Advances in On-line Instrumentation for Wastewater Process Control

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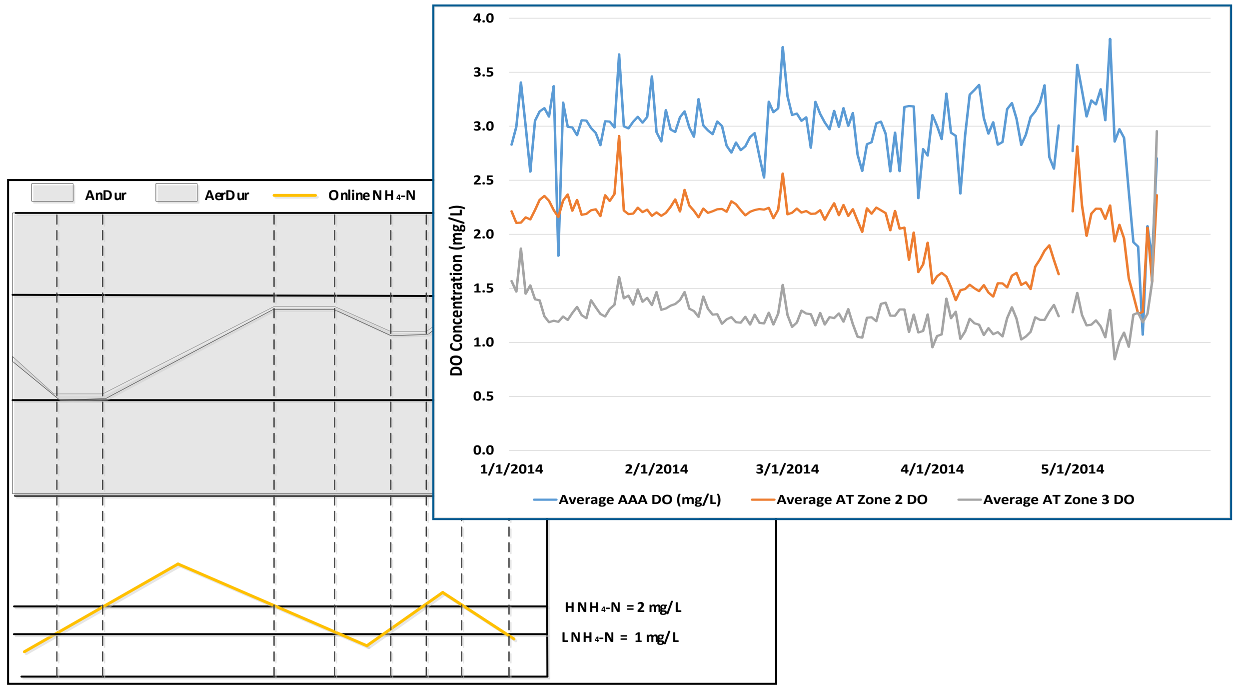

NEWEA
WORKING FOR WATER QUALITY

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HAZEN AND SAWYER
Environmental Engineers & Scientists

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Presentation Outline

1. Goals/Considerations

2. Background on Parameters of Interest and Measuring Techniques

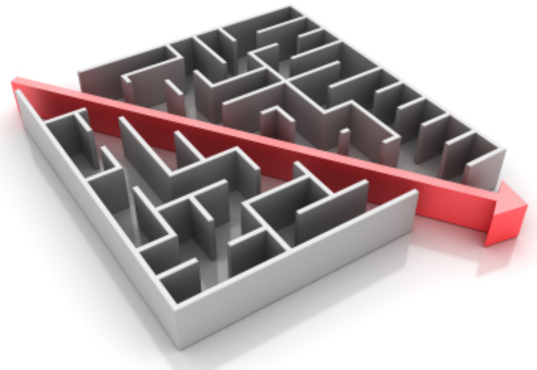
3. Case Studies Utilizing Instrumentation and Models

Goals/Considerations

Goals of Monitoring in WWTPs

- Better Understanding
- Advanced Warnings of Problems
- *Better Effluent Quality*
- *Reduced Energy Use*
- *Reduced Chemical Consumption*
- **Simplifying Wastewater Treatment**

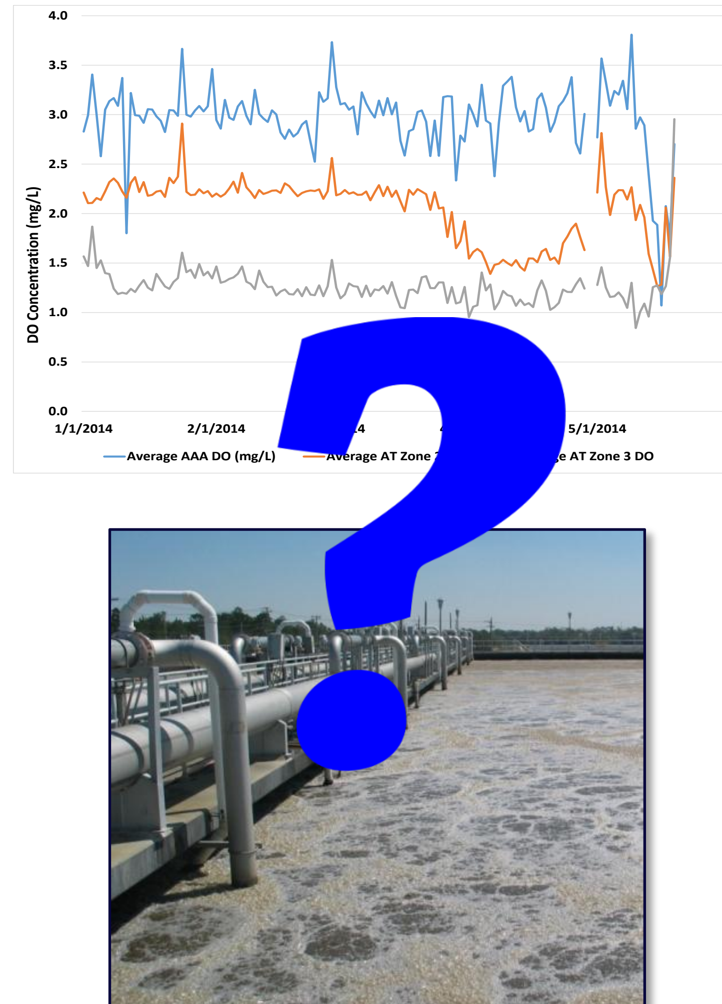
Courtesy of New York Times



Courtesy of PolicyMed

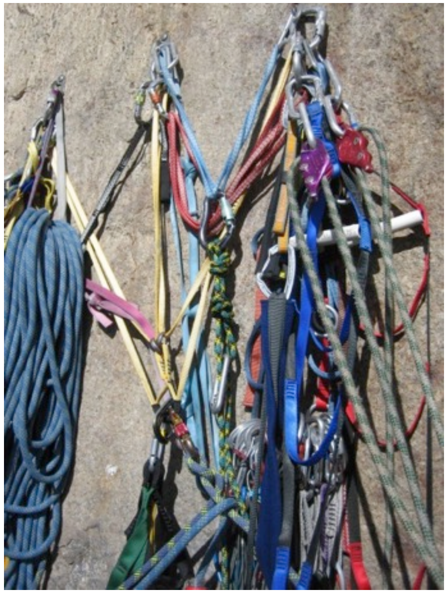
Considerations (High-Level)

- How can this information be used?
- Are staff resources available to adequately maintain the sensors **and review the data?**
- If cost-savings is a goal, is the overall control strategy going to work?



