Research on septage and bioaugmentation

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Acknowledgements

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Outline

1. Introduction
2. Methodology
3. Wastewater Characteristics
4. Septic Tank Conditions and Solids Accumulation

    Case Study: Goose Creek Rest Area

5. PFAS Analysis
6. Summary

The materials presented represent our own opinions and do not reflect the opinions of NOWRA

1. Introduction

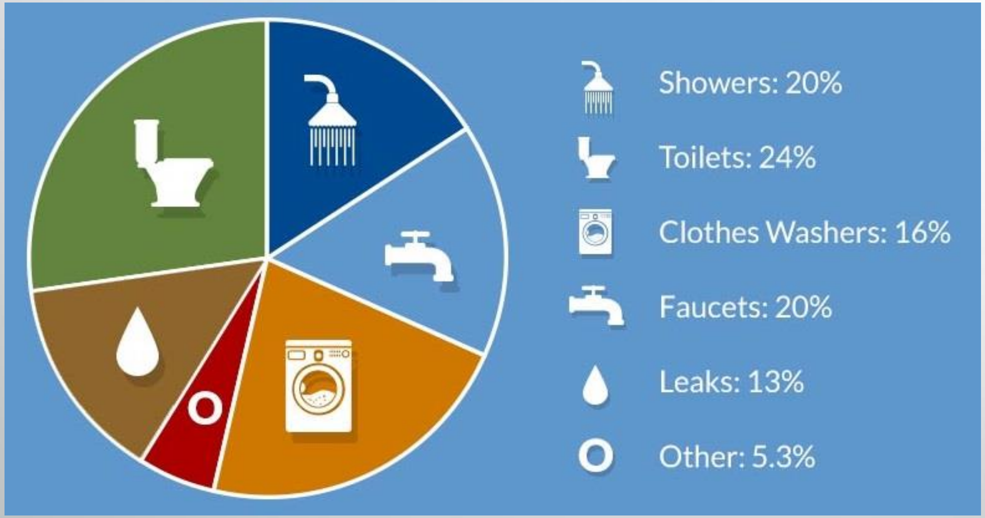
Rest Area Characteristics

- Often in remote areas ⟶ must treat wastewater onsite
- Include toilets and sinks, often heavily used
  - Many motorists passing through instead of fixed number of residents in a home
- Sometimes include other wastewater sources: drinking fountains, water conditioning or treatment units, irrigation, mop sinks
- Notably absent: cooking, bathing, and laundry facilities

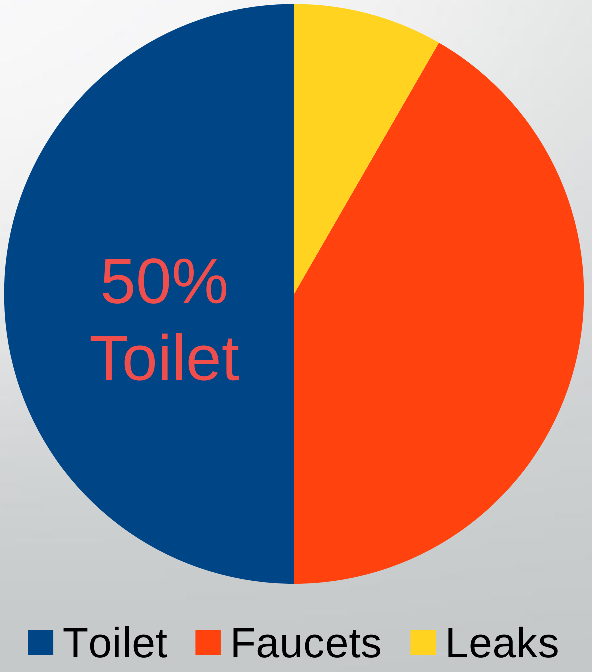
Wastewater Sources

Residential Water Use

(DeOreo et al, 2016)



Now remove cooking, bathing, and laundry; fix most leaks



Objectives of Study

- Primary: Characterize rest area septage
- Determine whether current maintenance practices (e.g., pumping frequency) could be made more efficient
- ‘Exploratory’ investigation of PFAS (an emerging class of contaminants) in rest area septage

2 – Methodology

Sample Collection

- Samples collected at annual or biannual pumping
- Septage mixed as drawn into truck
- Samples collected from truck
- Always used first load from first tank

Data Collected Onsite by Maintainers

- Sludge accumulation
- Scum accumulation
- Tank operating depth
- Relative volume filled
- Volume of septage removed
- Unnatural items (trash) in tanks
- Operational problems – baffles, alarms, corrosion

Laboratory Analyses of Samples

- pH (all sites)
- Oxygen Demand (all sites)
  - BOD
  - COD
- Suspended Solids (all sites)
  - TSS
- Nutrients (all sites)
  - TKN
  - Ammonia (as Nitrogen)
  - Phosphorus
- Oil and Grease (11 sites)
- Metals (11 sites)
  - Arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickle, selenium, zinc
- PFAS (4 sites)

3 – Wastewater Characteristics

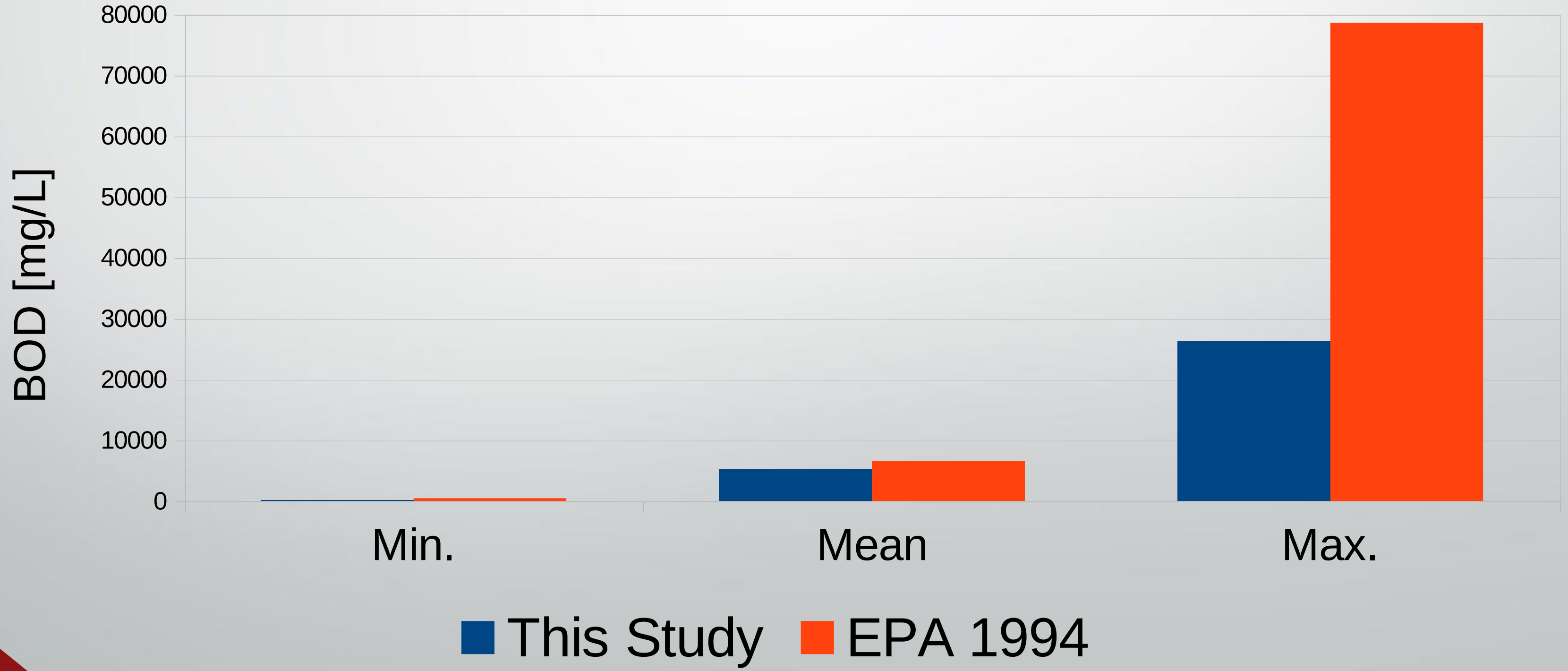
Results: BOD

	BOD Concentration [mg/L]
Minimum	92
Mean	5167
Maximum	26200
Standard Deviation	6031

Highly variable

Results: BOD

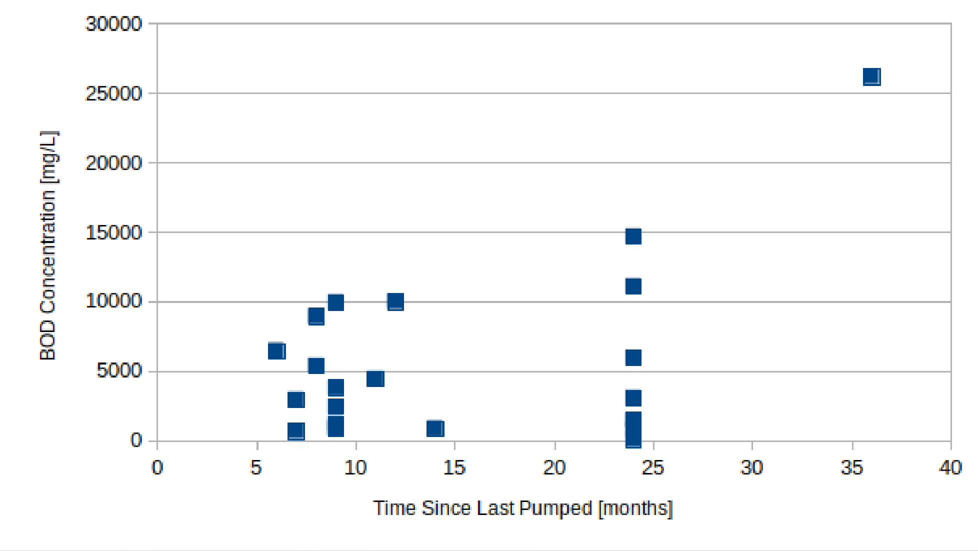
- Mean values similar to EPA mean
- No extraordinarily high values



BOD vs. months since tank pumped

- Maximum values trend upward
- Little overall correlation

($R^2 < 0.19$)



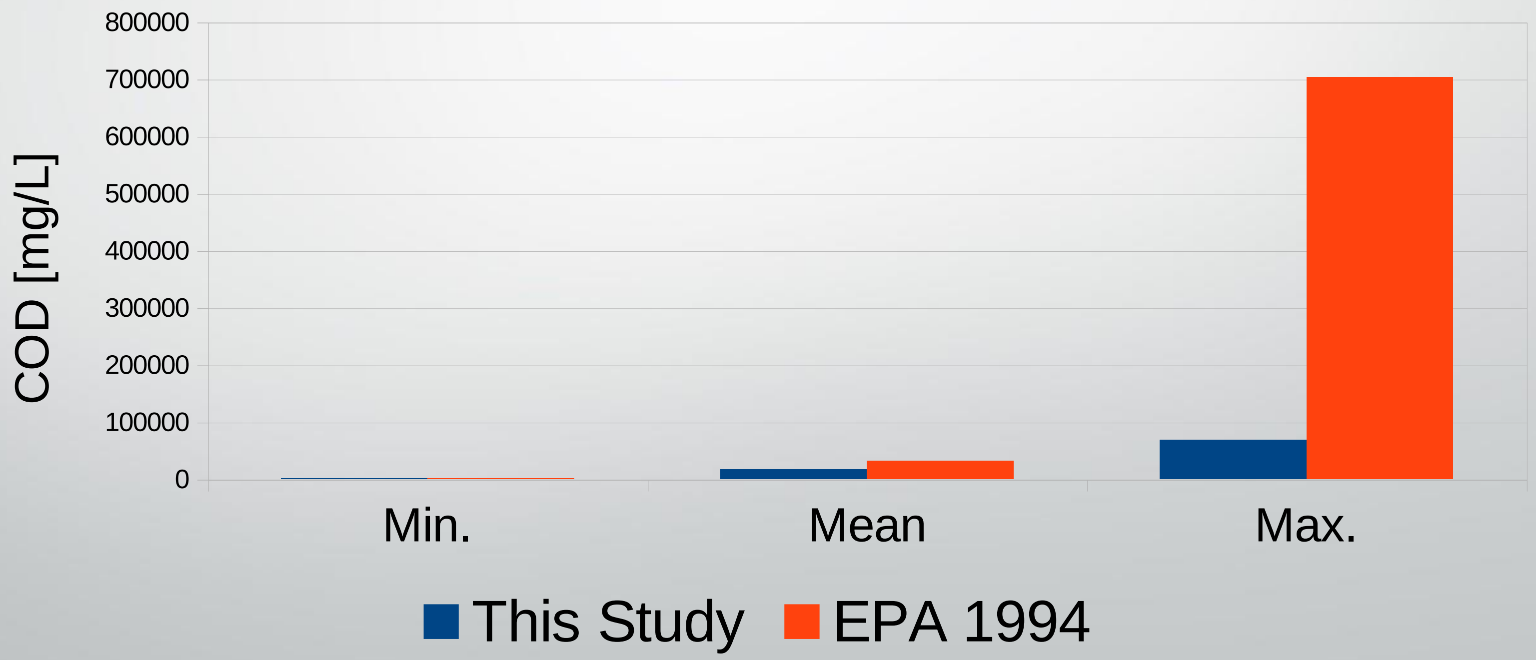
Results: COD

	COD Concentration [mg/L]
Minimum	1140
Mean	16765
Maximum	68700
Standard Deviation	19240

