MONITORING NITROGEN REMOVAL BY FLORIDA INGROUND NITROGEN-REDUCING BIOFILTERS

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Materials in this presentation represent author's own opinion and do not reflect opinions of NOWRA.

ACKNOWLEDGEMENTS

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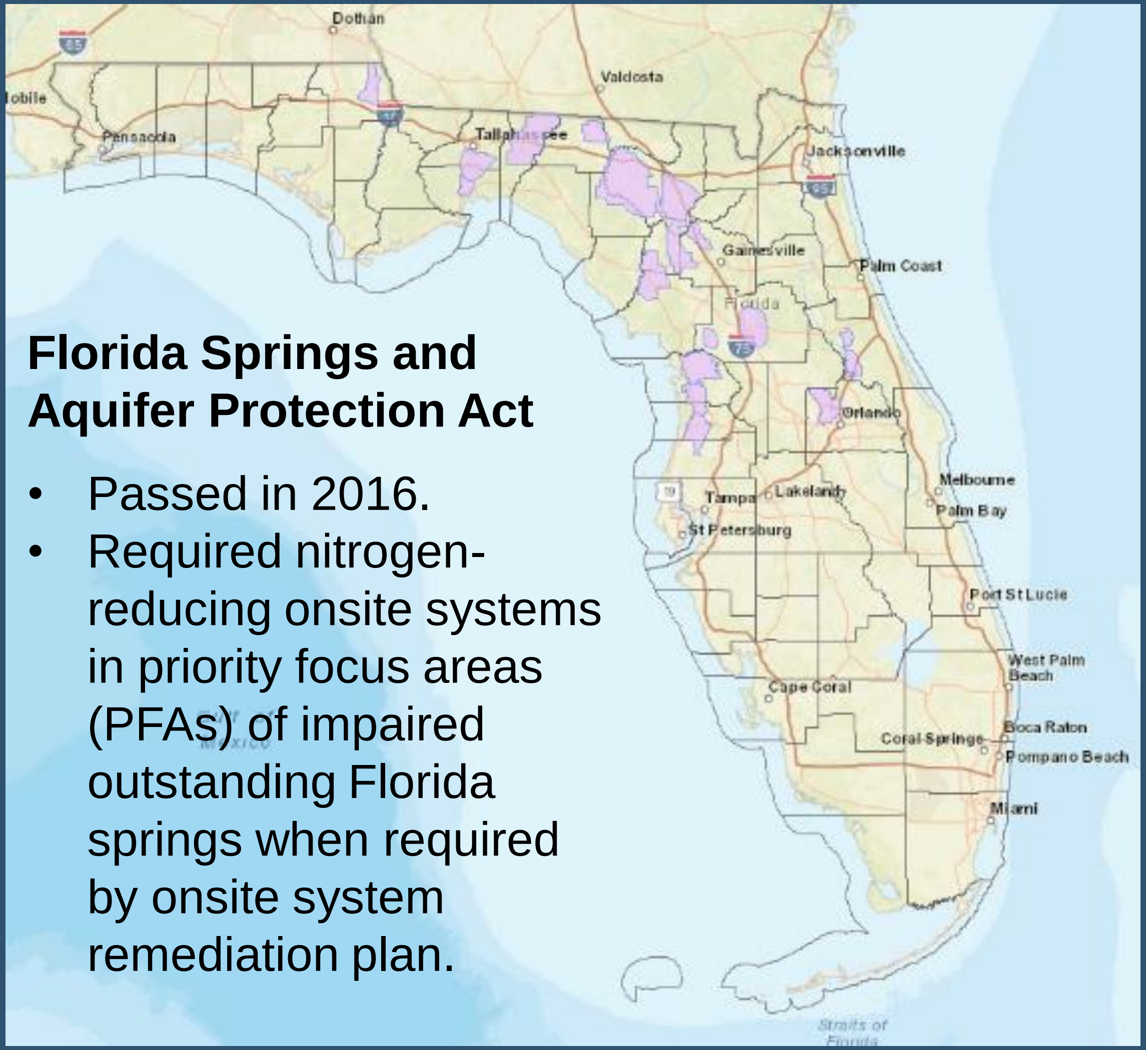
- Inground nitrogen-reducing biofilters (INRBs) monitored by this project were funded by the Florida Department of Environmental Protection's (DEP's) Spring and Aquifer Protection Fund through an agreement with Leon County.
- The INRBs and monitoring equipment were installed by Apalachee Backhoe and Septic Tank.
- Special thanks to Ms. Tanya Welborn and Dr. Sol Park for their invaluable support in organizing the sampling trips, coordinating laboratory analyses and facilitating the collection of samples from the monitored INRBs.

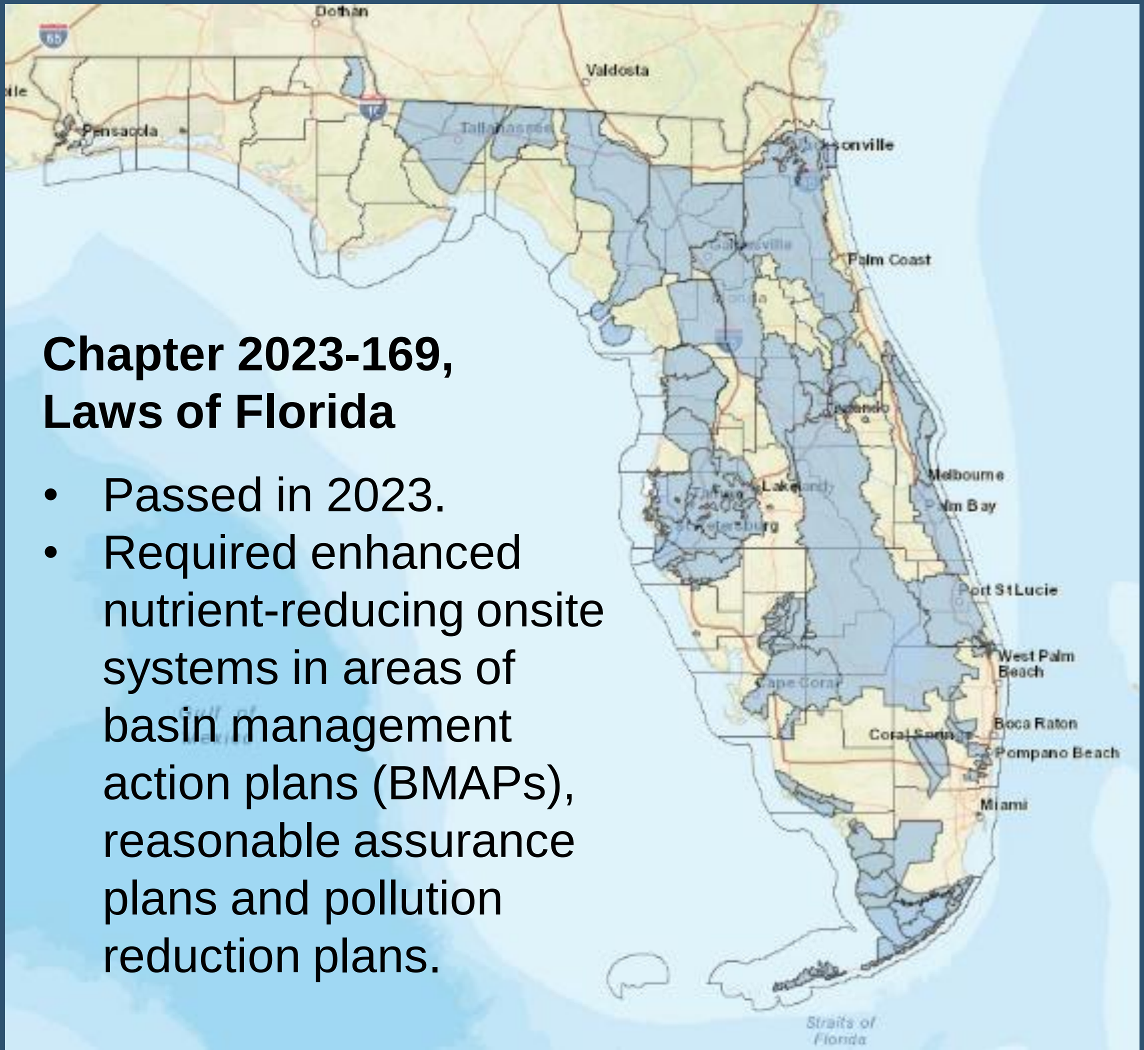
FLORIDA STATUTORY (F. S.) REQUIREMENTS

ENHANCED NUTRIENT-REDUCTION ONSITE SEWAGE TREATMENT SYSTEM



Florida Springs and Aquifer Protection Act

- Passed in 2016.
- Required nitrogen-reducing onsite systems in priority focus areas (PFAs) of impaired outstanding Florida springs when required by onsite system remediation plan.



Chapter 2023-169, Laws of Florida

- Passed in 2023.
- Required enhanced nutrient-reducing onsite systems in areas of basin management action plans (BMAPs), reasonable assurance plans and pollution reduction plans.

MODERN CONVENTIONAL OSTDS

- Modern conventional onsite sewage treatment and disposal system (OSTDS) effectively removes organic carbon (represented by biochemical oxygen demand [BOD]), total suspended solids (TSS), phosphorus and fecal coliform if the system is properly installed and maintained.

- Conventional OSTDS is not designed to remove nitrogen with high efficiency.

REMOVING NITROGEN FROM DOMESTIC WASTEWATER

Nitrogen exists in various forms and must be dealt with sequentially in each form to ensure removal.

Organic → **Nitrogen ammonia** → **Nitrate** → **Nitrogen gas**

Ammonification
septic/anaerobic

Nitrification
aerobic

Denitrification
Anoxic (need food)

NITROGEN-REDUCING OSTDS

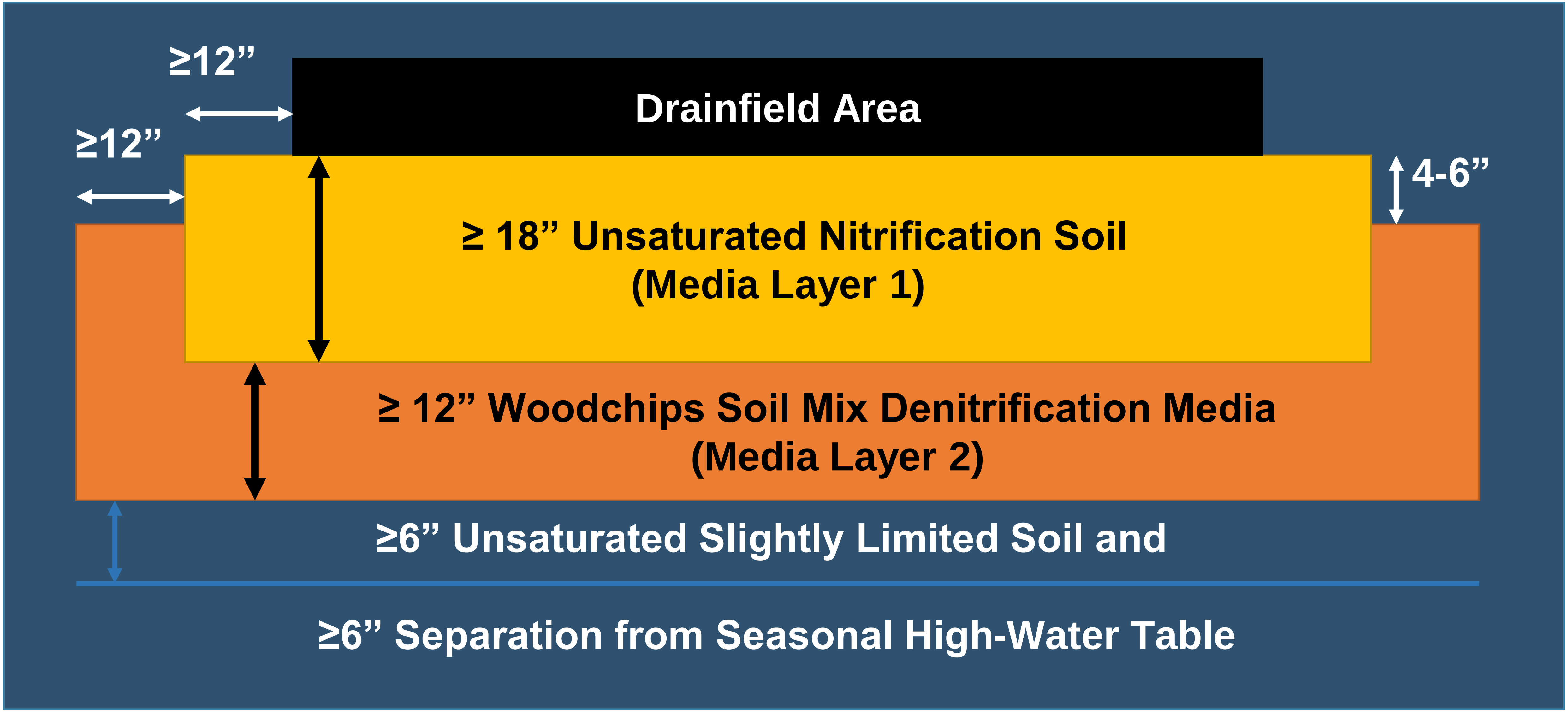
- Aerobic treatment units (ATU) certified as meeting the NSF 245 standard.
- Nitrogen-reducing performance-based treatment systems (PBTS).
- Inground nitrogen-reducing biofilters (INRB).

NITROGEN-REDUCING OSTDS FOR SPRINGS

- Between June 29, 2018, and July 1, 2023, more than 6,300 nitrogen-reducing OSTDS were installed in PFAs established by BMAPs for impaired outstanding Florida Springs.
- Includes both new systems that were required by OSTDS remediation plan and voluntary upgrades during repairs and modifications (some funded by DEP).

Type of Nitrogen-reducing OSTDS	Number of Systems Installed
ATU certified to NSF 245 standard	3,492
Nitrogen-reducing PBTS	197
INRB	2,622

INGROUND NITROGEN-REDUCING BIOFILTER



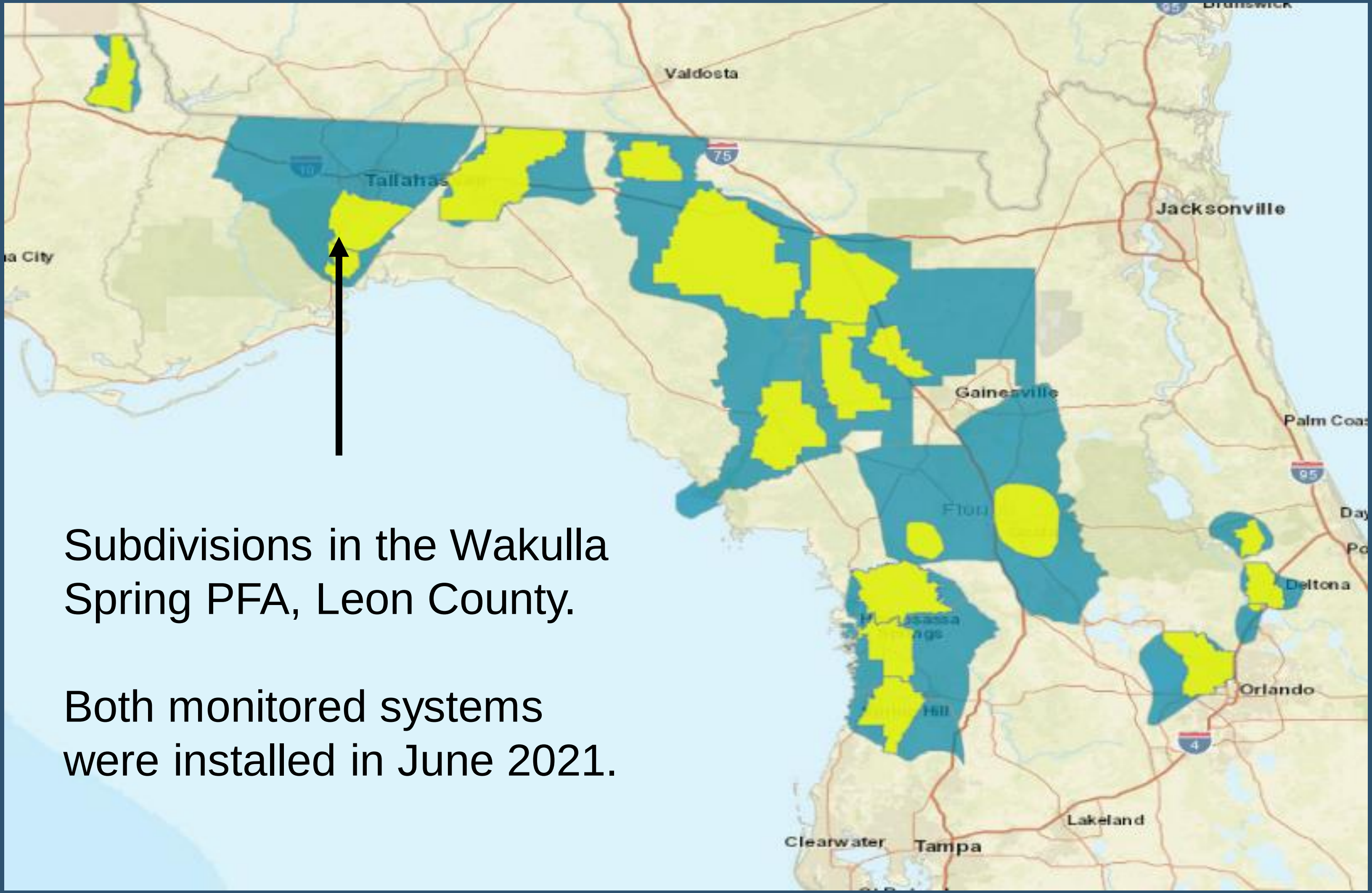
ONGOING INRB MONITORING PROJECTS

- Experimental prototypes of INRB installed previously showed about 65% nitrogen removal.
- Data from more systems are needed to provide more robust evaluation of the performance of the technology in Florida.
  - DEP's Onsite Sewage Program (OSP) is monitoring two INRB systems (this presentation).
  - OSP is working with DEP's Division of Environmental Assessment and Restoration to monitor four other INRBs in Leon County.
  - Monitoring equipment in an experimental INRB system installed in 2014 in Icheetucknee Springs State Park has been recently replaced for renewed monitoring.
  - OSP is looking for more volunteer INRB owners to participate in monitoring.

TWO INRBs MONITORED BY OSP

- The two INRBs monitored by this project were installed in June 2021.
- Monitoring equipment was installed when the two INRBs were constructed.
- Goals of this monitoring are as follows.
  - Evaluate the nitrogen-reducing efficiency of INRB systems.
  - Evaluate removal efficiency of phosphorus, fecal coliform and organic carbon.
  - Evaluate media decay through monitoring the change of elevations of media layers.
  - Compare monitoring results from different monitoring equipment (i.e., pan lysimeter and suction lysimeter).

PROJECT LOCATION



Subdivisions in the Wakulla Spring PFA, Leon County.

Both monitored systems were installed in June 2021.

BMAP Area

PFA

INRB SYSTEM MONITORING

- Inspect the systems to ensure proper function.
- Conduct elevation survey to evaluate change of depth of media layers.
- Collect samples.
  - Total kjeldahl nitrogen (TKN).
  - Ammonium nitrogen (NH4-N).
  - Nitrate/nitrite nitrogen (NOx-N).
  - Total phosphorus (TP).
  - Total organic carbon (TOC).
  - Fecal coliform.
  - Alkalinity.
  - Chloride.

INRB SYSTEM MONITORING (2)

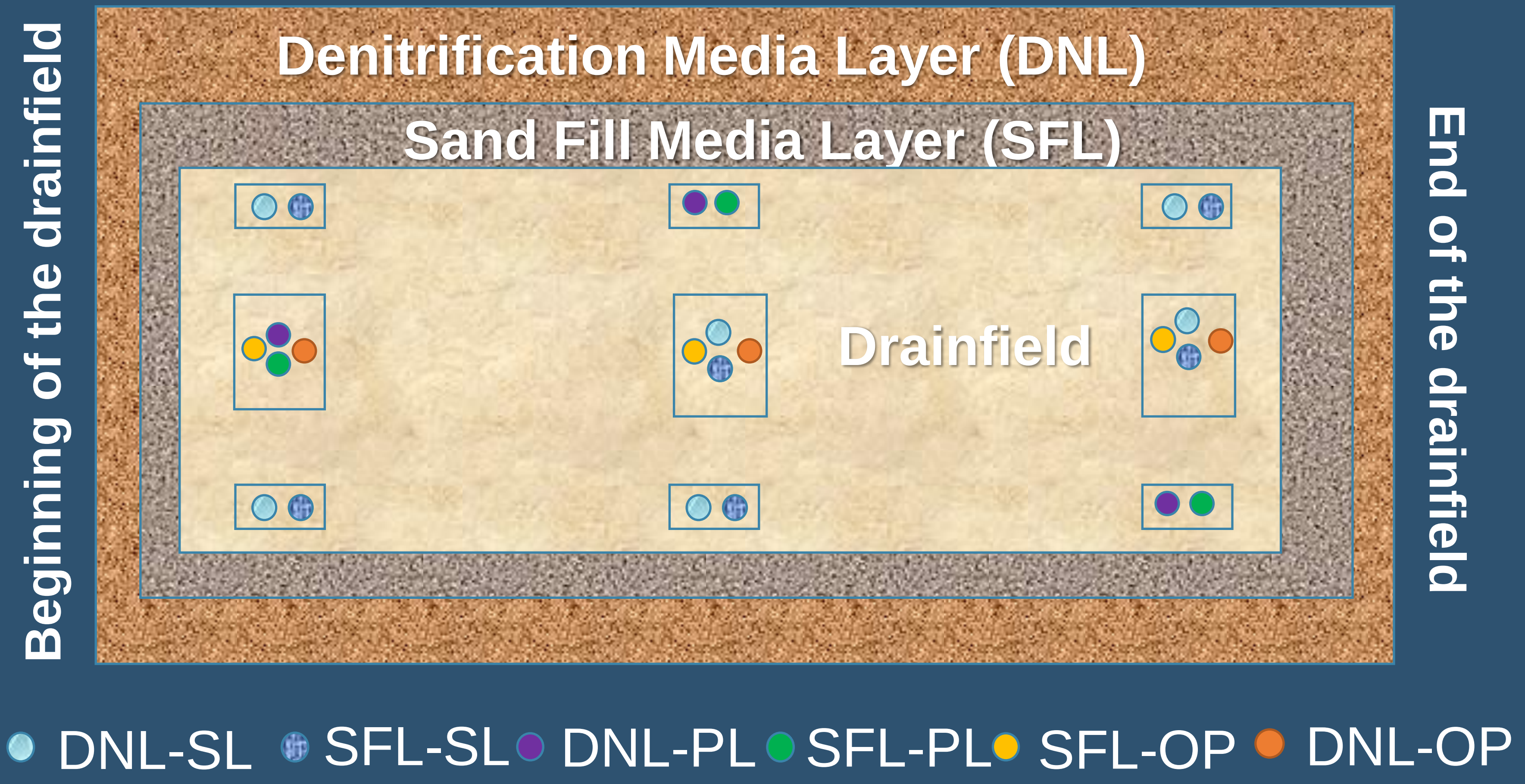
- Collect field measurements.
  - Water temperature.
  - Dissolved oxygen.
  - Specific conductivity.
  - pH.
  - Oxidation reduction potential (ORP).
  - Flowmeter reading.