Considerations (Detailed)

- Can the sensor monitor over the range/accuracy needed?
- How will the location of the sensor impact the measurement
- If a single sensor is "mission-critical", should there be redundancy (if so, how much)?



Background

Parameters of Interest

Conventional Parameters

- Dissolved Oxygen
- Temperature
- pH/alkalinity
- Oxidation-Reduction Potential
- Total Suspended Solids
- *Flow*

"Advanced" Parameters

- Ammonia
- Nitrate (NO_x-N)
- COD/BOD Surrogates
- Phosphorous

Dissolved Oxygen

- Amperometric Sensor
  - Low capital costs
  - Higher maintenance
  - Less reliable due to consumables
  - Higher **absolute** accuracy
- Optical Sensor
  - Higher capital costs ($1 – 2K)
  - Lower maintenance
  - More reliable due to ease of maintenance
  - Lower **absolute** accuracy

Courtesy of Hach

Courtesy of InsiteIG

Oxidation Reduction Potential (ORP)

- Measurement of Oxidizing and Reducing Conditions
- Represents State of Process
- Inexpensive, low-maintenance

Biochemical activity	Approximate ORP range
Carbon oxidation (carbonaceous biochemical oxygen demand stabilization)	+50 to +200
Polyphosphate accumulation	+50 to +250
Nitrification	+150 to +350
Denitrification	-50 to +50
Polyphosphate release	-40 to -175
Acid formation	-40 to -200
Sulfide formation	-50 to -250
Methane formation	-200 to -400

Courtesy of WET

Courtesy of Hach

Total Suspended Solids

- Many Optical Instruments (Visible/ Near-IR) on the Market
- Typically In-situ, bypass available
- Ensure Correct Measuring Range is Selected (Pathlength)

Courtesy of InsiteIG

Courtesy of Hach

Flow

- Different types of flow measurement devices
- Different devices are suitable for different types of installations
- Always consider the end use of the data (e.g. chemical pacing, simple trending, regulatory reporting)

Courtesy of Rosemont

Courtesy of Siemens

Ammonia

- In-situ ISE Probes
  - Accuracy/performance varies
  - Require calibration
  - Replacement of electrodes
- Cabinet-type analyzers
  - Accurate
  - Sample filtration and delivery challenging in WWTPs
  - Consumables replacement

Courtesy of WTW

Courtesy of ChemScan

Nitrate (Nitrite?)

- In-situ ISE Probes
  - Many MFRs performance varies
  - Often coupled with ammonia ISE
  - Calibration/replacement of electrodes
- In-situ UV
  - Utilizes absorbance from 200 – 220 nm
  - Many MFRs
  - Low O&M requirements/costs
- Cabinet-Type Analyzer
  - Pump/filter
  - Reagents
  - Accurate

Image Courtesy of WTW

Image Courtesy of s::can

Phosphorous

- Cabinet-Type Analyzer
  - Pump/filter
  - Reagents
  - Accurate
  - Many MFRs, costs vary

