# MONITORING NITROGEN REMOVAL BY FLORIDA'S INGROUND NITROGEN – REDUCING BIOFILTERS

**Nareg Krikorian, M.S., CEHP**
Onsite Sewage Program
Division of Water Resource Management
Florida Department of Environmental Protection

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# OUTLINE

- Acknowledgement.
- Introduction.
- Nitrogen reducing onsite sewage treatment and disposal systems.
- In-ground nitrogen-reducing biofilter (INRB) sampling methods.
- Results and discussion.

# ACKNOWLEDGEMENTS

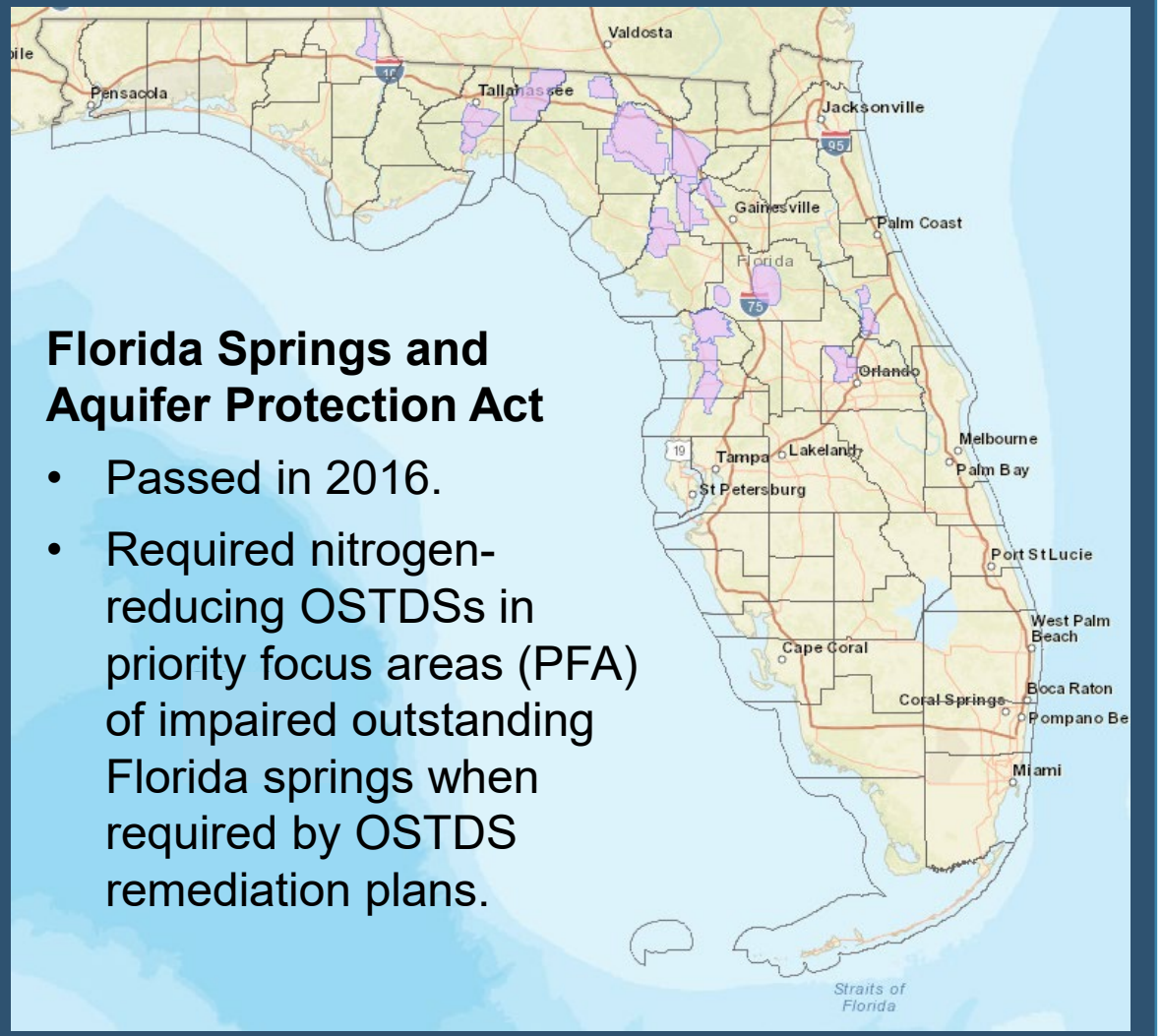

- The project is partially funded by:
  - The federal multipurpose fund from the U.S. Environmental Protection Agency (EPA).
  - The Spring and Aquifer Protection Fund from the Florida Department of Environmental Protection (DEP).
- The monitored INRB systems in Leon and Citrus Counties were constructed by:
  - Apalachee Backhoe and Septic.
  - Ace Septic and Waste.
- Special thanks to Ms. Debby Tipton, Ms. Tanya Welborn, Mr. Martin Schumann, and Dr. Xueqing Gao for their continuous support throughout the monitoring and sampling process of the INRB systems.

# INTRODUCTION

- Onsite sewage treatment and disposal systems (OSTDSs), commonly known as septic systems, are used by approximately 30% of Florida's establishments.
- Florida's estimated 2.6 million OSTDSs in operation represent approximately 12% of the septic systems in the U.S.
- Groundwater provides 90% of Florida's drinking water; therefore, it is important to properly plan, design, install, operate and maintain OSTDSs.

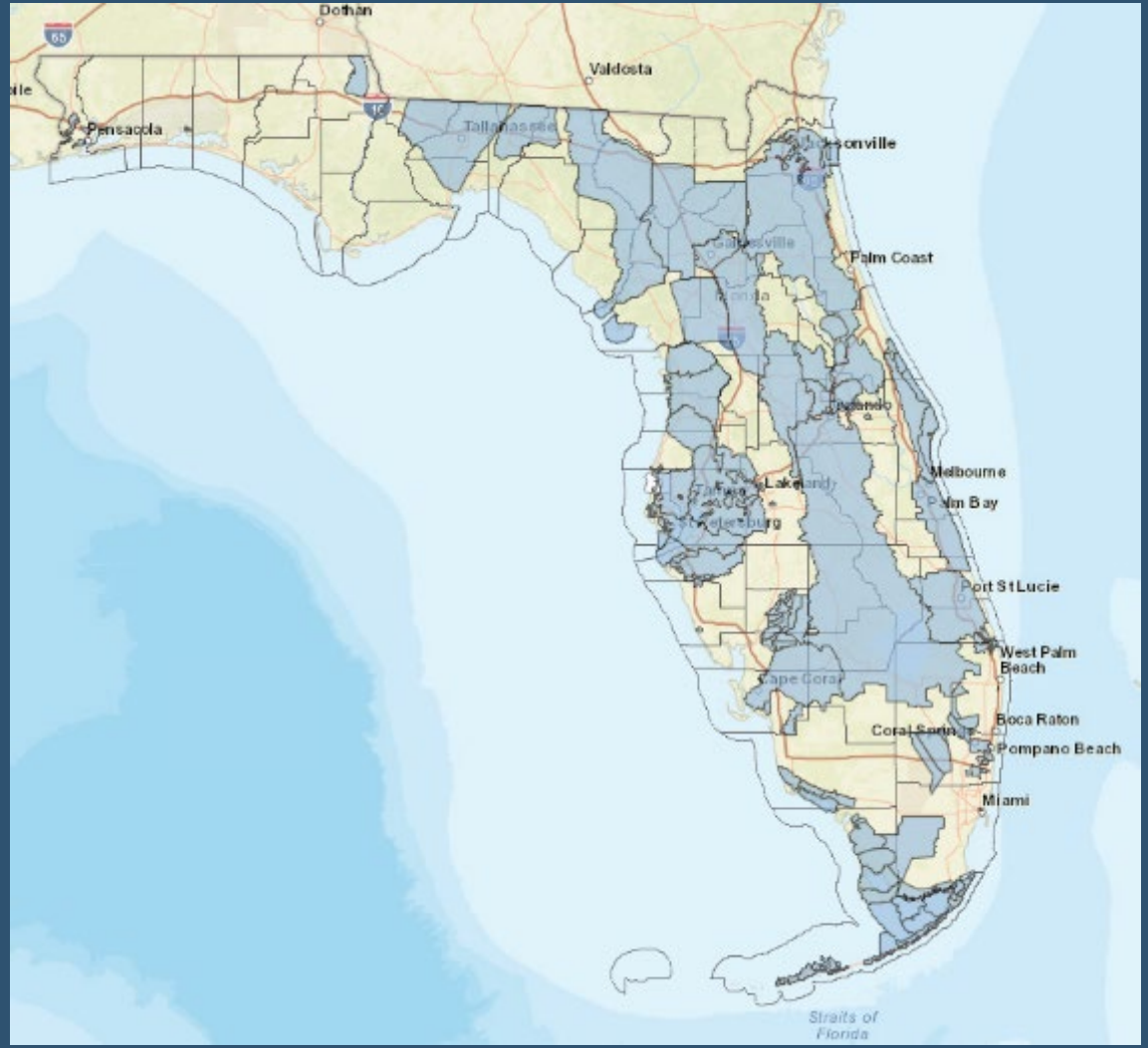
# FLORIDA STATUTORY REQUIREMENTS

## ENHANCED NUTRIENT-REDUCING OSTDSs



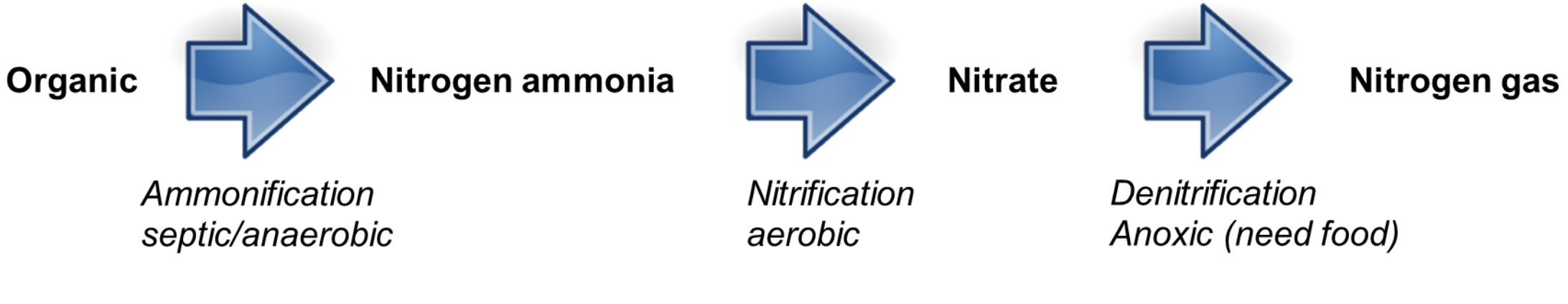

**Florida Springs and Aquifer Protection Act**

- Passed in 2016.
- Required nitrogen-reducing OSTDSs in priority focus areas (PFA) of impaired outstanding Florida springs when required by OSTDS remediation plans.



# REMOVING NITROGEN FROM DOMESTIC WASTEWATER

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



# ADVANCED SEPTIC SYSTEMS

## TYPES OF ADVANCED SEPTIC SYSTEMS

- Nitrogen-reducing OSTDSs include:
  - Aerobic treatment units (ATU) certified as meeting NSF/American National Standards Institute (ANSI) Standard 245.
  - Nitrogen-reducing performance-based treatment systems (PBTS).
  - INRBs.

# NITROGEN-REDUCING OSTDSs FOR SPRINGS

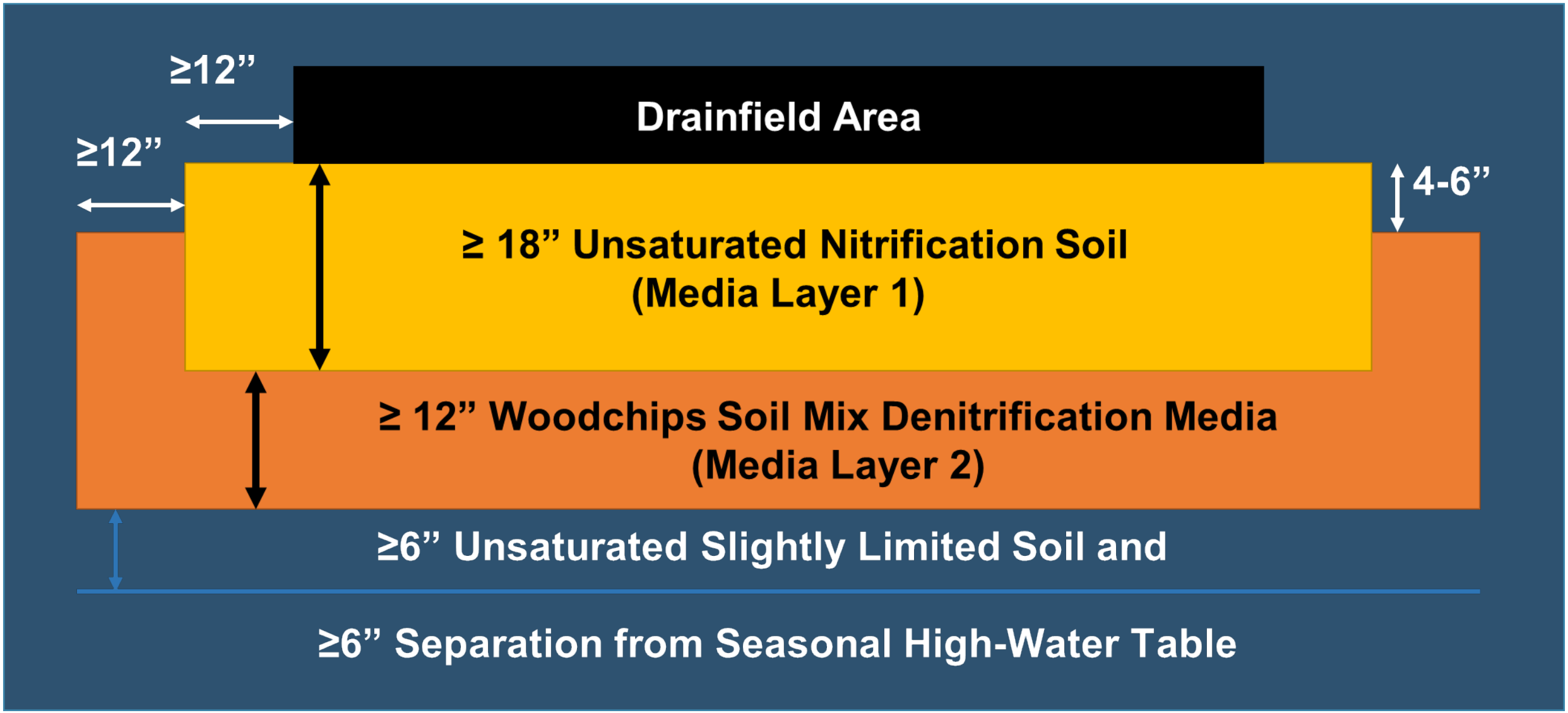
- More than 20,000 nitrogen-reducing OSTDS were installed in areas influenced by nitrogen-reducing requirements between Jan. 1, 2019, and April 19, 2025.
  - New systems required under springs OSTDS remediation plans.
  - New systems required in other areas by 2023 House Bill 1379.
  - Repairs and modifications required under springs OSTDS remediation plans (DeLeon, Wakulla, Wekiva).
  - 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 | 13,872 |
| Nitrogen-reducing PBTS | 692 |
| INRB | 5,561 |

# INRB COMPONENTS

- The INRB consists of:
  - Drainfield.
  - Media layer 1: unsaturated sandy media layer.
    - Nitrification: convert ammonia to nitrate.
  - Media layer 2: nitrogen-reducing media layer, mix of woody (lignocellulosic) material and fine aggregate.
    - Denitrification: convert nitrate to nitrogen gas.

# INRB COMPONENTS (2)

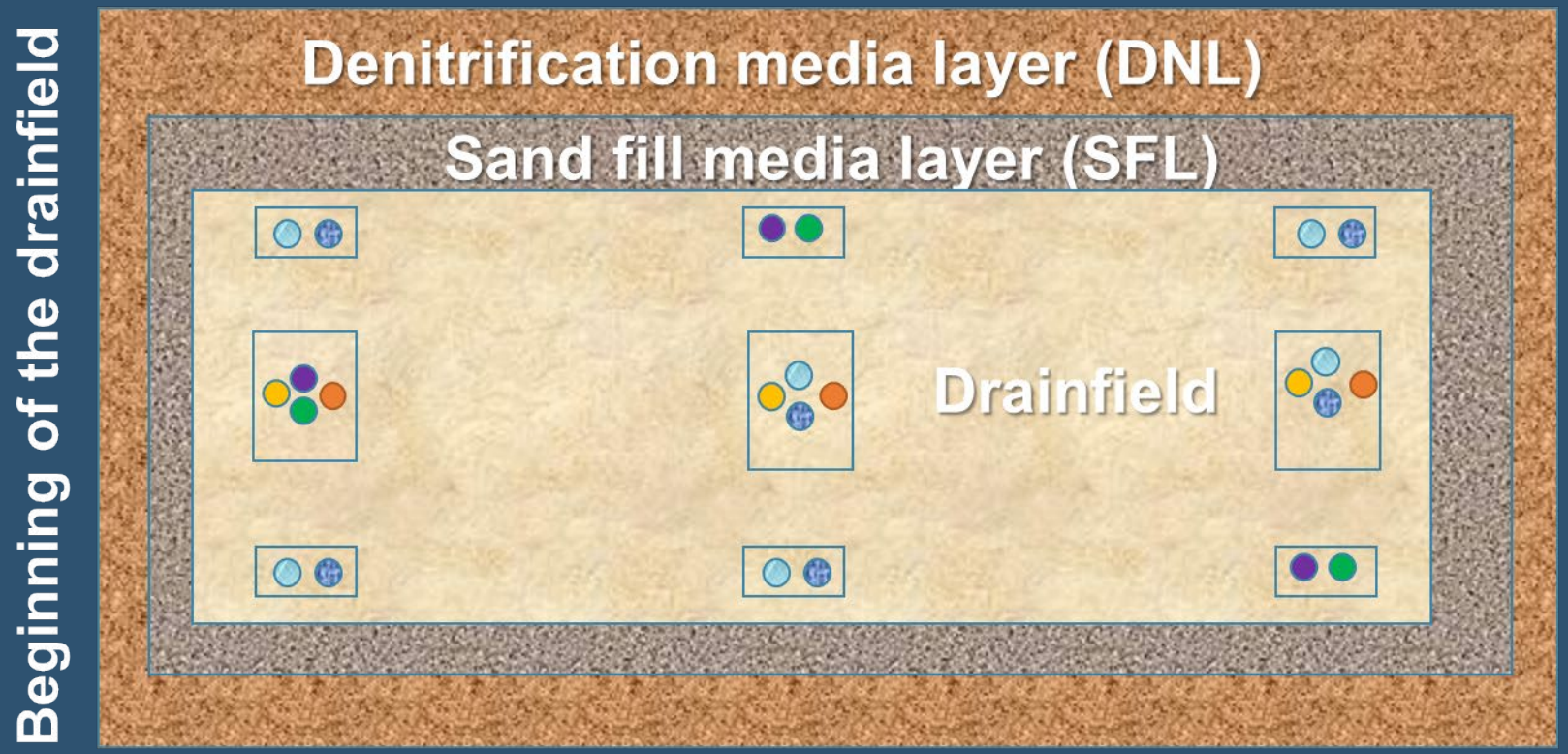


# OBJECTIVES

- Install and monitor INRBs.
  - Previously monitored two in Leon County.
  - Currently monitoring a third in Leon County and one in Citrus County.
  - Install monitoring equipment to obtain water samples.
    - Pan lysimeters (collect percolating water).
    - Suction lysimeters (collect soil moisture).
  - Install reference observation ports to monitor settling of materials over time.
  - Monitor at approximately quarterly intervals for two years (ongoing).

# INRB MONITORING

## TOP VIEW

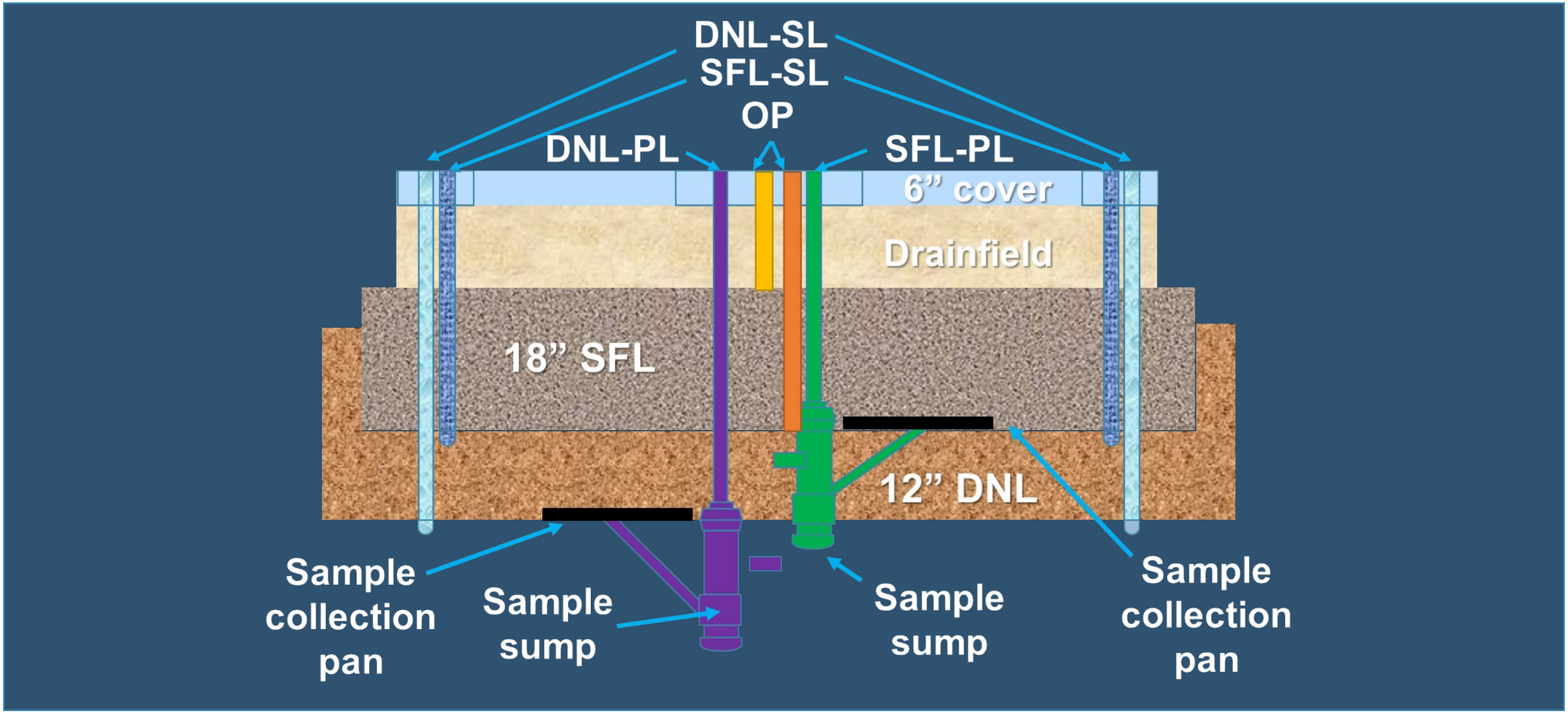



DNL-SL SFL-SL DNL-PL SFL-PL SFL-OP DNL-OP

**SL**: suction lysimeter. **PL**: pan lysimeter. **OP**: observation port.

# INRB MONITORING (2)

## FRONT VIEW



# MONITORING EQUIPMENT

Pan lysimeter (PL)

Suction lysimeter (SL)

