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Woodard & Curran

BNR Instrumentation & Controls Selection Adventure

WRF Project #5087: Implementation of Innovative Biological Nutrient Removal Processes through Improvement of Control Systems & Online Analytical Measurement Reliability & Accuracy

WRF Project 5087 Co-PIs

- Sue Guswa, PE, Woodard & Curran
- Paul Dombrowski, PE, PLS, BCEE, F.WEF, Woodard & Curran
- Amy Mueller, Ph.D, Northeastern University
- Maureen Neville, PE, Woodard & Curran
- Spencer Snowling, Ph.D, P.Eng, Hatch
- Nicholas Tooker, Ph.D, PE, University of Massachusetts, Amherst

Acknowledgements

WRF Project Advisory Committee

Phil Ackman, LASAN
Joe Husband, Arcadis
Gary Johnson, Retired, CTDEEP
Nathan Martin, Water Corporation
Tung Nguyen, NextGenWater
Heng Zhang, MWRD

WRF Staff

John Albert, Chief Research Officer
Stephanie Fevig, Research Program Manager

Case Study Partners

Justine Abrook, *Clean Water Services, Durham, OR*
Sean Driscoll, *Plymouth Wastewater Treatment Facility, Plymouth, MA*
Jason Fick, *City of Roseville, Roseville, CA*
Jeff Gamelli, *City of Westfield, Westfield, MA*
Eric Komiega, *Warren Wastewater Treatment Facility, Warren, RI*
Matthew LaPointe, *Springfield WWTF, Springfield, MA*
Ian Myers, *Metro Water Recovery, Denver, CO*
Heather Phillips, *City of Olathe, Olathe, KS*
Frank Russo, *Meriden Water Pollution Control Facility, Meriden, CT*
Karla Sangrey, *Upper Blackstone Clean Water, Millbury, MA*
Michael Williams, *Holyoke Water Pollution Control, Holyoke, MA*

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Project Partners

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NEIWPCC
SWS
BACWA BAY AREA CLEAN WATER AGENCIES
wef

Utility Partners

Clean Water Services, *Hillsboro, OR*
East Bay Municipal Utility District, *Oakland, CA*
Metro Water Recovery, *Denver, CO*
NYCDEP, *New York, NY*
City of Olathe, *Olathe, KS*
Town of Plymouth, *Plymouth, MA*
Silicon Valley Clean Water, *Redwood City, CA*
Springfield Water & Sewer Commission, *Springfield, MA*
Upper Blackstone Clean Water, *Millbury, MA*
Veolia (Holyoke Water Resource Recovery Facility), *Holyoke, MA*
City of Westfield, *Westfield, MA*

NEWEA Session Team

Nick Tooker, PE, PhD
University of Massachusetts Amherst

Maureen Neville, PE
Woodard & Curran

Jacob Fortin
Woodard & Curran

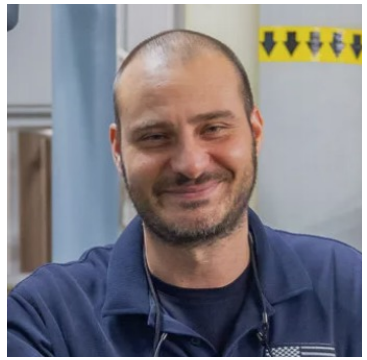
Allie Greenfield, PE
Woodard & Curran

Sue Guswa, PE
Woodard & Curran

Michael Andrus, PE
Upper Blackstone Clean Water

Jeff Gamelli
City of Westfield

Matt Nolen-Parkhouse
Veolia
(Springfield Water & Sewer Commission)



Jesse Freeman
Woodard & Curran
(Town of Plymouth)

Paul Dombrowski, PE
Woodard & Curran

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What type of water professional are you?

ⓘ Start presenting to display the poll results on this slide.

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What type of water professional are you? (or what type of place do you work?)

ⓘ Start presenting to display the poll results on this slide.

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WRF Project Overview

Maureen Neville, PE

Jacob Fortin

Woodard & Curran

Project Goal

Evaluate the technologies, configurations, performance, operations & maintenance (O&M) requirements, and costs of Biological Nutrient Removal (BNR) control systems and online instruments to:

- Synthesize the current state of the art
- Develop a framework for the practical and cost-effective implementation of BNR control systems with online instruments
- Serve and expand WRF's subscribers

Benefits for Users

Gain a **baseline understanding** of in-situ sensor and wet chemistry analyzer technology

Learn from the experiences at different WRRFs and connect with those utilities

Streamline the decision-making process and focus evaluation on most applicable systems

Promote successful implementation through **an evaluation framework to weigh benefits and costs**

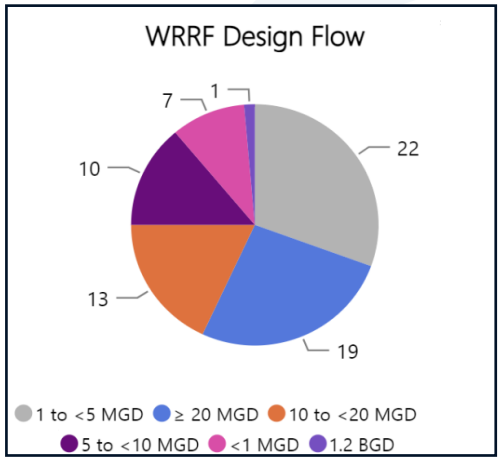
Receive **operations-focused, hands-on training utilizing a process simulator**

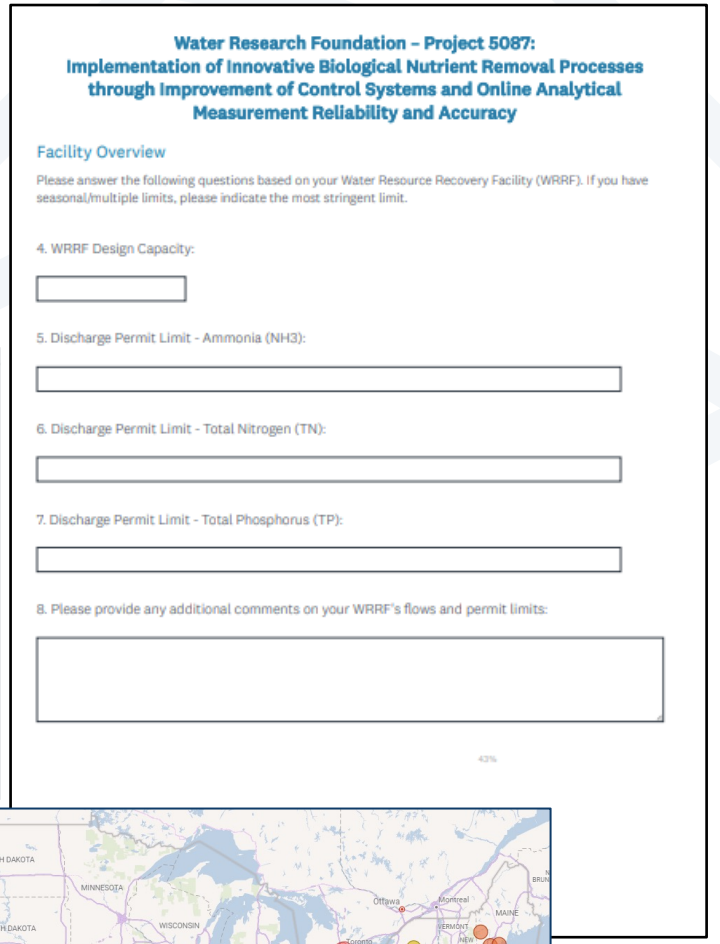
Project Tasks

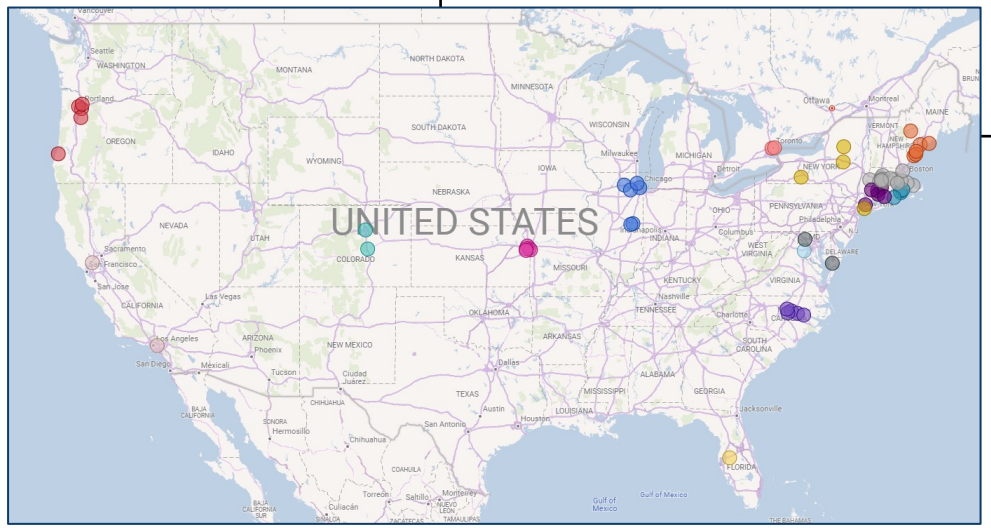
1. Literature Review for BNR Control Strategies & Online Instrumentation
2. Utility Survey
3. Sensor Testing
4. BNR Instrumentation & Controls Selection Adventure App
   - Survey Results & Case Studies
   - Instrument & Control System Matrices
   - Decision Flowcharts & ROI Calculator
   - Data Validation SOP
   - Project Overview
   - Acknowledgements
   - Acronyms & Abbreviations
   - References
5. *LIFT Webcast*
6. *Interactive Operator-Focused Training on Advanced BNR Controls*

Utility Survey Overview

- Collect quantitative & qualitative data from WRRFs including:
  - Permit Limits
  - Control Systems in Place
  - Sensors/Analyzers for Monitoring/Control
  - O&M Practices
  - Maintenance Time, Effort, and Cost
  - Improvements Noticed
  - Control System Benefits or Challenges
  - Sentiment Towards Systems







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Which BNR control systems do you use at your facility?