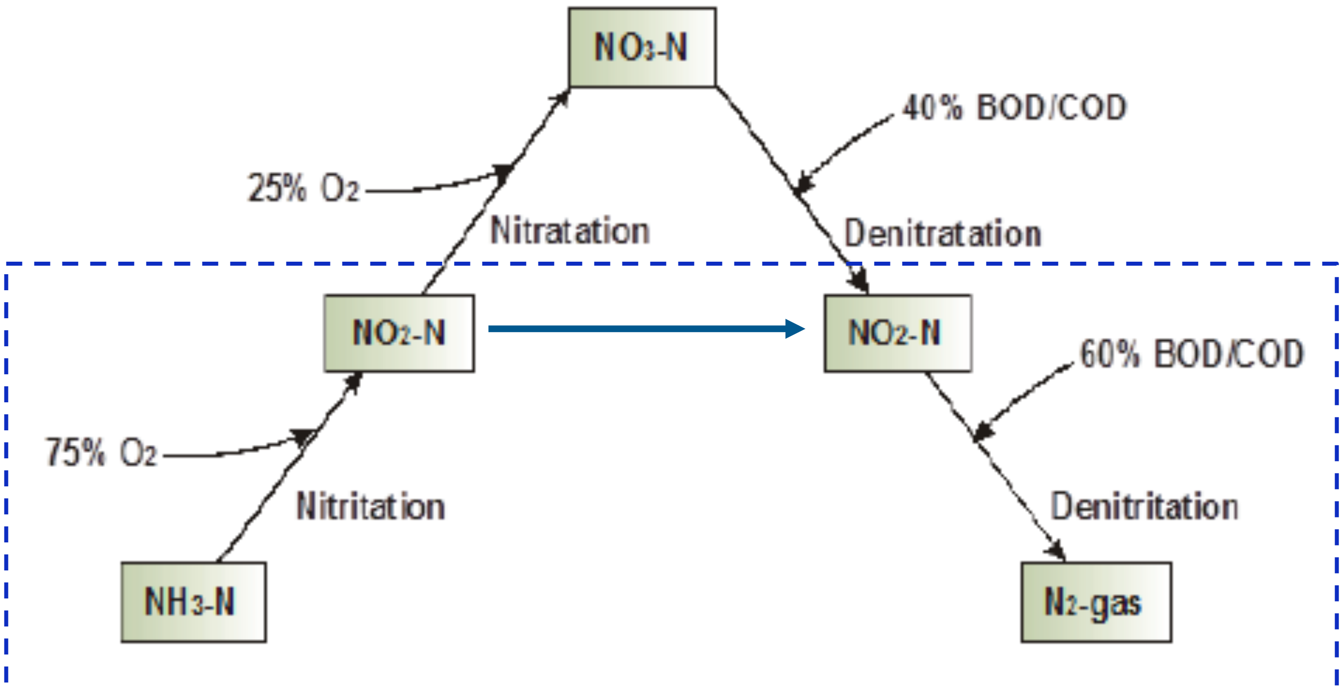
Courtesy of ChemScan

Case Study #1

Energy and Chemical Savings Through Ammonia-Based DO Control

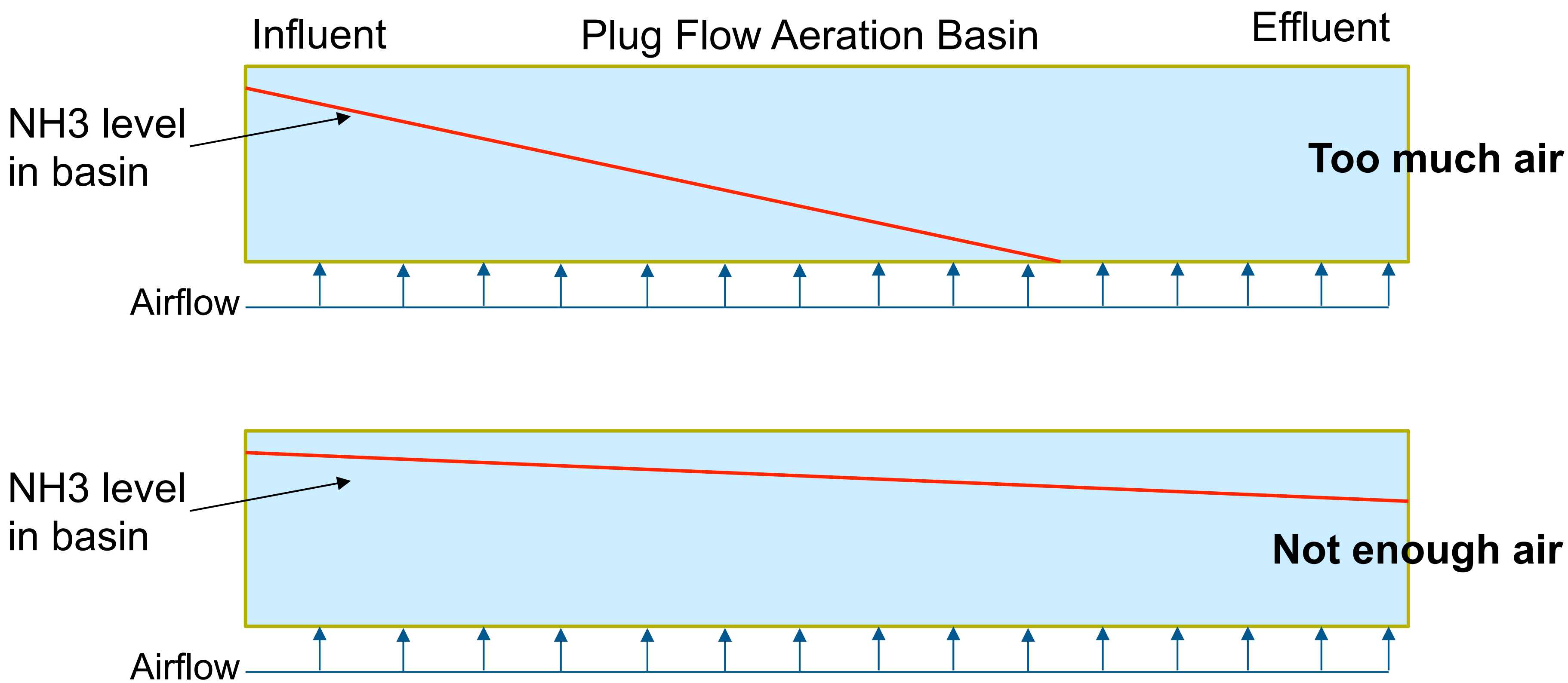
Case Study #1 – Background

- Ammonia-based DO control
- Modeled potential savings in energy/chemical



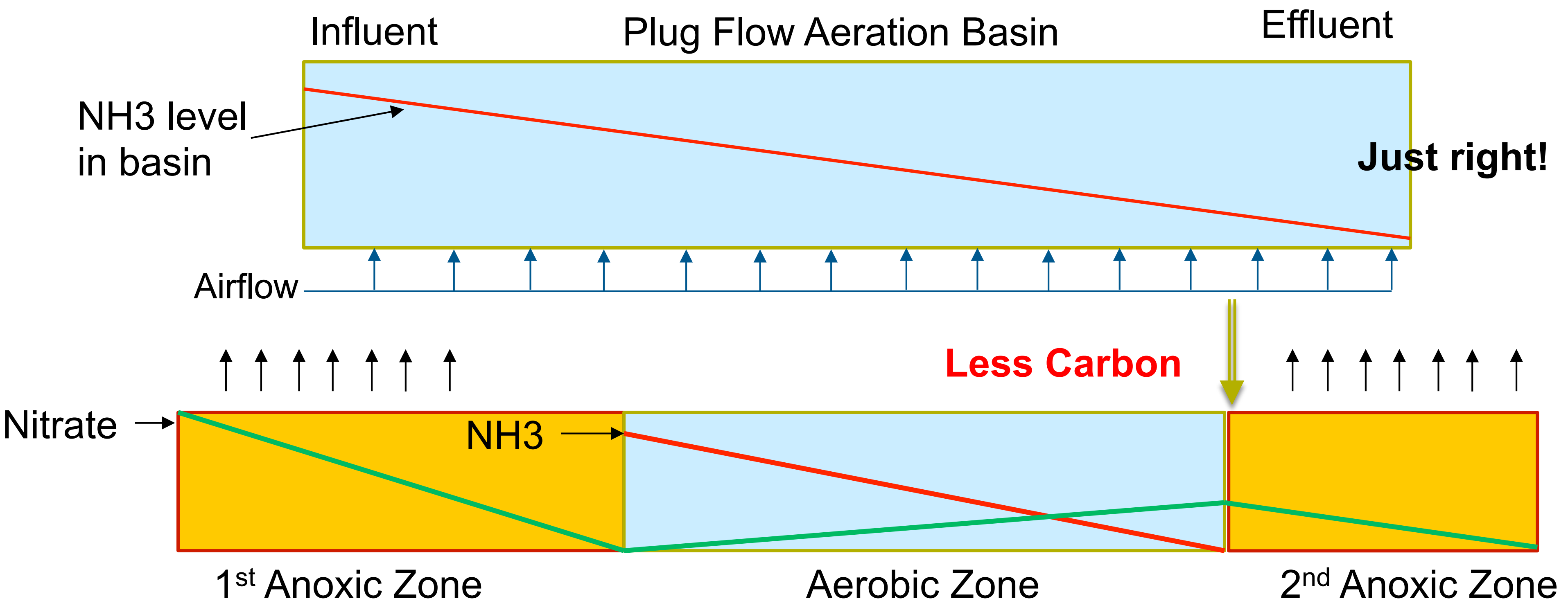
Nitrite-Shunt Reaction Path

Case Study #1 – Background

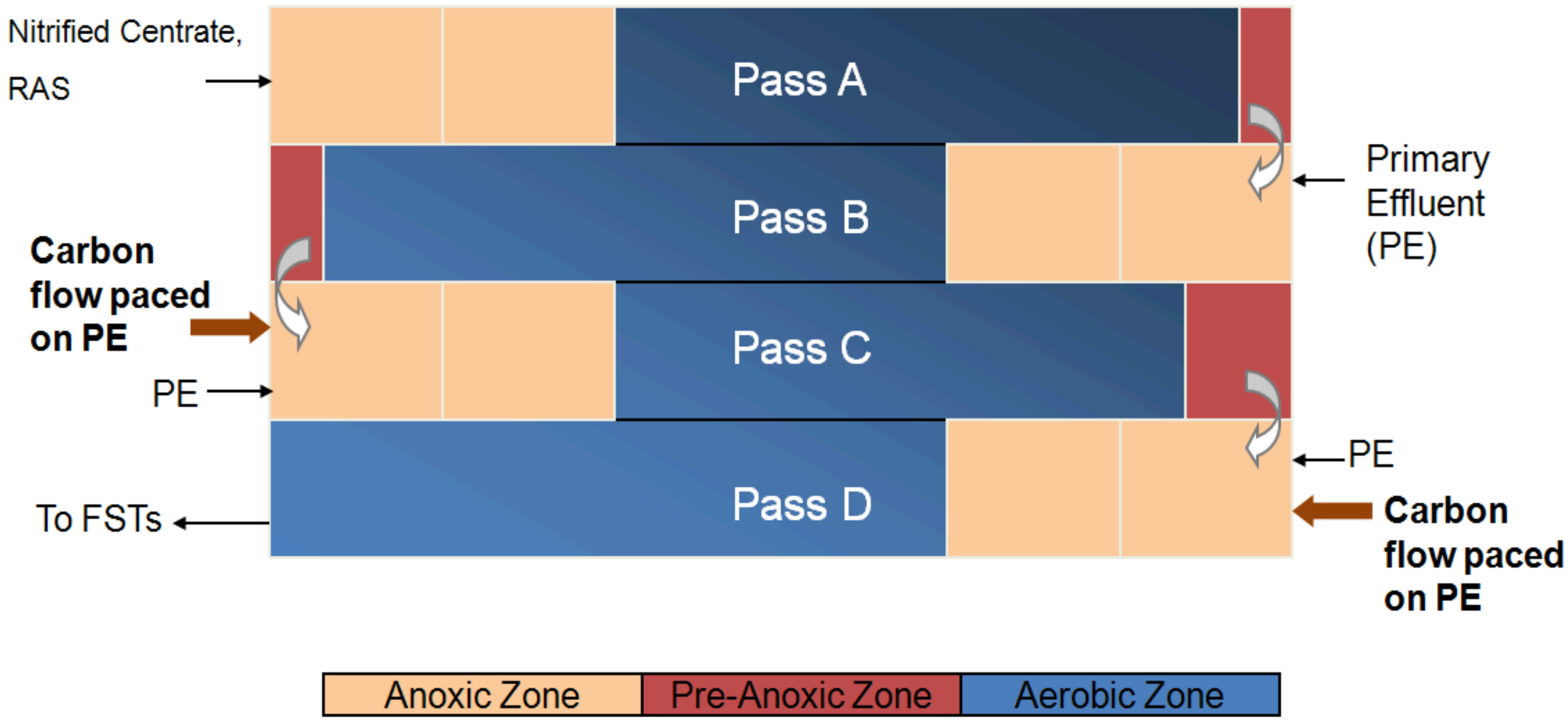


Case Study #1 – Background

- Operator selects effluent ammonia setpoint
- Ammonia > setpoint, DO increased
- Ammonia < setpoint, DO decreased



Case Study #1 – Background



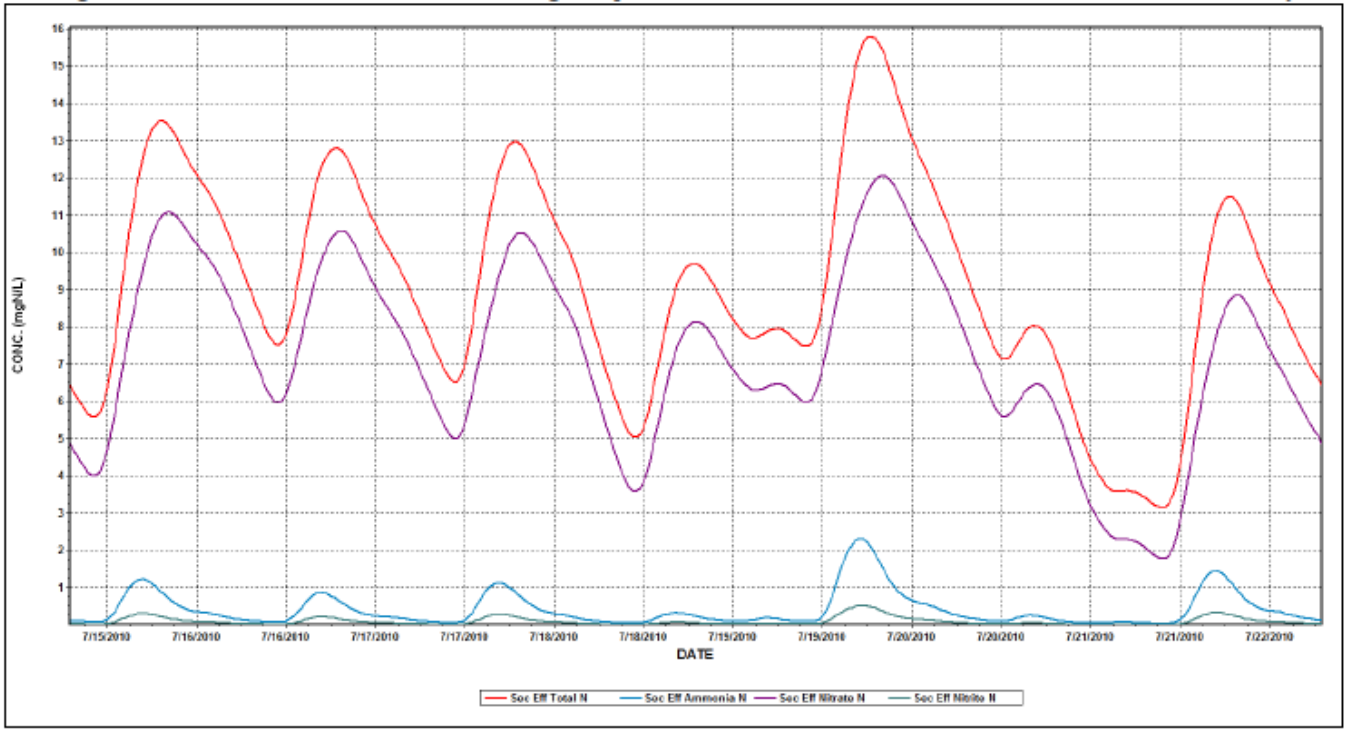
Case Study #1 – Process Model

- Process modeling concluded that process air (6%) and carbon (20%) savings ***<u>were</u>*** possible using an ammonia-based DO control scheme

	DO Setpoint Control		DO/NH3 Control	
Date	Total Nitrogen (Effluent)	Avg Daily SCFM	Total Nitrogen (Effluent)	Avg Daily SCFM
7/1/2013	10.6	10,400	10.6	9,900
7/2/2013	10.3	10,300	10.0	9,600
7/3/2013	10.0	10,300	9.8	9,800
7/4/2013	7.8	9,500	7.4	8,800
7/5/2013	12.2	11,500	12.4	10,800
7/6/2013	6.3	9,500	6.0	8,700
7/7/2013	8.1	10,900	8.4	10,400
Average	**9.3**	**10,300**	**9.2**	**9,700**

Case Study #1 – Process Model

- The ammonia-based DO control scheme relies on accurate ammonia measurement below 1 mg/L (NH3-N)

