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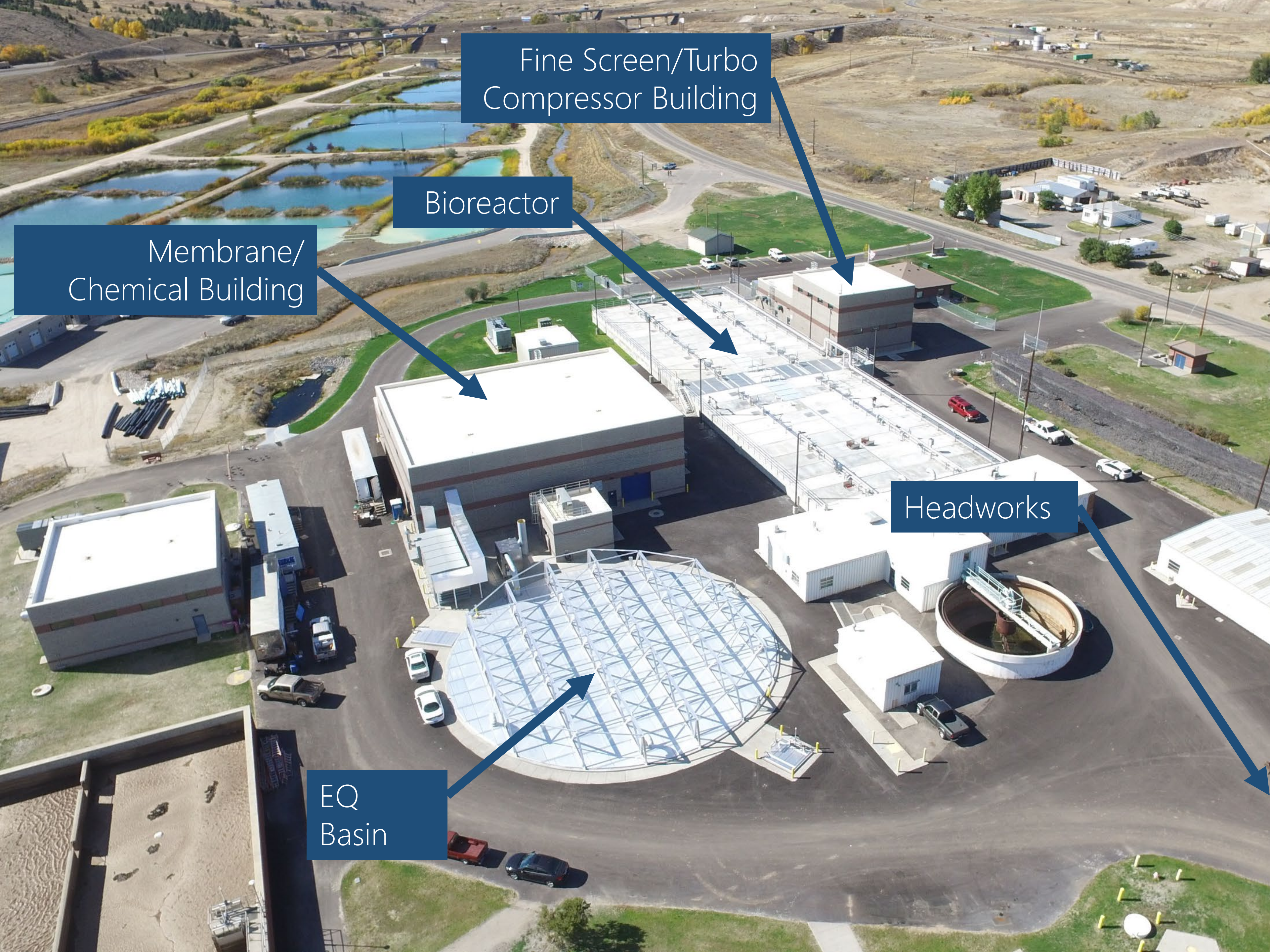
Dialing in a Membrane Bioreactor for Nutrient Removal

Butte-Silver Bow, Montana


Fine Screen/Turbo Compressor Building
Bioreactor
Membrane/ Chemical Building
Headworks
EQ Basin

The Numbers

- 2016 – new process taken into service
- 2017, 2018, 2019 – period of record for presented nutrient data
- 2007-2019 – period of record for presented metals data
- 3.9 mgd – overall current average plant flow
- 5.5 mgd – overall full build-out design average flow

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The Numbers

- 3.7 mg/L – average influent total phosphorous
- 28 mg/L – average influent total nitrogen
- 99 µg/L – average influent copper (TR)
- 295 µg/L – average influent zinc (TR)

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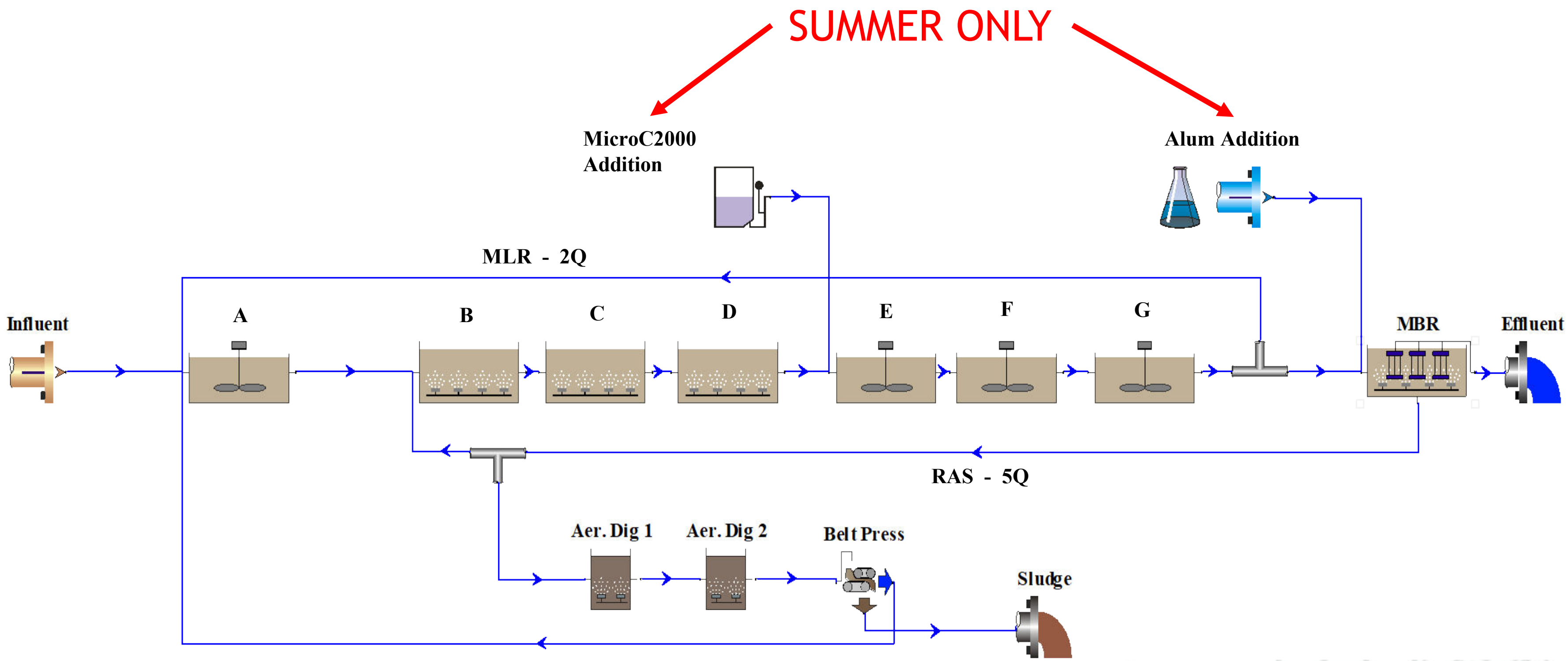
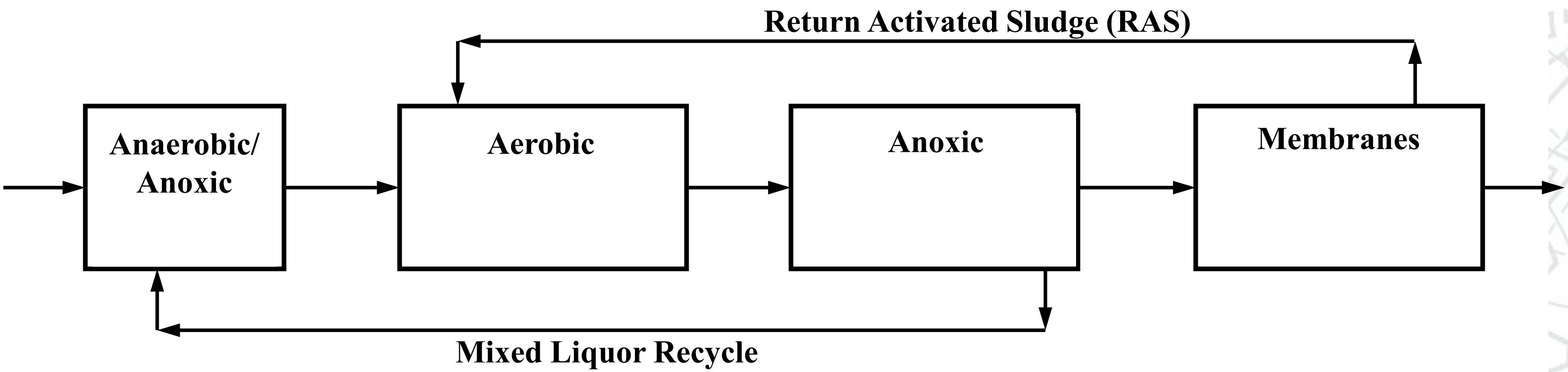
Bioreactor Processes



