PFCs
Tracers of Surface Water - Ground Water Interaction in Washington County, MN

MGWA Spring Conference
May 7, 2009

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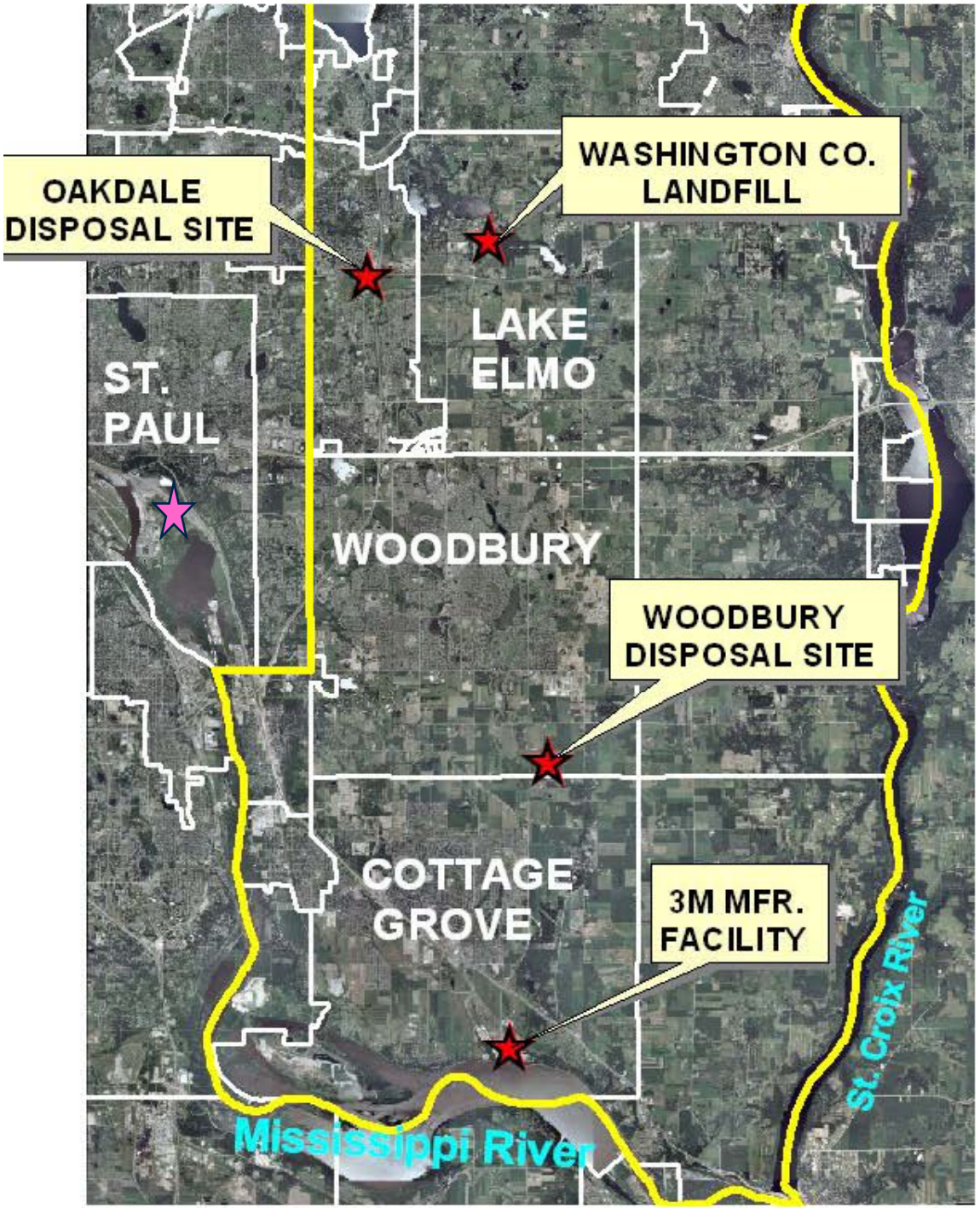
Environmental Health Division

SE Metro PFC Investigations

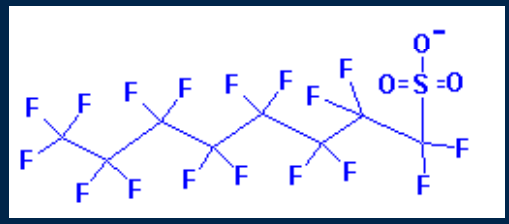
- **2003:** PFCs detected at 3M-Cottage Grove plant
- **2004-2005:** Investigation of disposal areas
  - PFOS and PFOA detected in Oakdale city wells
  - 19 well advisories issued in Lake Elmo
- **2006 - present:** Increased PFC analytical capacity and lowered drinking water criteria resulted in expanded investigation area
  - 11 communities affected; 204 well advisories
  - 200+ Lake Elmo homes connected to city water
  - Oakdale city water filtration plant built
  - Remedial actions planned at 4 sites

LOCATION OF 3M SITES IN WASHINGTON CO. MINNESOTA

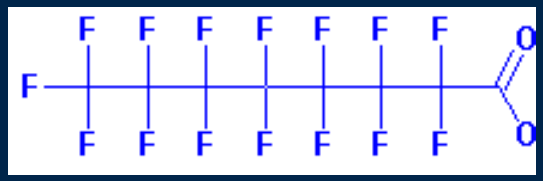


PFCs of Interest in Southeast Metro Area

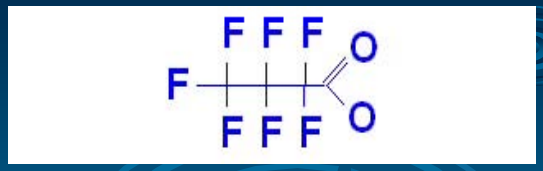
- **PFOS:** $C_8F_{17}SO_3^-$
  Perfluorooctane sulfonate and its salts



- **PFOA:** $C_8F_{15}O_2^-$
  Perfluorooctanoic acid and its salts



- **PFBA:** $C_4F_7O_2^-$
  Perfluorobutanoic acid and its salts



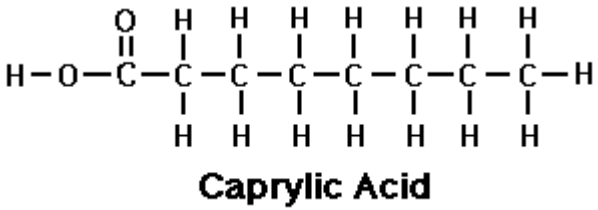
- Occasional detects: **PFPeA, PFHxA, PFHxS, PFBS**

MDH Drinking Water Guidelines

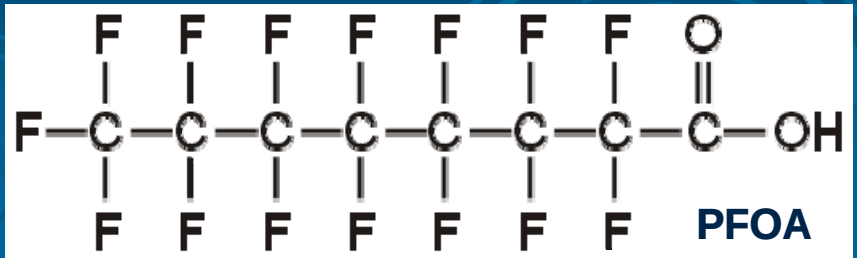
- **Health Risk Limits (promulgated in rule):**
  - **PFOS: 0.3 ppb**
  - **PFOA: 0.3 ppb**
- **Health Based Value (not promulgated):**
  - **PFBA: 7.0 ppb**
  - Protective for both long-term/lifetime and fetal exposures
  - Based on slight liver and thyroid effects

PFCs Behave in Unique Ways

- **Do not break down in the environment**
  - **C-F bond**
- **Do not adsorb readily to aquifer materials**
  - **Infiltrate rapidly to the groundwater**
  - **Move nearly as fast as the groundwater**
  - **Travel long distances**
- **Chemical structure similar to fatty acids**
  - **Readily adsorbed into blood serum of living organisms**
  - **May, in part, explain long half-lives in the body**

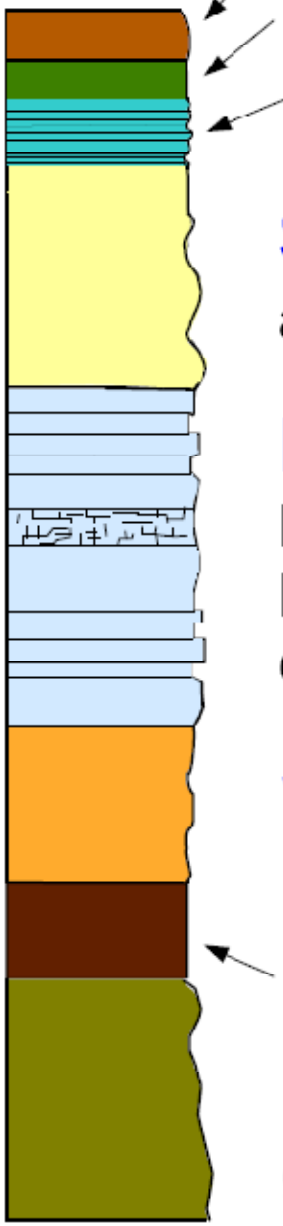


Caprylic Acid



PFOA

Bedrock Layers in South Washington Co.