MONITORING EQUIPMENT

Pan Lysimeter (PL)

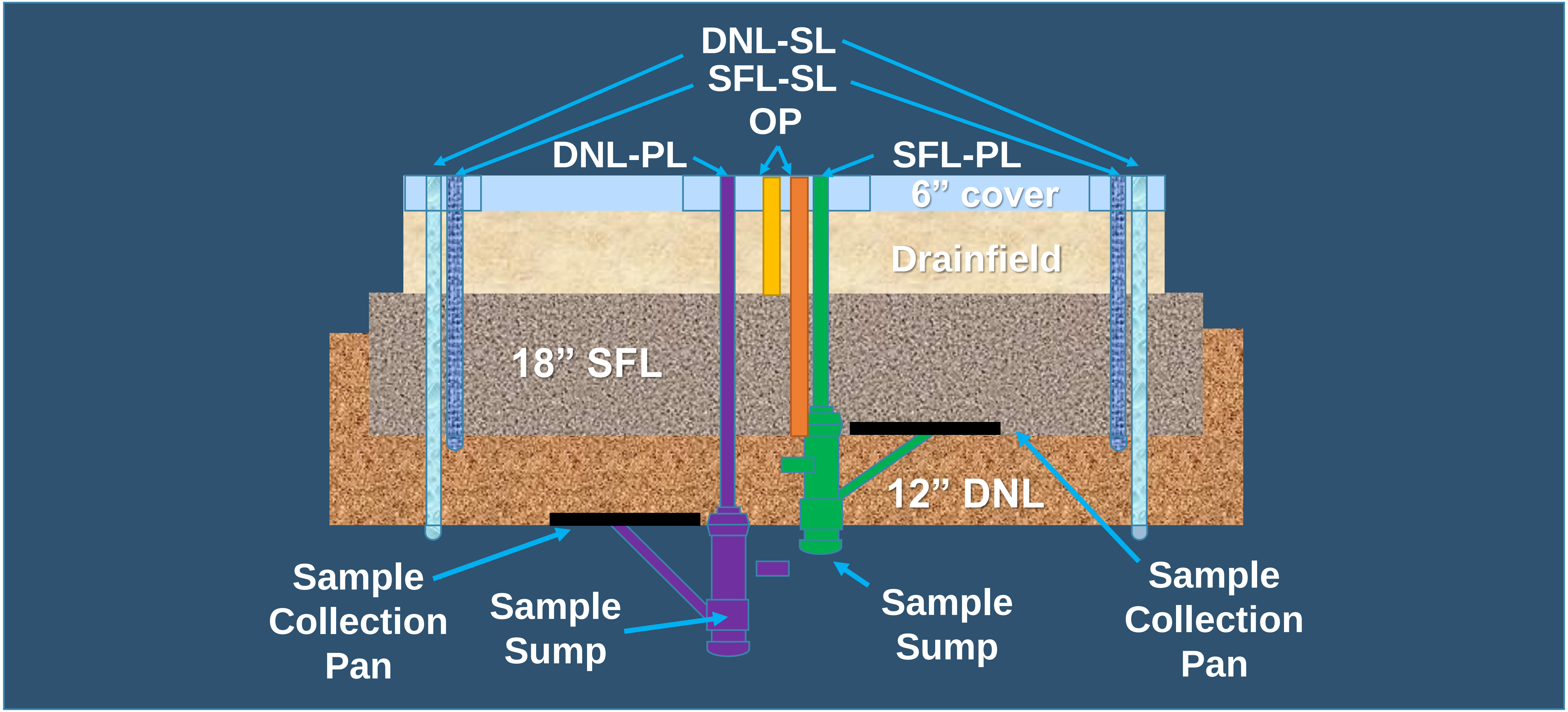
Suction Lysimeter (SL)

MONITORING EQUIPMENT ARRANGEMENT



SL: Suction Lysimeter. **PL**: Pan Lysimeter. **OP**: Observation Port.

MONITORING EQUIPMENT ARRANGEMENT (2)



MONITORING EQUIPMENT INSTALLATION

Bottom of INRB

Denitrification media

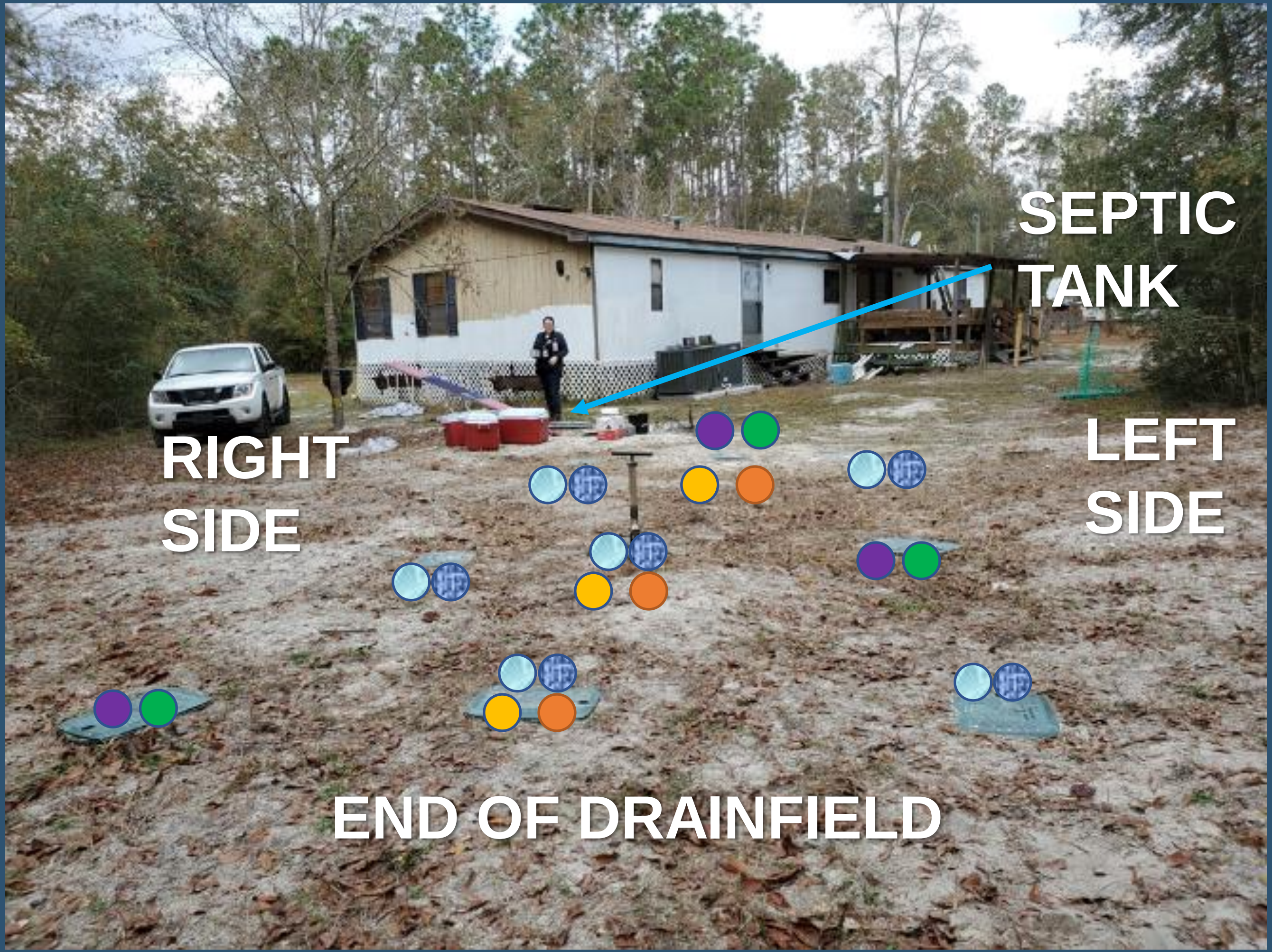
PL at the bottom of INRB

MONITORING EQUIPMENT INSTALLATION (2)

MONITORING EQUIPMENT INSTALLATION (3)

Top of sand fill media layer

SYSTEM 3 (S3)
INSTALLED JUNE 2021

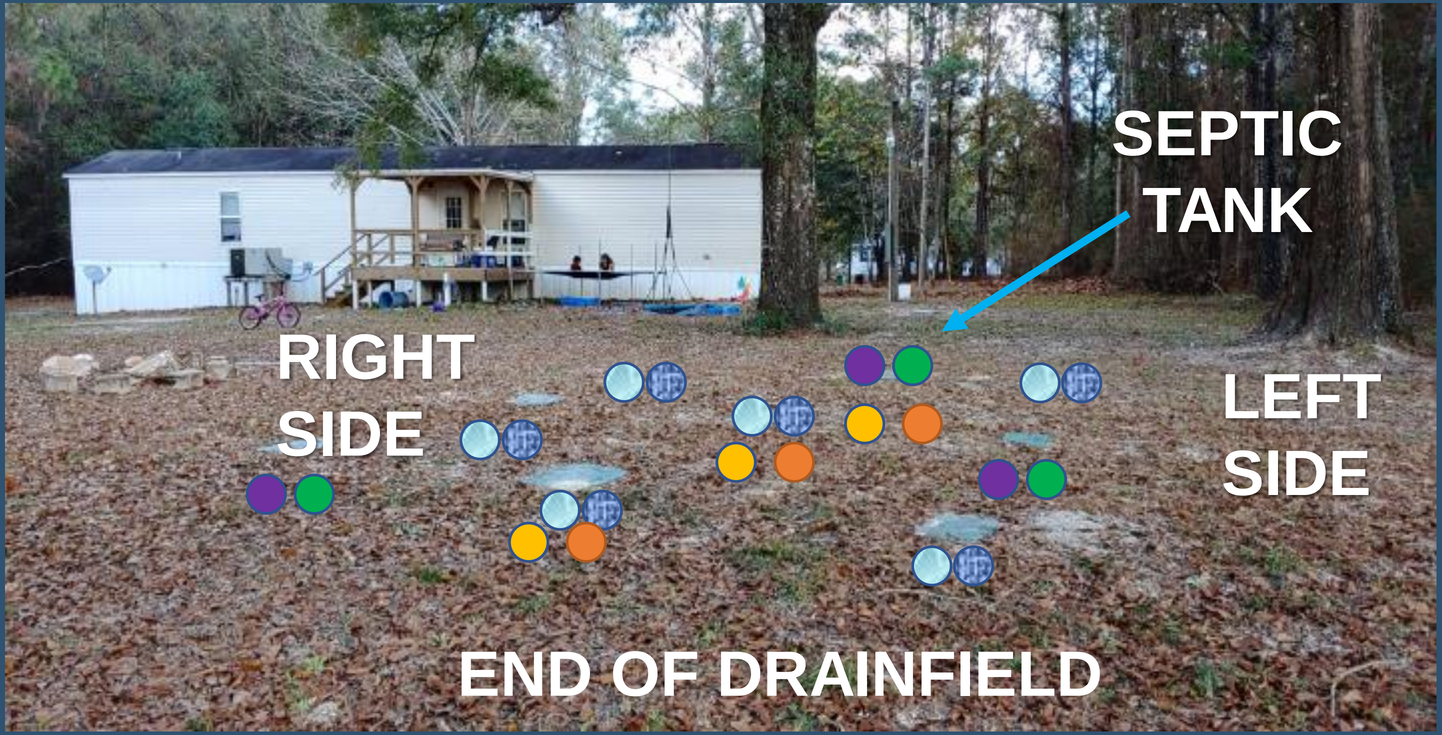


DNL	SFL
SL	SL
PL	PL
OP	OP

No irrigation.

SYSTEM 4 (S4)

INSTALLED JUNE 2021



DNL	SFL
SL	SL
PL	PL
OP	OP

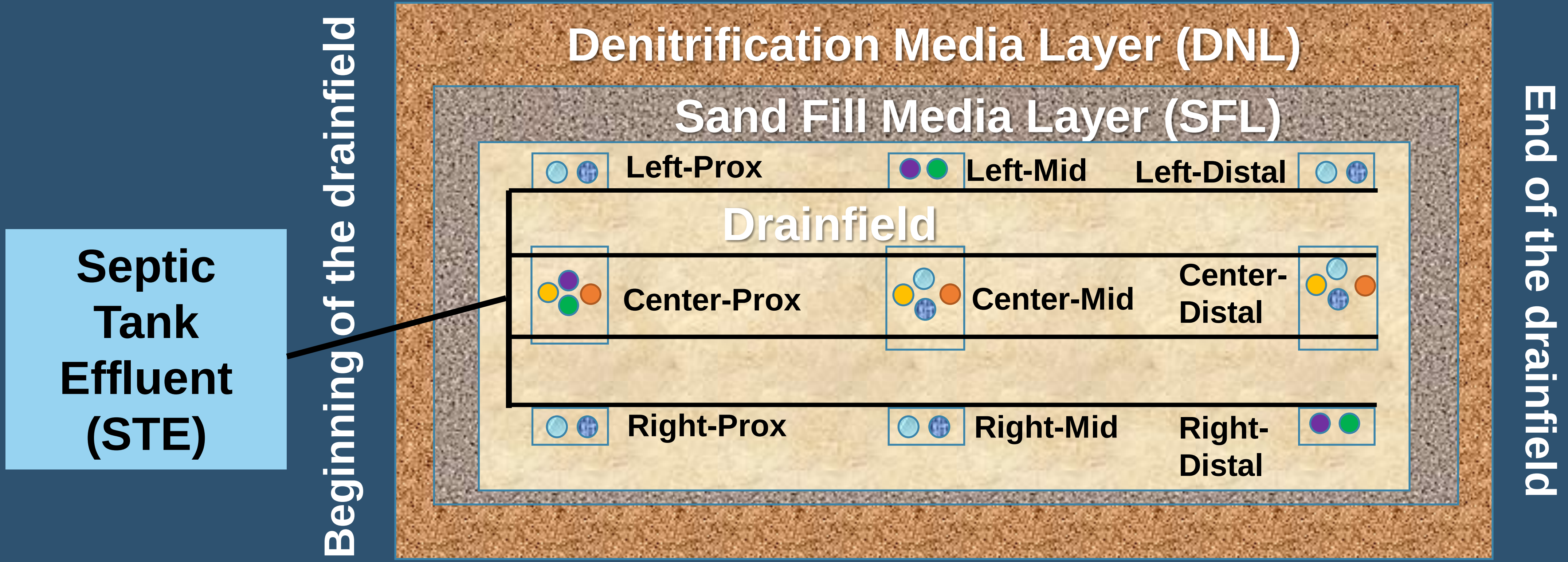
No irrigation.

PROPERTY CHARACTERISTICS

System	# of Bedrooms	Drainfield Size (square feet [ft^2])	Soil Type	# of Occupants	Mean Quarterly Average Daily Water Use (gallons per day [gpd])
S3	3	360	Fine Sand	1	18.3
S4	3	375	Fine Sand	4 - 5	726.8

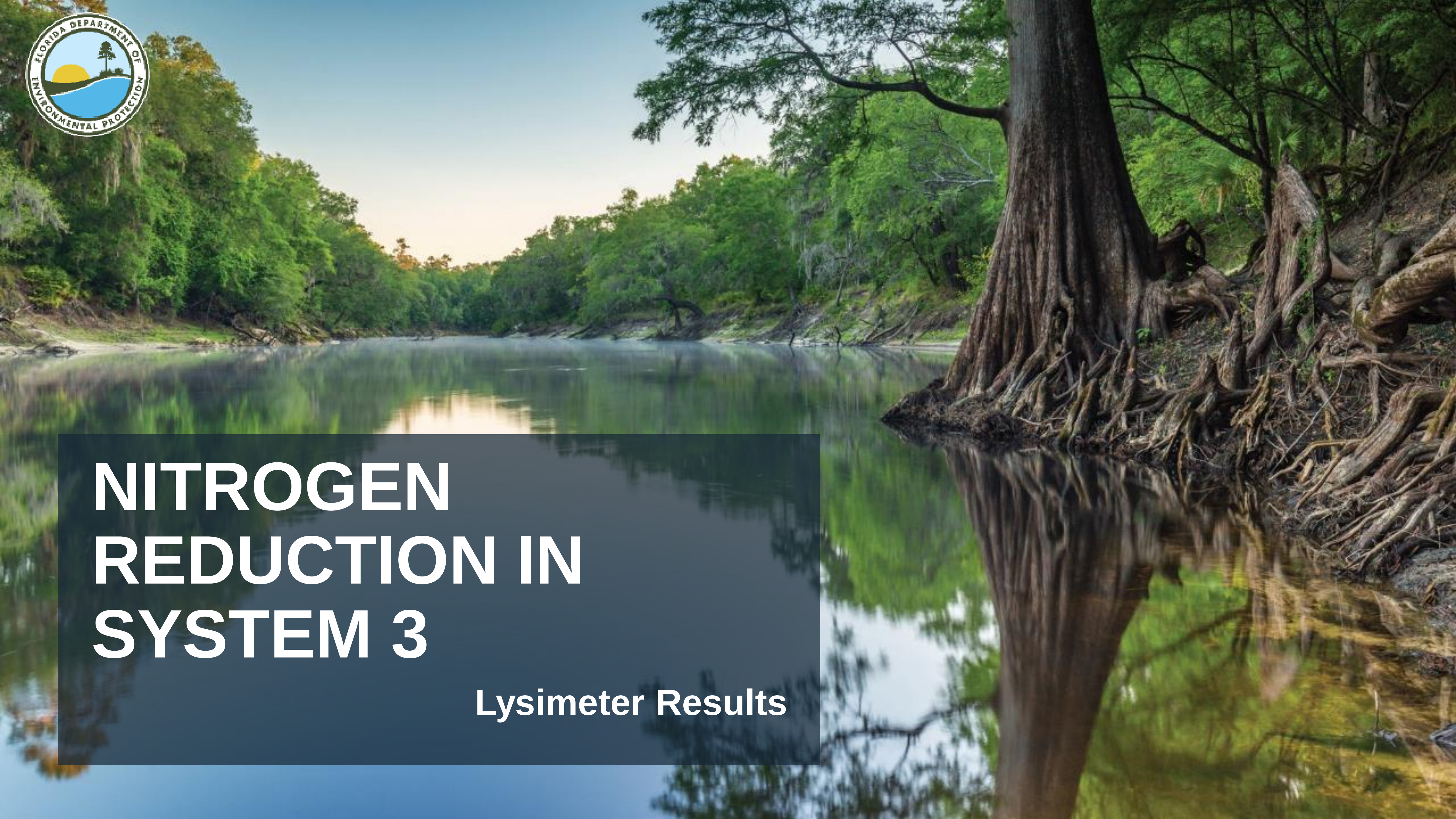
- Monitoring on both INRBs began in December 2021.
- Seven quarterly samplings had been conducted by the end of May 2023.

MONITORING EQUIPMENT ARRANGEMENT



DNL-SL SFL-SL DNL-PL SFL-PL SFL-OP DNL-OP

SL: Suction Lysimeter. **PL**: Pan Lysimeter. **OP**: Observation Port.