# MONITORING EQUIPMENT INSTALLATION

Bottom of INRB

Denitrification media

PL at the bottom of INRB

# MONITORING EQUIPMENT INSTALLATION (2)

PL at bottom of SFL

SL at bottom of DNL

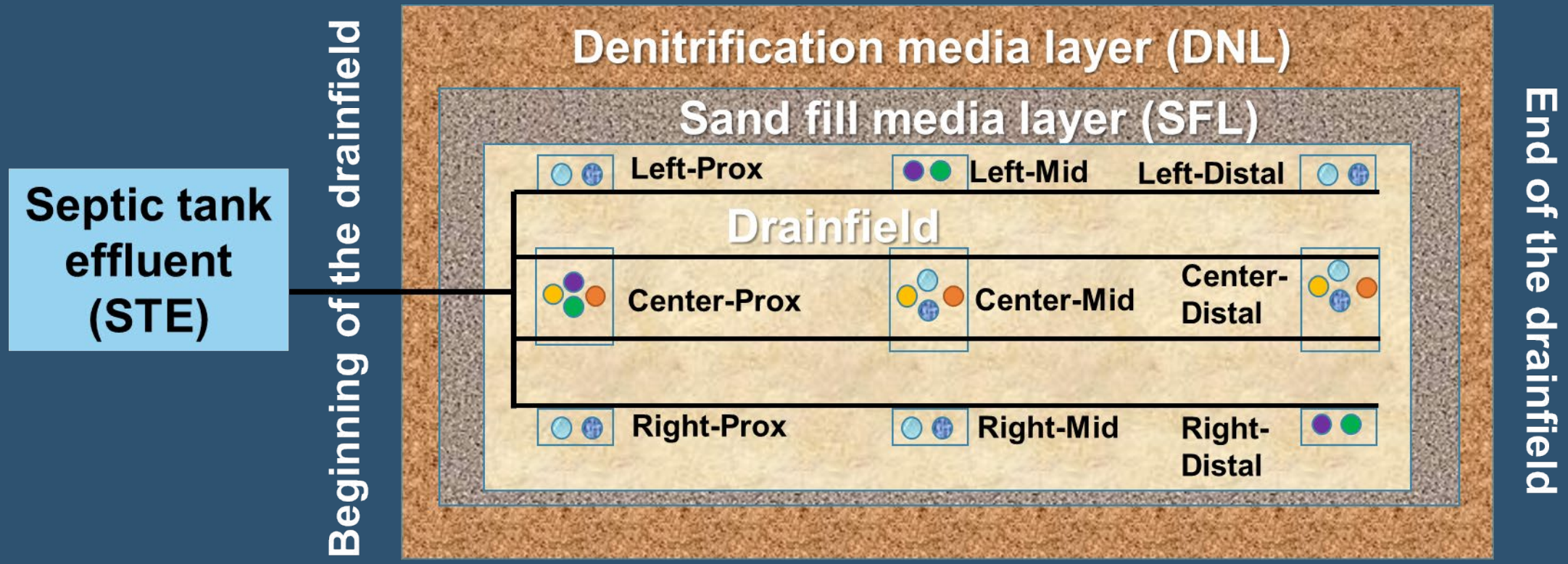
Top of DNL

Sand fill media

# MONITORING EQUIPMENT INSTALLATION (3)

Top of sand fill media layer

# MONITORING EQUIPMENT ARRANGEMENT




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

**SL**: suction lysimeter. **PL**: pan lysimeter. **OP**: observation port.

# INRB SYSTEM MONITORING

- Inspect the systems to ensure proper function.
- Conduct elevation survey to evaluate change of depth of media layers.
- Collect samples for:
  - Total Kjeldahl nitrogen (TKN), ammonium nitrogen ($NH_4$-N), and nitrate/nitrite nitrogen (NOx-N).
  - Total phosphorus (TP).
  - Total organic carbon (TOC).
  - Fecal coliform.
  - Alkalinity and chloride.

# INRB SYSTEM MONITORING (2)

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

# ONGOING INRB MONITORING PROJECTS

- Experimental prototypes of INRBs previously installed showed approximately 65% nitrogen removal.
- More data is required from more systems to provide a more robust evaluation of the INRB performance in Florida.
- DEP's Onsite Sewage Program (OSP):
  - Monitored two INRBs in Leon County.
  - Currently monitoring one INRB in Leon County and one in Citrus County.

# PREVIOUSLY MONITORED LEON COUNTY INRBS

Monitoring Nitrogen Removal by Florida INRBs

# PROPERTY CHARACTERISTICS

## SYSTEMS S3 AND S4

| System | Estimated Sewage Flow (gallons per day [gpd]) | Drainfield Size (square feet [$ft^2$]) | Soil Type | # of Occupants | Mean Quarterly Average Daily Water Use (gpd) |
|---|---|---|---|---|---|
| S3 | 300 | 360 | Fine Sand | 1 | 18.0 |
| S4 | 300 | 375 | Fine Sand | 4 - 5 | 446.9 |

- Monitoring of both INRBs began in December 2021.
- Eight quarterly samplings were conducted by September 2023.
- Neither property had an irrigation system (all water flow goes to system).

# AVERAGE NITROGEN REDUCTION

## SYSTEM 3

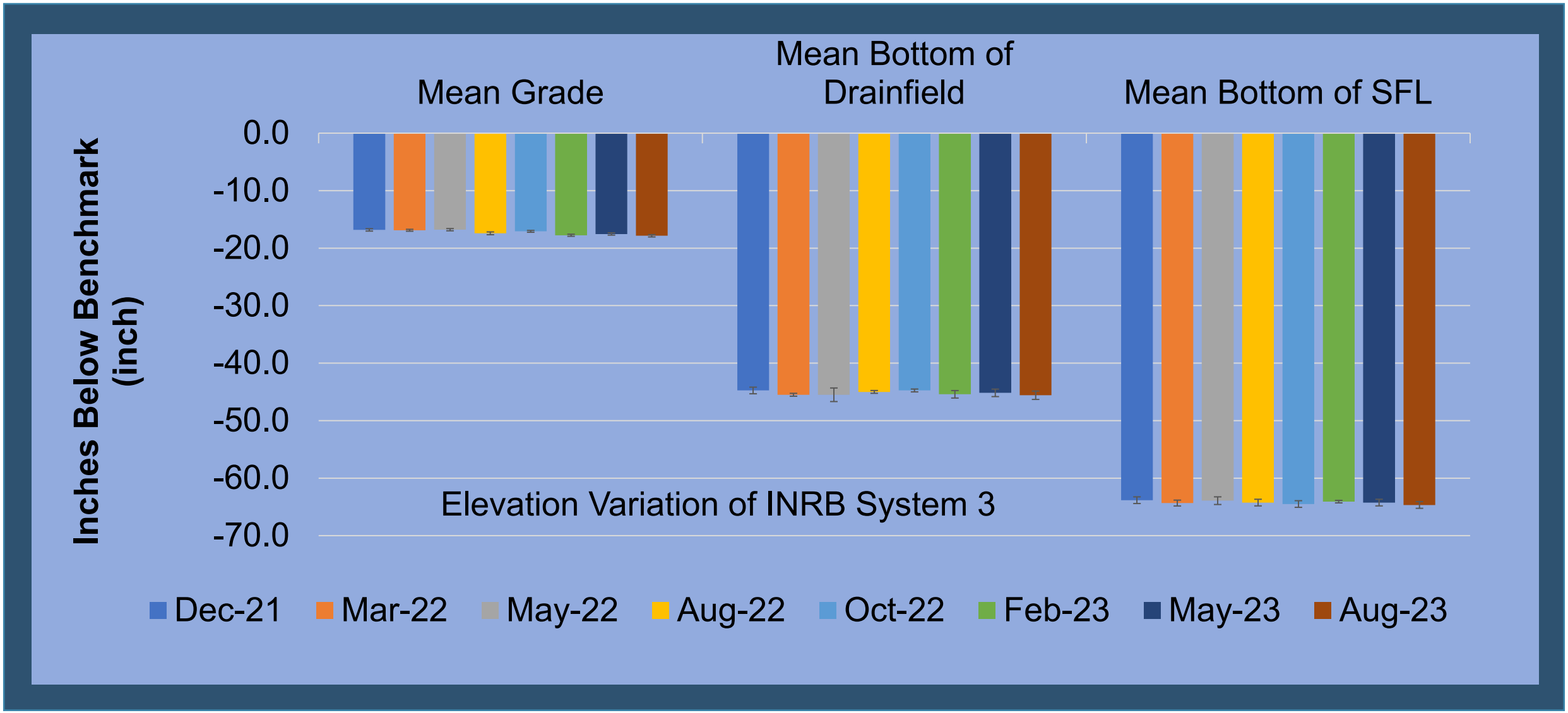
| Sampling Events | STE (mg/L) | Left-Prox (mg/L) | Right-Prox (mg/L) | Left-Prox Percent Nitrogen Reduction | Right-Prox Percent Nitrogen Reduction |
|---|---|---|---|---|---|
| 12/8/2021 | 230 | 2 | 160 | 99% | 30% |
| 3/2/2022 | 220 | 11 | 152 | 95% | 31% |
| 5/25/2022 | 220 | 3 | 39 | 99% | 82% |
| 8/24/2022 | 200 | 6 | 16 | 97% | 92% |
| 10/19/2022 | 200 | 2 | 21 | 99% | 90% |
| 2/22/2023 | 170 | 13 | 112 | 92% | 34% |
| 5/24/2023 | 190 | 2 | 3 | 99% | 98% |
| 8/23/2023 | 140 | 1 | 12 | 99% | 92% |
| **Mean** | **196** | **5** | **64** | **97%** | **69%** |
| **S.E.*** | **11** | **2** | **23** | **1%** | **11%** |

Overall average nitrogen reduction: **83%.**

*S.E.: Standard Error.

# ELEVATION CHANGE OF SYSTEM LAYERS

## SYSTEM 3



# AVERAGE NITROGEN REDUCTION S4

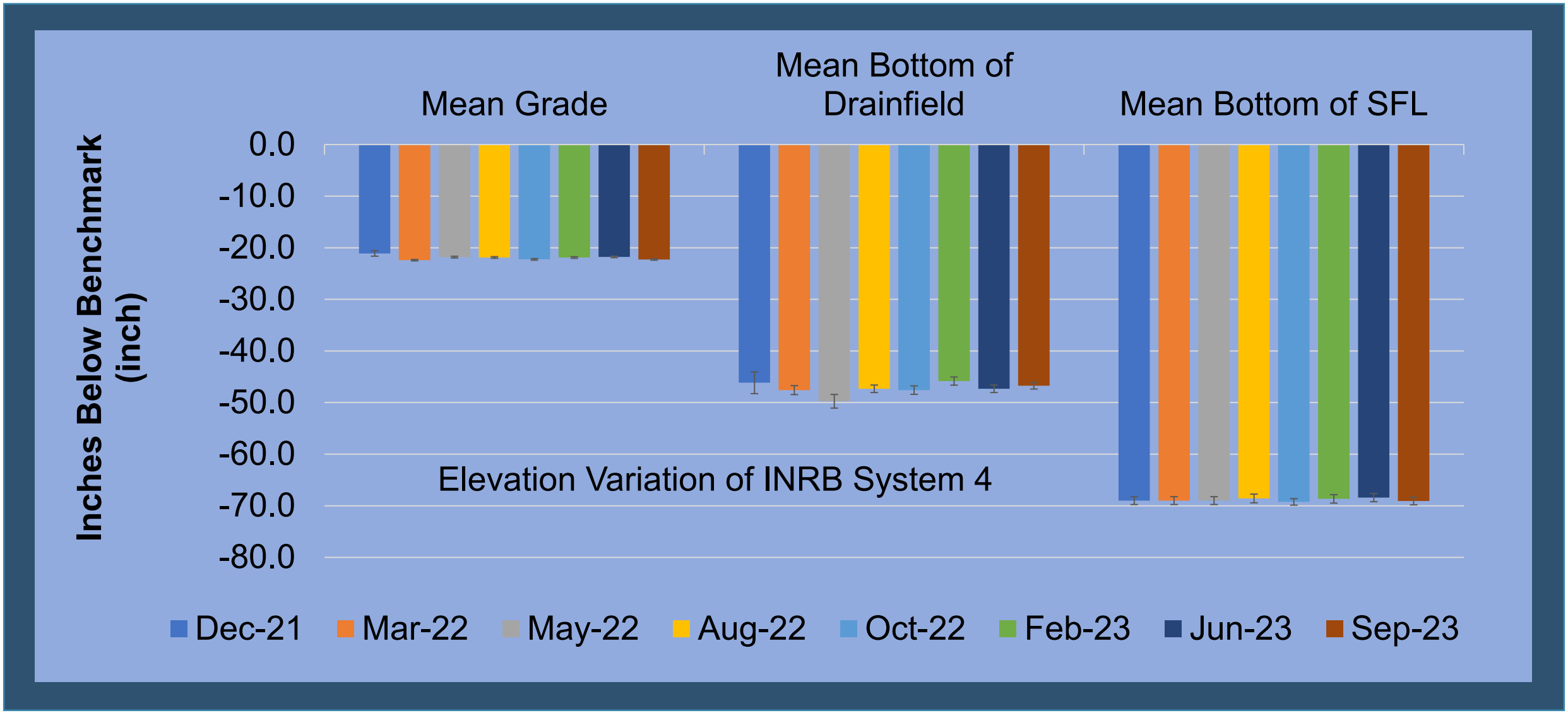
## SYSTEM 4

| Sampling Location | All Sampling Event Mean | Up to Design Flow Sampling Event Mean |
|---|---|---|
| Left-Prox | 52% | 80% |
| Center-Prox | 35% | 62% |
| Right-Prox | 51% | 77% |
| Left-Mid | 53% | 80% |
| Center-Mid | 33% | 69% |
| Right-Mid | 58% | 83% |
| Left-Distal | 12% | 63% |
| Center-Distal | 30% | 72% |
| Right-Distal | 54% | 81% |
| **Overall Mean** | **42%** | **74%** |

Note: Nitrogen-reduction calculated for each sampling event at each sampling site first, then averaged over events. Overall reduction was then calculated by averaging all locations.

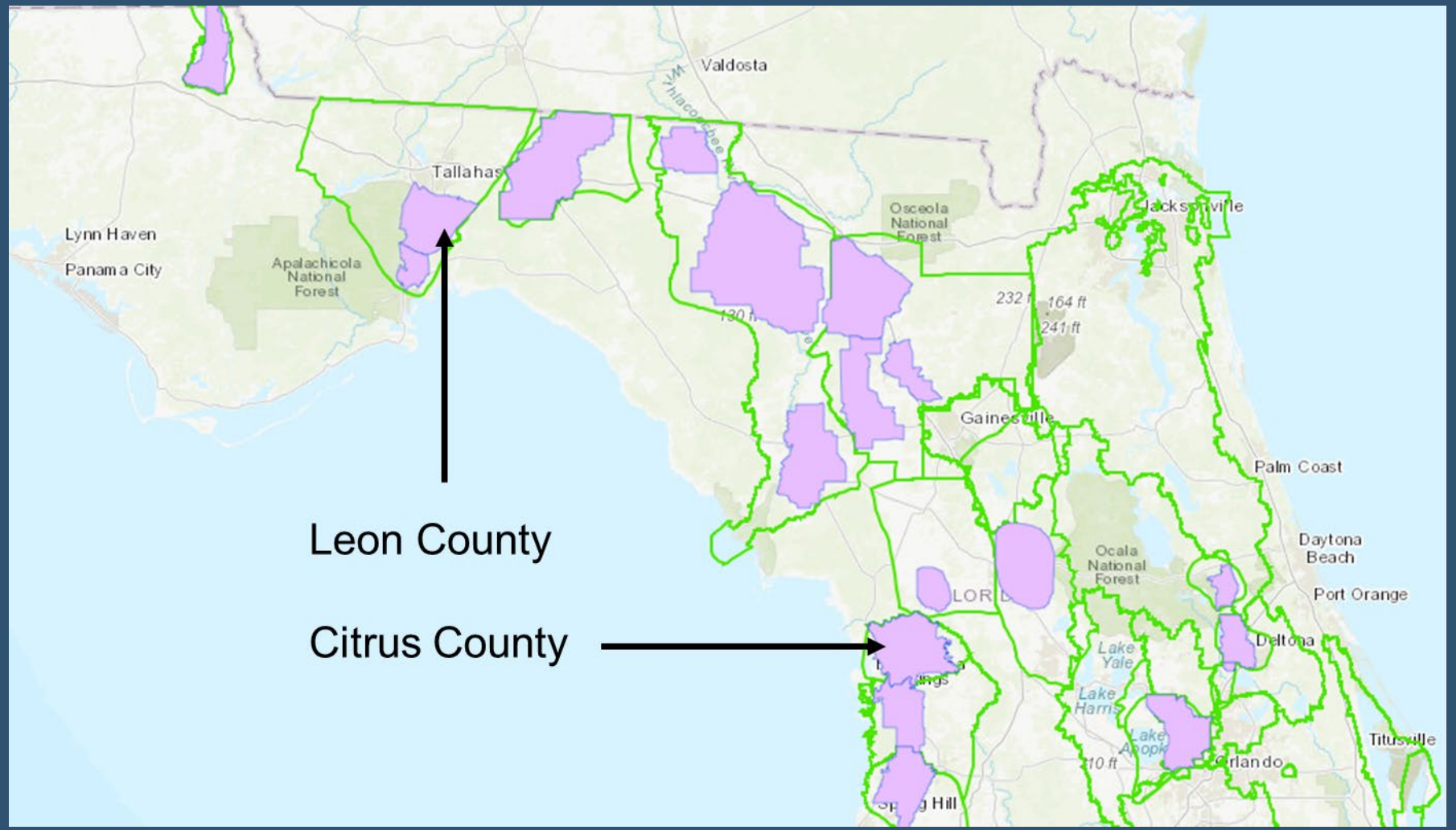
# ELEVATION CHANGE OF SYSTEM LAYERS S4

## SYSTEM 4



# PROJECT LOCATIONS

## SYSTEMS 5 AND 6



# PROPERTY CHARACTERISTICS S5 AND S6

## SYSTEMS S5 AND S6

| System | Estimated Sewage Flow (gallons per day [gpd]) | Drainfield Size (square feet [$ft^2$]) | Soil Type | # of Occupants | Mean Quarterly Average Daily Water Use (gpd) |
|---|---|---|---|---|---|
| S5<br>Leon County | 300 | 375 | Fine Sand | 5 | 189 |
| S6<br>Citrus County | 400 | 500 | Fine Sand | 2-5 | 89 |

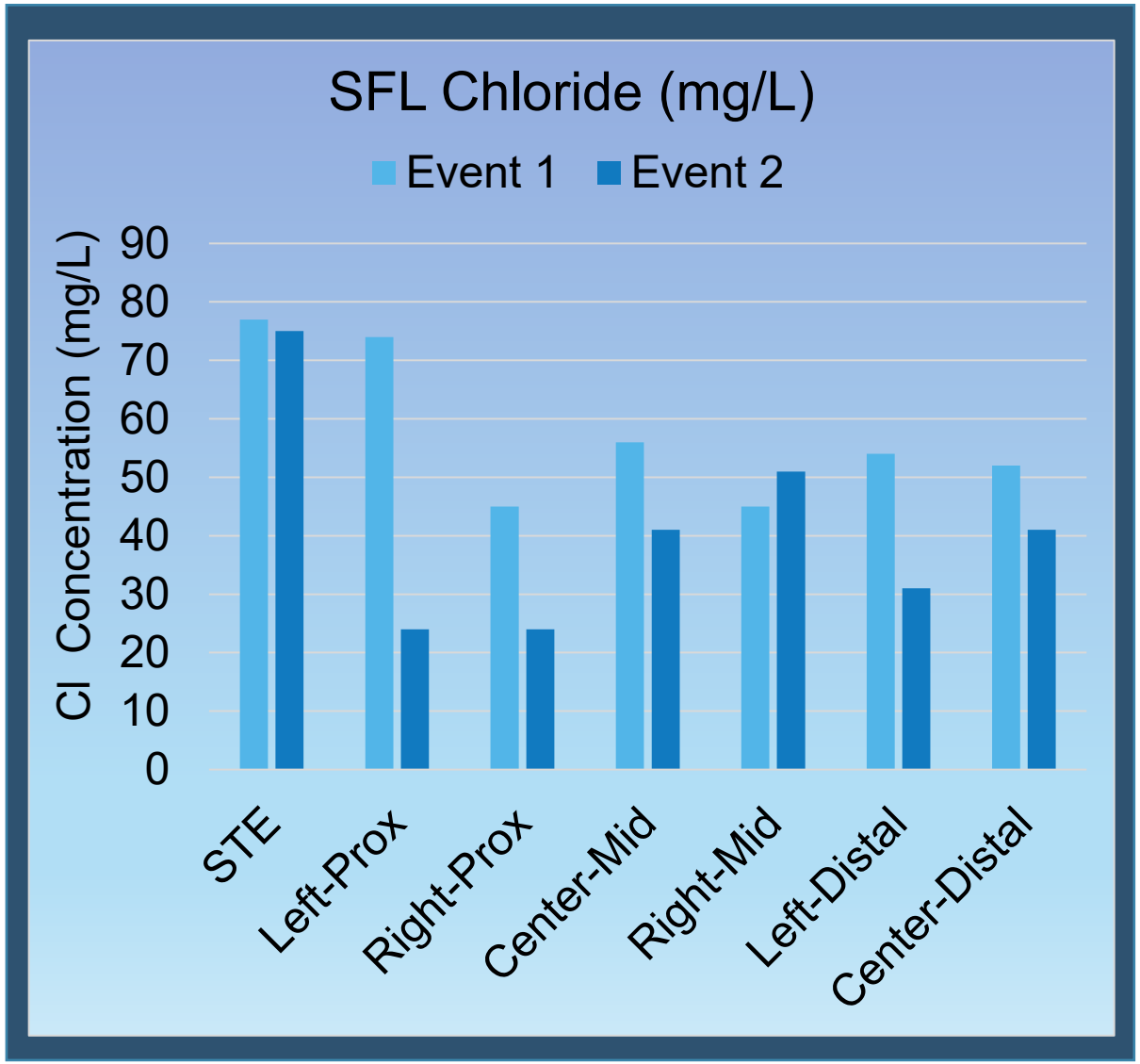
- Monitoring of Citrus County system INRB began in January 2024.
- Monitoring of Leon County system INRB began in November 2024.
- Neither property had an irrigation system (all water flow goes to system).