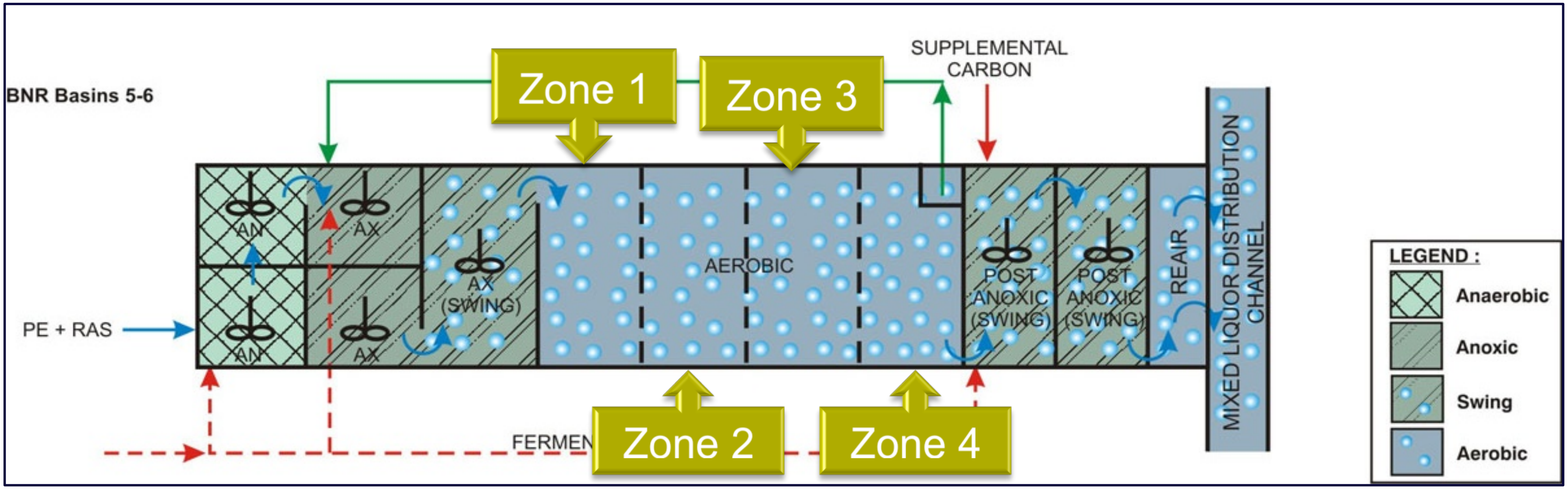


Case Study #1 – Implementation

- The ammonia sensors located on site were evaluated and could not measure below 1 mg/L with consistent accuracy.
- When automated operations using the ammonia sensors were attempted, process upsets resulted (loss of nitrification)
- ***The sensors must be reliable at the level needed for enhanced control***

Case Study #1 – Details

- If NH3-N < 0.75 mg/L
  - DO setpoint in Zone 2, 3 and 4 = 0.3 mg/L
- If NH3-N > 1.0 mg/L
  - DO setpoint in Zone 2, 3 and 4 = 2.0 mg/L