Highly variable

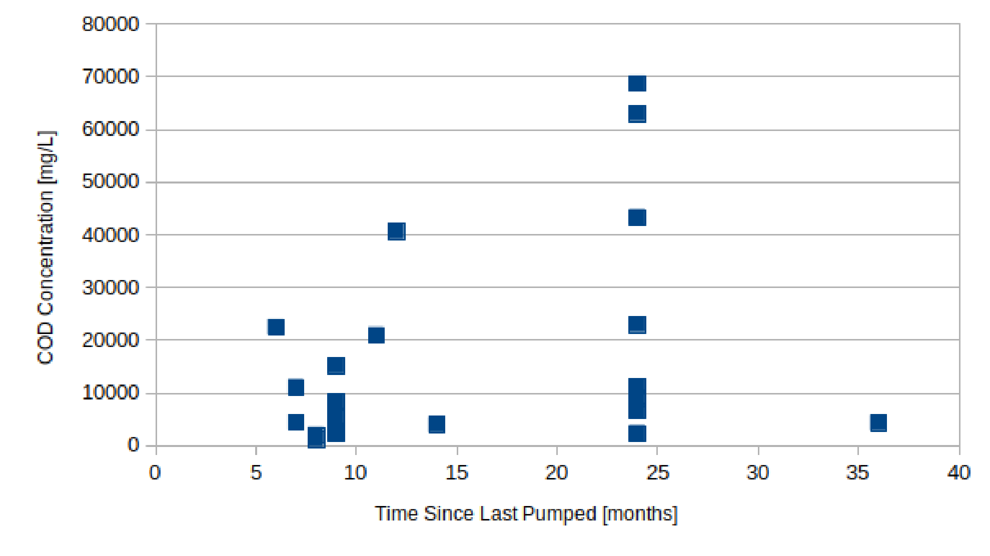
Results: COD

- Mean values similar to EPA mean
- No extraordinarily high values



COD vs months since tank pumped

- Maximum trends up
- No overall correlation
- Same trends as BOD



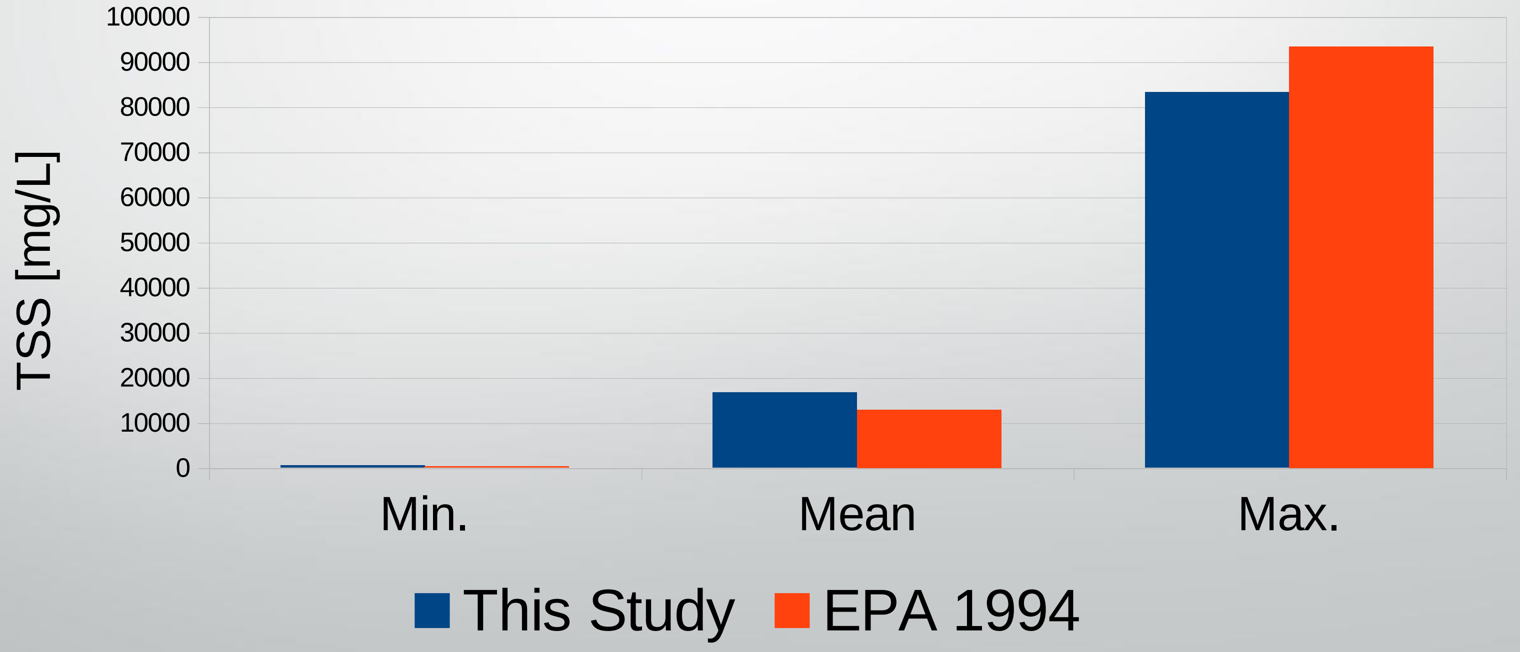
Results: TSS

	TSS Concentration [mg/L]
Minimum	480
Mean	16712
Maximum	83200
Standard Deviation	21234

Highly variable

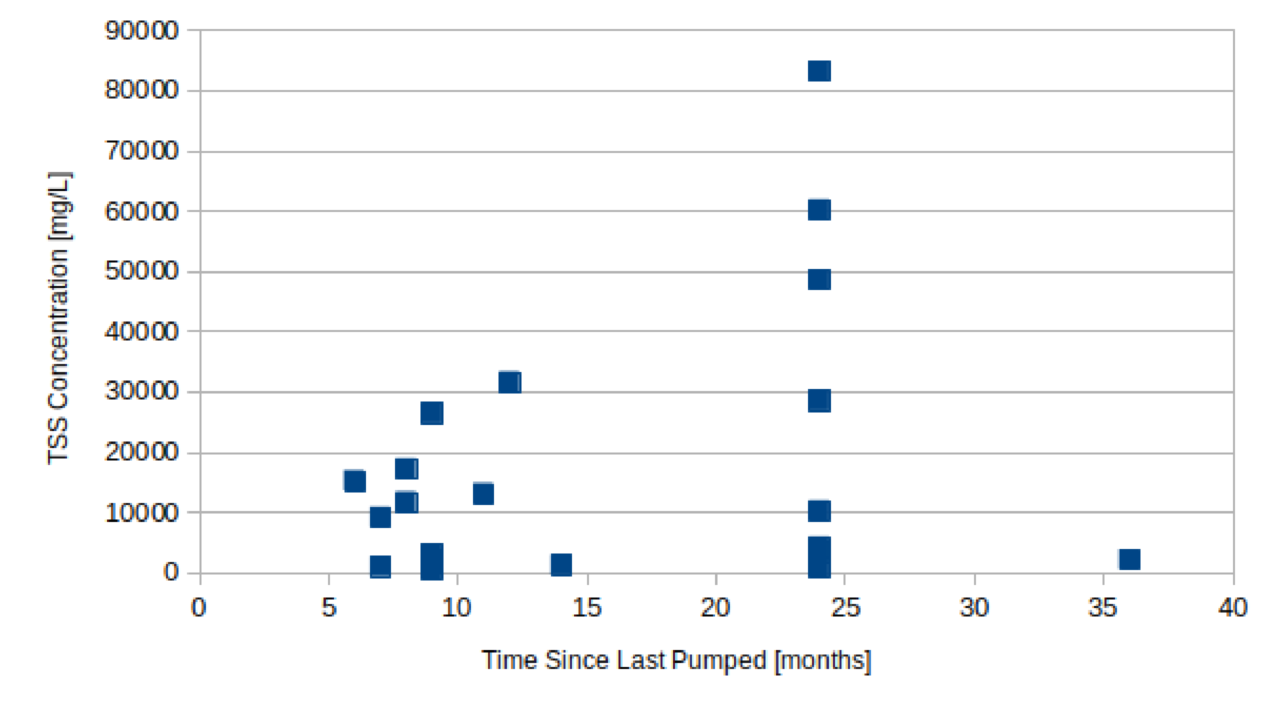
Results: TSS

- Mean values higher than EPA mean
- High values close to EPA maximum
- Low values higher than EPA minimum



TSS vs months since tank pumped

- Maximum trends up
- No overall correlation
- Same trends as BOD and COD



Results: TKN

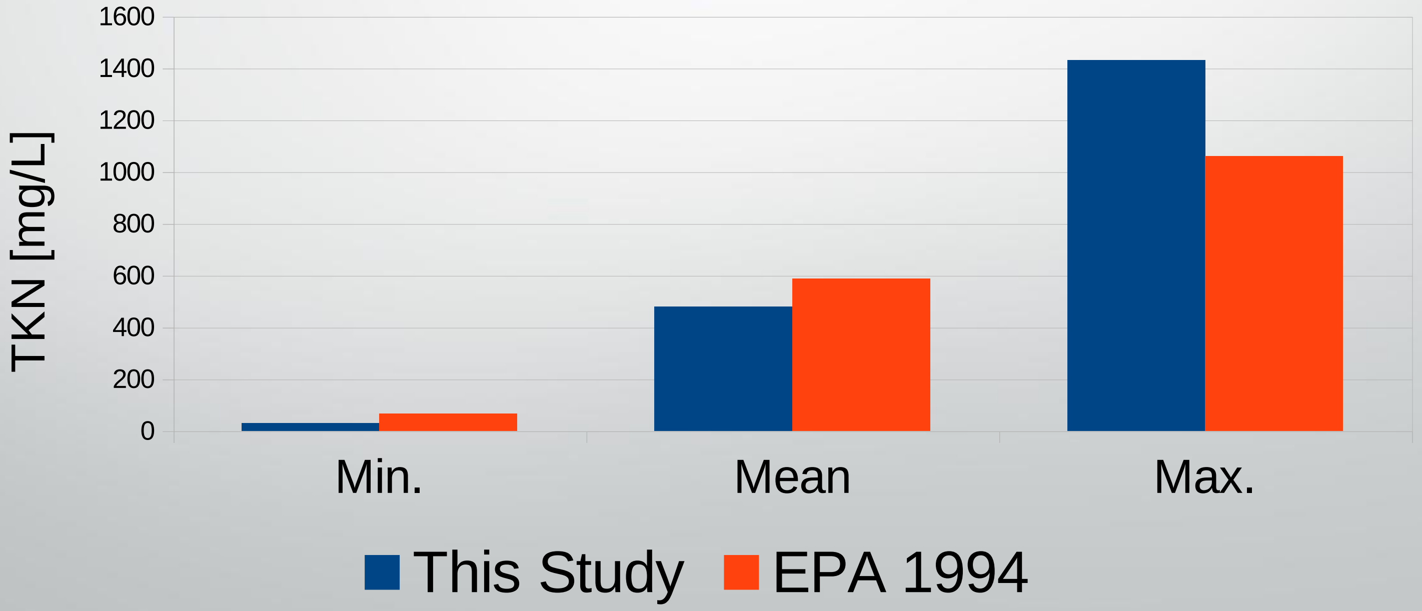
	TKN Concentration [mg/L]
Minimum	29
Mean	479
Maximum	1430
Standard Deviation	445

Highly variable

Lower coefficient of variation than BOD, COD, TSS (less variable relative to own values)

Results: TKN

- Lower minimum and higher maximum than EPA 1994
- More variable than expected
- Mean values similar



Results: Ammonia (as N)

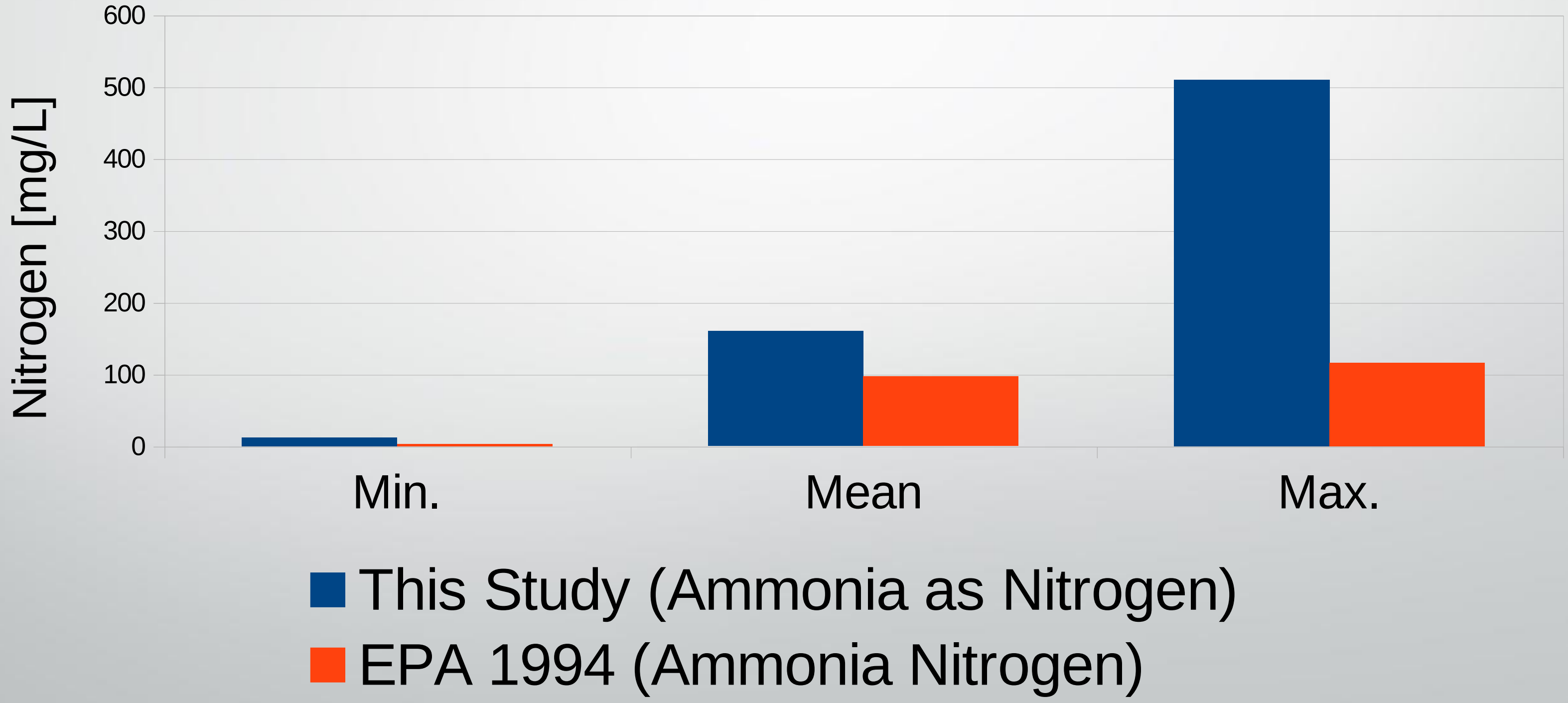
	Ammonia (as N) Concentration [mg/L]
Minimum	12
Mean	160
Maximum	510
Standard Deviation	111

Highly variable

Lower coefficient of variation than BOD, COD, TSS (less variable relative to own values)