Bioreactor Processes

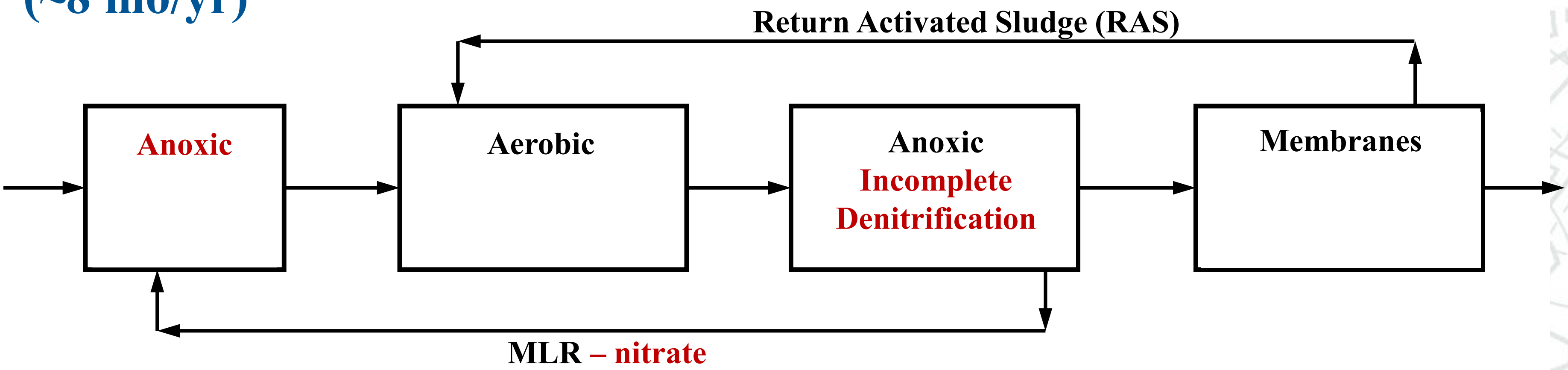


Bioreactor Processes

- **Anaerobic –**
  - Phosphorus accumulating organisms (PAOs) release phosphorous and consume/store readily available carbon source (volatile fatty acids, VFAs or "PAO candy")
- **Aerobic –**
  - Heterotrophs consume carbon (BOD) and use DO for respiration
  - Autotrophs convert ammonia to nitrate (NO_3), use dissolved CO_2 as food source, and DO for respiration
  - PAOs take up phosphorous while living off the stored "candy"
- **Anoxic –**
  - Heterotrophs are deprived of DO and turn to using the oxygen in NO_3 for facultative respiration and consume carbon (BOD)
  - Autotrophs and PAOs hang out without doing too much

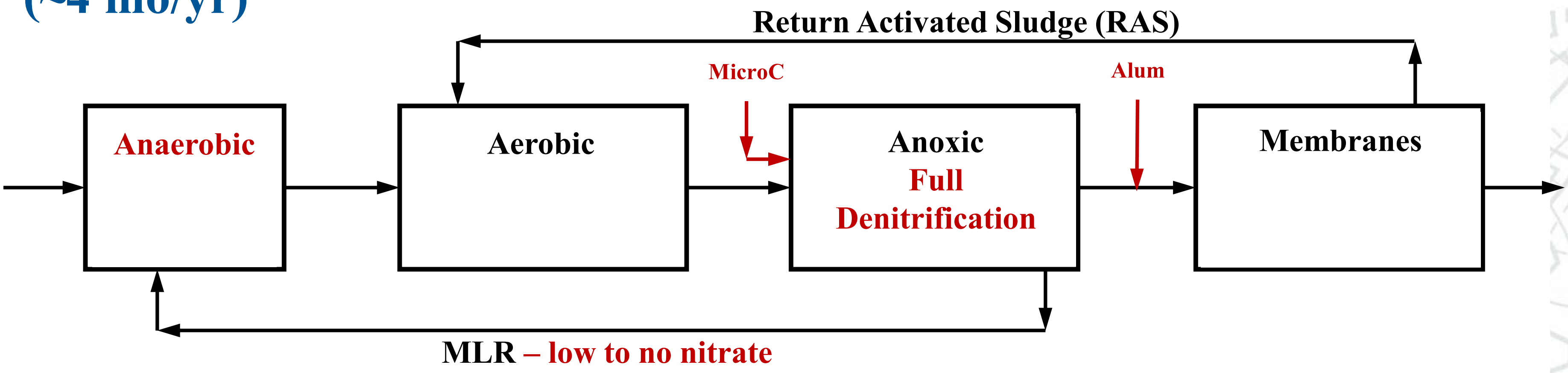
Bioreactor Processes

Non-Summer Operation (~8 mo/yr)



Bioreactor Processes

Summer Operation (~4 mo/yr)

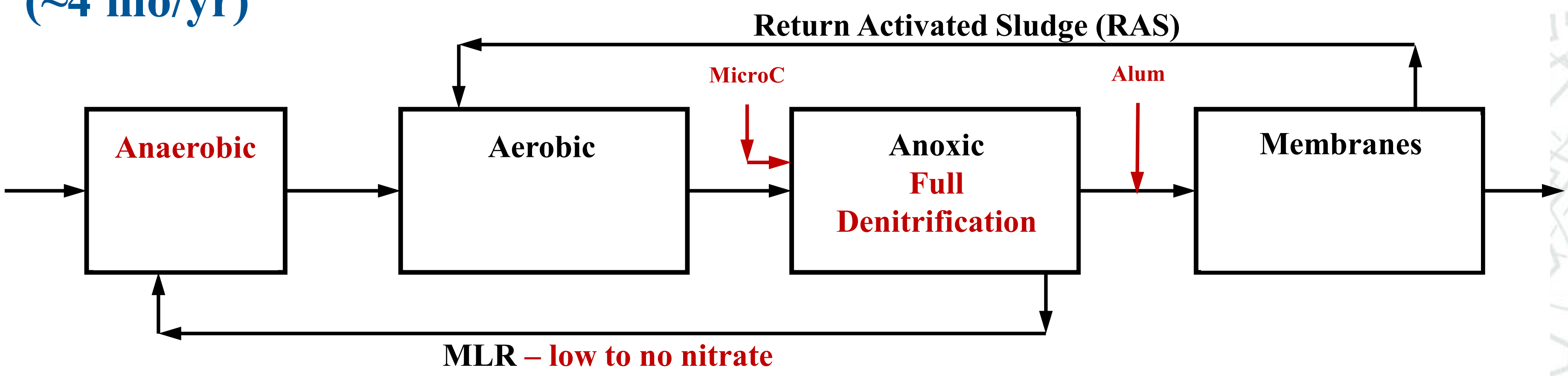


Chemical Info

- MicroC (Vita-Micro CS 70)
  - Proprietary glycerin-based carbon source for microorganisms, used here particularly for heterotrophs during denitrification and possibly during phosphorous release
- Alum (aluminum sulfate)
  - Metal salt that reacts with ortho-phosphate and other wastewater constituents to form solid precipitates

Bioreactor Processes

Summer Operation (~4 mo/yr)



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Membrane System

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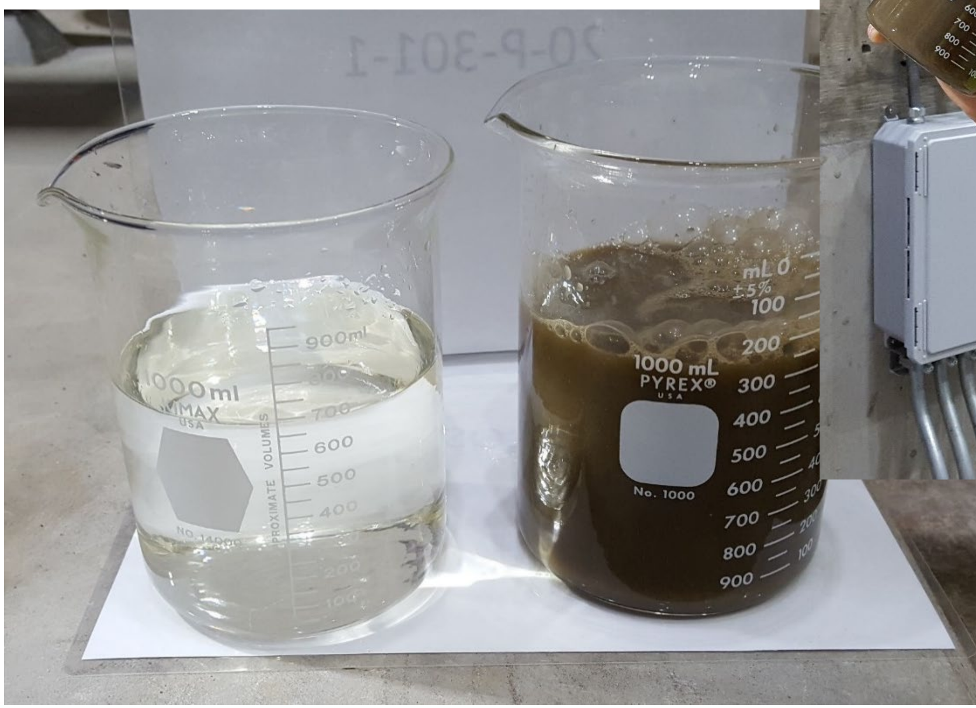
Membrane System