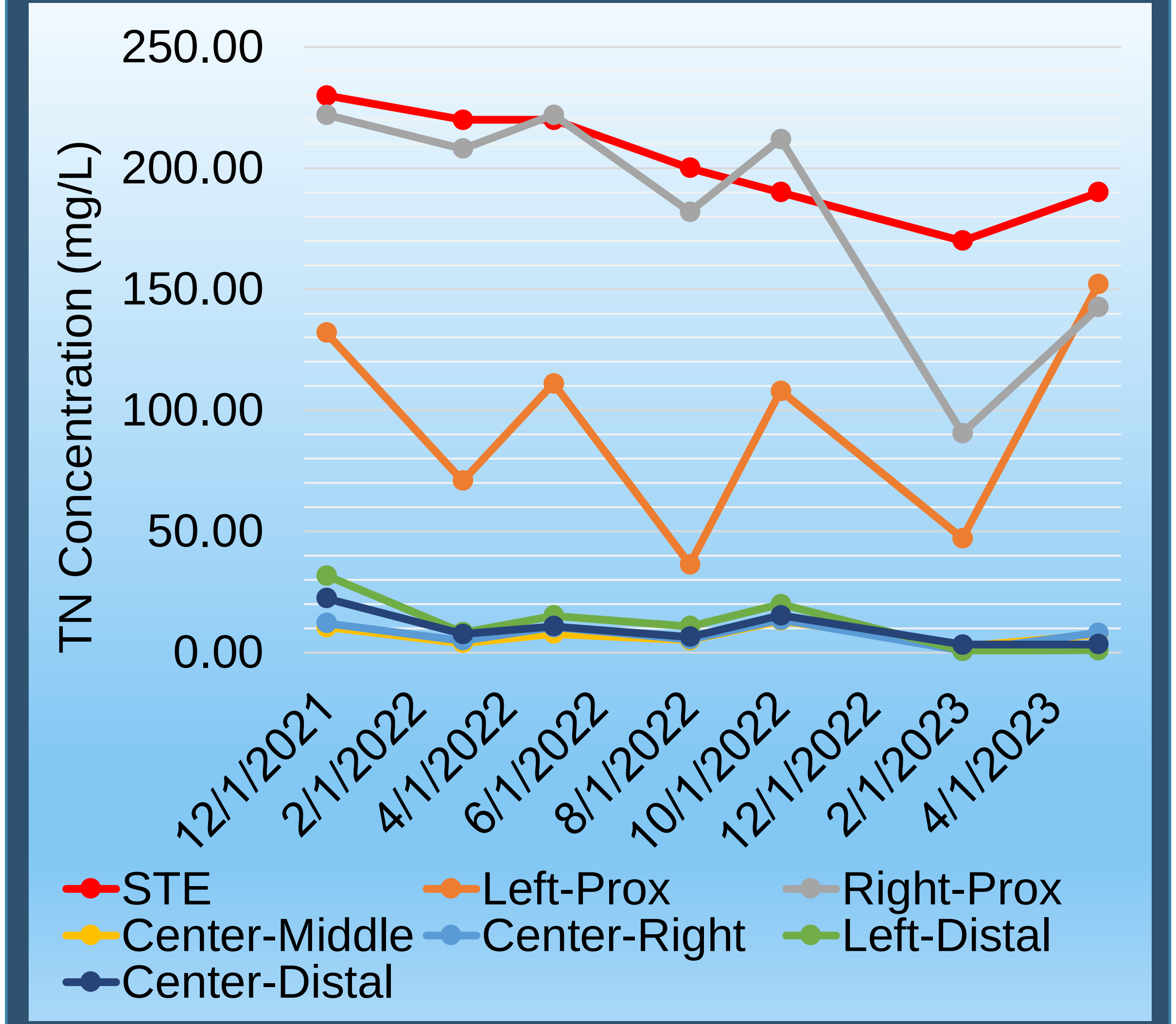


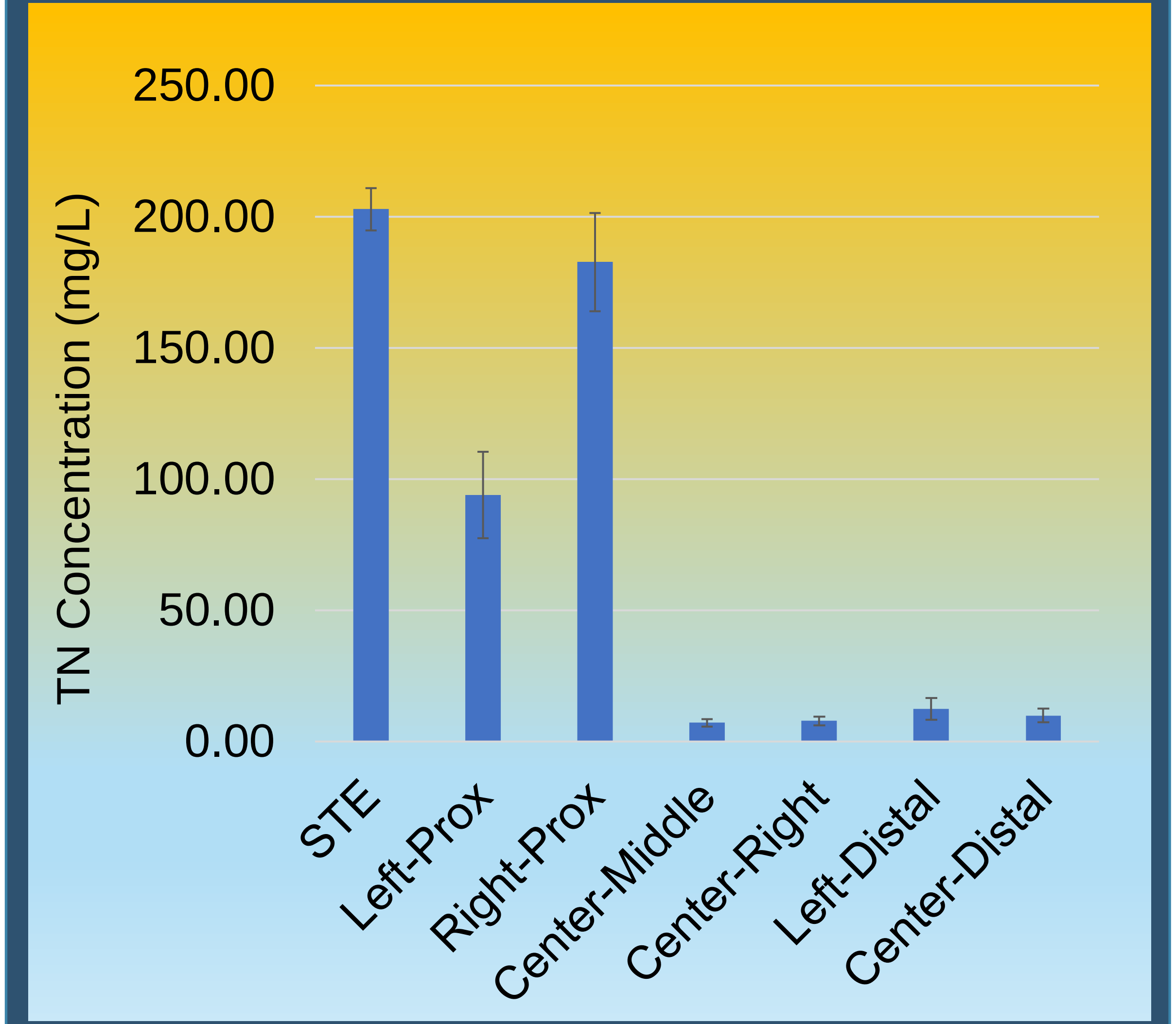
NITROGEN REDUCTION IN SYSTEM 3

Lysimeter Results

TOTAL NITROGEN CONCENTRATIONS

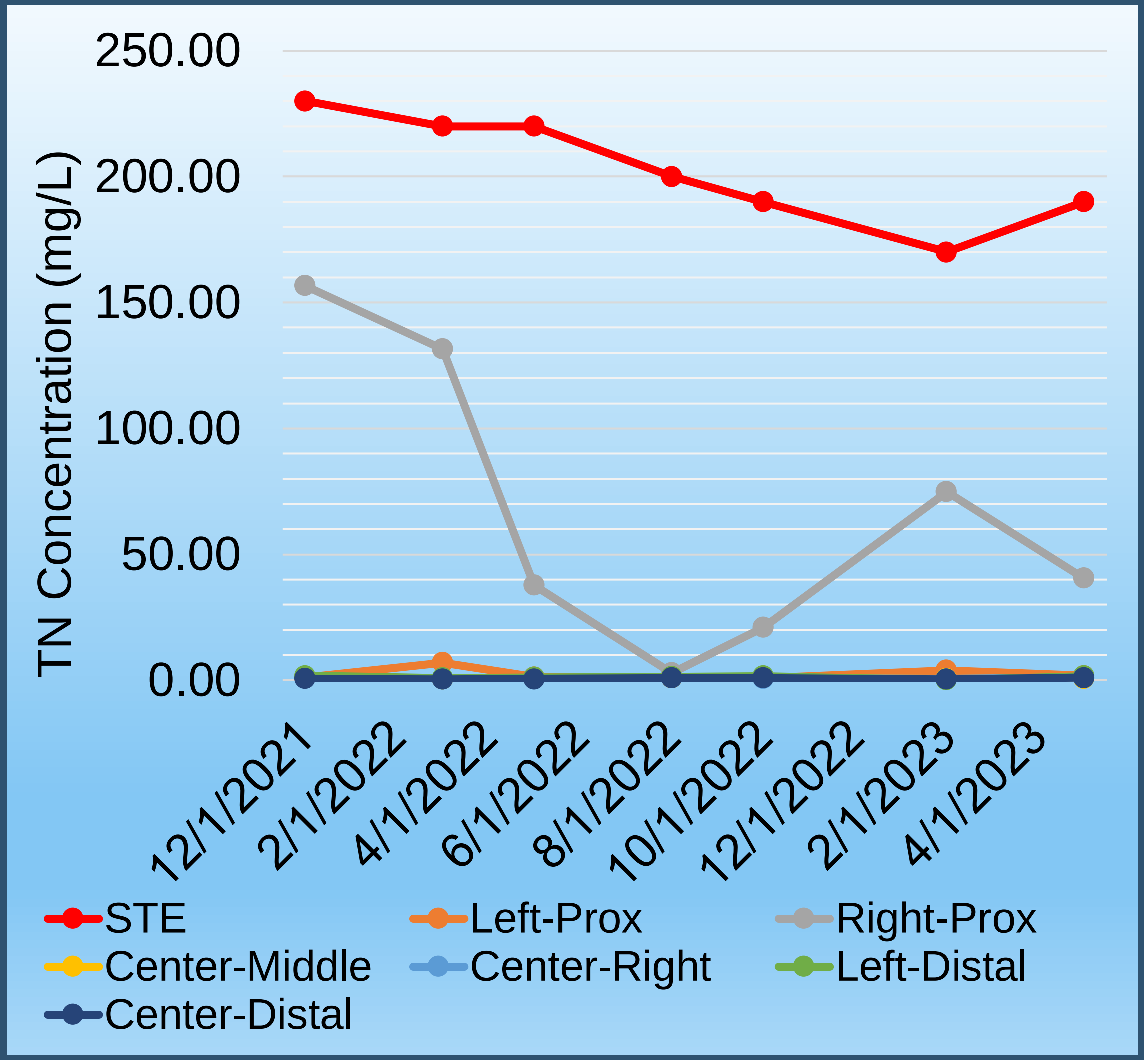
SYSTEM 3 – SFL EFFLUENT NOT ADJUSTED FOR DILUTION

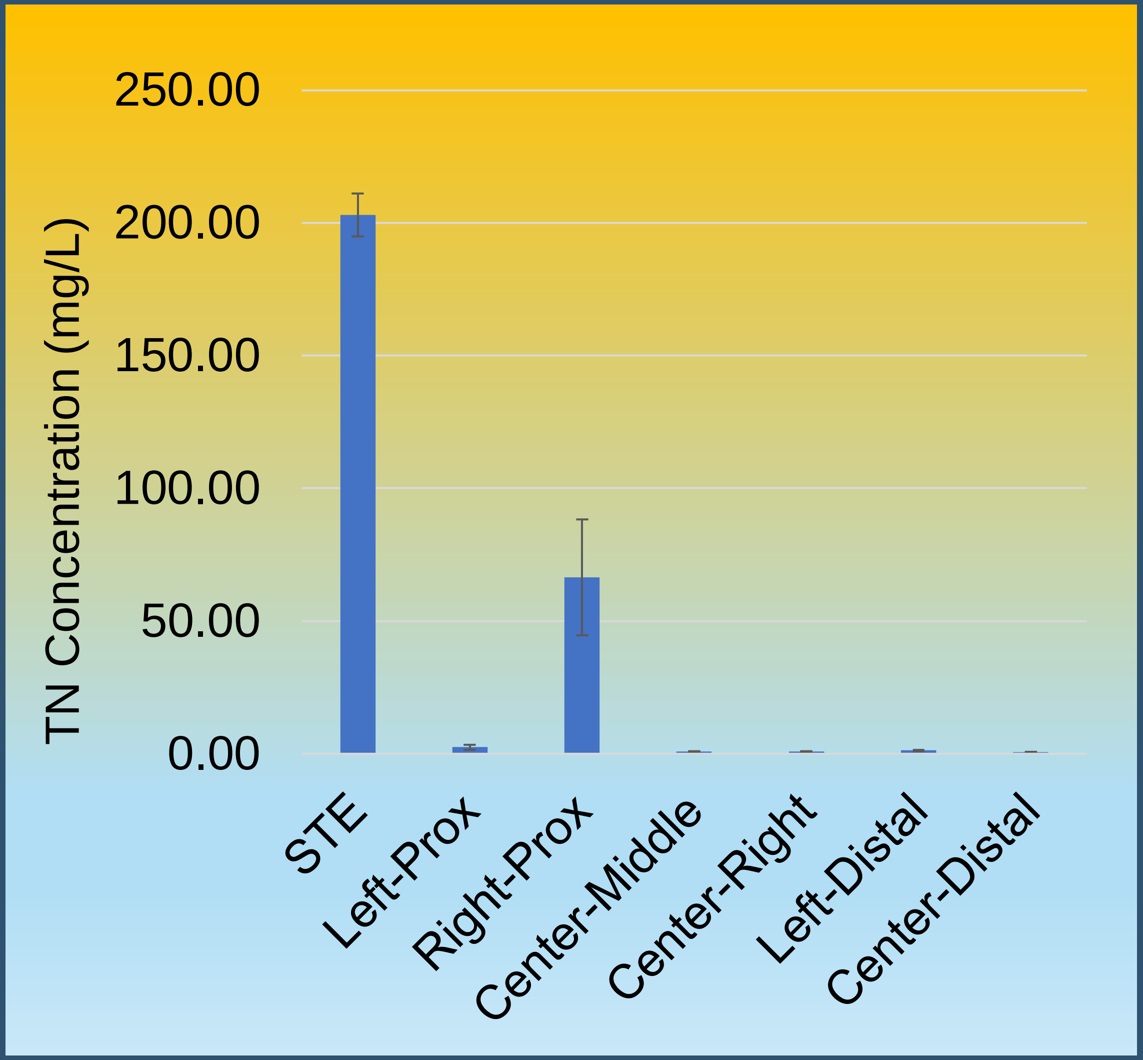




TOTAL NITROGEN CONCENTRATIONS (2)

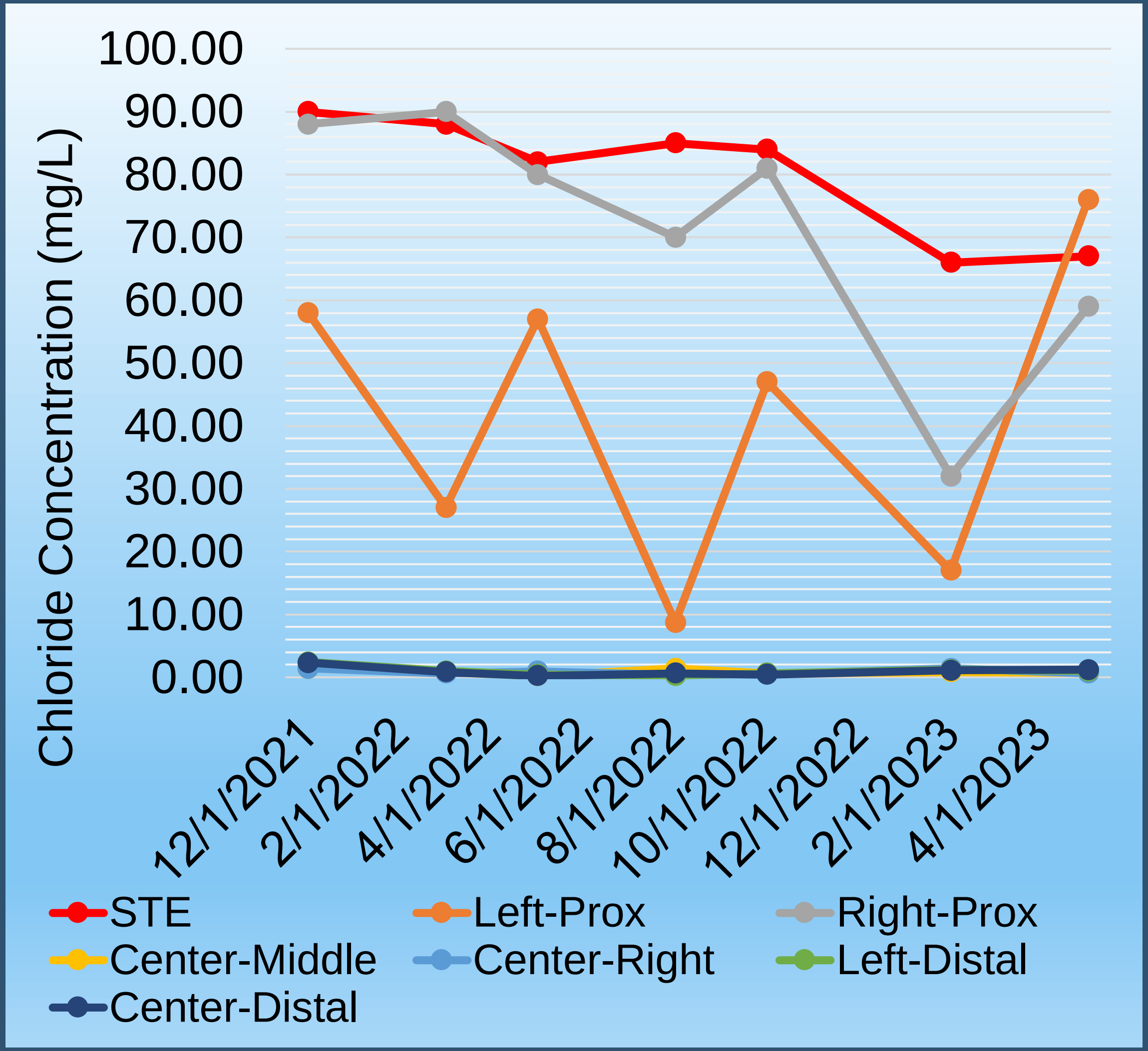
SYSTEM 3 – DNL EFFLUENT NOT ADJUSTED FOR DILUTION

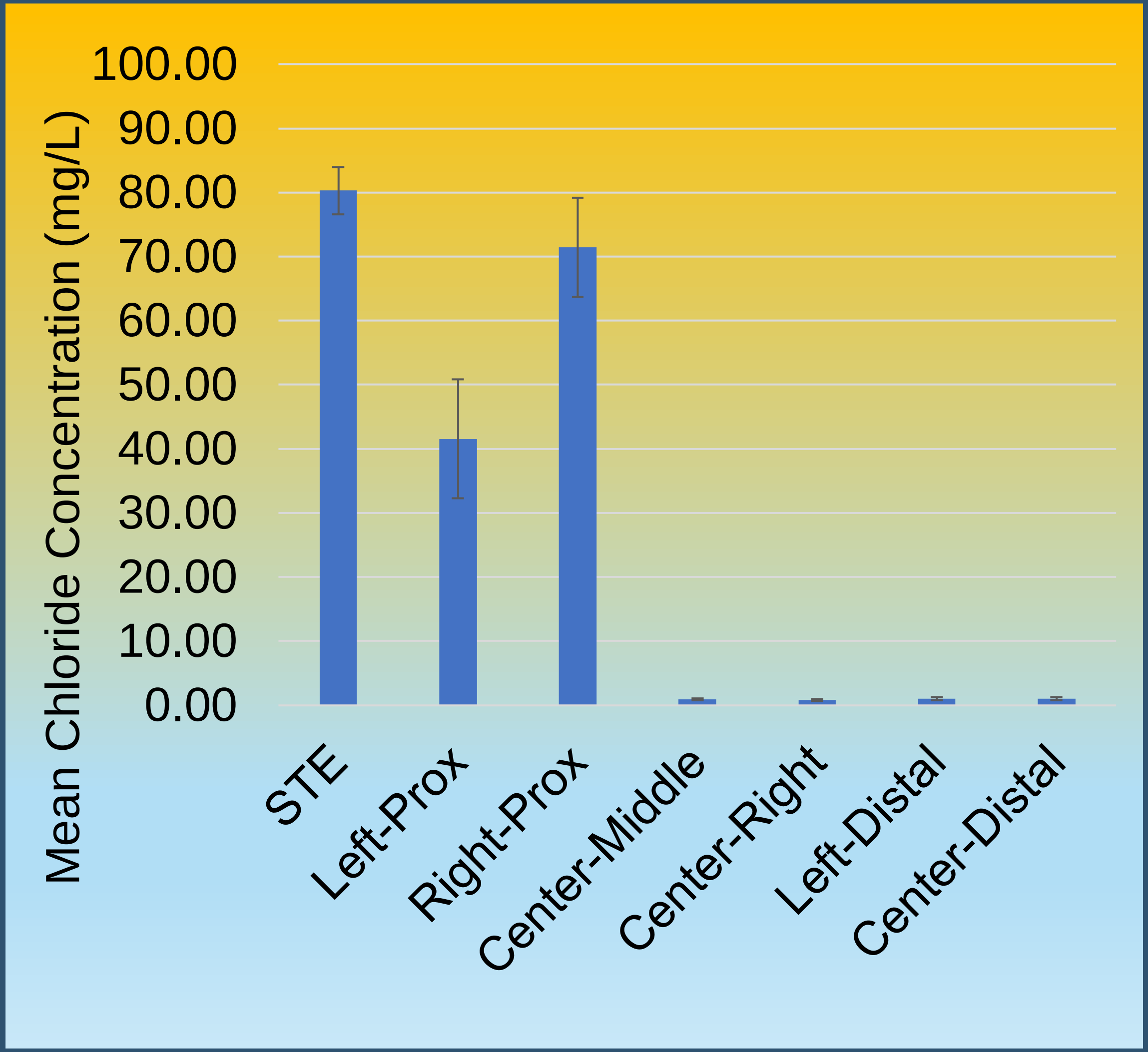




CHLORIDE CONCENTRATION (2)

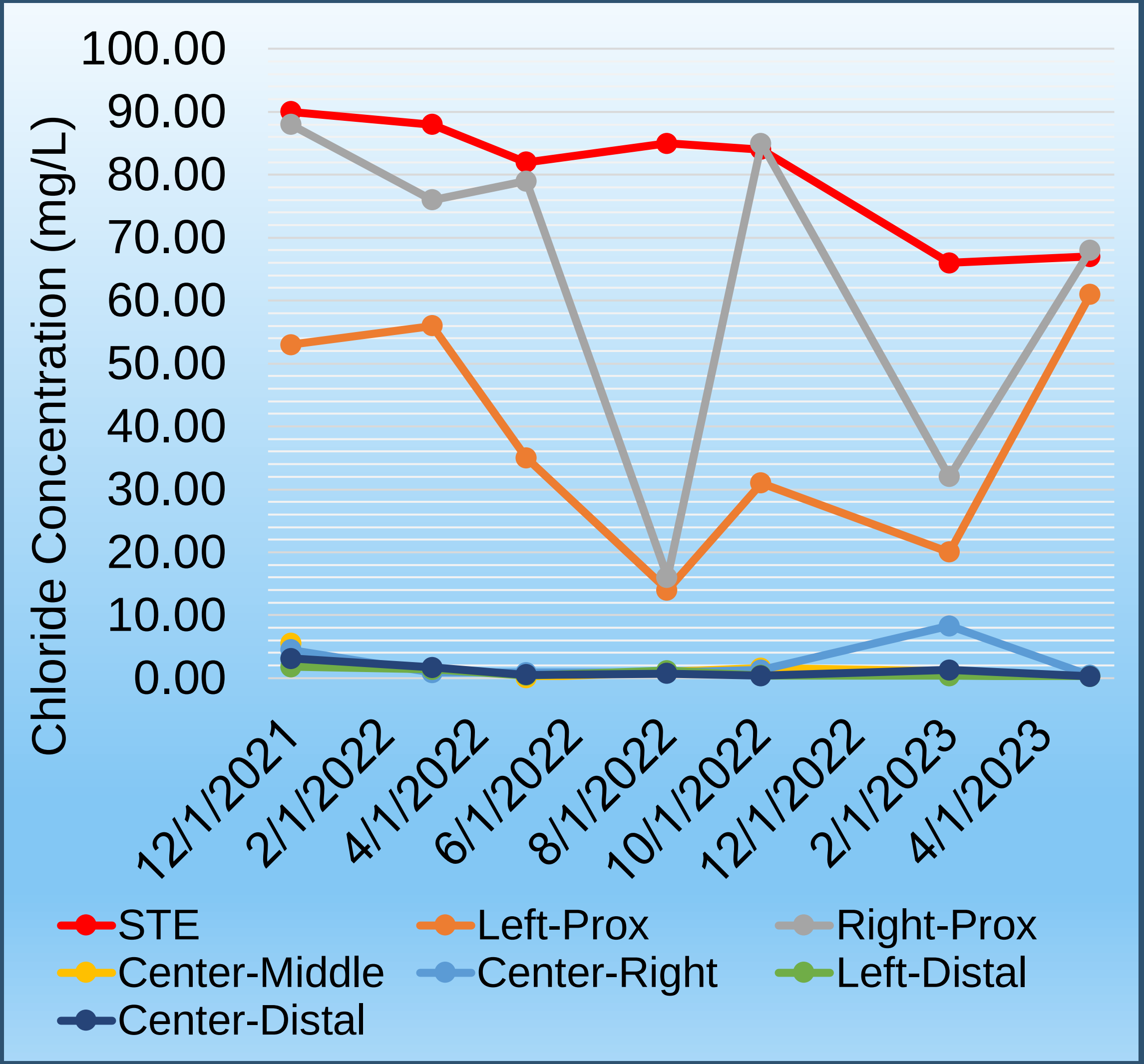
SYSTEM 3 – SFL MEDIA EFFLUENT

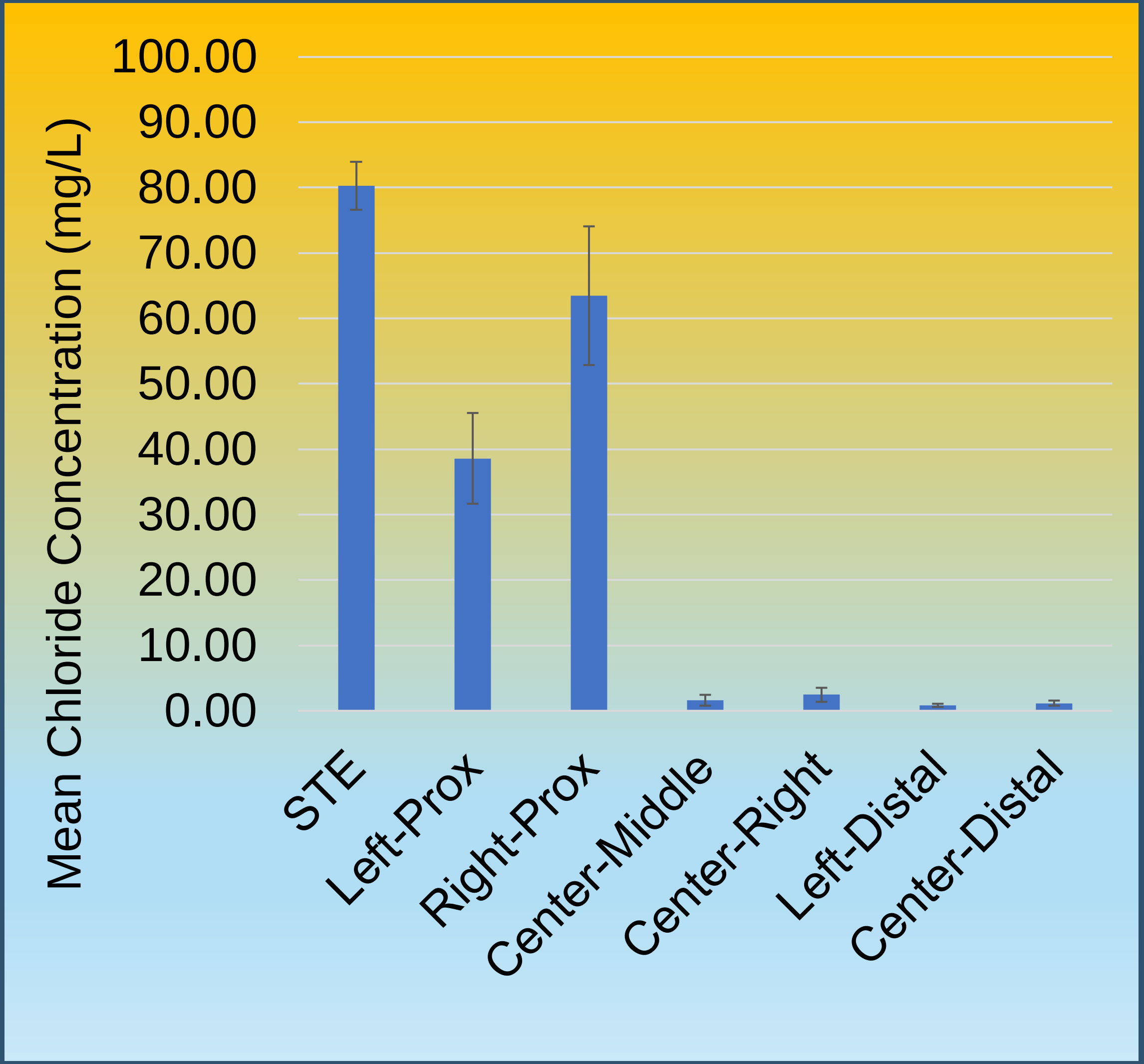




CHLORIDE CONCENTRATION (2)

