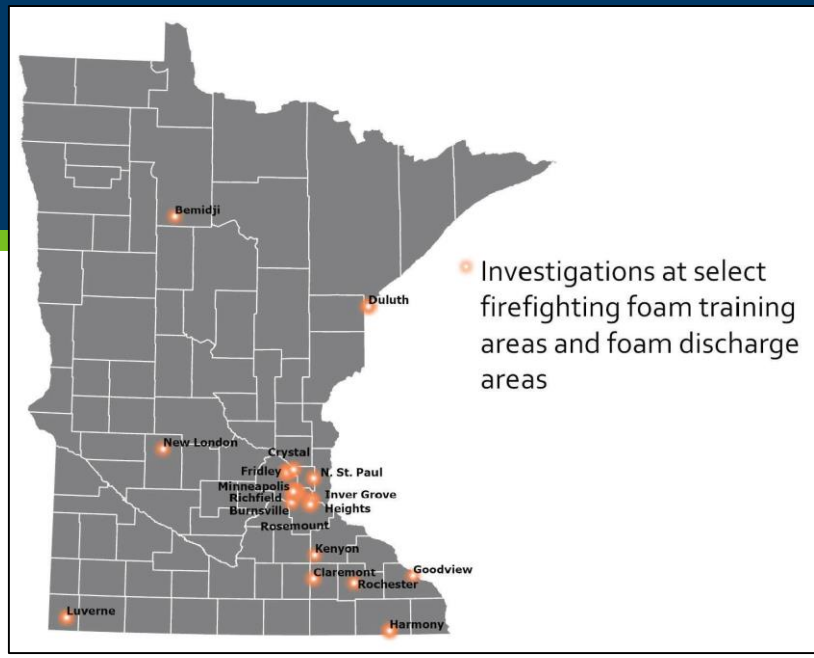
Opportunities for innovation?

- Restrictions about how the grant can be used
- Expectations for community participation
- Preserves 3M's obligations under the 2007 Consent Order

PFAS Statewide

- The East Metro area was our introduction to PFAS
- PFAS is becoming (and will remain) a statewide issue
- Efforts now focused on identifying:
  - Other major PFAS sites
  - Environmental monitoring
  - Identifying PFAS sources and conduits

Other PFAS Sites - AFFF



- **Statewide**
  - 2008-2009: MPCA and MDH evaluated fire-training areas and nearby drinking water (detects mainly of low level PFBA)
- **Bemidji Airport**
  - 2015: UCMR3 – PFOS exceeded EPA lifetime health advisories in 2 wells
  - 2016 – present: Increasing concentrations and lower MN values for PFOS & PFHxS – all wells exceed
- **Duluth Airport / Air National Guard Base**
  - 2 drinking water advisories issued
  - Surface water transport appears to be significant (again!)
- **Army National Guard Bases**
  - Evaluations in 2019-2020

Other PFAS Sites – Chrome Plating

- **Brainerd**
  - PFOS detected in fish ➡ WWTP ➡ chrome plater
  - Release pathway: sanitary sewer discharge
- **Minneapolis**
  - PFOS detected in fish ➡ lakes & wetlands ➡ stormwater ➡ chrome plater
  - Release pathway: Vent stack deposition on roof ➡ runoff and infiltration

Environmental Monitoring

Measuring the presence and levels of PFAS in Minnesota's environment

PFAS Sampling – Community Water Systems

143 Community Public Water Systems (CPWSs) sampled for PFAS

- UCMR3 (2013-2015) – 84 CPWSs sampled
- MN UCMP (2019) – 46 CPWSs sampled

13 CPWSs have ongoing sampling for PFAS

- Started in 2006
- Sampling frequencies range from quarterly to biennial
- About 250 samples per year