Membrane System

Treatment Performance



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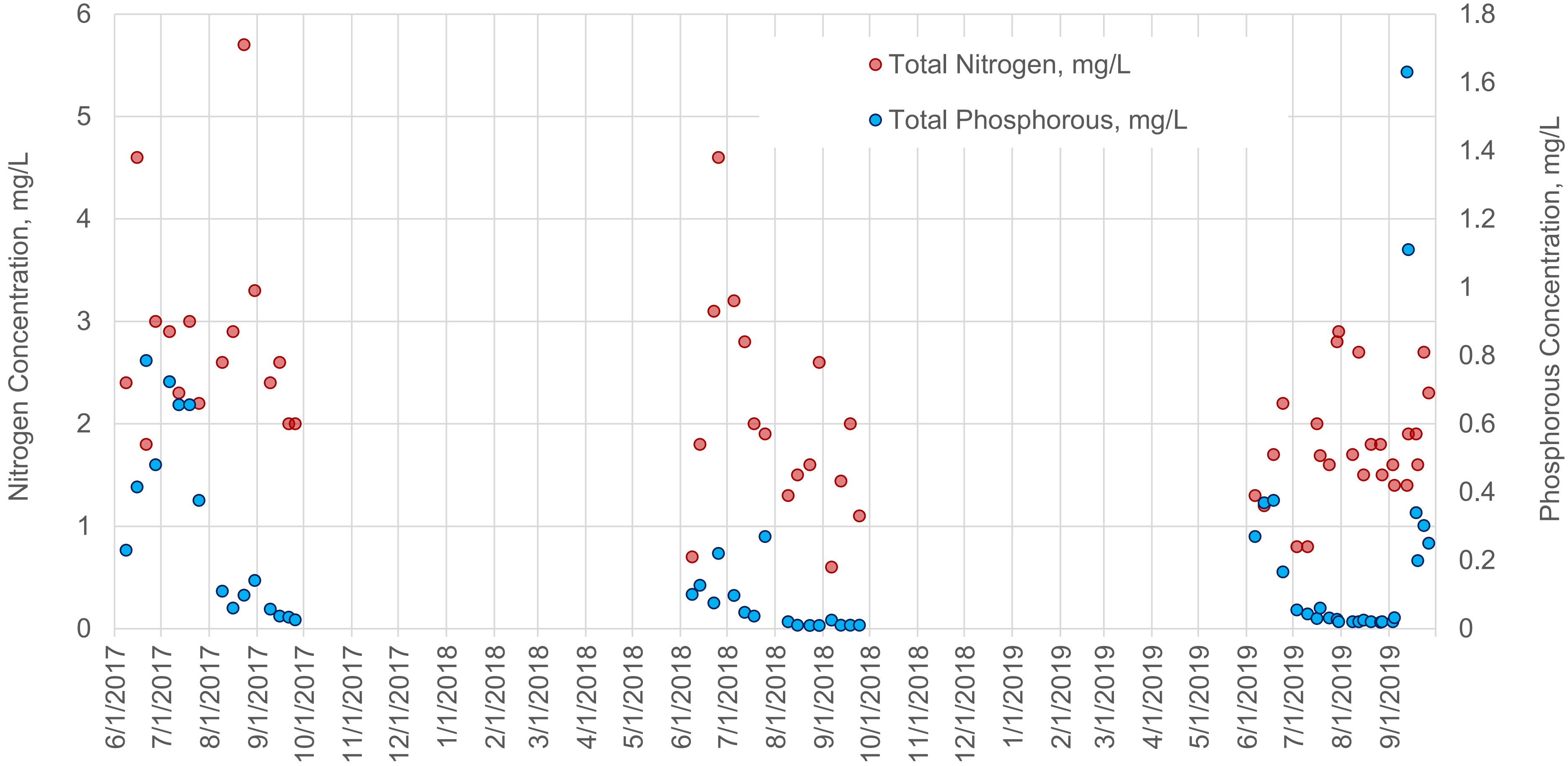
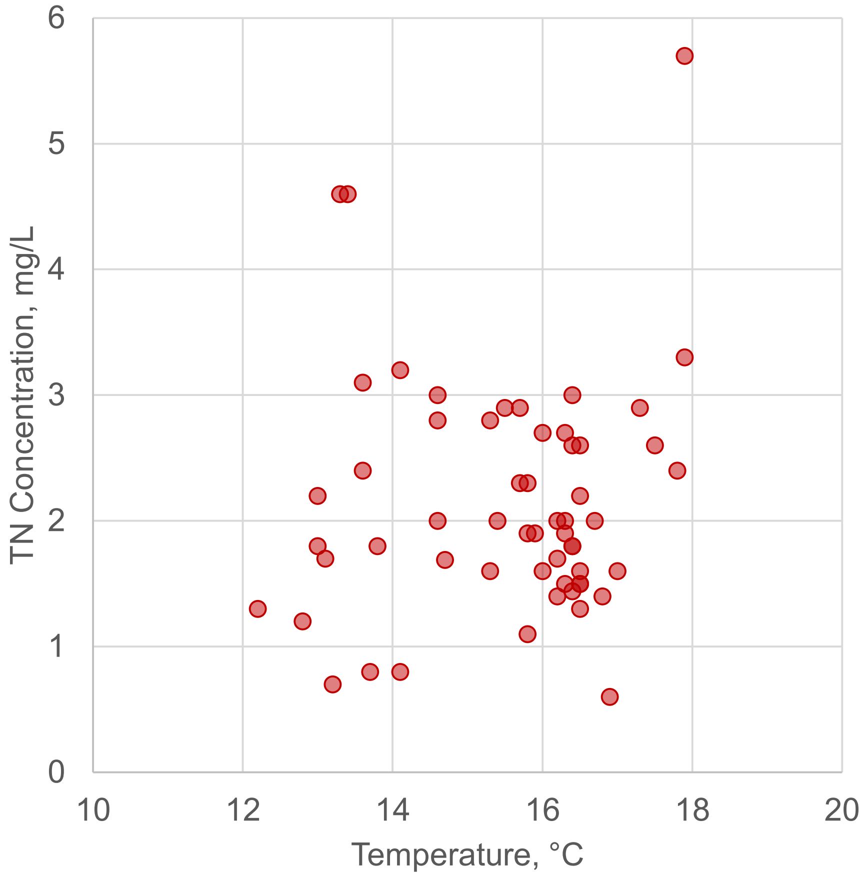
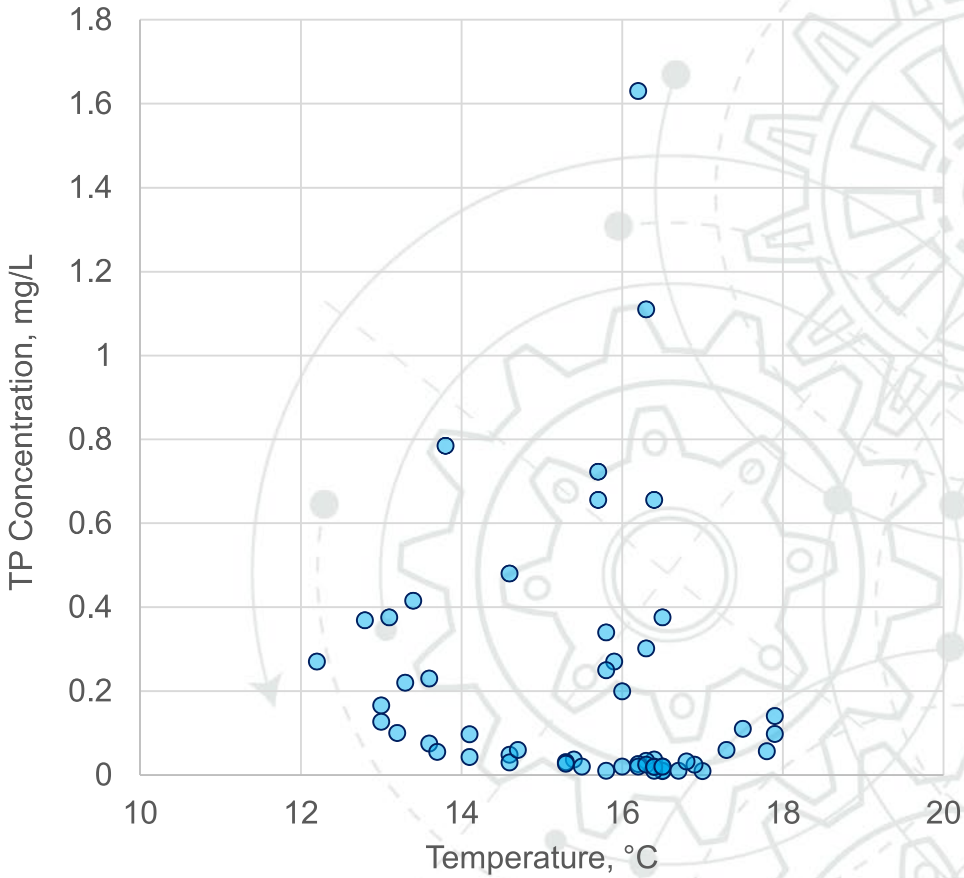
Effluent Nutrient Data Overview