Sedimentary Deposits: 0-100 ft. thick, sand and gravel with clay layers

Decorah Shale: 0-15 ft. thick

Platteville & Glenwood Formations: 0-30 ft. thick, thinly bedded limestone, dolomite, and shale

St. Peter Sandstone: 0-150 ft. thick; private well aquifer

Prairie du Chien Group: 130-200 ft. thick, heavily karsted dolomite with sandy and shaley layers – high transmissivity zone near Shakopee - Oneota contact; private well aquifer

Jordan Sandstone: 65-95 ft. thick; main aquifer used by city wells, also used by private wells

St. Lawrence Formation: 35-60 ft. thick, dolomitic sandy shale and siltstone - can help slow or stop downward movement of PFBA

Franconia Sandstone: 165 ft. thick, green glauconitic sandstone, private well aquifer near river

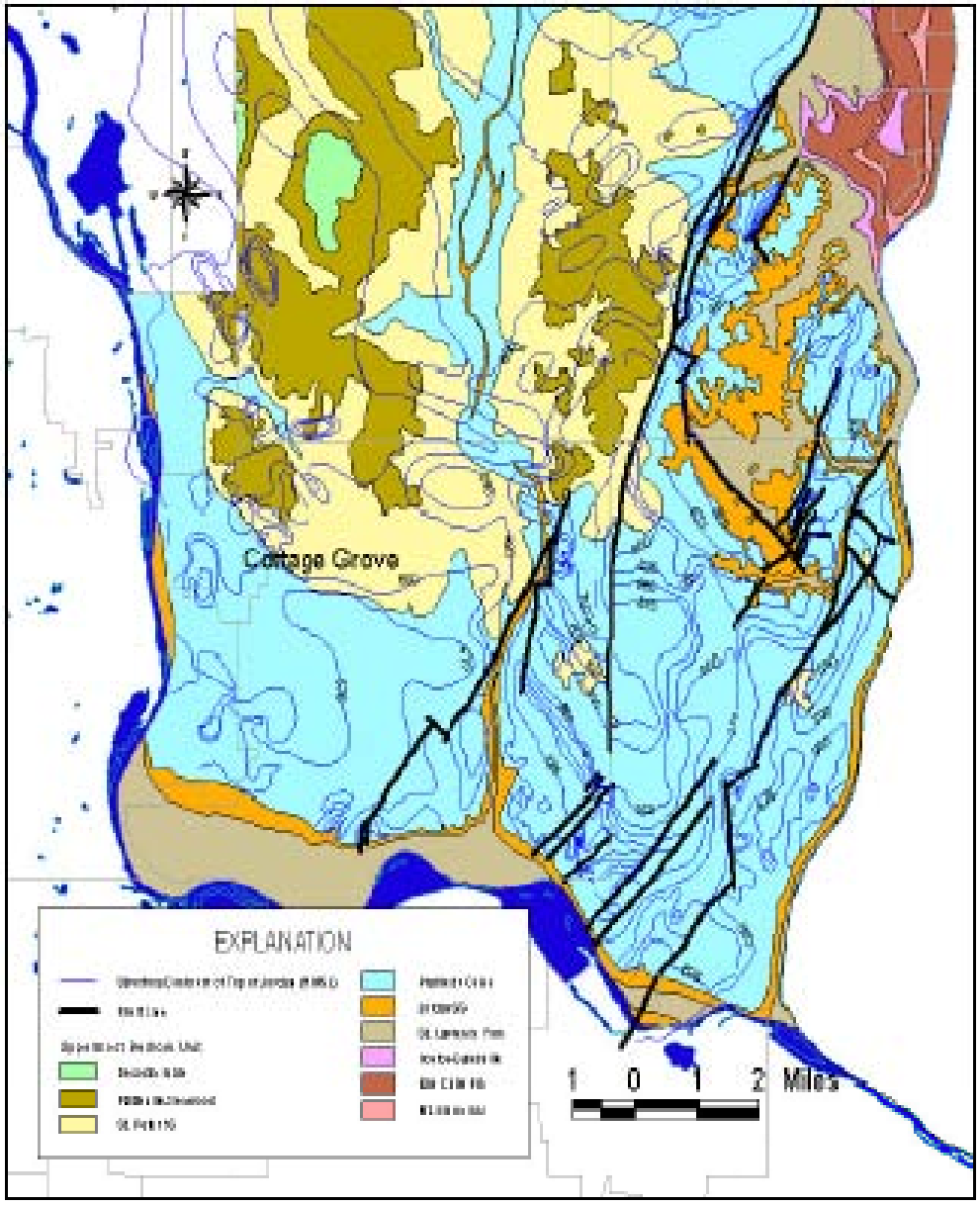
Bedrock Structure S. Washington Co.

Regional Scale (kms):
Bedrock Valleys – eroded as deep as the Jordan in some areas; associated karst in St. Peter and Prairie du Chien

Faults – NE-SW trending faults associated with St. Croix Anticline; up to 150 ft. displacement (Mossler, 2003)

Large Scale (10-100s m):
Joint Sets – and associated karst development in OPDC

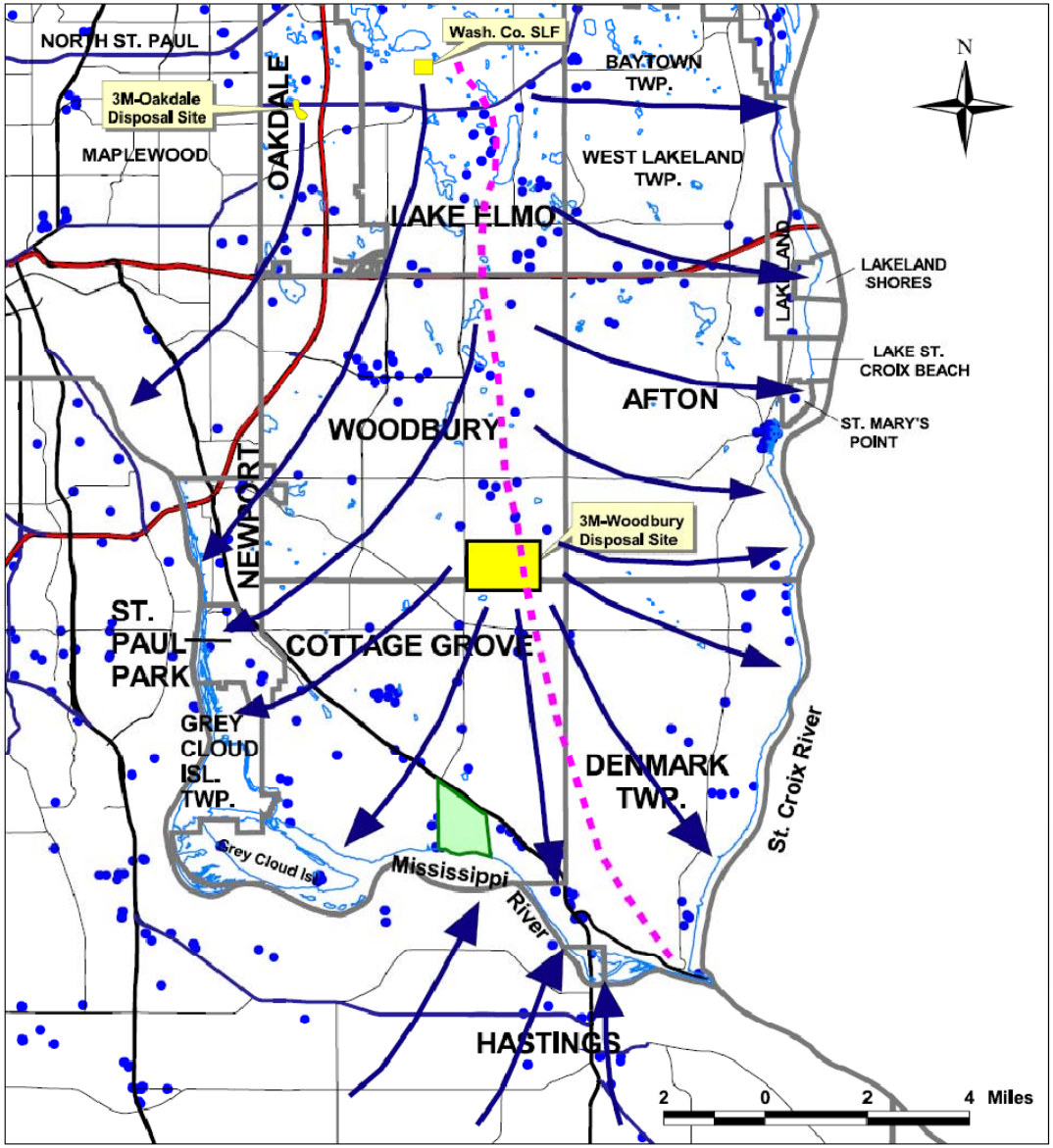
Small Scale (cm-10s m):
Fractures – bedding plane and vertical; esp. in Shakopee & upper 1/3 Oneota; varies spatially (Tipping, et al, 2006)



(adapted from Mossler, 2003)

Groundwater Flow

- A “groundwater divide” extends from north to south beneath the county
- East of the “divide” groundwater flows to the St. Croix River
- West of the “divide” groundwater flows to the Mississippi River
- Close to where the two rivers meet, the flow “fans out” toward either river
- Locally, groundwater flow and “divide” are influenced by pumping wells



General Groundwater Flow in S. Washington Co.