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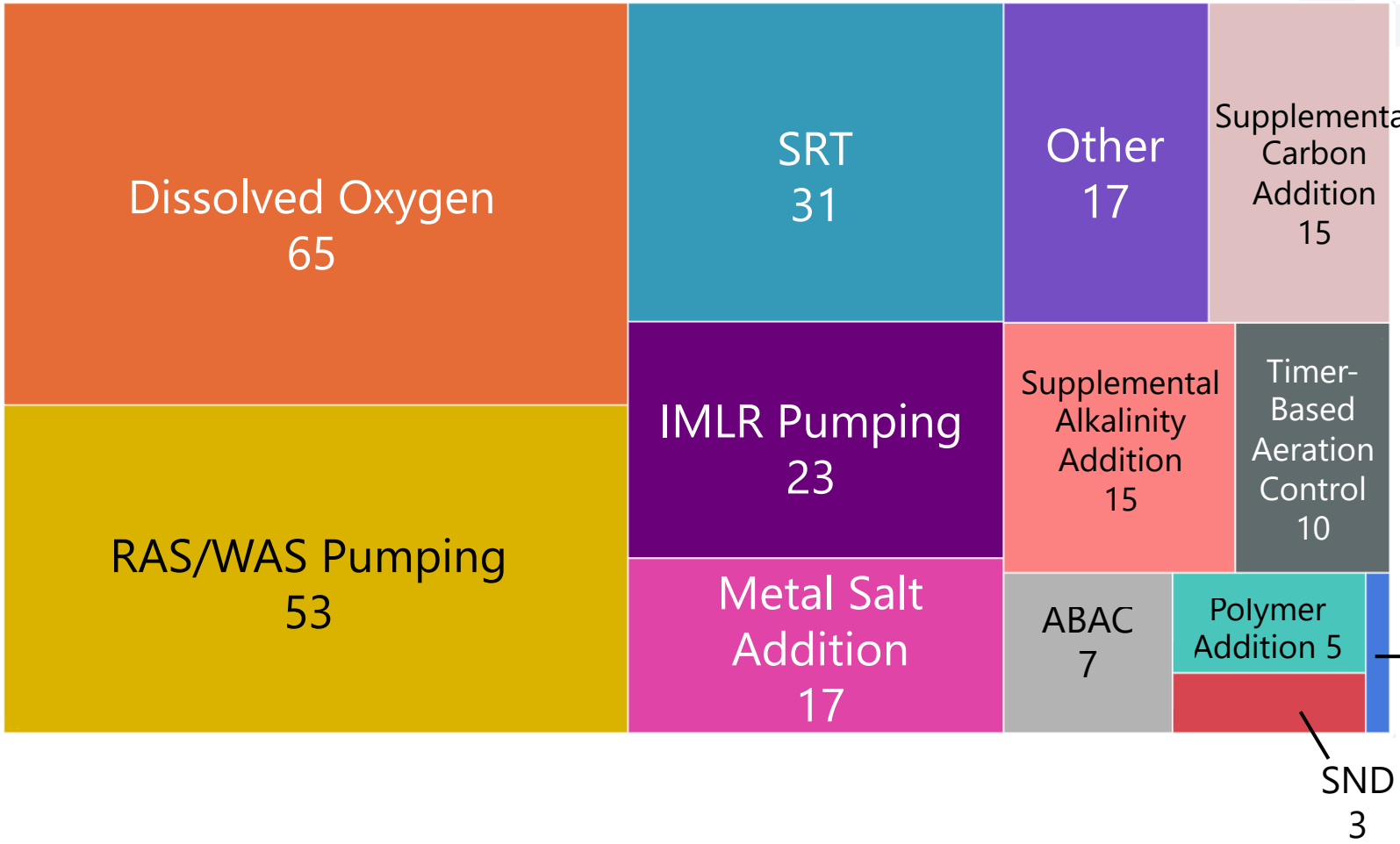
Utility survey: control systems utilized by WRRF respondents



Legend:

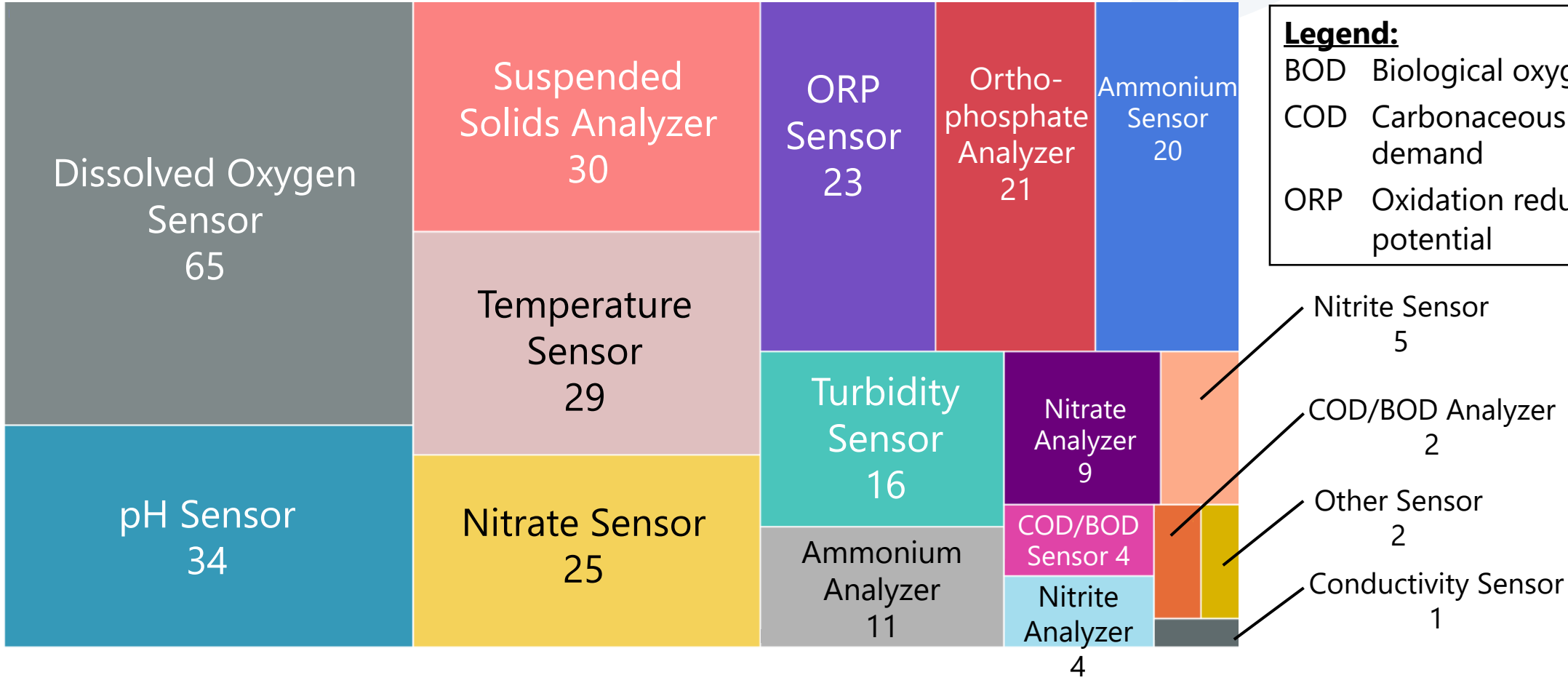
ABAC	Ammonia based aeration control
AVN	Ammonia versus nitrate
IMLR	Internal mixed liquor recycle
RAS	Return activated sludge
SND	Simultaneous nitrification-denitrification
SRT	Solids retention time
WAS	Waste activated sludge

slido

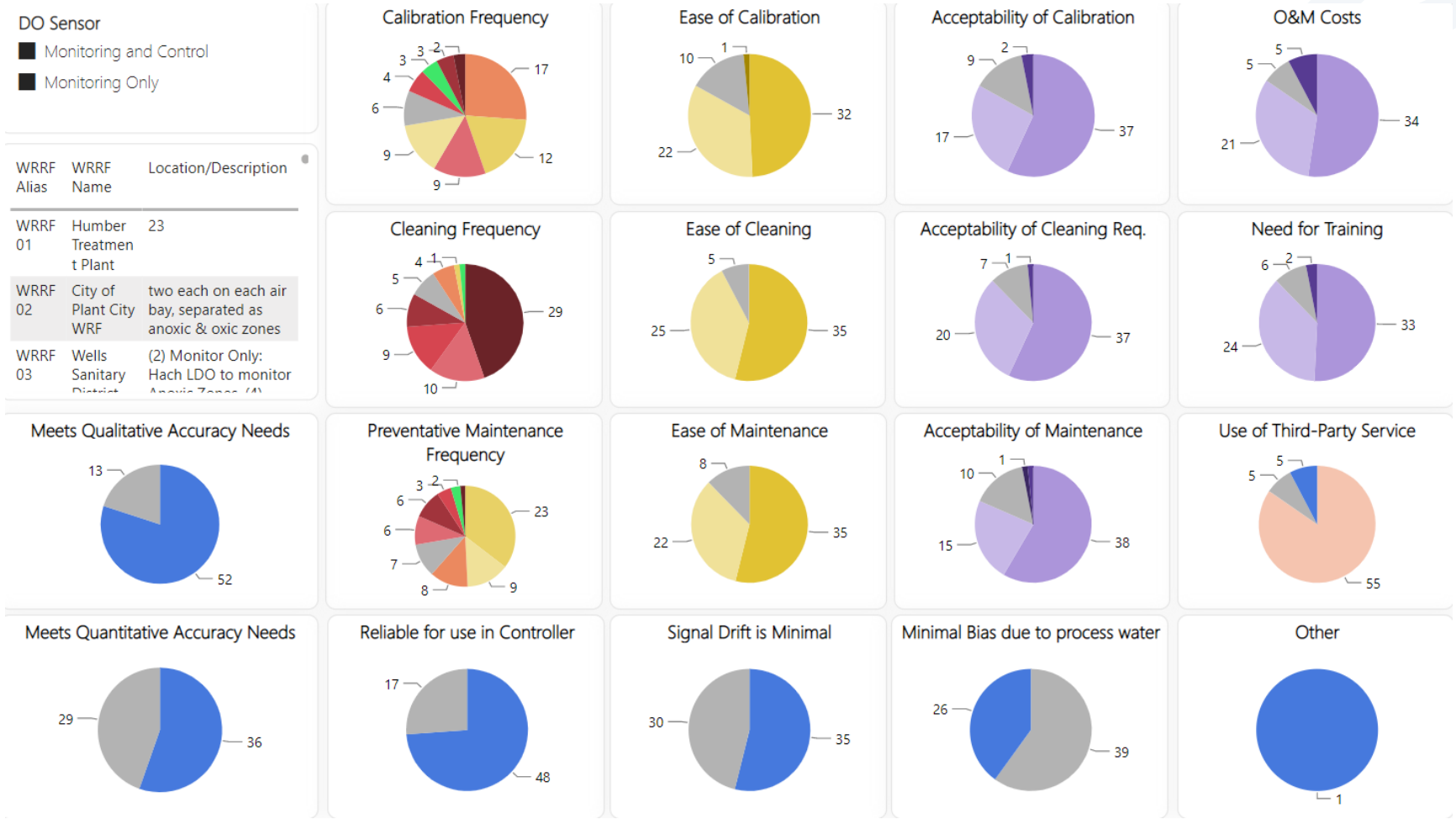
Which sensors/analyzers do you use at your facility?