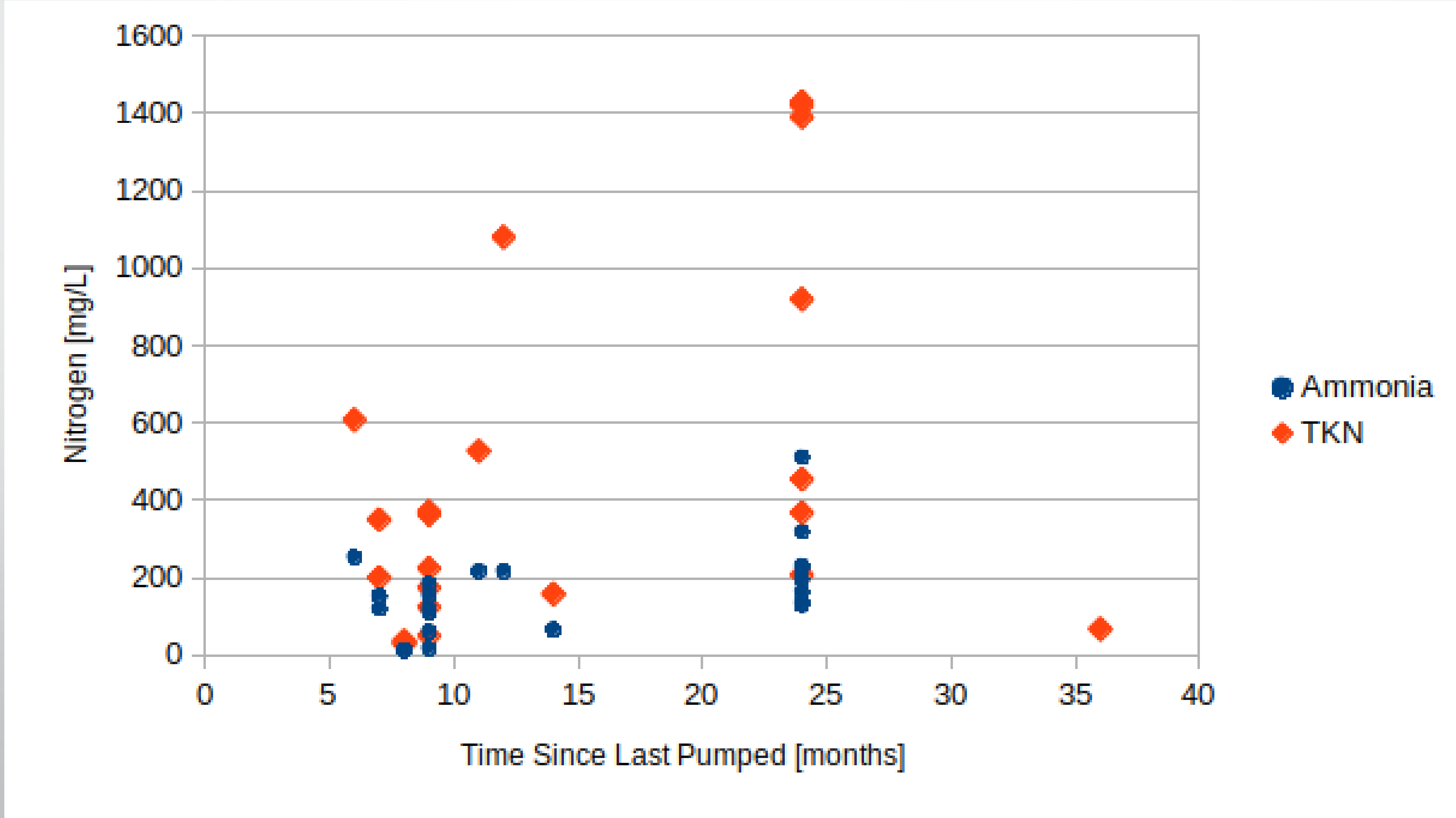
Results: Ammonia (as N)

- Consistently higher than EPA 1994



Nitrogen vs months since pumped

Same trends as BOD, COD, TSS



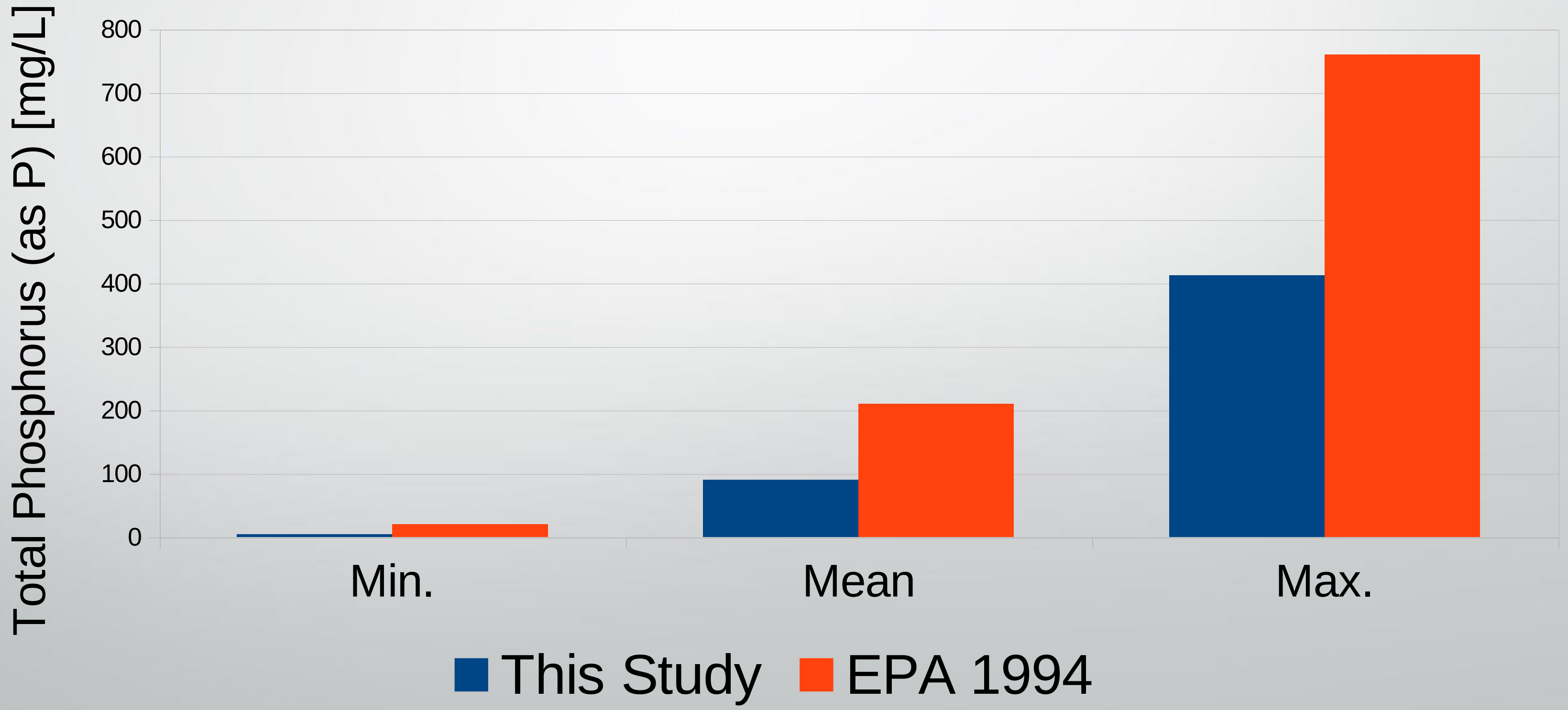
Results: Phosphorus (total as P)

	Phosphorus Concentration [mg/L]
Minimum	4
Mean	90
Maximum	412
Standard Deviation	103

Highly variable

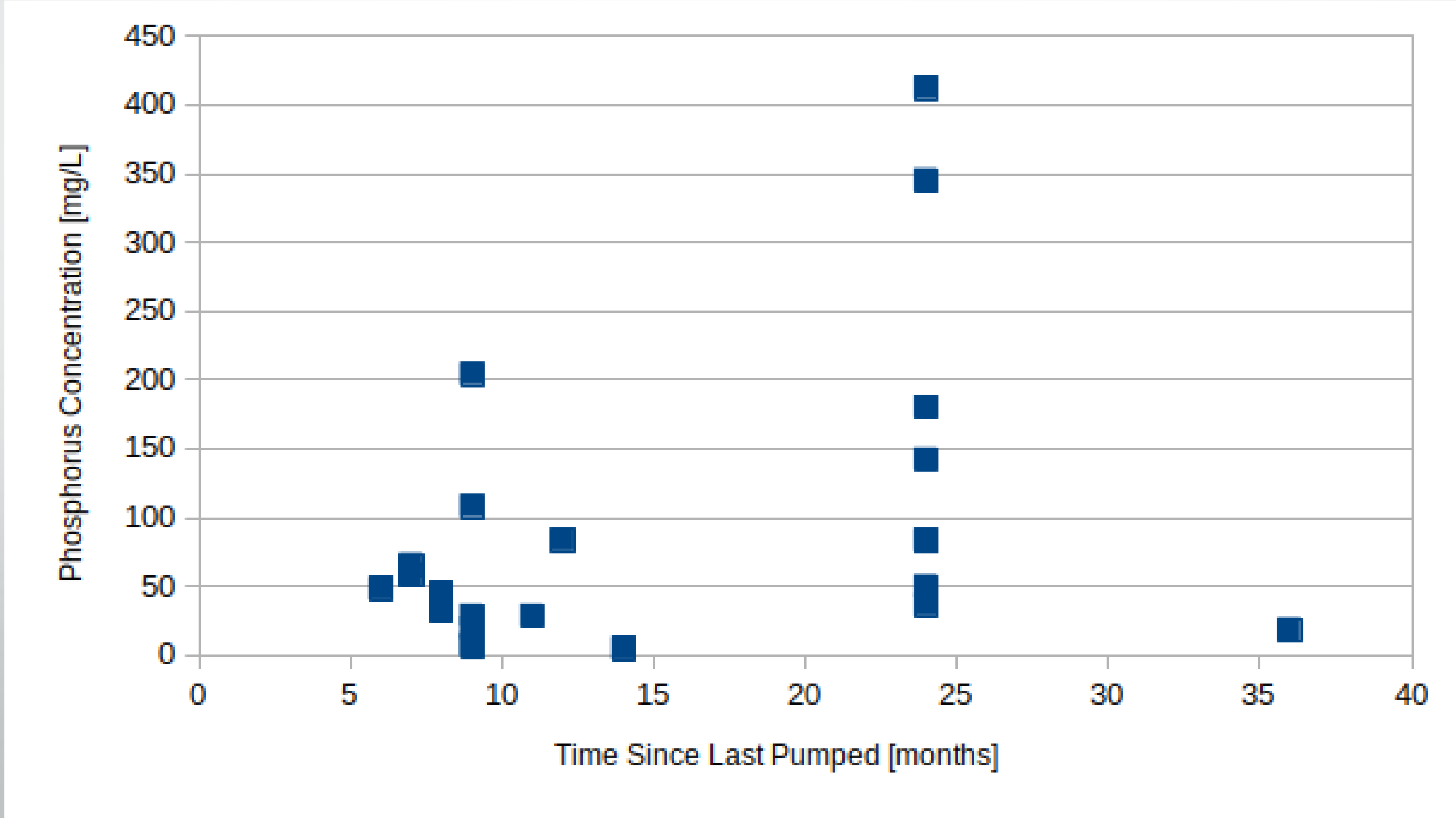
Results: Phosphorus (total as P)

- Consistently lower than EPA 1994



Phosphorus vs months since tank pumped

Same trends as BOD, COD, TSS, nitrogen)



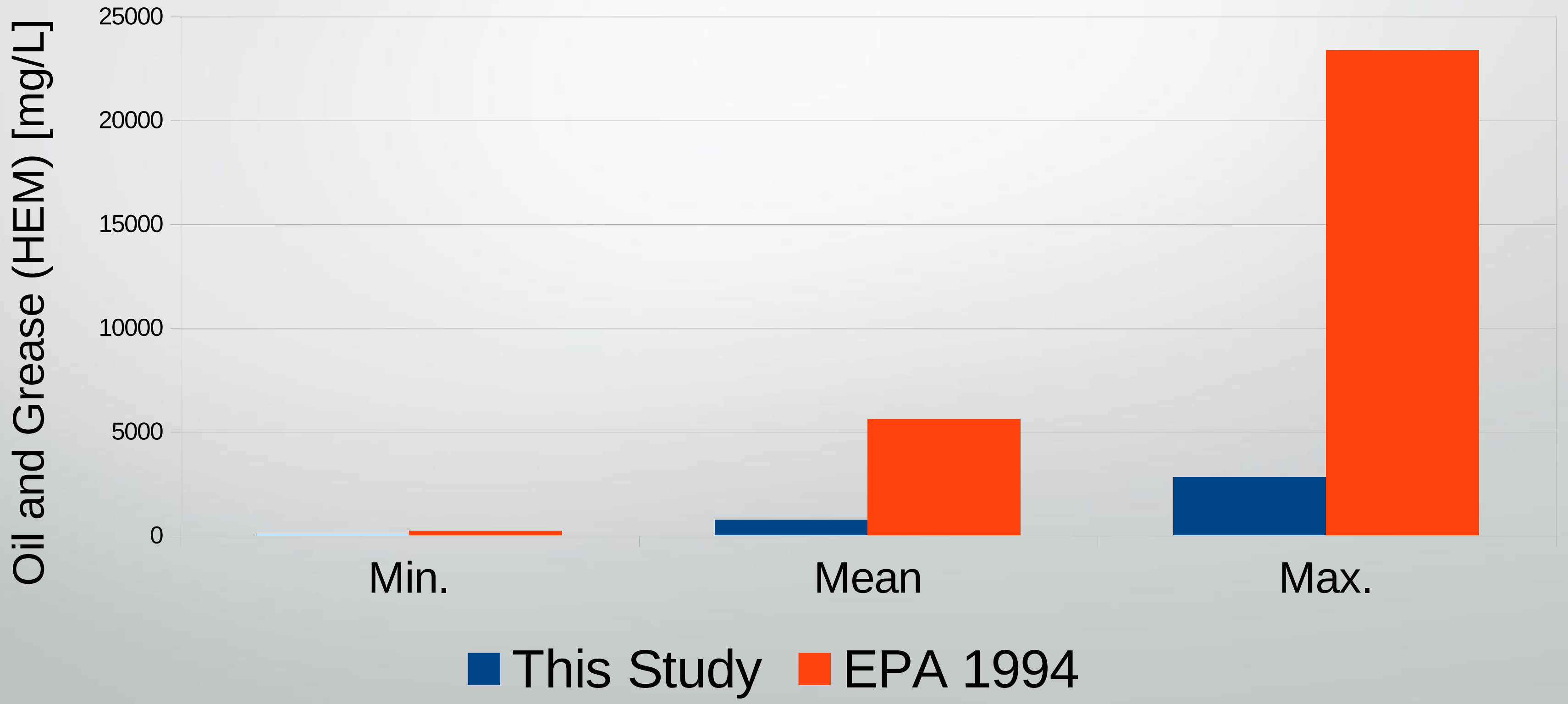
Results: Oil and Grease (HEM)

	Oil and Grease (HEM) Concentration [mg/L]
Minimum	18
Mean	748
Maximum	2800
Standard Deviation	1163