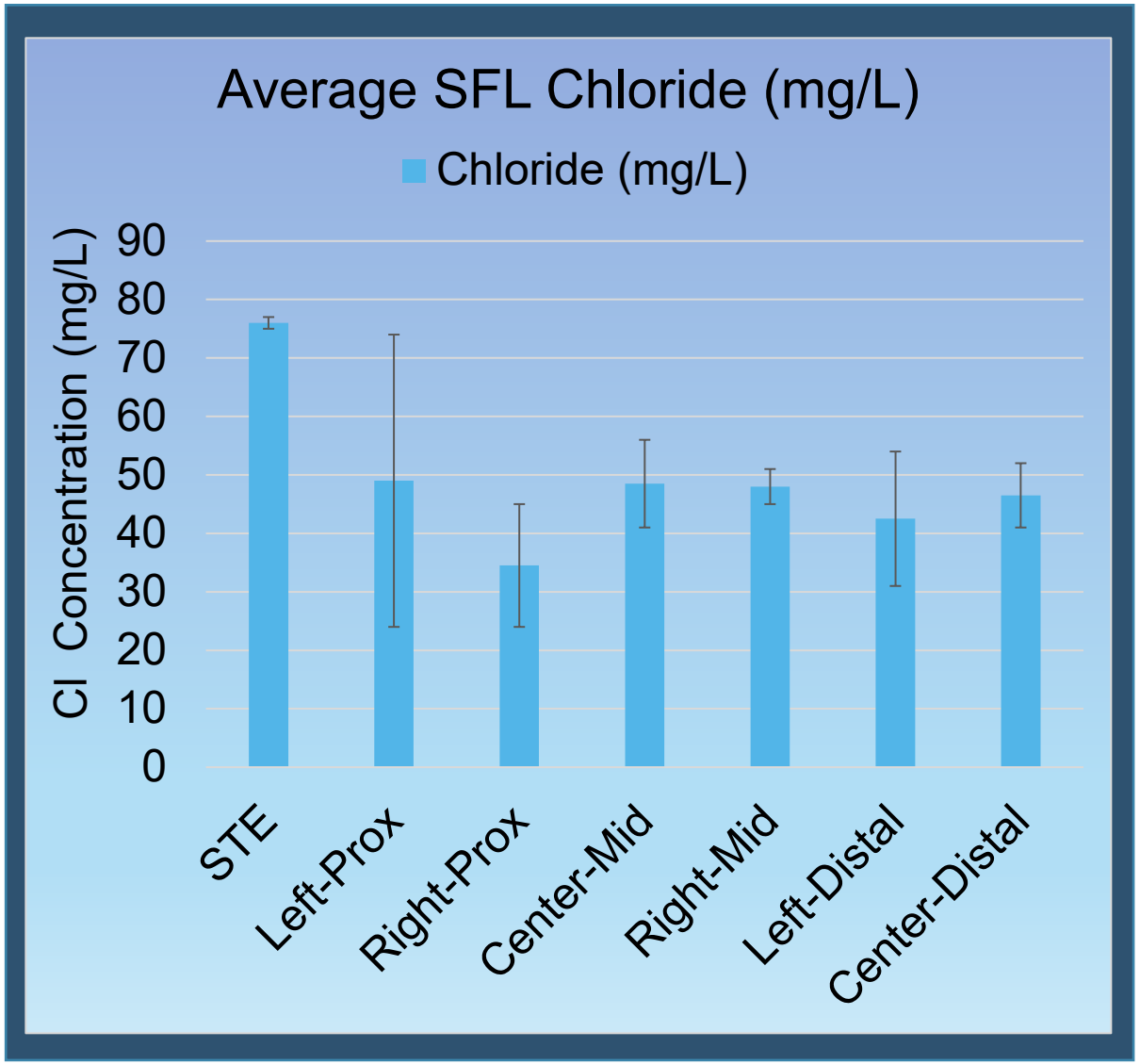
# LEON COUNTY INRB

Monitoring Nitrogen Removal by Florida INRBs

# CHLORIDE CONCENTRATION

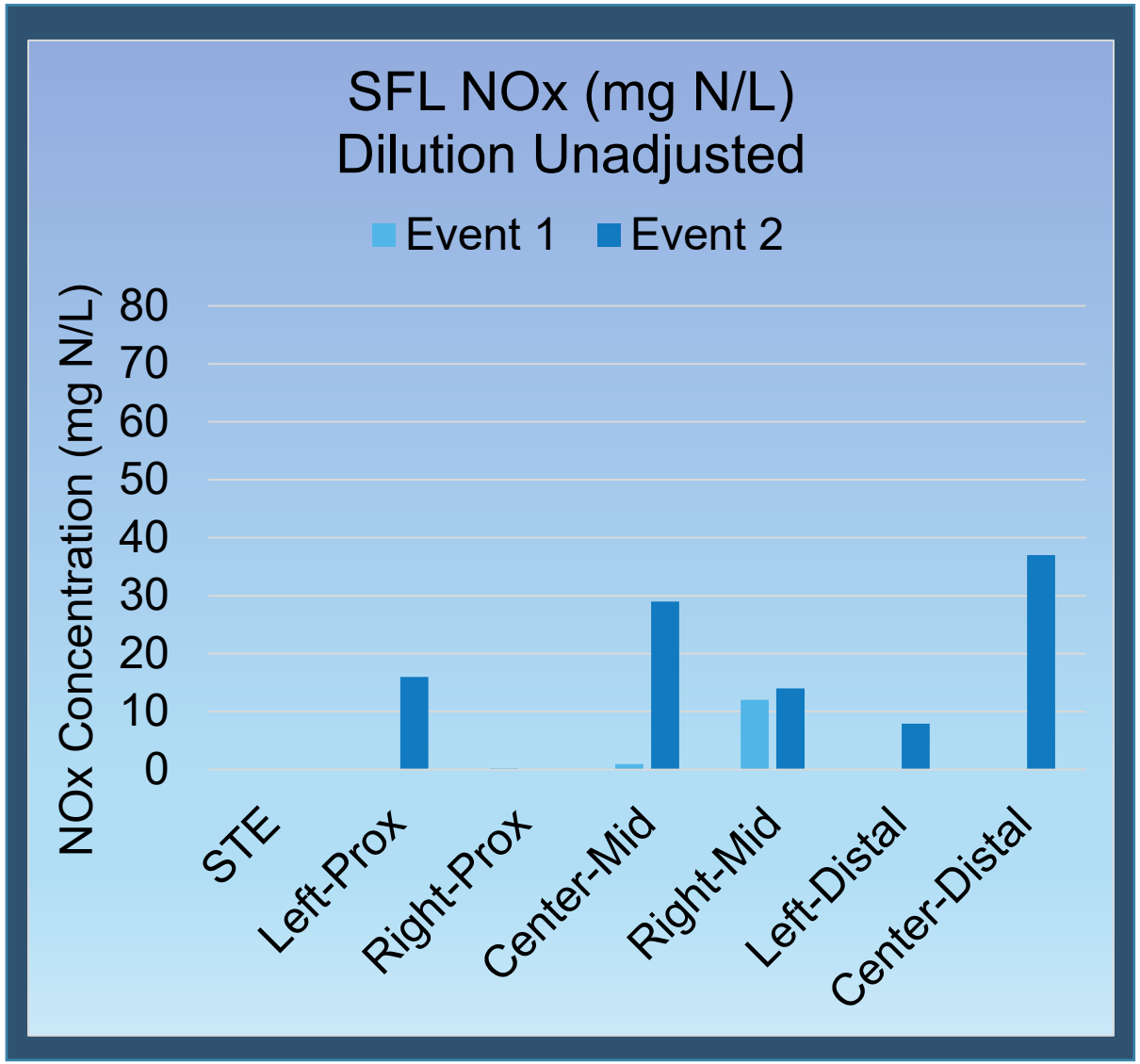
## SYSTEM 5 – SFL MEDIA EFFLUENT

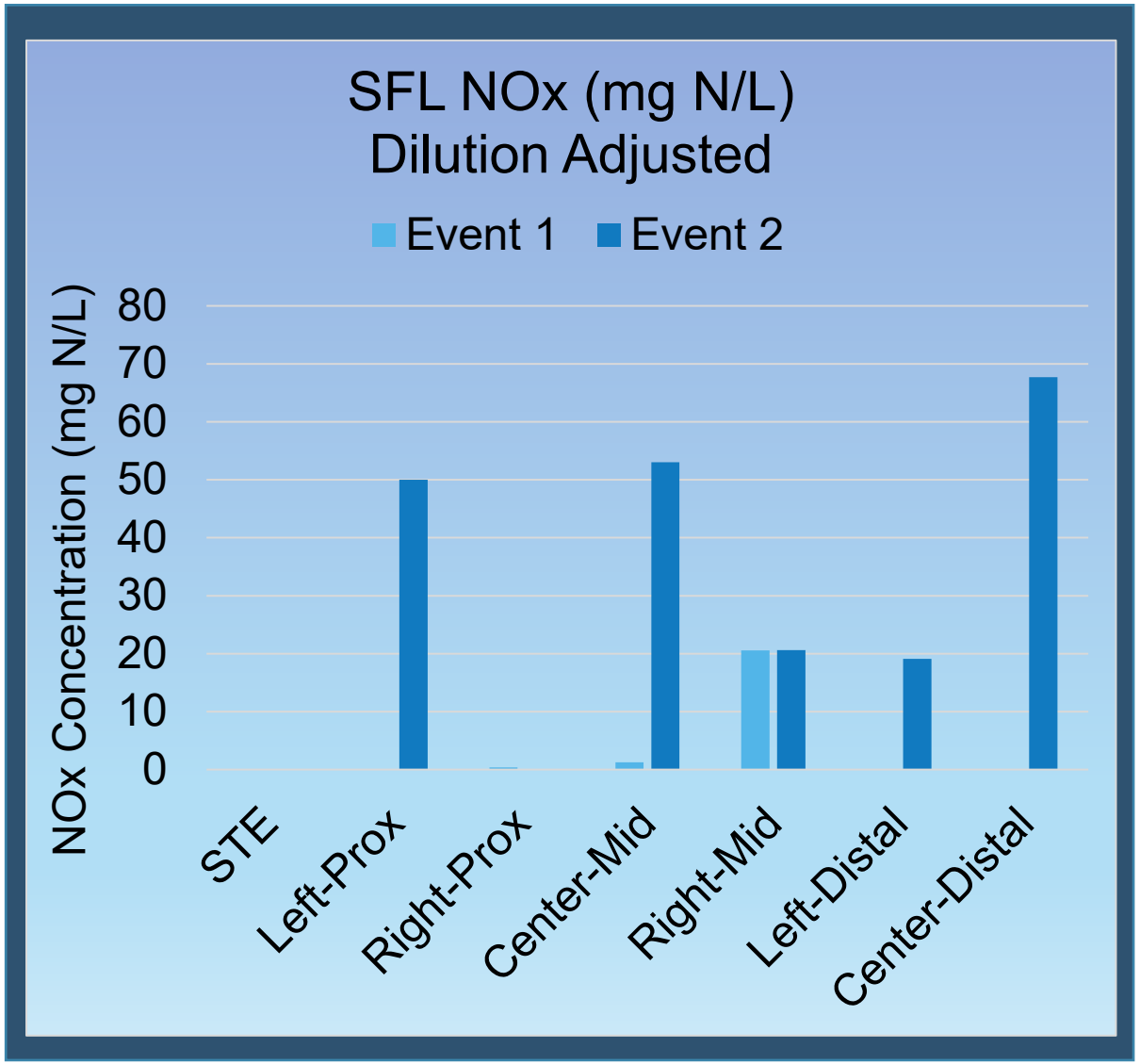


# $NO_X$ CONCENTRATION/EVENT

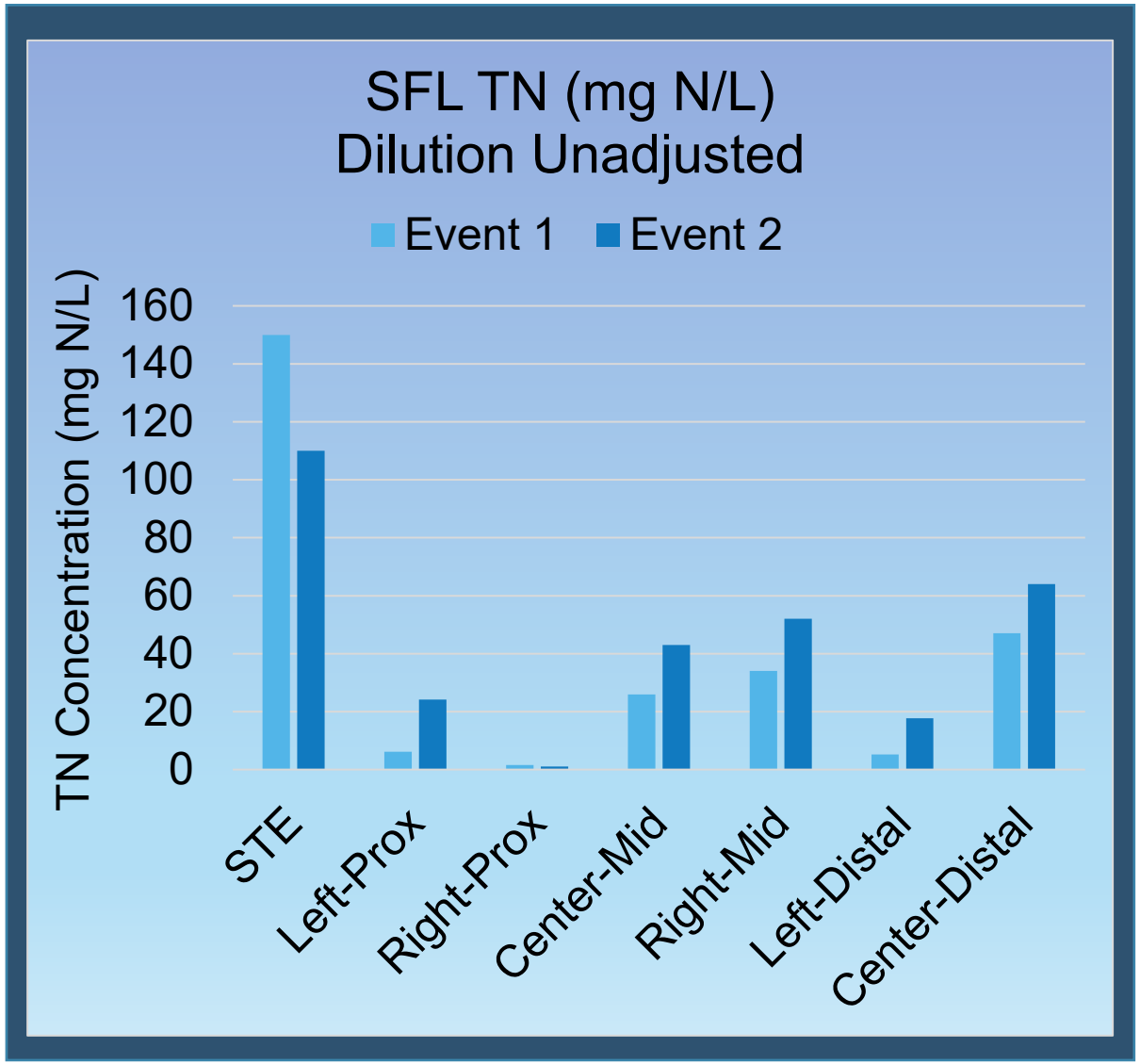
## SYSTEM 5 – SFL EFFLUENT

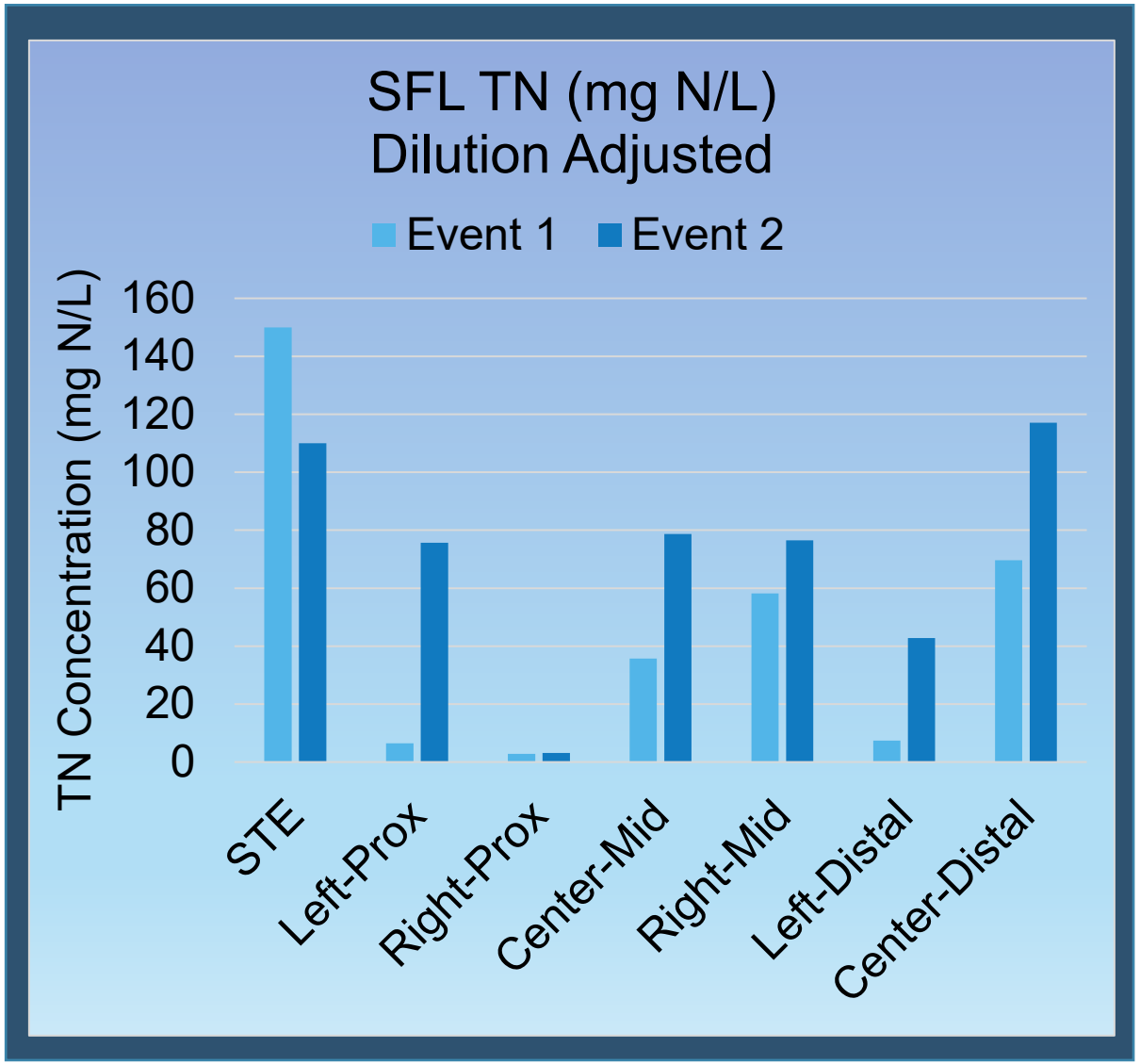


# TOTAL NITROGEN CONCENTRATION/EVENT

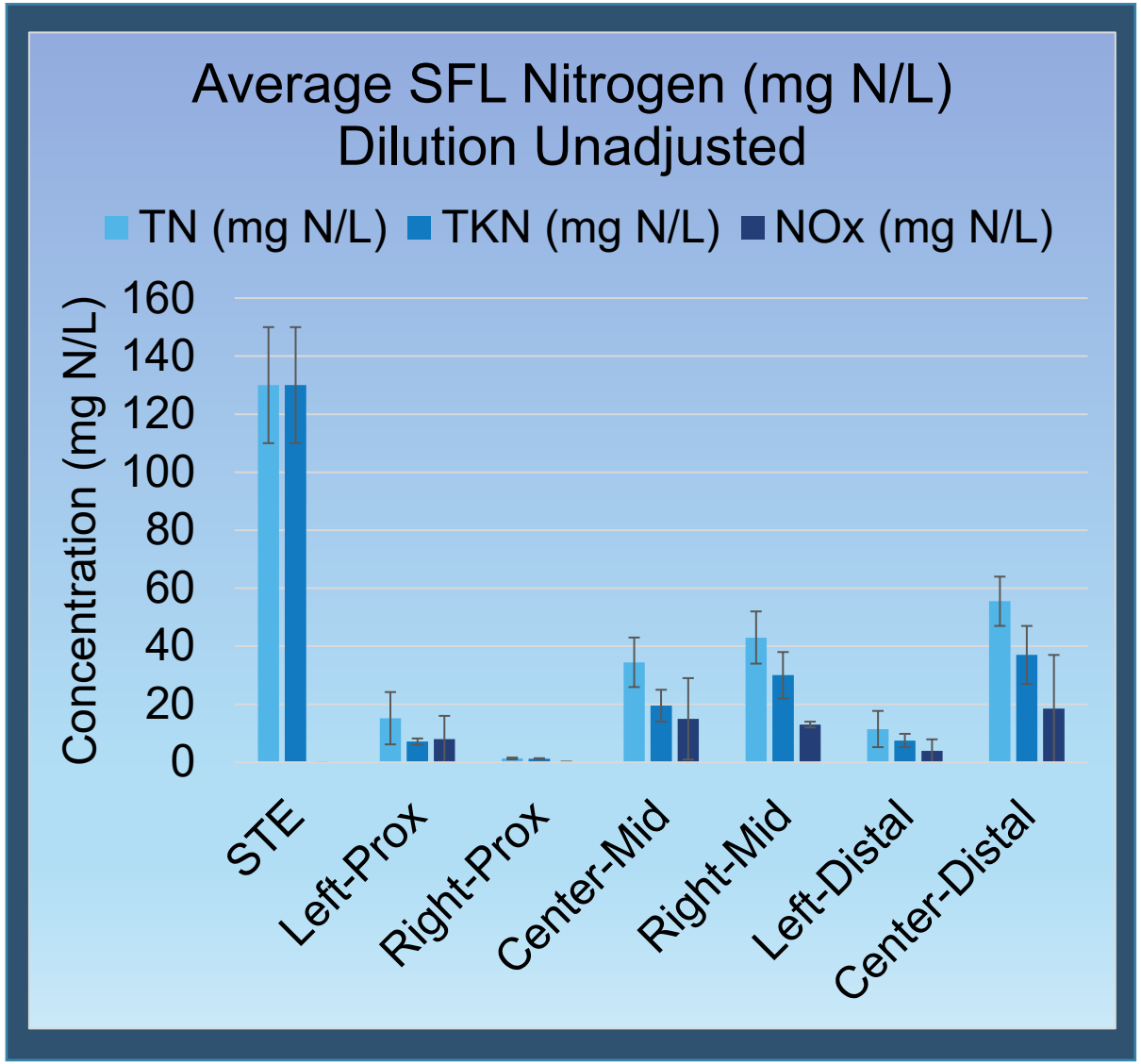
## SYSTEM 5 – SFL EFFLUENT

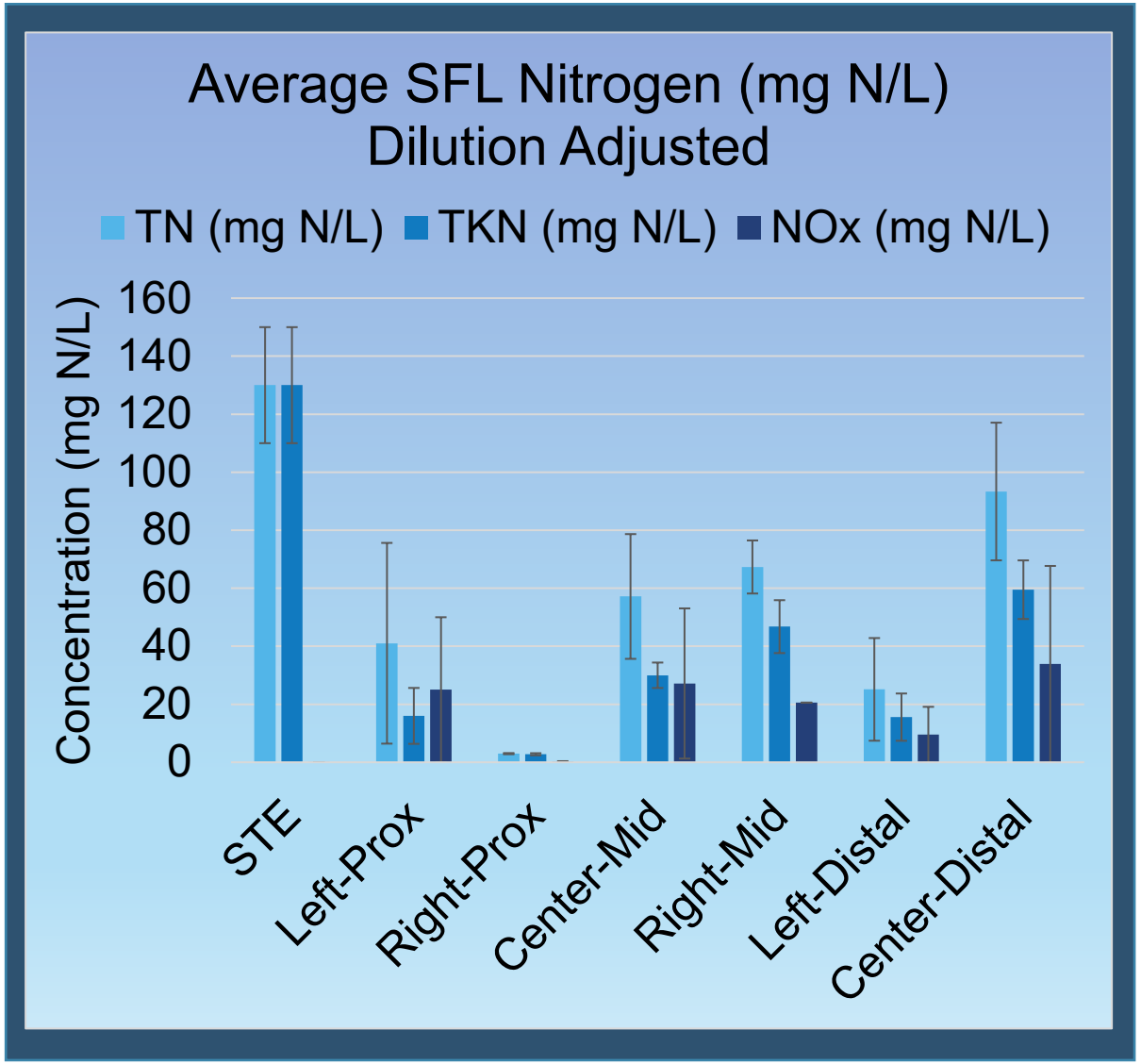


# AVERAGE NITROGEN CONCENTRATIONS

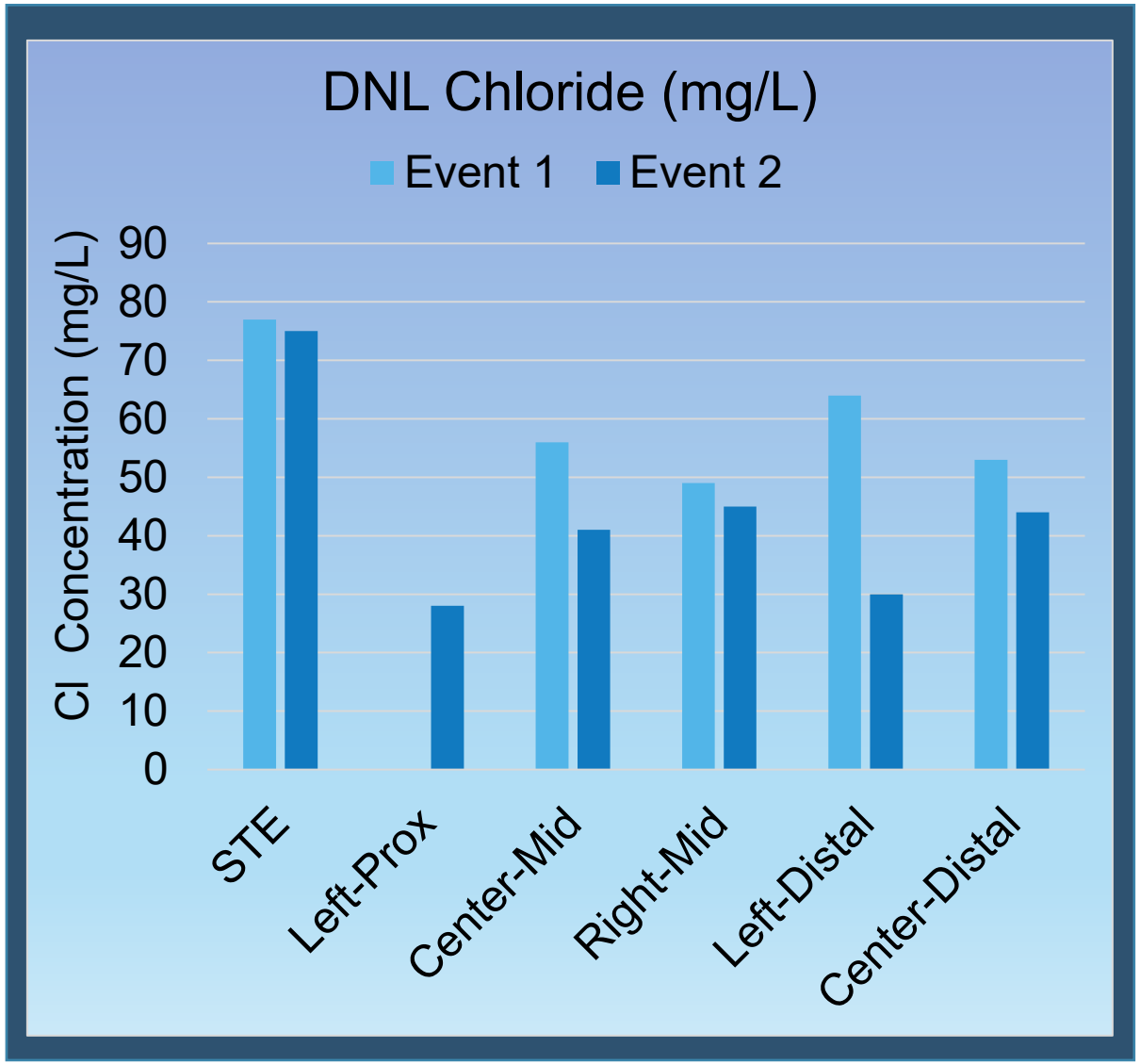
