Tighe&Bond

Engineers | Environmental Specialists

DESIGNING ENERGY EFFICIENCY AND NITROGEN REMOVAL OPTIMIZATION FOR A MAJOR WPCF UPGRADE IN SOUTHINGTON, CT

NEWEA Annual Conference – January 27, 2020

Cynthia M. Castellon, PE
Christopher Bone, PE

Tighe&Bond

SOUTHINGTON WPCF

- **Design Capacities**
  - Design Average Daily Flow Rate 7.4 mgd
  - Design Peak Hourly Flow Rate 15.9 mgd
  - Build-Out Peak Hourly Flow Rate 24.3 mgd

- **Construction and Upgrades**
  - 1957 – Original Plant Construction
  - 1964 – Primary and Secondary Treatment Expansion
  - 1965 – Sludge Handling Expansion
  - 1979 – Major Upgrade, Nitrification, Intermediate Treatment
  - 1995 – UV Disinfection System
  - 2007 – Denitrification Filters
  - 2015 – Sludge Handling Upgrades and Odor Control
  - 2020 – Major Upgrade, Phosphorus Removal

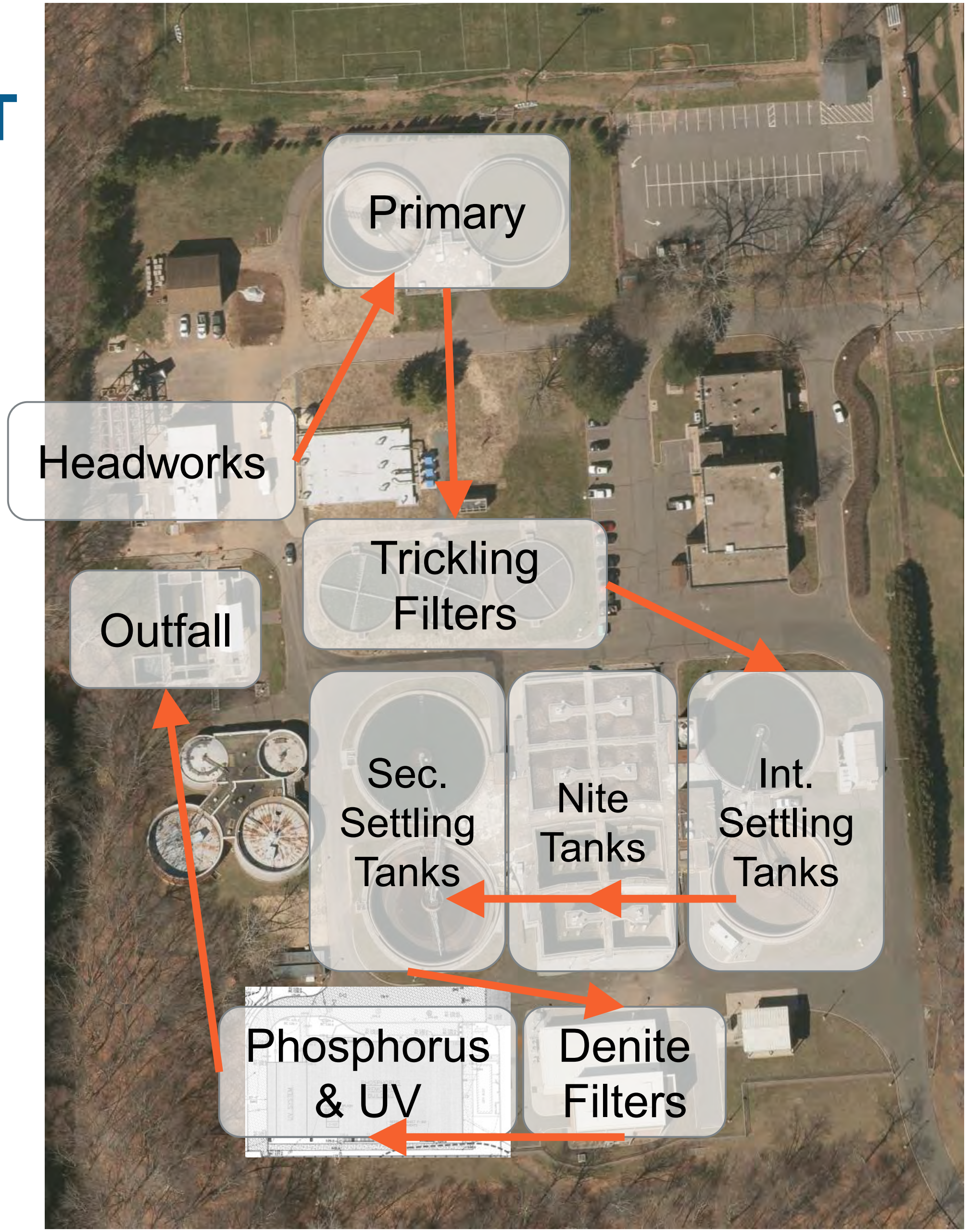
DRIVERS FOR UPGRADE

- **New Phosphorus Effluent Limits**
  - Seasonal – April 1 through October 31
  - 7.53 lbs/day by April 2022
  - Equivalent to 0.2 mg/L at current ADF of 4.5 mgd
- **Aging Infrastructure**
  - WPCF, Collection System, and Pump Stations
  - Equipment upgrades
  - Structural and architectural repairs
  - Electrical system improvements
- **Improve Energy Efficiency**
  - Modernize plant
  - Upgrade motors, drives, control systems, and building HVAC systems

SOUTHINGTON WPCF UPGRADE

- **Construction**
  - Construction Cost of ~$40 M
  - ~50% complete as of Dec-19
- **Funding**
  - Clean Water Fund
    - 50% grant for construction costs related to phosphorus removal
    - 30% grant for construction costs related to biological nitrogen removal
    - 20% grant for balance of costs not related to nutrient removal
  - Energy Utility Rebate Incentive