Future Community Water System Sampling

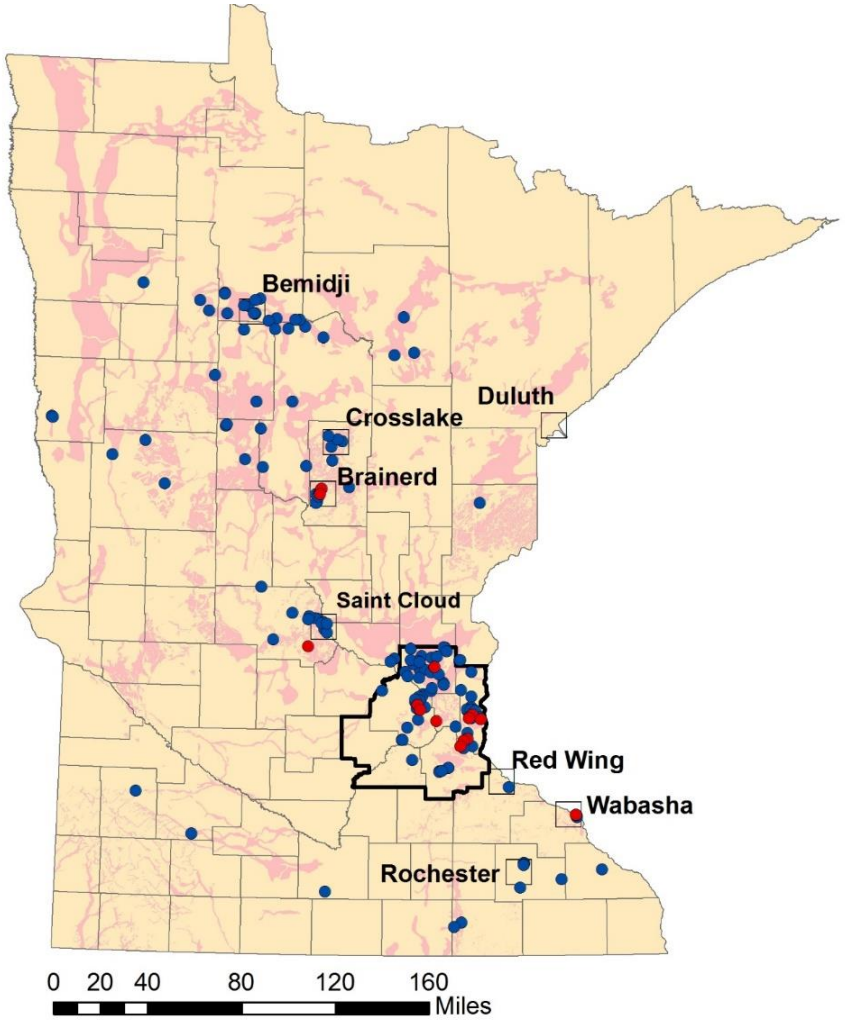
EPA Grant/CWF CEC Funds– Additional PFAS sampling starting in 2020

- Plan includes 125 CPWSs
- Most sites not sampled previously
- Semi-random with over-selection for hydrogeologically “vulnerable” wells

UCMR5 – PFAS expected to be included

- Will use new EPA Method 533 – published at end of 2019
- AWIA requires testing of all 3,300 – 10,000 population systems, **IF** sufficient appropriations and lab capacity are available
  - Would add 90 CPWSs to this sampling list – total of ~ 180 systems