ⓘ Start presenting to display the poll results on this slide.

Utility survey: sensors/analyzers utilized by WRRF respondents

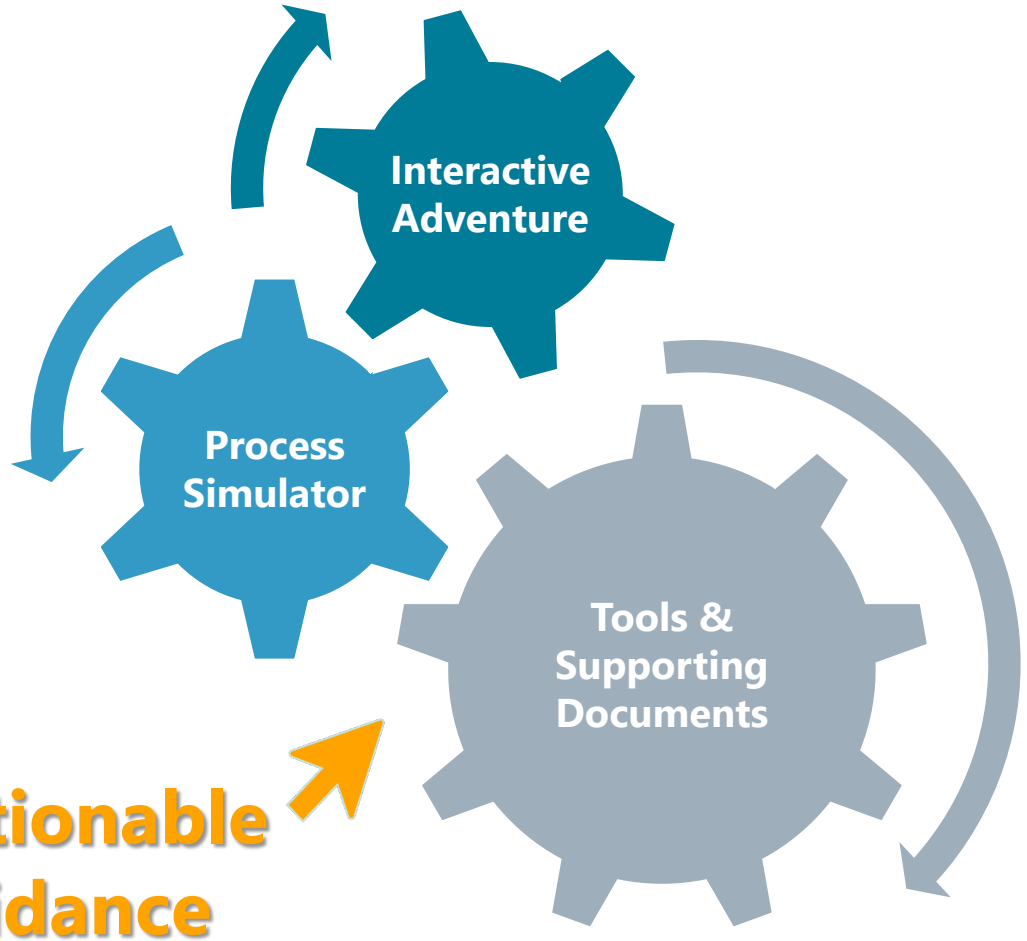


Utility Survey: Overall summary & key outcomes



- DO sensors are most common
- O&M is critical and can be expensive
  - Weekly cleaning common
- BNR controls are worth it…but there are challenges

Project Deliverable: BNR I&C Selection Adventure App



- Set of usable tools - **easy entry point**
- Target audience
  - Operators, engineers & utility directors
  - Small, medium & large WRRFs
- Interactive website
  - Presents the breadth and applicability of BNR control systems and associated online instruments

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Selection Adventure App

Allie Greenfield, PE

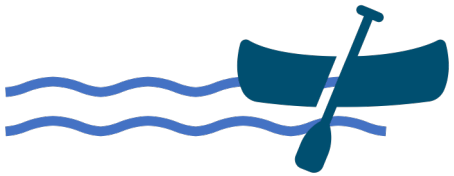
Woodard & Curran

Get your phone ready...

SCAN ME!

Let’s Try it!

BNR Instrumentation & Controls Selection Adventure App



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Which biological nutrient removal (BNR) control systems and sensors/analyzers might be right for your Water Resource Recovery Facility (WRRF)? This BNR Instrumentation & Controls Selection Adventure App helps you decide! Please answer a series of short multiple-choice questions to lead you to a customized list of potential options and a set of tools that you can use to complete your selection assessment. The tools include:

- Control system summary matrix
- Instrumentation summaries
- Utility survey results
- Case studies
- Decision flowcharts
- Return on investment calculator
- Data validation SOP
- Training opportunities
- Project overview
- Acknowledgements
- Acronyms & abbreviations
- References

This is your adventure, and you get to choose your route. The more questions you answer, the more customized the suggested BNR control system options will be for your WRRF. At any time, you can take a shortcut directly to your final destination that contains all of the project tools.

Start Your Adventure

Take a Shortcut Directly to the options list & tools →

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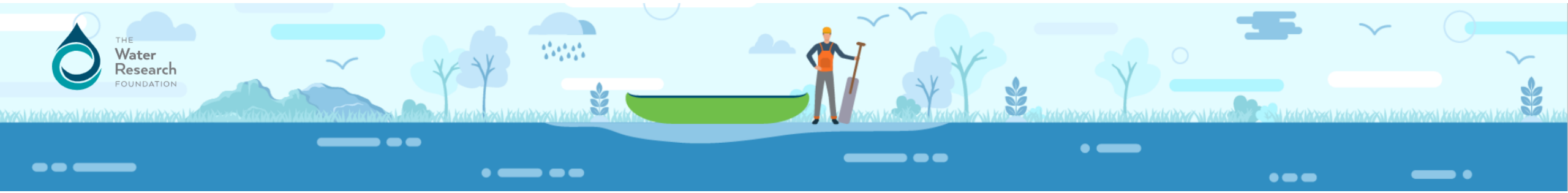


Start the Adventure! Please answer the following question to jump into your canoe and head down the river:

Question 1/3

What is your reason for being here today (choose one)?

Nitrogen

Phosphorus

Both nitrogen and phosphorus

I'm just exploring

Keep Paddling to Continue Your Adventure

Take a Shortcut Directly to the Destination

Keep paddling! Please answer the following question to continue the adventure:

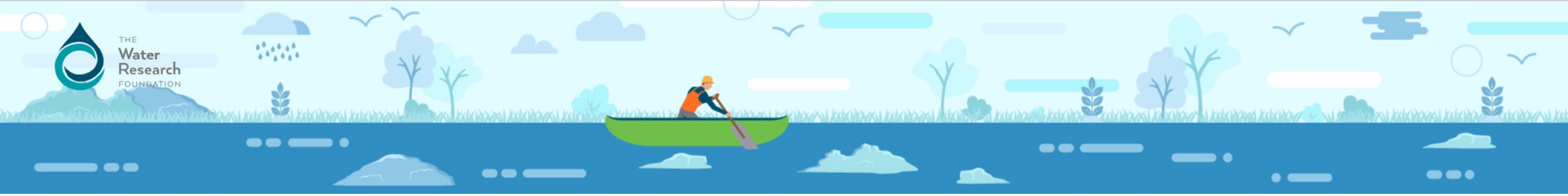
Question 2/3

What systems do you want to control (chose all that apply):

- [x] Aeration
- [x] Chemical
- [ ] Pumping

Shoot the Rapids to Continue Your Adventure

Take a Shortcut Directly to the Destination



Shoot the Rapids! Please answer the following question to get to the scenic lookout:

Question 3/3

What best describes your vision for a BNR control system (choose one)?

I want minimal instrumentation to maintain

I want lots of control and the ability to optimize performance and minimize chemical & energy costs. I'm OK with additional capital and O&M costs associated with the instruments

The middle ground between these two visions

Land the Canoe at the Scenic Lookout Point

Take a Shortcut Directly to the Destination

Scenic Lookout Point:

You made it to the scenic lookout point where you can view your customized list of potential BNR control systems for your WRRF based on your choices along the river:

Dissolved Oxygen (DO)

DO control is an aeration control system where a DO setpoint is compared to measured DO within the aerobic zone of the BNR tanks, and based on the difference between those values, a controller adjusts the airflow rate by opening or closing modulating control valves along the air delivery piping and/or turning up or down the aeration device(s).