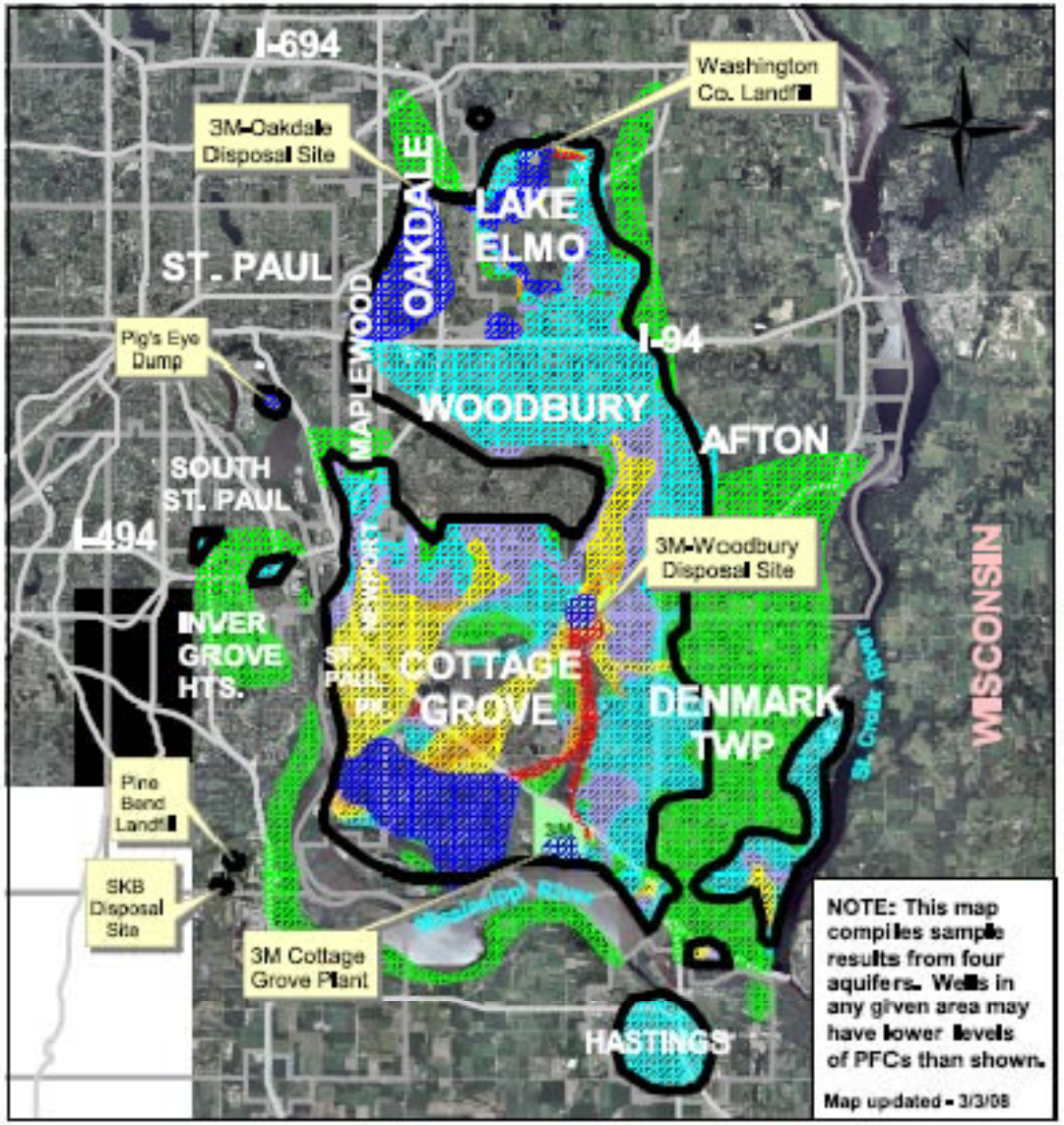
Regional groundwater divide

Regional groundwater flow direction

Prepared: 1/23/07

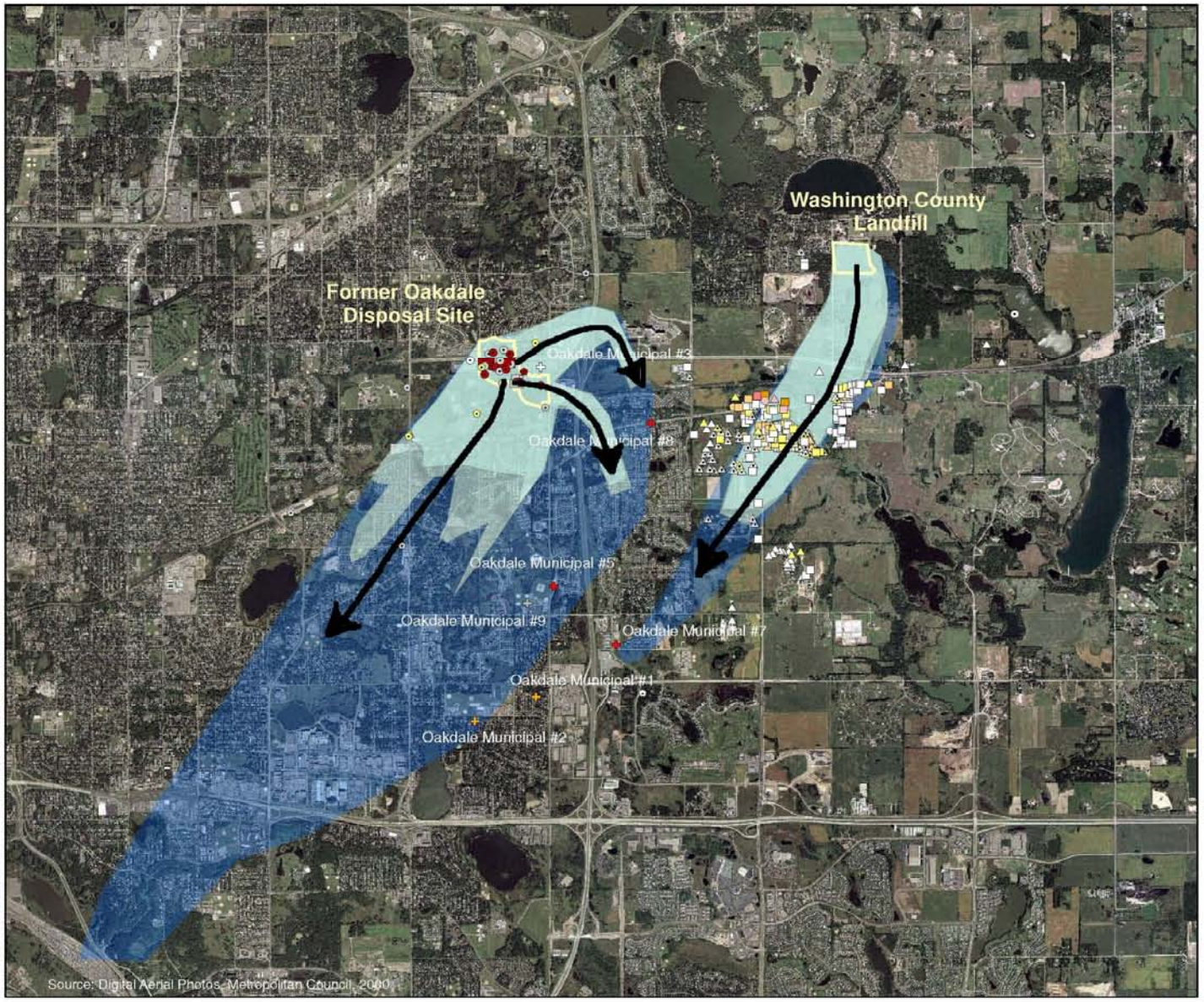
Result: Extremely Large Plumes

- Over 100 sq. mi.
  - Models did not predict
- PFBA most widespread PFC
  - More PFBA in source areas
  - More mobile
- Distribution controlled by
  - Bedrock features
  - Groundwater pumping
  - Surface water
- Several “anomalous” areas - evidence of SW-GW interaction?
  - PFOS in Lake Elmo
  - PFBA beyond the “divide”
  - PFBA across Mississippi R.



PFOS in the Lake Elmo Area

Predicted PFC Plume



Legend

PFC - Oakdale Municipal Wells

- Non-detect
- <0.1 ppb PFOA/PFOS
- >0.5 ppb PFOA/PFOS
- Not Measured

- Plume Estimate 2005 (MODPATH)
- Plume Estimate 1984 (MODPATH)
- Plume Estimate 1982 (MODPATH)

Aquifer Symbol

- Multiple Aquifers
- Prairie du Chien
- Platteville Formation
- St. Peter Sandstone
- Quaternary Aquifer
- Unknown Aquifer

PFOA Detection Range Color Key

- Non-detect
- .01-.5 ug/L
- .51-1.0 ug/L
- 1.01-1.5 ug/L
- 1.51-2.0 ug/L
- 2.01-2.5 ug/L
- 2.51-3.0 ug/L
- >3 ug/L