PFAS in Groundwater



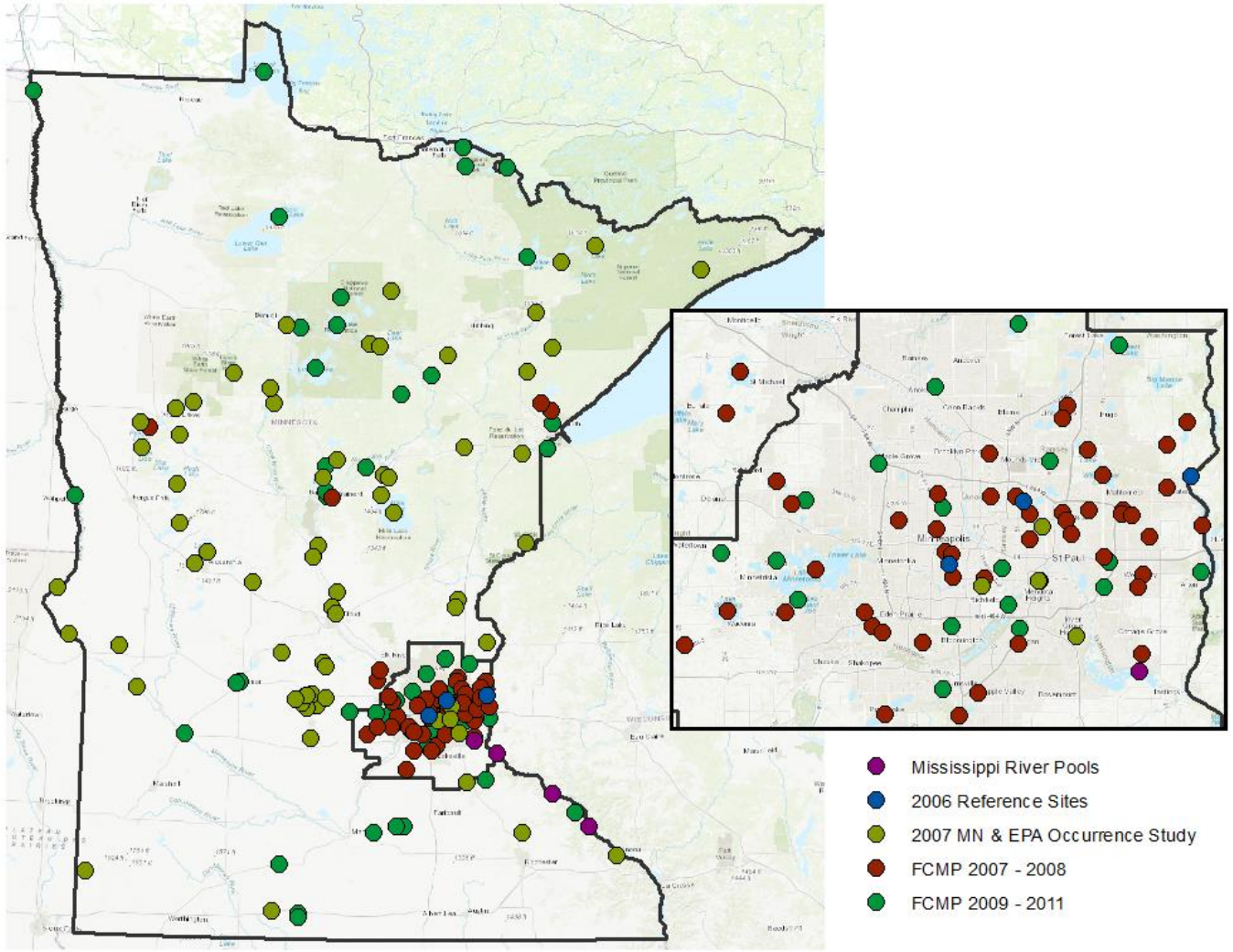
- Shallow groundwater sampling in 2008
- Ambient groundwater network was sampled for PFAS compounds in 2013
  - Limited follow-up in 2017
  - Entire network re-sampled in 2019
- 70% of tested wells contained PFAS…mainly PFBA
- PFOA concentrations in eight wells exceeded MDH's 2017 HBV
- PFOS concentrations in ten wells exceeded MDH's 2019 HBV
- PFAS concentrations declined between 2013 and 2017 in the wells that were re-sampled
- 2019 results are pending

Surface Water and Fish Tissue

Surface waters in Minnesota are protected for multiple uses – recreation, aquatic consumption, aquatic life