Simultaneous Nitrification & Denitrification (SND)

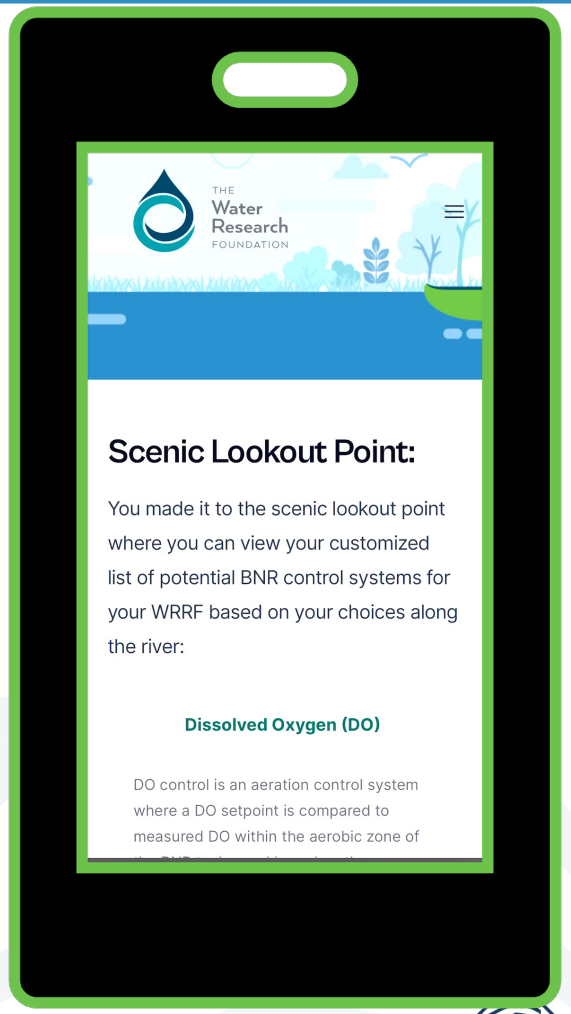
SND is an aeration control system where the DO setpoint is low, typically less than 1 mg/L, to drive both nitrification and denitrification reactions within the same reactor. The DO setpoint is compared to measured DO within the aerobic zone, and based on the difference between those values, a controller adjusts the airflow rate by opening or closing modulating control valves along the air delivery piping and/or turning up or down the aeration device(s). Ammonium and nitrate are typically monitored, too.

Timer-based Aeration Control (also called intermittent or cyclic aeration)

Timer-based aeration control is an aeration control

Internal Mixed Liquor Recycle (IMLR) Pumping with a nitrate analyzer/sensor

MLR pumping control optimizes the volume of



The Final Destination:

These tools and supporting project documents will aid you in completing your adventure and selecting your BNR control system. Click on each tool to view, download, and print the associated electronic hardcopy (pdf) or spreadsheet file (xls) (ROI calculator).

Tools

- Control System Summary Matrix
- Utility Survey Results
- Decision Flowcharts
- Data Validation SOP
- Instrument Summary Matrices
- Case Studies
- Return on Investment Calculator
- Training Opportunities

Control System Summary Matrix

Aeration

Pumping

Chemical Addition

✓Description

Control System	Description	Outcomes & Performance	Potential configurations	Related Instrumentation[1]	Additional Considerations
Dissolved Oxygen (DO)	DO control is an aeration control system where a DO setpoint is compared to measured DO within the aerobic zone of the BNR tanks, and based on the difference between those values, a controller adjusts the airflow rate by opening or closing modulating control valves along the air delivery piping and/or turning up or down the aeration device(s).	• Improve energy efficiency • Better control of DO concentrations returned to non-aerated zones within bioreactors (improving denitrification and EBPR performance)	Feedback control with DO setpoints with direct aeration control, flow-based control, or pressure-based control	• DO sensor(s) • Airflow meters and/or pressure indicators	Combine with flow-based most-open-valve (MOV) control or floating-pressure-based control of the blowers to optimize energy savings Programming should include maximum and minimum DO setpoints to mitigate risk of performance impacts from over- or under-aeration and the ability to alarm potentially-faulty instrument readings and unstable control

AvN™

Timer-Based

Aerobic SRT

Load-based equalization

Metal Salts

Polymer

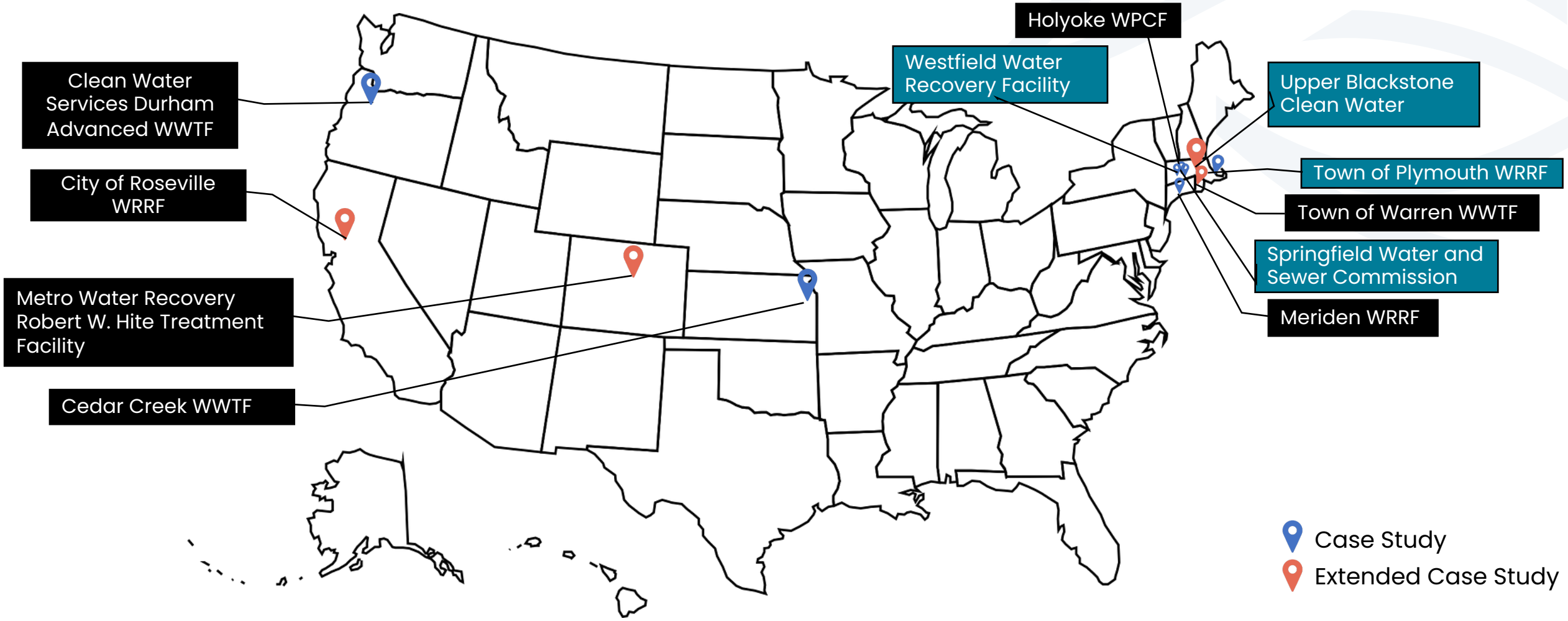
✓Additional Considerations

Instrumentation Summary Matrices

Dissolved Oxygen Instruments

Product Details				Performance	O&M Requirements			Additional Considerations			Costs
Sensor/ Analyzer	Type/ Mechanism	Manufacturer	Model	Detection range	Manufacturers recommended calibration frequency	Inspection & Maintenance as Part of the Service Contract	Maintenance by the User	Pre-filtration required (if any)	Reported interferences	Any other needs (cooling water, compressed air, other)	Instrument Cost
Sensor	Electrochemical - Lead Silver Galvanic sensor	ECD	DO90 Trace DO2	0.0 - 20.0 mg/L	Factory calibrated; no calibration needed.	No routine servicing.	Replace sensor caps every two years.	None	None	None	$2,000-$3,000
	Optical	Hach	LDO sc Model 2								
		YSI	IQ SensorNet FDO								
		Endress + Hausser	Oxymax COS61								
		In-Situ	RDOX; 750w2 Portable Monitor - OxyTechw2 RDO; MPX4 Multiparameter Sonde	0.0 - 60.0 mg/L					Alcohols >5%; hydrogen peroxide > 3%; sodium hypochlorite (commercial bleach) > 3%; gaseous sulfur dioxide; gaseous chlorine. Do not use in organic solvents.		
		Horiba	LAQUA-DO2000						None		

Case Studies



Case Studies, continued

BNR Systems:

- MLE (with and without S2EBPR), AO & A2O
- 4- and 5-Stage Bardenpho
- HPO
- SBR
- Step Feed

Control Systems:

- Aeration
  - DO, ABAC & timer-based
- Pumping
  - SRT, IMLR & RAS/WAS
- Chemical addition
  - Carbon, alkalinity & metal salts

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Decision Flowcharts

Sue Guswa, PE

Woodard & Curran

Tools

- Control System Summary Matrix
- Utility Survey Results
- Decision Flowcharts
- Data Validation SOP
- Instrument Summary Matrices
- Case Studies
- Return on Investment Calculator
- Training Opportunities