Highly variable

Results: Oil and Grease

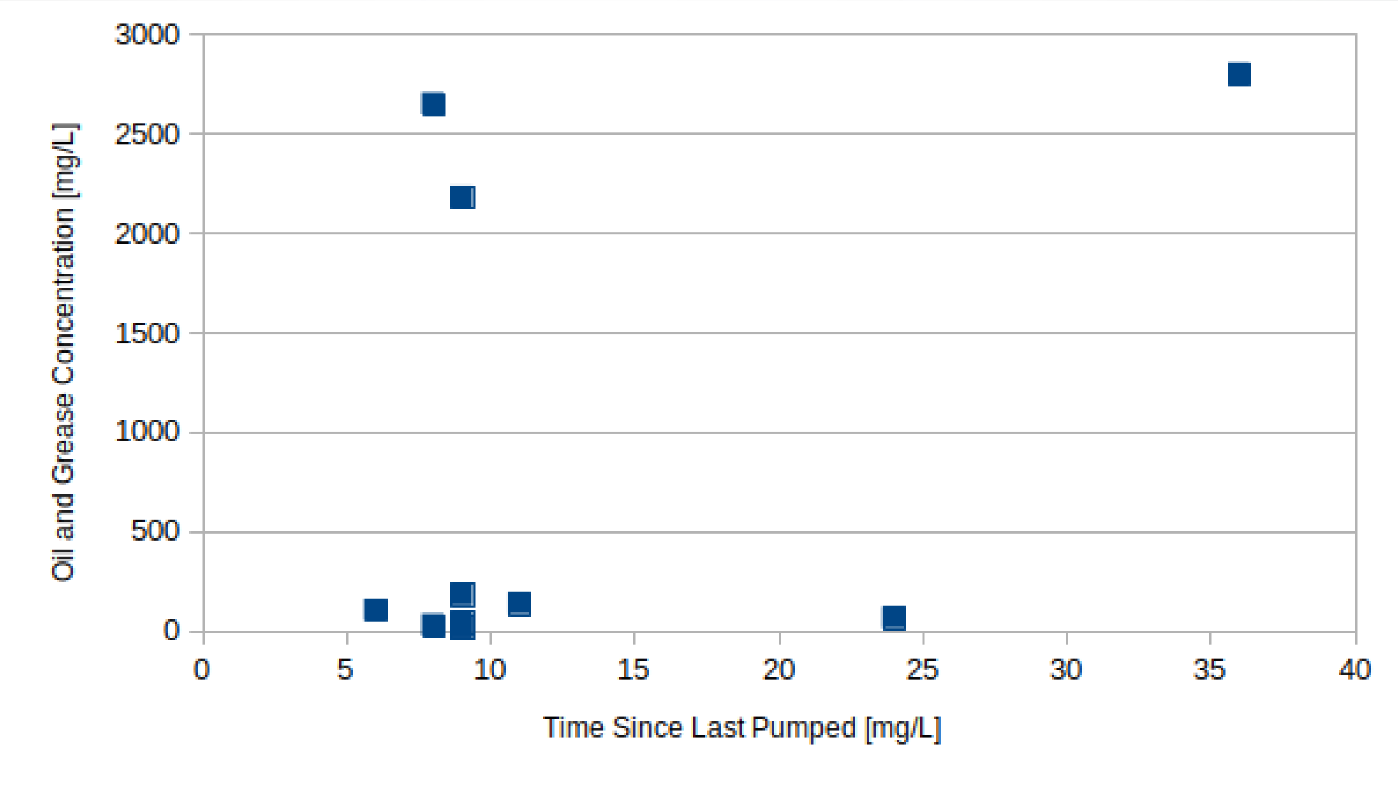
- Consistently lower than EPA 1994



Oil and grease vs months since tank last pumped

Trends less obvious

Still little to no correlation



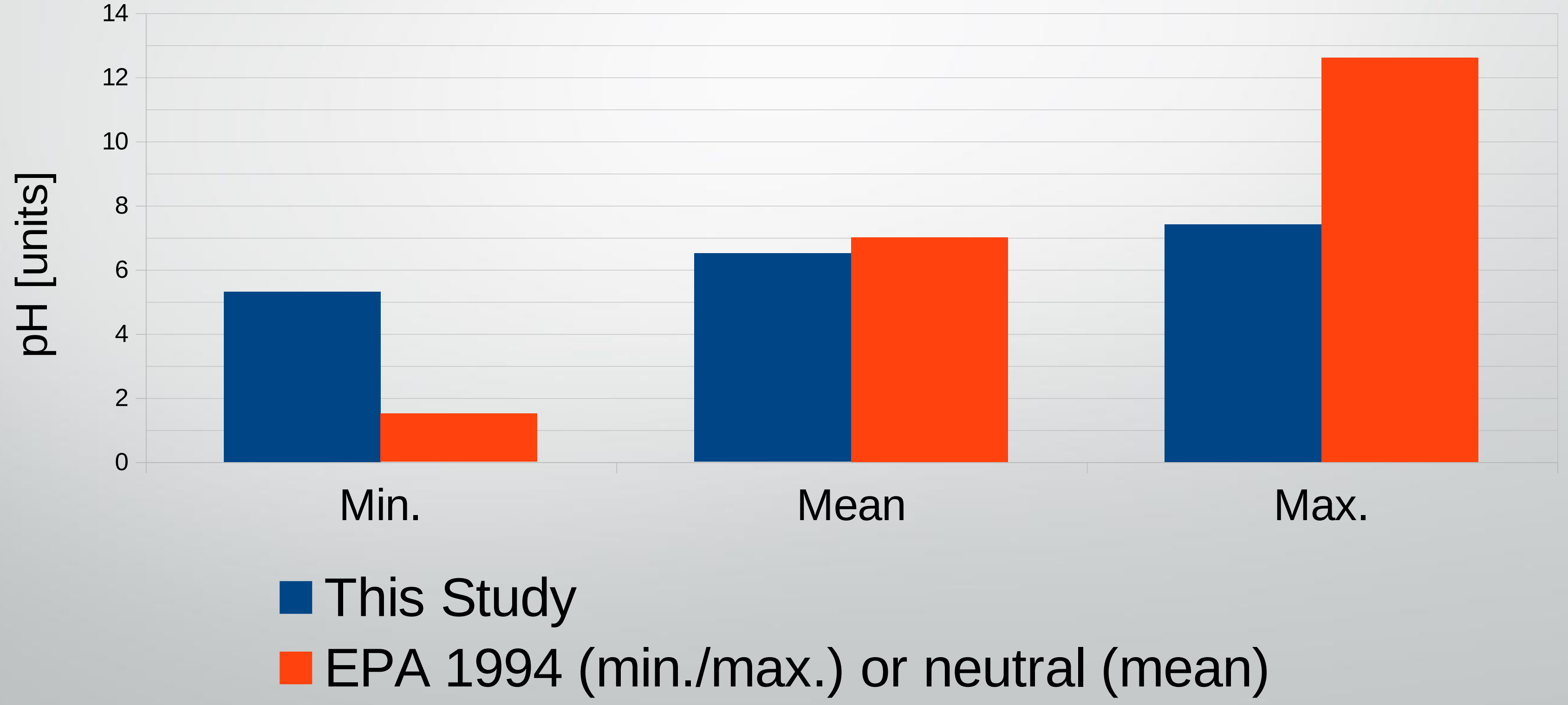
Results: pH

	pH [units]
Minimum	5.3
Mean	6.5
Maximum	7.4
Standard Deviation	0.7

Generally acidic - neutral

Results: pH

- Well within range of EPA 1994



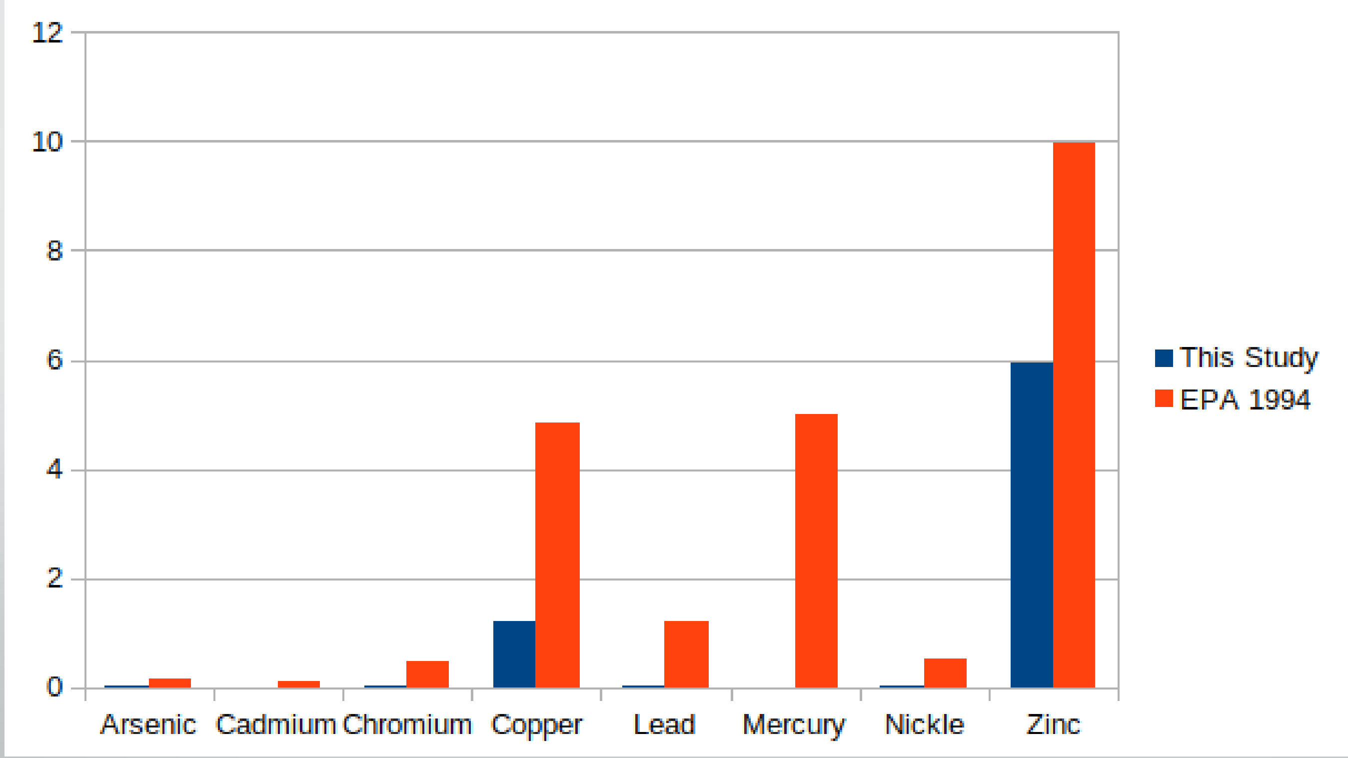
Scale is linear

Results: Metals

Non-detection treated as zero

Metal	Mean [mg/L]	Standard Deviation [mg/L]	Detections (out of 11)	High Concentrations
Arsenic	0.05	0.16	2	0
Cadmium	0.003	0.006	2	0
Chromium	0.03	0.07	4	0
Copper	1.24	2.38	11	0
Lead	0.04	0.10	2	0
Mercury	0.00069	0.00153	3	0
Molybdenum	0.03	0.06	4	0
Nickle	0.05	0.11	5	0
Selenium	0.01	0.02	4	0
Zinc	5.93	10.1	11	2

Results: Metals – Mean Concentrations



Results: Metals

- Copper and zinc detected at all sites; other metals not detected at most
- No mean concentrations above EPA mean
- Two individual zinc concentrations above EPA mean; none above EPA maximum
- High coefficients of variation (concentrations variable relative to own values)

General Conclusions

- All parameters are highly variable (except perhaps pH)
- Nitrogen (TKN and ammonia) less so than other parameters
- TKN has a wider range than suggested by literature values
- Copper and zinc only commonly-detected metals of those tested

Rest Area Septage Characteristics

Parameter	Rest Area vs Residential Septage
BOD	Similar
COD	Similar
TSS	Higher at rest areas
TKN	Similar; rest areas may be more variable
Ammonia (as N)	Higher at rest areas
Phosphorus (total as P)	Lower at rest areas
Oil and Grease (HEM)	Lower at rest areas
pH	Similar; rest areas acidic
Metals (all those tested)	Lower at rest areas

Maintenance-Related Trends

- Maximum concentrations tend to increase with longer periods between pumping (for all parameters except oil and grease, pH)
- Little to no overall correlation between concentrations and time between pumping

If not time between pumping, then what?

- Not yet studied
- Some possible factors:
  - Septic tank capacity
  - Total (daily/monthly/etc) flow
  - Difference between actual and design flow
  - Fixtures (low flow, ultra low flow)

4 - Septic Tank Conditions and Solids Accumulation

Physical Tank Conditions

Problem with Tank Condition	Number of Sites (out of 24)
Damaged baffles	1
Corrosion of outlet or inlet walls	2
Corrosion of tank partition	1
Corrosion of risers	1
Non-functional alarms	1

Unnatural Items in Septic Tanks

Item in Septic Tank	Number of Sites (out of 24)
Trash and clothing	9
Needles	9
Wipes	10

Solids Accumulation

Solids Accumulation Condition	Number of Sites (out of 24)
Heavy solids, scum up to lid of septic tank	4
Heavy solids, sludge up to pump in pump tank	1
Heavy solids, scum possibly obstructing inlet of septic tank	1
Heavy solids, difficulty pumping but no operational concern	3
No heavy solids accumulation	15

Conclusions: Tank Conditions

- As with every septic system, regular pumping is important for correct operation. (So is checking and servicing alarms.)
- Rest areas should provide trash cans in restrooms and signage about what should and should not be flushed to reduce trash and clothing entering septic tanks
- Sharps containers should also be provided to reduce needles entering septic tanks – these can pose a safety risk to maintainers

Sludge Accumulation by Tank

Blank space indicates tank not present in system; only sites with data for multiple tanks shown; all values in inches

Septic I	Septic II	Pretreatment	Pump
9	No data		0
15	6	0	
12	4		0
14	12	4	0
12	1		
Heavy			Up to pump
Heavy			0
12	6	12	No data
5	4		0
Mild	Mild		
Heavy			Mild
Heavy			Mild

Scum Accumulation by Tank

Blank space indicates tank not present in system; only sites with data for multiple tanks shown; all values in inches

Septic I	Septic II	Pretreatment	Pump Tank
14	No data		0
6	0	0	
36	0		0
6	1	0	0
18	3		
>24			No data
>24			Some
0	1	0	No data
10	1		0
Mild	Mild		0
>24			0
>24			0

Conclusions: Solids Accumulation

- Second tank in series usually has at least half as much sludge as first, sometimes nearly as much
- No significant scum accumulation in second or any subsequent tanks
- Final tank in series usually has little to no solids accumulation

Implications for Maintenance

- Second tanks in series likely need to be pumped just as frequently as first tanks
- Pump tanks/final tanks in series probably do not need to be pumped as frequently, as long as they are monitored and earlier tanks are properly maintained

Case Study: Goose Creek Rest Area Bioaugmentation

Goose Creek:
Site and System Details

- Among the busiest highway rest areas in Minnesota
- Built with ultra low flow fixtures
  - 1.6 gpf toilets
  - 0.125 gpf urinals
  - 0.5 gpm faucets
- 9,700 gallon septic tank
- System designed for 3,600 gpd
- Peak recorded flow: 2,186 gpd

Goose Creek: Site and System Details

- 7,000 gallon flow equilibration (EQ) tank follows septic tank
- Effluent treated by two aerobic treatment units (ATUs) following equilibration
- Treated effluent flows into dosing tank
- Three pressurized soil treatment beds receive treated, dosed effluent from dosing tank
- Re-circulation disabled during study

Goose Creek: The Problem

- Solids quickly build up at the inlet side of the septic tank
- Thought to be caused by heavy toilet use and low-flow fixtures
- Despite peak flows well under design capacity, the system requires frequent pumping to prevent failure
- Multiple pumping events required each year

Goose Creek as the Typical Rest Area

- Goose Creek illustrates the challenges of the typical rest area
  - Relatively remote → Needs onsite sewage treatment
  - Heavy toilet use and few other wastewater sources leads to high solids concentration and heavy organic loading
- Also illustrates the typical solutions
  - Conventional solution: Frequent pumping → Reliable, expensive
  - Possible emerging solution: Bioaugmentation
  - Even bioaugmented sites require regular pumping