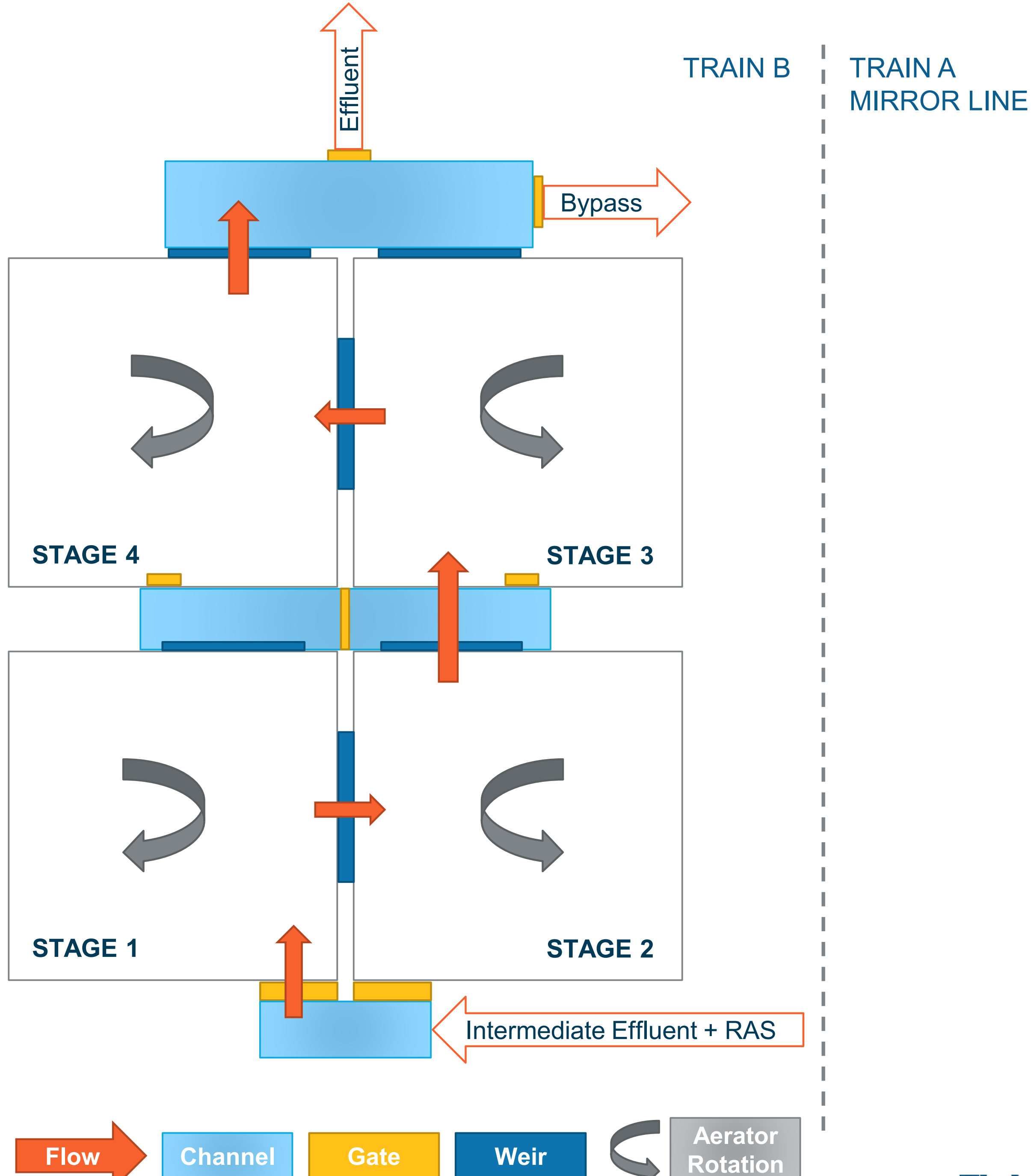
LIQUID TREATMENT



Tighe&Bond

NITRIFICATION REACTORS

NITRIFICATION REACTORS



TRAIN B
TRAIN A
MIRROR LINE
Effluent
Bypass
STAGE 4
STAGE 3
STAGE 1
STAGE 2
Intermediate Effluent + RAS
Flow
Channel
Gate
Weir
Aerator Rotation

FACILITIES PLAN – EQUIPMENT EVALUATION

- **Condition Assessment**
  - Condition and Age of equipment warranted replacement

- **Replacement Alternatives**
  - #1: Fine Bubble Diffusers and Blowers with VFDs
  - #2: New Surface Aerators with VFDs
  - ~~#3: Mixer / Aerator Units and Blowers with VFDs~~