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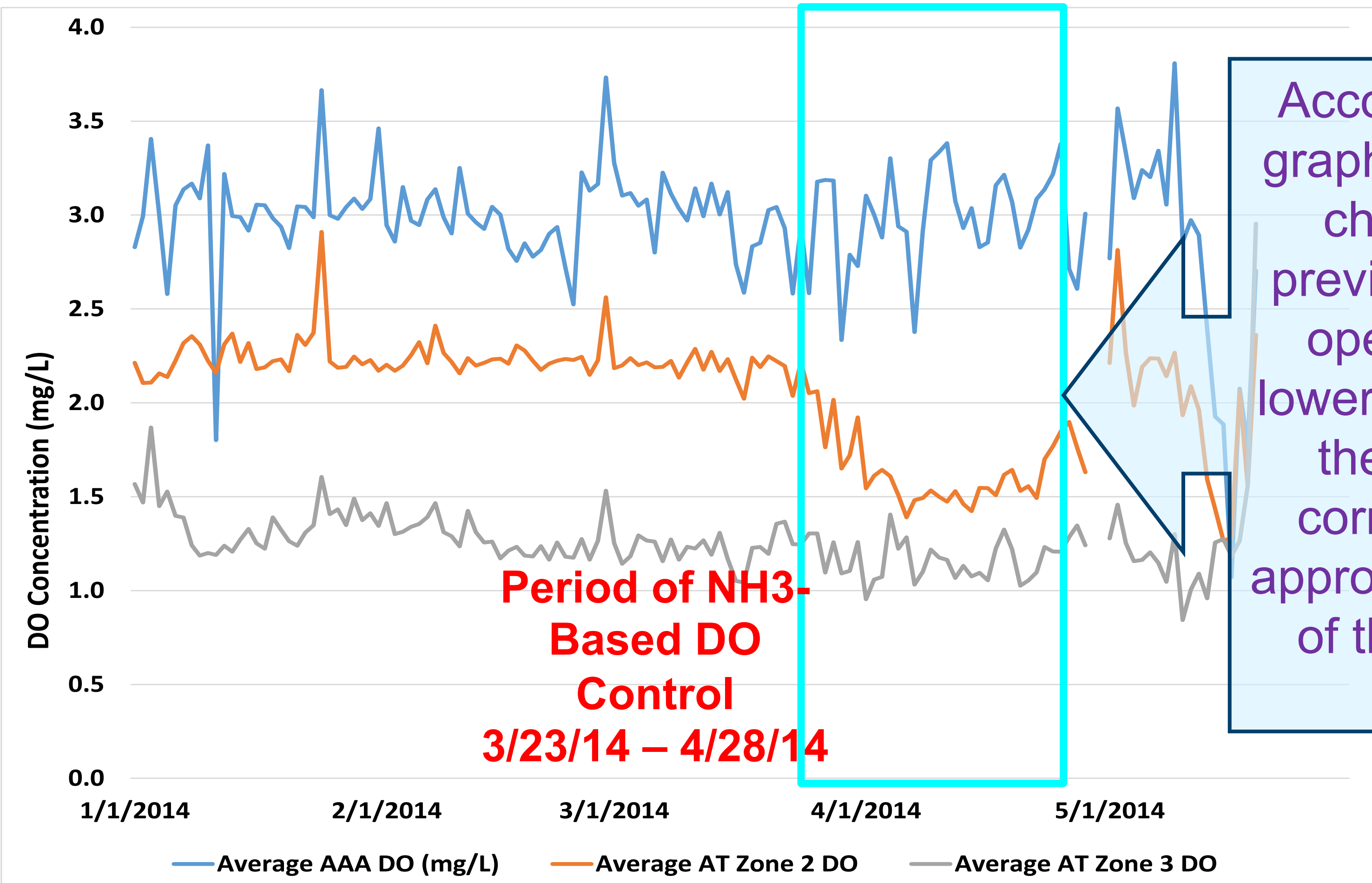
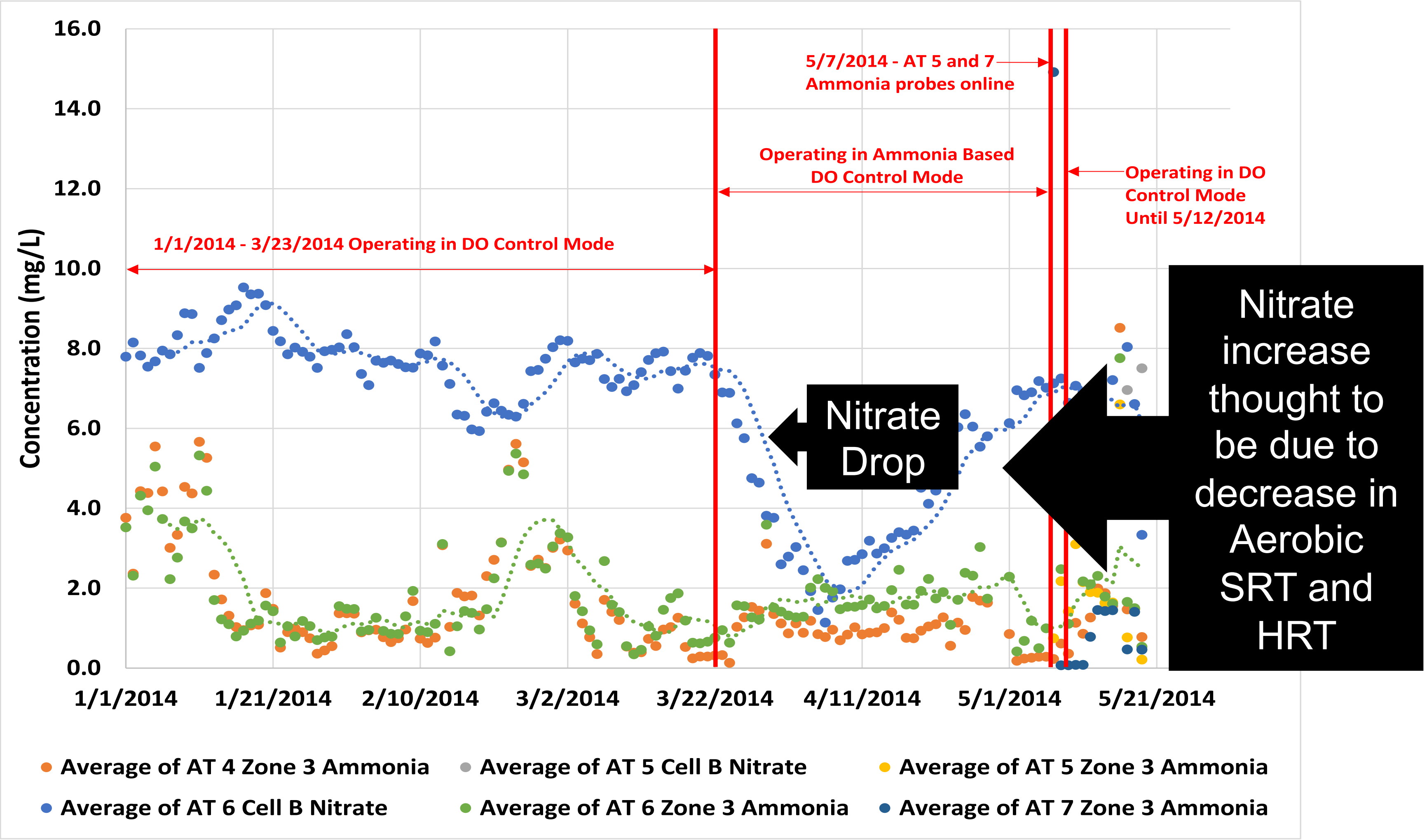
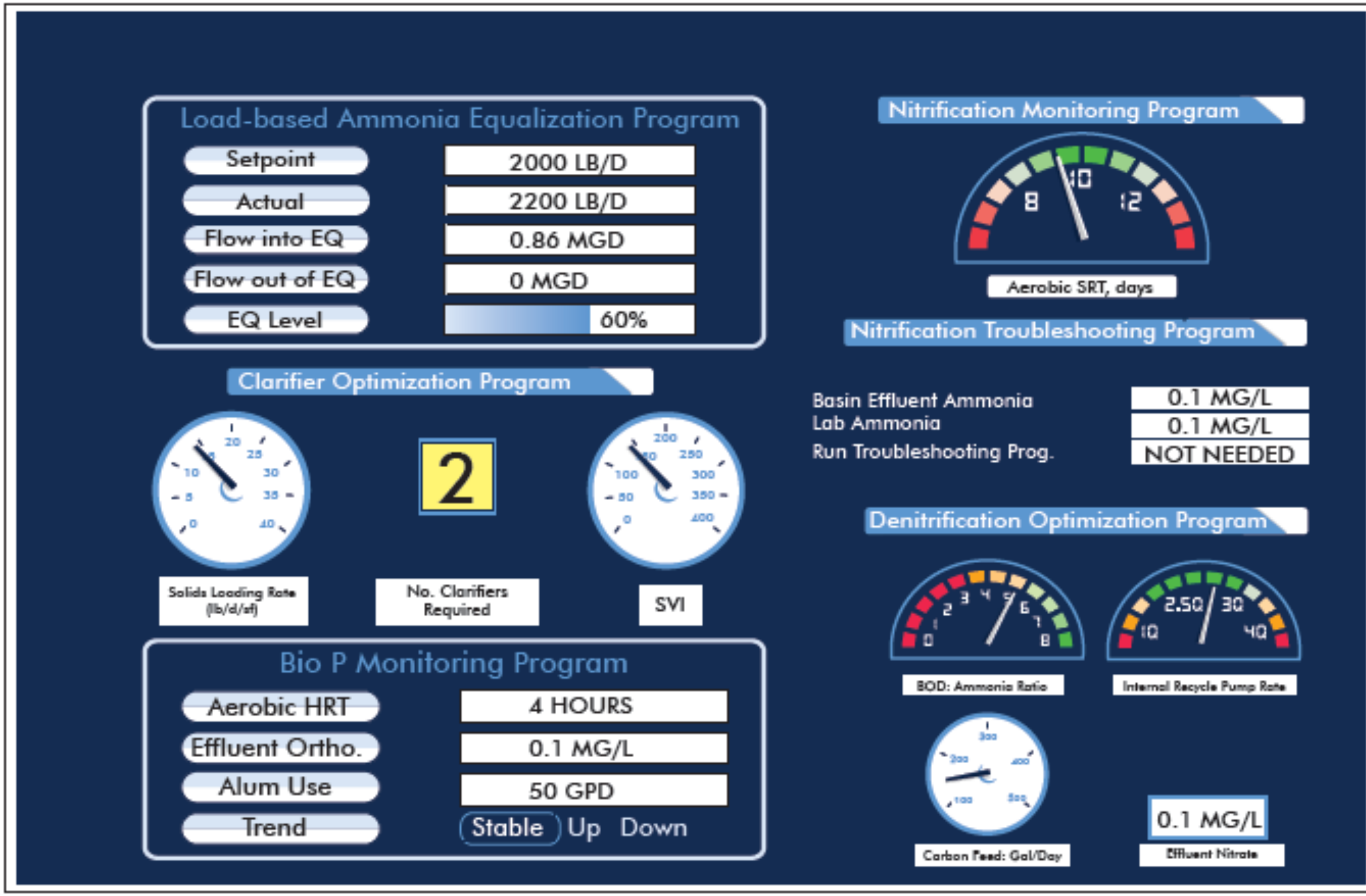


According to this graph, the biggest change from previous mode of operation was lowering the DO in the zone that corresponds to approximately 65% of their aerobic volume.