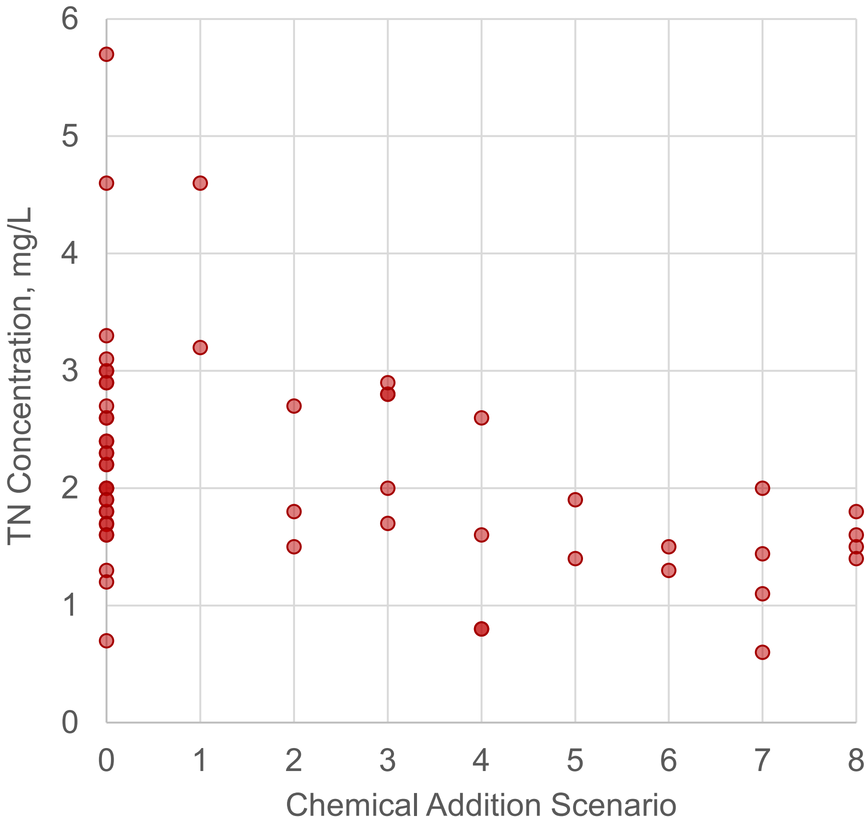


Effluent Nutrients vs. Temperature



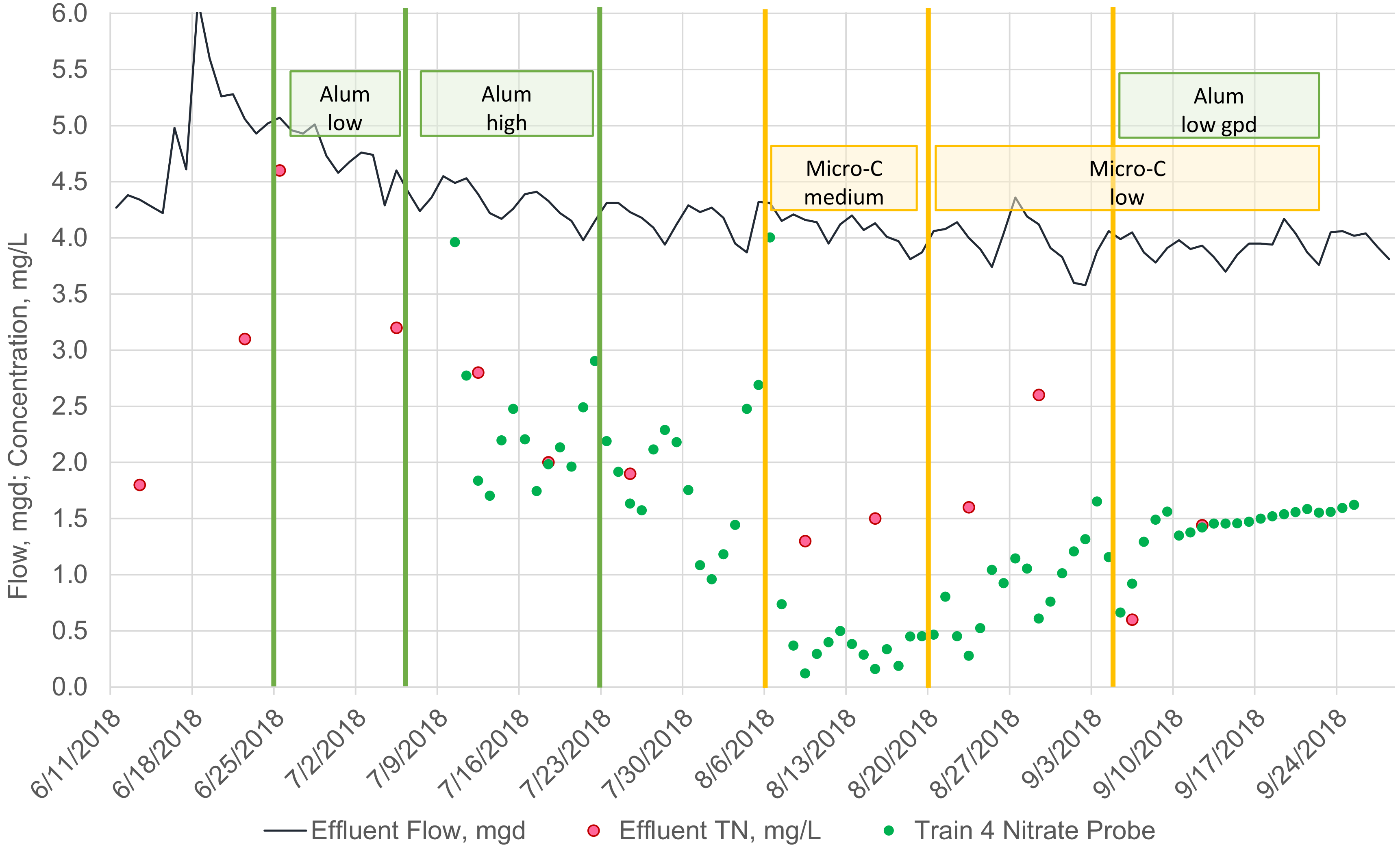


Effluent Nitrogen vs. Chemical Addition

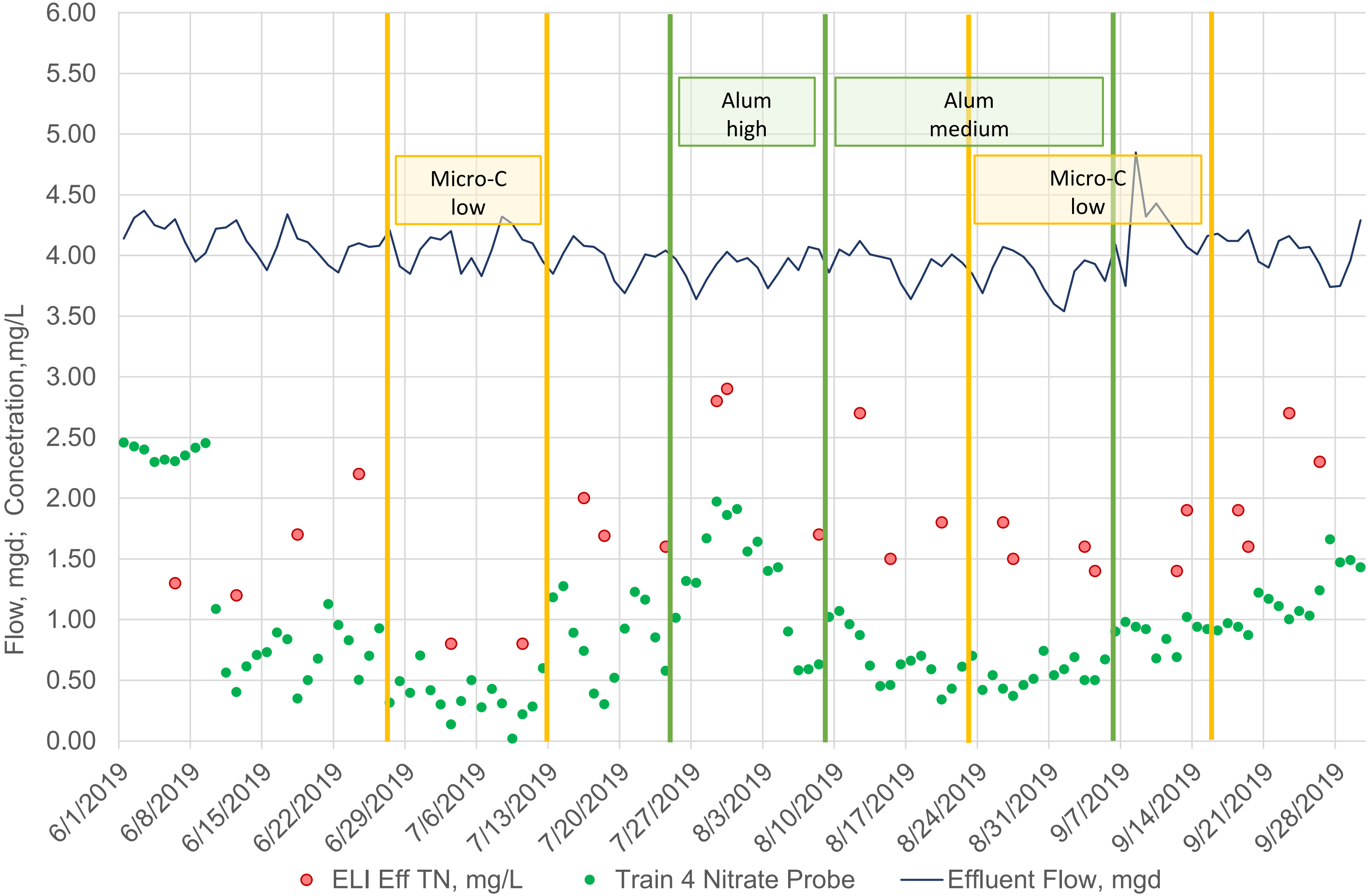


- 0-No chemical addition
- 1-Alum low dose
- 2-Alum medium dose
- 3-Alum high dose
- 4-MicroC low dose
- 5-MicroC medium dose
- 6-MicroC high dose
- 7-Alum low + MicroC low
- 8-Alum high + MicroC high