Goose Creek: Bioaugmentation

- "Biological additives [...] do not appear to significantly enhance normal biological decomposition processes in the septic tank." - *Onsite Wastewater Treatment Systems Manual*, US EPA, 2002
- Some may reduce solids accumulation, but this may increase contaminant loading of effluent, possibly damaging soil treatment system
- On the other hand, bioaugmentation has worked in grease traps (Tzirita et al, 2019) and wastewater treatment plants (Nzila et. al, 2016)

Goose Creek: Bioaugmentation

- Ydro Process® Biotechnology, developed by Tradeworks Environmental Incorporated
- Manufacturer claims:
  - Increases rate and efficiency of biodegradation
  - Reduces fats, oils, and greases
  - Reduces H_2S
  - Reduces sludge accumulation
  - Reduces NO_x emissions
  - Enhances overall performance of biological treatment stages

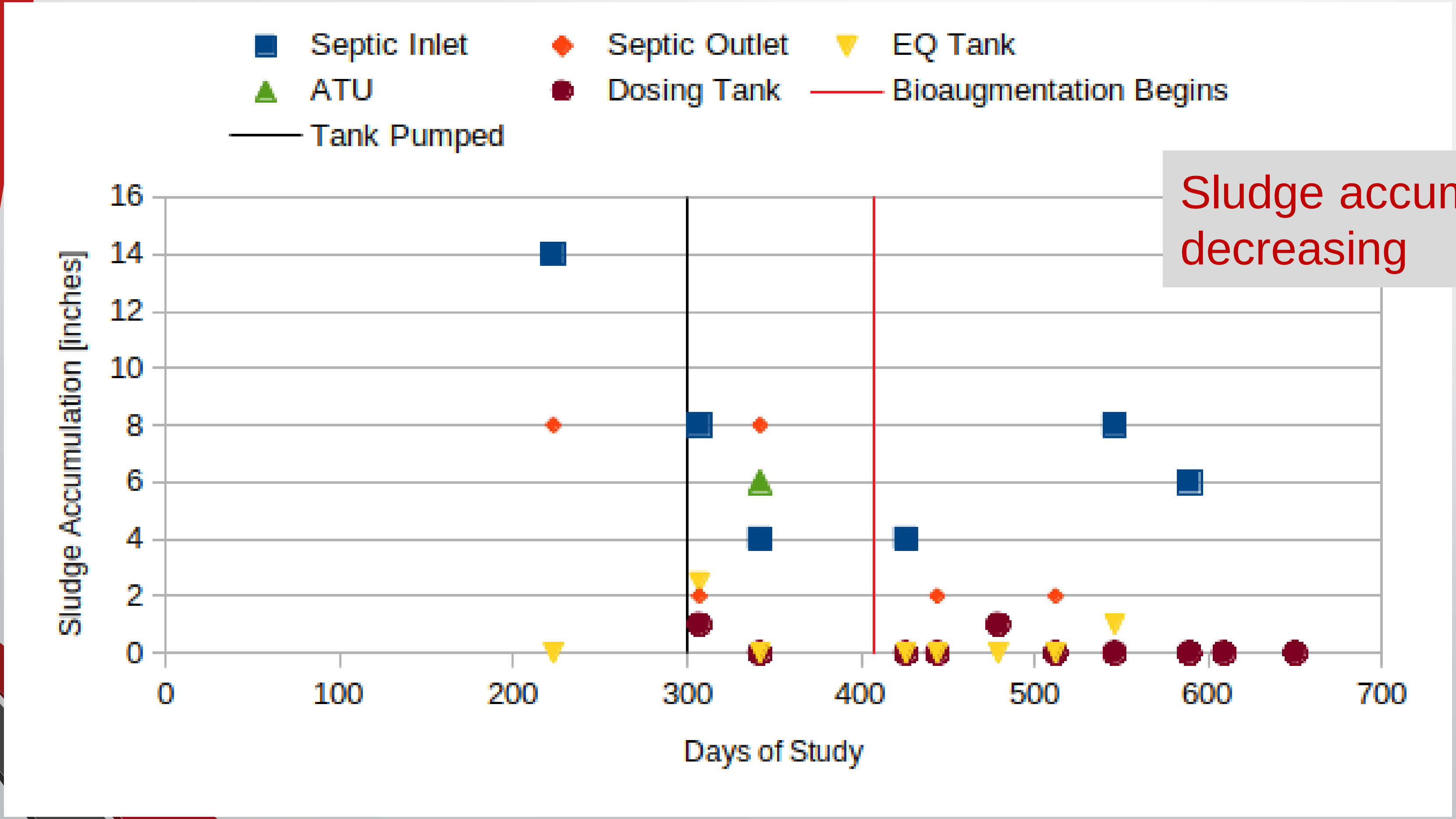
Goose Creek:
Bioaugmentation Product Dosing

- Used manufacturer-recommended dosing
- Two large doses at beginning of treatment, followed by two smaller doses per week throughout treatment
- Each dose flushed down toilet mixed with tap water

Goose Creek:
Performance Monitoring

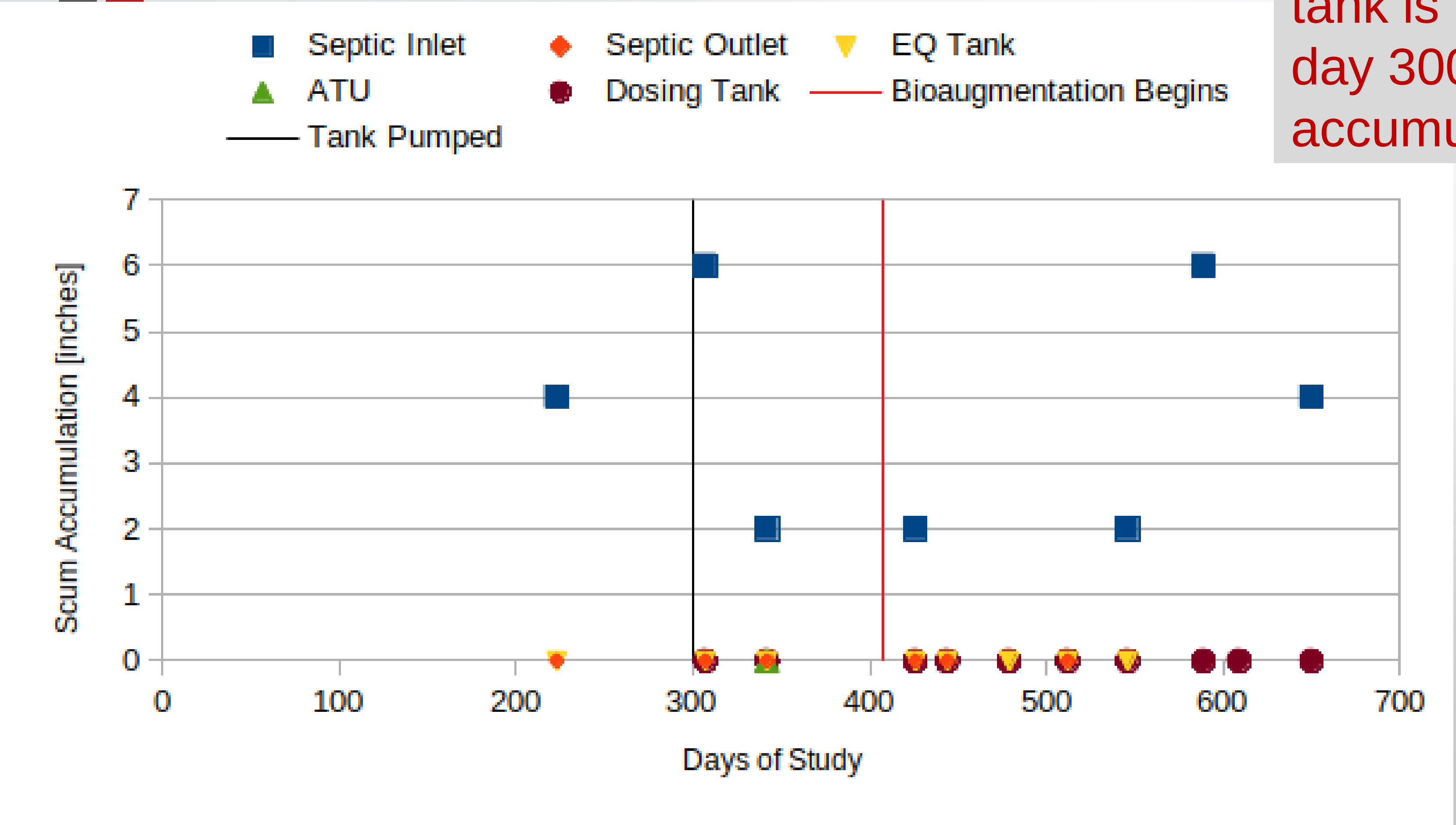
- Scum and sludge accumulation measured in dosing tank and septic tank inlet
- Effluent samples taken monthly from dosing tank and either septic tank outlet or equilibration tank
- Dosing tank sample field tested for DO
- Samples laboratory tested for BOD, TKN, nitrate and nitrite, TSS, and total phosphorus concentrations

Goose Creek:
Results – Sludge Accumulation



Sludge accumulation decreasing

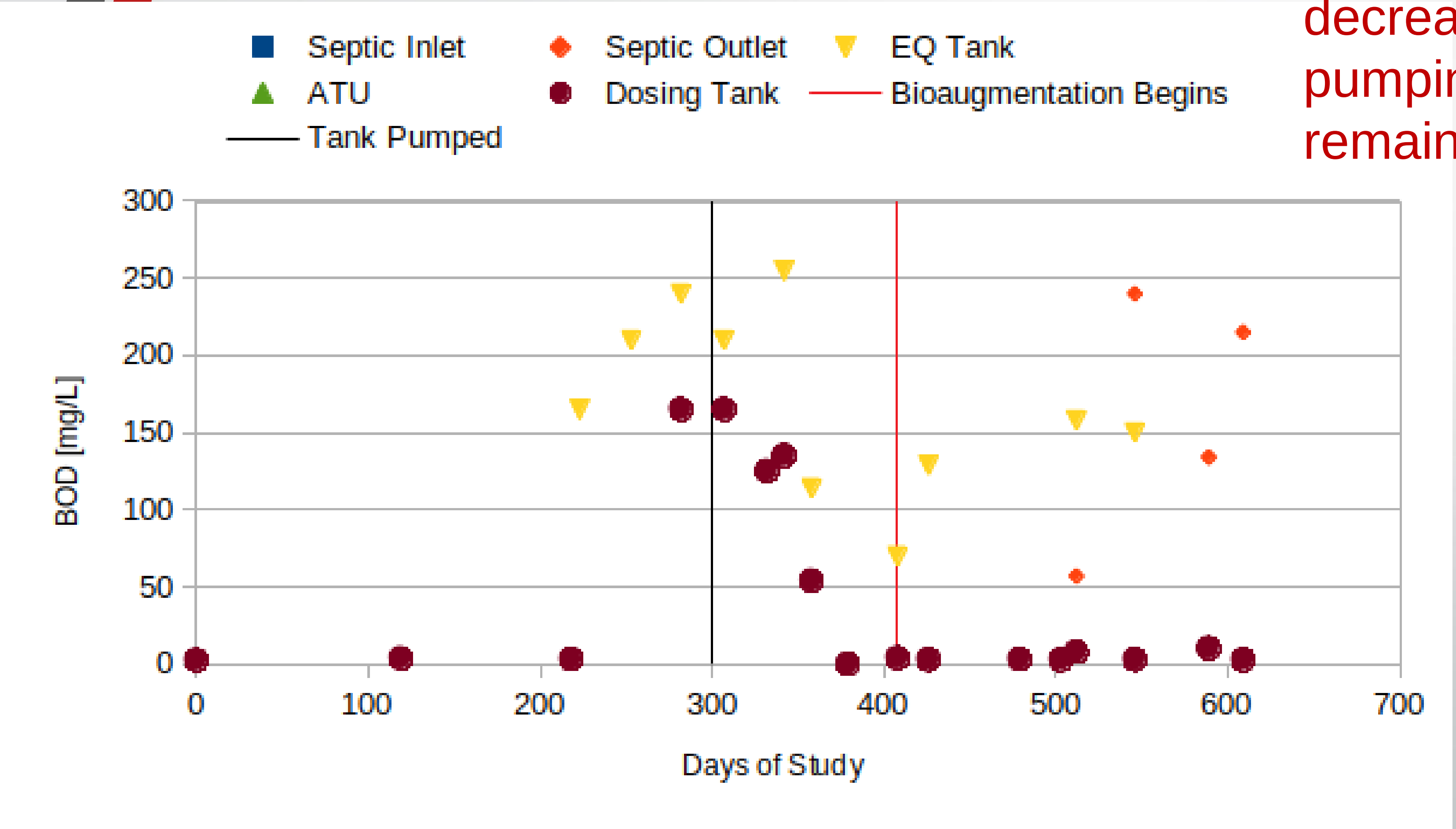
Goose Creek:
Results – Scum Accumulation