Supporting Project Documents

- Project Report
- Acknowledgements
- Acronyms & Abbreviations
- References

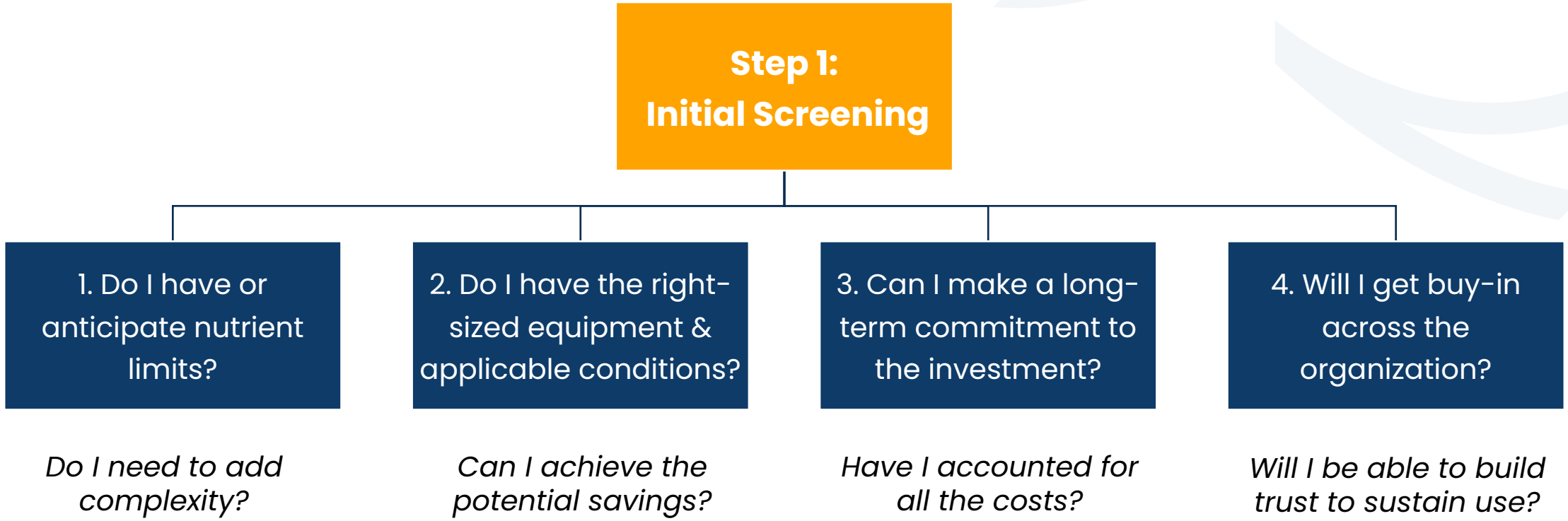
Tool: Decision Flowcharts

The ***Decision Flowcharts*** tool and related ***Return on Investment Calculator*** tool are intended to help you answer the question:

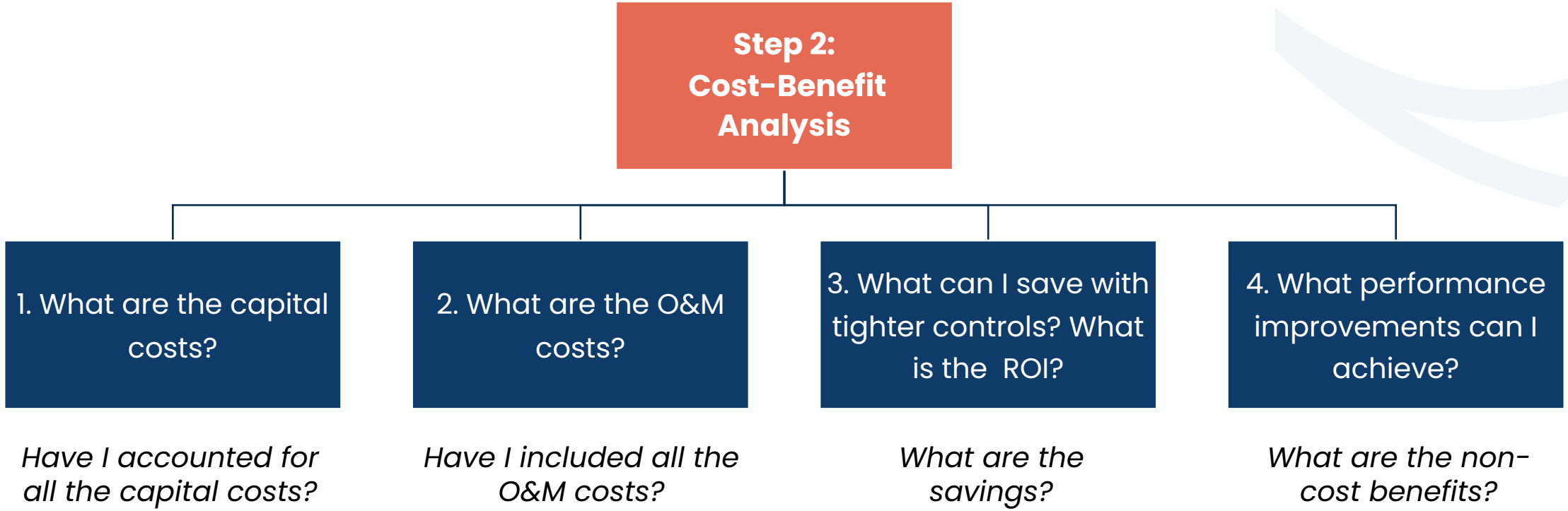
Should I invest in BNR instrumentation & controls for my WRRF?

1. Initial Screening → 2. Cost-Benefit Analysis → 3. Evaluation of Critical Success Factors

Step 1: Initial screening approach



Step 2: Cost-Benefit Analysis



Tool: Return on Investment Calculator

- **Capital Costs**
  - Controls
  - Instrumentation
  - Other Costs
- **O&M Costs**
  - Controls
  - Instrumentation
  - Data Validation & Management
- **O&M Savings**
  - Energy
  - Chemicals
  - Labor
  - Sludge
  - Other

1. Capital Costs:

A. Controls:

Control System	Control Program Development/ Purchase Cost	Installation Cost	Startup & Commissioning Cost	Other C	Subtotal (sum of cost
ABAC (proprietary system)	$25,000				

B. Instrumentation:

Instrument(s)	Instrument Cost (Total)	Accessories Cost (transmitter, cleaning units, supports, and etc.) (Total)	Installation Cost (Percent of Instruments & Accessories)	Other Co
Dissolved Oxygen sensor	$6,000	$3,000	$3,600	
ISE Ammonia sensor	$8,000	$3,000	$4,400	

Annual O&M Savings:

Two options are available for estimating the annual O&M savings:
- Option 1 allows for direct entry of quantities of materials saved and associated u
- Option 2 estimates savings based on overall WRRF budget, estimated breakdow

Option 2 Annual Savings - Percent Savings Calculator

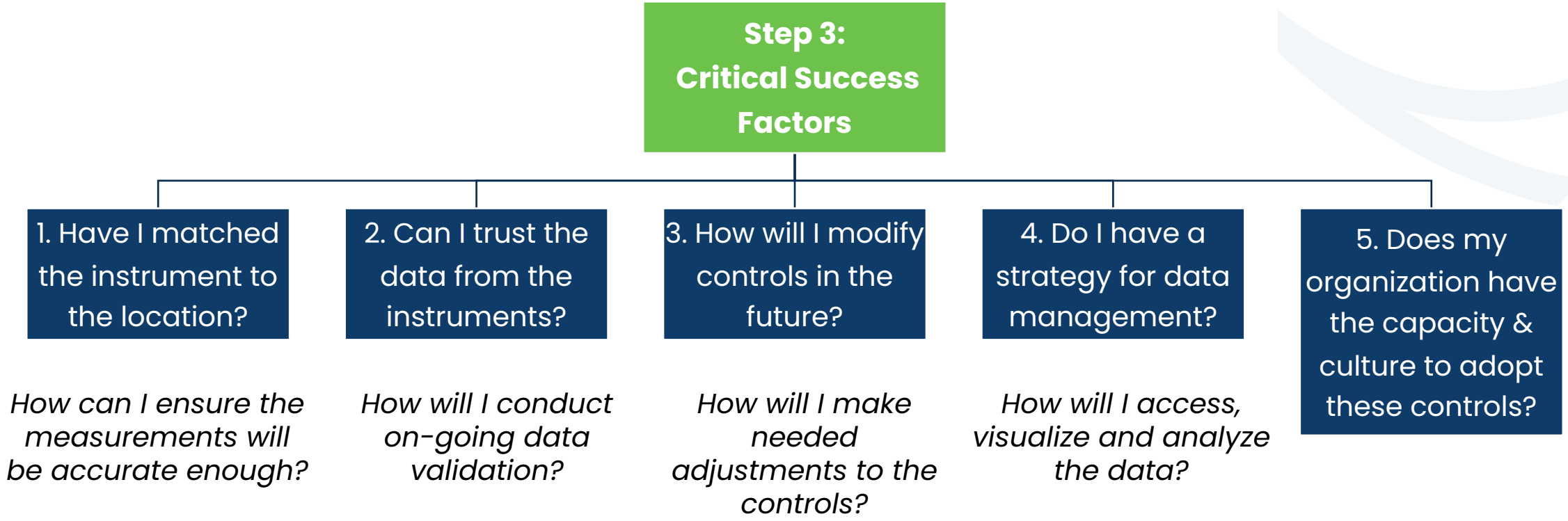
Item	Total annual budget:		$ 2,000,000
Labor as percent of total	40	%	$ 800,000
Electricity as percent of total	30	%	$ 600,000
Sludge Disposal as percent of total	25	%	$ 500,000
Chemical as percent of total	5	%	$ 100,000
Other as percent of total	0	%	$ -
	OK		
	Percent Savings		**Savings**
Labor	0	%	$ -
Electricity	15	%	$ 90,000
Sludge Disposal	0	%	$ -

Net Annual Savings & Return on Investment:

Net Annual Savings =	**$26,500**	*Net Annual Savings = Total Annual Savings - Total Annual O&M Costs - Annual Capital Recovery Costs*
Return on Investment (ROI) =	**4.0 Years**	*ROI = Capital Costs/(Annual Savings - Annual O&M Costs)*