Nitrogen 2018



Nitrogen 2019



Effluent Phosphorous vs. Chemical Addition

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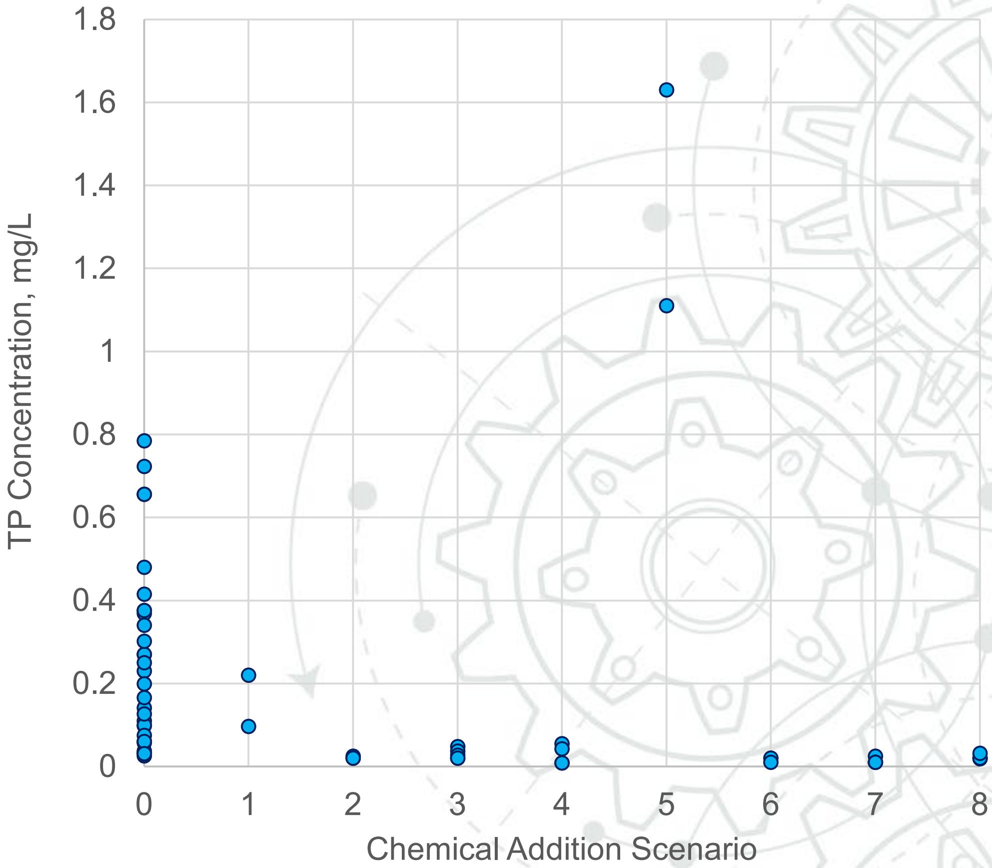
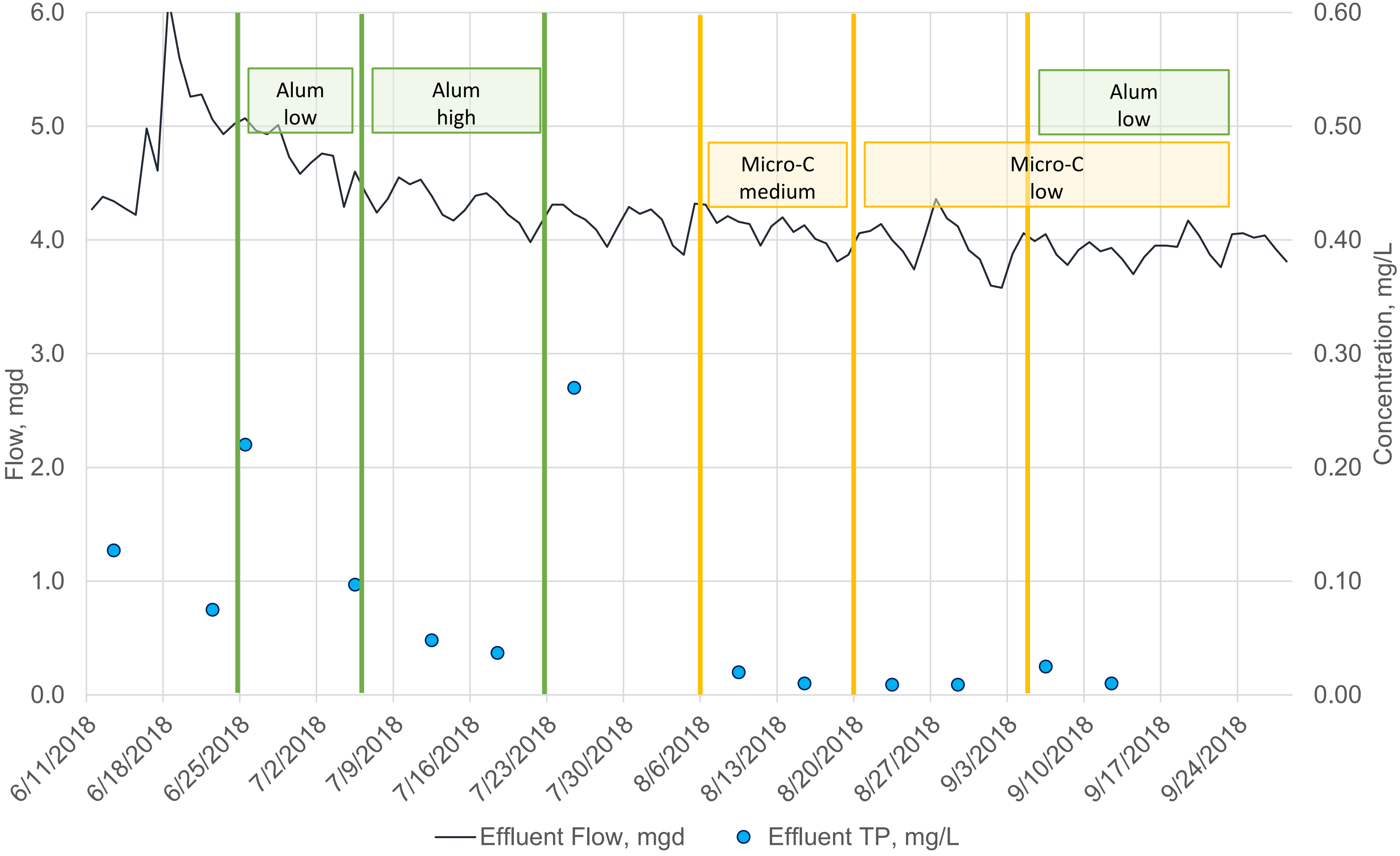
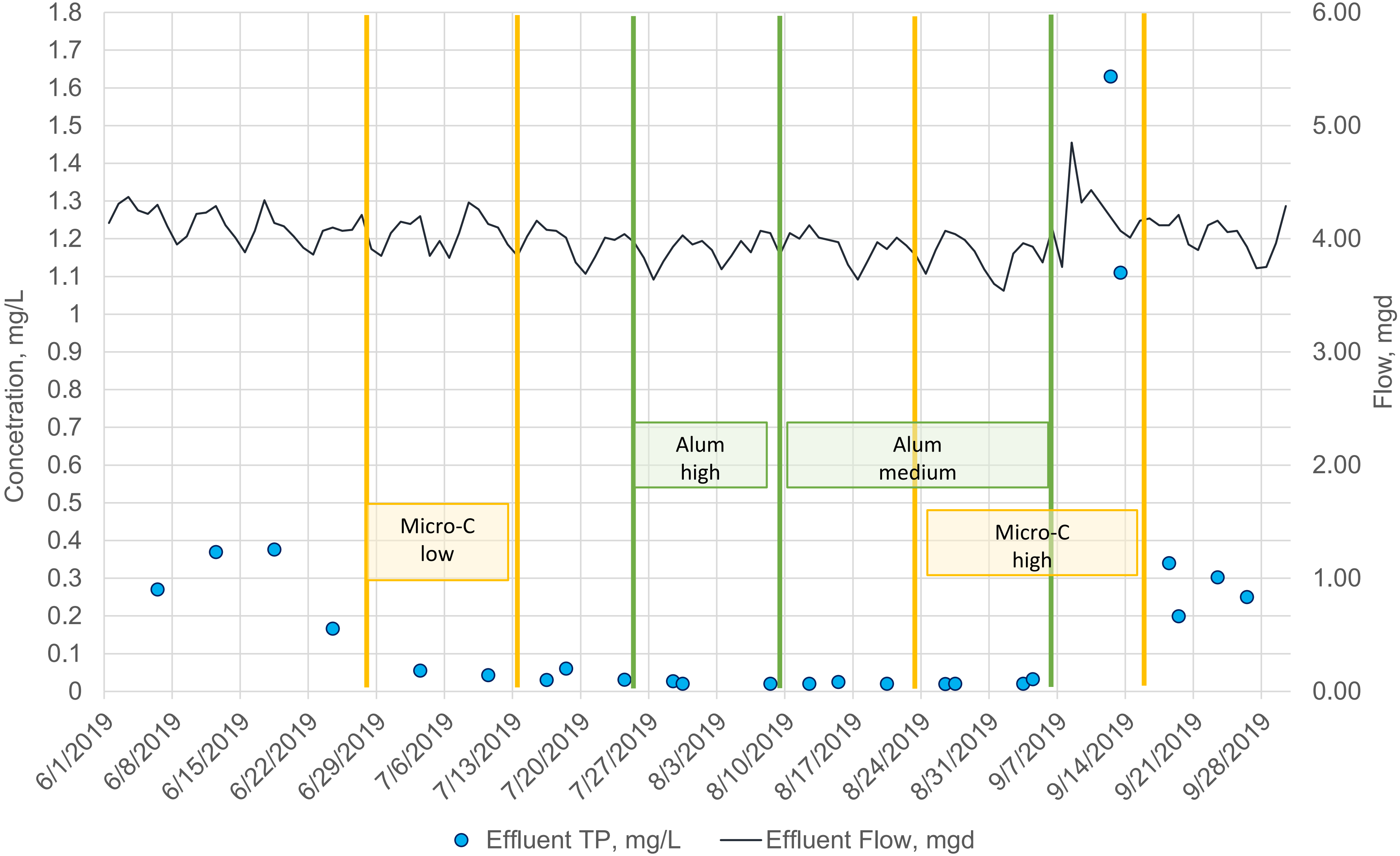


Phosphorous 2018



Phosphorous 2019



Recap

- Alum does reduce effluent TP
  - May remove too much phosphate from the process
    - Phosphate becomes limiting nutrient, hampering growth of denitrifying bacteria
    - Stops/reduces bio-P removal
- MicroC does reduce effluent TN
- MicroC also reduces effluent TP
  - Acts as “PAO candy” and stimulates biological phosphorous removal
- Combining them does not produce additional removal

Conclusions

- MicroC alone is effective in reducing effluent nutrient concentrations when compared to no chemical addition
  - TP w/o chemical addition: < 0.4 mg/L
  - TP w/ chemical addition: < 0.1 mg/L
  - TN w/o chemical addition: < 3.0 mg/L
  - TN w/ chemical addition: < 1.5 mg/L
- Is this additional reduction in effluent nutrients worth the cost and environmental impact of manufacture and transport of the chemicals?

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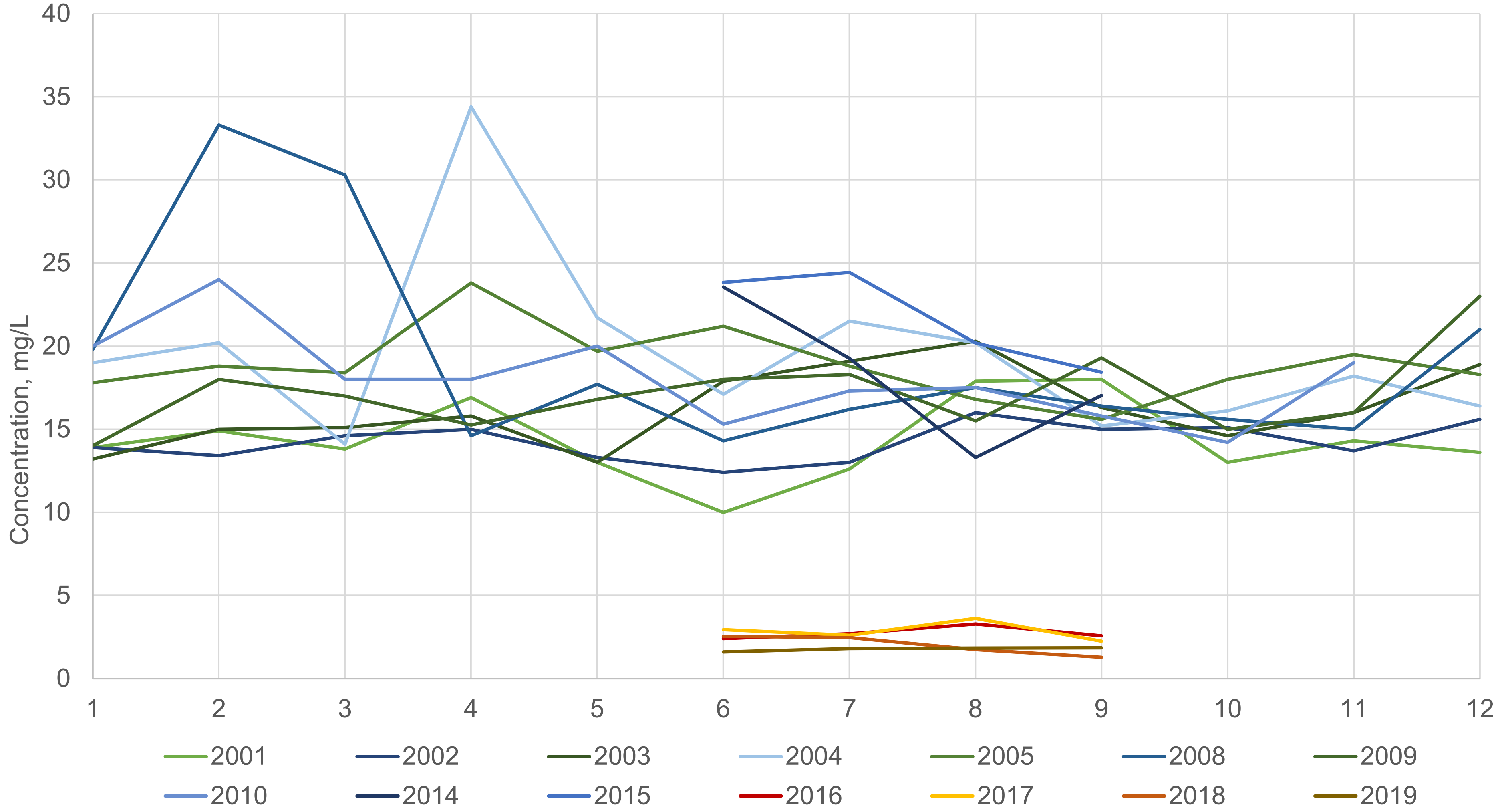
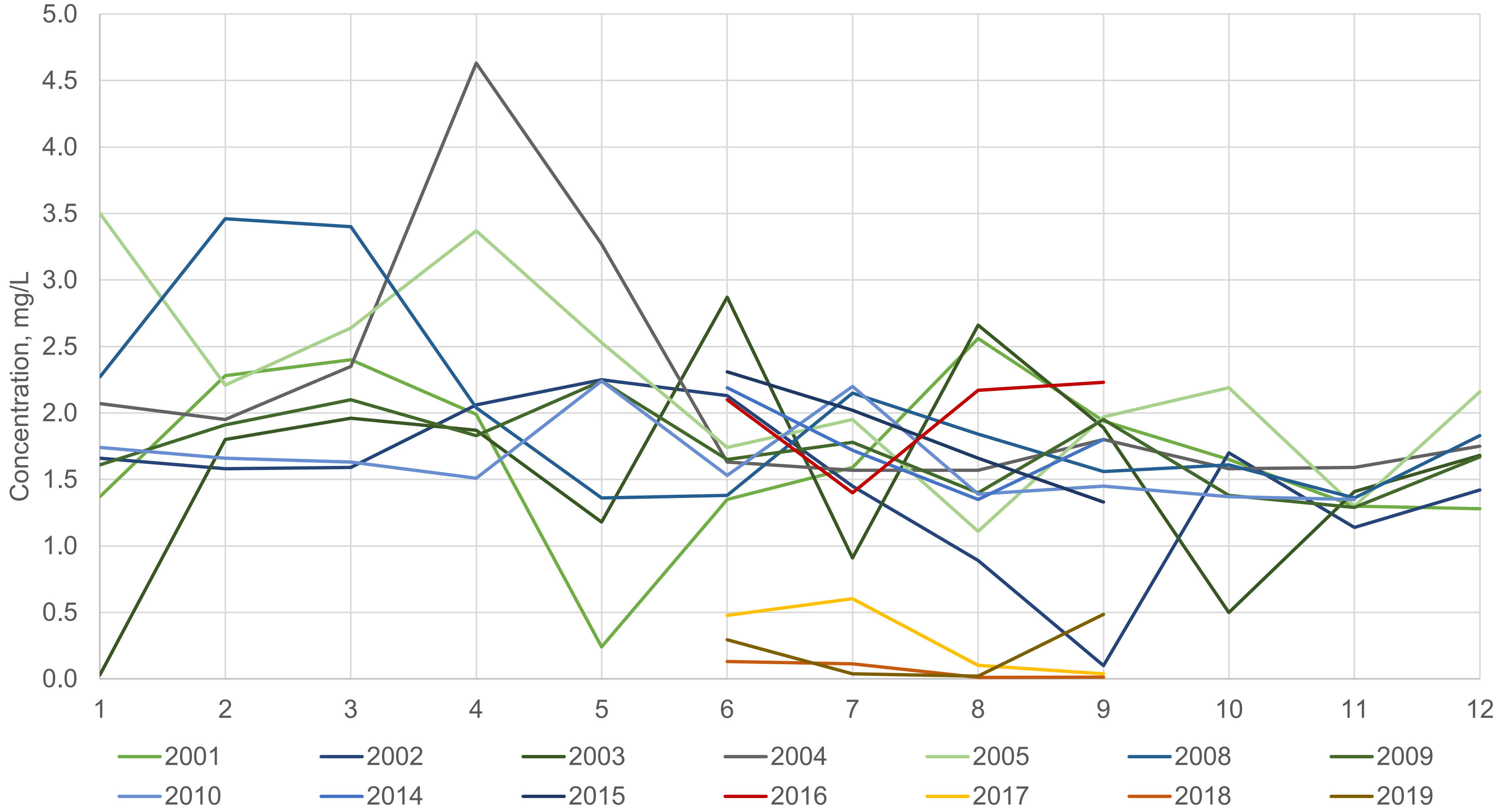
Restoring Silver Bow Creek