Scum drops when tank is pumped (near day 300) but may be accumulating again

No clear trend in scum accumulation

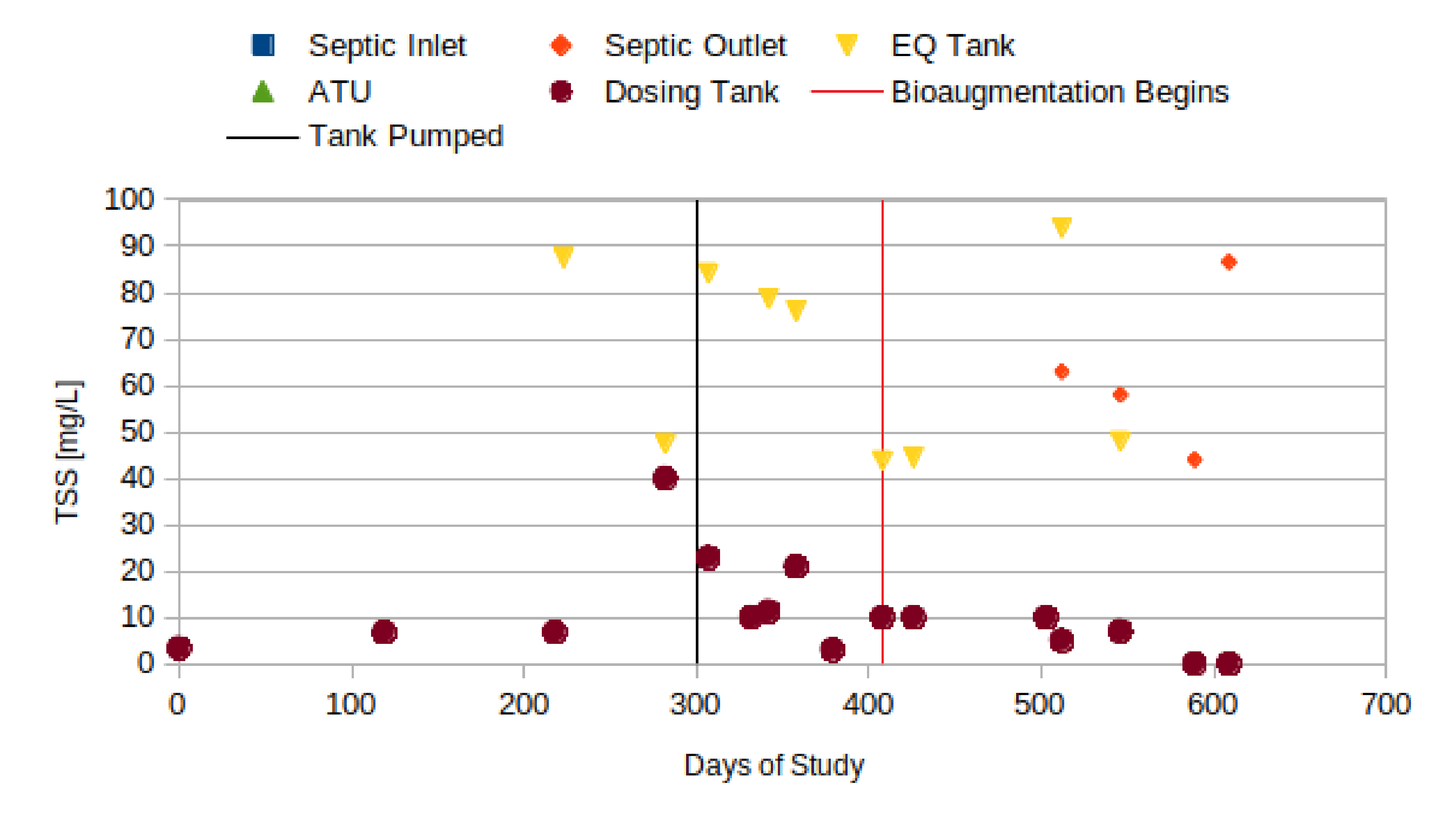
Goose Creek: Results – BOD



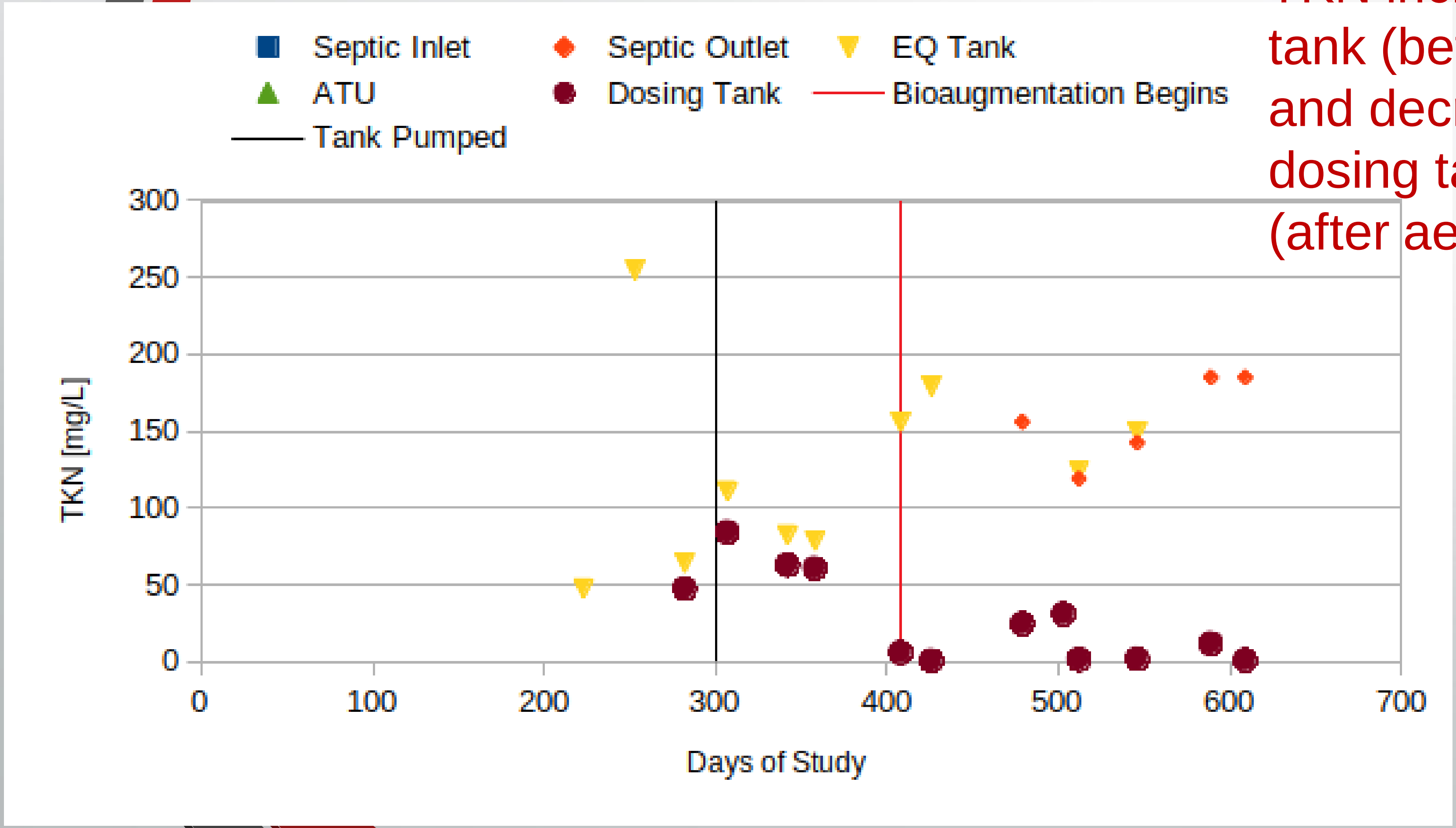
BOD concentrations decrease after pumping and remain fairly stable

Goose Creek: Results – TSS

TSS levels are stable

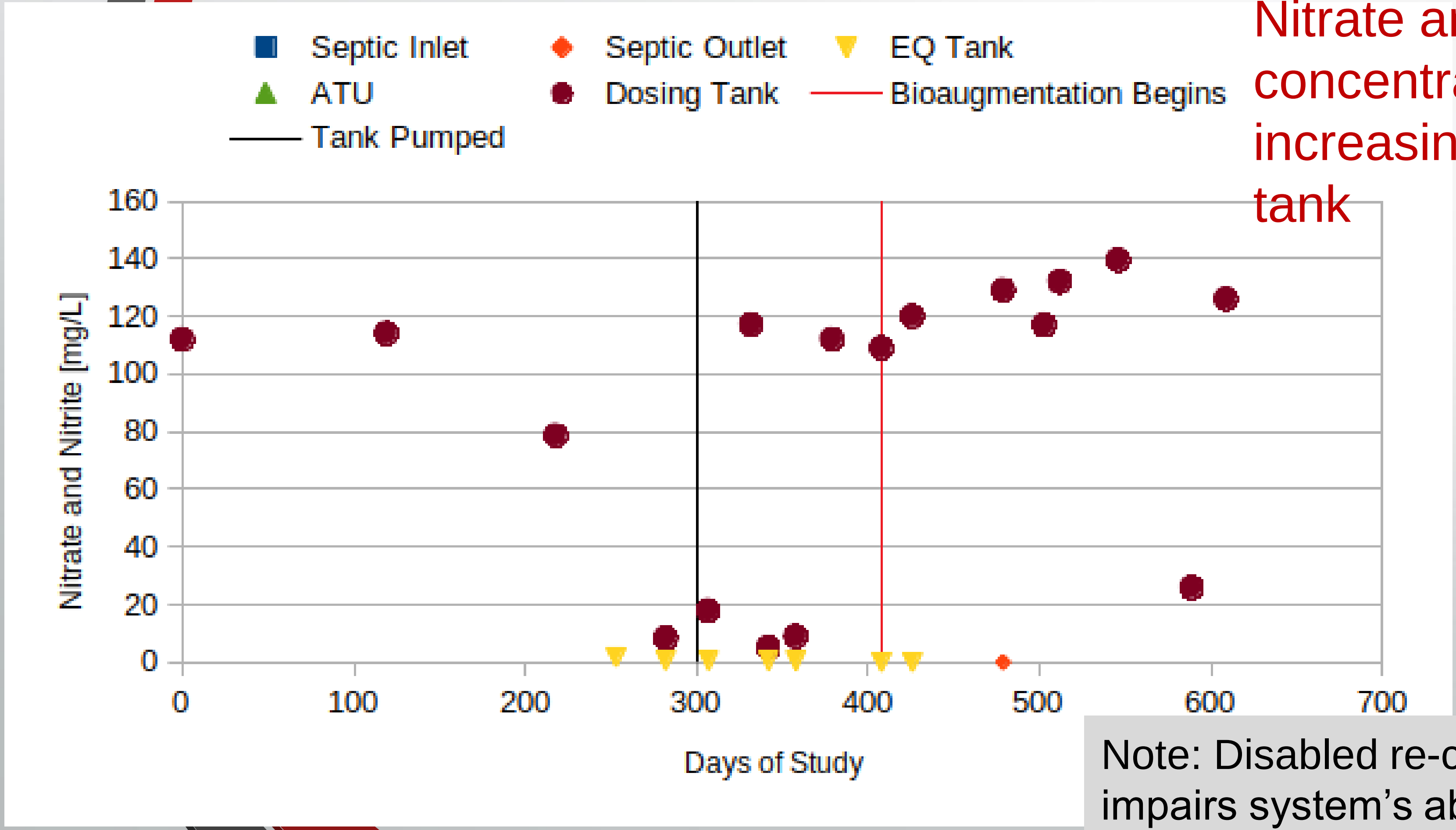


Goose Creek: Results – TKN



TKN increasing in EQ tank (before aeration) and decreasing in dosing tank (after aeration)

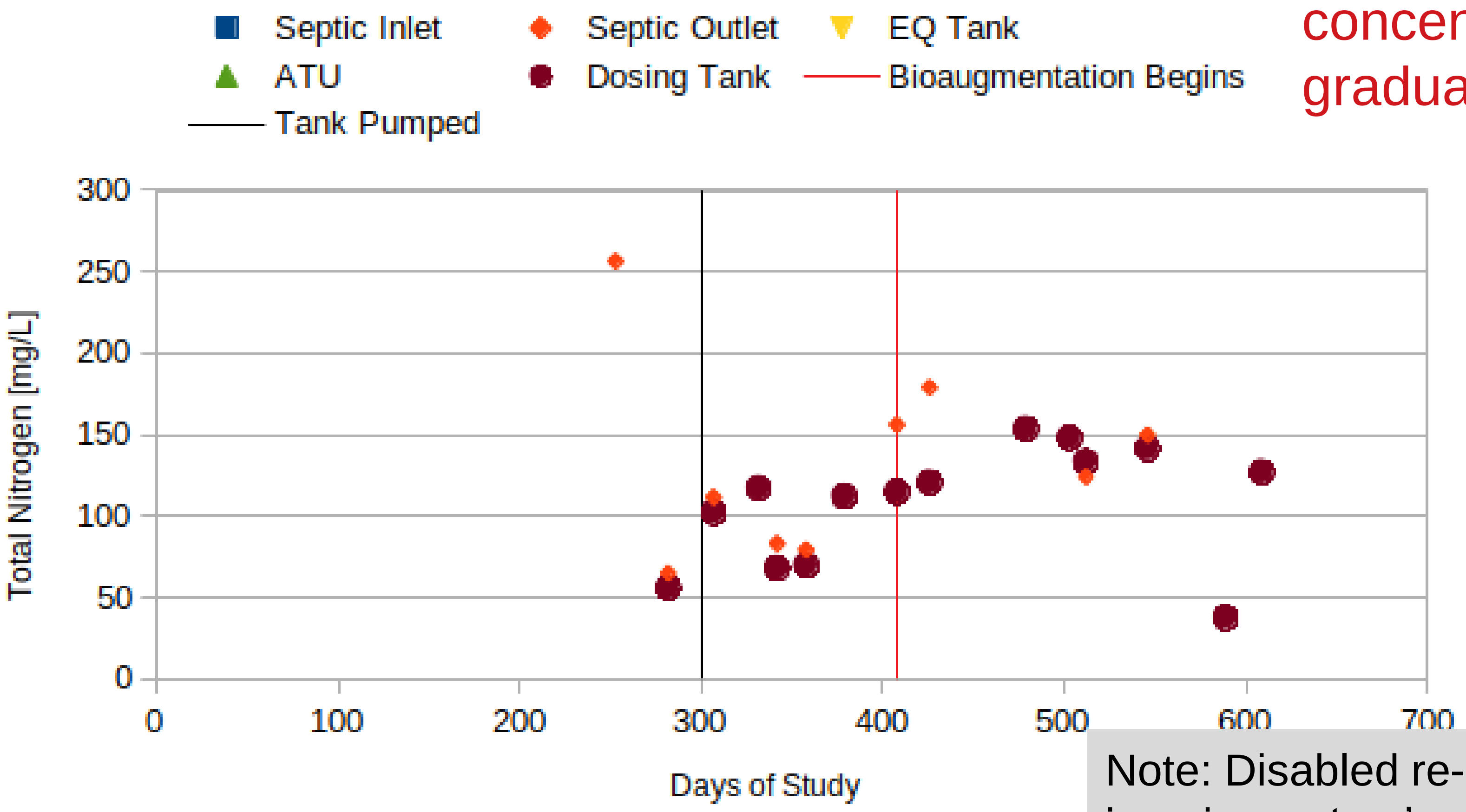
Goose Creek:
Results – Nitrate and Nitrite