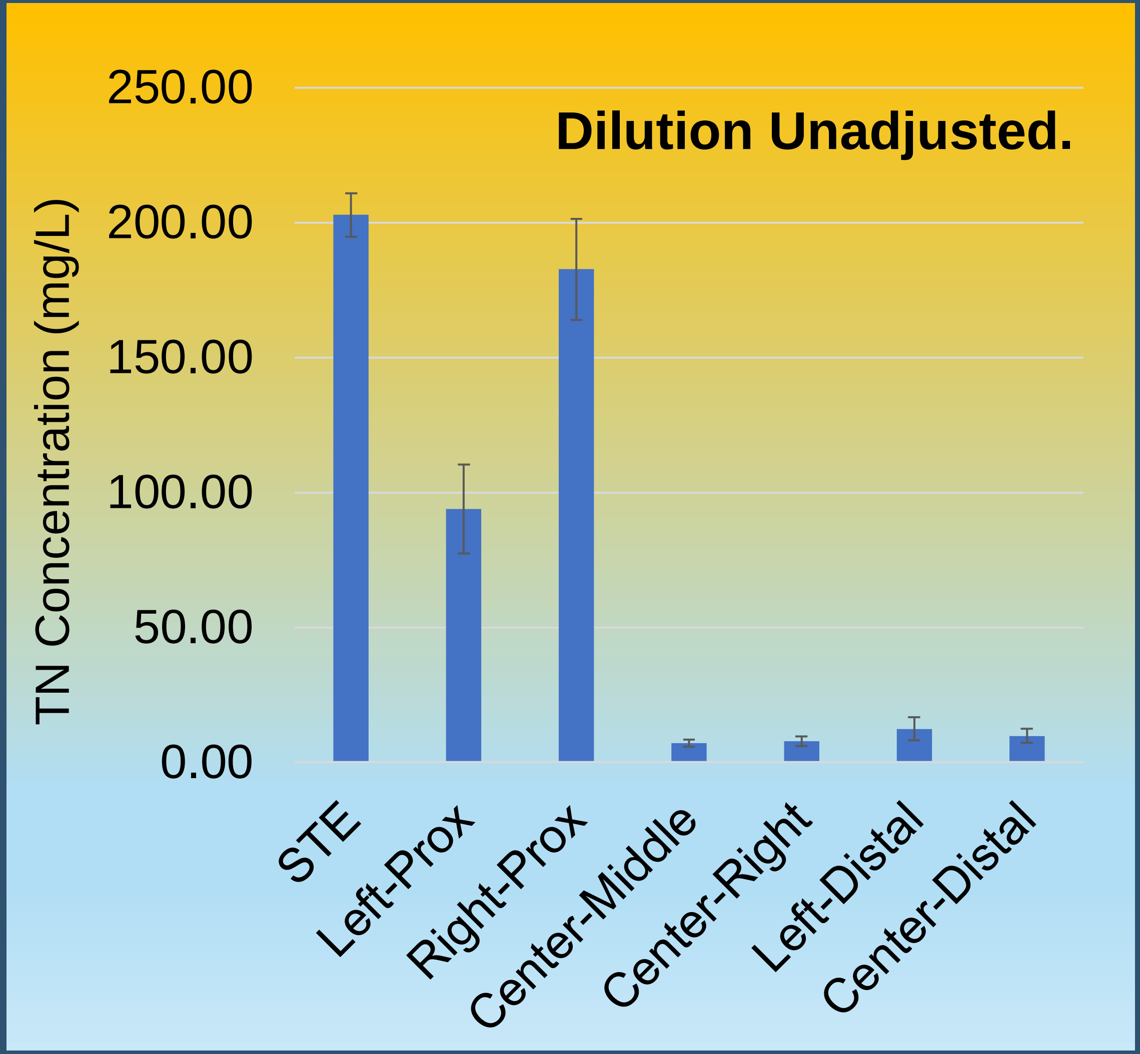
SYSTEM 3 – DNL MEDIA EFFLUENT

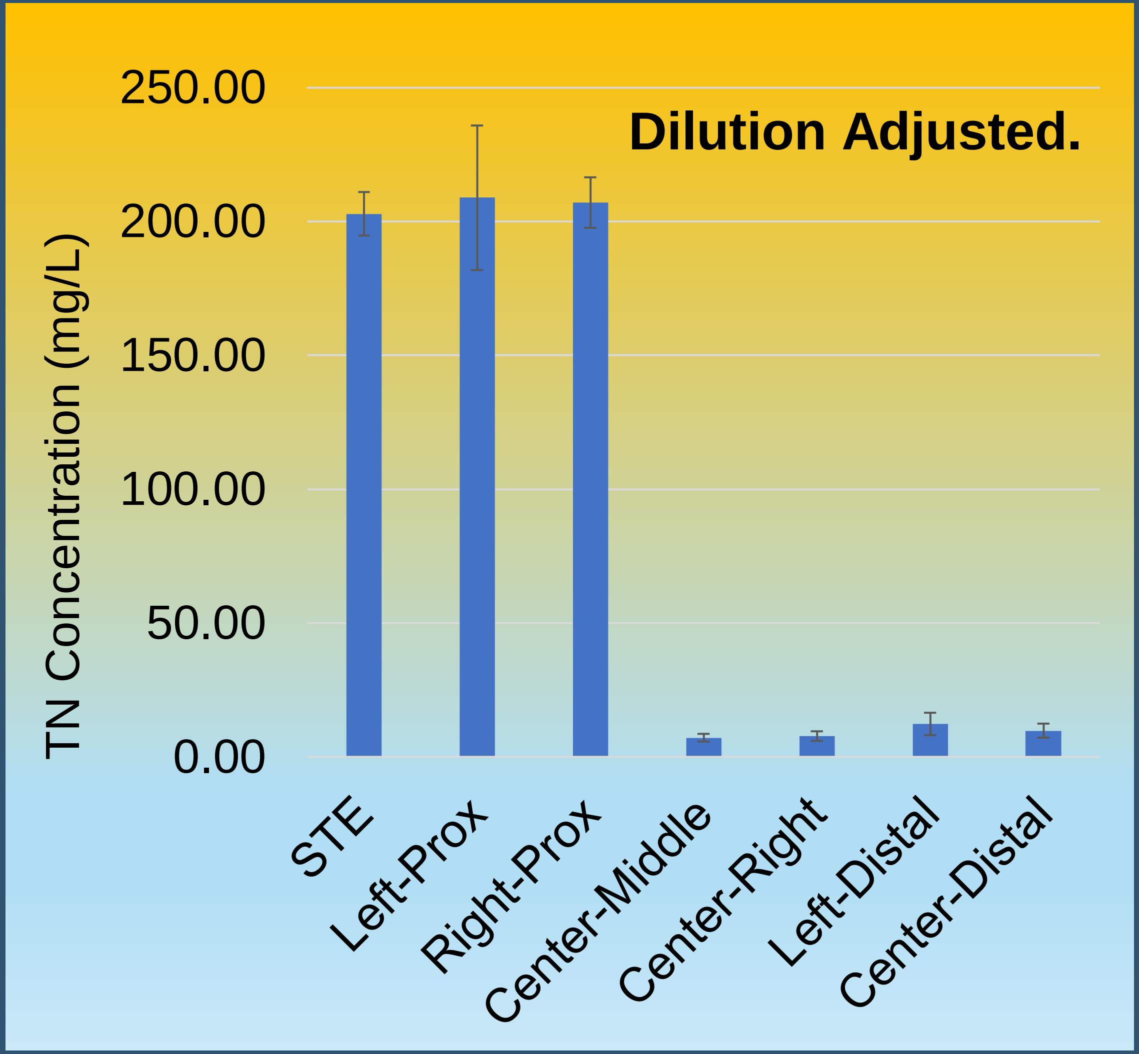




AVERAGE NITROGEN CONCENTRATIONS

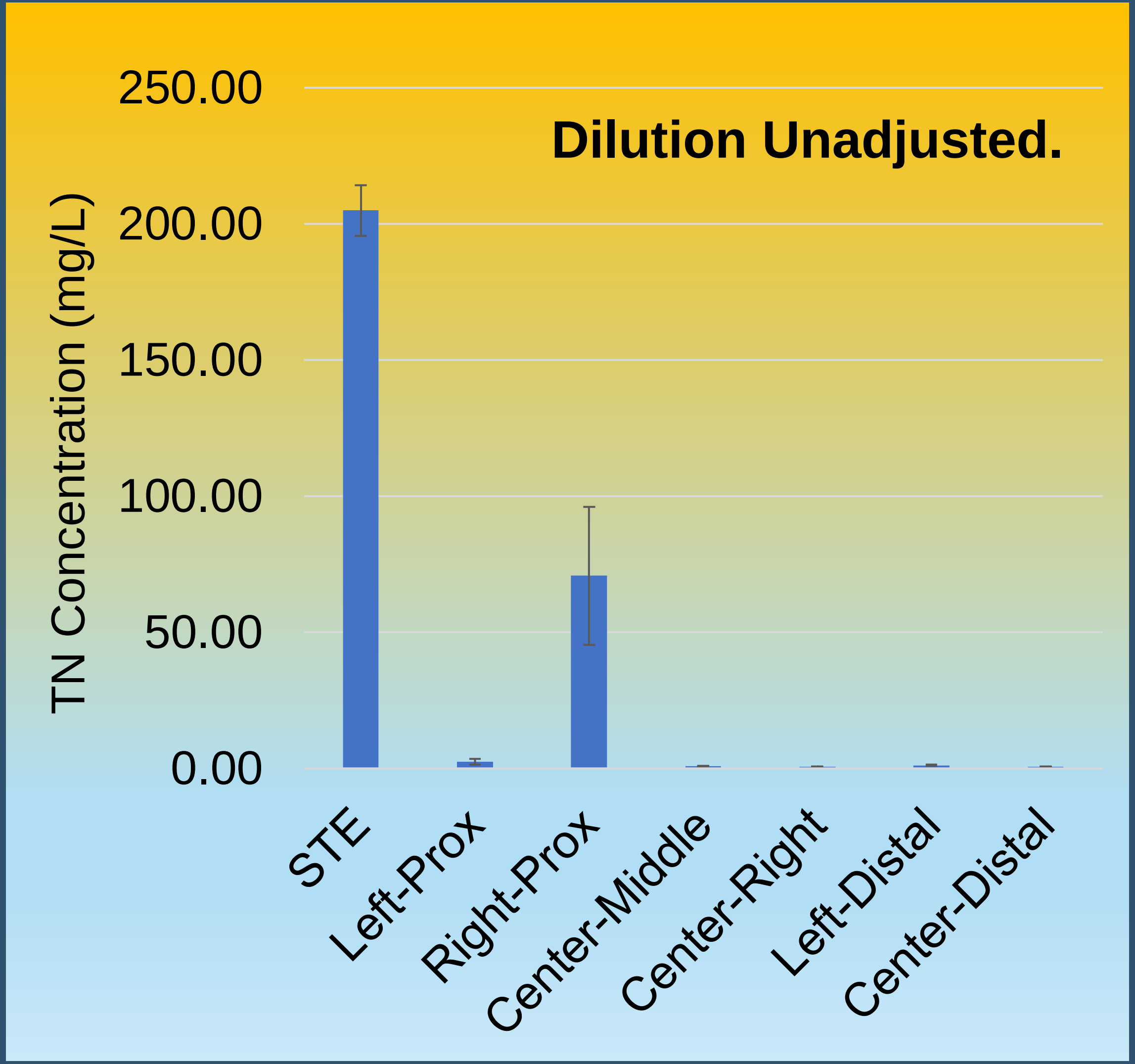
SYSTEM 3 – SFL MEDIA EFFLUENT

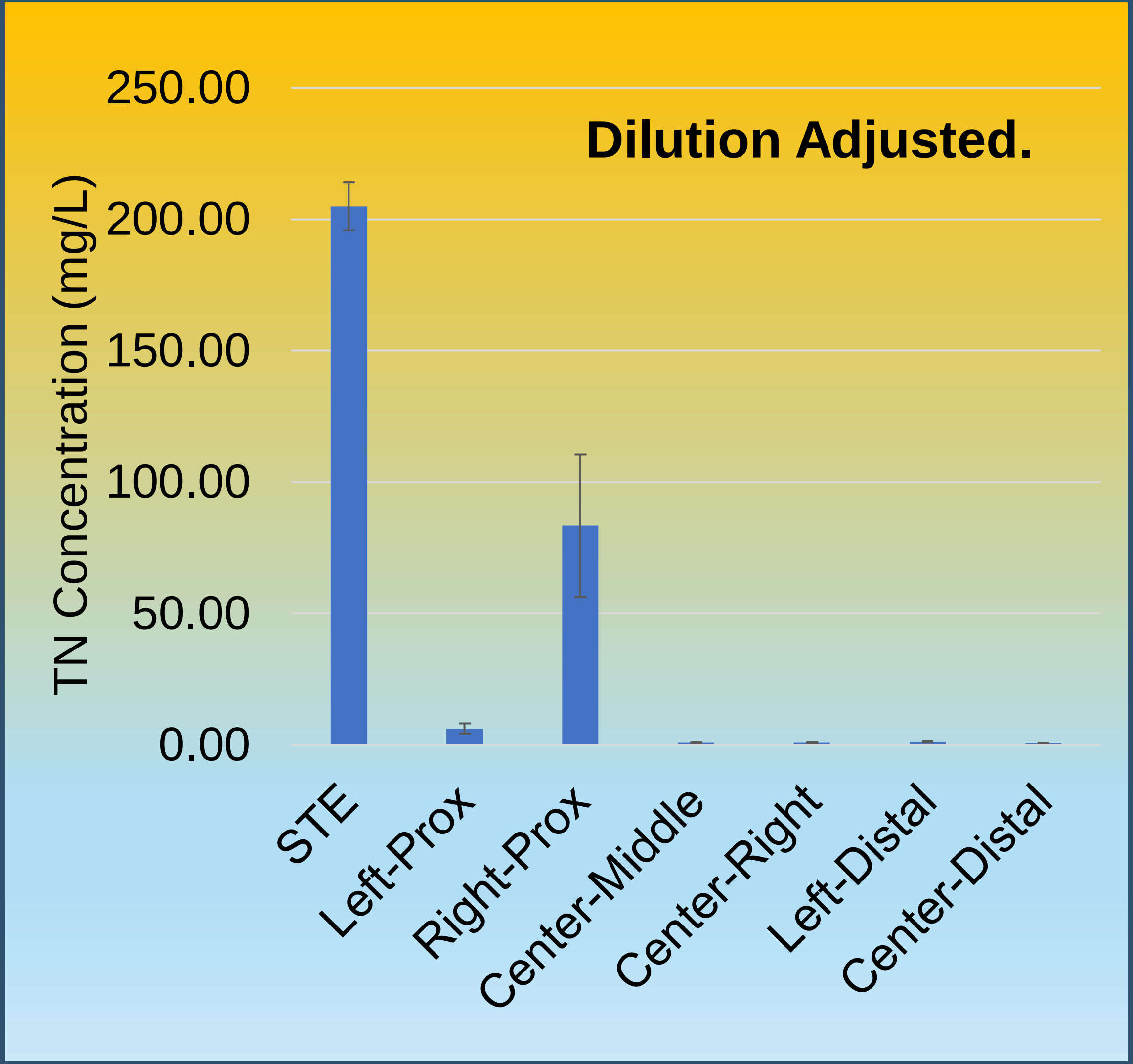




AVERAGE NITROGEN CONCENTRATIONS (2)