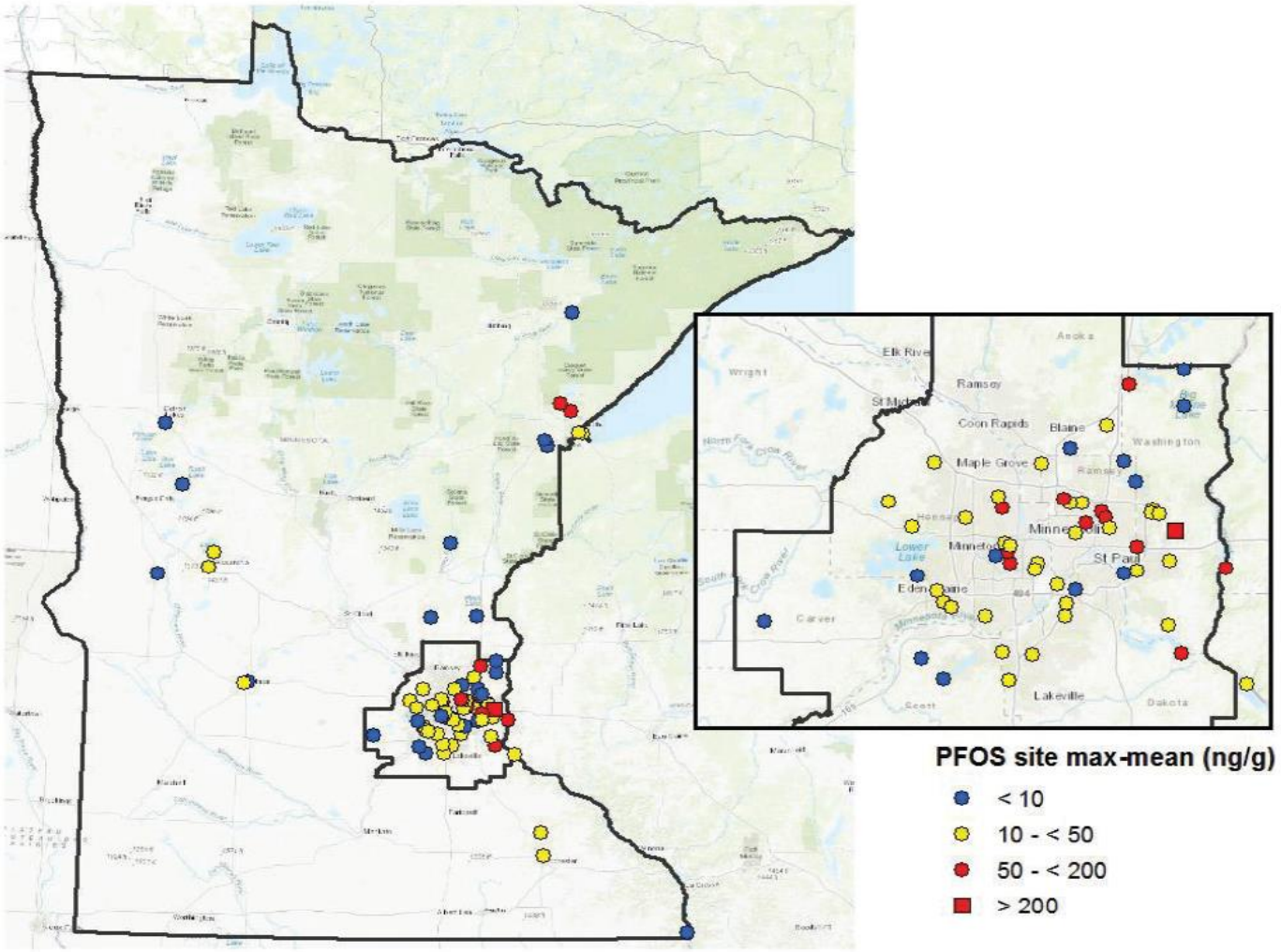
- Main concern to date has been PFAS accumulation in fish and impacts to human health
  - 10 waterbodies listed as impaired for aquatic consumption
  - Revising and developing site-specific criteria for PFOS in fish tissue
- Information on other impacts is less developed