## SYSTEM 5 – SFL EFFLUENT

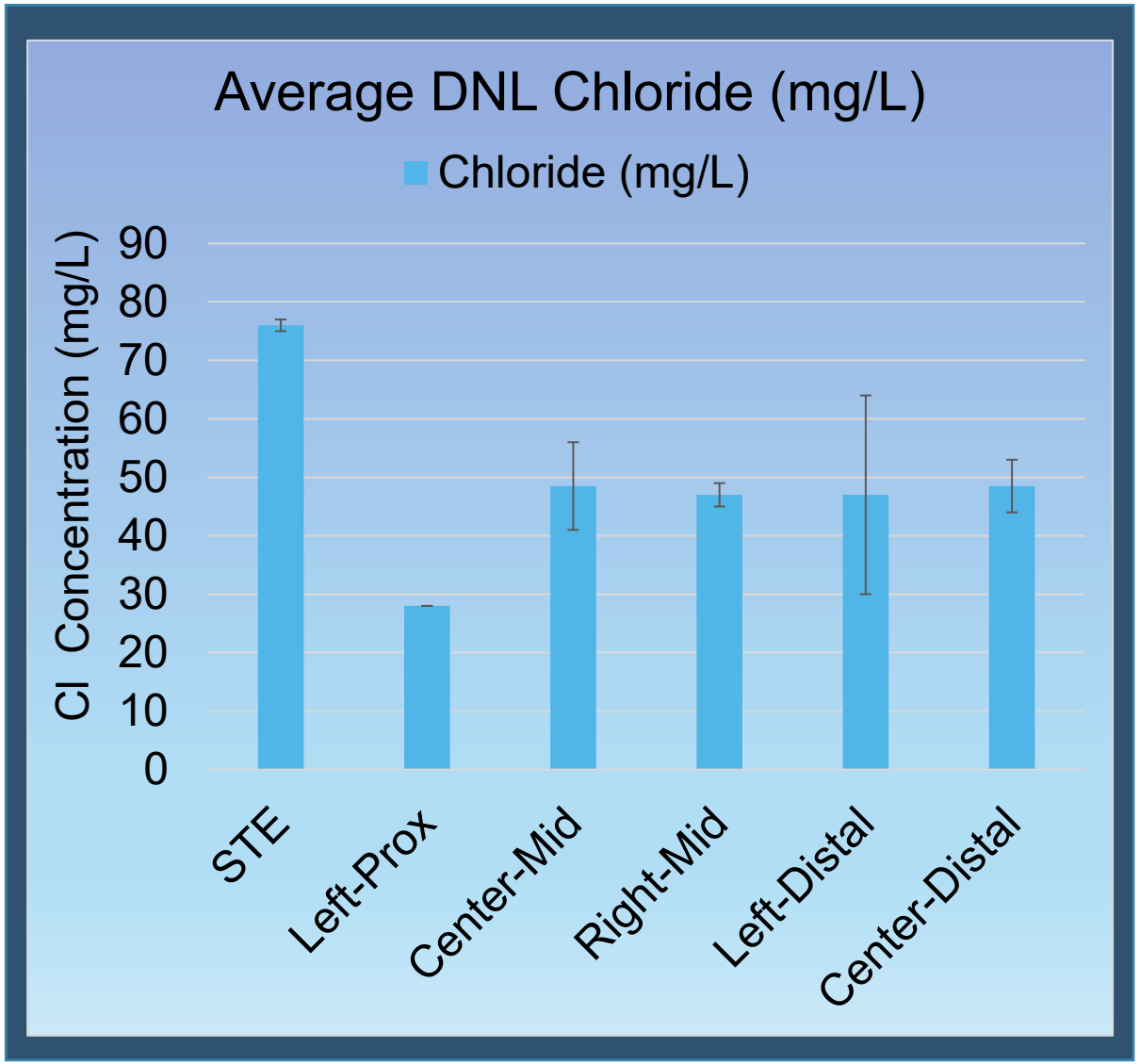


# CHLORIDE CONCENTRATION S5

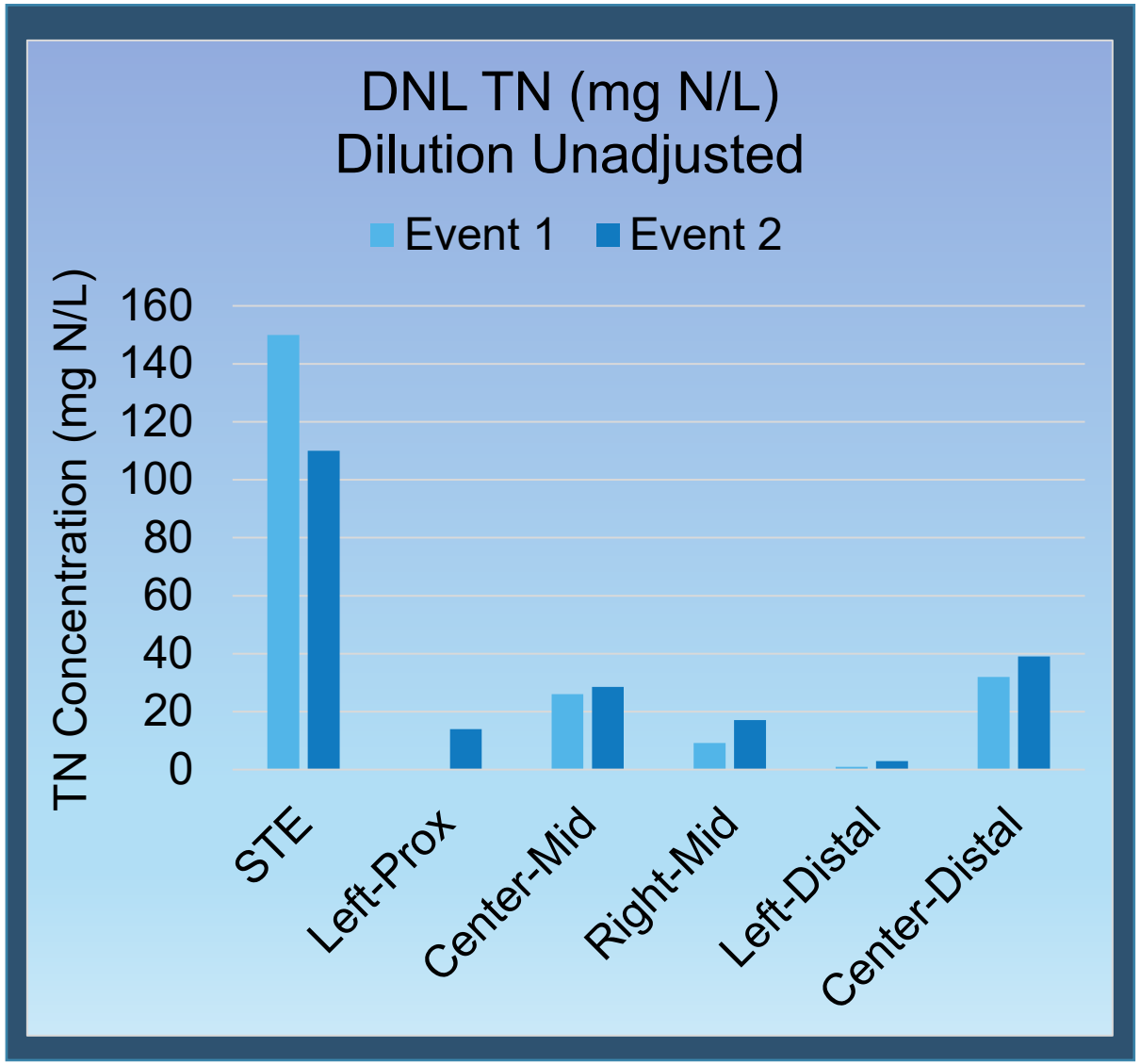
## SYSTEM 5 – DNL MEDIA EFFLUENT

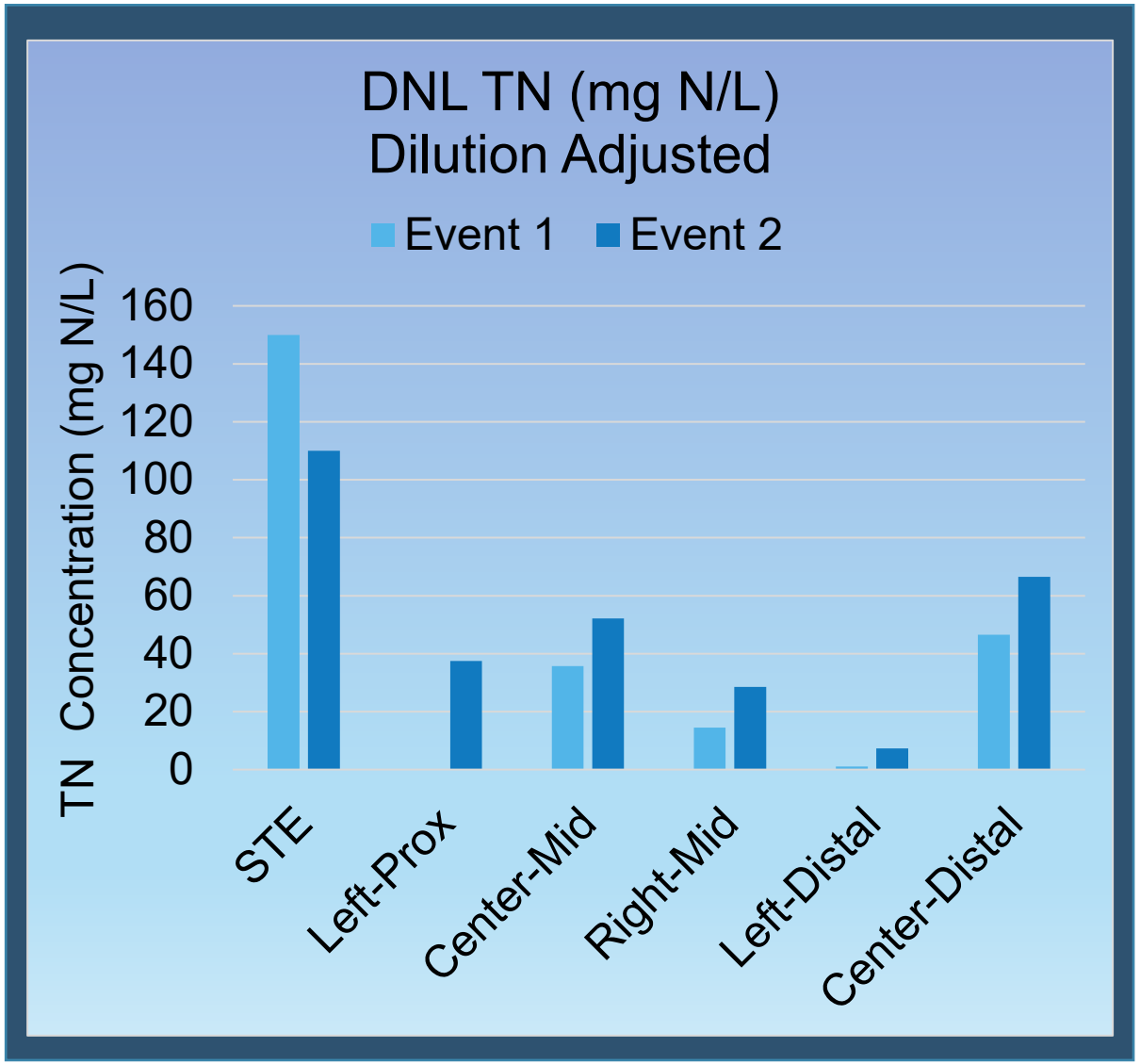


# TOTAL NITROGEN CONCENTRATION/EVENT S5

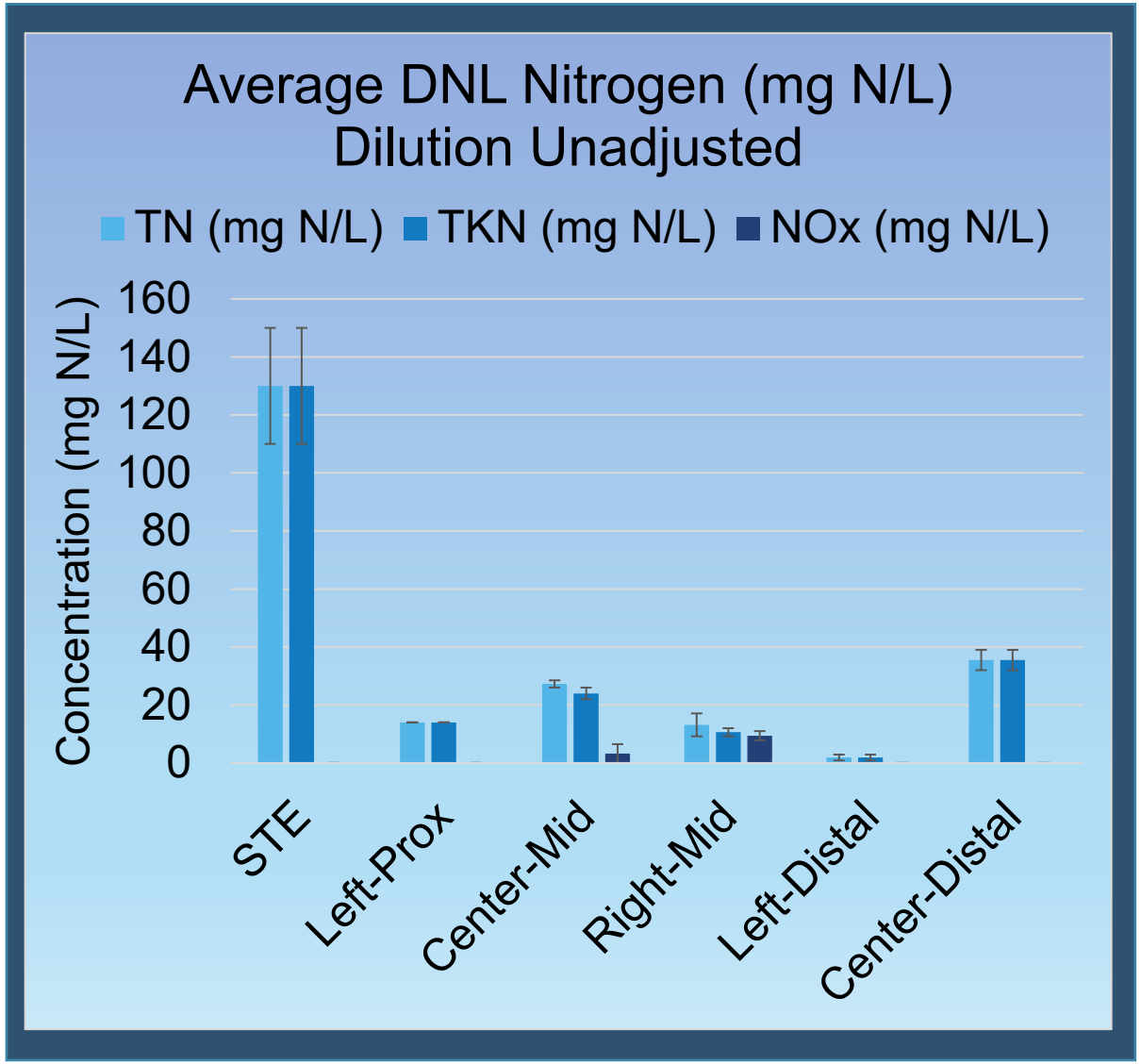
## SYSTEM 5 – DNL EFFLUENT

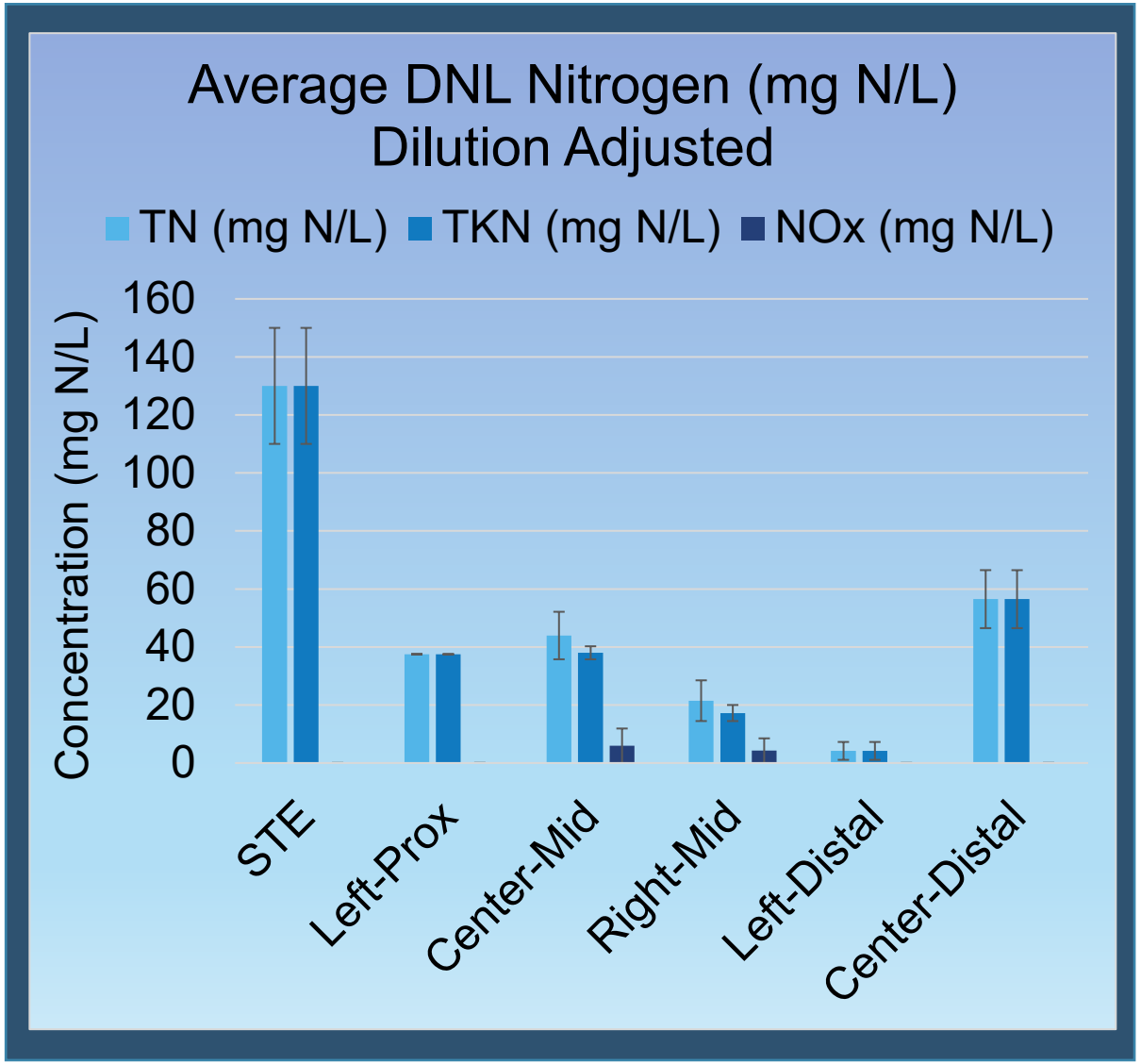


# AVERAGE NITROGEN CONCENTRATIONS S5

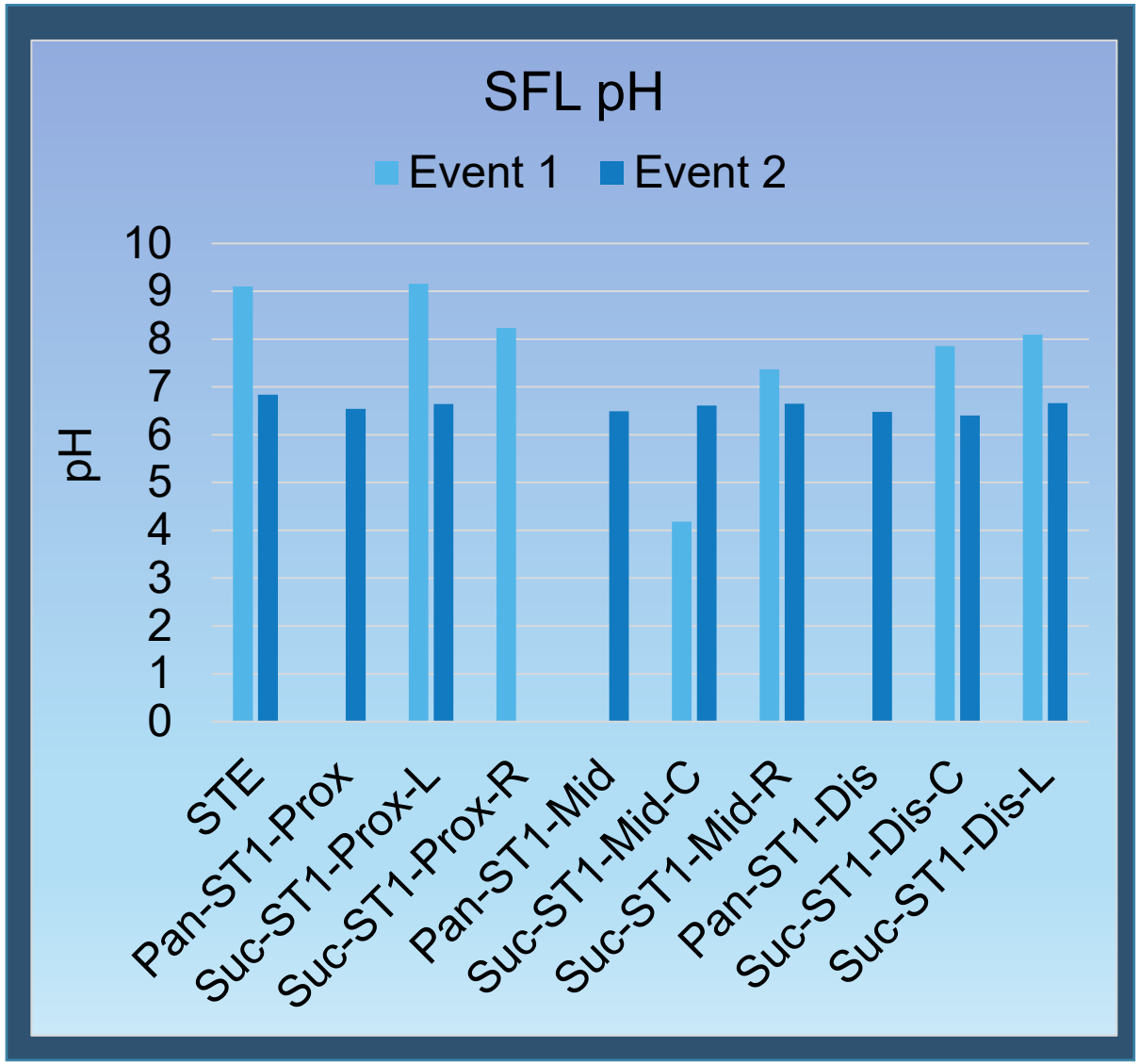
## SYSTEM 5 – DNL EFFLUENT

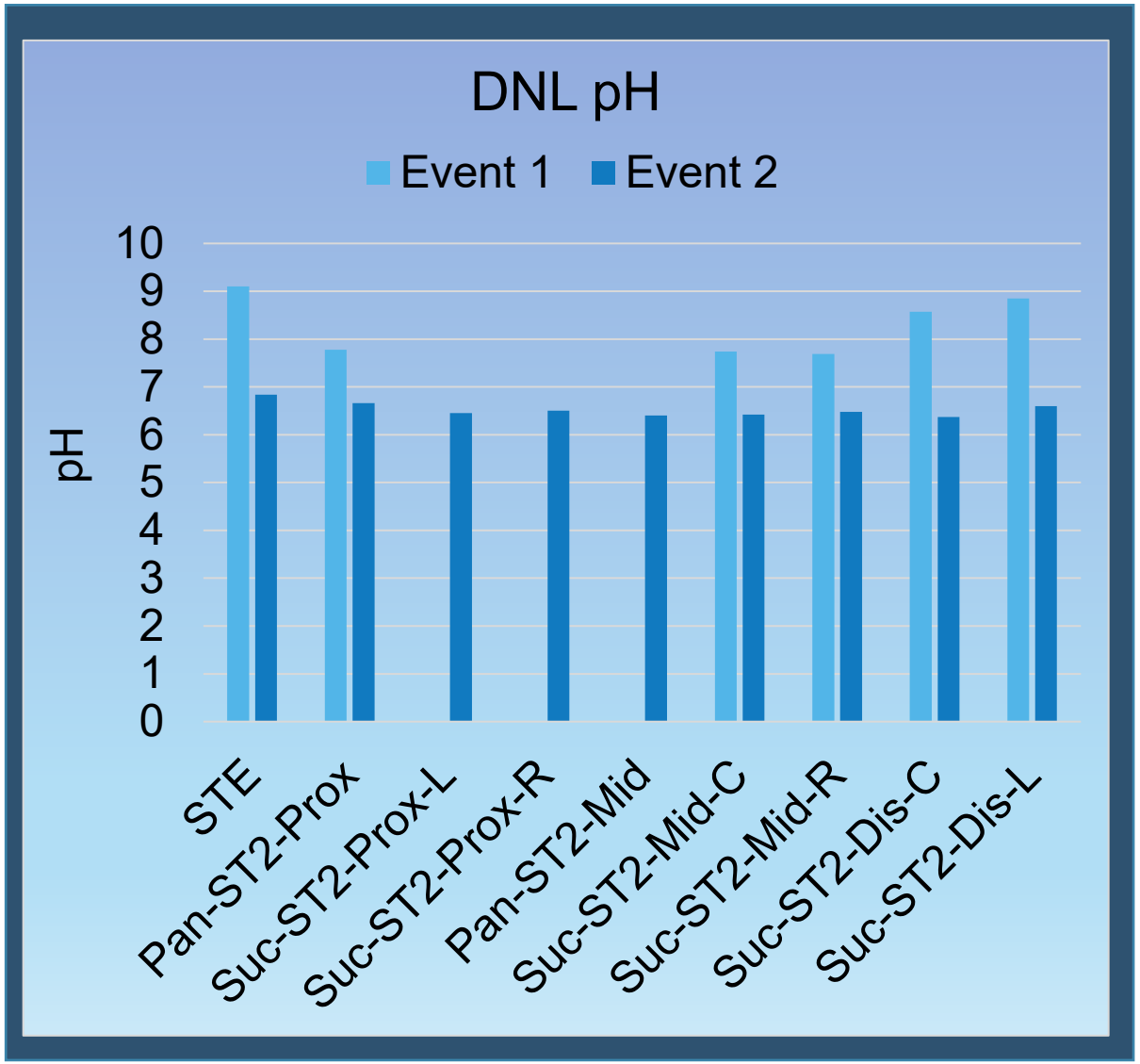


# PH VALUES

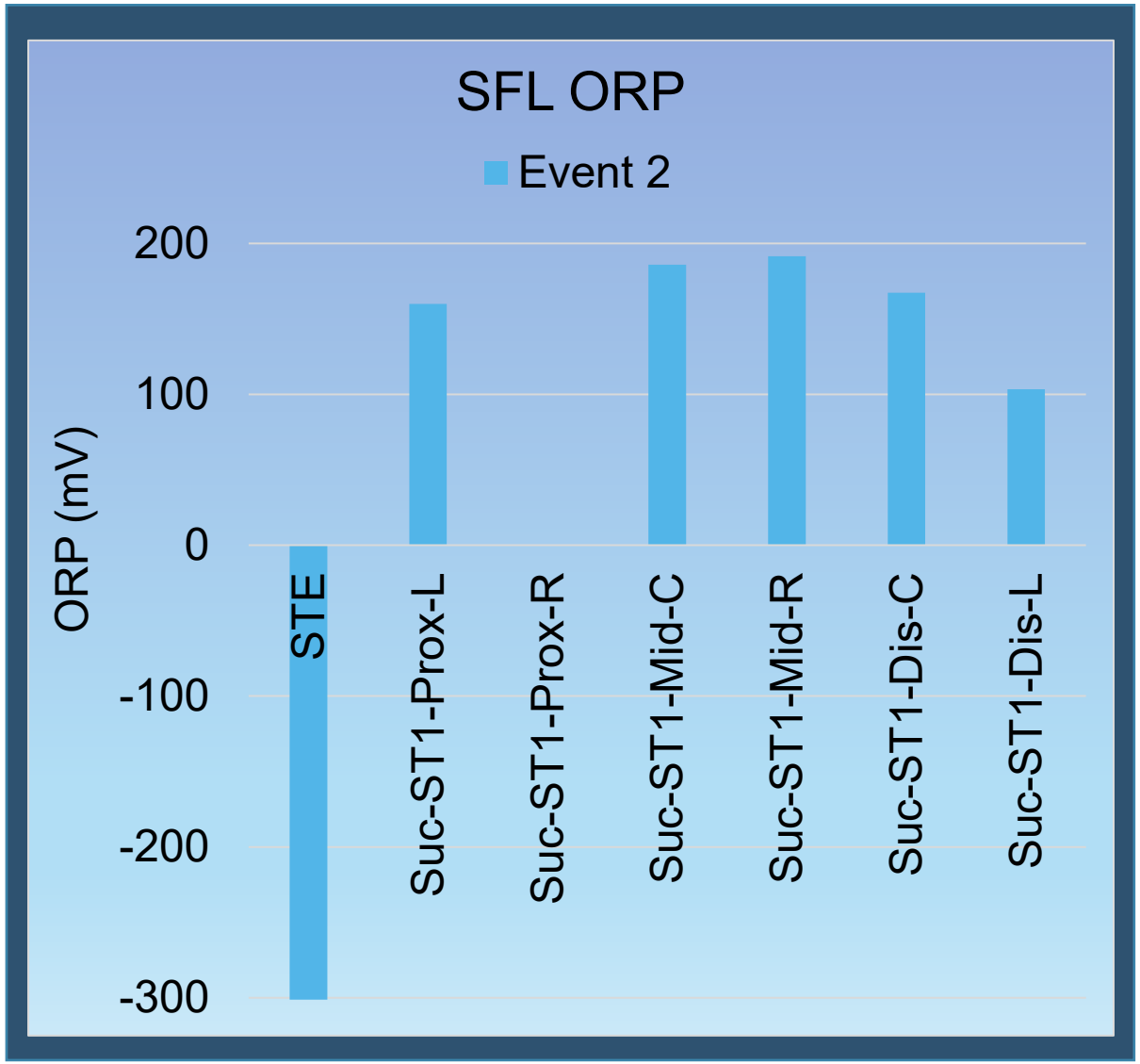
## SYSTEM 5 – SFL VERSUS DNL EFFLUENT

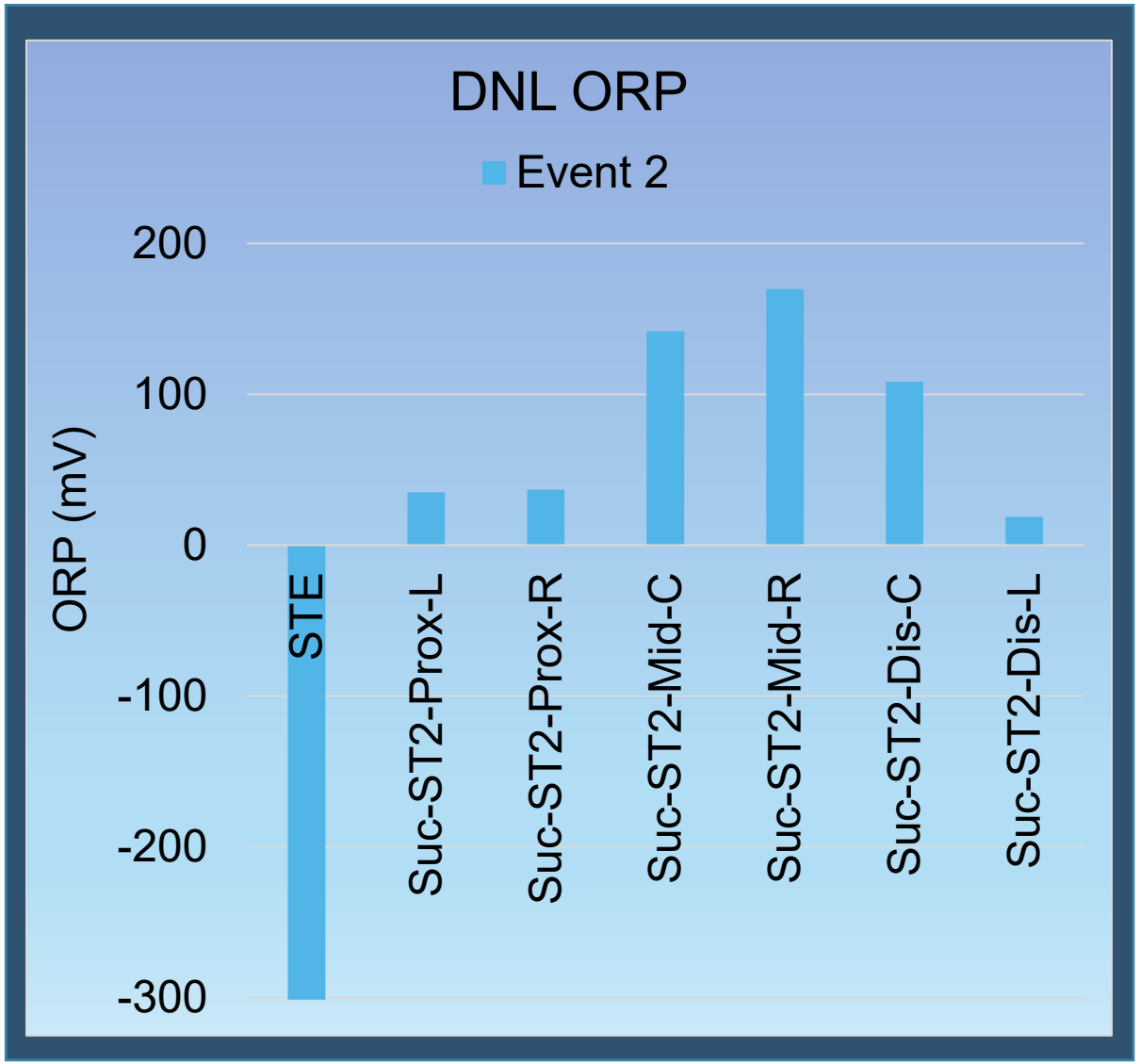