Feet
5,000

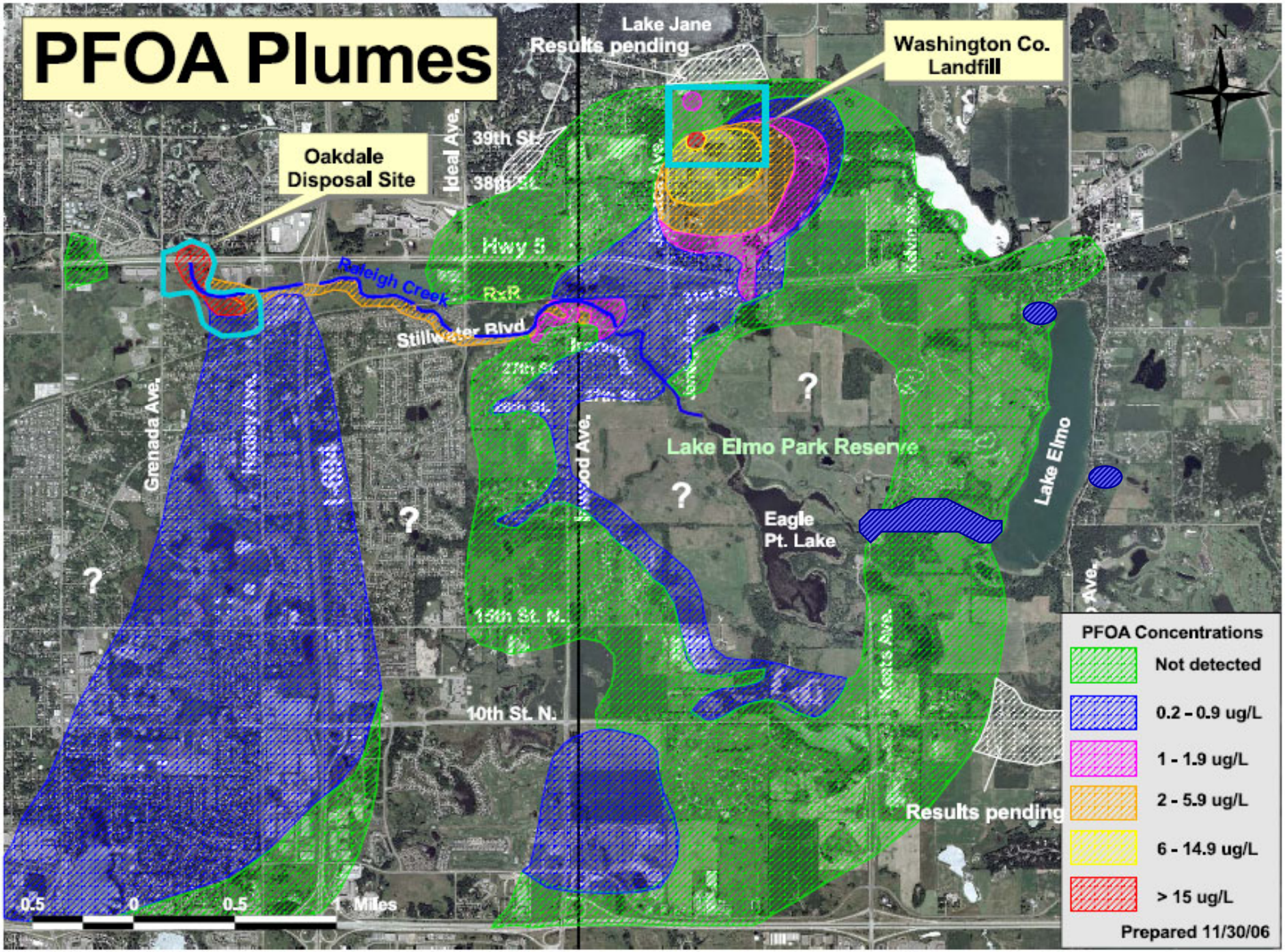
Meters
500 0 500 1,000 1,500 2,000

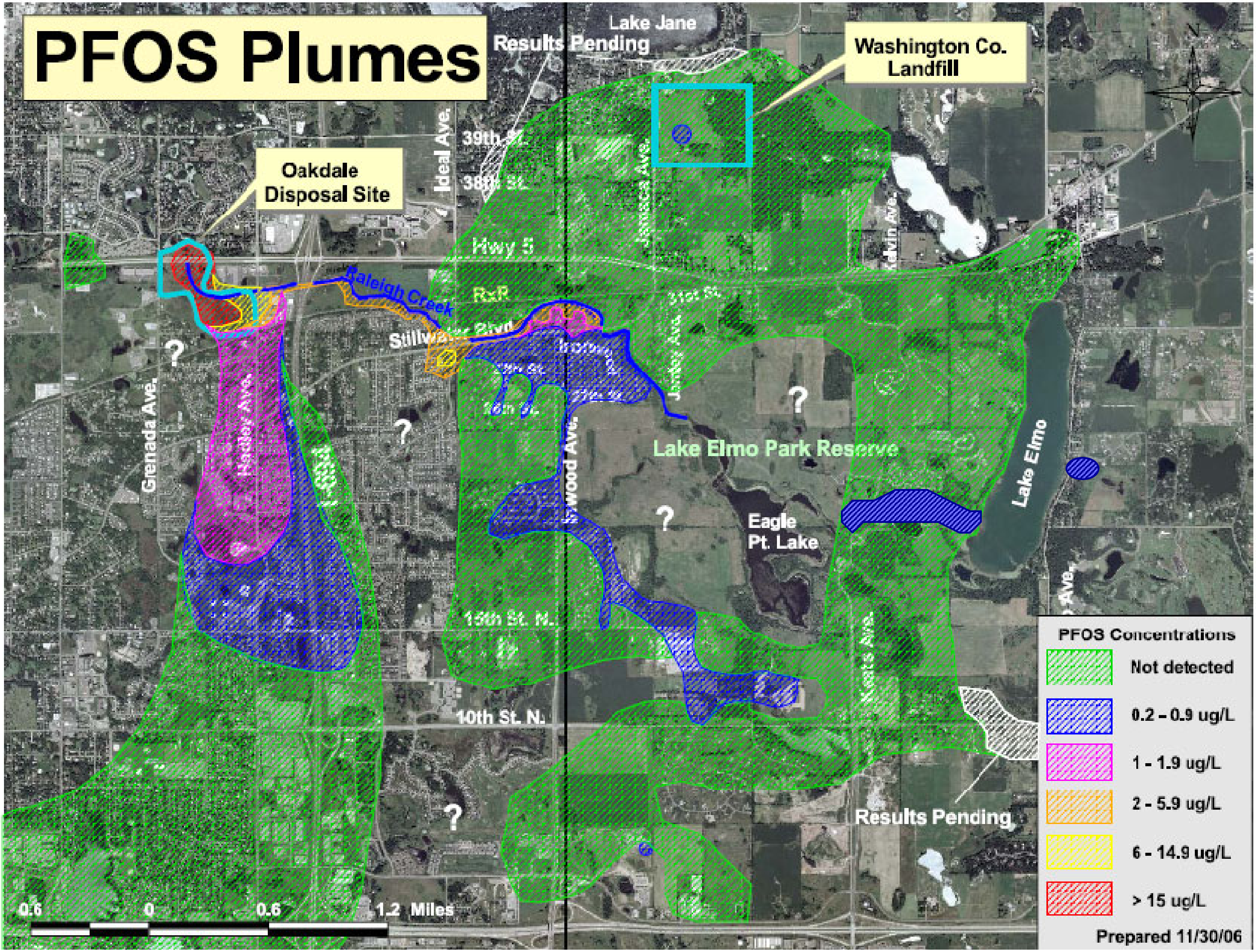
Figure 7

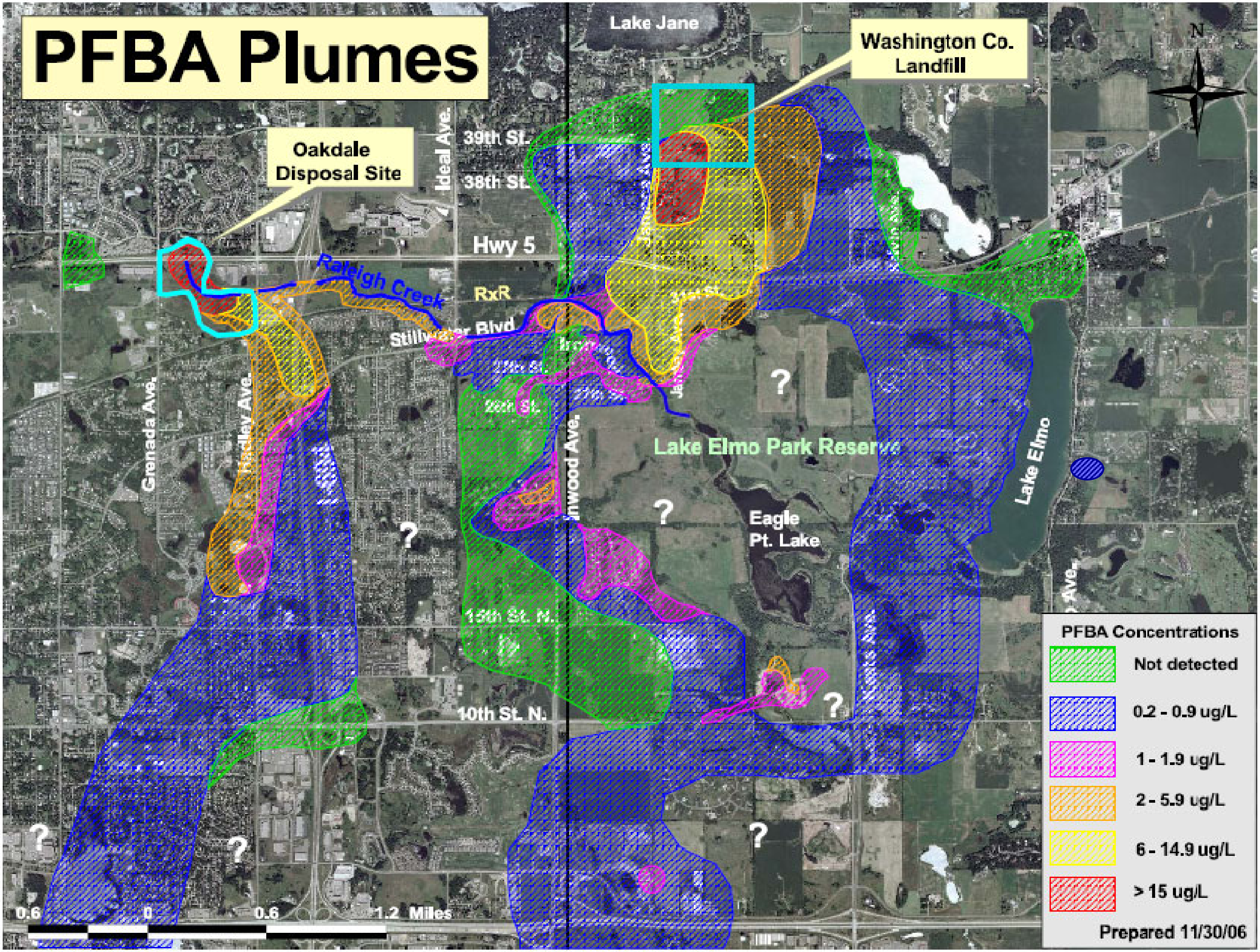
PREDICTED PFC PLUME LOCATIONS (MODPATH)