Case Study #1 – Details



Case Study #1 – Next Steps



Case Study #2

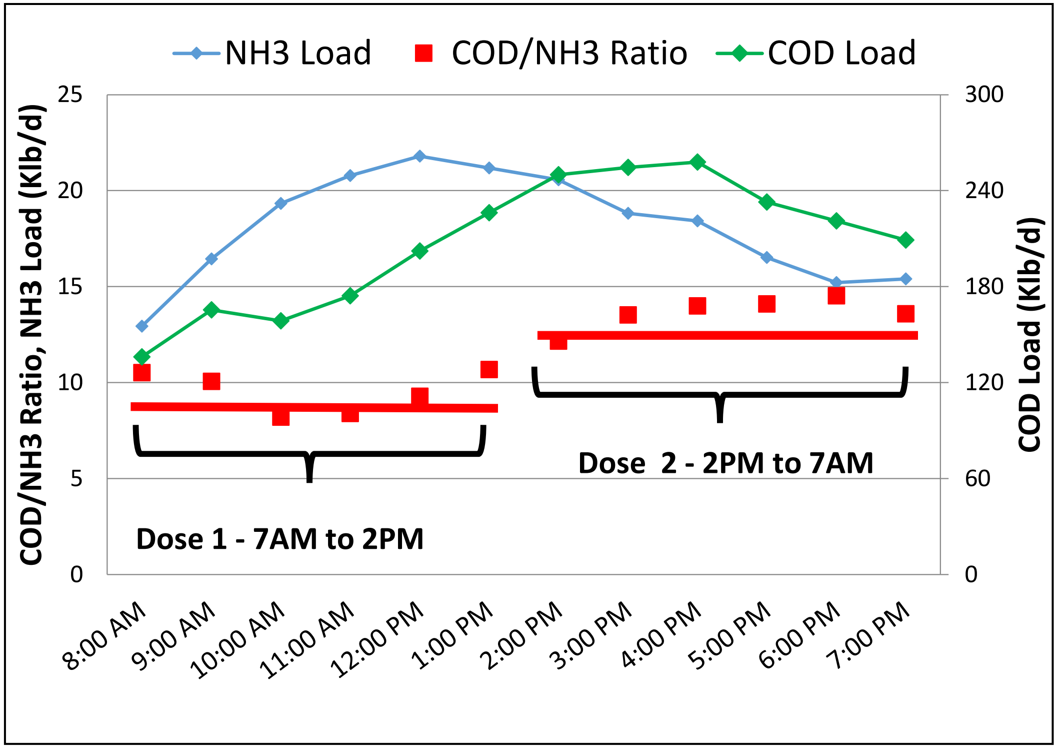
Optimizing Carbon Dosing

Case Study #2 – Background

- Five (5) WWTPs where supplemental carbon added to enhance denitrification
- Utilization of nitrate instrumentation to optimize carbon addition rate
- Evaluated different sensor locations and control schemes to determine best ROI (BioWin)

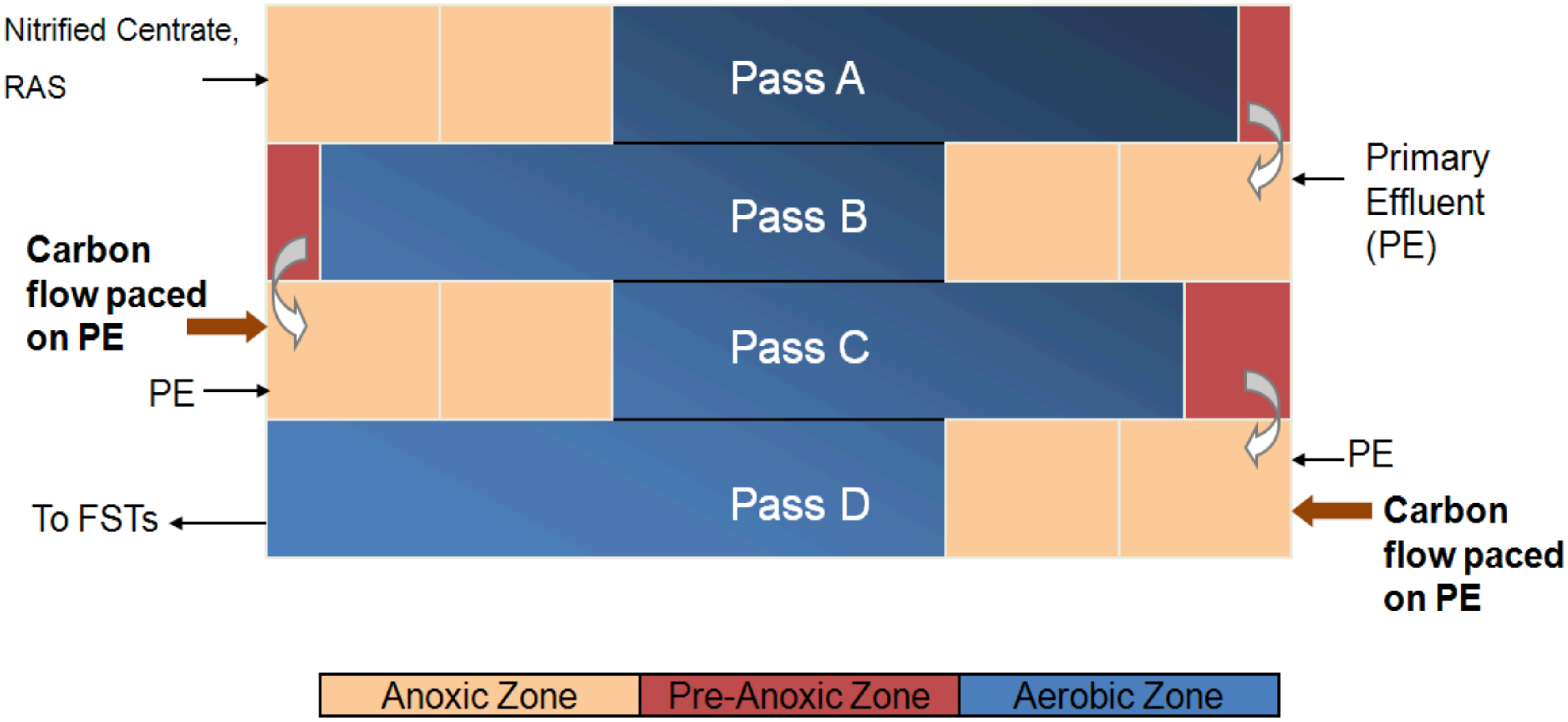
Case Study #2 - Background

- NH3-N load varies significantly throughout the day
- COD/NH3-N ratio also varies throughout the day