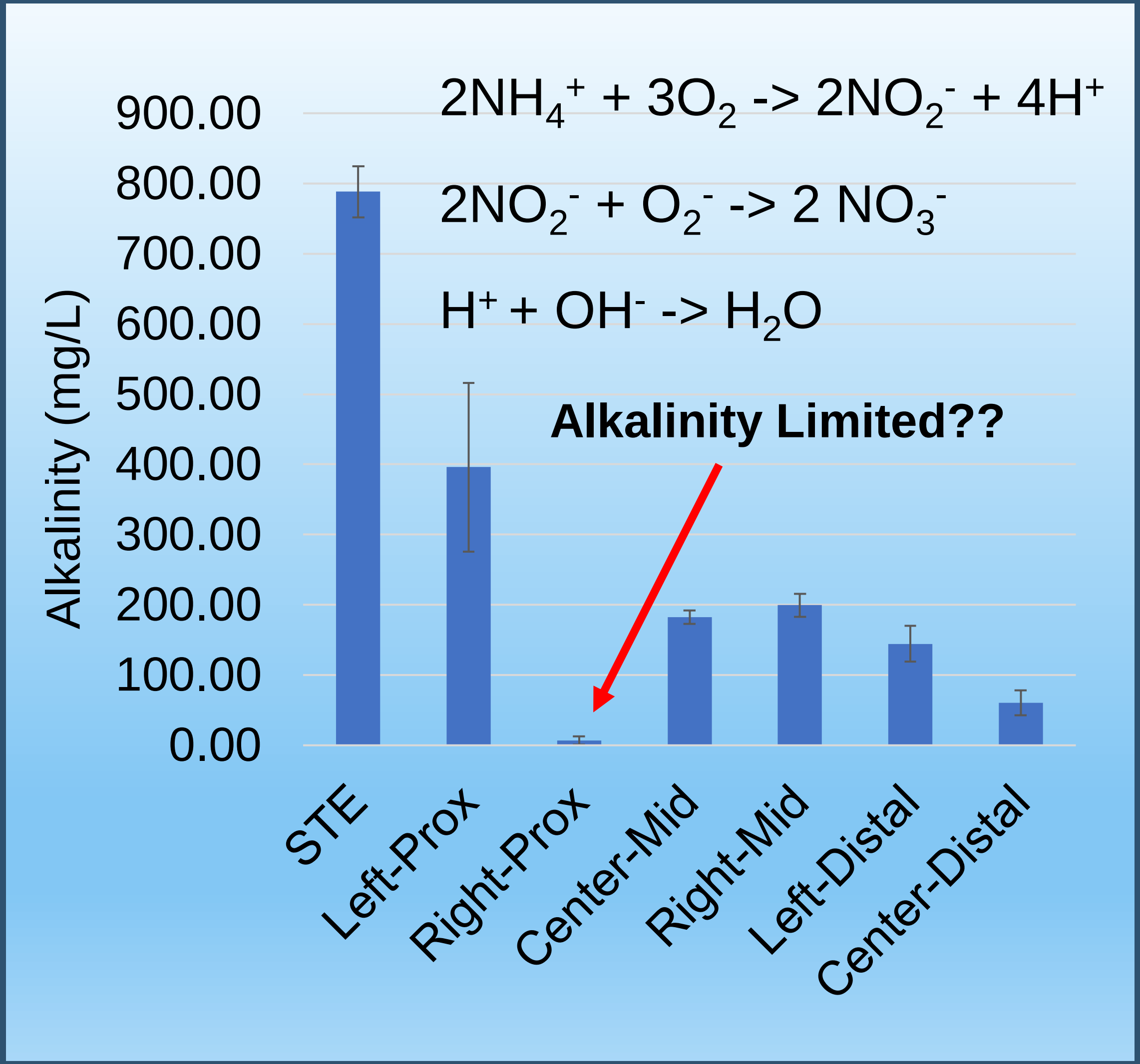
SYSTEM 3 – DNL EFFLUENT

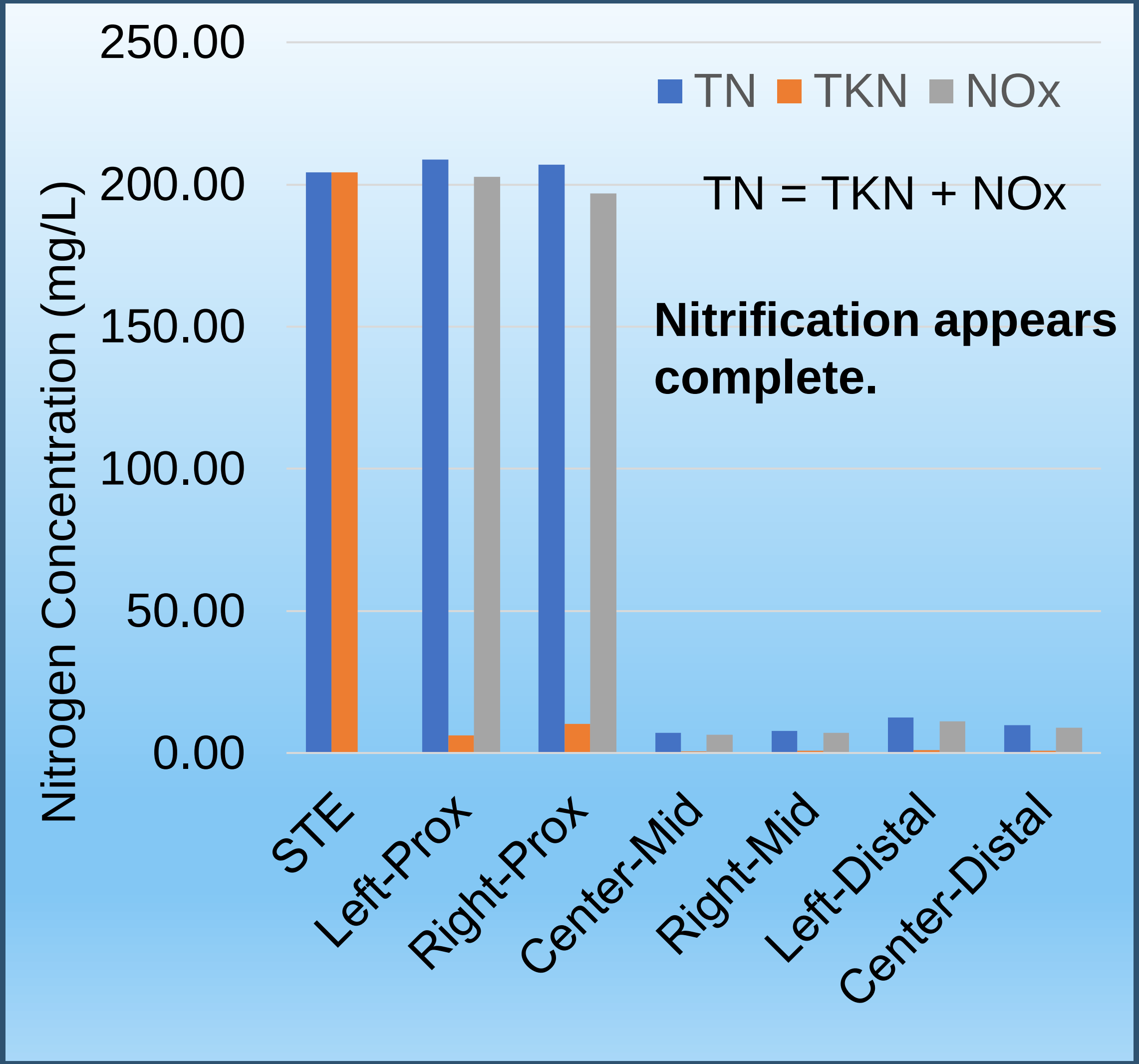




FACTORS IMPACTING NITROGEN REMOVAL

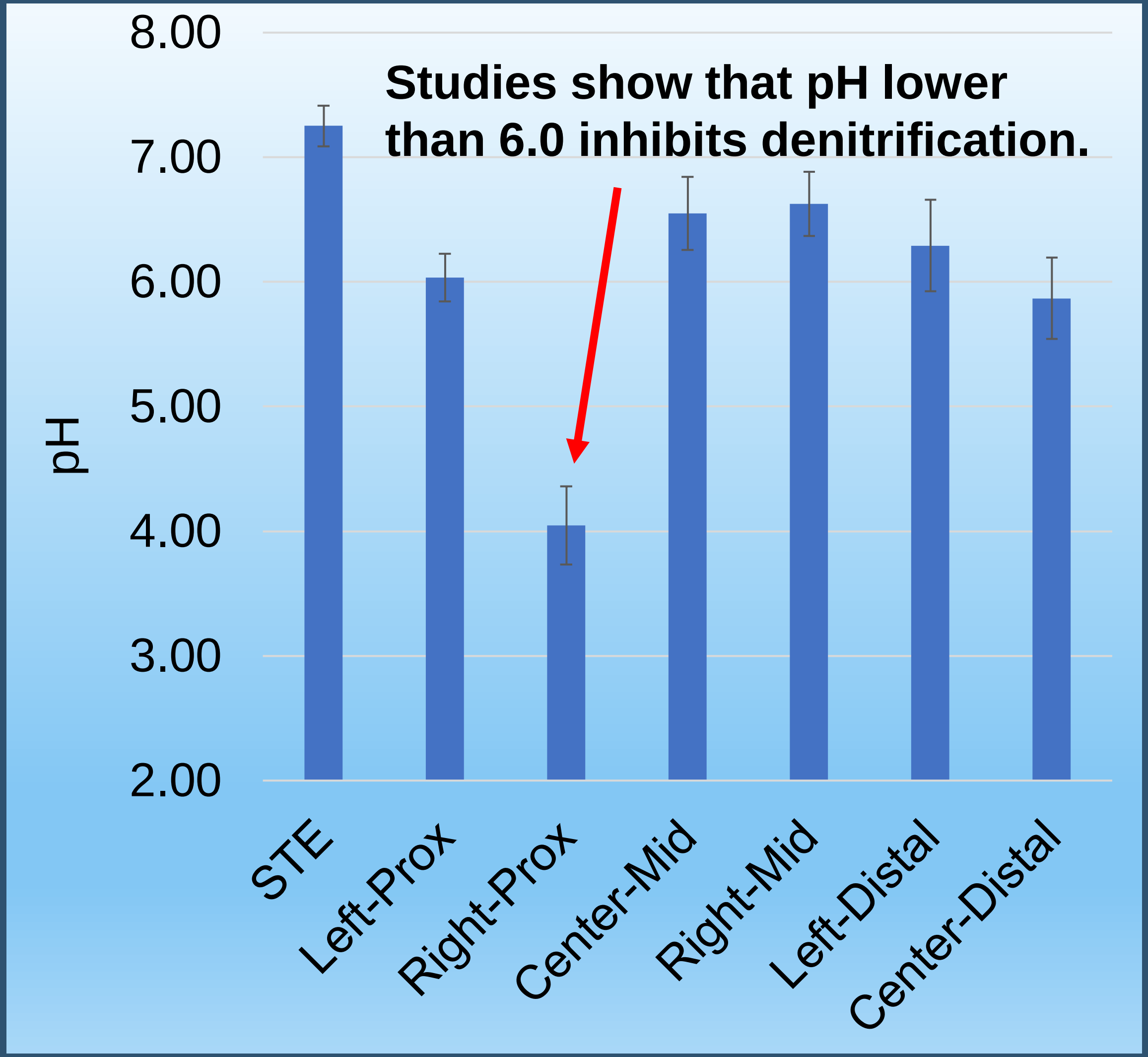
SYSTEM 3 – SFL EFFLUENT

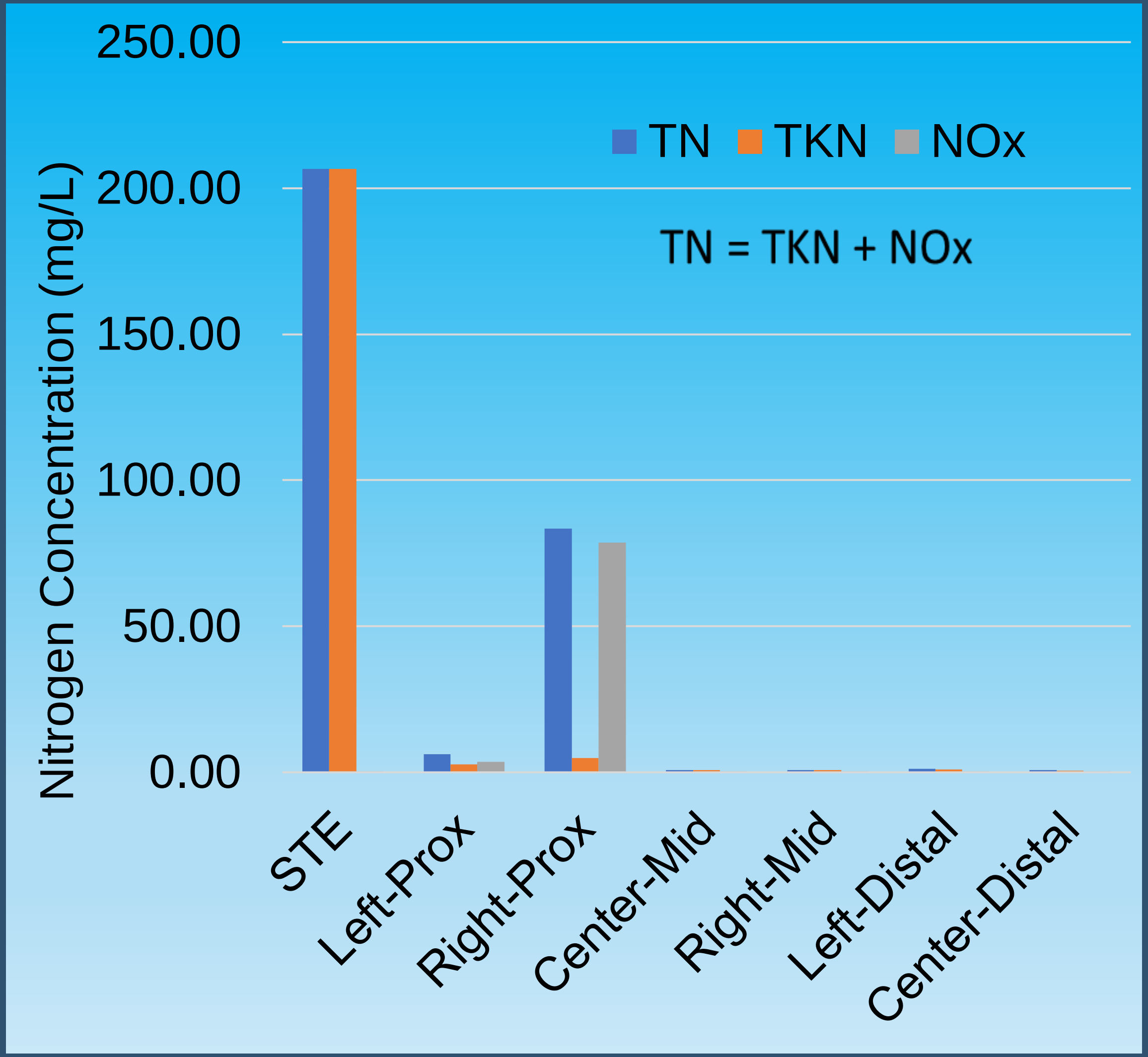




LOW PH INHIBITS DENITRIFICATION?

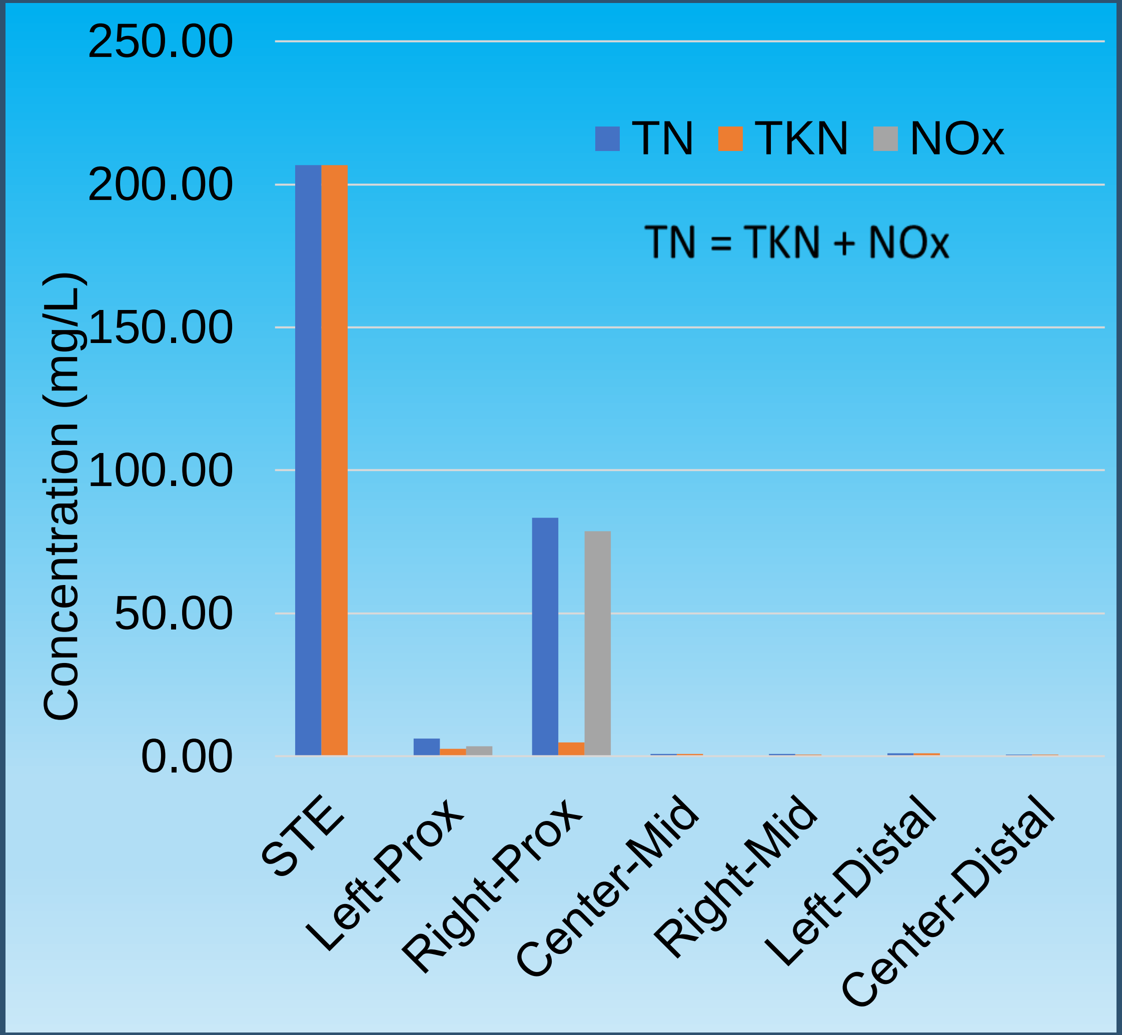
SYSTEM 3 – DNL MEDIA EFFLUENT





AVERAGE NITROGEN REDUCTION EFFICIENCY

SYSTEM 3



Sampling Events	STE (mg/L)	Left-Prox (mg/L)	Right-Prox (mg/L)	Left-Prox N-Removal Efficiency	Right-Prox N-Removal Efficiency
12/8/2021	230.01	1.70	160.26	99.3%	30.3%
3/2/2022	220.01	10.98	152.38	95.0%	30.7%
5/25/2022	220.00	3.09	39.13	98.6%	82.2%
8/24/2022	200.07	5.65	15.62	97.2%	92.2%
10/19/2022	200.07	2.36	21.00	98.8%	89.5%
2/22/2023	170.00	12.97	112.20	92.4%	34.0%
5/24/2023	190.01	1.88	3.45	99.0%	98.2%
Mean	**204.31**	**5.52**	**72.01**	**97.2%**	**65.3%**
SE*	**7.82**	**1.75**	**25.55**	**1.0%**	**12.0%**

Overall mean nitrogen reduction efficiency: **81.2%.**

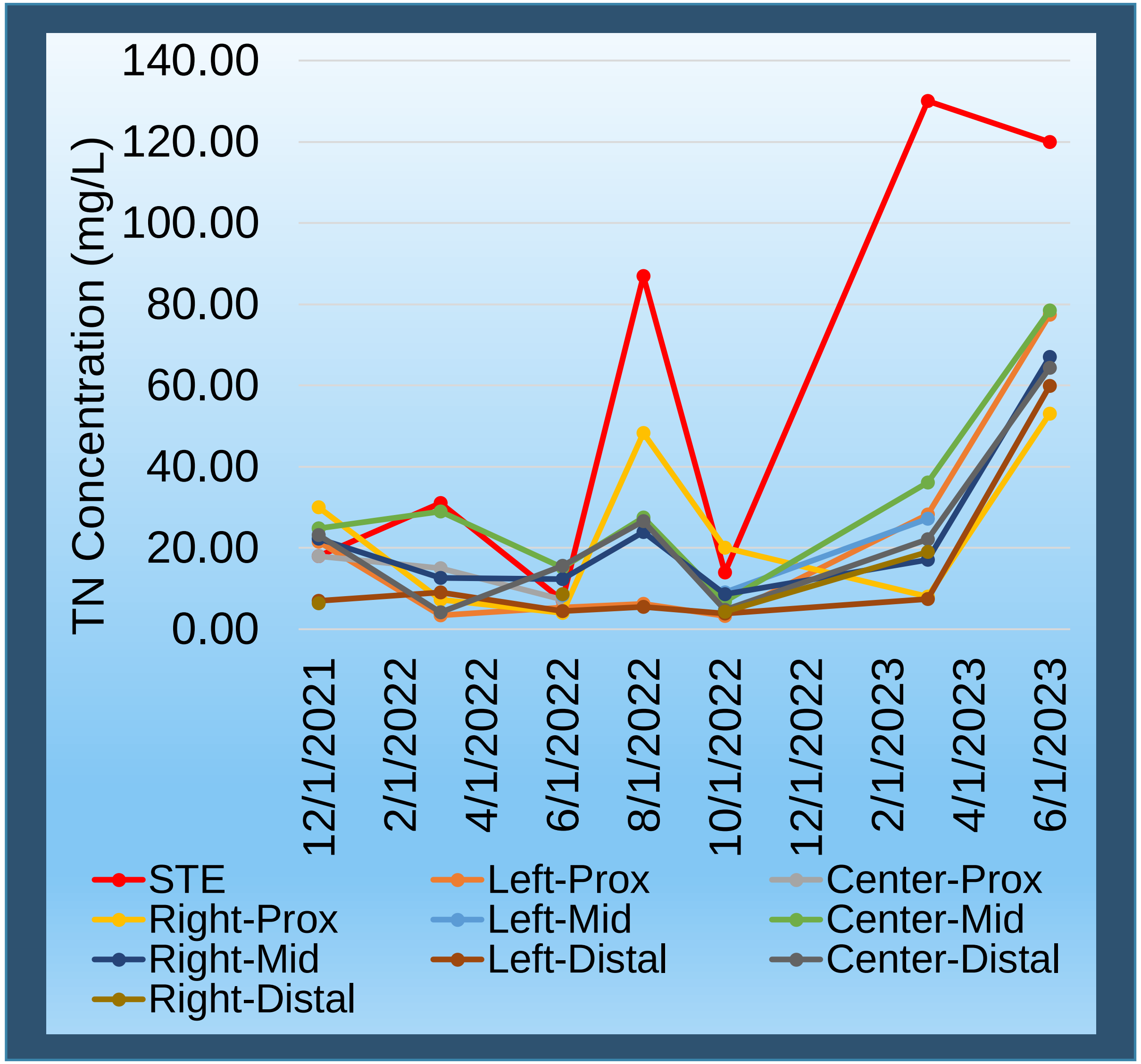
*SE: Standard Error.