# ORP VALUES

## SYSTEM 5 – SFL VERSUS DNL EFFLUENT



# AVERAGE NITROGEN REDUCTION S5

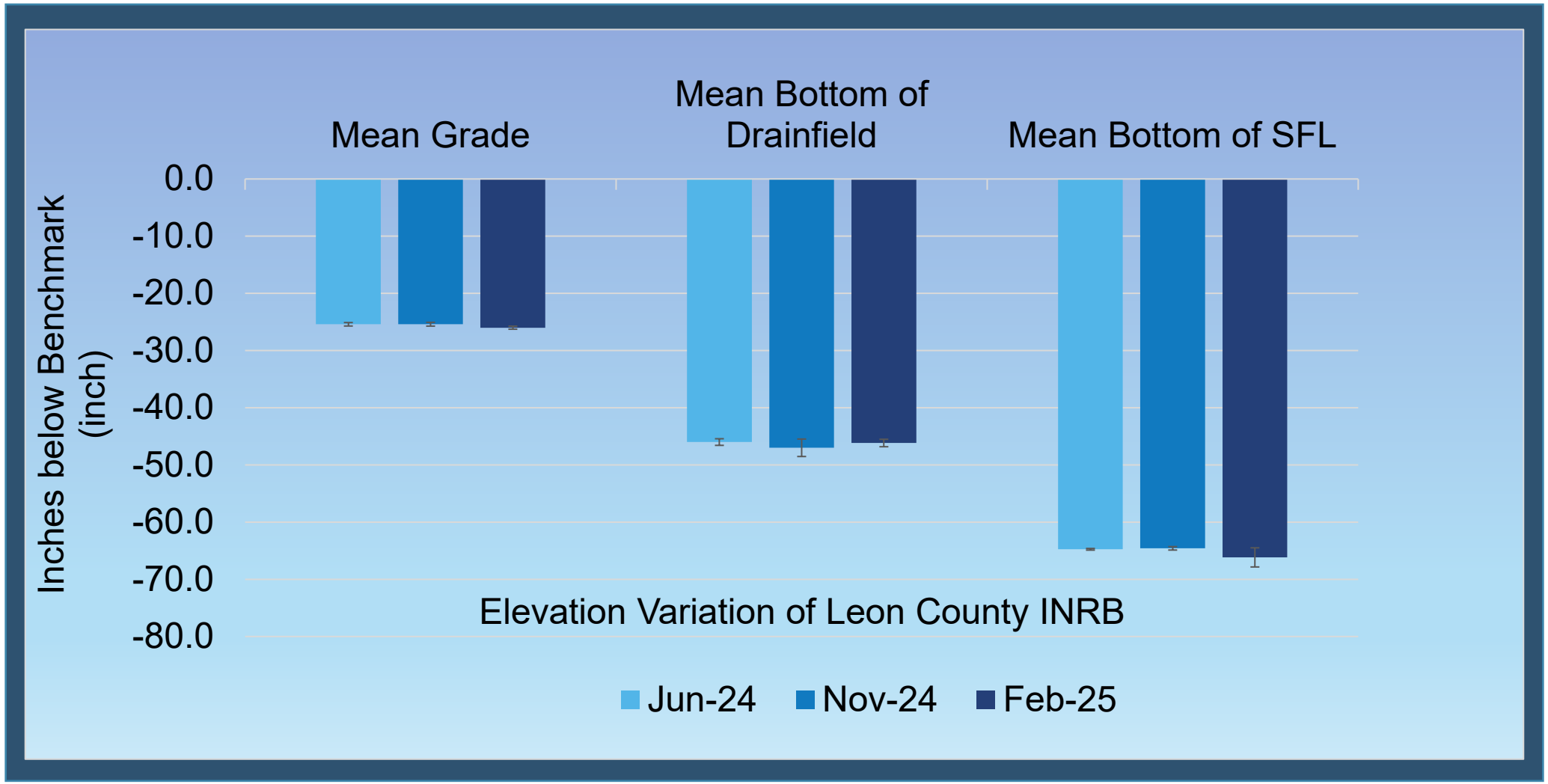
## SYSTEM 5 – DNL – ADJUSTED

| Location | Event 1 | Event 2 | Average | Percent Nitrogen Reduction | Percent Nitrogen Reduction | Average in Monitoring Location |
|---|---|---|---|---|---|---|
| STE (mg/L) | 150 | 110 | 130 | Event 1 | Event 2 | All events |
| Center-Mid (mg/L) | 36 | 52 | 44 | 76% | 53% | 66% |
| Right-Mid (mg/L) | 15 | 29 | 22 | 90% | 74% | 82% |
| Left-Distal (mg/L) | 1 | 7 | 4 | 99% | 94% | 97% |
| Center-Distal (mg/L) | 47 | 67 | 57 | 69% | 39% | 54% |
| Average for each event | | | | **84%** | **65%** | |