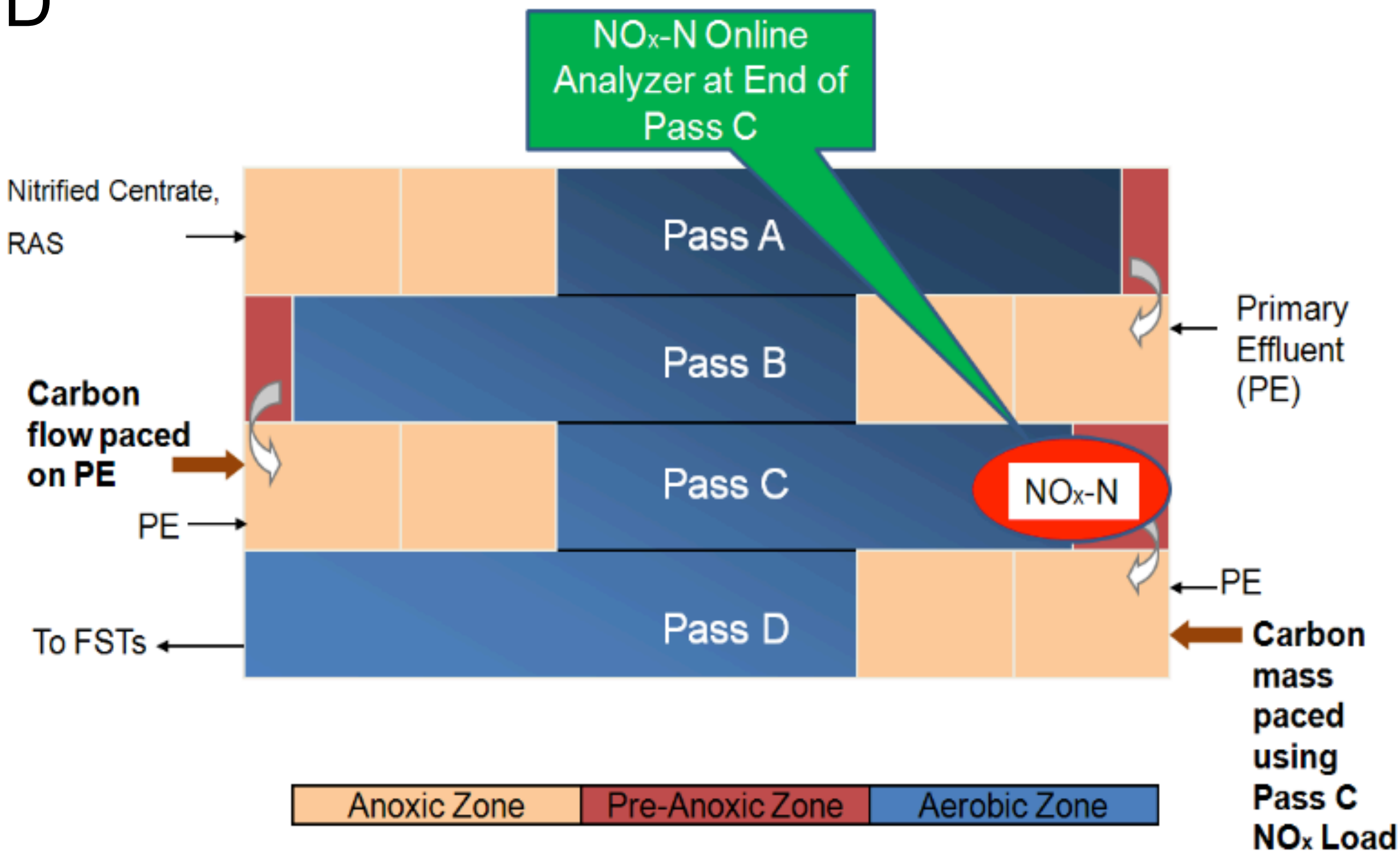
Case Study #2 – Dosing Strategy 1

- Flow-paced carbon addition based on influent flow rate



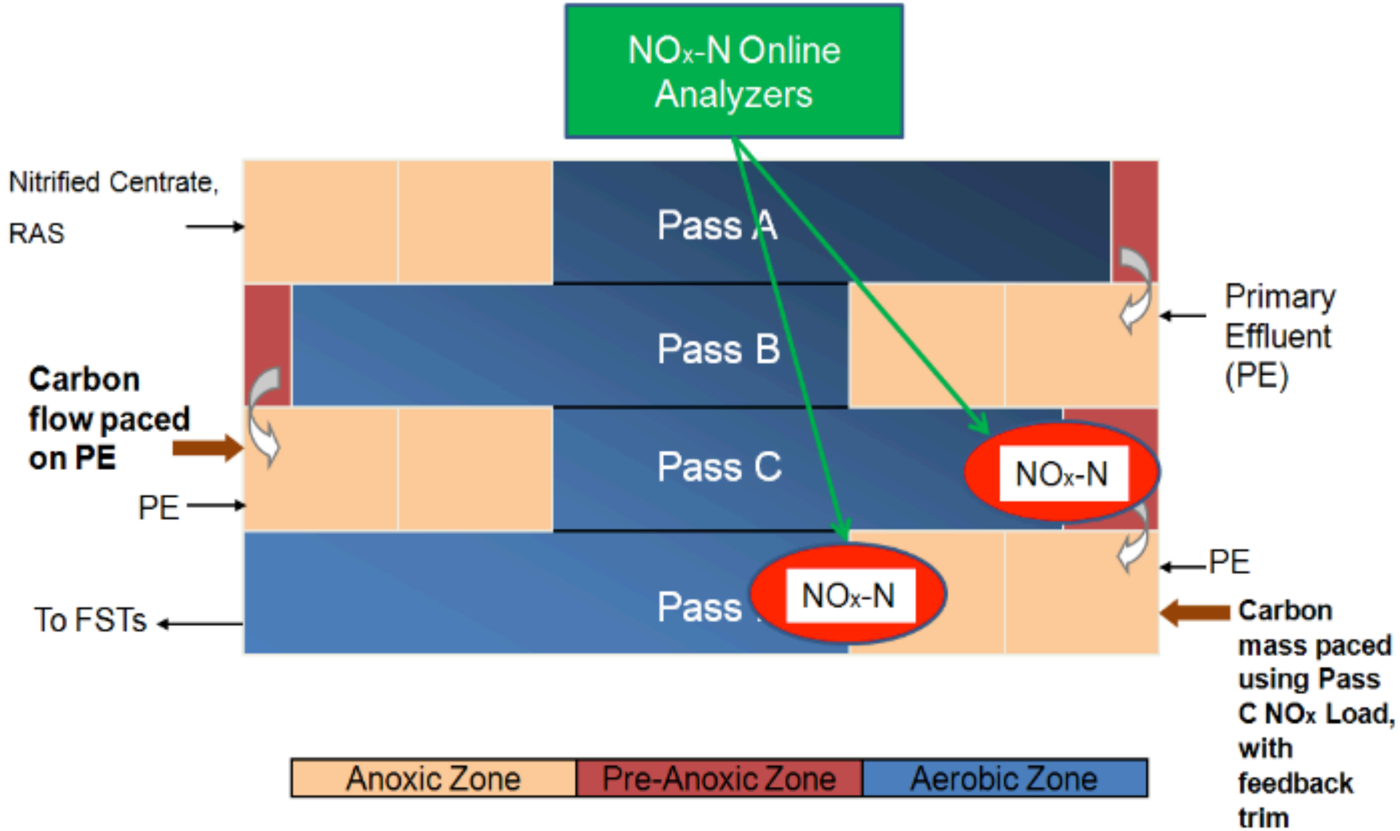
Case Study #2 – Dosing Strategy 2

1. Mass-paced carbon addition based on ratio of COD to Nitrate/Nitrite entering the head of Pass D



Case Study #2 – Dosing Strategy 3

- Feedback trim based on the Nitrate/Nitrite concentration at the end of the Pass D anoxic zone



Case Study #2 – Summary of Results

- Plant A shows that the more sophisticated strategy results in greater savings

	Strategy 1		Strategy 2		Strategy 3		% Carbon Savings over Strategy 1	
	Eff TN	Carbon	Eff TN	Carbon	Eff TN	Carbon	Strategy 2	Strategy 3
	mg/L	gpd	mg/L	gpd	mg/L	gpd		
Plant A	8.9	6,620	8.8	6,270	8.9	5,870	**5.3%**	**11.4%**
Plant B	6.8	2,190	6.8	1,940	n/a		**11.3%**	n/a
Plant C	8.3	7,910	8.2	7,850	n/a		**0.8%**	n/a
Plant D	5.2	820	5.2	760	n/a		**7.6%**	n/a
Plant E	5.9	4,090	6.0	3,910	n/a		**4.3%**	n/a

Conclusions

- Instrumentation has clear benefits for advanced WWTP processes
- Understanding goals and considerations up front is essential for success
- Process modeling can help understand the concrete benefits of a control scheme and help the decision-making process

Questions?