Total Nitrogen



Total Phosphorous



Nutrient Load to Silver Bow Creek

	Total Nitrogen	Total Phosphorous
Average for 2015	21.7 mg/L / 665 lb/d	1.83 mg/L / 56 lb/d
Average for 2016	2.75 mg/L / 85 lb/d	1.98 mg/L / 61 lb/d
Average for 2017	2.86 mg/L / 98 lb/d	0.31 mg/L / 10 lb/d
Average for 2018	2.09 mg/L / 74 lb/d	0.05 mg/L / 1.8 lb/d
Average for 2019	1.79 mg/L / 60 lb/d	0.22 mg/L / 7.4 lb/d

Averages for June through September for each year.

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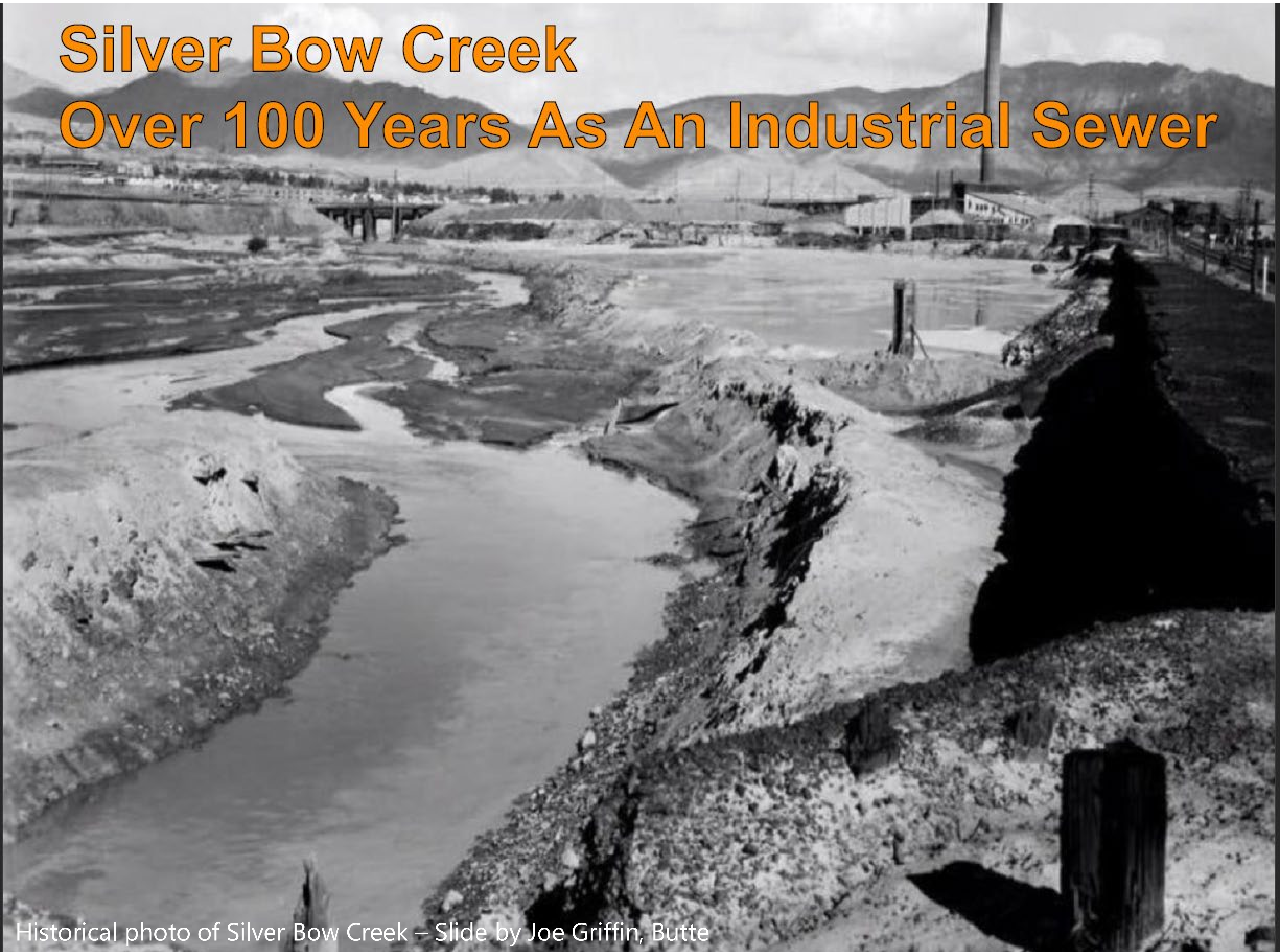
Silver Bow Creek
Over 100 Years As An Industrial Sewer



Historical photo of Silver Bow Creek – Slide by Joe Griffin, Butte

Metals

- Process was not specifically designed to remove metals
- Higher biomass concentration in new process was speculated to take up and adsorb metals at a greater rate than previous process
- Ultrafiltration was expected to help with removal of particulate metals and those associated with biomass

The Numbers

- 2007-2019 – period of record for presented metals data
- 99 µg/L – average influent total recoverable copper
  - 14-22 µg/L – WQ Standard for Silver Bow Creek (2019)
- 295 µg/L – average influent total recoverable zinc
  - 180 µg/L – WQ Standard for Silver Bow Creek (2019)