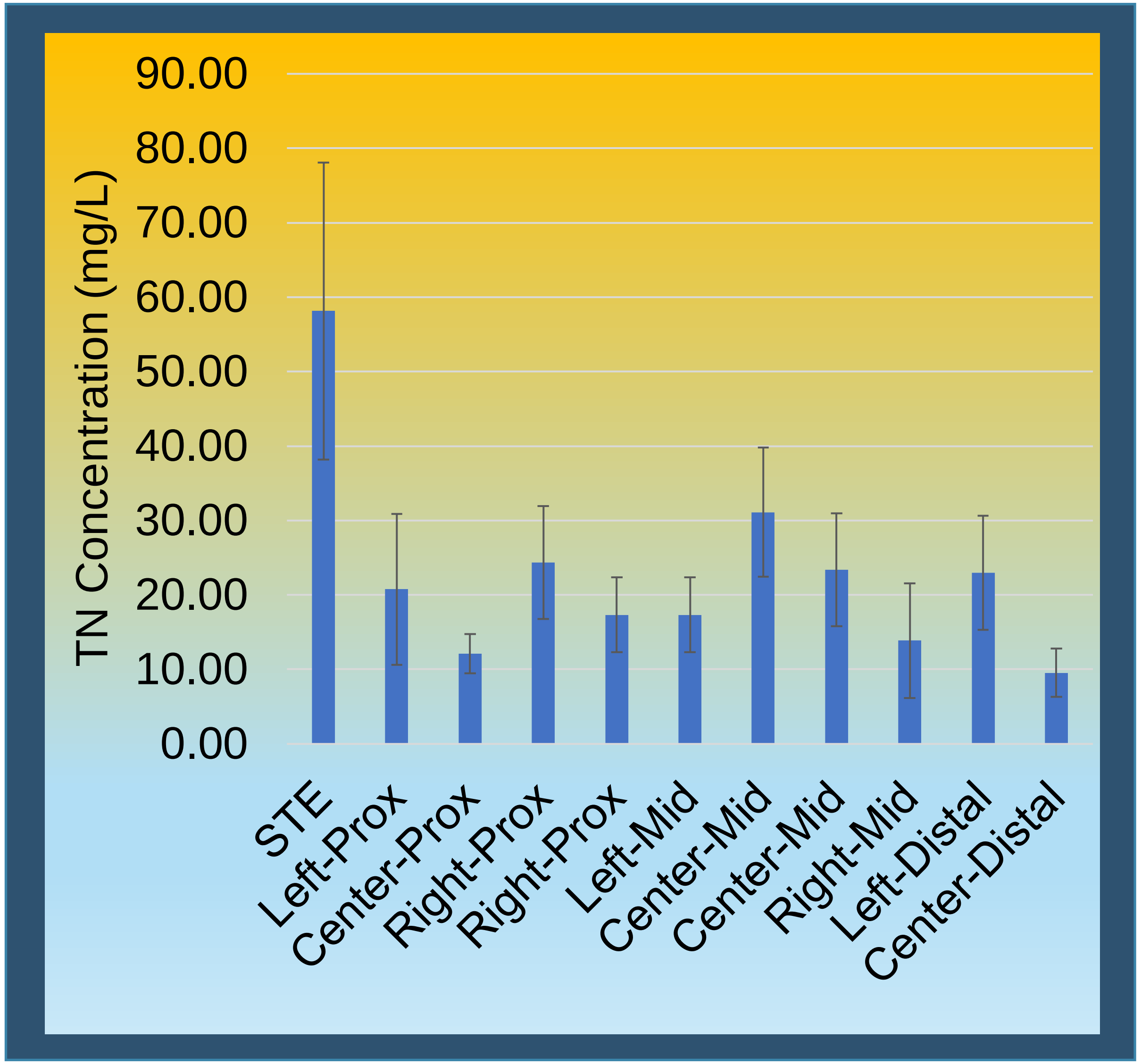
NITROGEN REDUCTION IN SYSTEM 4

Lysimeter Results

TOTAL NITROGEN CONCENTRATIONS

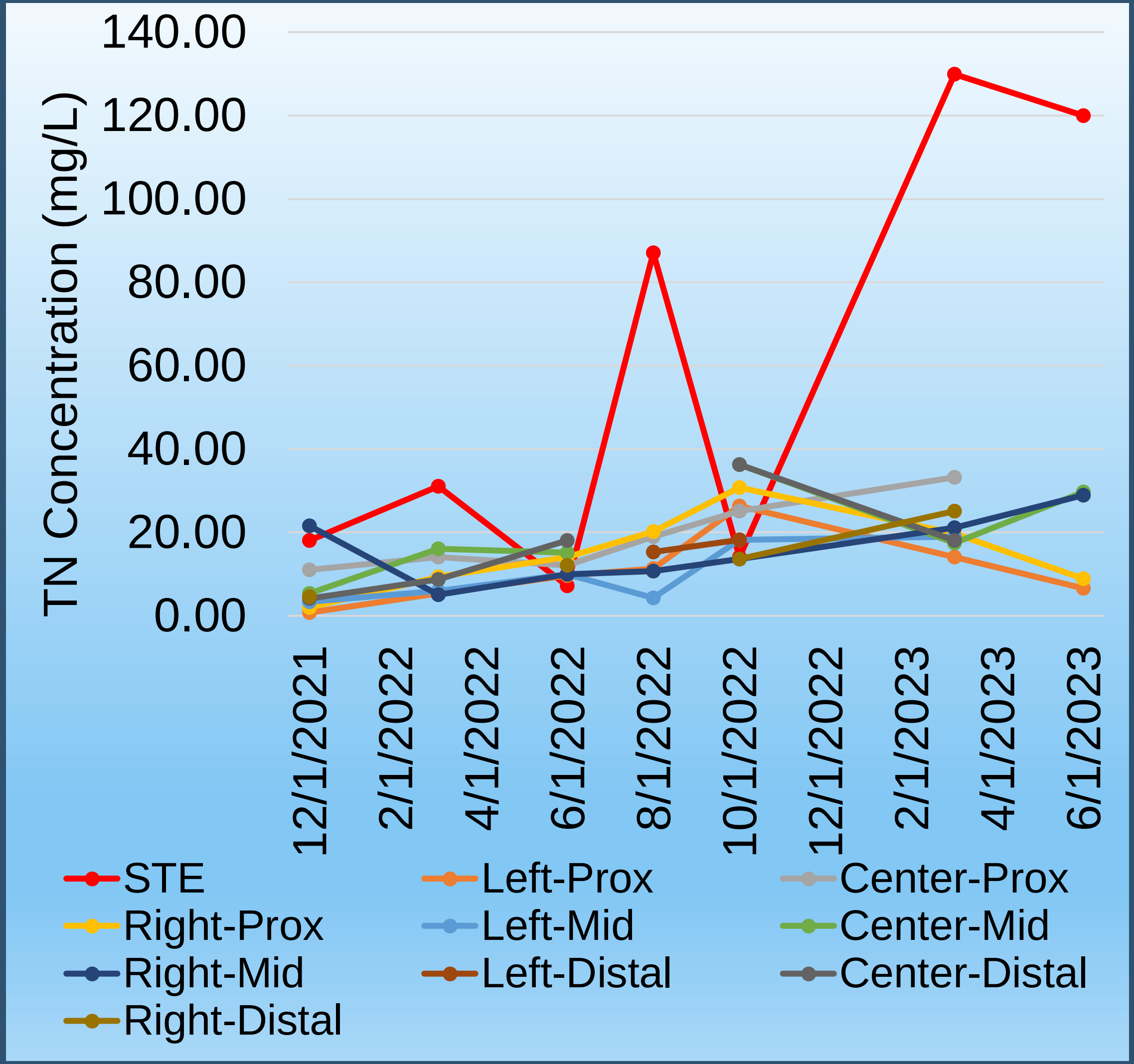
SYSTEM 4 – SFL MEDIA EFFLUENT NOT ADJUSTED FOR DILUTION

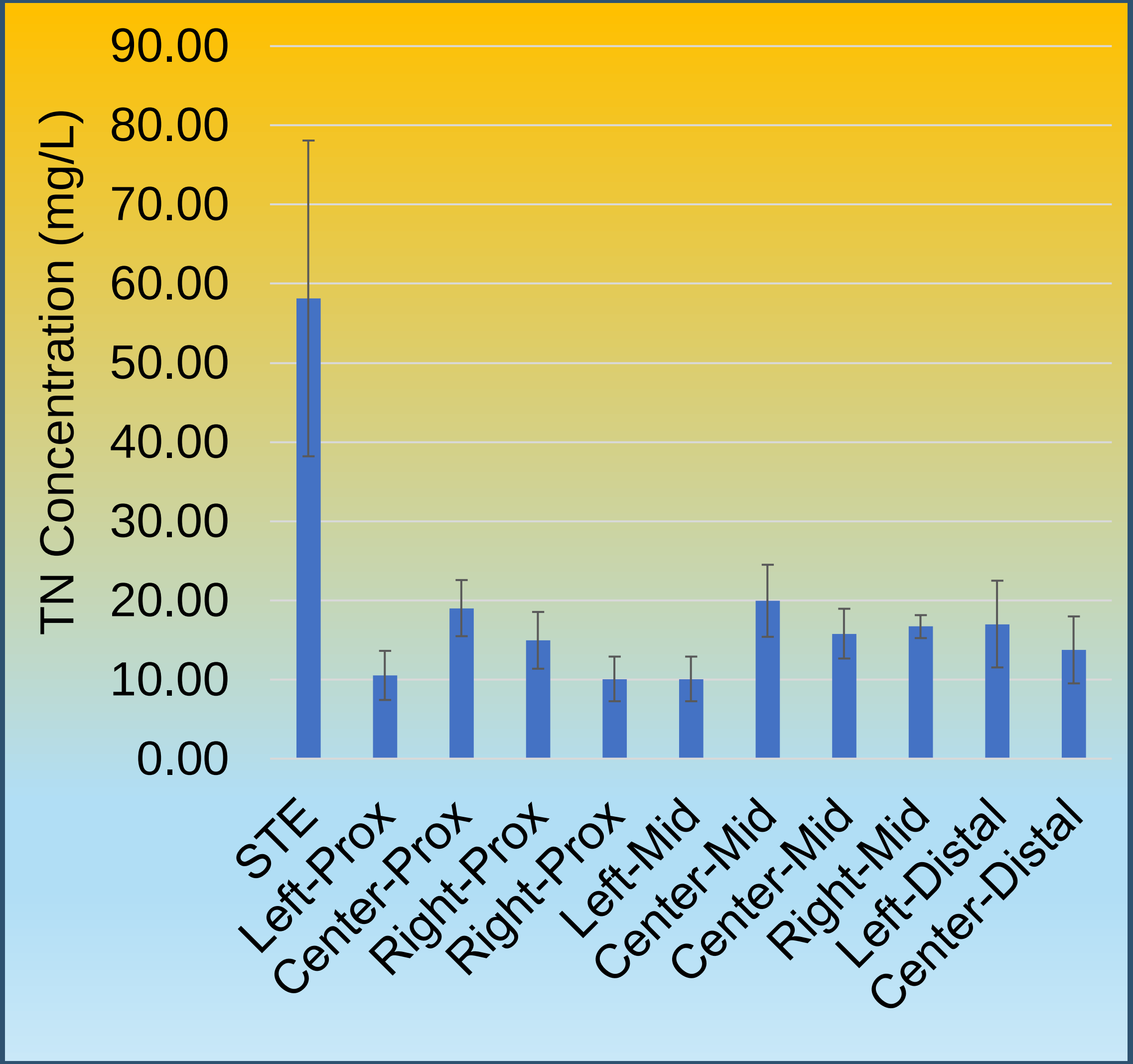




TOTAL NITROGEN CONCENTRATIONS (2)

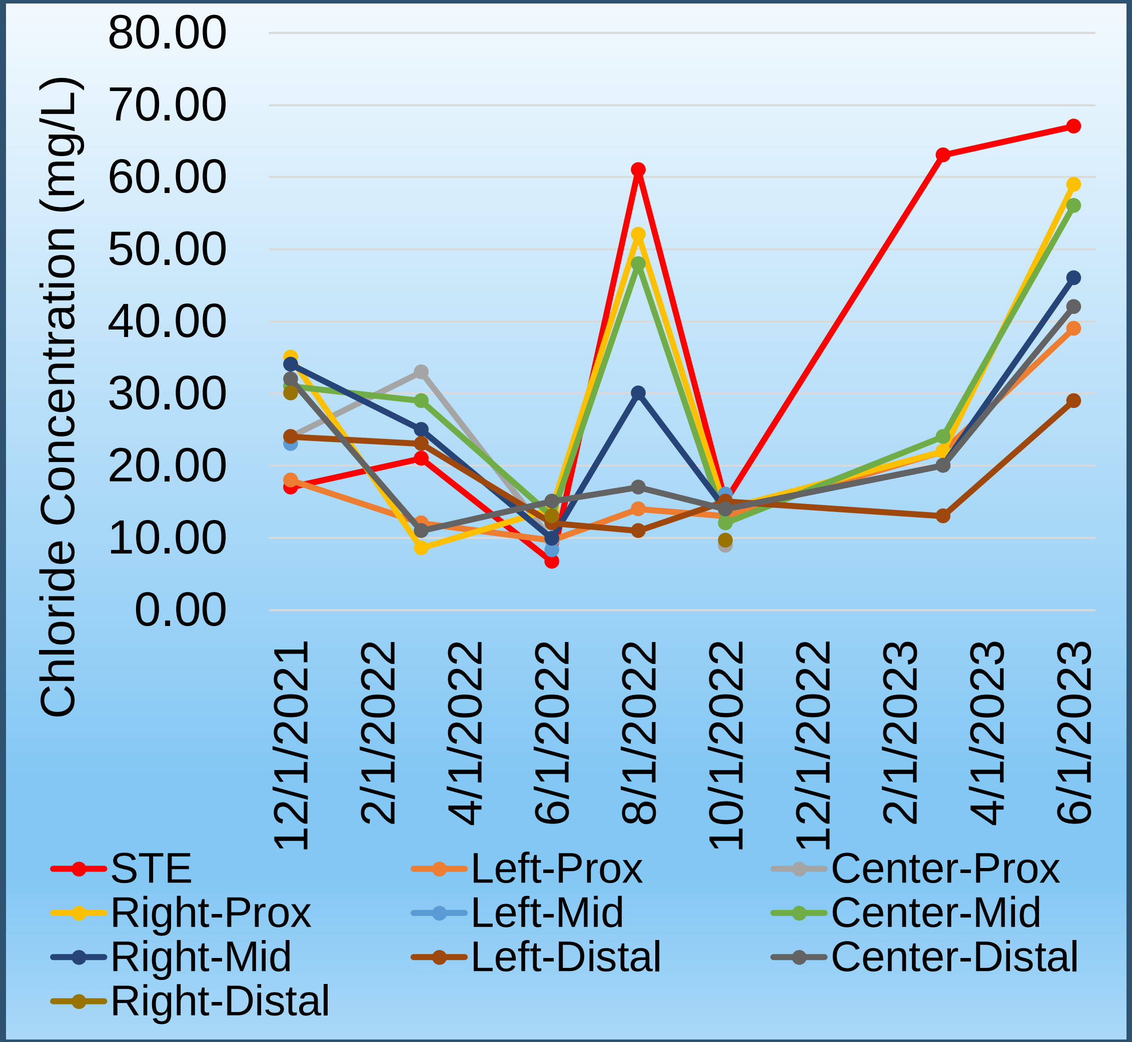
SYSTEM 4 – DNL EFFLUENT NOT ADJUSTED FOR DILUTION

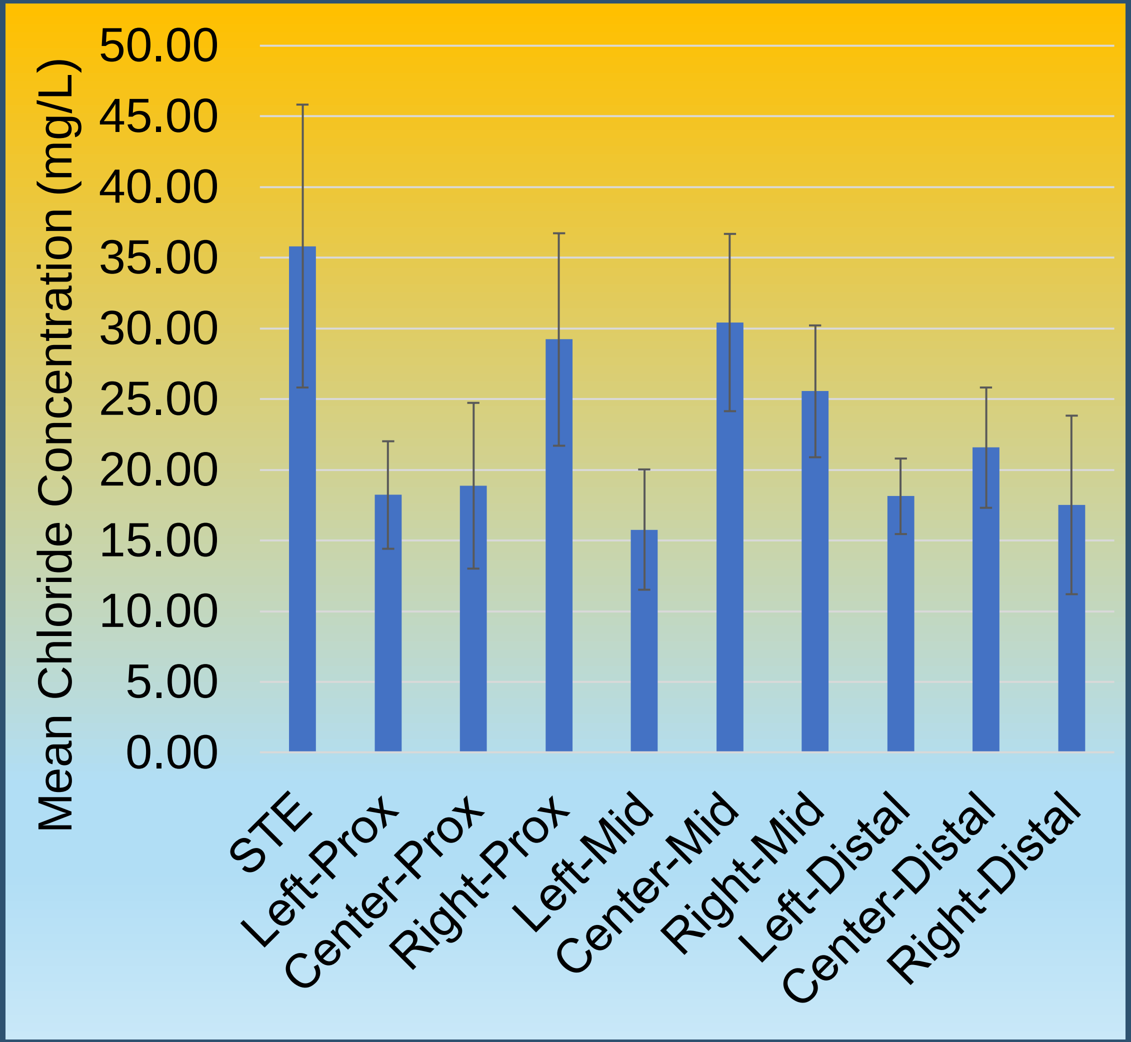




CHLORIDE CONCENTRATIONS

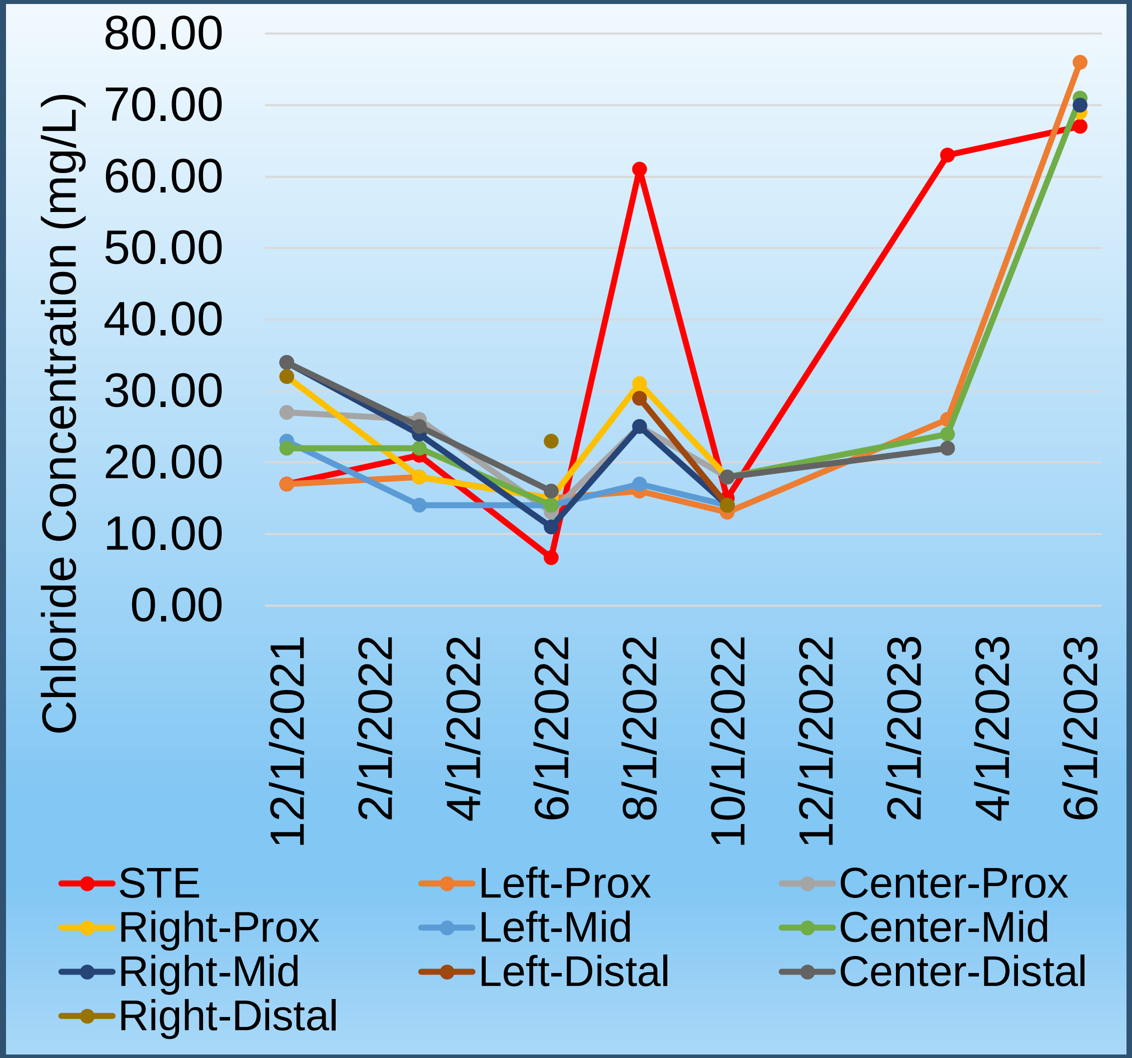
SYSTEM 4 – CHLORIDE CONCENTRATIONS FROM SFL MEDIA

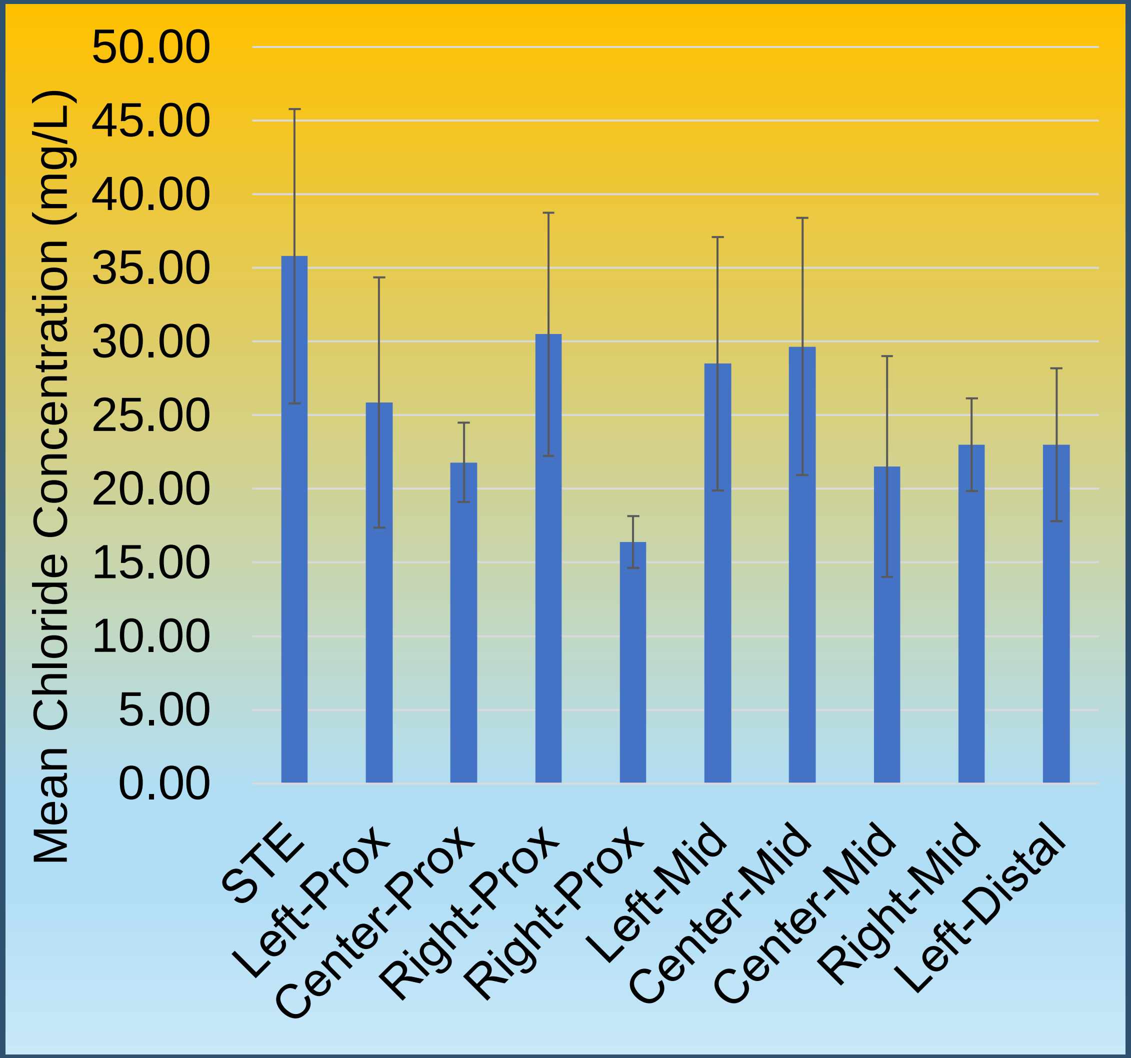




CHLORIDE CONCENTRATIONS (2)