- **Evaluation**
  - Capital Costs
  - Annual Operating Costs (energy, maintenance)
  - Process Impacts

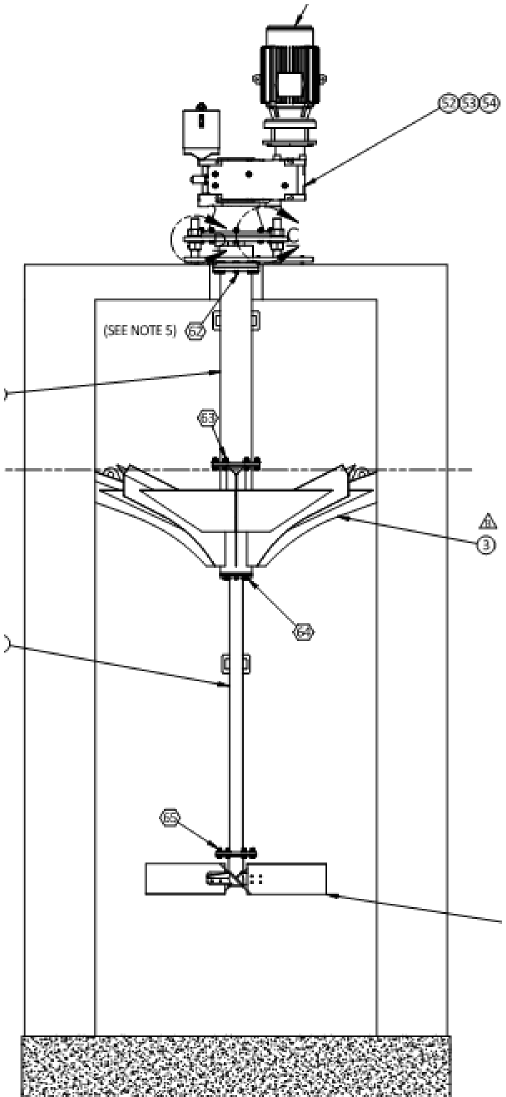
ALTERNATIVES ANALYSIS

- **#1 Fine Bubble**
  - Pros:
    - Lower operating costs (3%)
    - Higher O_2 transfer efficiency
  - Cons
    - May overaerate if:
      - Diffuser turndown, or
      - Minimum air required for mixing

      are greater than minimum process requirements
    - New blower building required
    - Baffles in each basin required to prevent flow short-circuiting
    - Protect offline diffusers from ice and sunlight