Former Oakdale Disposal Site/Washington County Landfill Groundwater Modeling

Minnesota Pollution Control Agency
Washington County, Minnesota


PFOA Plumes
Lake Jane
Results pending
Washington Co.
Landfill
Oakdale
Disposal Site
Ideal Ave.
39th St.
38th St.
Hwy 5
Raleigh Creek
R×R
Stillwater Blvd
Grenada Ave.
Lake Elmo Park Reserve
Lake Elmo
Eagle
Pt. Lake
19th St. N.
10th St. N.
Results pending
N
0.5 0 0.5 1 Miles
PFOA Concentrations
Not detected
0.2 – 0.9 ug/L
1 - 1.9 ug/L
2 - 5.9 ug/L
6 - 14.9 ug/L
> 15 ug/L
Prepared 11/30/06


PFOS Plumes
Lake Jane
Results Pending
Washington Co.
Landfill
Oakdale
Disposal Site
Ideal Ave.
39th St.
38th St.
Hwy 5
Raleigh Creek
RxR
Stillwater Blvd
Jamaca Ave.
Jamaca Ave.
31st St.
Grenada Ave.
Lake Elmo Park Reserve
Lake Elmo
Eagle
Pt. Lake
15th St. N.
10th St. N.
Keats Ave.
Results Pending
0.6
0
0.6
1.2 Miles
PFOS Concentrations
Not detected
0.2 – 0.9 ug/L
1 - 1.9 ug/L
2 - 5.9 ug/L
6 - 14.9 ug/L
> 15 ug/L
Prepared 11/30/06


PFBA Plumes
Lake Jane
Washington Co. Landfill
Oakdale Disposal Site
39th St.
38th St.
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Hwy 5
Raleigh Creek
RxR
Stillwater Blvd
Grenada Ave.
Hadley Ave.
Inwood Ave.
Lake Elmo Park Reserve
Eagle Pt. Lake
Lake Elmo
15th St. N.
10th St. N.
?
0.6 0 0.6 1.2 Miles
N
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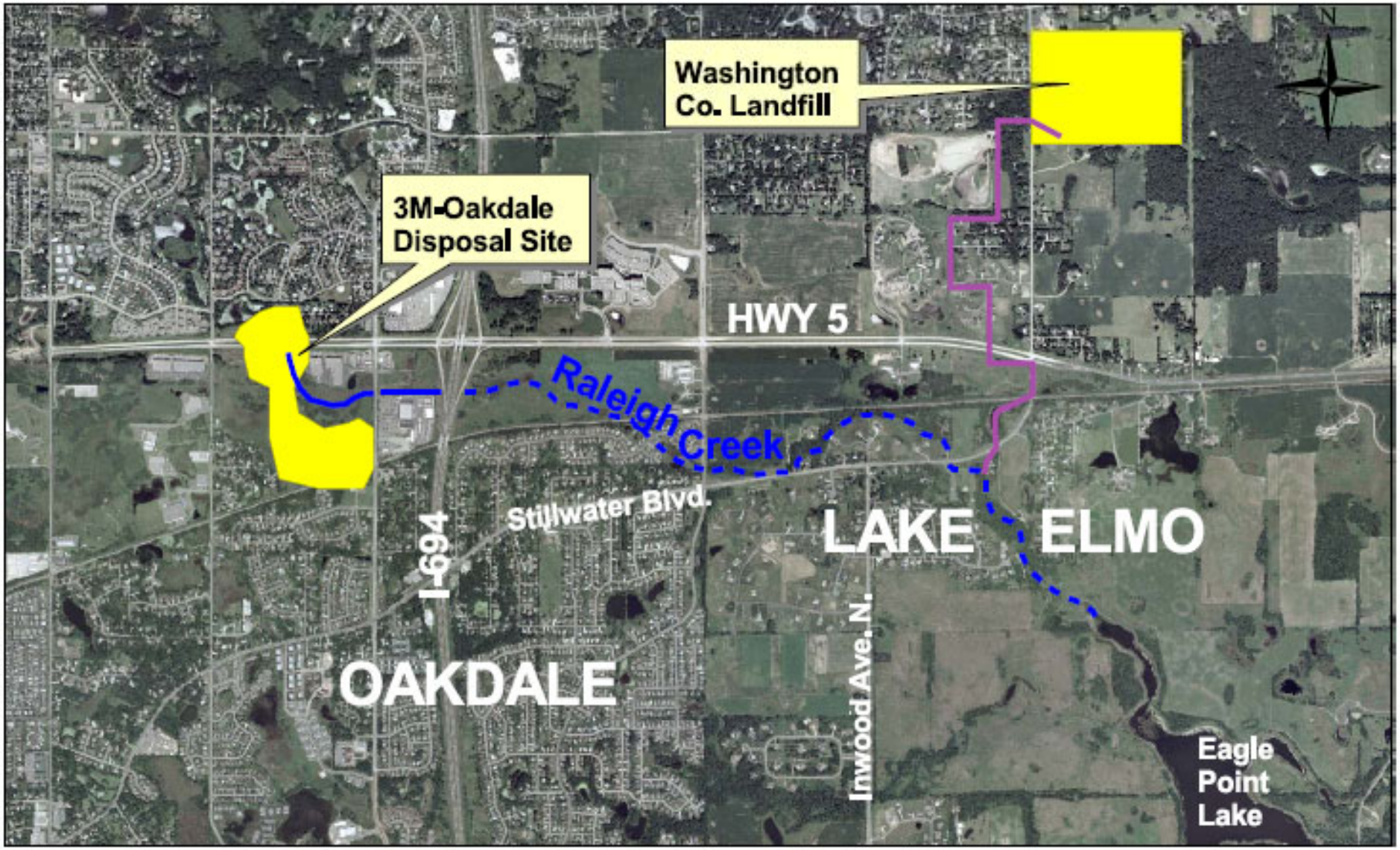


Figure 9: Raleigh Creek

"Gaining" stream section of creek*

"Losing" stream section of creek*

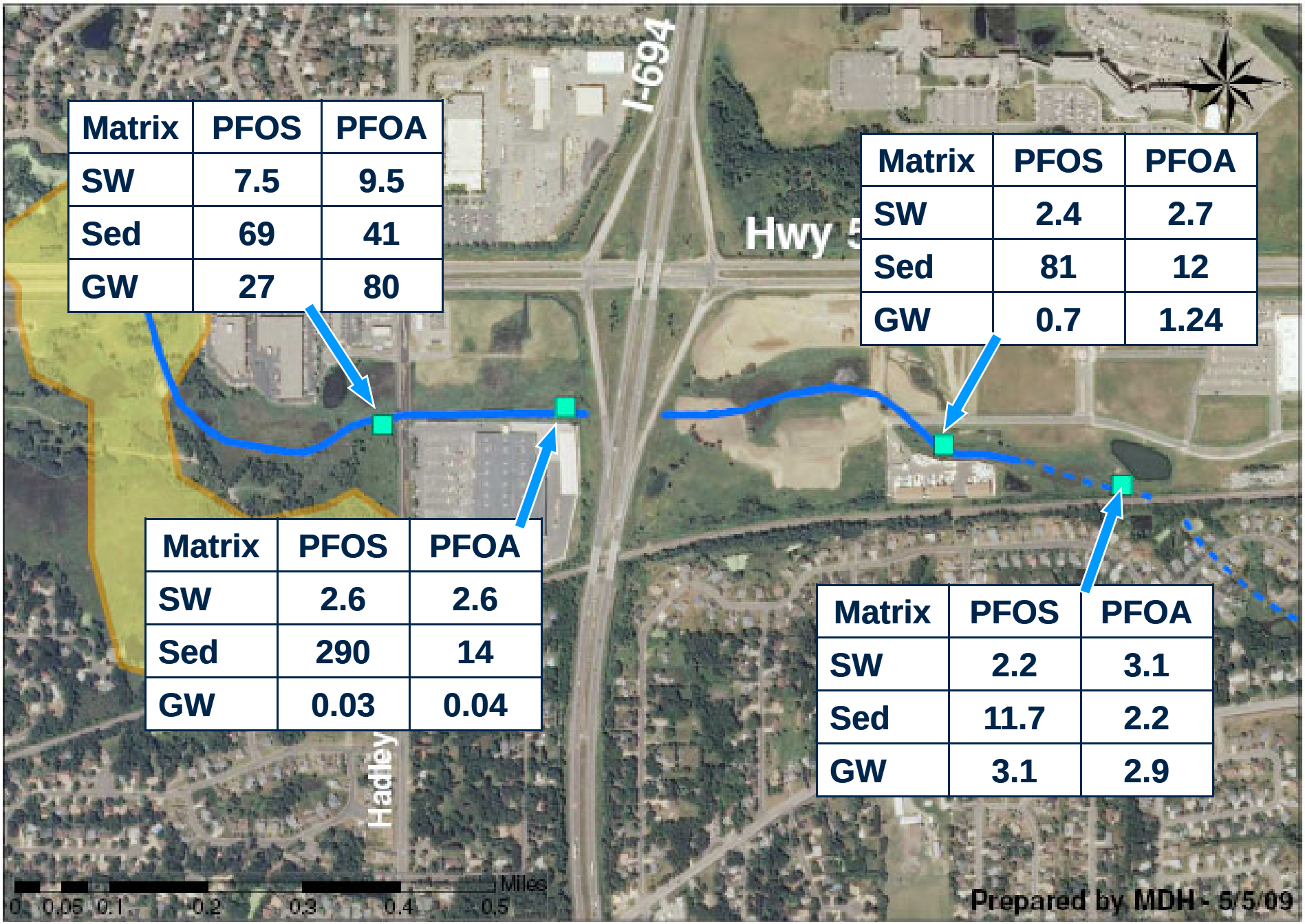
Route of 1988-1995 discharge from landfill to the creek