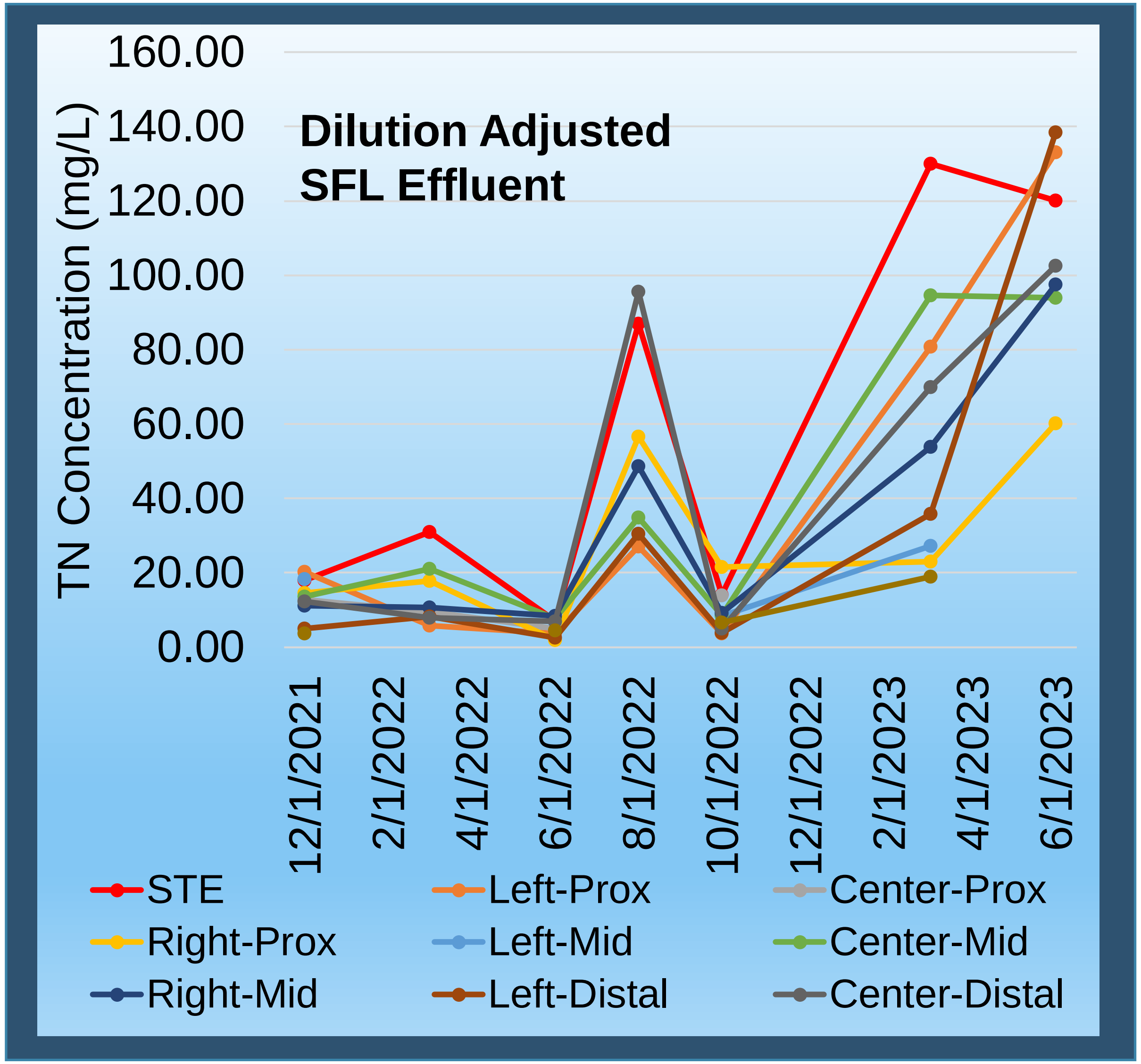
SYSTEM 4 – CHLORIDE CONCENTRATION FROM DNL MEDIA

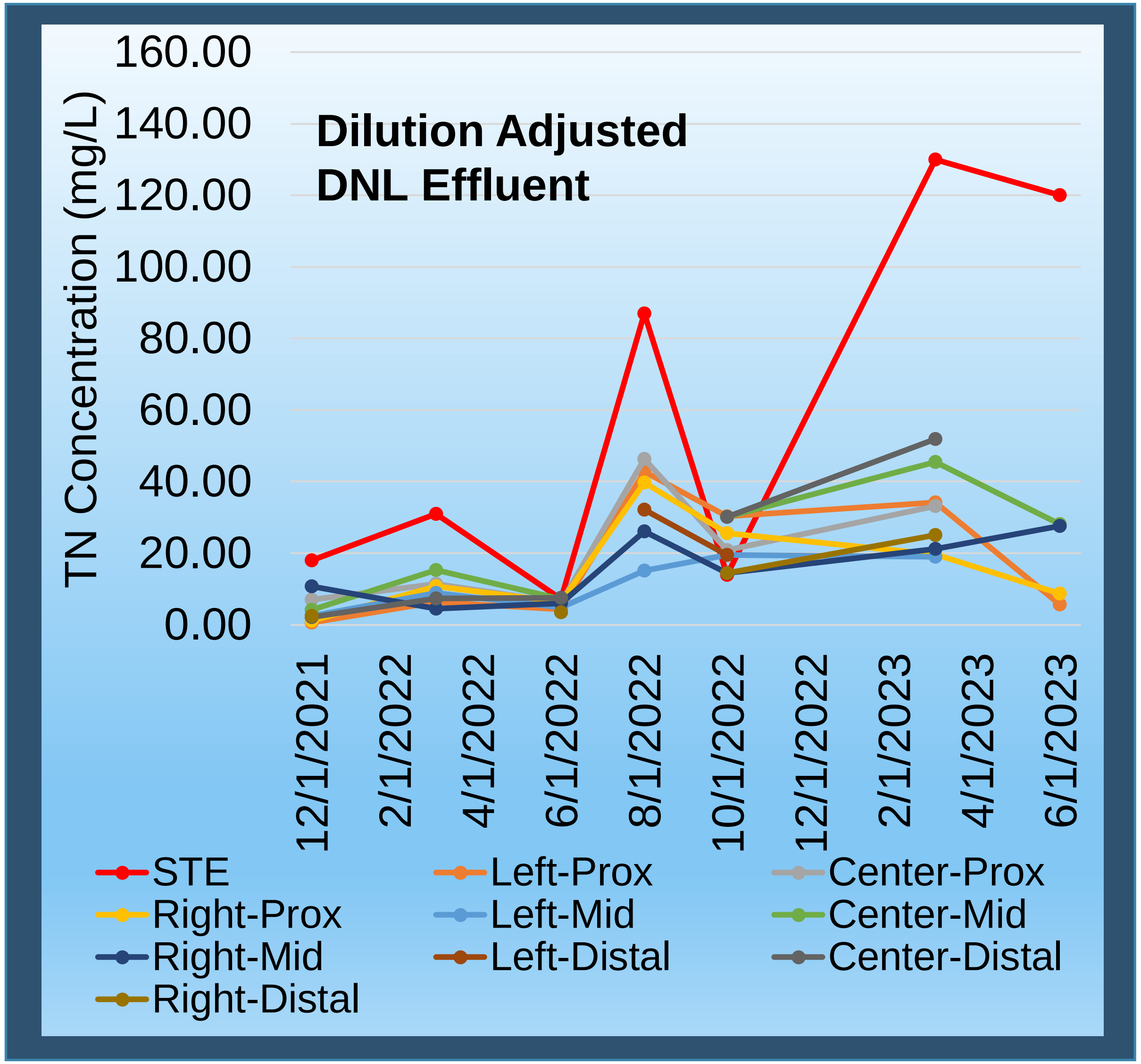




NITROGEN CONCENTRATIONS

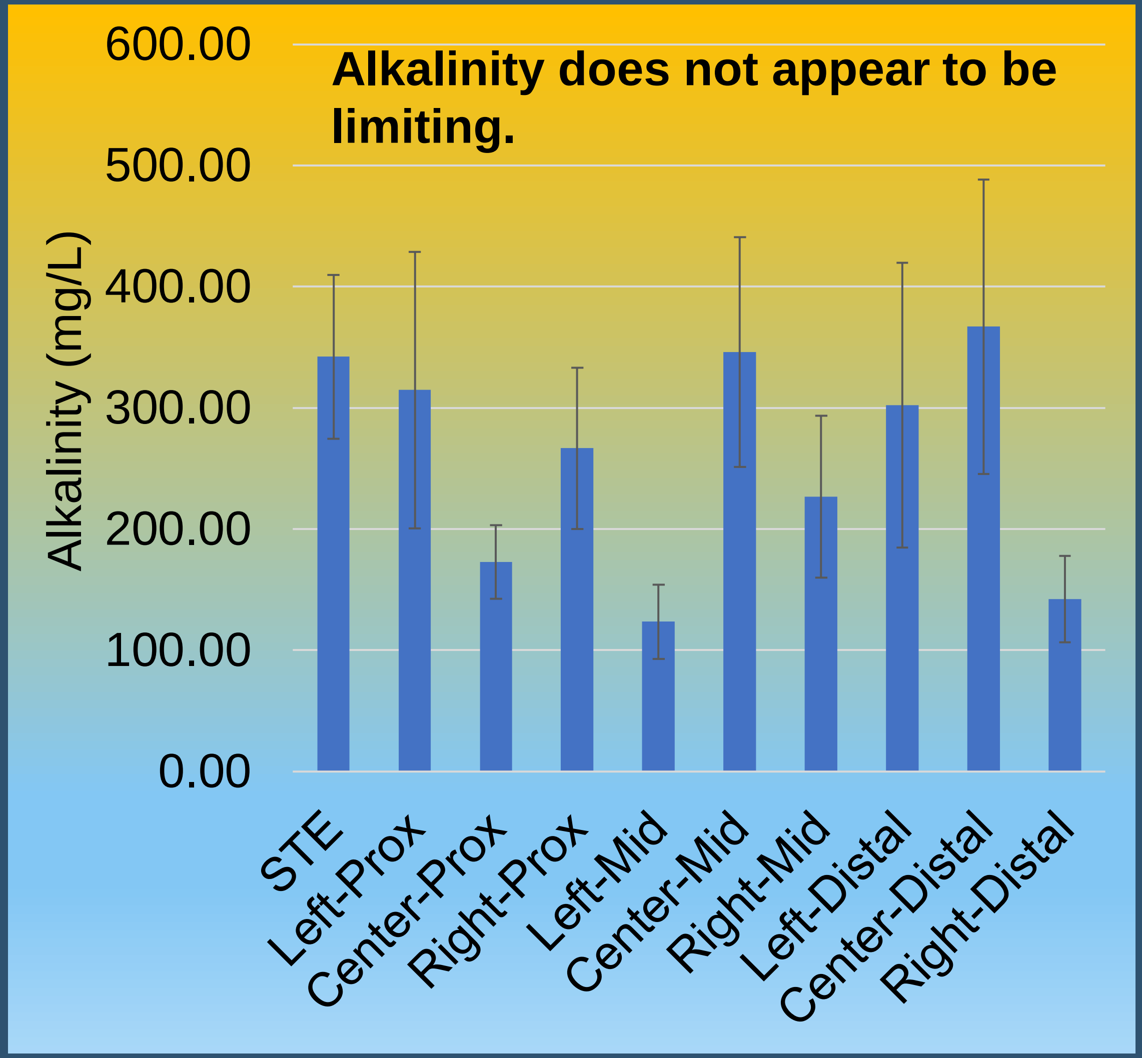
SYSTEM 4 – DILUTION ADJUSTED TN CONCENTRATION

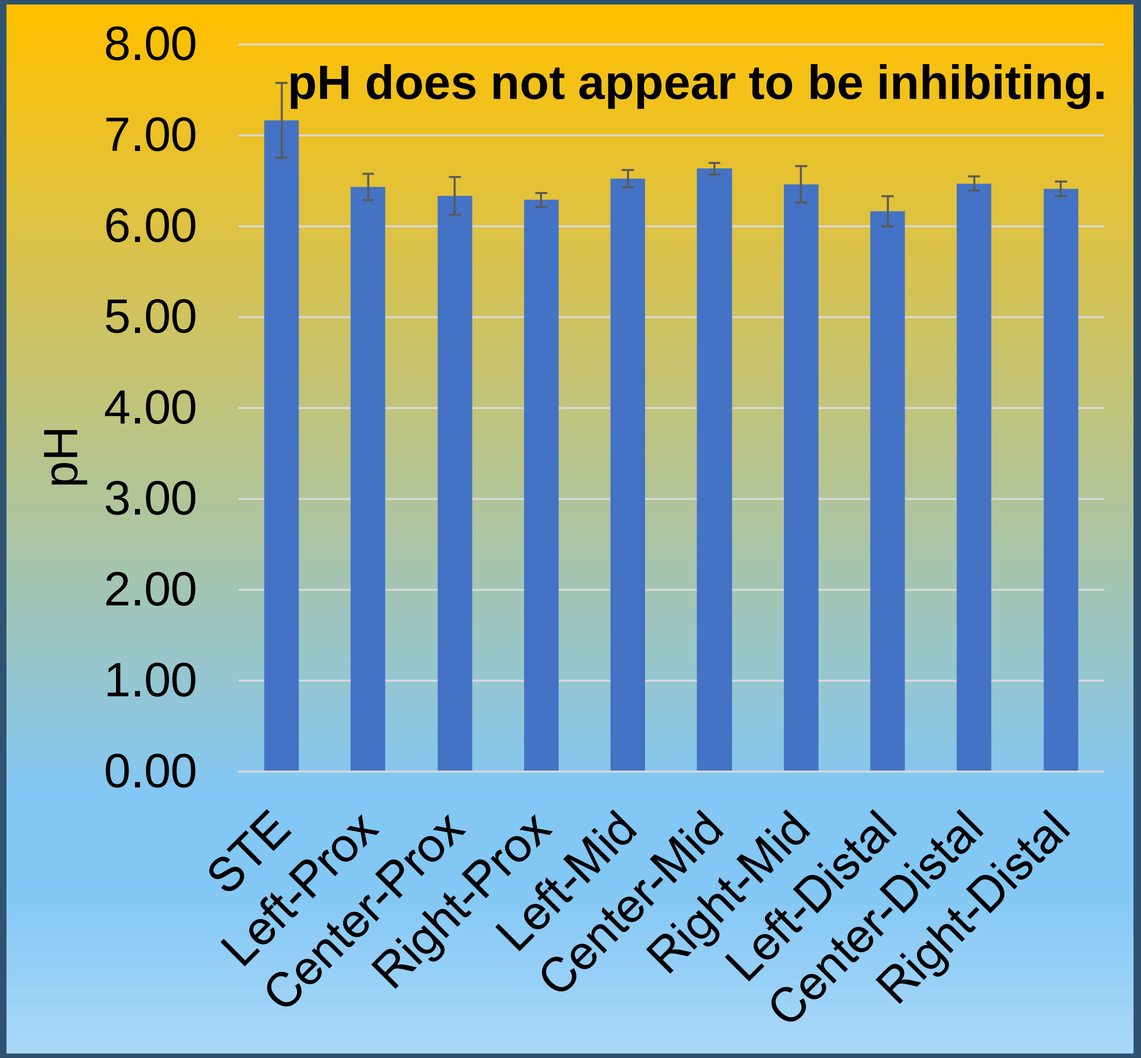




ALKALINITY AND PH

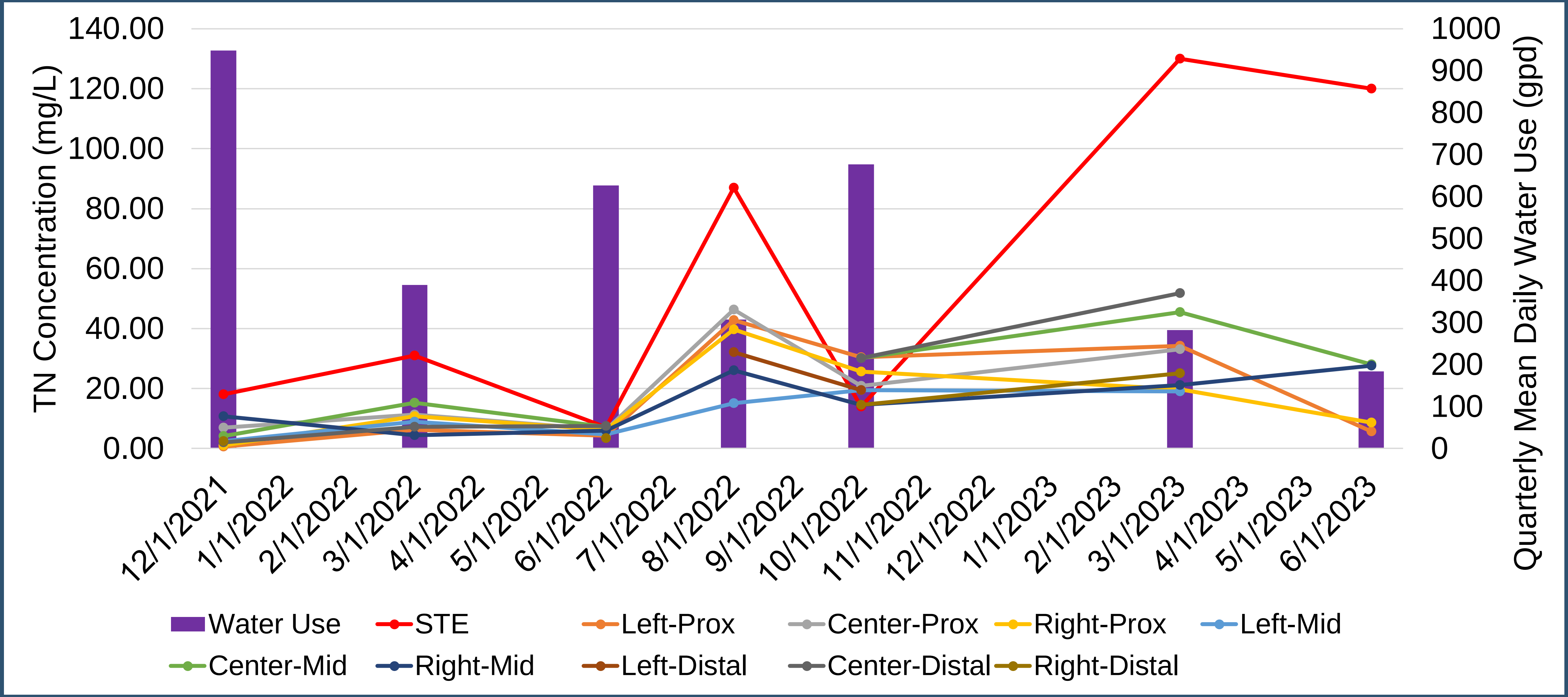
SYSTEM 4 SFL EFFLUENT





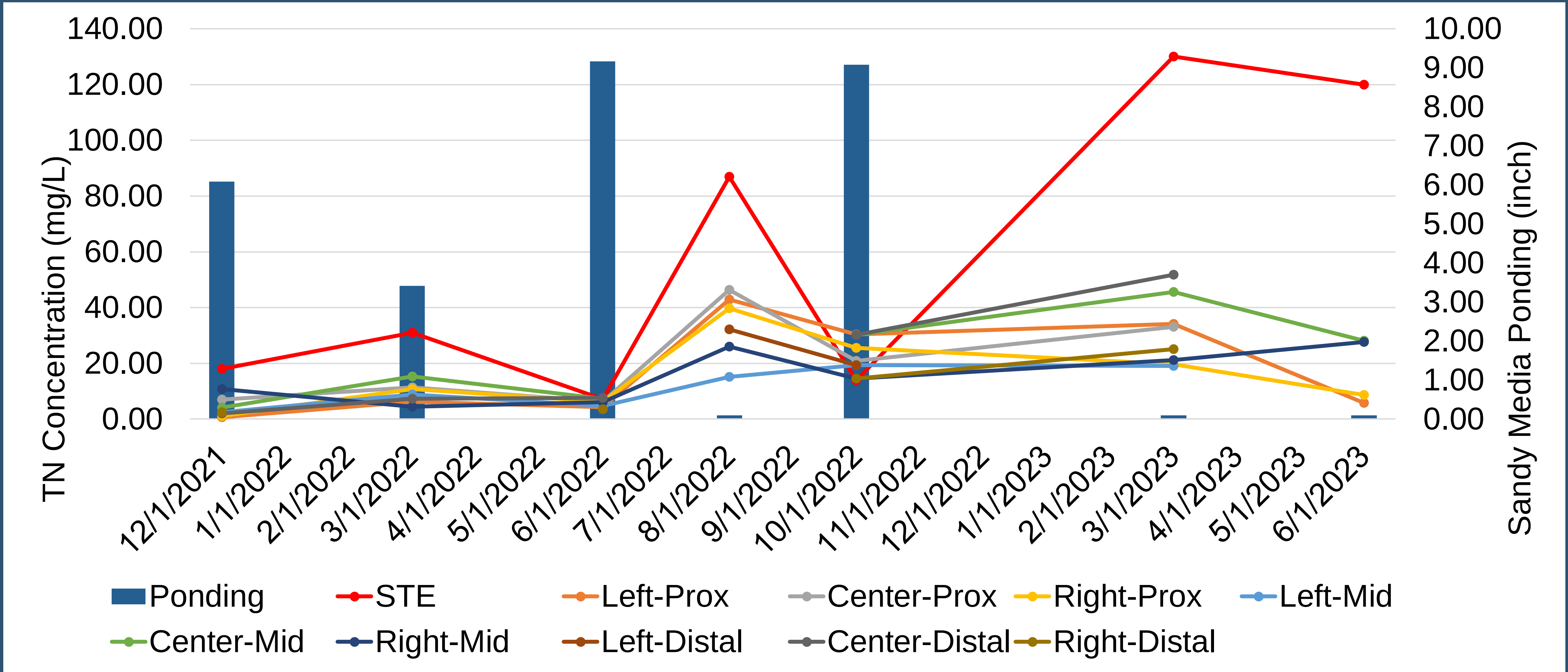
NITROGEN CONCENTRATIONS V. WATER USE

SYSTEM 4 – DILUTION ADJUSTED DNL TN CONCENTRATION



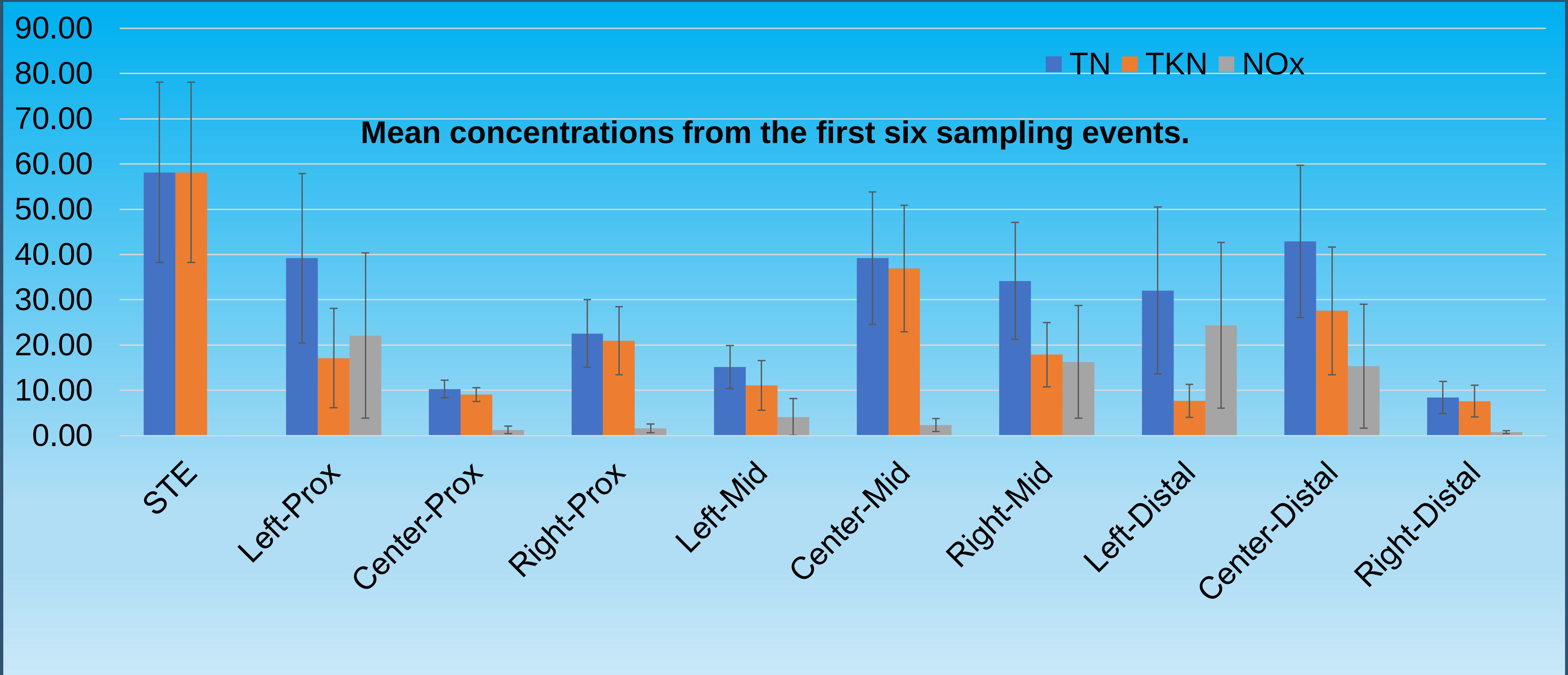
NITROGEN CONCENTRATIONS V. SFL PONDING

SYSTEM 4 – DILUTION ADJUSTED DNL TN CONCENTRATION



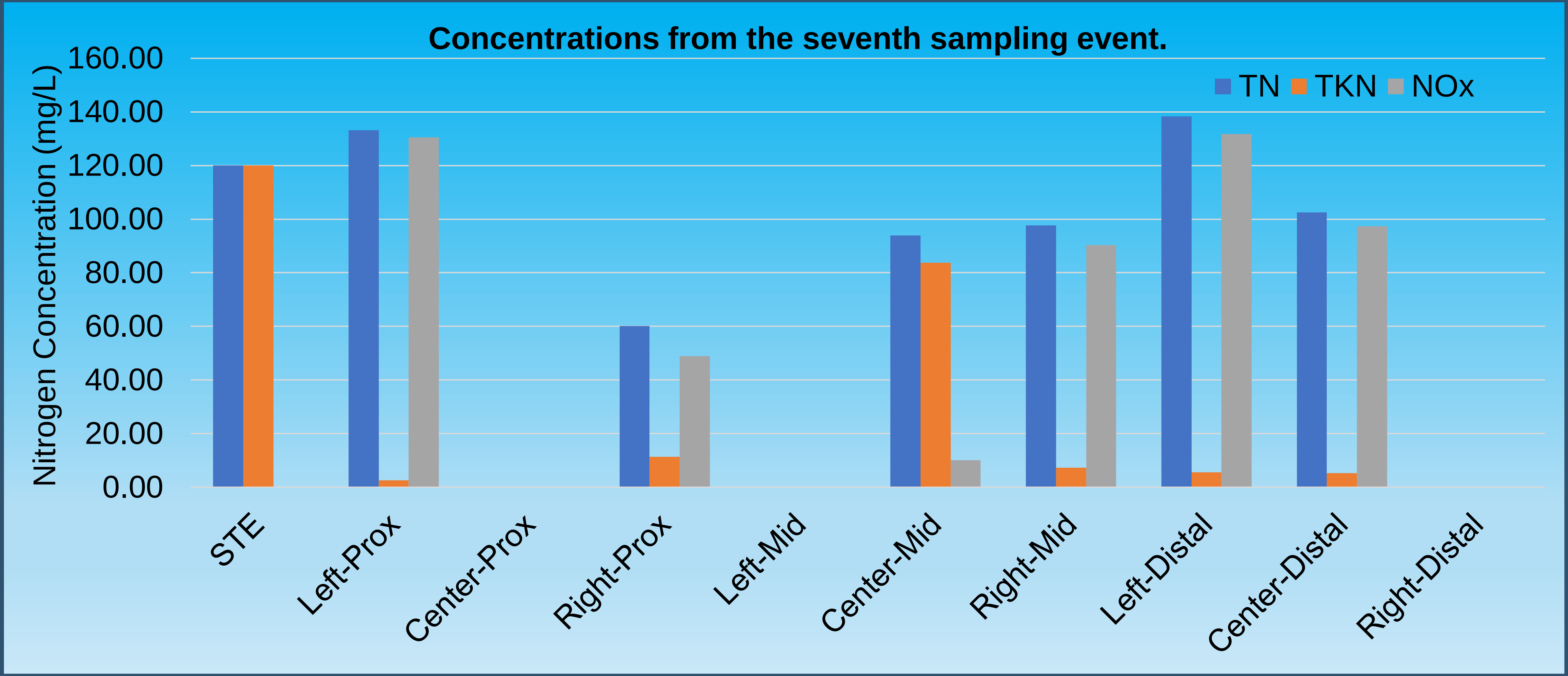
CONCENTRATION OF NITROGEN SPECIES

SYSTEM 4 – DILUTION ADJUSTED SFL CONCENTRATIONS



CONCENTRATION OF NITROGEN SPECIES (2)

SYSTEM 4 – DILUTION ADJUSTED SFL CONCENTRATIONS



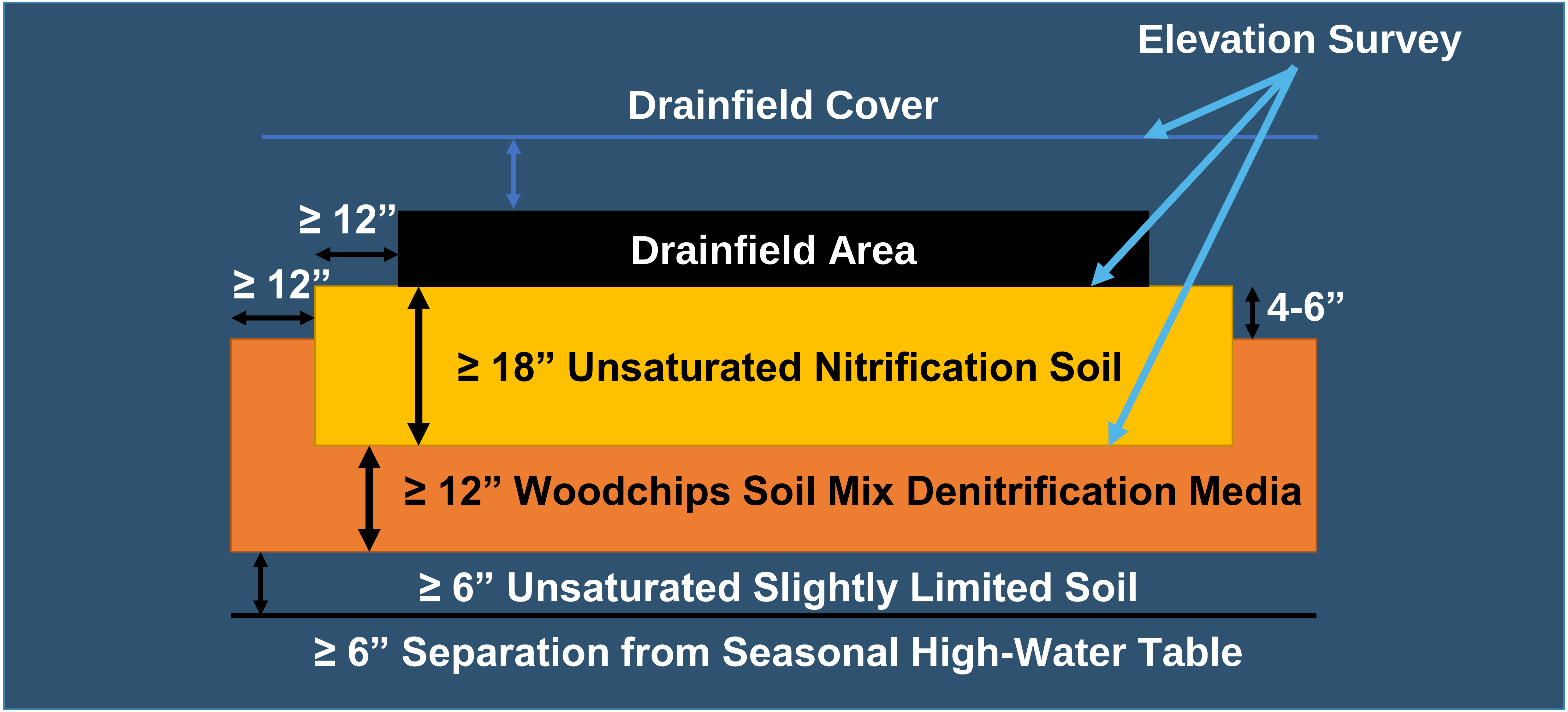
NITROGEN REMOVAL EFFICIENCY

SYSTEM 4

Sampling Location	All Sampling Event Mean	Low Flow Sampling Event Mean
Left-Prox	45.5%	74.8%
Center-Prox	35.0%	61.6%
Right-Prox	44.7%	72.0%
Left-Mid	53.4%	79.8%
Center-Mid	25.3%	64.1%
Right-Mid	52.6%	79.1%
Left-Distal	12.2%	63.0%
Center-Distal	20.7%	68.3%
Right-Distal	53.7%	80.7%
Overall Mean	**38.1%**	**71.5%**

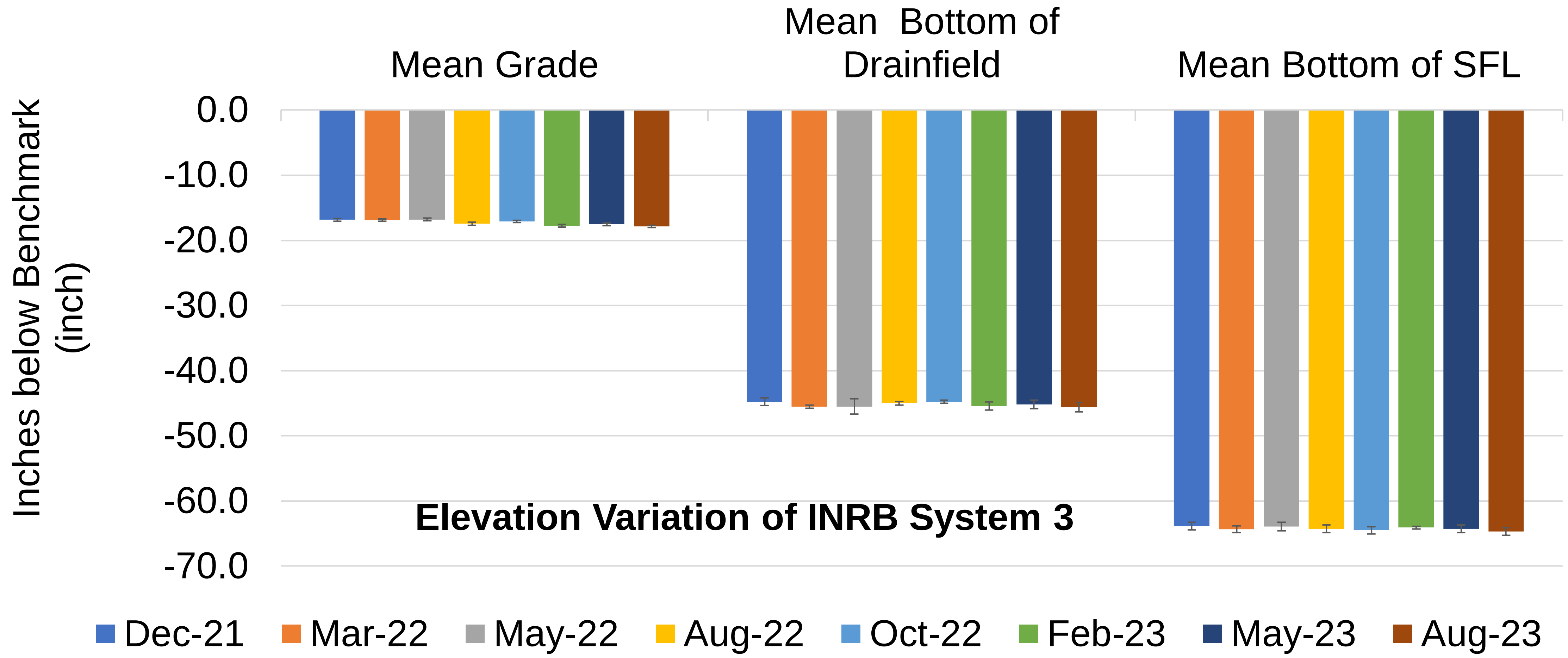
Note: Percent nitrogen-reduction was calculated for each sampling event first. The overall mean percent reduction was then calculated by averaging all event percent reductions.

ELEVATION CHANGE OF SYSTEM LAYERS



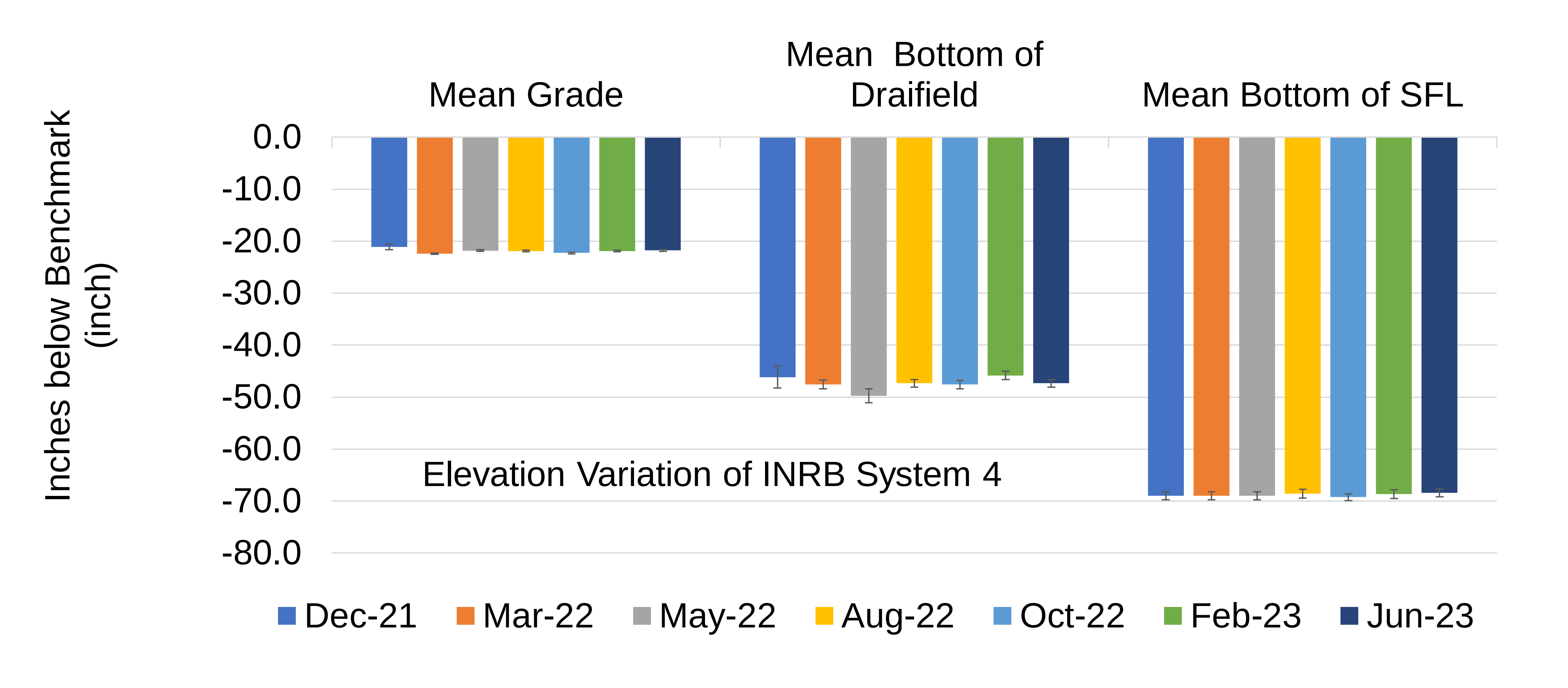
ELEVATION CHANGE OF SYSTEM LAYERS (2)

SYSTEM 3



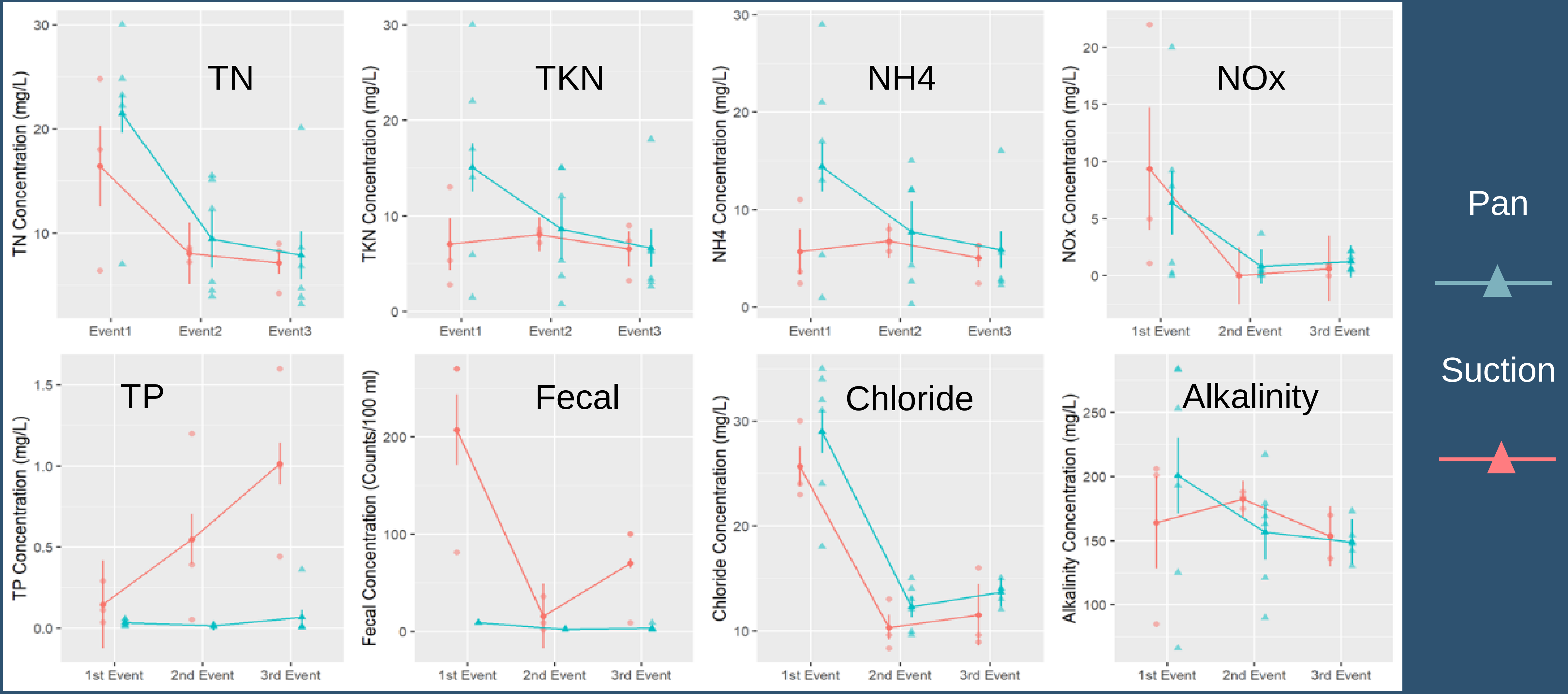
ELEVATION CHANGE OF SYSTEM LAYERS (3)

SYSTEM 4



PAN AND SUCTION LYSIMETERS COMPARISON

SYSTEM 4 SFL EFFLUENT CONCENTRATION



ANALYSIS OF VARIANCE WITH REPEATED MEASURE

SYSTEM 4 SFL EFFLUENT CONCENTRATION TEST PROBABILITY

Parameter	Lysimeter Type	Sampling Event	Lysimeter Type : Sampling Event
TN	0.469	**0.003**	0.683
TKN	0.432	0.322	0.330
NH4	0.334	0.283	0.297
NOx	0.797	0.063	0.603
TP	**0.010**	**0.007**	**0.010**
Fecal Coliform	**0.004**	**<0.001**	**0.001**
Chloride	0.198	**<0.001**	0.858
Alkalinity	0.925	0.479	0.472

SUMMARY

1. Hydraulic condition had impact on nitrogen treatment efficiency.

- The low-flow INRB (S3) showed uneven distribution of wastewater.
  - Denitrification was limited in the area receiving the most wastewater.