- **#2 Surface Aerators**
  - Pros:
    - Lower capital costs (33%)
    - Ability to decrease speeds during minimum process air demands and use lower impeller to mix
    - Vigorous agitation prevents short-circuiting
    - Replacement in kind
  - Cons
    - Less energy efficient
    - Lower O_2 transfer efficiency

RECOMMENDED ALTERNATIVE



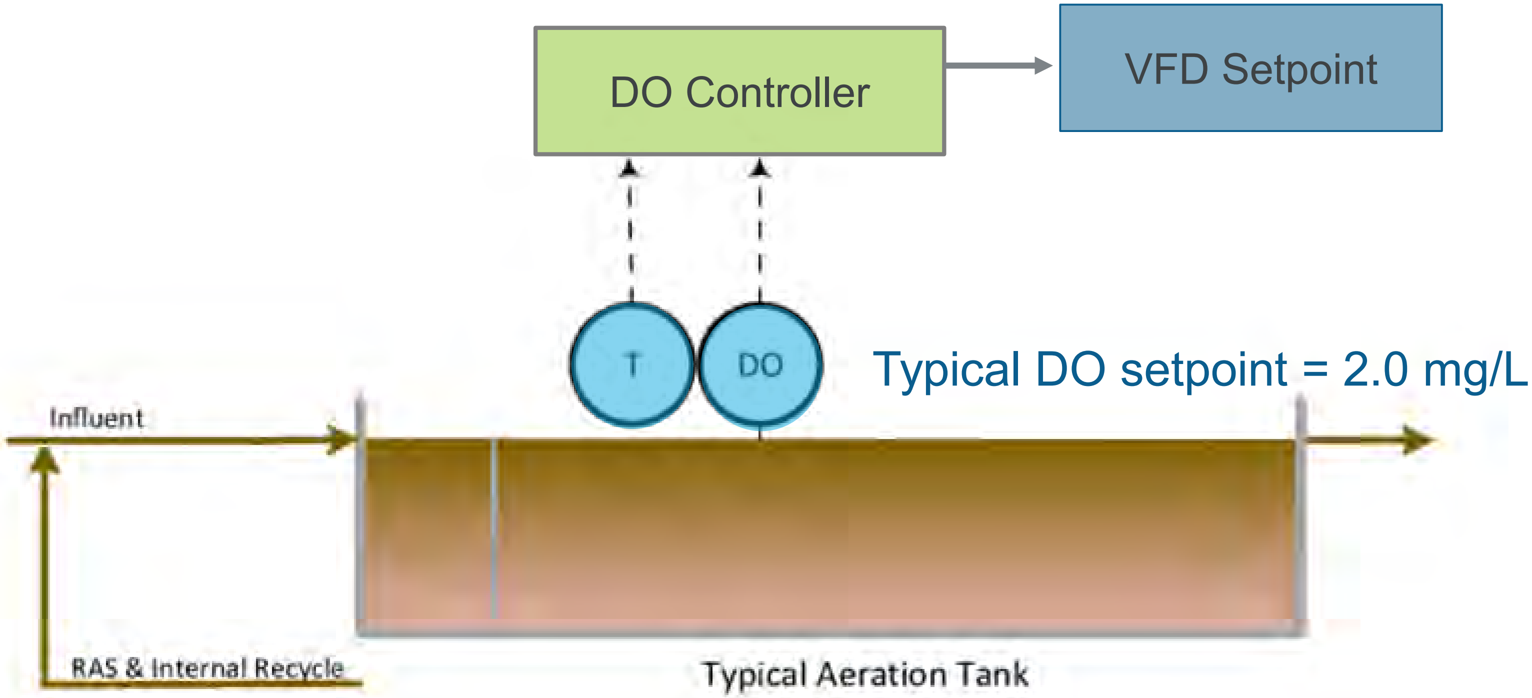
Sketch courtesy of Ovivo

- **#2 Surface Aerators**
  - Pros:
    - Lower capital costs (33%)
    - Ability to decrease speeds during minimum process air demands and use lower impeller to mix
    - Vigorous agitation prevents short-circuiting
    - Replacement in kind
  - Cons
    - Less energy efficient
    - Lower O_2 transfer efficiency