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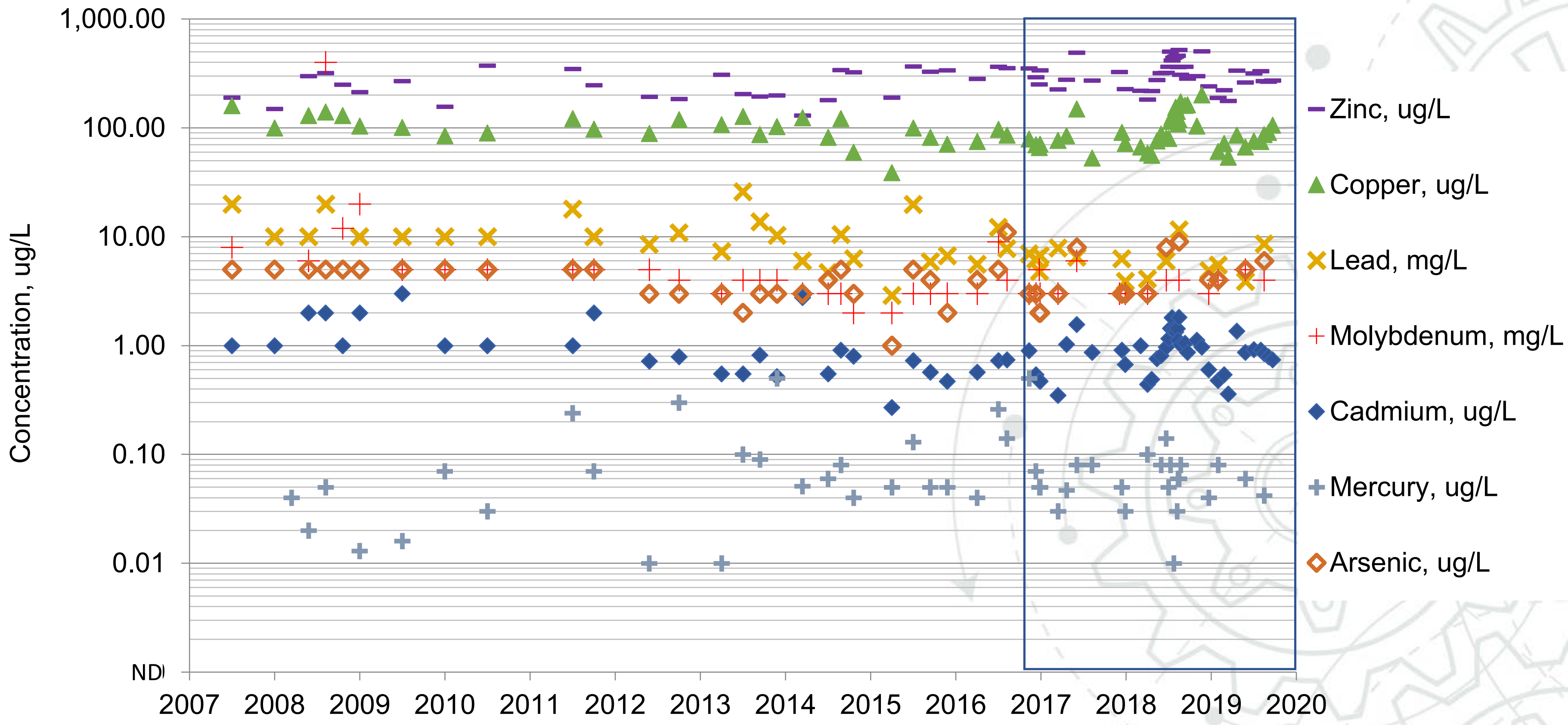
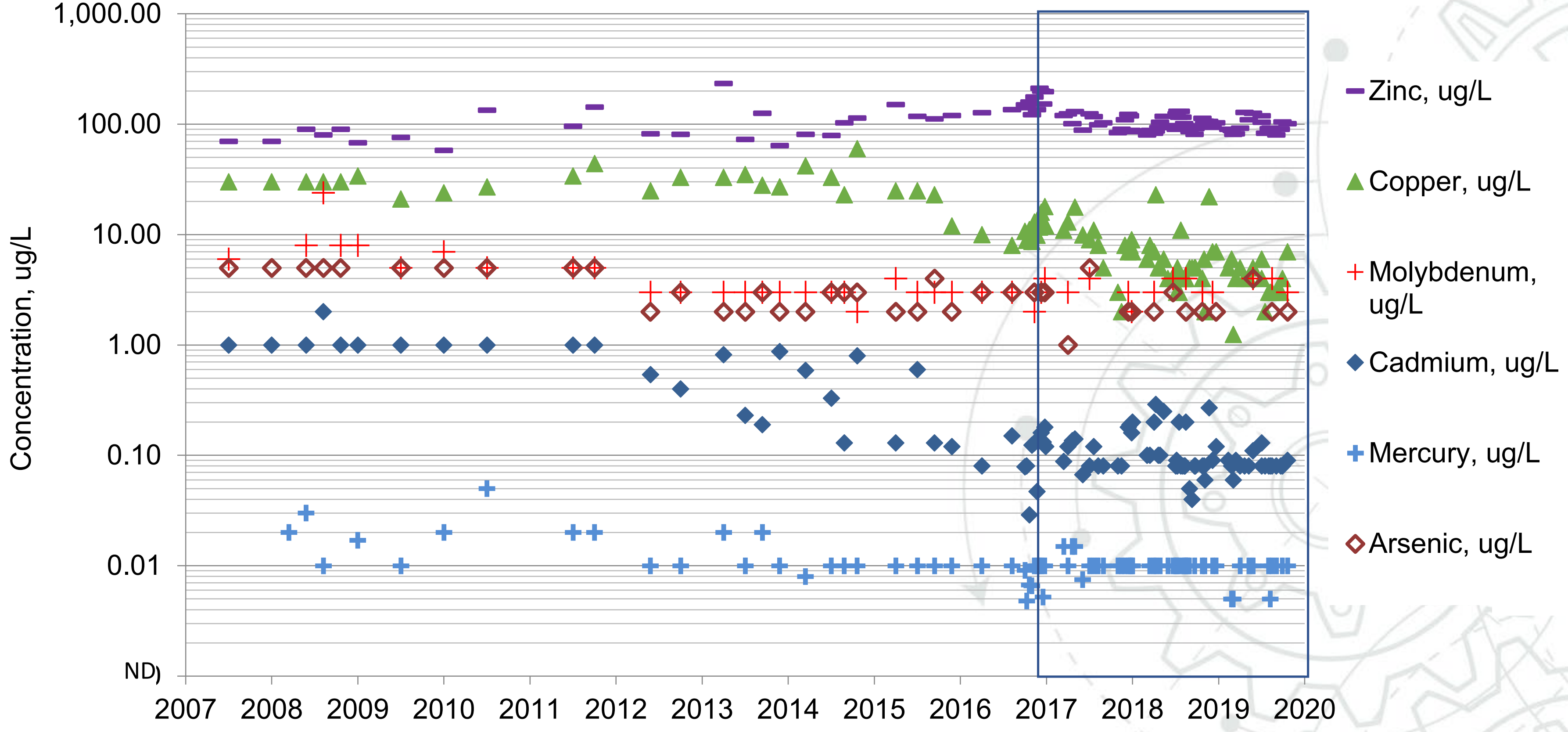
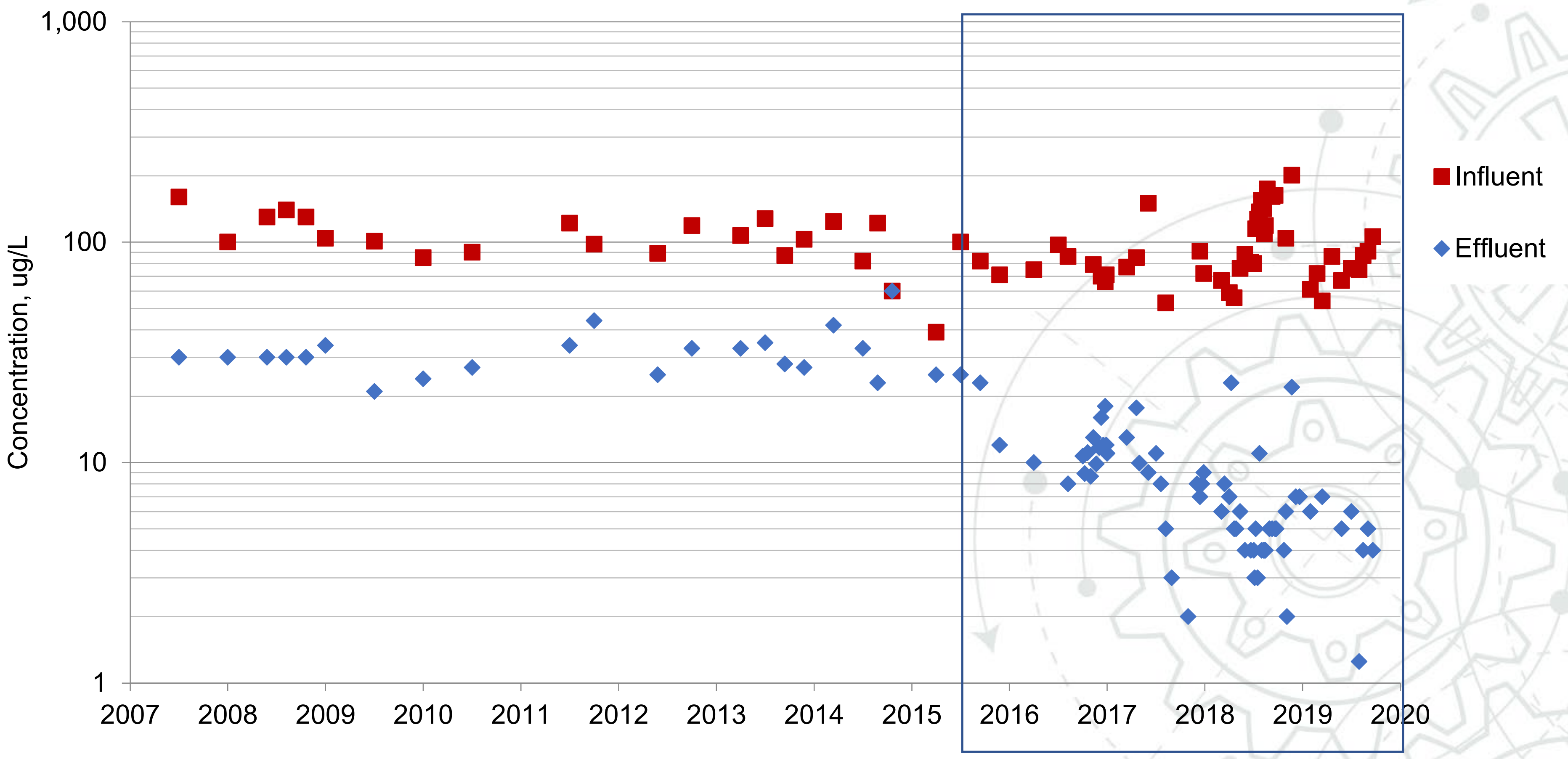
Influent Metals since 2007