Nitrate and nitrite concentration increasing in dosing tank

Note: Disabled re-circulation impairs system's ability to denitrify

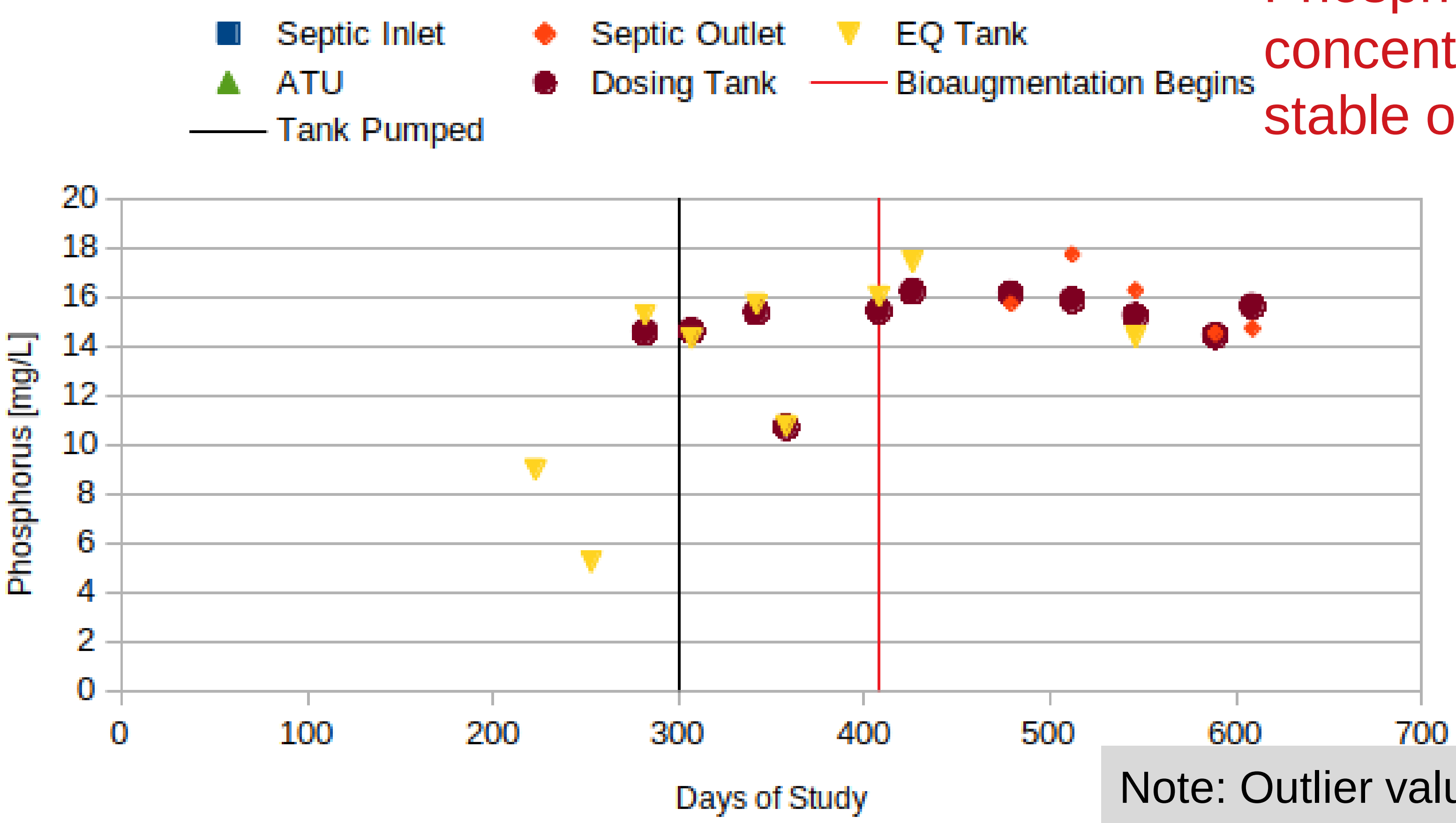
Goose Creek:
Results – Total Nitrogen



Total nitrogen concentration gradually increasing

Note: Disabled re-circulation impairs system's ability to denitrify

Goose Creek: Results – Phosphorus

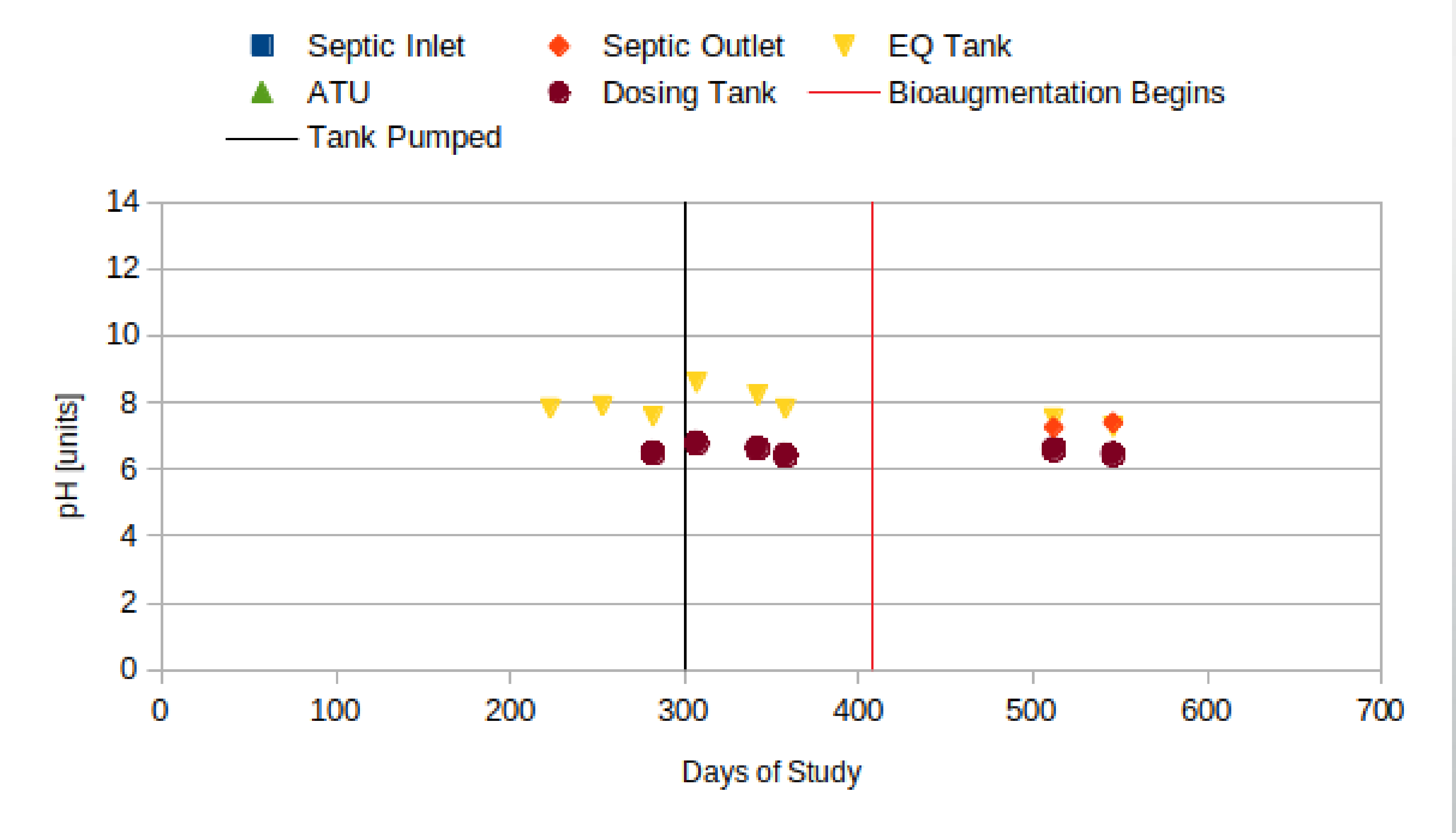


Phosphorus concentration appears stable or decreasing

Note: Outlier value of 150 [mg/L] in EQ tank on Day 512 not shown

Goose Creek: Results – pH

pH is stable



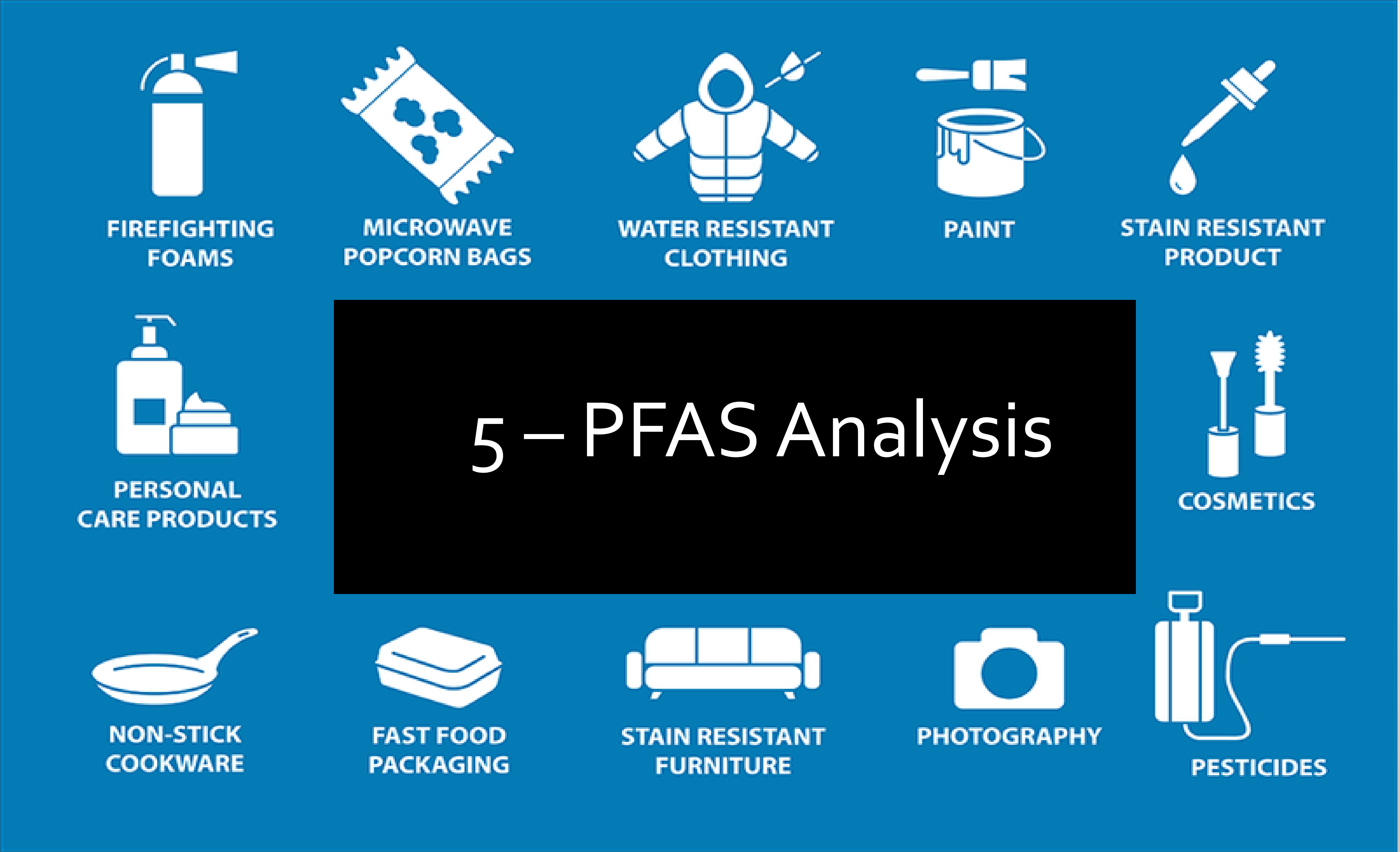
Goose Creek: Bioaugmentation Conclusions

- Sludge decreasing and scum accumulation slowed – bioaugmentation fulfilling intended purpose
- TKN increasing before aeration; nitrate increasing and DO decreasing after aeration; total nitrogen increasing – more nitrogen compounds treated by ATU, denitrification likely impaired by disabled re-circulation
- BOD, TSS, phosphorus, and pH stable – bioaugmentation not causing any unexpected problems
- During bioaugmentation testing, tank was pumped yearly instead of multiple times per year

Goose Creek: Implications

- Reduces solids accumulation allows decreased pumping frequency, which saves money and effort
- Increased nitrogen concentrations indicate denitrification is impaired by disabled circulation; bioaugmentation may also be releasing nitrogen from solids into effluent
- Since Goose Creek has aeration units, increased nitrogen in septic effluent is acceptable (as long as levels in dosing tank remain acceptable)
- Bioaugmentation can help, but system must have adequate nitrogen removal capability

5 – PFAS Analysis



PFAS Analysis

- Tested four sites
- Three sites with no known PFAS contamination, one with contamination
- Used EPA Draft Method 1633
- Tested for 40 substances