* see page 22 or glossary

Groundwater-Surface Water Interaction Effect on PFC Migration

- **Raleigh Creek**
  - Allowed transport of PFOS and other PFCs from 3M-Oakdale site to Eagle Pt. Lake and Lake Elmo
  - May account for PFOS in fish in Lake Elmo
- **Stormwater discharge from Washington Co. landfill (1988-1995)**
  - Discharged to Raleigh Creek approximately:
    - 1,000+ lb PFBA
    - 75+ lb PFOA
    - 1.5+ lb PFOS
  - Helped spread PFCs (esp. PFBA) beyond expected area

3M Surface Water, Sediment & Groundwater Samples

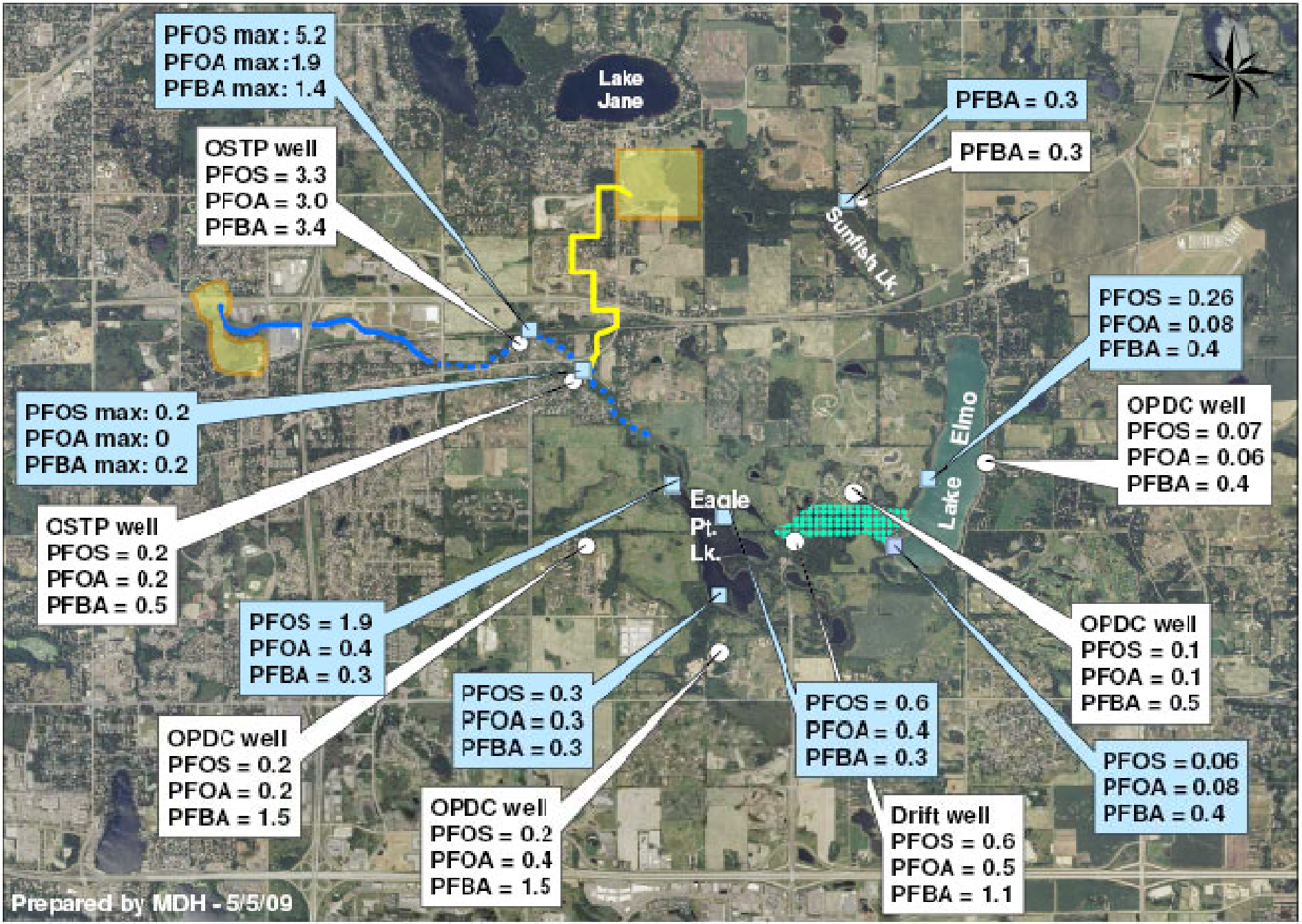


Matrix	PFOS	PFOA
SW	7.5	9.5
Sed	69	41
GW	27	80

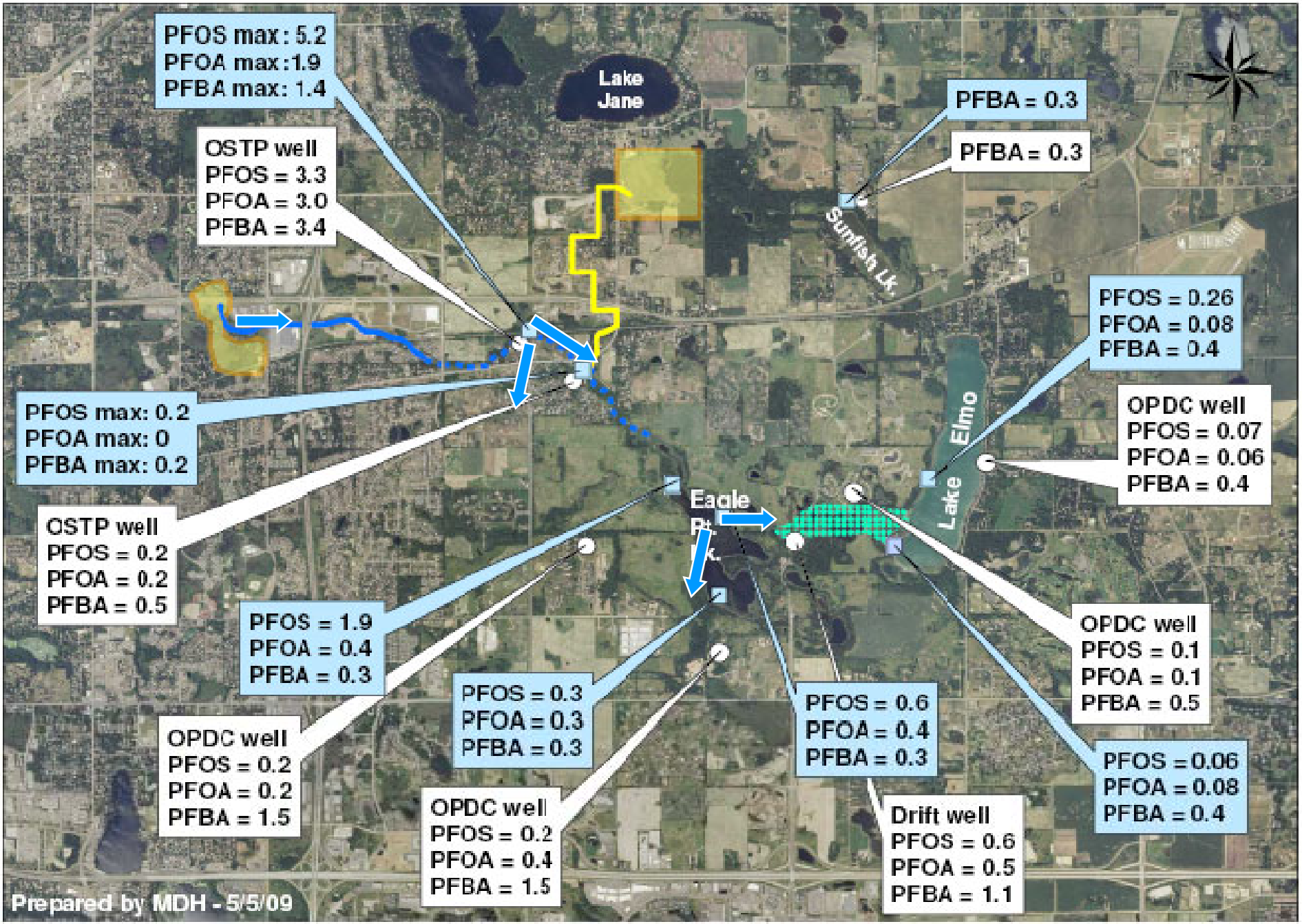
Matrix	PFOS	PFOA
SW	2.4	2.7
Sed	81	12
GW	0.7	1.24

