# Piloting a Pre-Anoxic Fixed Film Process for Nitrogen Removal at the Poquonock WPCF

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# Background

– The Metropolitan District ("MDC")

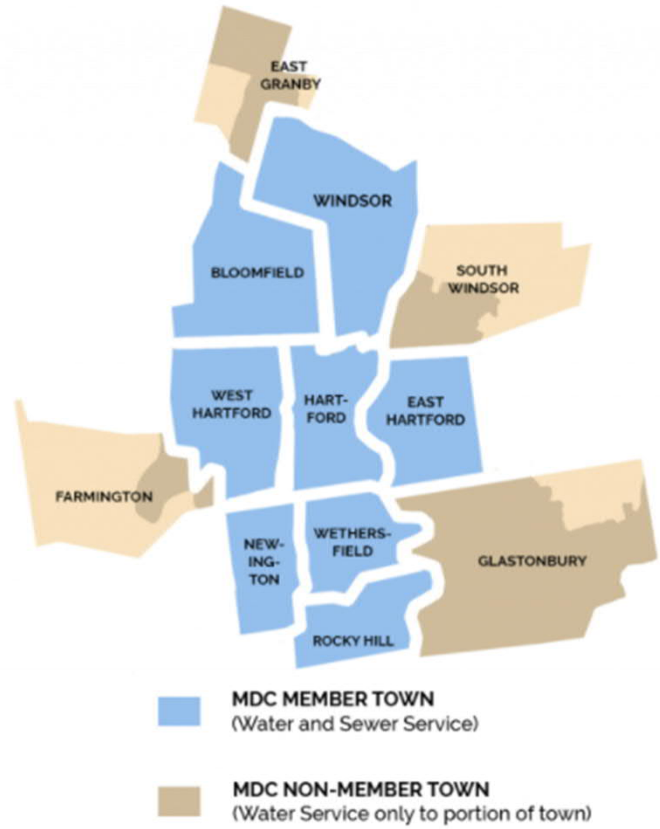
- Non-profit municipal corporation established in 1929
- Provides water and wastewater services to eight communities in greater Hartford, CT region, with partial water service to four others.
- Owns and operates four water pollution control facilities ("WPCFs")

  o Hartford WPCF

  o East Hartford WPCF

  o Rocky Hill WPCF

  o Poquonock WPCF (PWPCF)



# Background

– Poquonock WPCF, Windsor, CT
  - Originally constructed 1962, upgrades in 1979 and 1990
  - Rated for 5 mgd, but averages 2 to 2.5 mgd
  - Process configuration
    - o Headworks w/grit screening
    - o Primary sedimentation
    - o Trickling filters
    - o Secondary sedimentation
    - o Disinfection w/sodium hypochlorite
    - o TF slough to primaries, then to digestion
  - No provisions for total nitrogen (TN) treatment
    - o Subject to CT General Permit for Nitrogen
      - – Assigns goals for annual mass loading limit w/equivalency factor
      - – Plants that discharge less load sell credits; plants that discharge more buy them.
    - o Goal for TN discharge is 98 lbs/d (4.7 mg/l TN @ 2.5 mgd)
    - o Actual discharges higher…..requires buying credits

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# Project Development

- Concept Design and Facility Plan (2014 – AECOM)
  - Evaluated a variety of options for PWPCF liquid train
    - Abandonment of PWPCF, bring flow to Hartford
    - Upgrade of Trickling Filters for BOD only treatment
    - Upgrade of plant to Activated Sludge for TN treatment
    - Upgrade of Trickling Filters, additional fixed film (MBBR) process for partial TN treatment

- Trickling Filter Upgrades Report (2018 – AECOM)
  - Extend useful life of existing plant
    - Address deficiencies
    - Review MBBR option for partial TN treatment.
    - What could be accomplished with simplicity and cost containment being design objectives?
    - Report Conclusions
      - Upgrade of North and South Trickling Filters with new cross-flow plastic media
      - Addition of new pre-anoxic MBBR for partial TN treatment
        - Piloting recommended
      - Add fine screen and washer/compactor
      - Address hydraulic deficiencies

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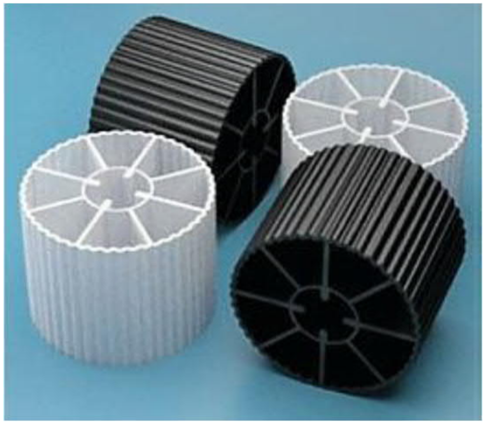
# Background – Overview of MBBR Technology