  - Possibly a result of low availability of alkalinity (nitrification) and low pH (denitrification).
- Very limited denitrification in the wood chip layer was observed from the high-flow INRB (S4).
  - Incomplete nitrification likely resulted from SFL ponding caused by high water use.
  - Higher nitrogen reducing efficiencies were observed when the water use decreased to close to the rule-based estimated sewage flow for property (300 gpd).
  - When no ponding was observed during periods of lower water use, more complete nitrification and higher nitrogen removal were observed.

SUMMARY (2)

2. Results suggest nitrogen reducing efficiency of at least 65% is achievable when hydraulic loading to the drainfield does not cause ponding of the SFL.

    - Ensuring household water use does not exceed the estimated flow from the property and using a pressurized distribution system may improve the nitrogen treatment efficiency.

3. Two years after the two systems were constructed, no obvious settling was observed for either the SFL or the DNL layers.

    - This suggests that the organic carbon in the DNL has not been substantially consumed.

SUMMARY (3)

4. Analyses of variance with repeated measures was conducted to compare parameter concentrations between samples collected using pan lysimeters and samples collected using suction lysimeters.

   - Only three sampling events, high-flow conditions, little nitrification.
   - Concentrations of nitrogen species, chloride, and alkalinity from the suction lysimeters did not differ significantly from concentrations from the pan lysimeters.
   - TP and fecal coliform concentrations from the suction lysimeters were significantly lower than concentrations from the pan lysimeters.
   - These observations suggest the following.
     - Suction lysimeters could be a reasonable alternative to pan lysimeters for nitrogen species monitoring when pan lysimeters are not feasible (e.g., low flow conditions).
     - Use of suction lysimeters may underestimate TP and fecal coliform concentrations.

SUMMARY (4)

5. Sampling of more systems and longer sampling periods are needed to evaluate more thoroughly the performance of INRBs.

6. More data needed to evaluate the similarity and difference between the samples collected using suction lysimeters and pan lysimeters.

THANK YOU

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