Gathering Fish Tissue Data: 2004 - 2012



- Earliest collections where 3M Cottage Grove Plant discharges wastewater
- Some targeted sampling sites (AFFF, WWTP effluent, plating)
- By 2012, data from 155 lakes + 8 rivers

Gathering Data: 2018 Survey of PFAS in Fish and Water



- 95% of waterways tested had at least one fish with detectable PFOS
- 26% of the water samples (19 of 70) had detectable PFOS
- At least one PFAS chemical detected in every water sample
- 10 waterbody impairments based on fish consumption advice of 1 meal/mo. or less
- Expanding fish and water sampling to assess risks statewide
- Reduce inputs to waterbodies by identifying sources to WWTPs

Next Steps and Needs

- Identify protective fish tissue concentration and translate to water concentrations – focus on PFOS
- Continue to monitor fish tissue and water concentrations, and add sediment testing
  - 2020 Plan: 15 previously sampled waters, 5 new waters
  - 2021 Plan: 30 – 40 sites (funding dependent)
- Improve understanding of bioaccumulation
- Determine need for statewide water quality standard for PFOS in fish tissue

Other Surface Water Needs – Risk Assessment

- Consider how to incorporate MDH health values into statewide water quality standards for drinking waters (surface and groundwater)
- Risk assessment of recreational use of surface waters with higher levels of PFAS
- Risk assessment for PFAS foam (in progress)
- Evaluate PFAS risks to aquatic life and wildlife that drink from surface waters
  - Could result in a statewide water quality standard
  - DNR sampling deer near known PFAS sites with surface water impacts this fall

PFAS Sources and Conduits

Sources

- Direct generation and use of PFAS

Conduits

- May be where PFAS enters the environment but do not generate PFAS
- Pass through PFAS that comes from everyday residential and commercial use and from industrial sources