DESIGN PHASE – CONTROLS EVALUATION

- **Existing Controls**
  - Two-speed aerators
  - Speed controlled based on dissolved oxygen levels in each basin
  - Mostly operate at low speed (90% of the time)
  - Low speed maintains DO at 2.5 to 4.5 mg/L
- **Upgrade Alternatives**
  - #1: DO based aeration control with turndown
  - #2: Ammonia based aeration control
- **Evaluation**
  - Detailed capital and annual costs evaluation, per DEEP sole-source request
  - Energy efficiency
  - Process impacts

#1: DO BASED CONTROL



Inputs

Controller

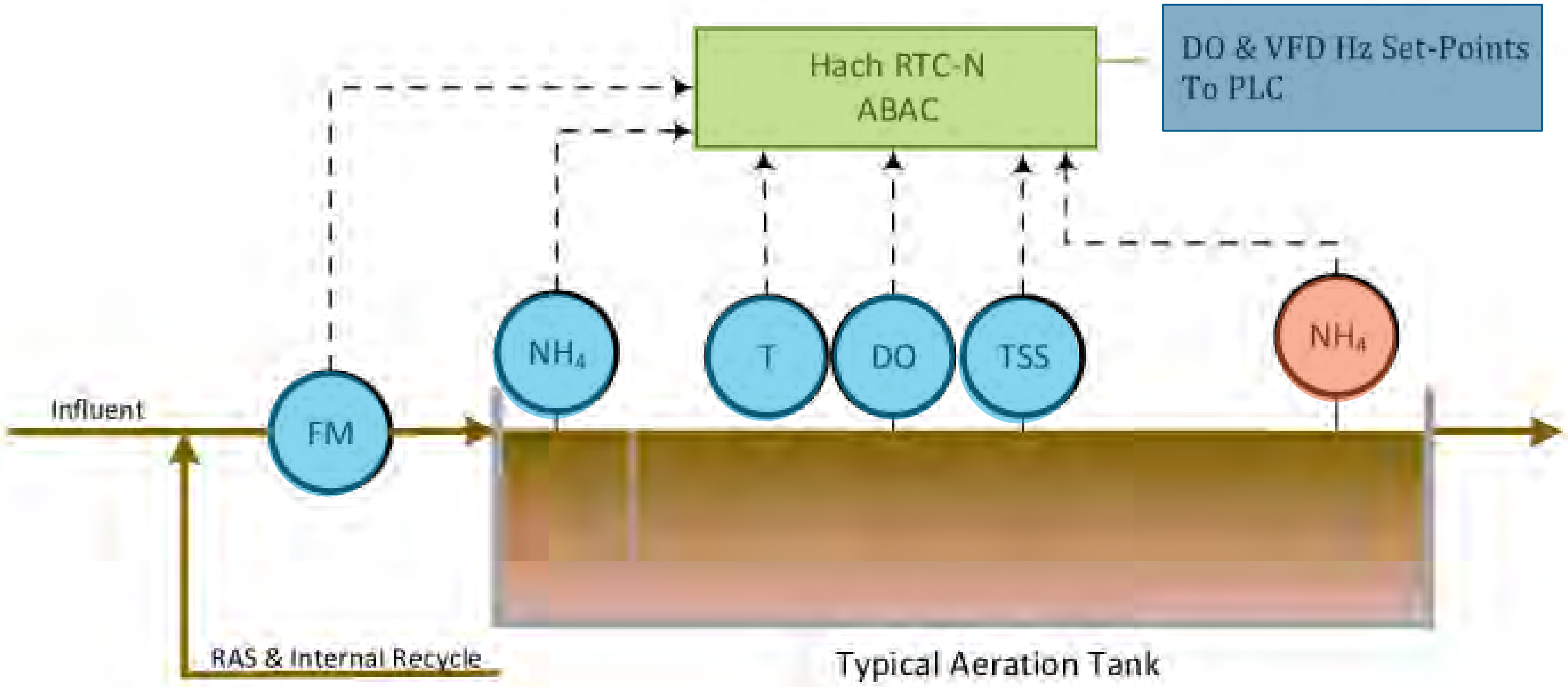
Output

#1: DO BASED CONTROL

- **Pros**
  - VFDs allow tighter control of aerator speeds
  - Maintain DO close to setpoint
  - May decrease over-aerating
  - Results in energy savings
  - Typical control strategy

- **Cons**
  - Slow to respond to changing BOD and ammonia loads
  - Potential to under-aerate or over-aerate during lag
  - High DO can impact denitrification and increase methanol usage

#2: AMMONIA BASED CONTROL



Typical DO setpoint = 0.2 mg/L