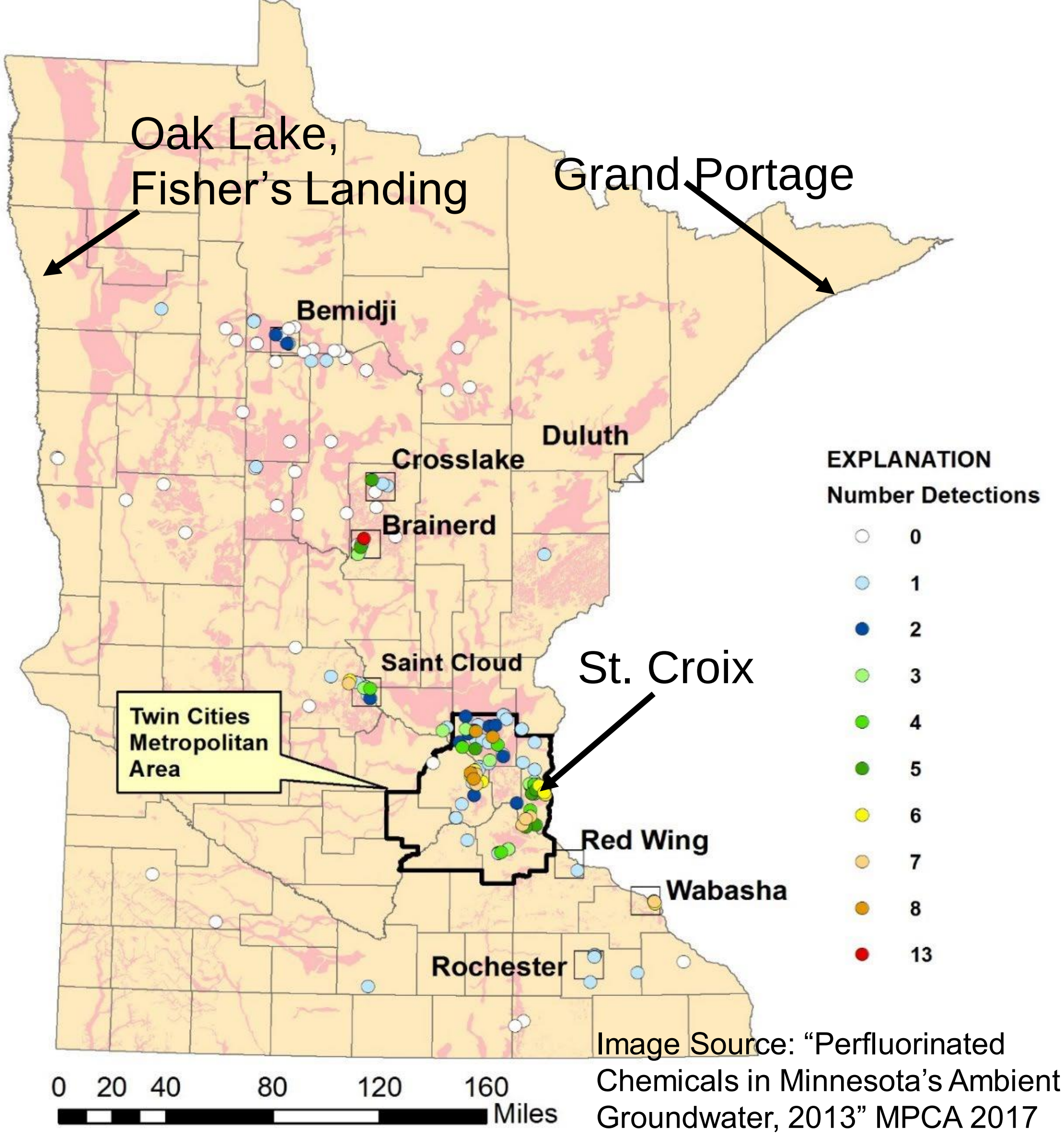


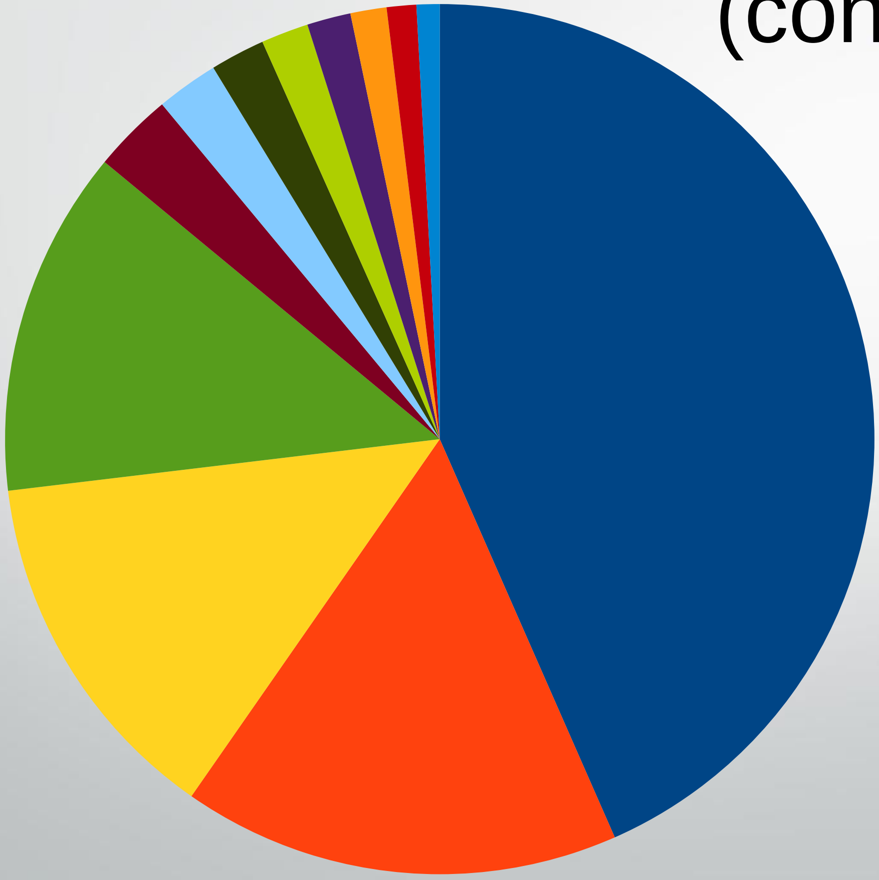
Image Source: "Perfluorinated Chemicals in Minnesota's Ambient Groundwater, 2013" MPCA 2017

Results: PFAS

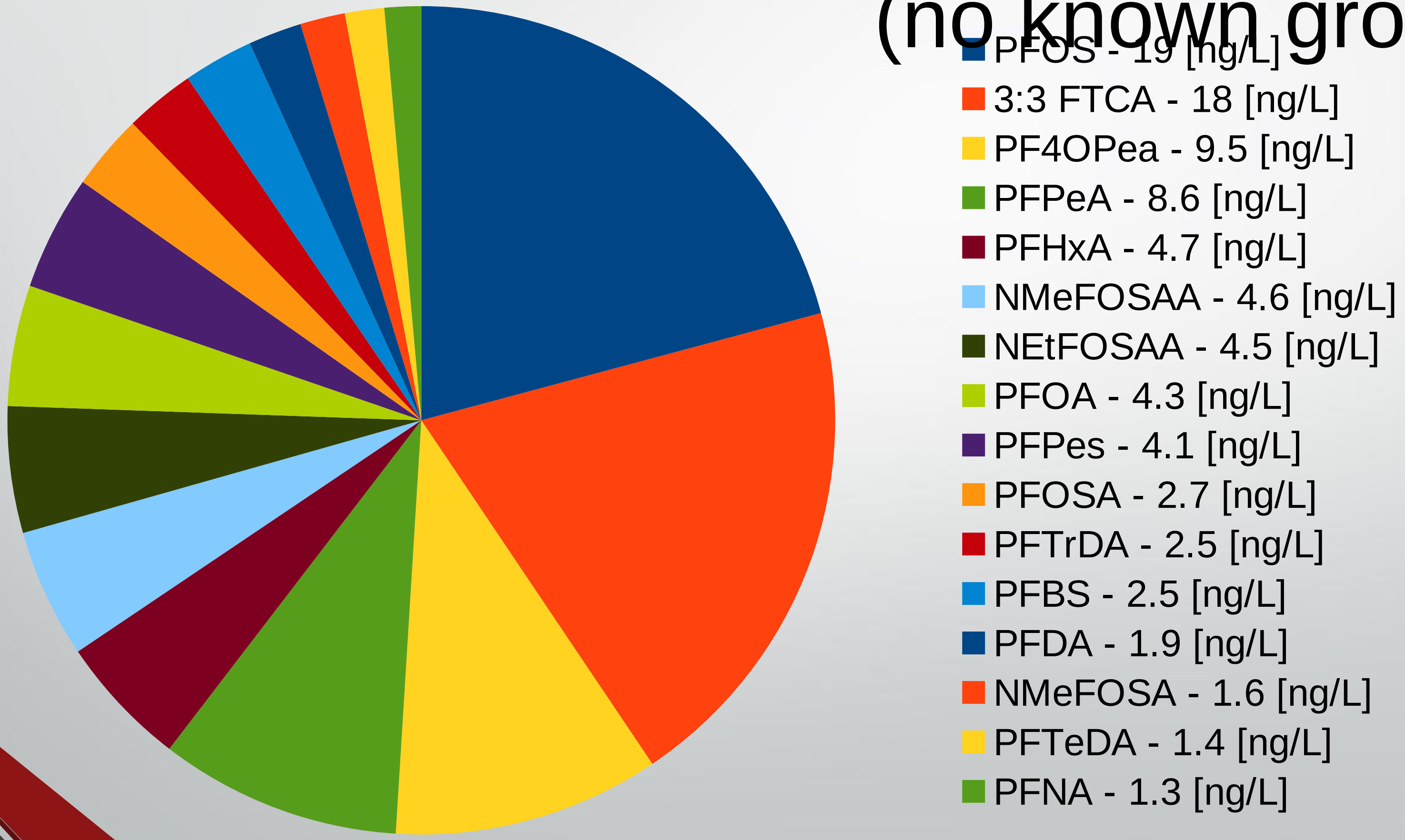
Site	Location	Known PFAS Contamination	Total PFAS [ng/L]
Oak Lake	Northwest MN	No	0.0
Fisher’s Landing	Northwest MN	No	0.0
Grand Portage	Northeast MN	No	91.2
St. Croix*	Eastern MN	Yes	736.3

Total PFAS represents sum of concentrations of 40 tested substances
* St. Croix groundwater has known PFAS contamination

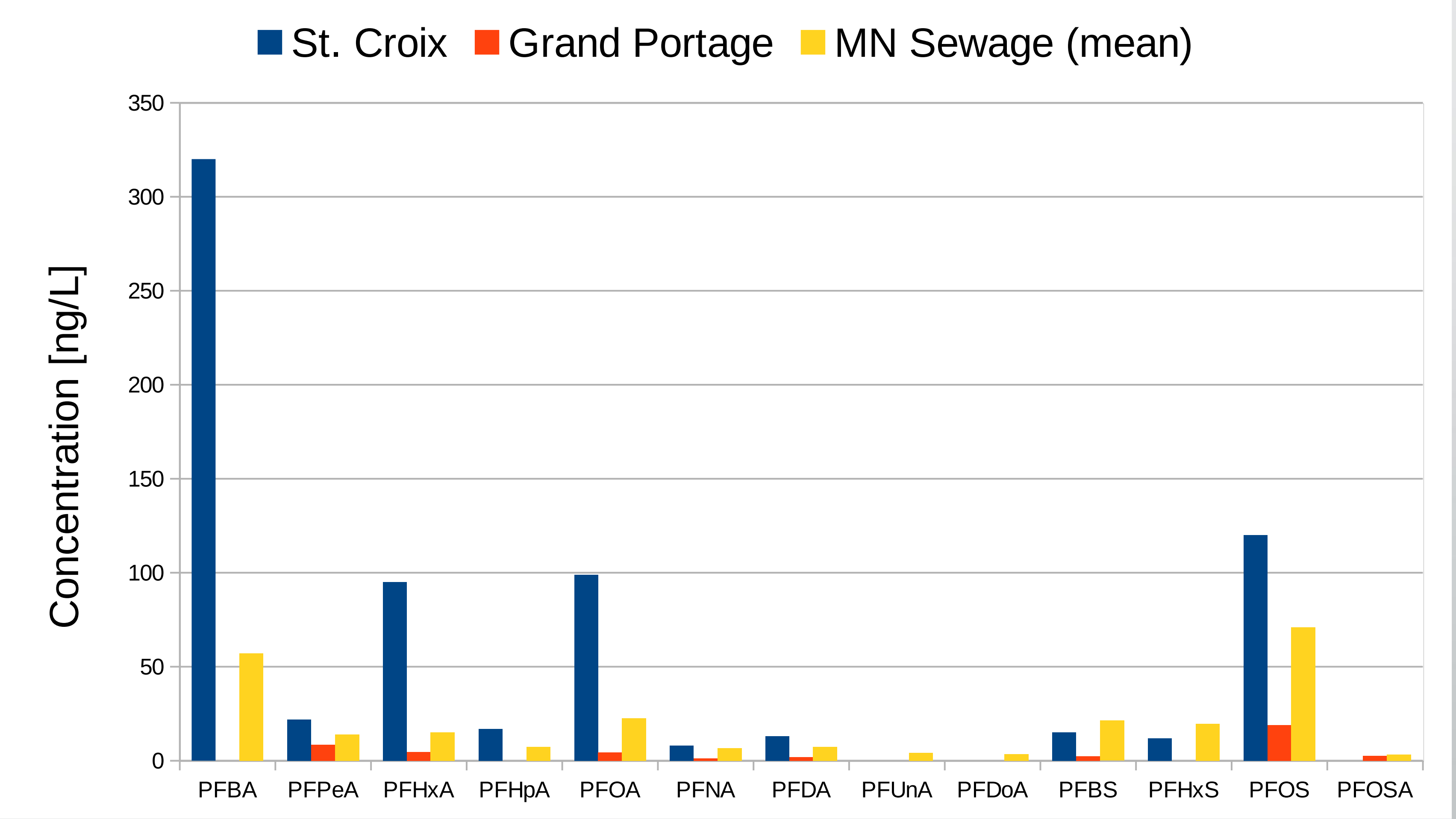
St. Croix PFAS
(contaminated groundwat



Grand Portage (no known groundwater

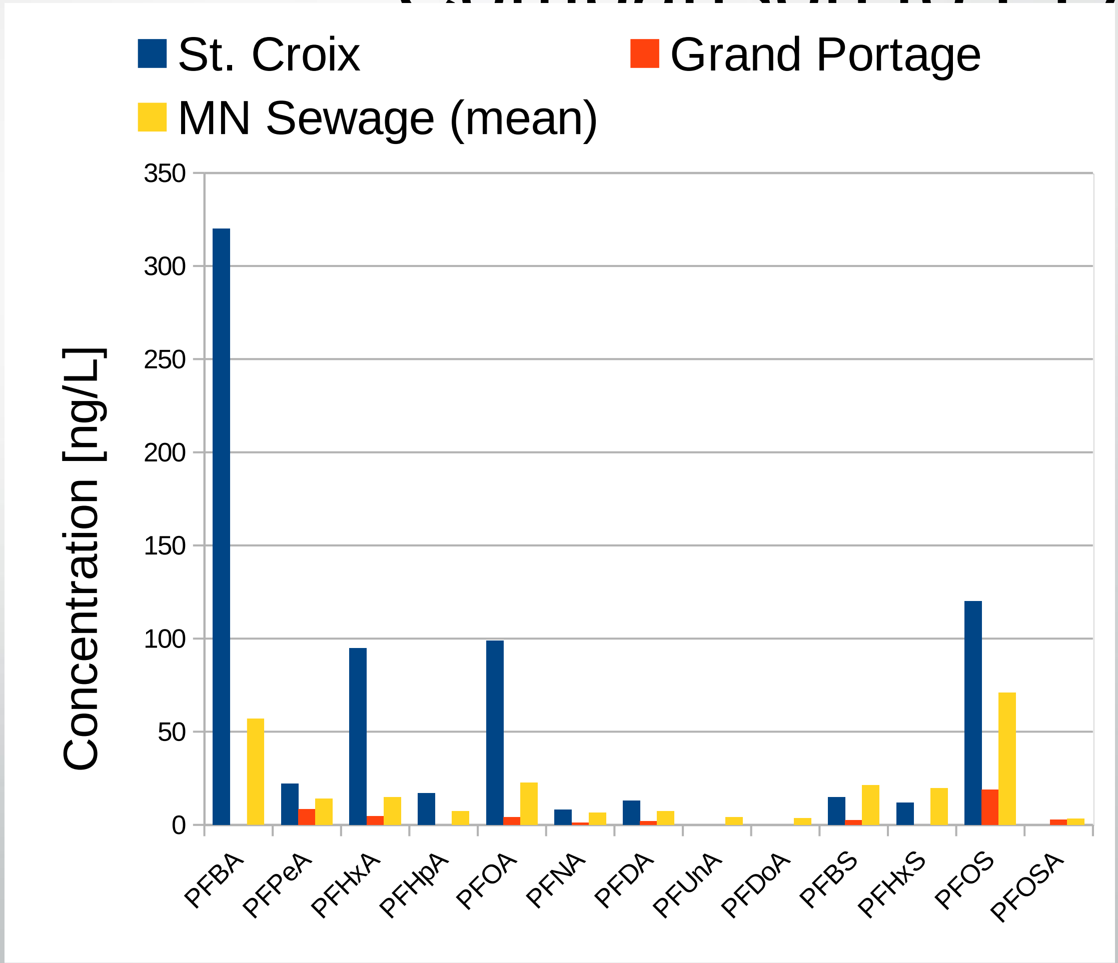


Comparison to PFA



Comparison to PFA

- PFBA, PFHxA, PFOA, and PFOS concentrations much higher at St. Croix rest area than in sewage
- Concentrations of other PFAS similar in sewage and St. Croix septage
- Total PFAS concentration higher at St. Croix than in sewage
- Grand Portage concentrations lower than sewage



Conclusions: PFAS

- No PFAS detected at two Northwest MN rest areas
- Some PFAS detected at Northeast MN rest area without known PFAS contamination in groundwater – most common substances PFOS, 3:3 FTCA, PF3OPea, PFPeA
- Significantly more PFAS detected at Eastern MN rest area with known PFAS contamination in groundwater – mostly PFBA, PFOS, PFOA, PFHxA; more than in sewage


7 - Summary

Rest Area Septage Characteristics

Parameter	Rest Area vs Residential Septage
BOD	Similar
COD	Similar
TSS	Higher at rest areas
TKN	Similar; rest areas may be more variable
Ammonia (as N)	Higher at rest areas
Phosphorus (total as P)	Lower at rest areas
Oil and Grease (HEM)	Lower at rest areas
pH	Similar; rest areas acidic
Metals (all those tested)	Lower at rest areas

Rest Area Septage Characteristics

- All parameters are highly variable (except perhaps pH)
- Nitrogen (TKN and ammonia) less variable than other parameters
- TKN has a wider range than suggested by literature values
- Low average metals concentrations, with no especially high concentrations at any site

Thank you for your attention!

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References

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