– Moving Bed Bio-Reactor ("MBBR")
- Developed in Scandinavia.
- Designed to provide cold weather robustness without diffusion limitations of other fixed film processes.
- Media typically comprised of small polyethylene carriers.
  - o Media typically 10 to 25 mm in diameter
  - o Biofilm attaches to media.
  - o Media is suspended and mixed throughout water column.
    - – Provide surface renewal at interface between film and bulk water column.
    - – Reduced substrate diffusion limitations.
- Can be employed in aerobic or anoxic applications.
- When employed with return activated sludge, considered IFAS (Integrated Fixed-film Activated Sludge).



**Typical MBBR Media**

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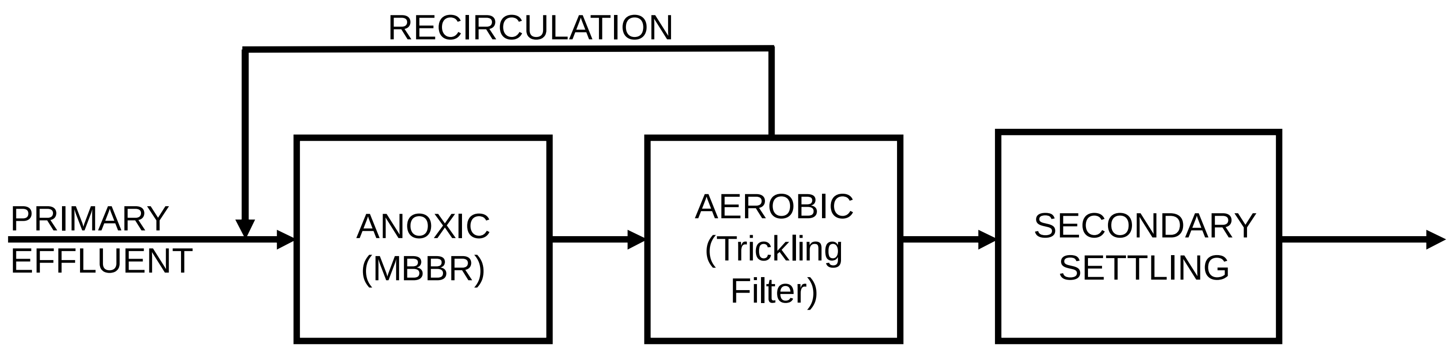
# Background – Application at PWPCF

- To maintain adequate flow to trickling filters, plant typically recycles trickling filter flow back to primary effluent wet well.
  - Current recycle flow is approximately 0.6 mgd, but can be set higher
  - Recycle flow rich in $NO_3$-N.
  - If mixed with a carbon source in right environment, there's an opportunity to denitrify.
- A pre-anoxic process upstream of trickling filters could mimic widely applied MLE process.
  - Keep it fixed film, to minimize solids loading on tricking filters
- Since nitrogen removal is a goal and not a permit requirement, determine optimum size of TN process to get the most nitrogen removal for money spent.



# Development of Pilot

- Why Pilot?
  - MBBR is a well-established technology, however not as widely applied in North America
  - Poquonock WPCF is a somewhat unique application
    - o Upstream of Trickling Filters (TF)
    - o Inherent issues with elevated DO in recycle
    - o Confirm typically applied design parameters
      - Surface area loading rate/HRT
    - o Desire to assess impact of recycle ratio
    - o Define full scale implication of process
- Pilot Unit Selected
  - 600-gallon nominal volume
  - Operating Depth of 4 feet
  - Media fill of 40%
  - Nominal feed rate of 8 gpm
  - Feed from primary effluent wetwell
    - o Contains both primary effluent (carbon source) and recycle from TF (nitrate rich).
  - Target recycle changed from TF feed of 2.5 mgd to nominally 3.25 mgd
- Pilot Run from mid-August to late-November 2019