Inputs

Biological Model (ASM1)

Output

Feedback

Sketch courtesy of Hach

#2: AMMONIA BASED CONTROL

- **Pros**
  - Provide minimum oxygen required for full nitrification by monitoring ammonia
  - Average DO residual of 0.2 mg/L
  - Faster response to changes in loads with feed-forward loop
  - Tighter DO control leading to less DO in denitrification process, decrease methanol
  - Reduce energy by matching oxygen supply to the oxygen demand in real time

- **Cons**
  - Requires additional instrumentation and maintenance for ammonia and TSS sensors
  - Requires complex programming or proprietary package
  - Complex control strategy

ECONOMIC EVALUATION OF CONTROLS

- **Capital Costs ($ Thousands)**

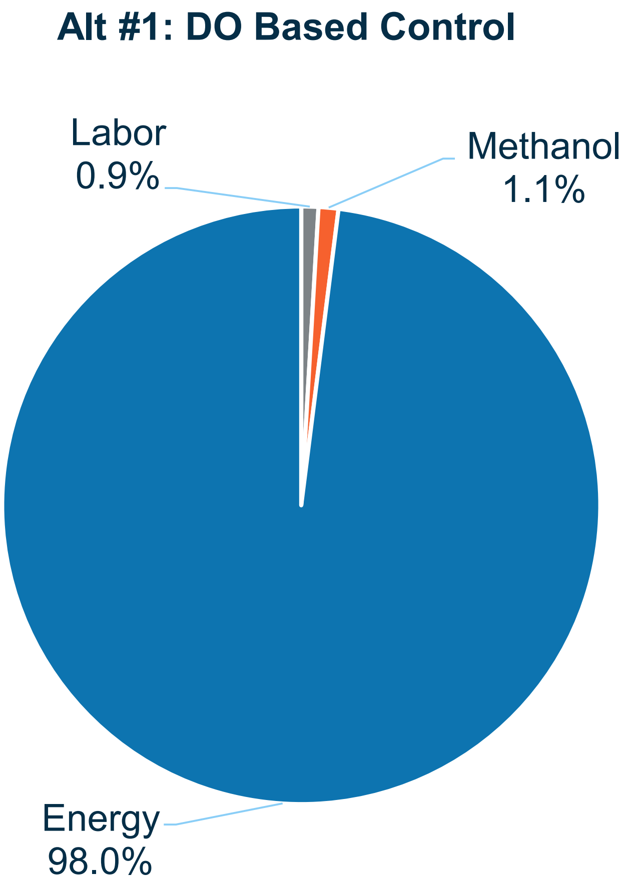
Items	Alternative #1 DO Based Control	Alternative #2 Ammonia Based Control
Instrumentation and Mounting Hardware *	4 DO Probes	4 DO Probes 2 Ammonia Probes 1 TSS Probe
Controllers *	2 total	5 total, plus proprietary real time control module
SCADA System Integration	$	$$
Electrical	$	$$
Overall	$440	$570