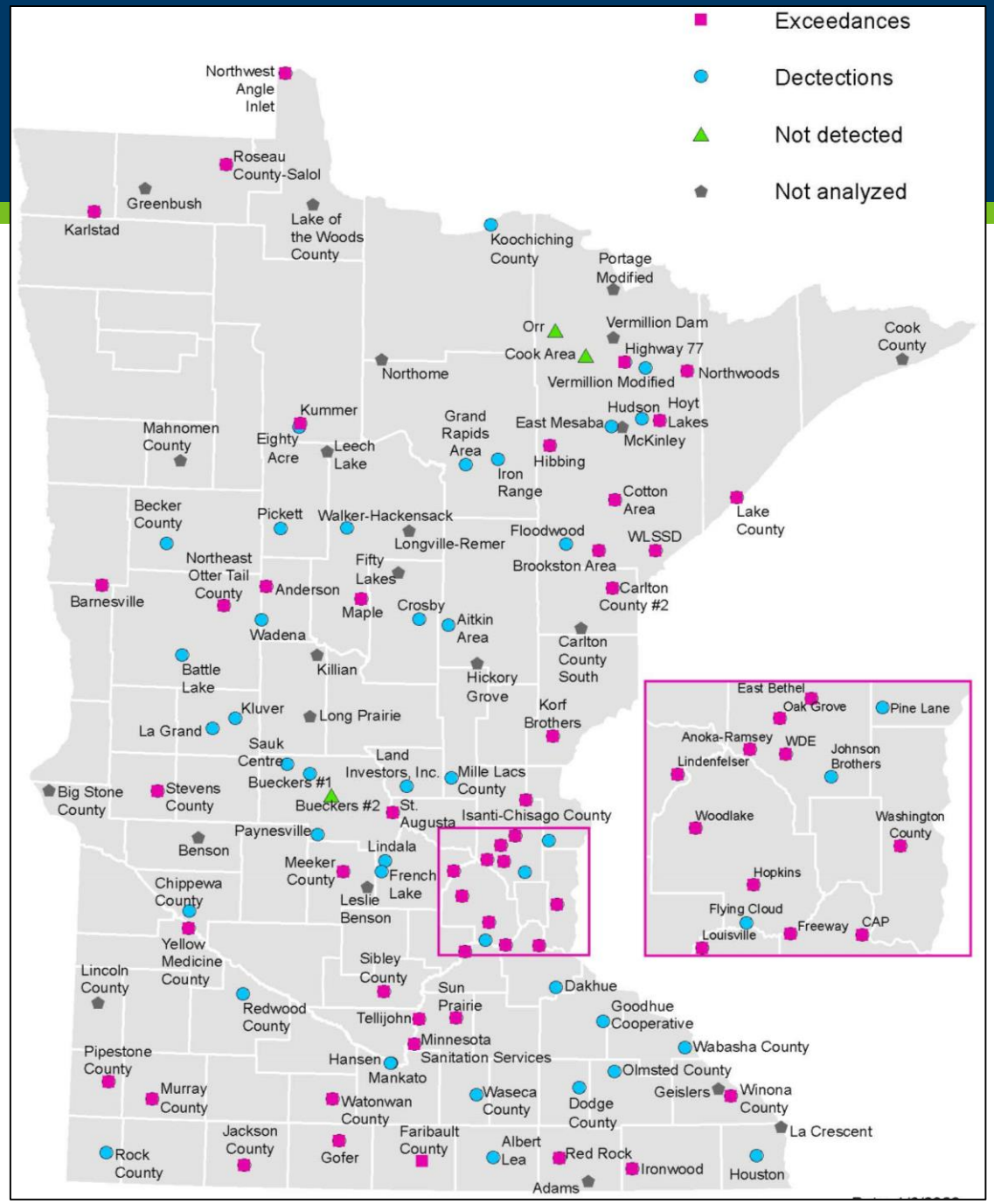
PFAS Source Inventory – Pilot Project

- MPCA developing a protocol to evaluate and prioritize PFAS source investigations
- 4 counties selected for pilot study
- Industrial types were chosen based on national research (NAICS codes)
- Industries identified that COULD have used PFAS in their processes, but any given individual facility MAY not have used PFAS
- Protocol is a tool to prioritize if sampling may be warranted at facilities near sources of drinking water or surface waters
  - Airports – fire fighting foam usage
  - Plating facilities
  - Waterproofing industries
  - Refineries – fire fighting foam usage
  - Commercial printing and paper mills
  - Landfills/disposal facilities

PFAS Source Inventory – Pilot Project

Next Steps

- Validate the protocol with known historical release sites
- Sample 10 sites near industries identified to test protocol
- Utilize protocol as a tool as sites enter into the remediation programs at the MPCA



Conduits: Solid Waste

Discovery: PFAS was detected in various Closed Landfills beginning in 2012.

Private wells have been impacted near 4 closed landfills with low levels of PFAS. Wells now have treatment or well replacement.

90 landfills have been sampled – 97% of them have had detections.

PFAS Source: Disposal of mixed municipal solid wastes in landfills (relatively low concentrations present – except Washington County due to 3M disposal)

Next Steps: Continue PFAS sampling. Implement treatment, if needed.

Conduits: Landfill Leachate

Discovery: Landfill leachate is taken to WWTPs or land applied. 8 of 21 Municipal Solid Waste (MSW) landfills in MN land apply. All landfills that monitor leachate for PFAS have concentrations that have exceeded the MDH standard.

All landfills that land apply leachate monitor groundwater for PFAS - 4 exceeded the MDH standard. MPCA established guidance regarding application rates and areas.

PFAS Source: Likely conduit of PFAS consumer products, needs more investigation.