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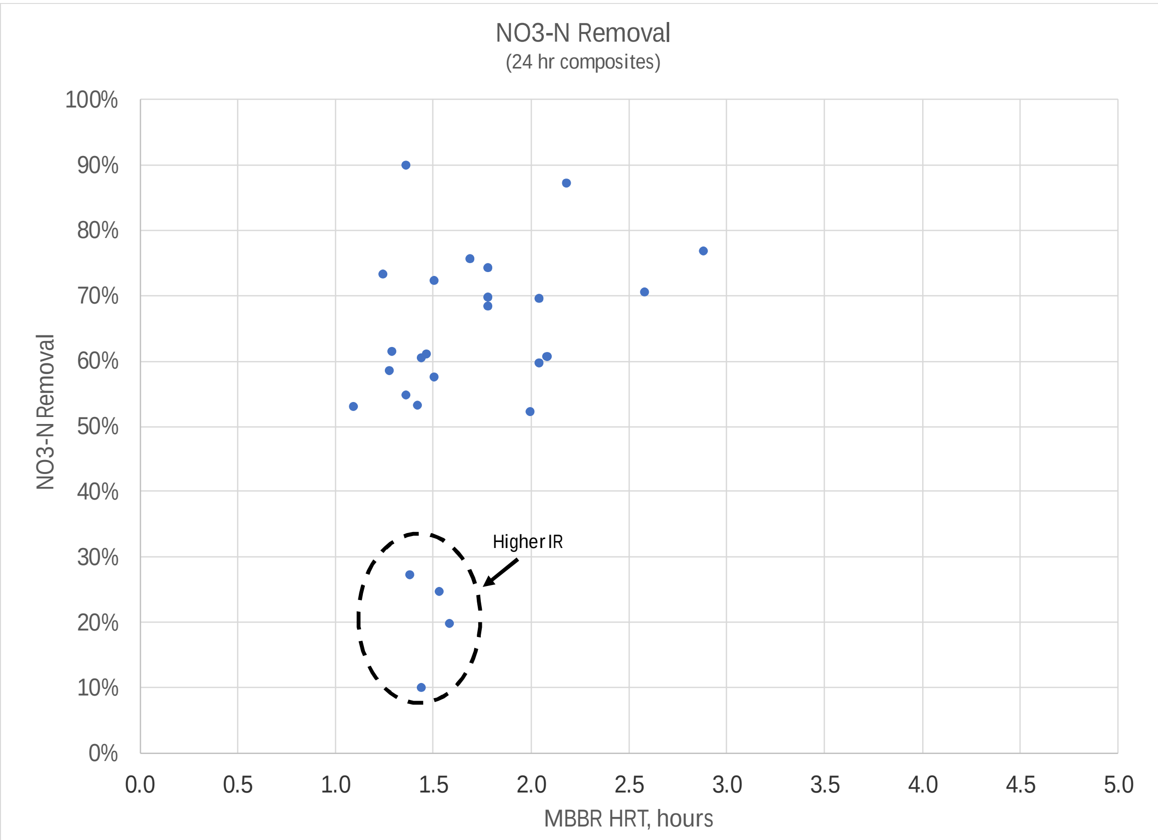
# Pilot Results – Process Performance

– Impact of HRT/Feed Flow




- Observations
  - Difficulties in control resulted in many different variables changing at once.
    - o Feed pump flow
    - o Influent flow
    - o Recycle $NO_3$ concentration
  - Excepting period of high IR, no real impact of HRT on $NO_3$ removal rates over range studied.
  - $NO_3$ removals averaged approximately 65%.
    - o Note this is % removal across MBBR, not total.