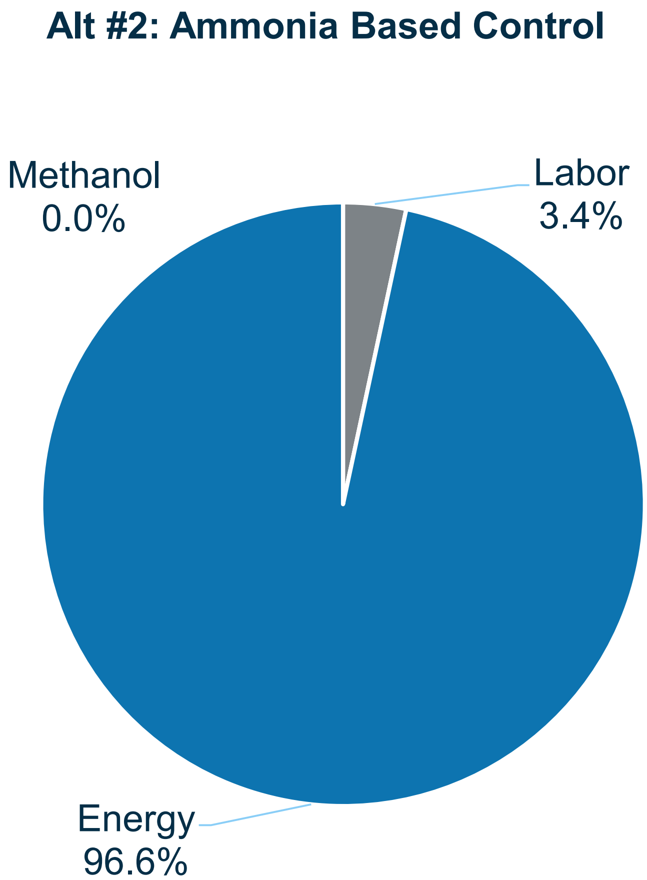
** Mounting hardware and Controllers for two trains, Probes for online train only*

Tighe&Bond

ECONOMIC EVALUATION OF CONTROLS

- **Annual Costs (as percentages)**





ECONOMIC EVALUATION OF CONTROLS

- **Operating Costs – Energy Assumptions**
  - Included motor and VFD part-load efficiencies
  - Actual oxygen requirements based on BOD and TKN
  - Energy to maintain DO residual of
    - 2.0 mg/L (Alt #1) vs. 0.2 mg/L (Alt #2),
    - Based on oxygen transfer rate for new aerators
  - Continuous operation and varying loads & speeds

ECONOMIC EVALUATION OF CONTROLS

- **Operating Costs – Labor Assumptions**
  - Staff time for routine and preventative maintenance of probes

  - Spare parts and equipment replacement costs

- **Operating Savings – Methanol Use**
  - Comparison of methanol usage to counteract presence of residual oxygen levels:
    - DO of 2.0 mg/L for Alt #1: DO Based Control
    - DO of 0.2 mg/L for Alt #2: Ammonia Based Control

  - Evaluate turndown capability of existing methanol feed pumps

ECONOMIC EVALUATION OF CONTROLS

- **Annual Costs ($ Thousands)**

Items	Alternative #1 DO Based Control	Alternative #2 Ammonia Based Control
Energy	$131	$110
Labor	$1.2	$3.9
Methanol	$1.4	$0
Overall	$133.6	$113.9

ECONOMIC EVALUATION OF CONTROLS

- **Life Cycle Costs ($ Thousands)**

	Alternative #1 DO Based Control	Alternative #2 Ammonia Based Control
Capital Costs	$440	$570
Annual Operating Costs	$133.6	$113.9
Present Worth Total (20-year life cycle) *	$2,470	**$2,110**

** Including major equipment replacement costs over 20 years*

SELECTION OF AMMONIA BASED CONTROLS - A CLOSER LOOK:

- **Favorable Economics**
  - Lower operating costs, lower life cycle costs despite higher capital
  - Clean Water Funding for Nitrogen Removal
  - Energy Utility Rebates for Energy Efficiency
- **Process Optimization**
  - Tighter control of DO and aerator speeds
  - Less over-aerating and less DO in denitrification process
  - Real time monitoring and control
- **Operational Considerations**
  - Increased complexity and more instruments
  - Operators conducted extensive ammonia probe trial
  - Interest in process improvements and energy savings