Snippets of Downloadable Excel file

Step 3: Evaluation of critical success factors approach

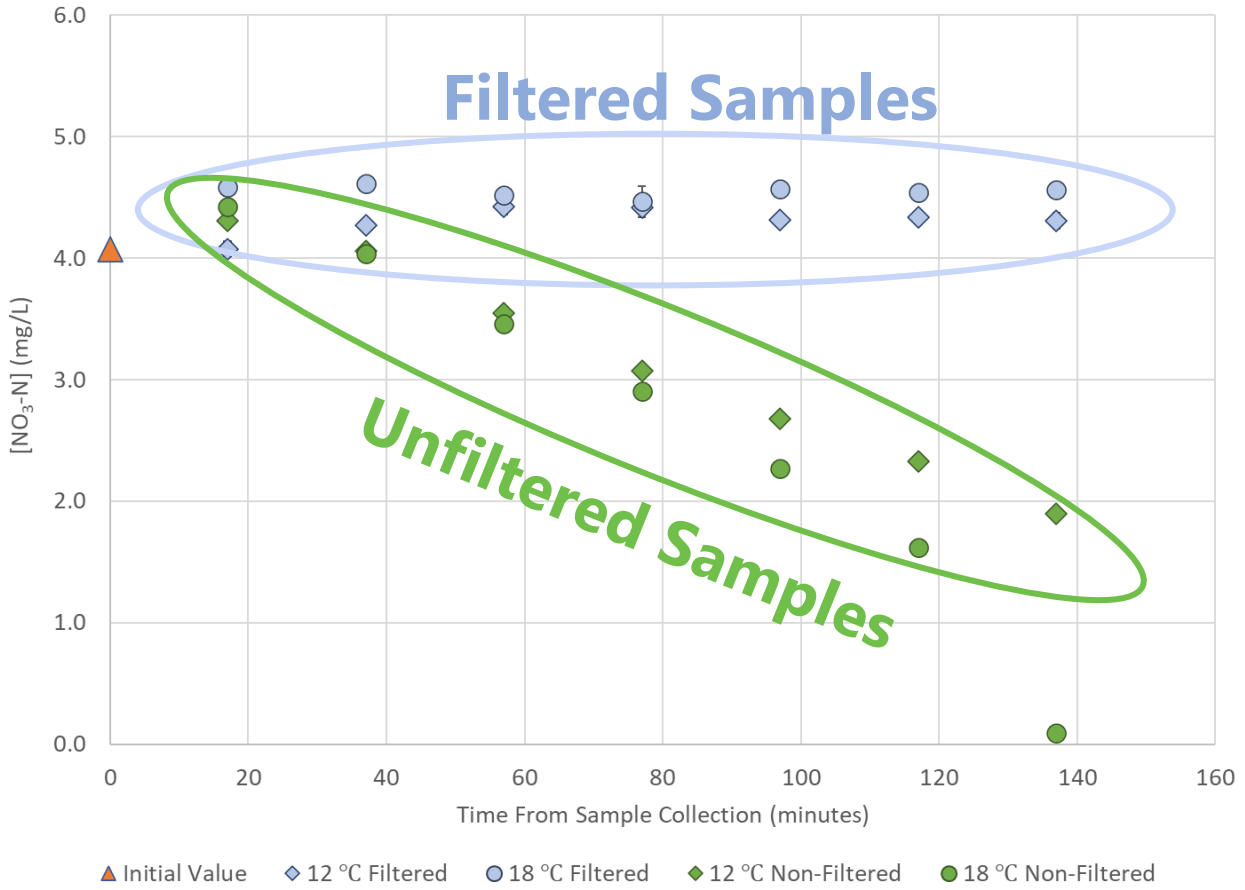


Tool: Data Validation SOP

- Starting point for utilities as they build their own SOP

1. Sample Collection
2. Sample Analysis
3. Matrix Adjustments

- Field testing conducted at UMass Amherst
  - Routine sensor cleaning (1-2 times/week)
  - Immediate filtration is critical



Nitrate Concentration as a Function of Time After Sample Collection With and Without Filtration and Refrigeration

Thank You!

- **Nick Tooker, PE, PhD**, University of Massachusetts, Amherst: *NBTooker@UMass.edu*
- **Maureen Neville, PE**, Woodard & Curran: *MNeville@WoodardCurran.com*
- **Jacob Fortin**, Woodard & Curran: *JFortin@WoodardCurran.com*
- **Allie Greenfield, PE**, Woodard & Curran: *AGreenfield@WoodardCurran.com*
- **Sue Guswa, PE**, Woodard & Curran: *SGuswa@WoodardCurran.com*
- **Michael Andrus, PE**, UBCW: *MAndrus@UBCleanWater.org*
- **Jeff Gamelli**, City of Westfield: *j.gamelli@CityofWestfield.org*
- **Matthew Nolen-Parkhouse**, Veolia: *Matthew.Nolen-Parkhouse@Veolia.com*
- **Jesse Freeman**, Woodard & Curran *JFreeman@WoodardCurran.com*
- **Paul Dombrowski, PE**, Woodard & Curran: *PDombrowski@WoodardCurran.com*

BNR Instrumentation & Controls Selection Adventure

https://wrf-bnr-selection-app.woodardcurran.com

Panel Discussion

Moderator: Nick Tooker

Michael Andrus, PE, Upper Blackstone Clean Water
Jeff Gamelli, City of Westfield
Matthew Nolen-Parkhouse, Veolia
Jesse Freeman, Woodard & Curran

Woodard & Curran

UPPER BLACKSTONE CLEAN WATER

Case Study:

Upper Blackstone Clean Water

Michael Andrus, PE

Deputy Director

UBCW

UPPER BLACKSTONE CLEAN WATER

- Serves 250,000 population
- 30 MGD dry weather flow (120+ MGD during wet weather)
- BNR plant with 4 A^2O trains
- Nutrient Limits
  - TN: 5 mg-N/L
  - TP: 0.1 mg-P/L (0.45 mg/L interim)
- Regional Biosolids Incinerator
- Discharge to the Blackstone River

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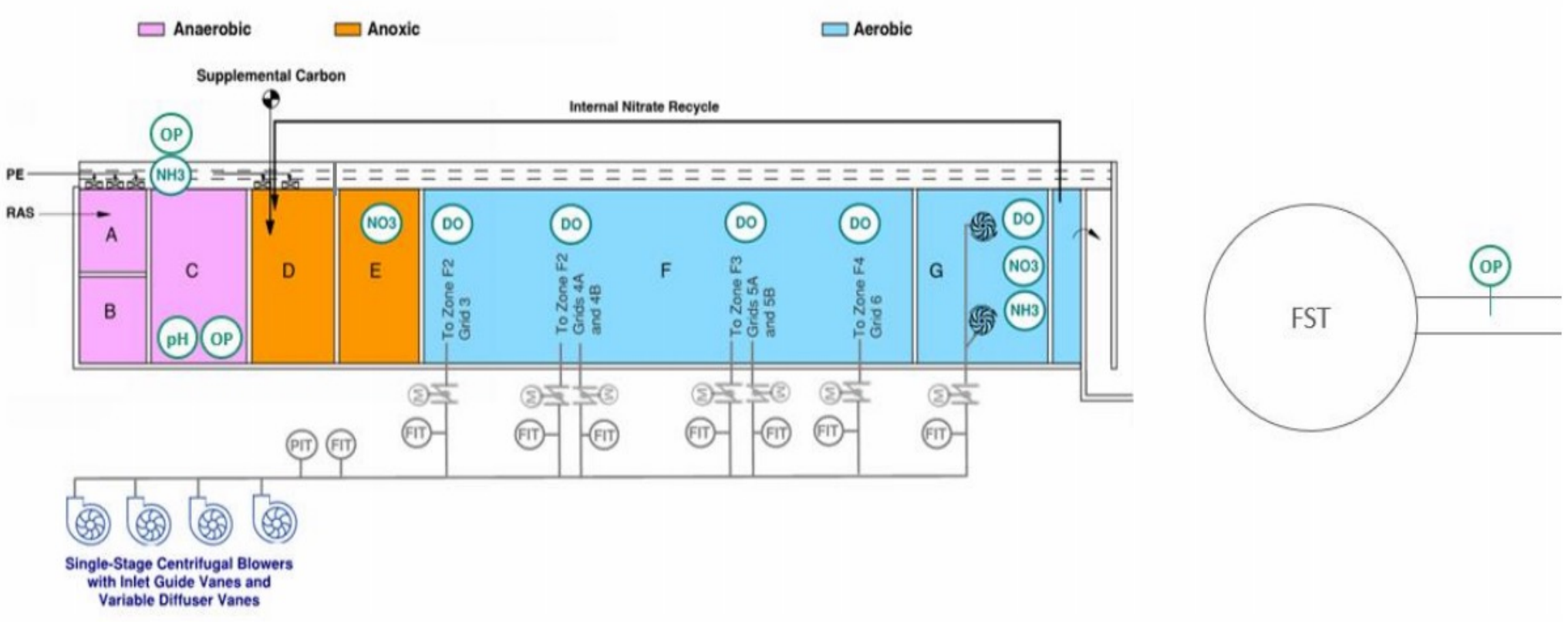


Figure 3. BNR Process Schematic with Instrument Locations.

Source: Modified from Neville, et. al., September 2019.

INSTRUMENTATION SOLUTIONS

- Nitrack Controller – Micro C pacing for Nitrogen
- DO Probes, Iris valves and MOV control for aeration
- pH Meters for Alkalinity and pH control
- Phosphax Analyzer for Phosphorus (monitoring)

Woodard & Curran

THANK YOU!