Matrix	PFOS	PFOA
SW	2.6	2.6
Sed	290	14
GW	0.03	0.04

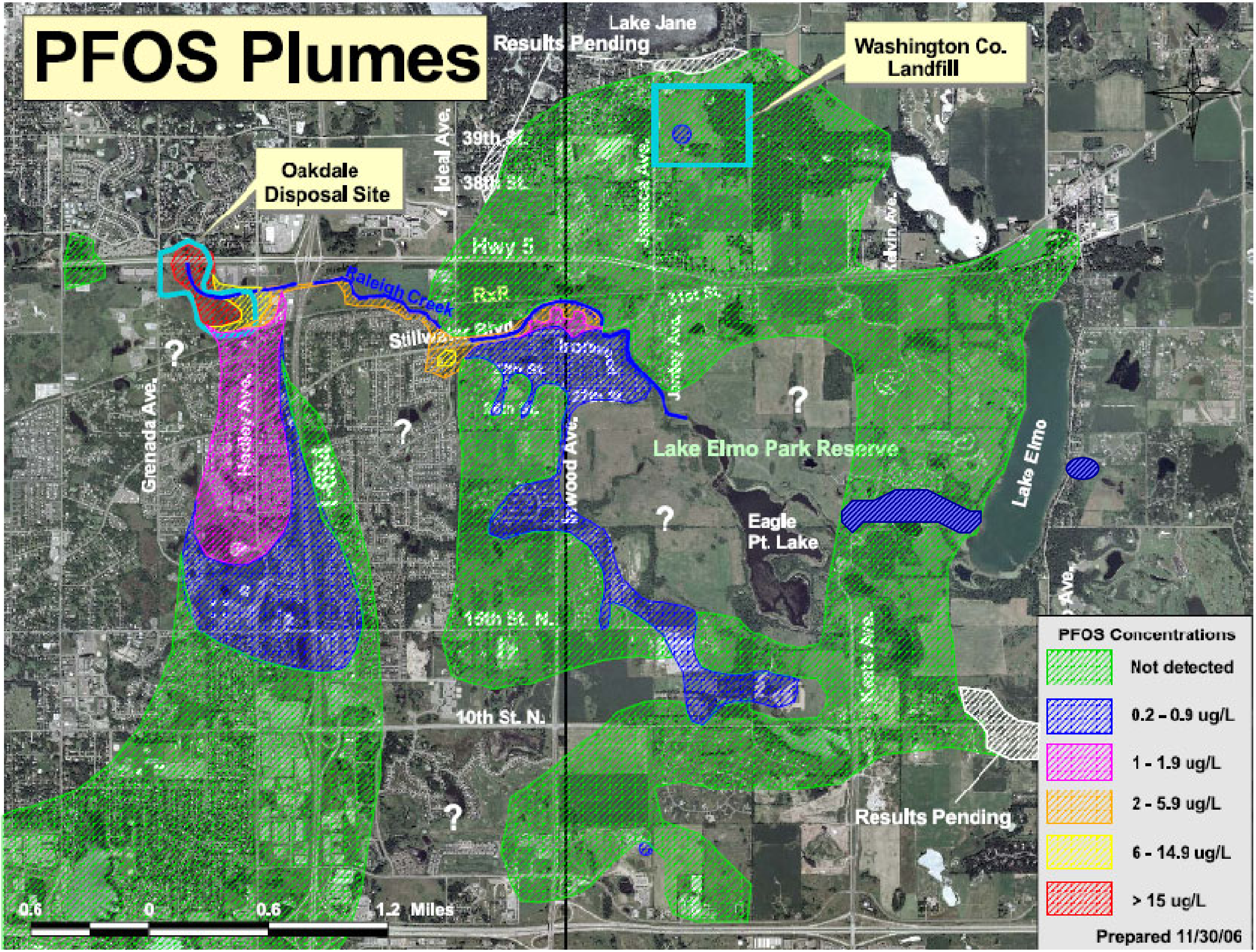
Matrix	PFOS	PFOA
SW	2.2	3.1
Sed	11.7	2.2
GW	3.1	2.9



Surface Water and Groundwater PFC Concentrations (ppb)



Surface Water and Groundwater PFC Concentrations (ppb)



PFOS Plumes
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0.6
0
0.6
1.2 Miles
PFOS Concentrations
Not detected
0.2 – 0.9 ug/L
1 - 1.9 ug/L
2 - 5.9 ug/L
6 - 14.9 ug/L
> 15 ug/L
Prepared 11/30/06

PFBA Beyond the “Divide”

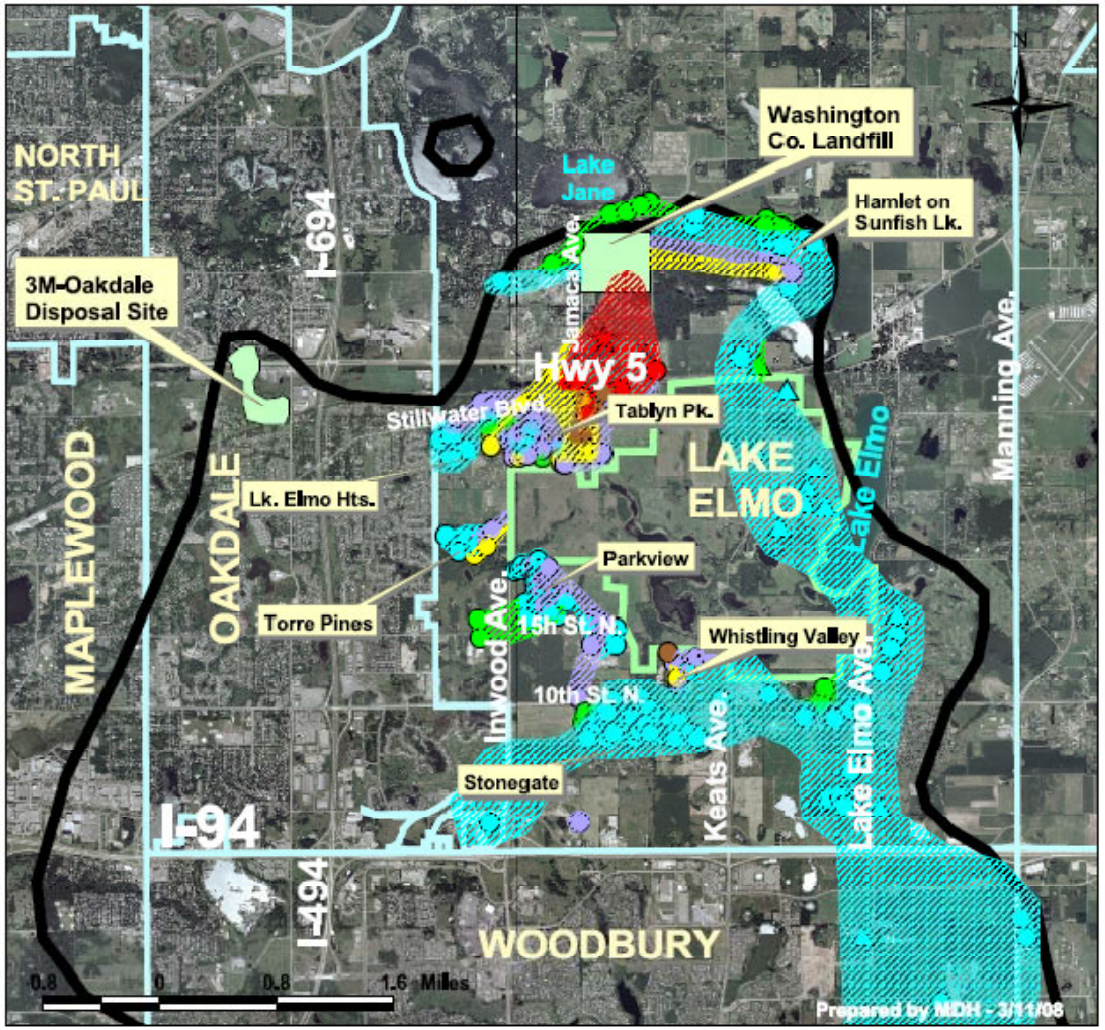
PFBA Distribution

"Finger" of PFBA extends eastward to newer development north of Sunfish Lake.

Likely due to:

- **location of infiltration pond**
- **bedrock valley**
- **high transmissivity zone in the OPDC**

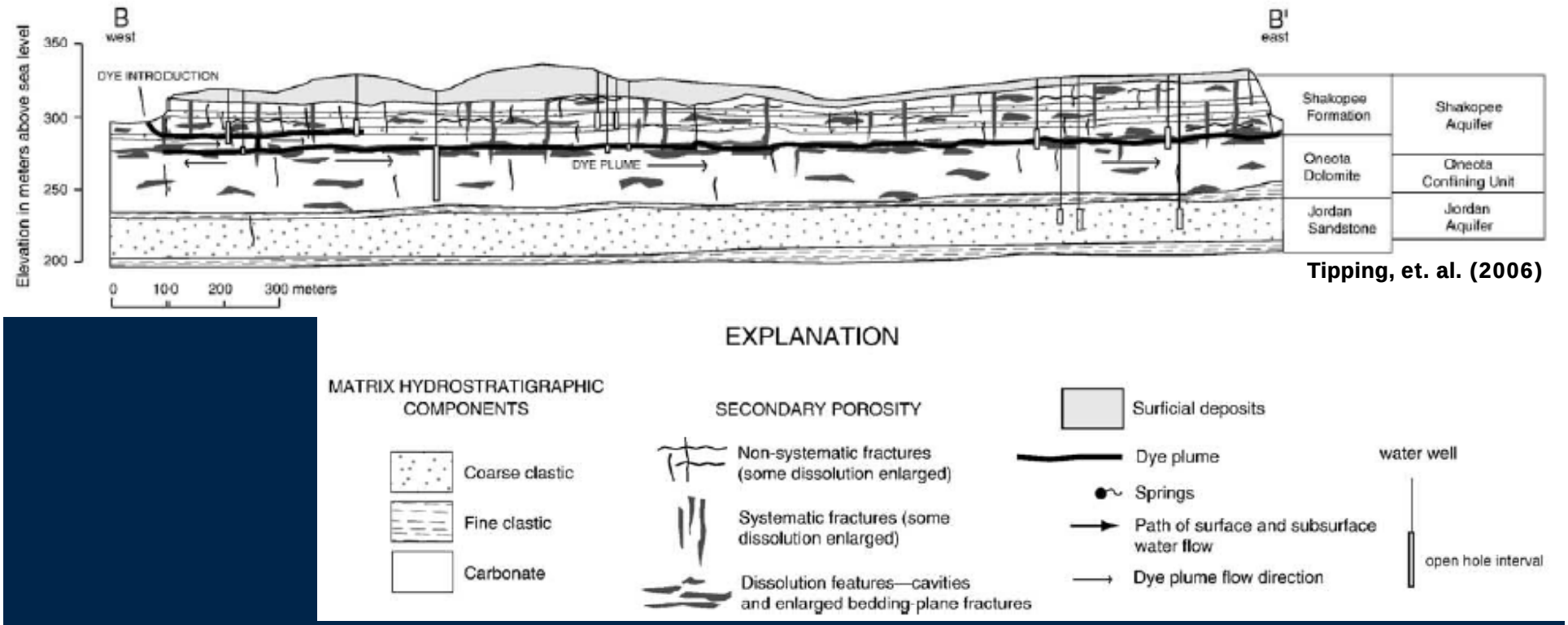
Permitted PFCs to migrate "across" groundwater divide