ACKNOWLEDGMENTS

Tighe & Bond

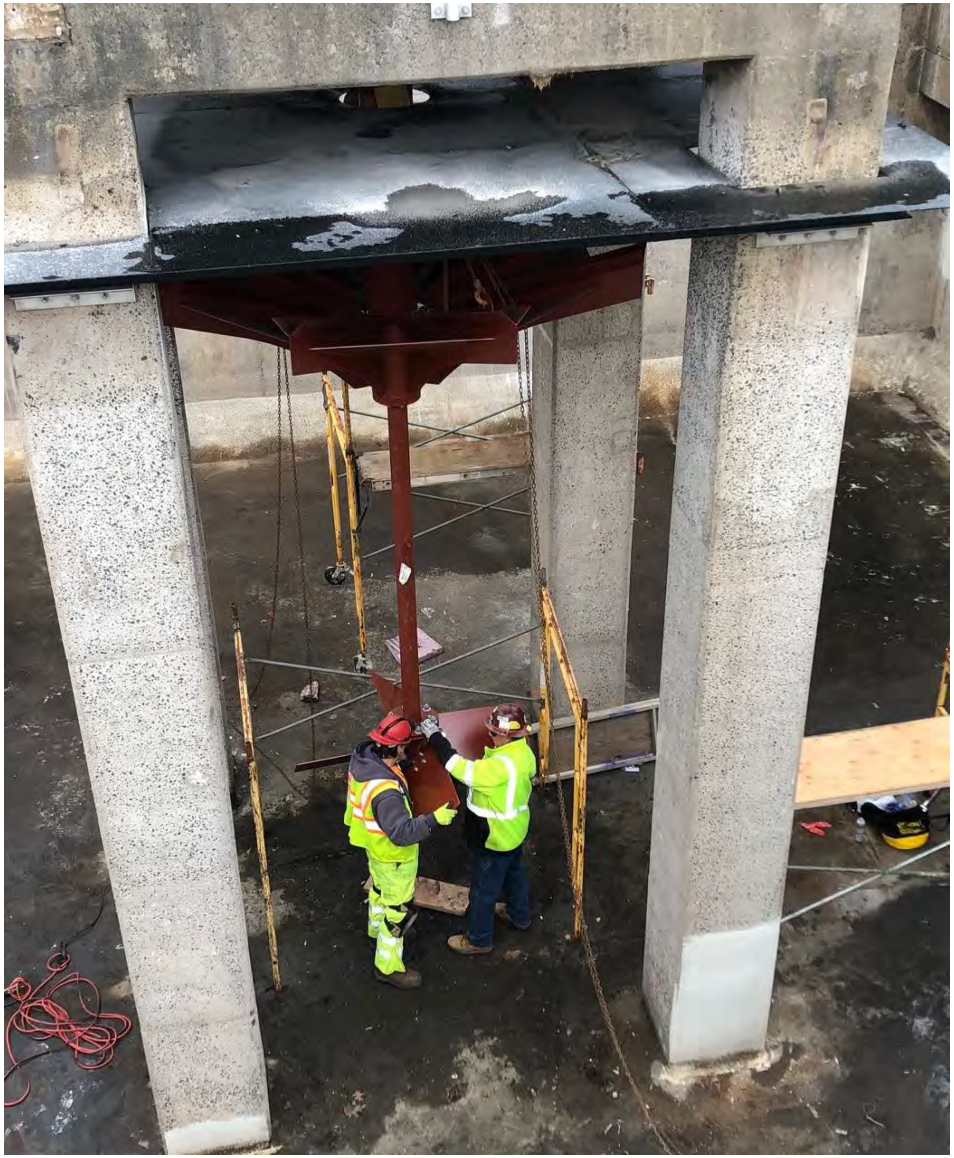
Steve Seigal
Chris Bone
Fred Mueller
Amy Sowitcky

Southington Town & WPCF

Keith Hayden
James Grappone
Kiari Williams
Keith Langston
Steve Gregory

CT DEEP

Steve Muollo



QUESTIONS?

Cynthia M. Castellon, PE
cmcastellon@tighebond.com