Michael Andrus, PE | Deputy Director

MAndrus@UBCleanWater.org

UPPER BLACKSTONE CLEAN WATER

Woodard & Curran

Case Study:

Westfield Water Recovery Facility

Jeffrey Gamelli

Deputy Superintendent

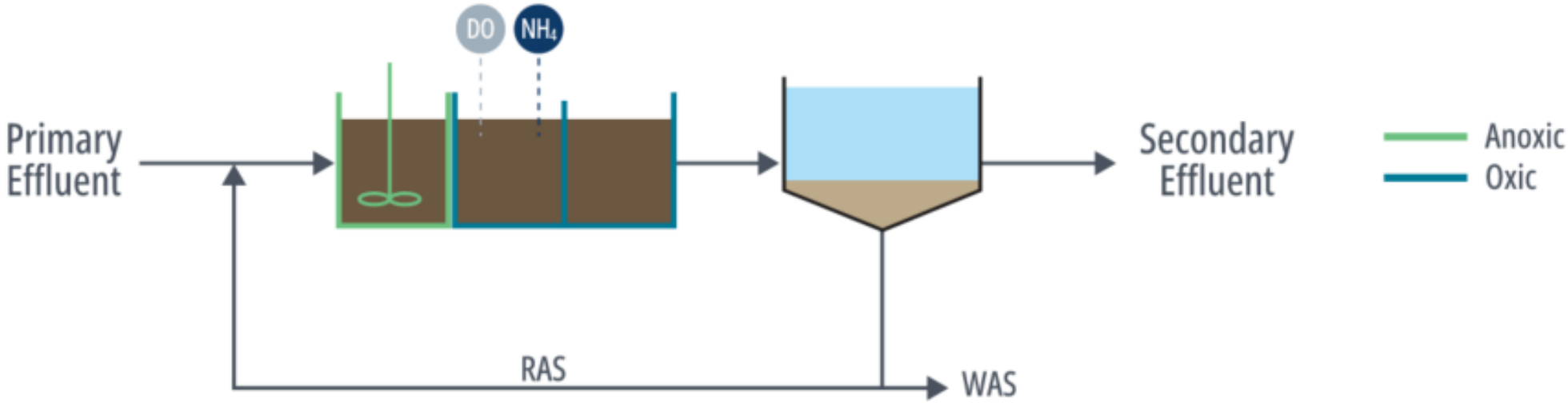
City of Westfield

Westfield WRF

- Flow:
  - Design ADF: 6.1 mgd
  - Typical ADF: 3.4 mgd
- Permit Limits:
  - Ammonia: 3 mg/L (summer limit)
  - Total Nitrogen: 407 lbs/day rolling annual average (equivalent to 8 mg/L at permitted design flow)
  - Total Phosphorus
    - 0.46 mg/L April 1 – October 31
    - 1 mg/L TP November 1 – March 31
- BNR Process:
  - Conventional Activated Sludge – Modified AO
- Controls:
  - Aeration control: Dissolved Oxygen (DO) Control, Ammonia-based Aeration Control (ABAC)
  - Chemical addition: Supplemental Alkalinity Addition, Metal Salt Addition, Return Activated Sludge (RAS), Waste Activated Sludge (WAS) Pumping

Source: City of Westfield Water Recovery Facility, October 2023.

Westfield BNR Instrumentation



Sensors & Analyzers	
Automatic Control System:	DO Sensor, Ammonium Sensor
BNR Monitoring:	DO Sensor, pH Sensor, Ammonium Sensor, Phosphate Analyzer, Suspended Solids Sensor, Oxidation Reduction Potential (ORP) Sensor, Temperature Sensor

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Case Study: Plymouth WRRF

Jesse Freeman

Lead Operator

Woodard & Curran

Plymouth WRRF

- Design Flow:
  - 3 mgd average annual daily flow
- Permit Limits:
  - Nitrate (as N): 10 mg/L
  - Total Nitrogen: 10 mg/L
- BNR Process:
  - Sequencing batch reactor (SBR)
- Controls:
  - Aeration: Timer-based aeration control
  - Chemical Addition: Supplemental alkalinity & metal salts

Source: Microsoft Bing, June 2023.

Plymouth BNR Instrumentation (monitoring only)

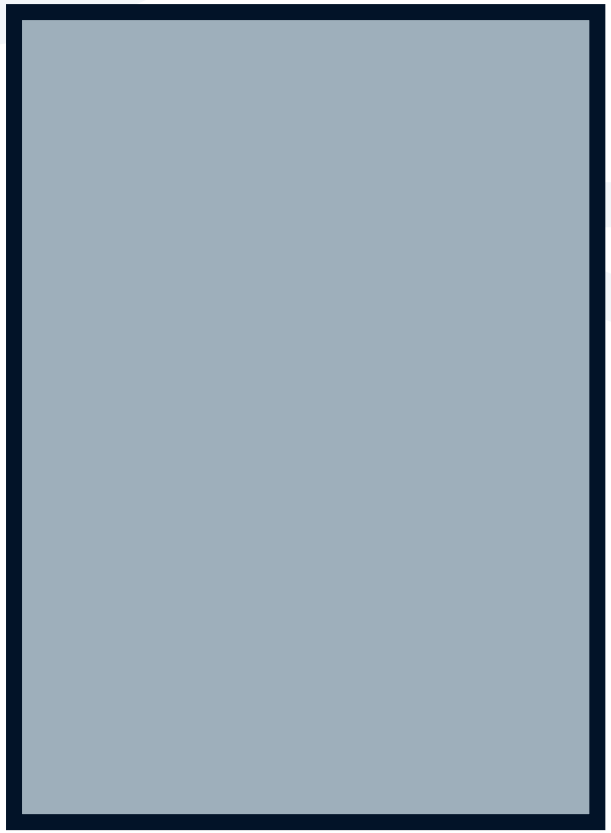
SBR 1

Sensors:
- Dissolved Oxygen
- pH
- ORP
- Ammonium
- Nitrate/Nitrite

SBR 2

Sensors:
- Dissolved Oxygen
- pH
- ORP
- Ammonium
- Nitrate/Nitrite

SBR 3 (offline)



And Suspended Solids Sensor located in Chlorine Contact Tank

Woodard & Curran

Case Study:

Springfield Regional Wastewater Treatment Facility

Matt Nolen-Parkhouse

Assistant Project Manager

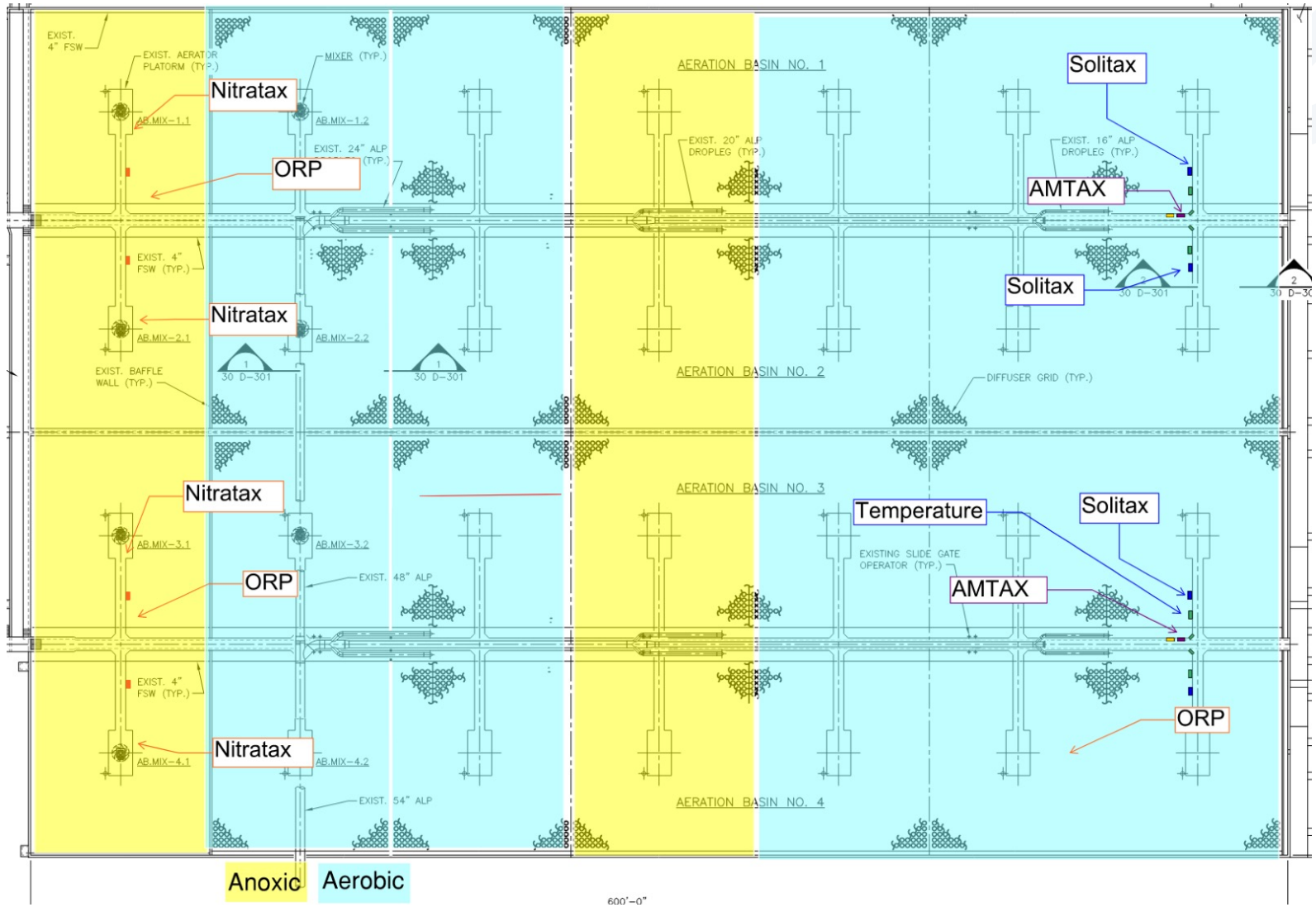
Veolia

Springfield Regional Wastewater Treatment Facility

- Flow (CSO Facility):
  - 67 mgd design ADF
  - 40 mgd typical ADF
- Permit Limits:
  - 2,794 lbs/day TN (5 mg/L at 67 MGD)
- BNR Process:
  - Hybrid step feed process with two anoxic zones and IMLR from last aerobic zone to first anoxic zone
- Controls:
  - Aeration: Hach RTC-N (Proprietary control, Ammonia Based Aeration Control (ABAC)/ Dissolved Oxygen (DO))
  - Pumping: Internal Mixed Liquor (IMLR) control (flow-paced)

Source: Google Earth, Sept 2022.

Springfield BNR Instrumentation



Source: Springfield Water and Sewer Commission, Sept 2022.