PFBA in Prairie du Chien - Lake Elmo

PFBA Concentration Ranges

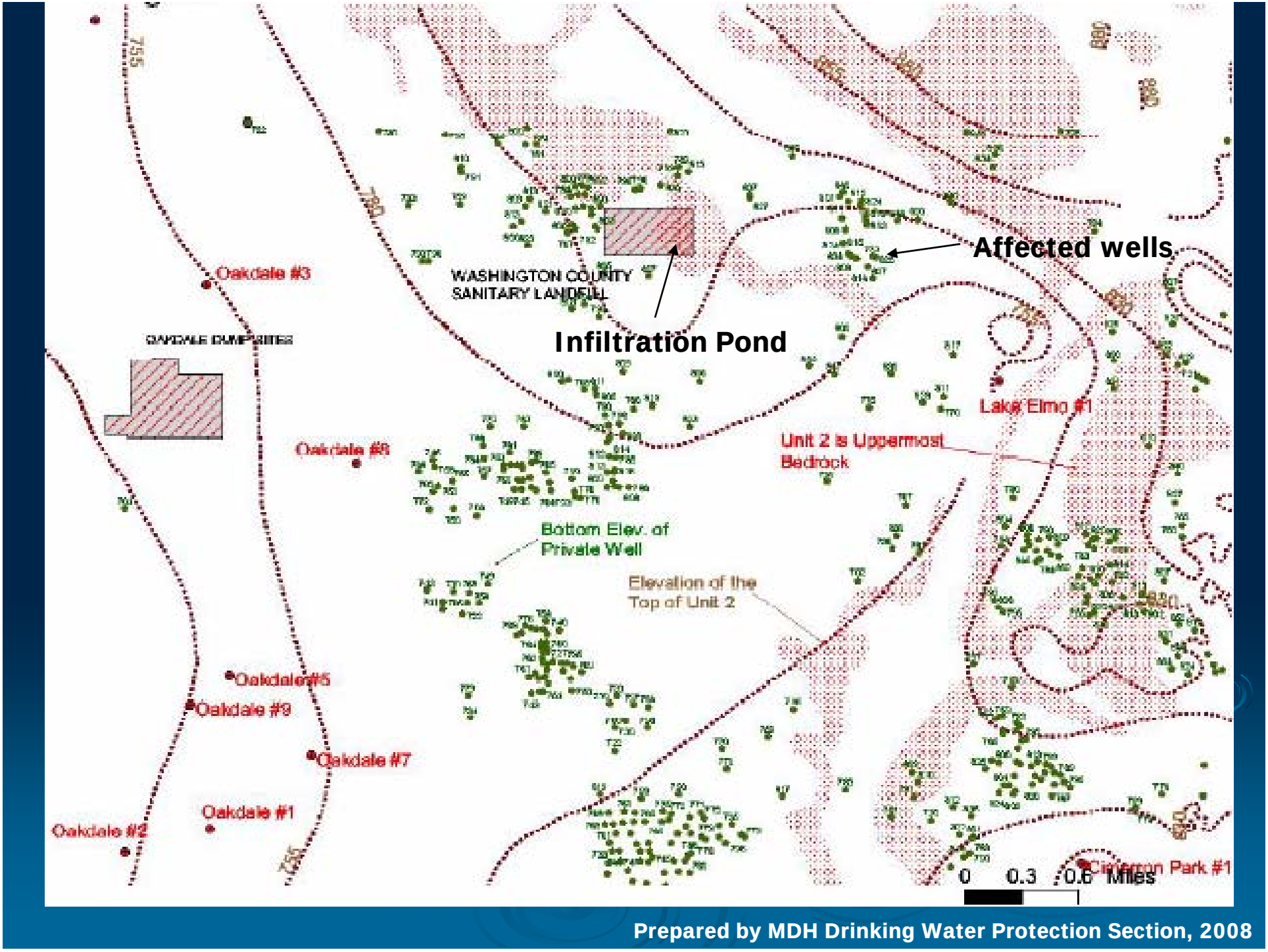
- Not detected
- 0.2 - 0.9 ppb
- 1.0- 1.6 ppb
- 1.7 - 3.4 ppb (25-49% HBV)
- 3.5 - 5.1 ppb (50-74% HBV)
- 5.2 - 6.9 ppb (75-99% HBV)
- ≥ 7 ppb
- Extent of PFCs in all aquifers
- Lk. Elmo Pk. Reserve
- ○ Private well
- □ City well
- △ Non-community public well



Tipping, et. al. (2006)

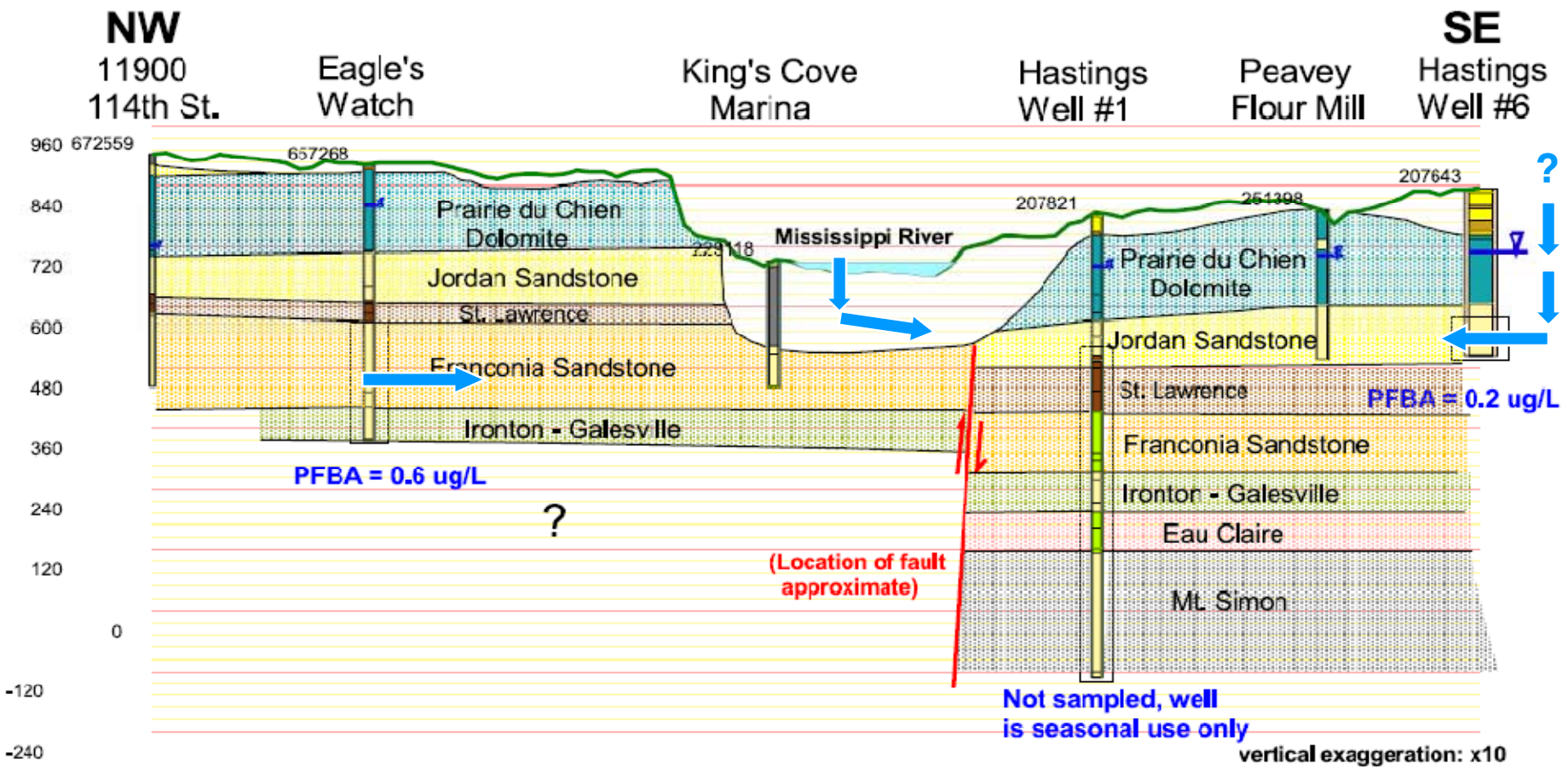
High Transmissivity Zone – Prairie du Chien

Tipping, et al (2006) noted that the Shakopee and upper 1/3 of the Oneota has ubiquitous solution widened fractures. Fracture abundance increases as the depth to the Shakopee decreases.



Prepared by MDH Drinking Water Protection Section, 2008

PFBA Across the Mississippi River



Possible Migration Pathways for PFCs To Reach Hastings City Wells

Groundwater, Surface Water-Ground Water Interactions, or a Combination ?

Conclusions

- **PFCs are highly conservative in the environment**
  - **Can migrate through a diversity of surface and ground water environments relatively unchanged beyond dilution**
- **This makes PFCs an excellent tracer of surface water – ground water interactions**
  - **Lake Elmo: PFOS and PFBA**
  - **Hastings?**
- **PFCs also make excellent structural tracers**
  - **PFBA has been used in tracer studies**
  - **Distribution reflects regional to small-scale structural features in Washington Co.**
    - **Also micro-scale structures and flow paths, if we could evaluate it**

Acknowledgements

- MDH - Environmental Health Division
- MPCA – Closed Landfill & Superfund
- Minnesota Geological Survey
- Washington County
- Valley Creek Watershed District
- University of Minnesota
- Delta Environmental Consultants
- Barr Engineering
- ATSDR
- USGS
- 3M Company

Questions?