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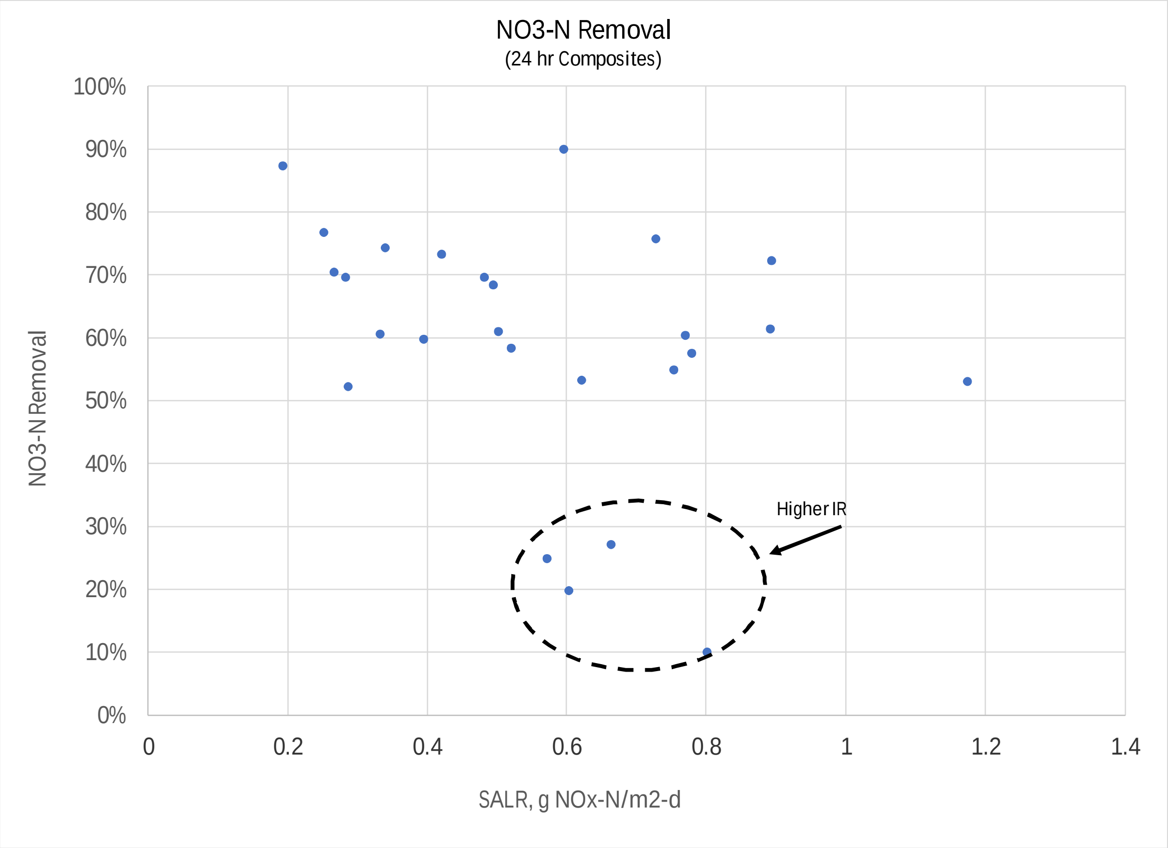
# Pilot Results – Process Performance

– Impact of Surface Area Loading Rate (“SALR”)




– Observations

- Similarly, no real affect from SALR changes.
- Typical design range 0.8 to 1.0 g NOx-N/m2-d

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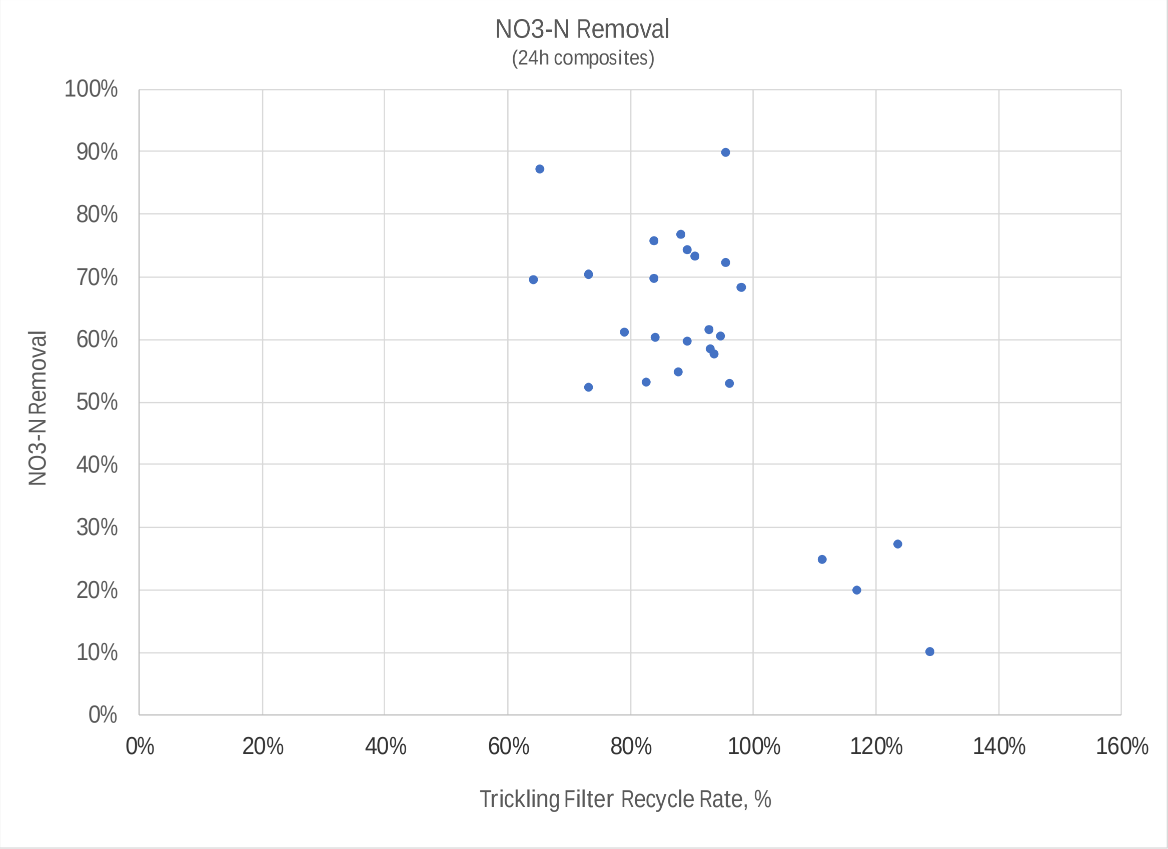
# Pilot Results – Process Performance