Sensors & Analyzers	
Automatic Control System:	• DO Sensor, • Nitrate analyzer, • Ammonium analyzer, • Total Suspended Solids (TSS), • Temperature
BNR Monitoring:	• DO Sensor, • Nitrate analyzer, • Ammonium analyzer, • Total Suspended Solids (TSS), Temperature

slido

Audience Q&A Session

ⓘ Start presenting to display the audience questions on this slide.

Panel Discussion

Moderator: Nick Tooker

Michael Andrus, PE, Upper Blackstone Clean Water
Jeff Gamelli, City of Westfield
Matthew Nolen-Parkhouse, Veolia
Jesse Freeman, Woodard & Curran

Woodard & Curran

Woodard & Curran

Simulator Training

Paul Dombrowski

Woodard & Curran

Simulator BNR Control Training Exercises

- The **WRF Project 5087 Simulator** contains the following BNR control schemes, allowing users to interactively experiment with different control options and training exercises:
  - SRT control (via WAS)
  - DO control via airflow
  - Ammonia-Based Aeration Control (ABAC) of DO setpoints
  - PO_4-P control via metal salt addition
  - NO_3-N control via supplemental carbon addition and IMLR pumping
- Simulator has both steady-state and dynamic influent flow functionality, illustrating how operational changes affect effluent quality under diurnal and wet weather flow conditions

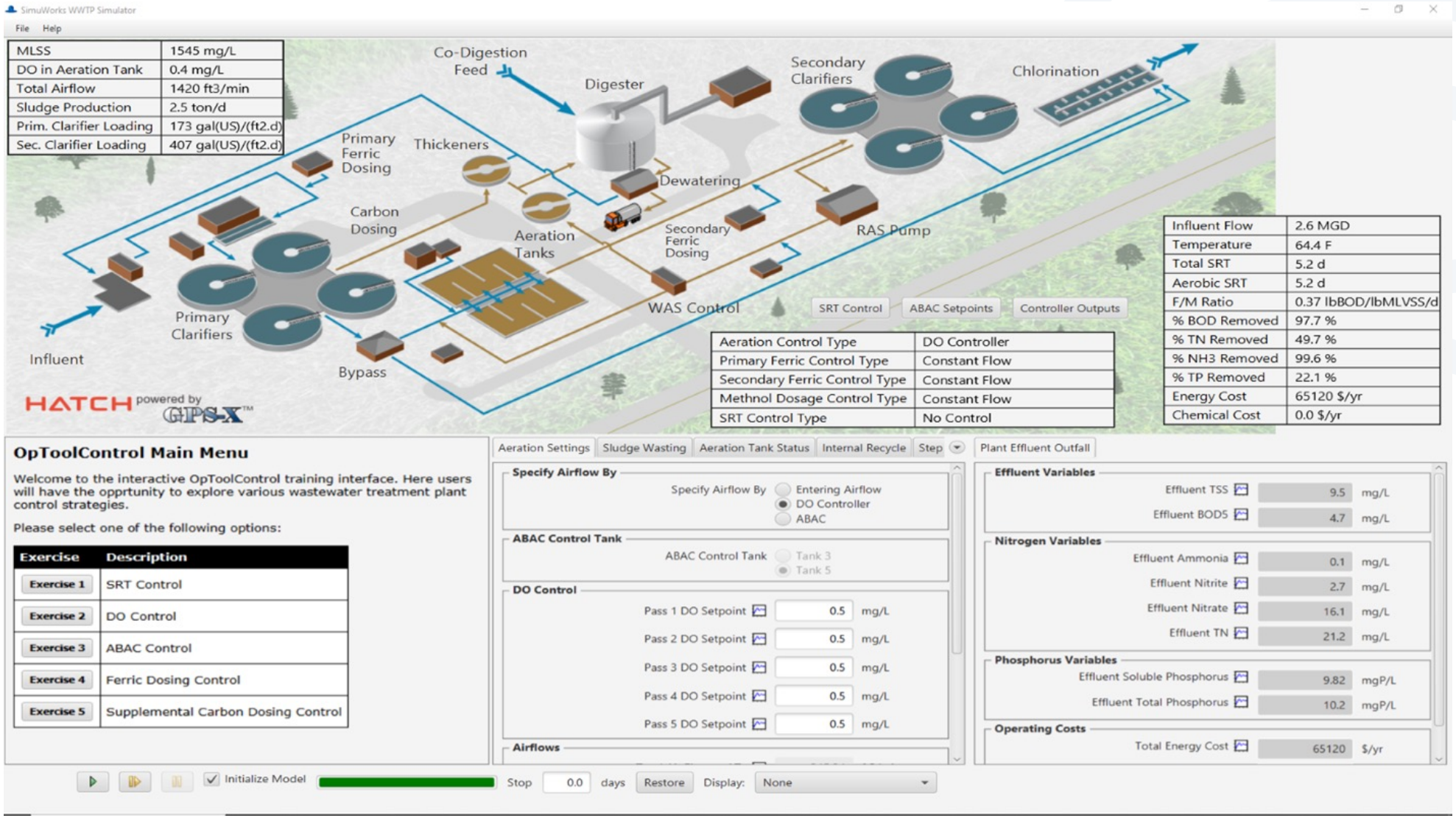
Simulator Introduction

- The **SimuWorks**™ simulator is an interactive hands-on training tool based on **GPS-X™** from Hatch (formerly Hydromantis)

- **SimuWorks**™ has been available for over a decade and part of WEFTEC Operations Challenge since 2016

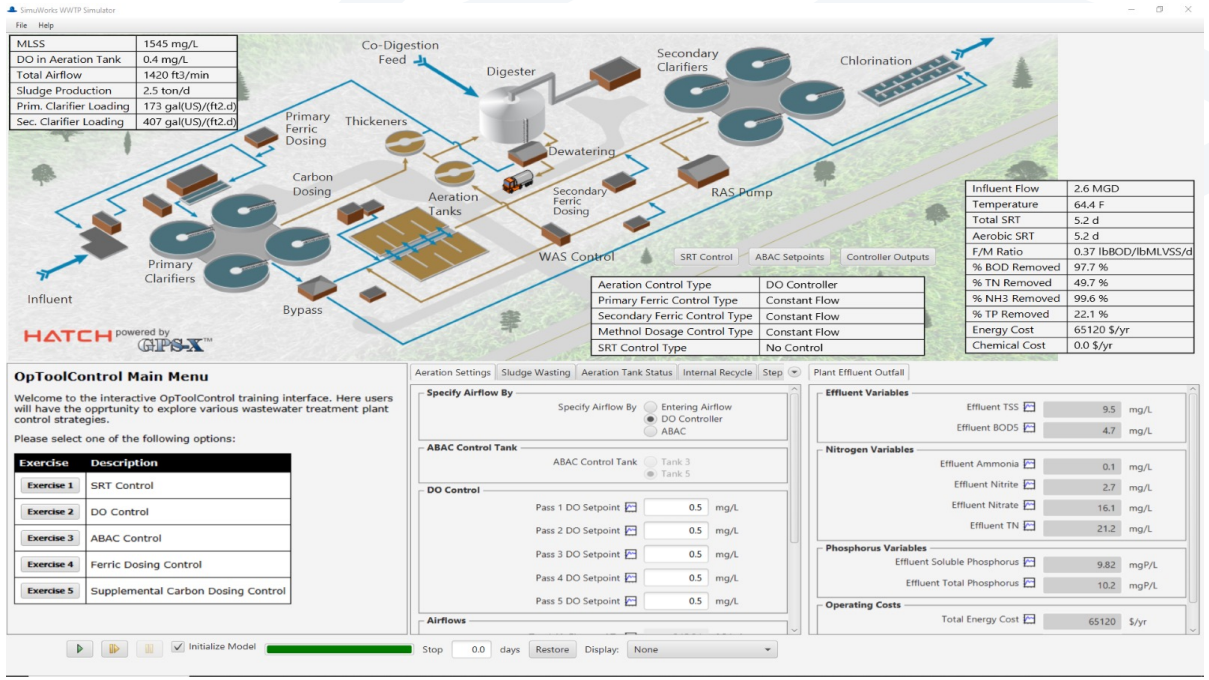
- **WRF Project 5087 Simulator** incorporates various instrumentation and control options that allow:
  - Open Simulation Mode to develop and run interactive simulations
  - Prepared, self-paced exercises that walk the user through how sensors and controls can improve operation, performance and cost.

Simulator BNR Control Training Exercises



Where can I learn more?

- **BNR Instrumentation & Controls Selection Adventure App**
  - Interactive adventure
  - Tools (8)
  - Supporting Project Documents
  - *Accessed from a link on the WRF website and hosted by Woodard & Curran*
  - **https://wrf-bnr-selection-app.woodardcurran.com**
- **Simulator**
  - *Accessed from a link on the WRF website and hosted by Hatch for one year after final deliverable is complete*
  - *WRF LIFT Webinar & additional opportunities to use simulator at trainings through industry associations*



Example screenshot from Simulator used in interactive operations-focused training

Thank You!

- **Nick Tooker, PE, PhD**, University of Massachusetts, Amherst: *NBTooker@UMass.edu*
- **Maureen Neville, PE**, Woodard & Curran: *MNeville@WoodardCurran.com*
- **Jacob Fortin**, Woodard & Curran: *JFortin@WoodardCurran.com*
- **Allie Greenfield, PE**, Woodard & Curran: *AGreenfield@WoodardCurran.com*
- **Sue Guswa, PE**, Woodard & Curran: *SGuswa@WoodardCurran.com*
- **Michael Andrus, PE**, UBCW: *MAndrus@UBCleanWater.org*
- **Jeff Gamelli**, City of Westfield: *j.gamelli@CityofWestfield.org*
- **Matthew Nolen-Parkhouse**, Veolia: *Matthew.Nolen-Parkhouse@Veolia.com*
- **Jesse Freeman**, Woodard & Curran *JFreeman@WoodardCurran.com*
- **Paul Dombrowski, PE**, Woodard & Curran: *PDombrowski@WoodardCurran.com*

BNR Instrumentation & Controls Selection Adventure

https://wrf-bnr-selection-app.woodardcurran.com