**Overall average percent nitrogen reduction ~ 75%.**

# ELEVATION CHANGE OF SYSTEM LAYERS S5

## SYSTEM 5

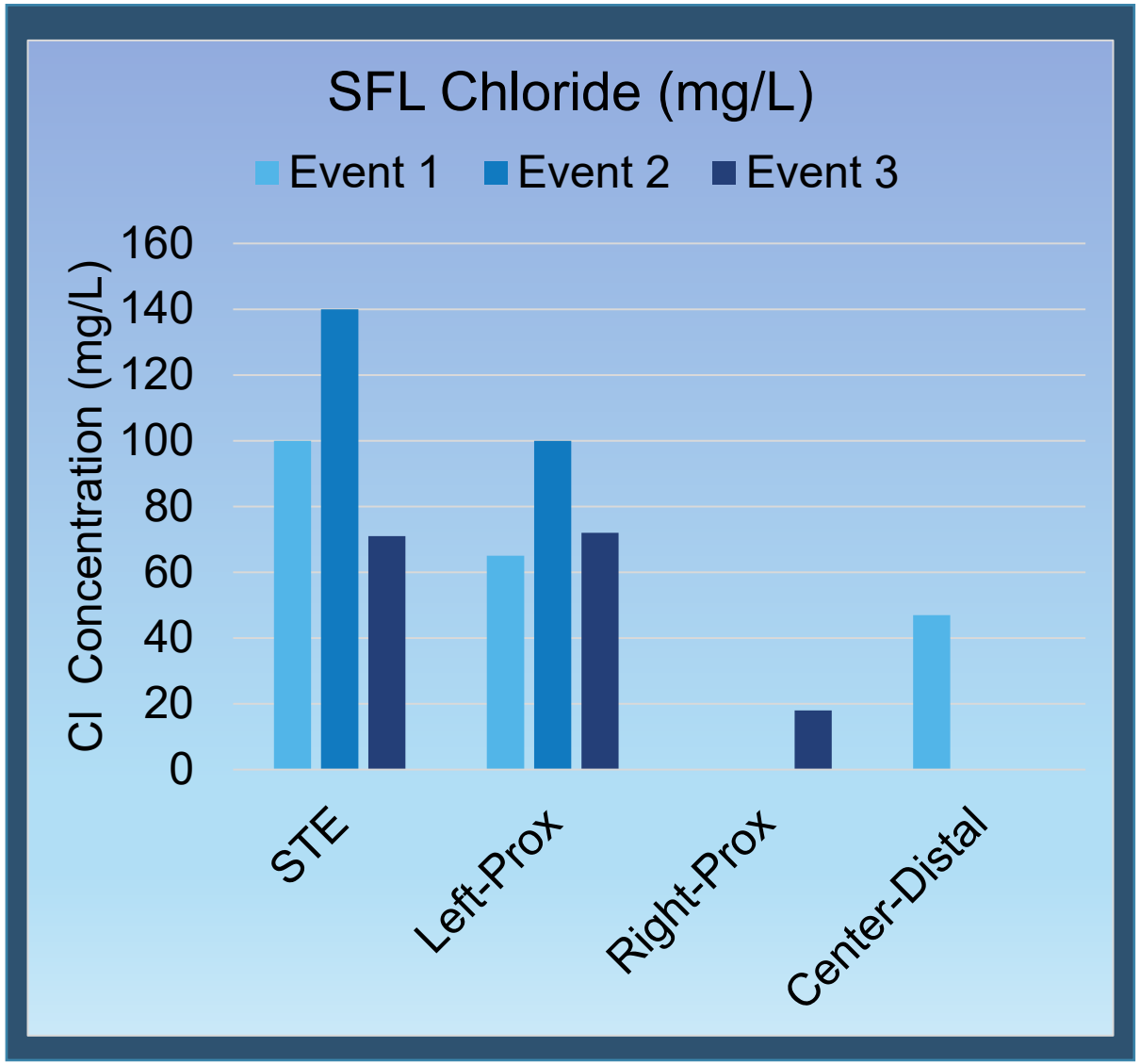


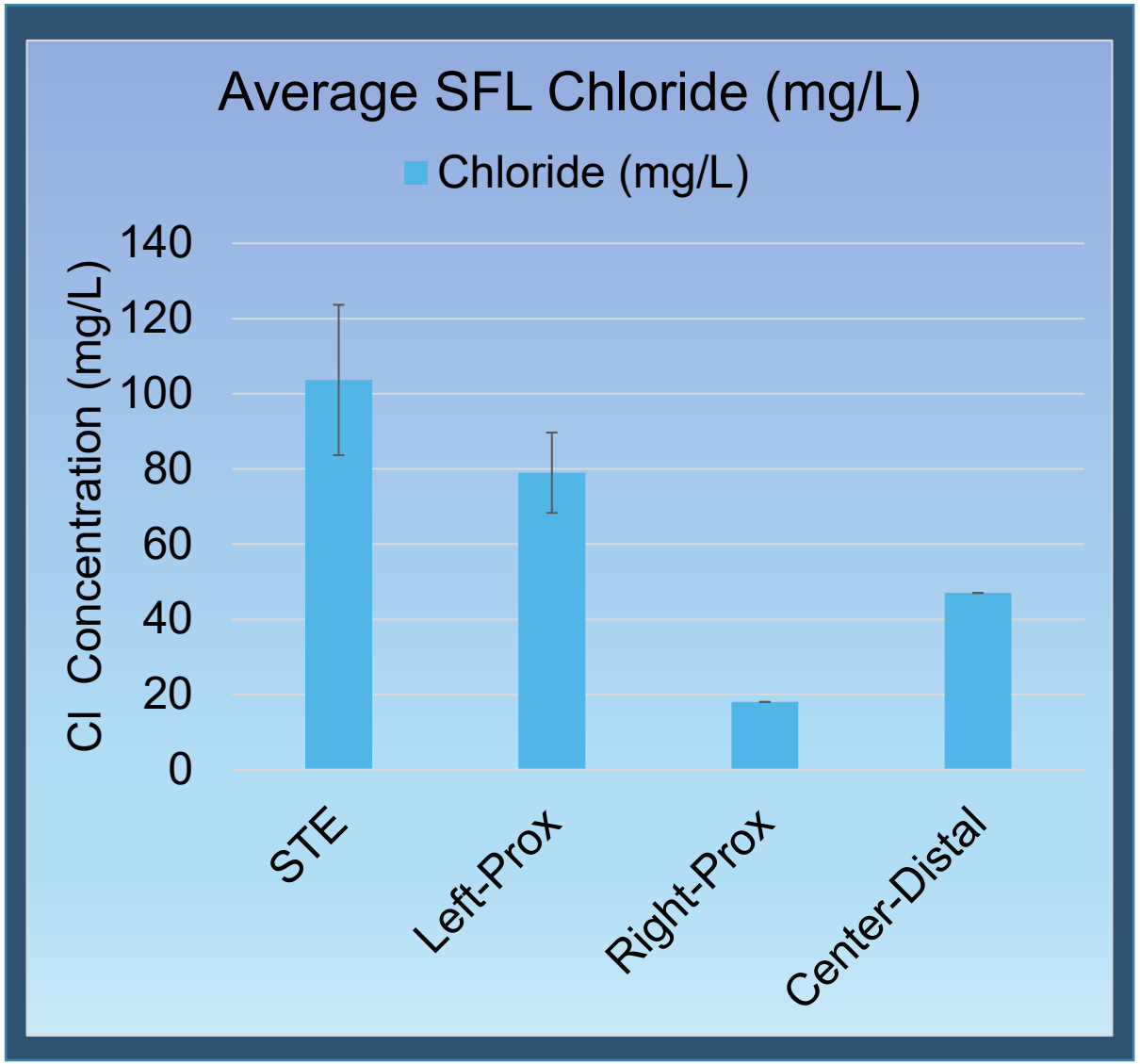
# CITRUS COUNTY INRB

Monitoring Nitrogen Removal by Florida INRBs

# CHLORIDE CONCENTRATION S6

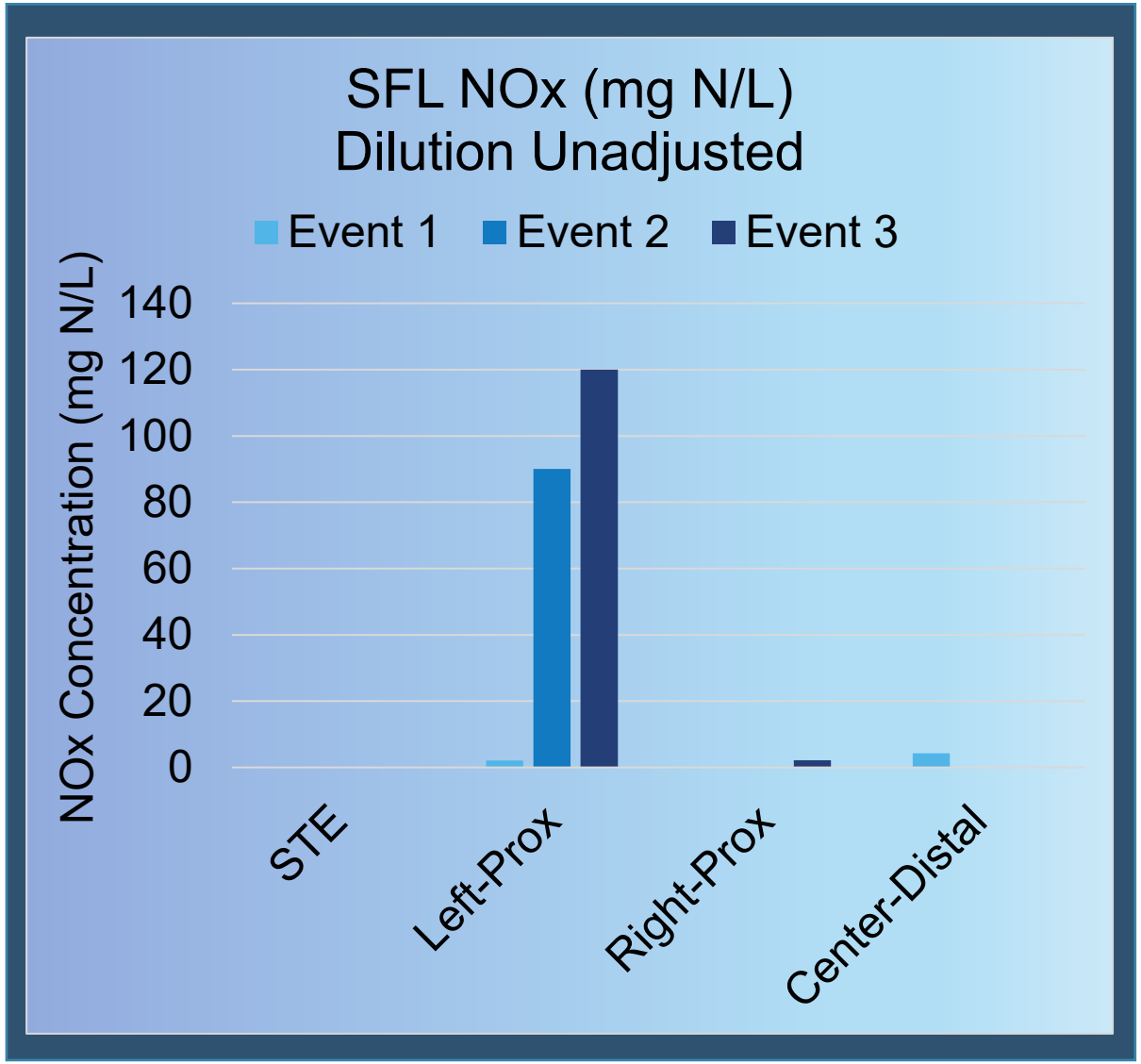
## SYSTEM 6 – SFL MEDIA EFFLUENT

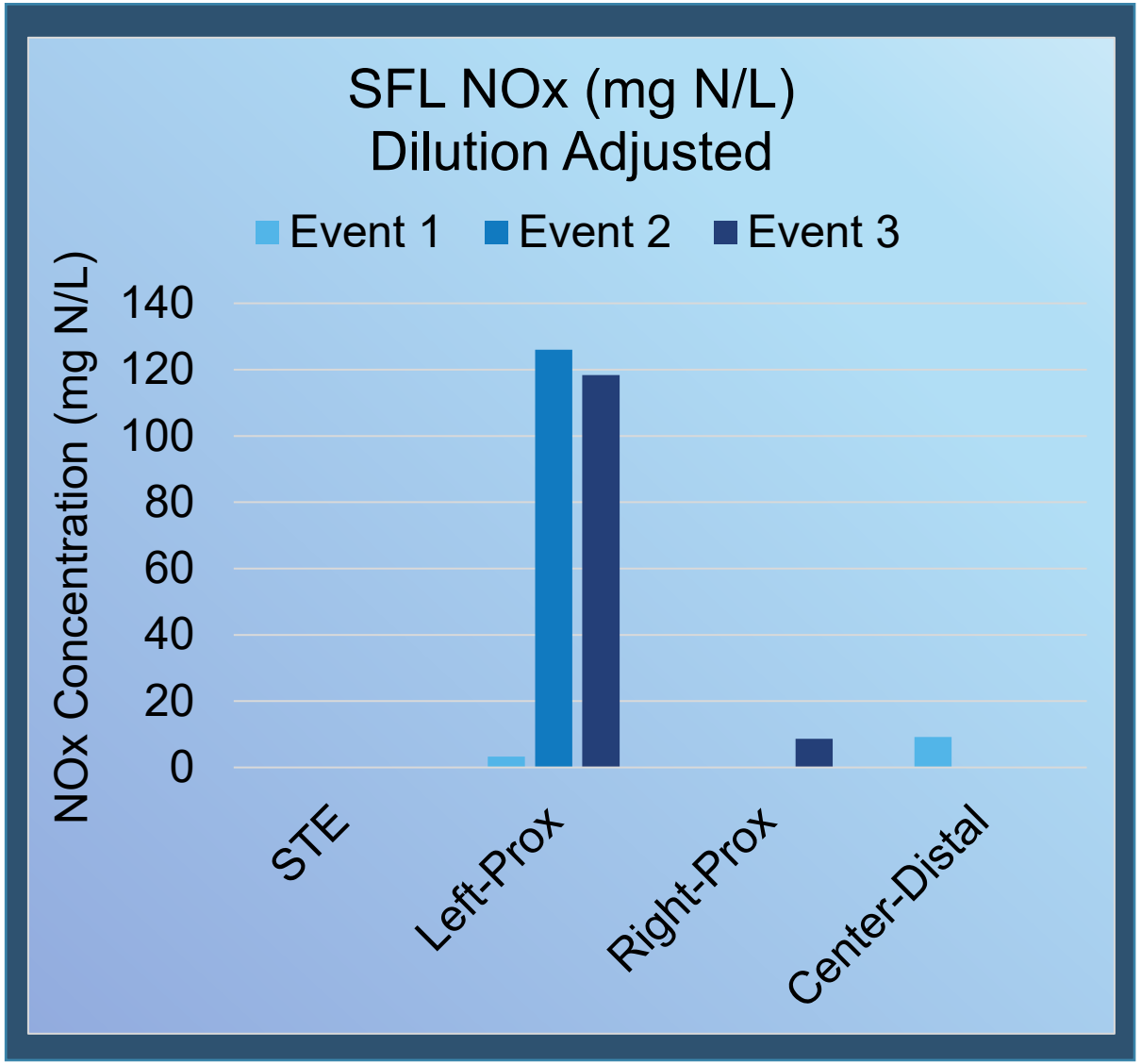


# $NO_X$ CONCENTRATION/EVENT S6

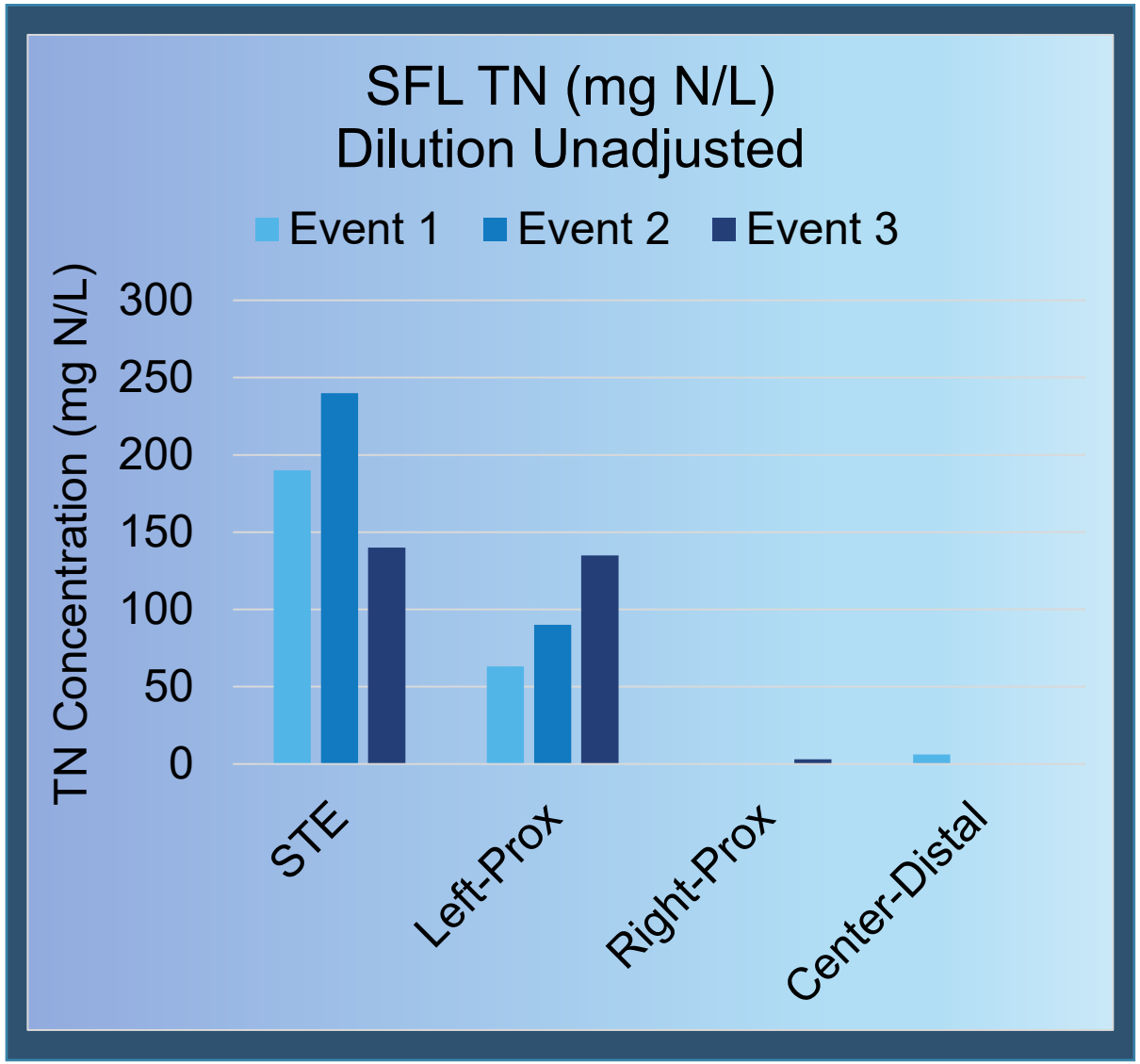
## SYSTEM 6 – SFL EFFLUENT

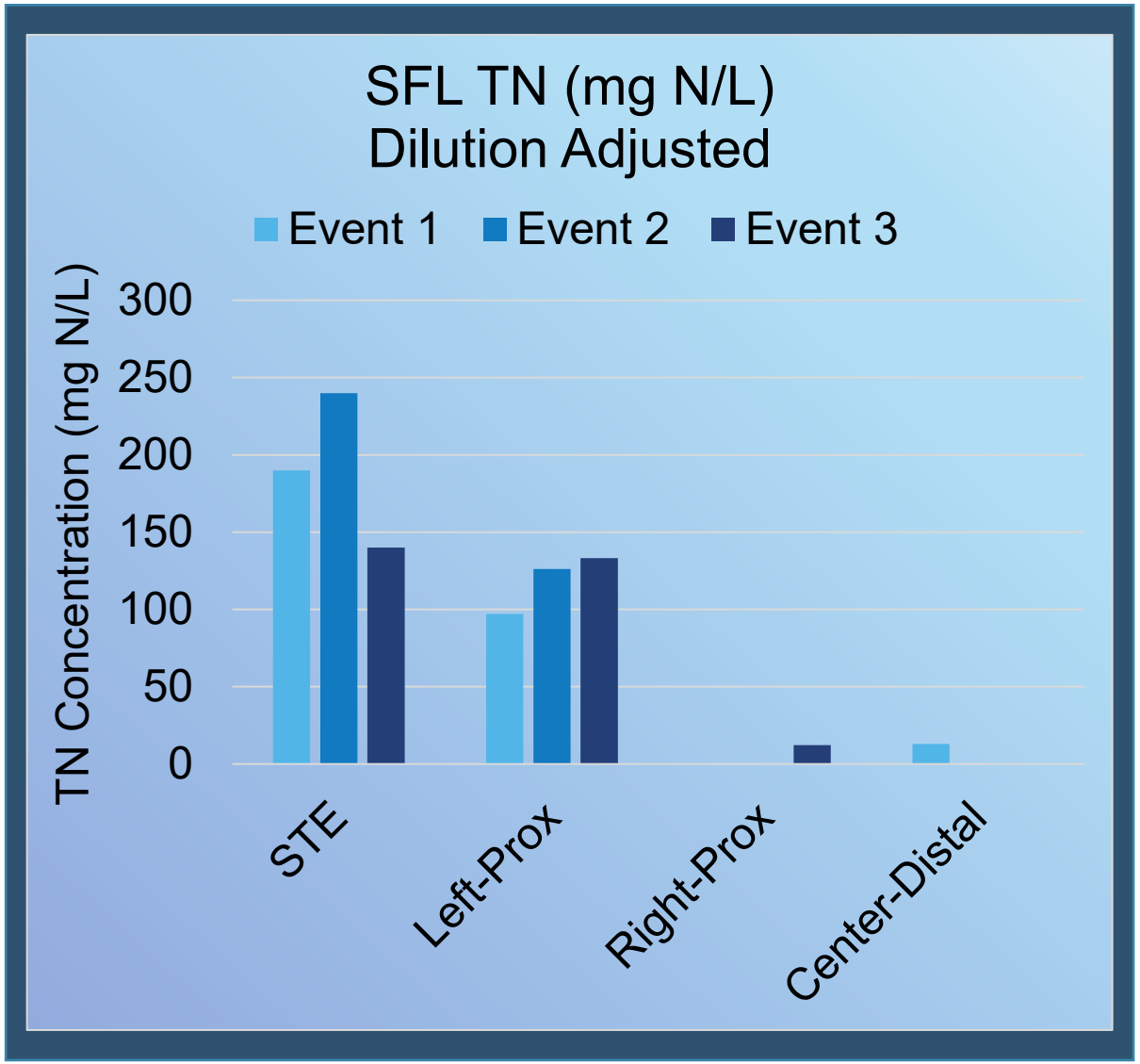


# TOTAL NITROGEN CONCENTRATION/EVENT S6

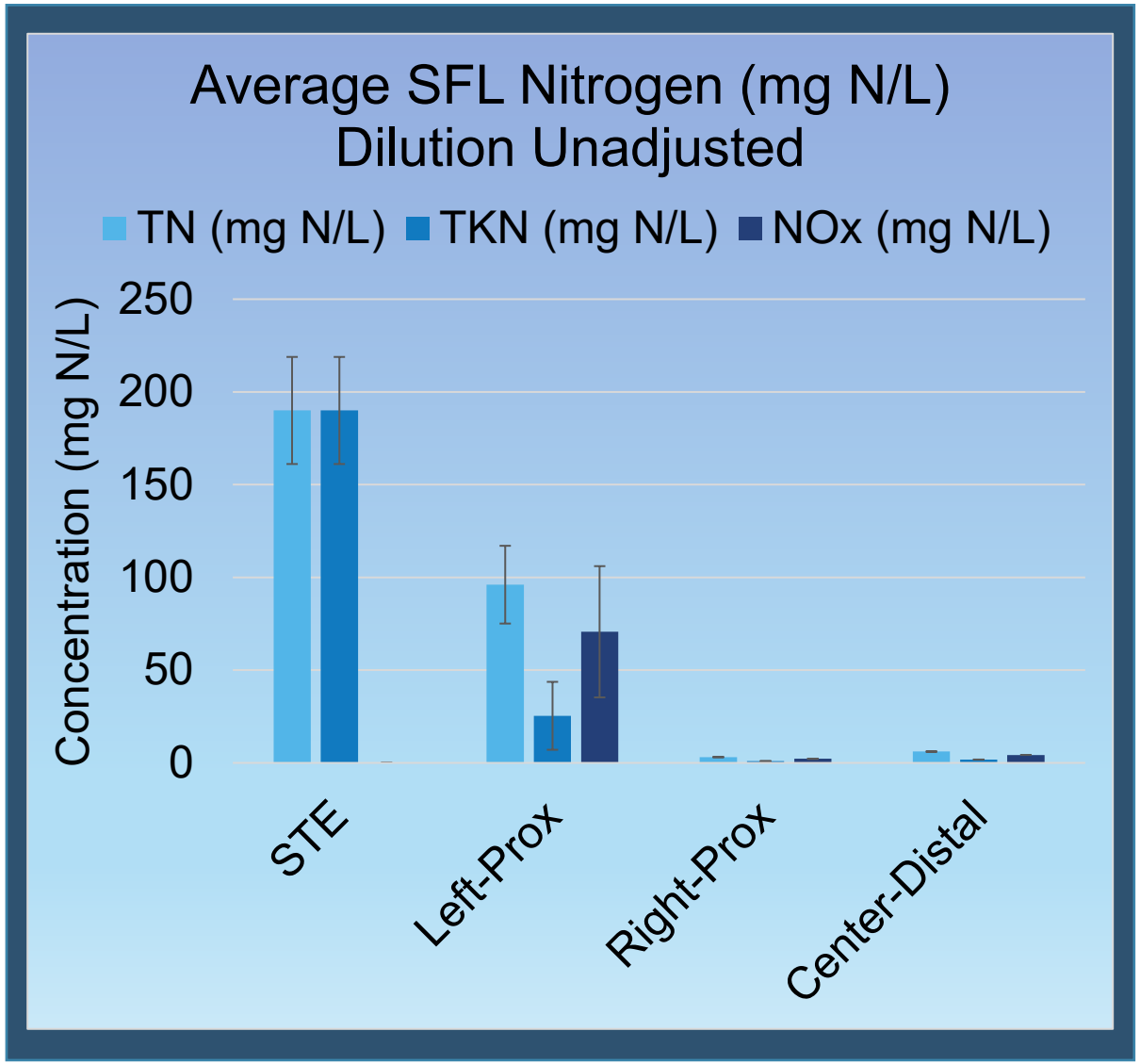
## SYSTEM 6 – SFL EFFLUENT

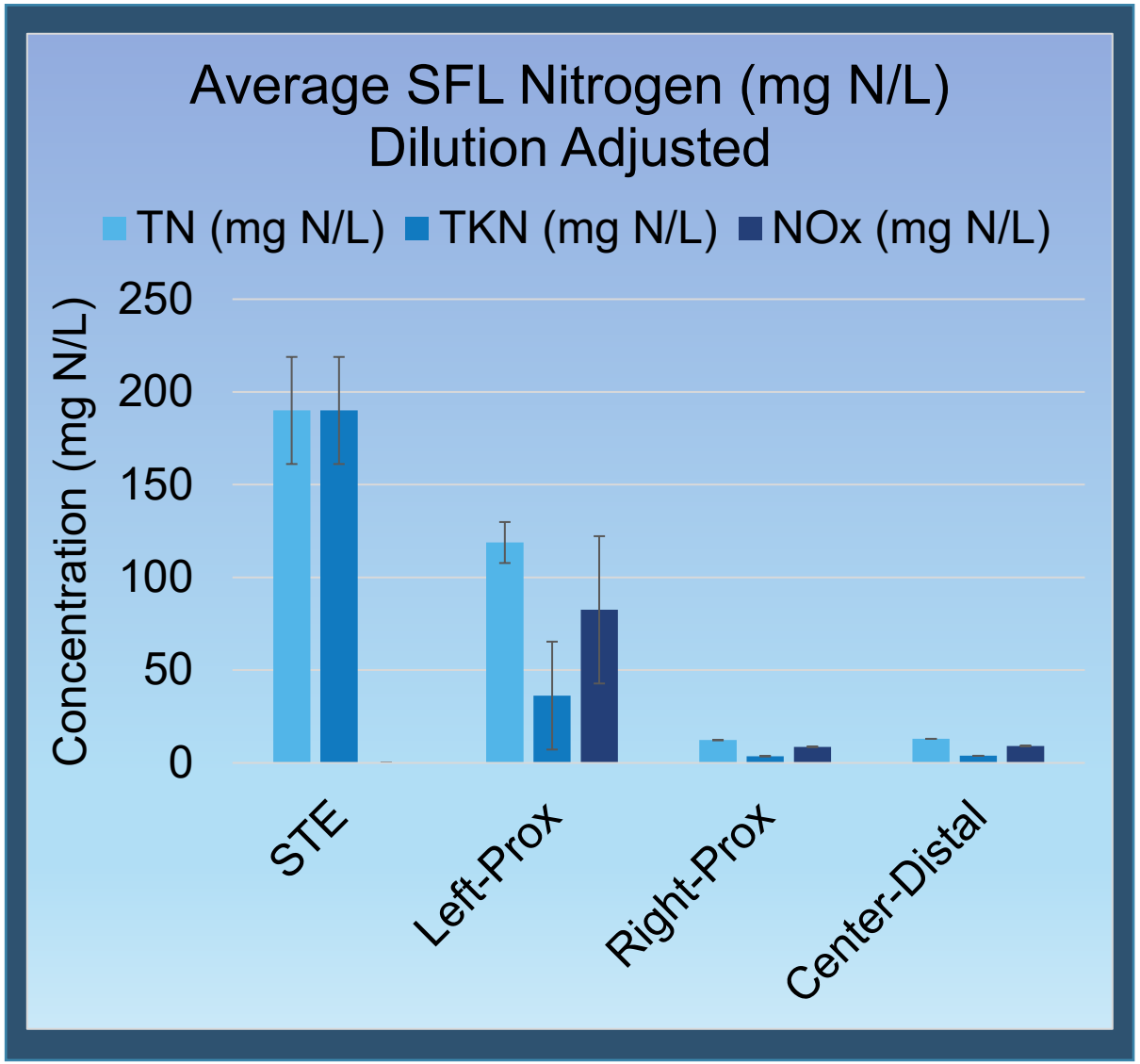


# AVERAGE NITROGEN CONCENTRATIONS S6

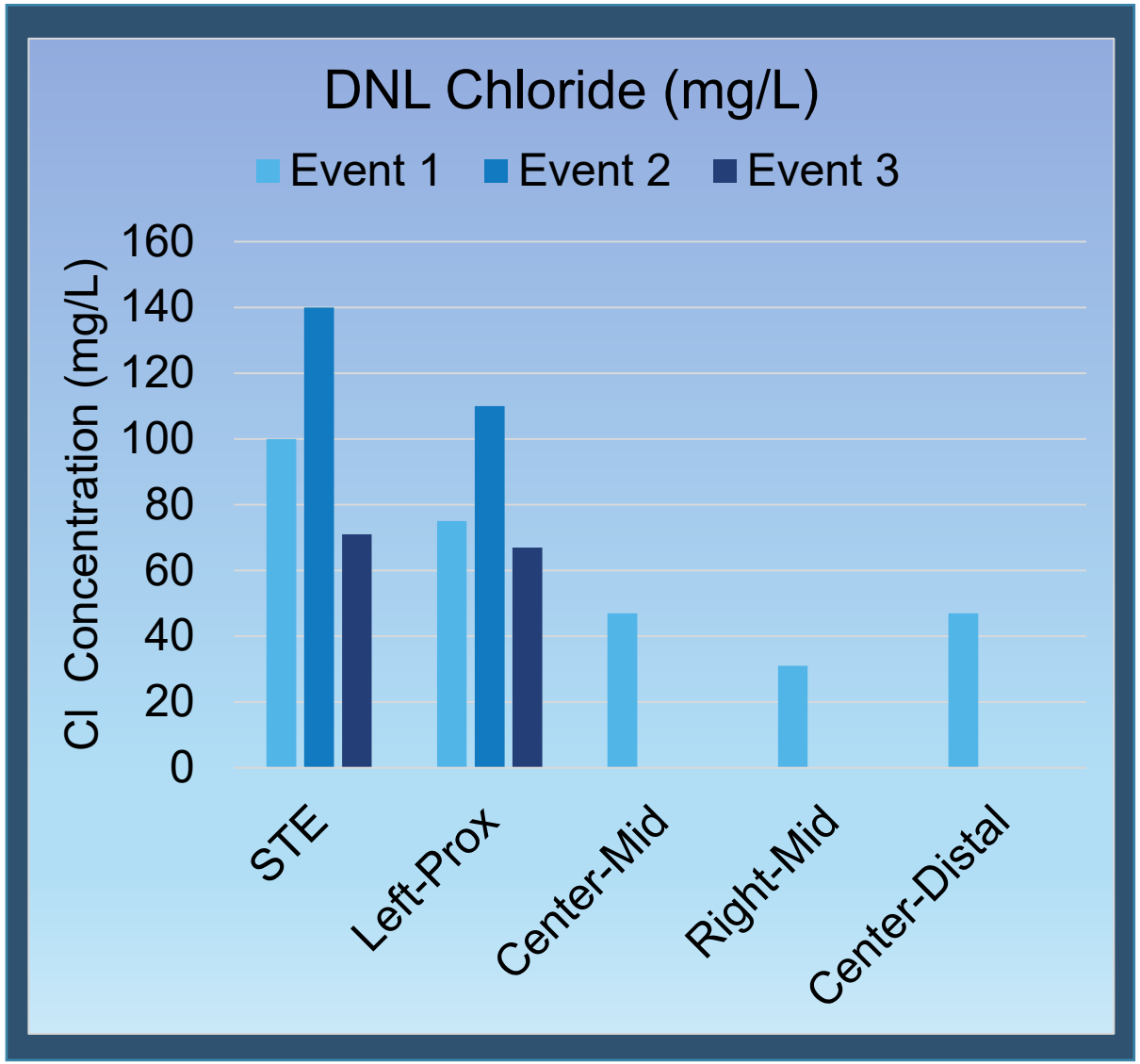
## SYSTEM 6 – SFL EFFLUENT

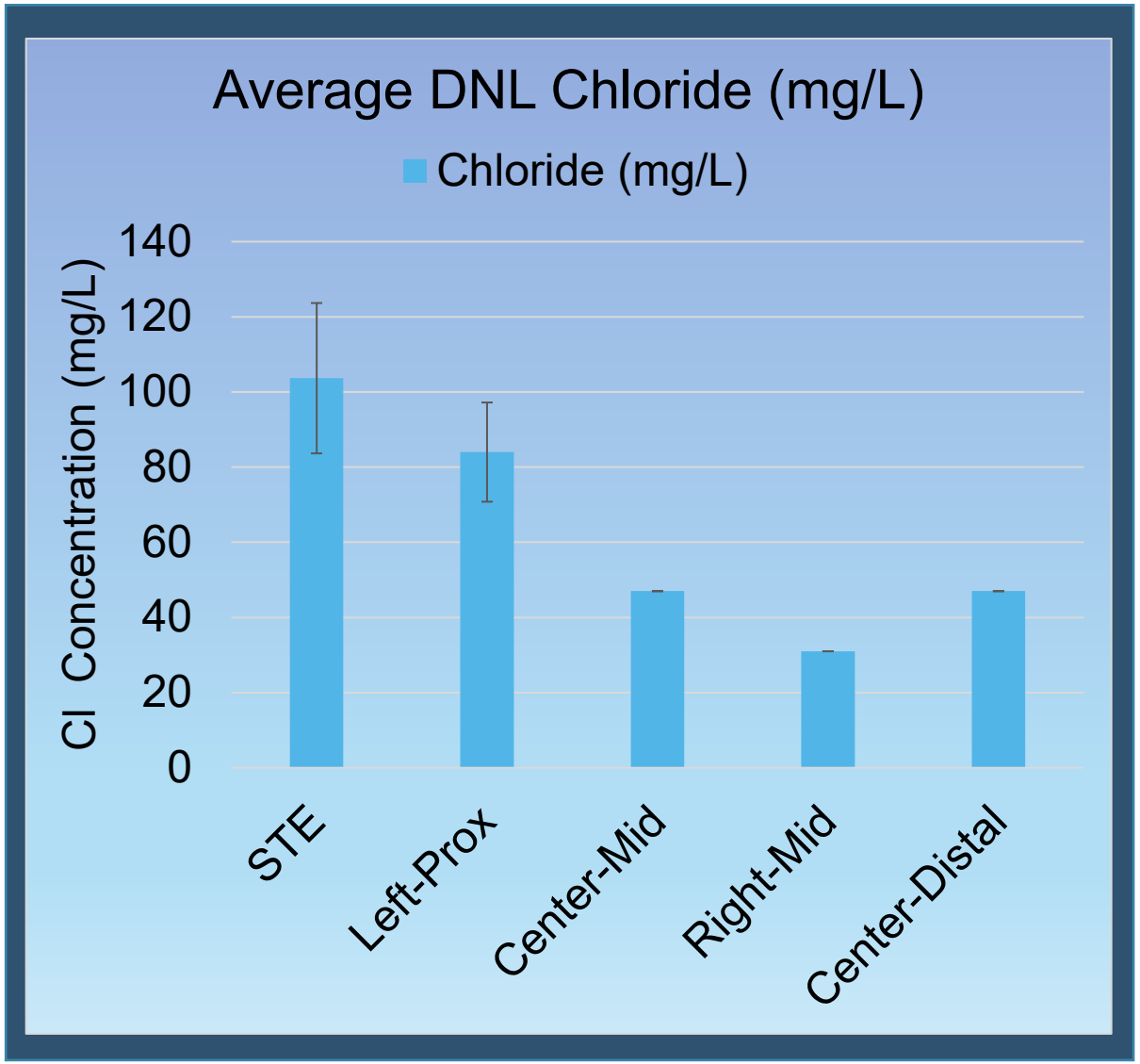


# CHLORIDE CONCENTRATION S6 DNL

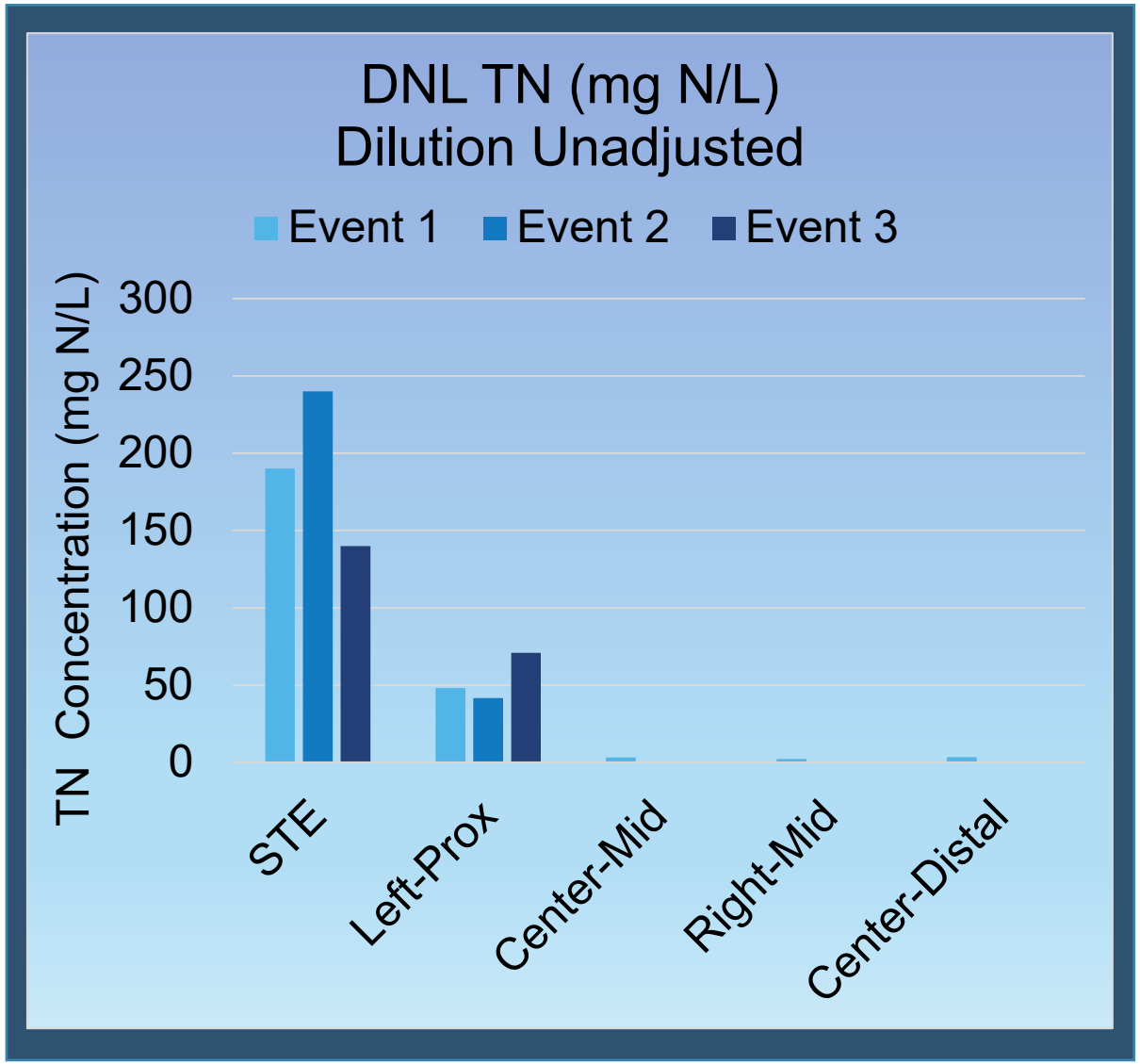
## SYSTEM 6 – DNL MEDIA EFFLUENT

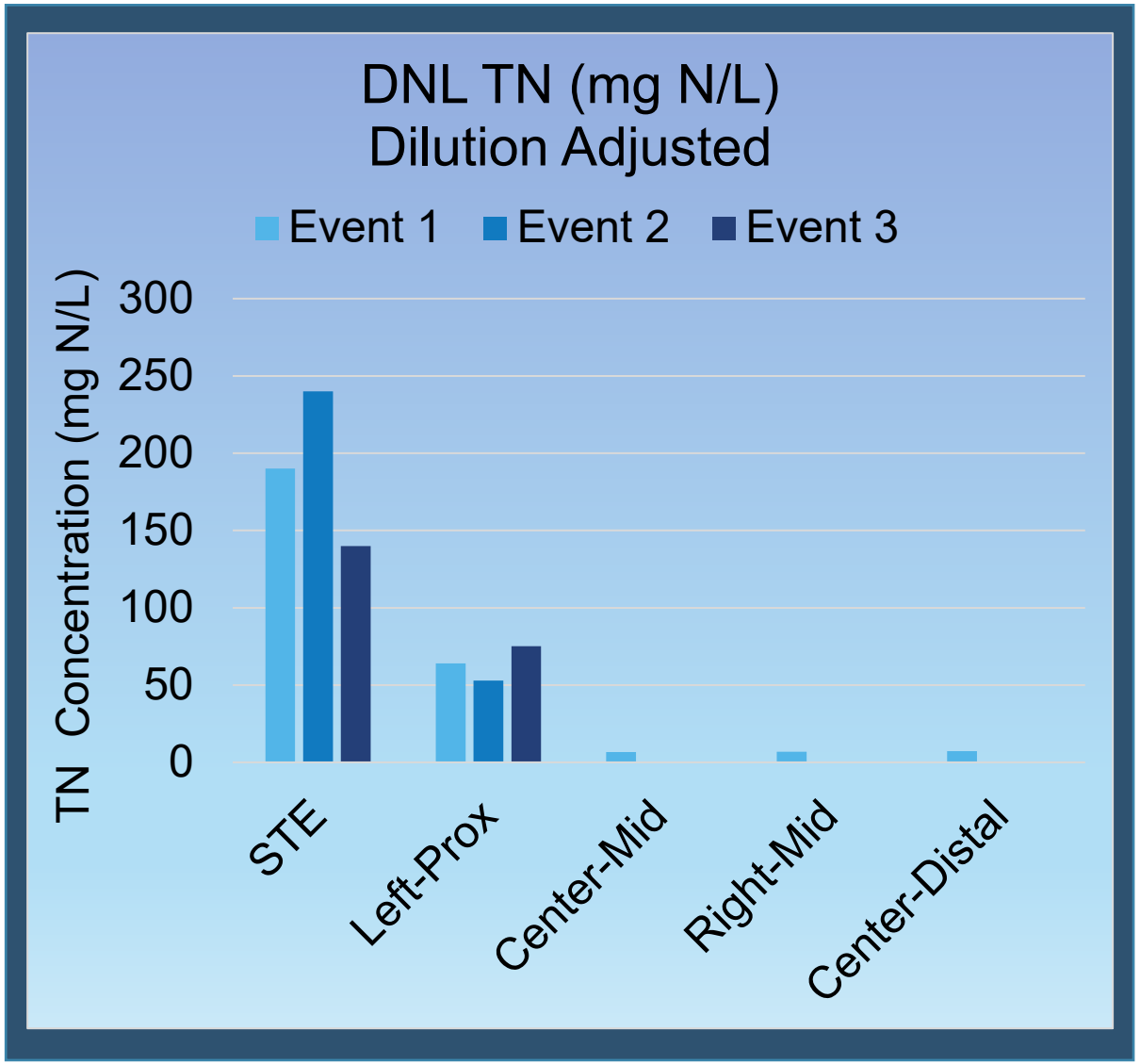


# TOTAL NITROGEN CONCENTRATION/EVENT S6

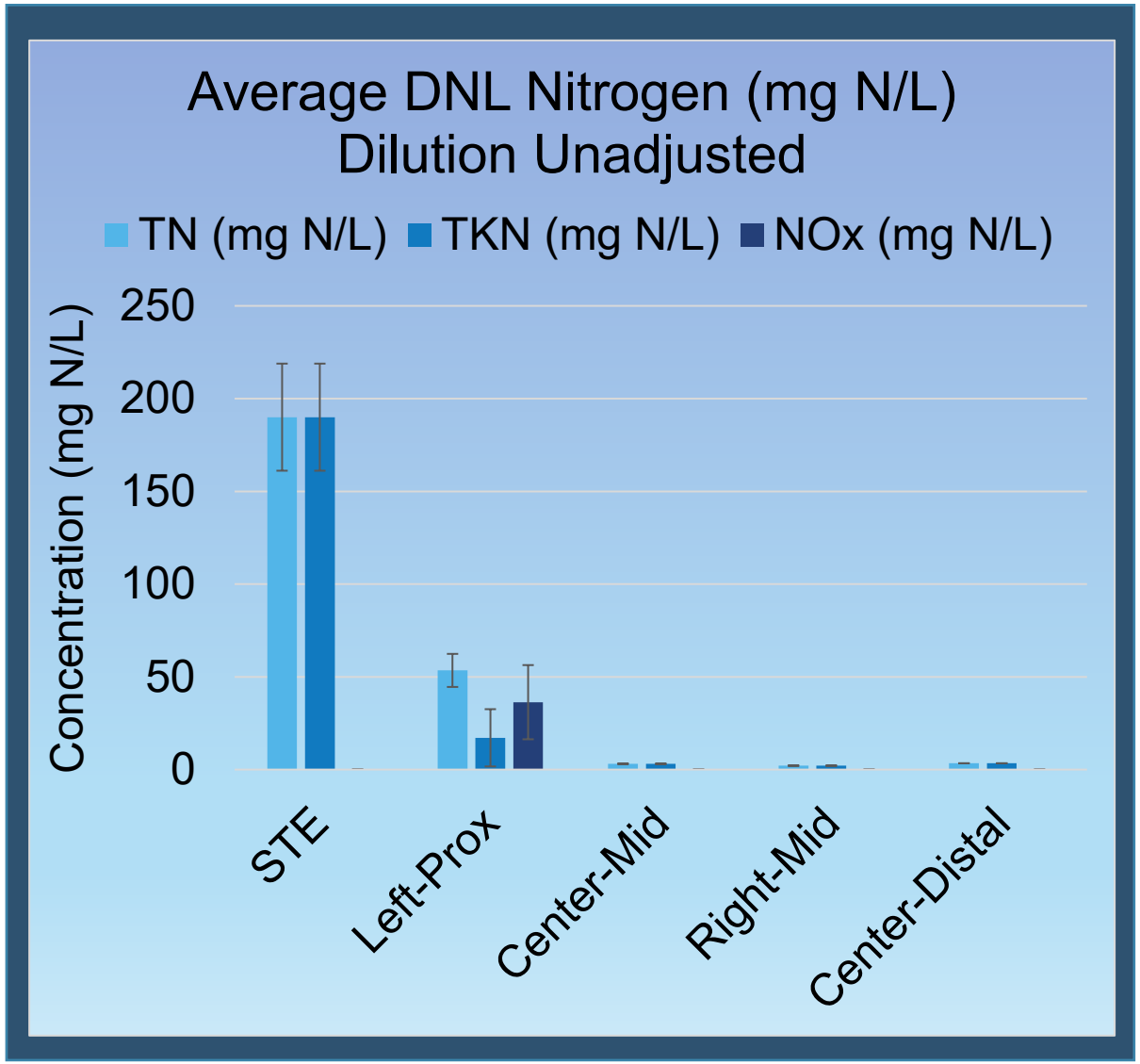
## SYSTEM 6 – DNL EFFLUENT

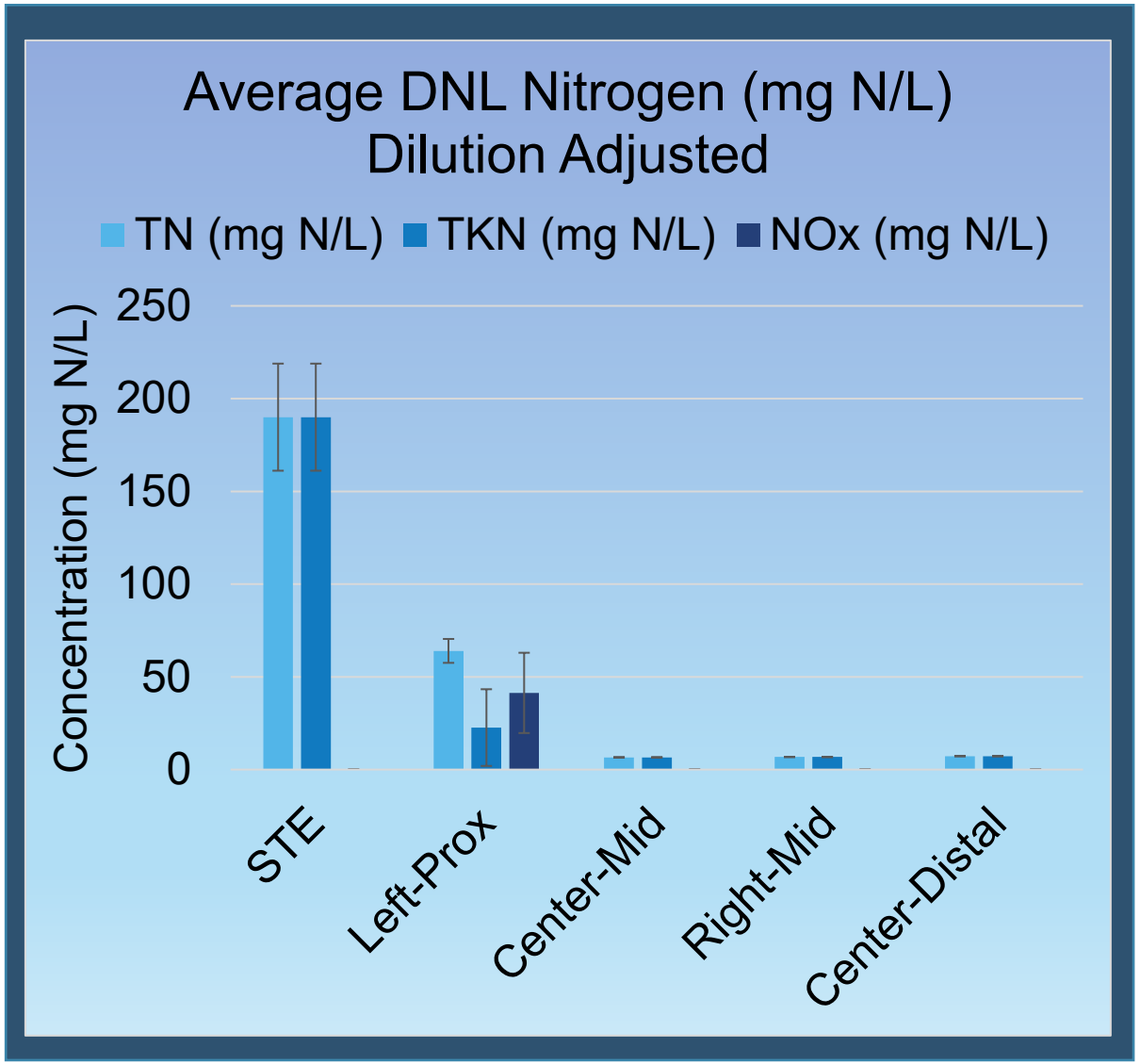


# AVERAGE NITROGEN CONCENTRATIONS S6

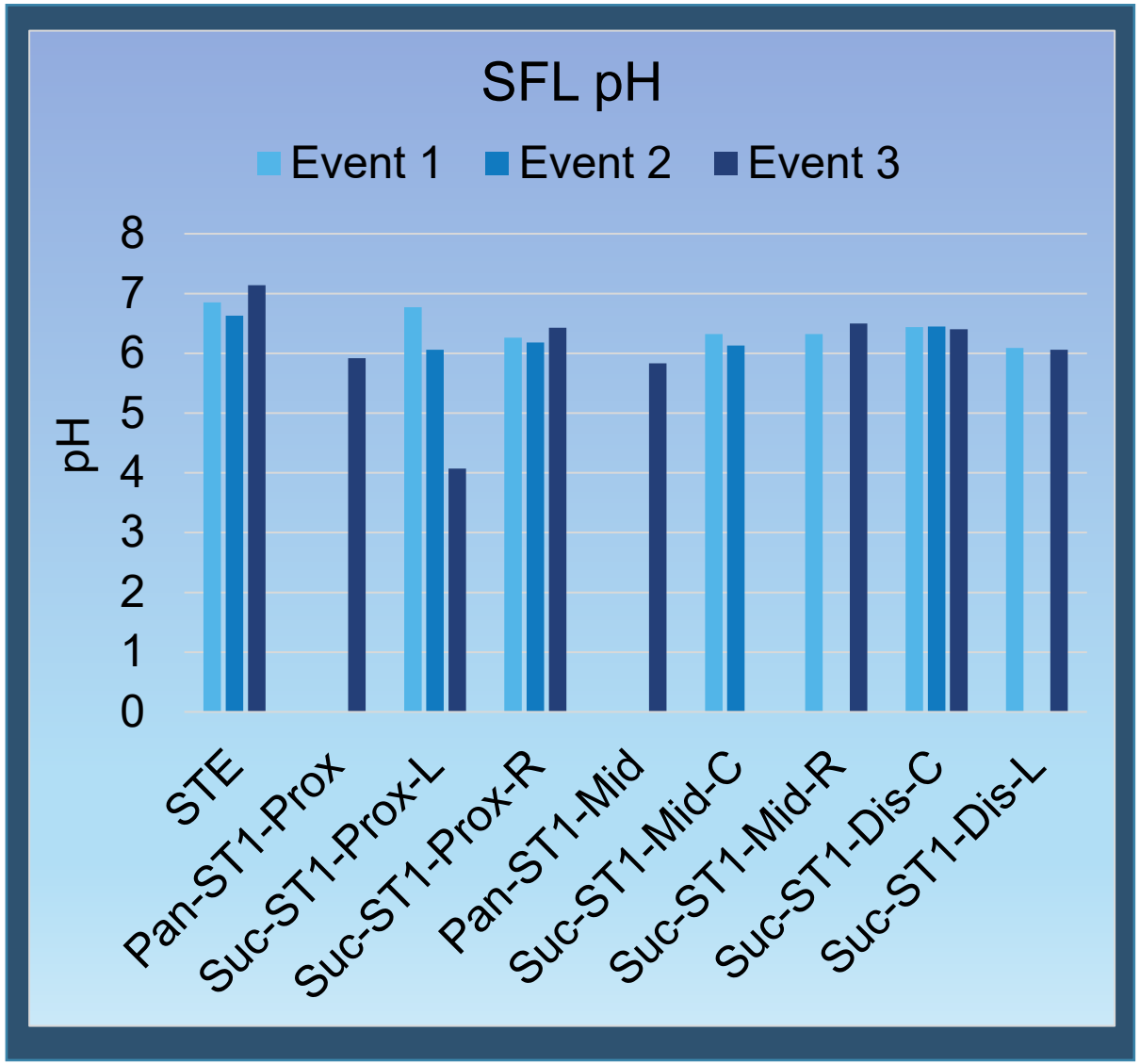