Next Steps: MPCA is working with landfills on alternative solutions to manage the leachate. 3 landfills proposed pre-treatment of the leachate to remove PFAS:

- Thermal evaporator (60 gal/hr) – evaluation proceeding
- Electrochemical wastewater treatment + mechanical evaporator (75 gal/min) – on hold, vapor dispersion concerns
- In-pond mechanical evaporator – on hold, vapor dispersion concerns

Conduits: Compost Sites

Discovery: Compost sites manage contact water several different ways – send to a WWTP or through land application (not currently).

2019 study of contact water to check for the presence of PFAS – 7 facilities. At least one sampling event at all facilities showed an exceedance of an MDH health value for PFAS.

PFAS Source: Likely conduit of PFAS consumer products, such as food package and service ware, needs more investigation.

Next Steps: Better understand sources, amounts and impacts of PFAS at compost sites, as well as potential treatment options

Conduits: Wastewater Treatment Plants

Discovery: 2007 and 2008 survey of 80 municipal and industrial treatment plant effluent (including biosolids sampling at 40 facilities). Work in other states. Mostly low concentrations, but some higher.

PFAS Source: Municipal largely conduit of PFAS from upstream sources. Needs additional investigation.

Next Steps: Further investigation into influent, effluent, and sources. LCCMR proposal for biosolids.

Legislation & Regulation

Legislation

- Currently 25 bills introduced – hazardous substance designation, product bans, funding for infrastructure, treatment, state agency capacity (lab, investigation, remediation), research (Univ. of MN), establishing state task force, etc.

Regulation

- Use “presence & levels” data gap analysis, on-going sampling, and predictive tools to prioritize sources and inform regulatory approaches
- Evaluating ways to evaluate risk of total PFAS or groups of PFAS to set additional guidance values

Lessons Learned – Fate & Transport

- Expect to be surprised…but general predictions about partitioning are suppored by site data
- Surface water is a critical transport pathway
- Groundwater – Surface Water interactions are very important
  - May create complex plumes
  - Isolated contaminated areas far from source areas
- Site remediation may have unintended consequences
  - Oxidation of precursors
- New EPA Method 533 includes PFBA – be ready to find it everywhere

Lessons Learned – Risk Assessment

- Drinking water is a major exposure pathway
- Still much to be done to identify and evaluate other routes of exposure
- Critical need for PFAS uptake and partitioning studies in livestock (meat, eggs, dairy), wildlife, and plants
- Critical need for more ambient monitoring
  - What is “background” for different land uses?
  - How common are PFAS foam occurrences?
  - How ubiquitous is PFBA? PFPeA? Are they increasing over time?

ITRC PFAS Fact Sheets

- Available online [https://pfas-1.itrcweb.org/fact-sheets]
  - History and Use
  - Naming Conventions & Physical and Chemical Properties
  - Regulations, Guidance and Advisories
    - Guidance values tables updated bi-monthly (US – federal & states, international)
  - Environmental Fate & Transport
  - Site Characterization Tools, Sampling Techniques, & Laboratory Analytical Methods
  - Remediation Technologies & Methods
  - AFFF
- Tailored to the needs of state regulatory program staff – concise, current, web-based

Other ITRC PFAS Products – in the works

- **Technical-Regulatory Document**
  - More in-depth exploration of current state of knowledge of PFAS
  - Includes toxicology, risk communication, stakeholder perspectives, and case studies
- **Internet Based Training Modules**
- **Risk Communication Toolkit**
- **Ask The Experts (on-line companion to tech-reg doc and trng modules)**
  - More info/registration - https://itrcweb.org/Training/Pfas

For more information

- https://www.health.state.mn.us/communities/environment/hazardous/topics/pfcs.html
- https://www.pca.state.mn.us/waste/pfas-minnesota
- https://www.pca.state.mn.us/waste/pfas-pollution

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- AXYS Laboratories
- Barr Engineering
- Antea Group
- AECOM
- Wood plc
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The opinions expressed are those of the author and do not necessarily reflect the official views of ATSDR, the CDC, the Department of Health and Human Services, or the Minnesota Department of Health.

Thank You!

Questions?

Ginny Yingling
virginia.yingling@state.mn.us
651-201-4930