Effluent Metals since 2007

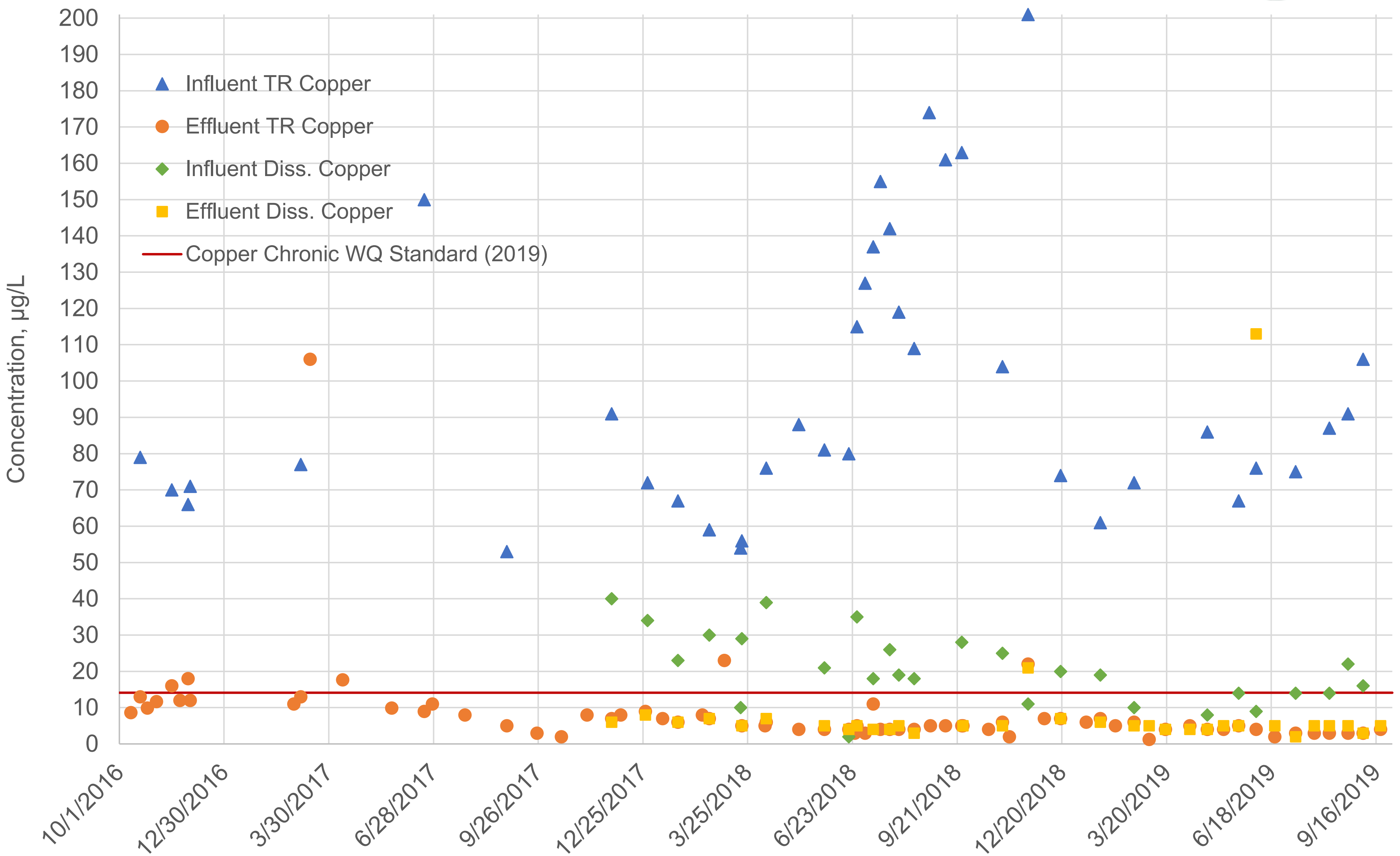


Copper

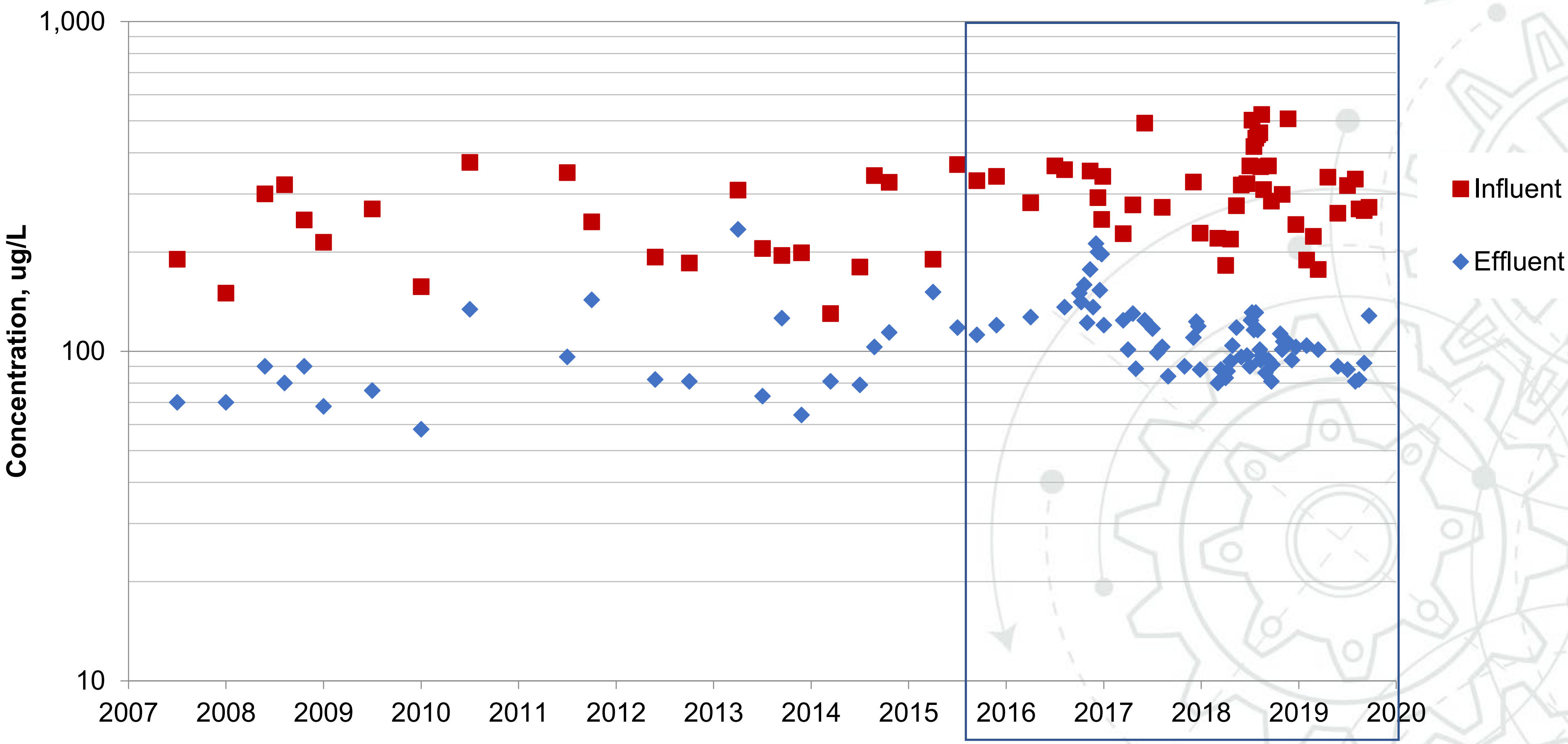


1,000
100
10
1
Concentration, ug/L
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Influent
Effluent

Copper 2016-2019



Zinc



1,000
100
10
Concentration, ug/L
2007
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2019
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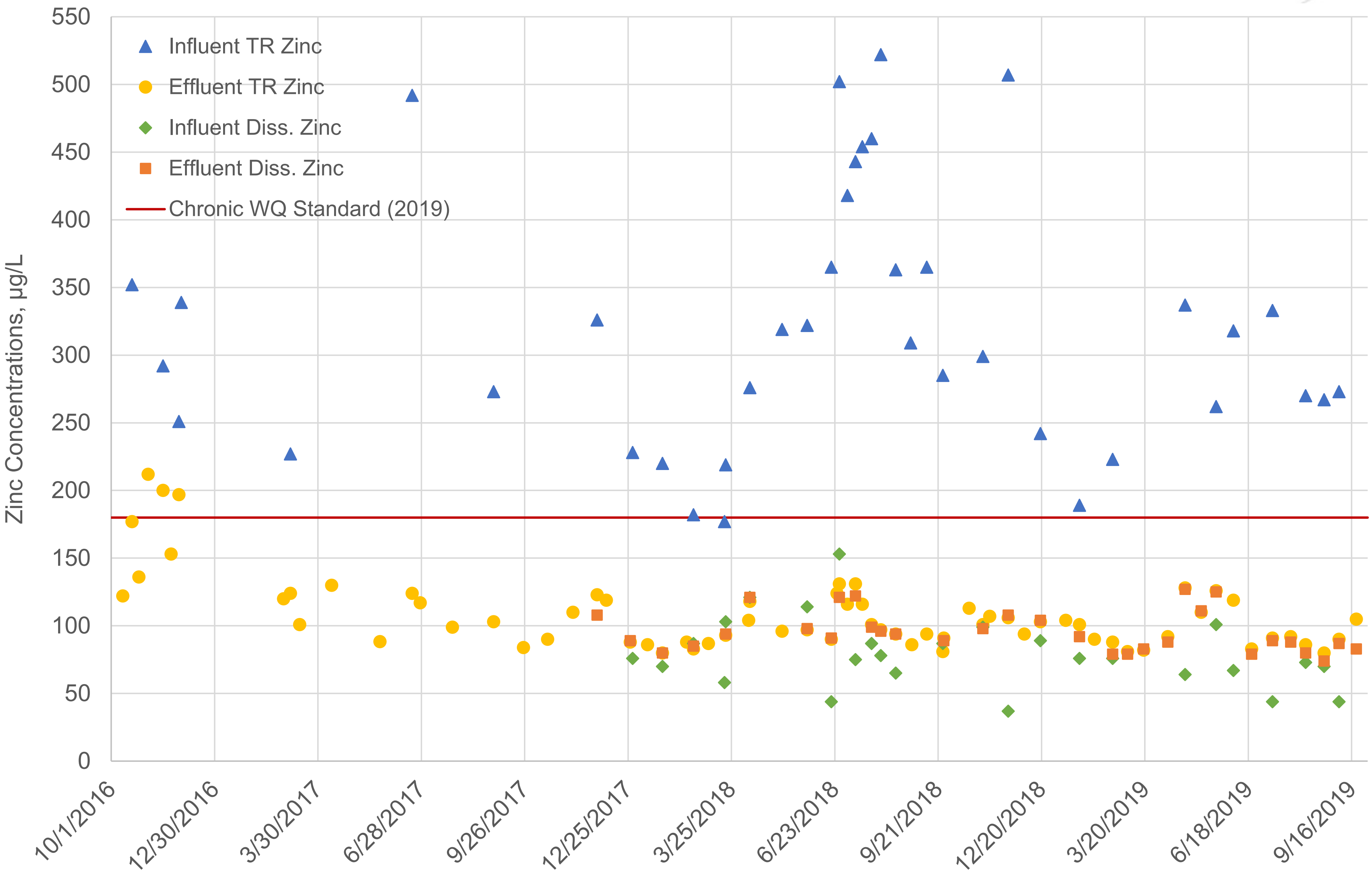
Influent
Effluent

Zinc 2016-2019



Metals Load to Silver Bow Creek,

pounds per day

	Copper (TR)	Zinc (TR)
Average 2007-2015	30 µg/L / 0.90 lb/d	101 µg/L / 3.0 lb/d
Average 2016-2019	6.88 µg/L / 0.22 lb/d	108 µg/L / 3.5 lb/d

Averages for year-round sampling results
2007-2015 average flow = 3.6 mgd
2016-2019 average flow = 3.9 mgd

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Pipe dreams? Maybe not…

Rendering published in the Montana Standard, Nov. 21, 2016

Questions?

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