## SYSTEM 6 – DNL EFFLUENT

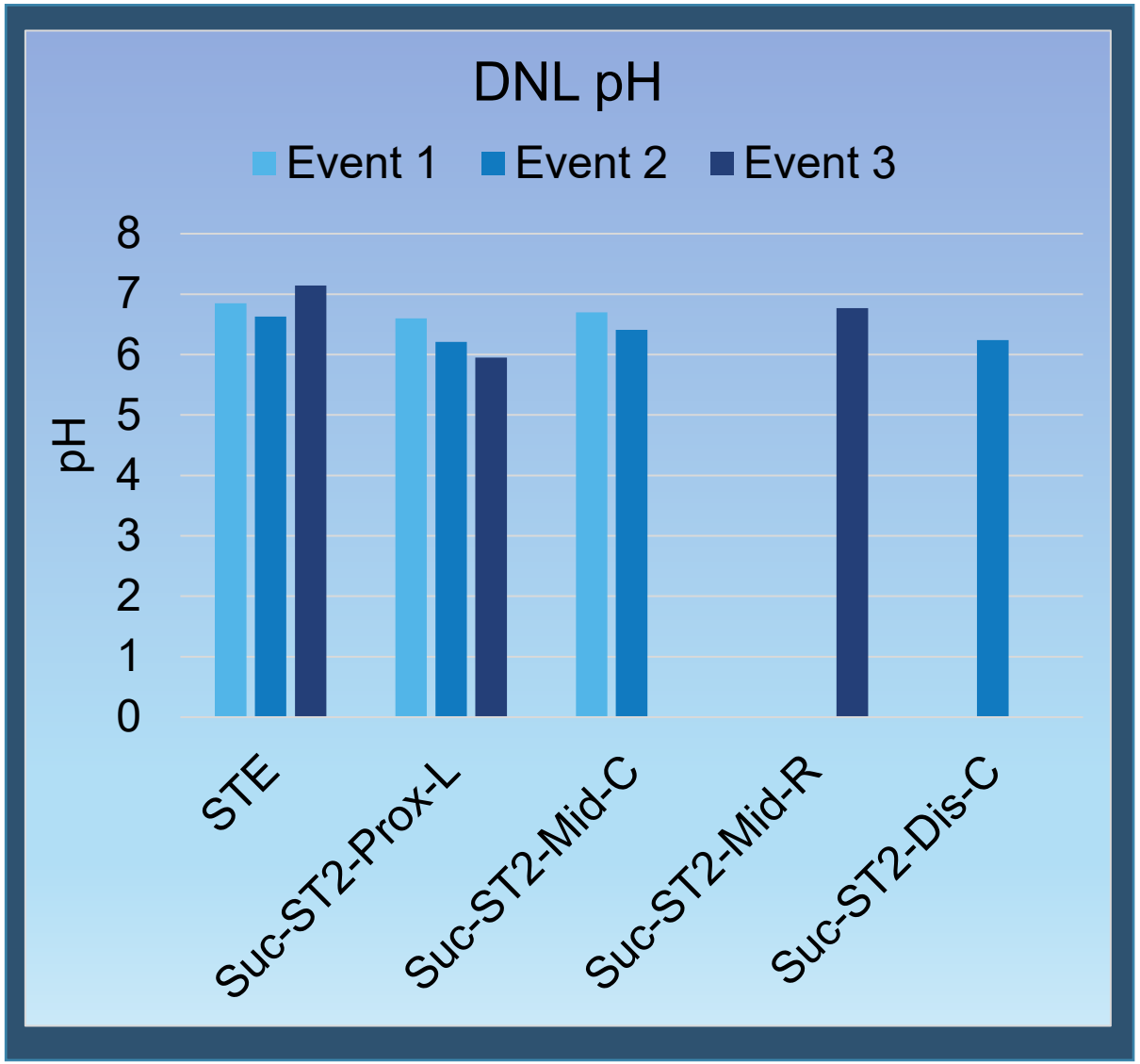


# PH VALUES S6

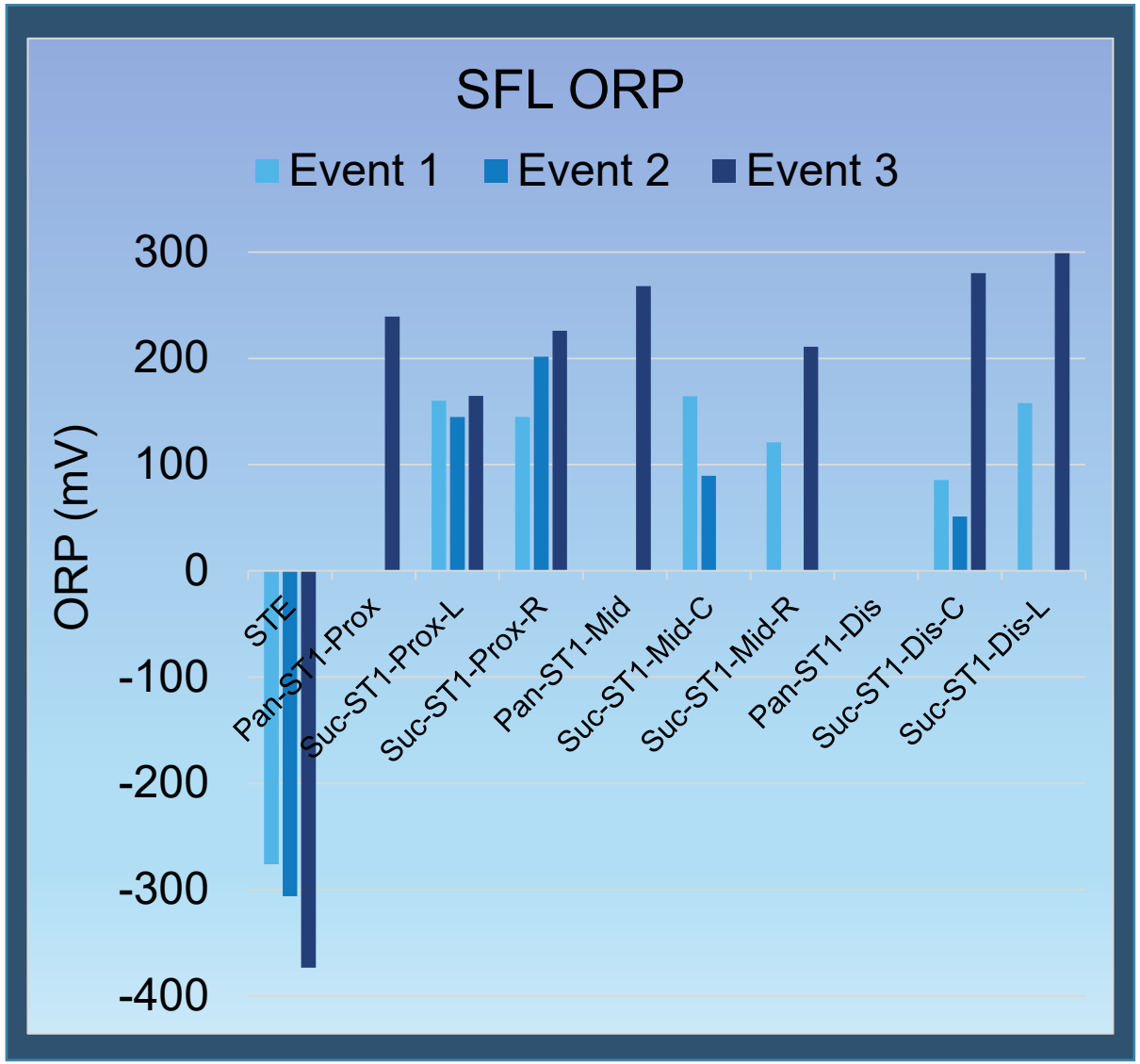
## SYSTEM 6 – SFL VERSUS DNL EFFLUENT

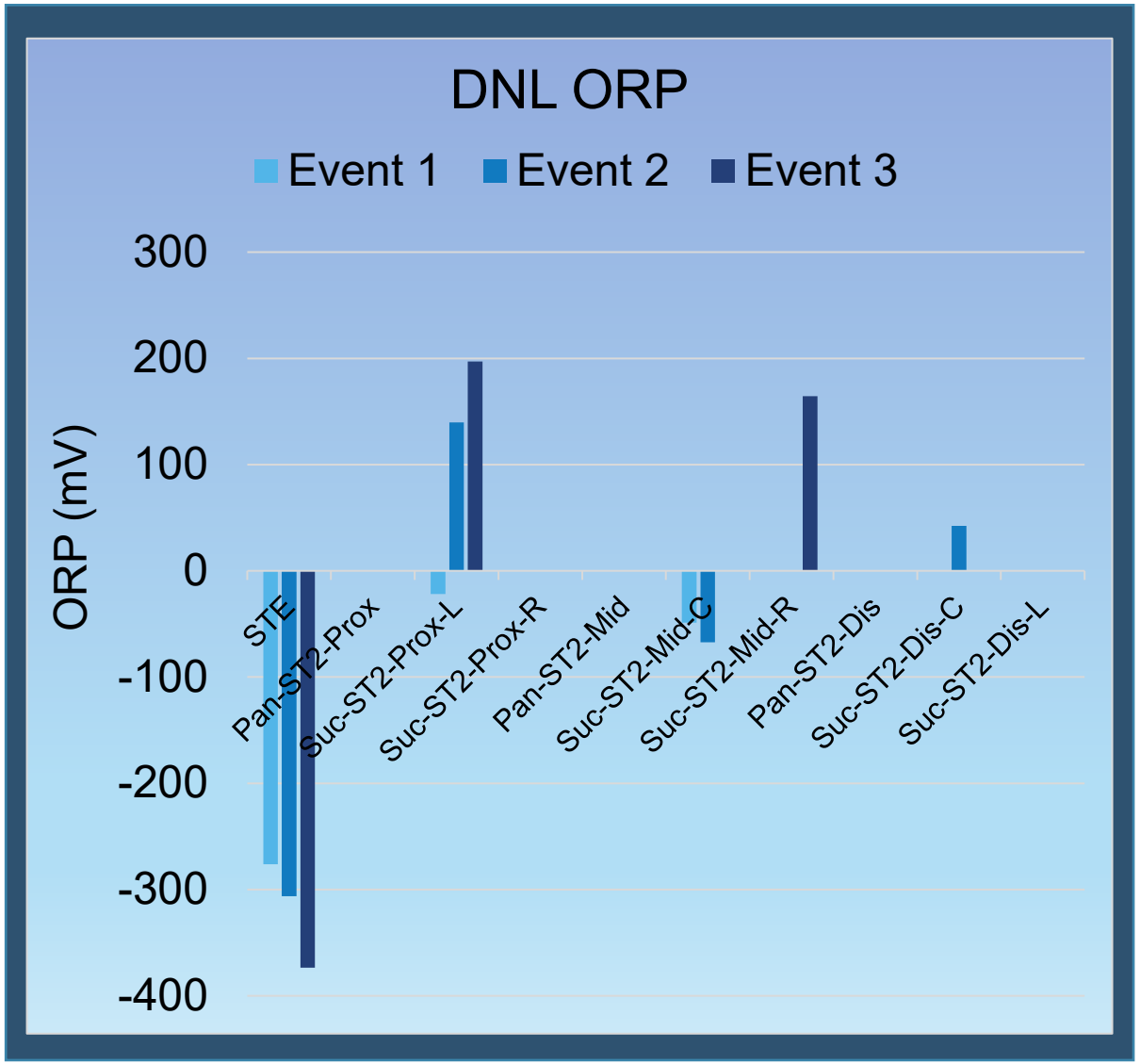


# ORP VALUES S6

## SYSTEM 6 – SFL VERSUS DNL EFFLUENT



# AVERAGE NITROGEN REDUCTION S6

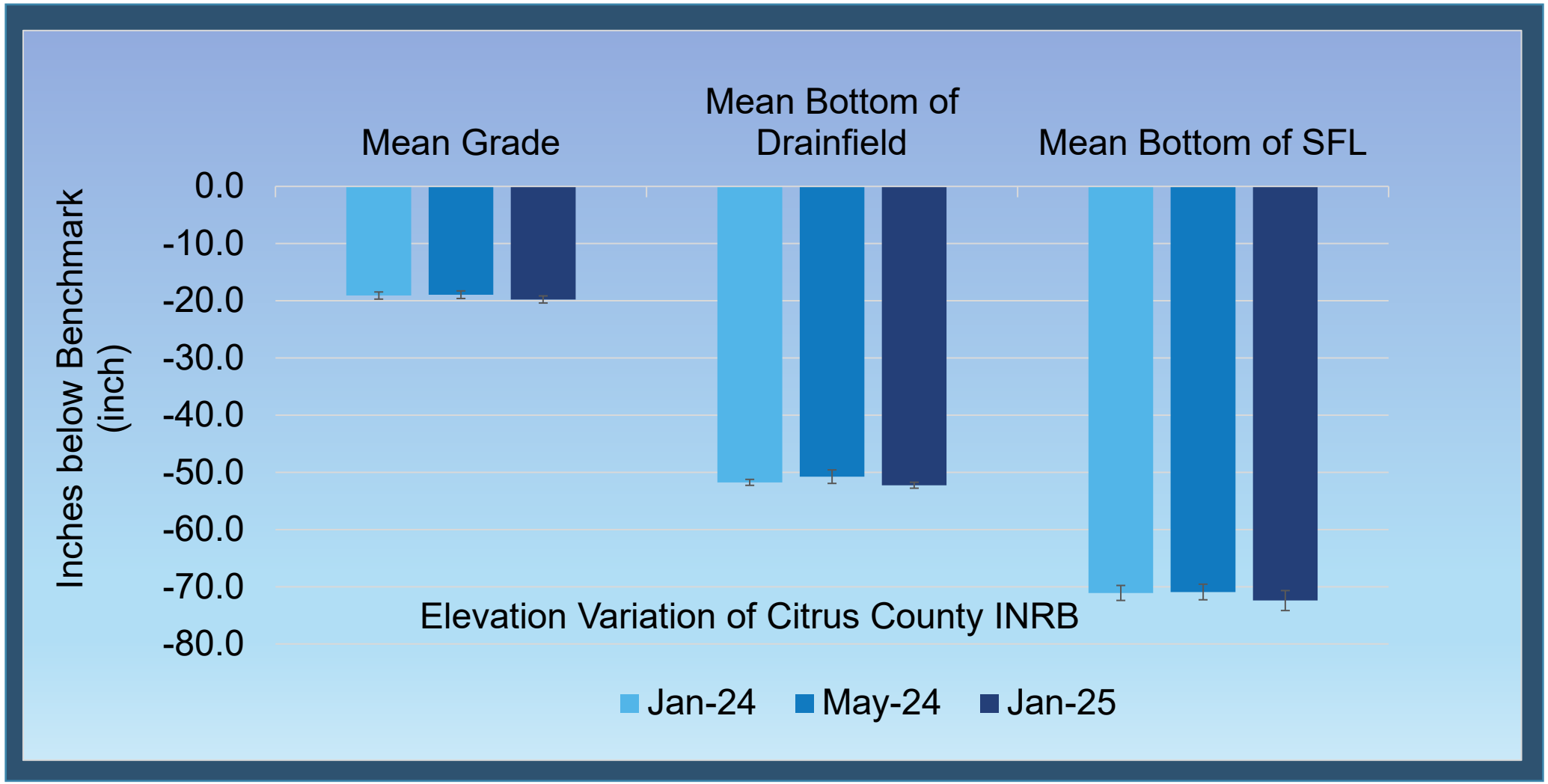
## SYSTEM 6 – DNL – ADJUSTED

| Location | Event 1 | Event 2 | Event 3 | Average | Percent Nitrogen Reduction | Percent Nitrogen Reduction | Percent Nitrogen Reduction | Average in Monitoring Location |
|---|---|---|---|---|---|---|---|---|
| STE (mg/L) | 190 | 240 | 140 | 190 | Event 1 | Event 2 | Event 3 | All events |
| Left-Prox (mg/L) | 64 | 53 | 75 | 64 | 66% | 78% | 46% | **63%** |
| Center-Mid (mg/L) | 7 | N/A | N/A | 7 | 96% | N/A | N/A | **96%** |
| Right-Mid (mg/L) | 7 | N/A | N/A | 7 | 96% | N/A | N/A | **96%** |
| Center-Distal (mg/L) | 7 | N/A | N/A | 7 | 96% | N/A | N/A | **96%** |
| Average for each event | | | | | **89%** | **78%** | **46%** | |

**Overall percent nitrogen reduction ~ 71%.**

# ELEVATION CHANGE OF SYSTEM LAYERS S6

## SYSTEM 6



# SUMMARY

- Presented results of monitoring from two INRBs in Leon County and initial results from two additional INRBs.
- After adjusting for dilution, estimates for nitrogen reduction were as follows:
  - INRB S3: 83%.
  - INRB S4: 42% (up to design flow: 74%).
  - INRB S5 (two events): 75%.
  - INRB S6 (three events): 71%.
- Nitrogen reduction is consistent with expectations.
- Monitoring of elevations did not show settling of drainfields over time.

# SUMMARY AND OUTLOOK

- Distribution of effluent in the drainfield is uneven.
  - For higher flows more sampling points detect effluent.
- Pan lysimeters were rarely successful in recovering effluent.
- Media layer 1 (nitrification layer) does sometimes not completely nitrify (turn TKN into NOx) effluent.
  - This may be influenced by low pH and ORP.
  - Some nitrogen reduction occurs in this layer.
- Media layer 2 (denitrification layer) does sometimes not completely denitrify (remove NOx from) effluent.
  - This may be influenced by relatively high ORP in those locations.
- Further monitoring of this and other systems is planned.

# THANK YOU

**Nareg Krikorian, M.S., CEHP**
Onsite Sewage Program
Division of Water Resource Management
Florida Department of Environmental Protection

Contact Information:
850-245-8580
Nareg.Krikorian@FloridaDEP.gov