– Impact of Recycle Rate




## – Observations

- Recycle rate, which impacts surface area loading rate, not a real issue until over 100%.
- Sharp drop off above 100%.
- Possible explanations
  - o Threshold of available primary effluent carbon being exceeded
  - o Environmental conditions with reactor
    - – DO/ORP

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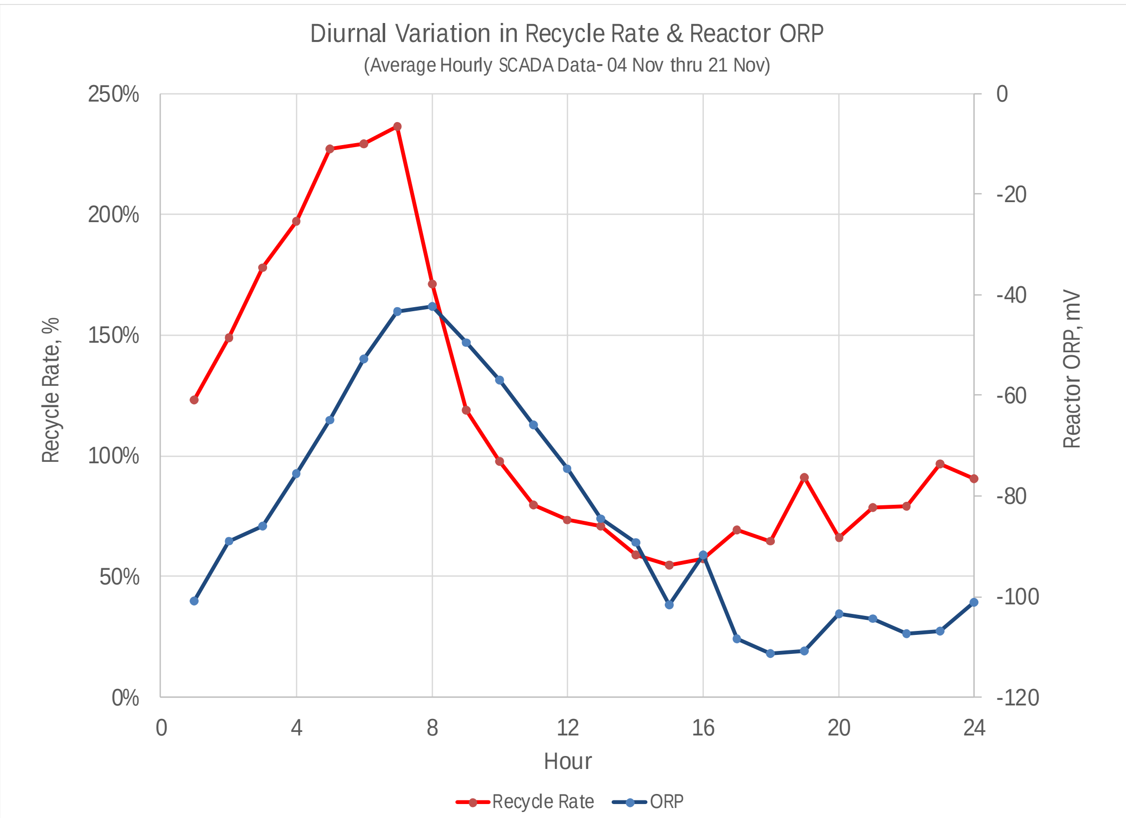
# Pilot Results – Process Performance

– Diurnal Variation in Recycle Rate & Reactor ORP




– Spot observations of hourly SCADA data suggested diurnal ORP variation

- Graph of averages shows strong correlation between recycle rate and ORP
- Increasing recycle rate from midnight to daylight hours due to low influent flow
  - o Constant TF feed
  - o Lower primary effluent (PEFF) flow compensated for by higher TF recycle
- Some lag in ORP response, reactor HRT

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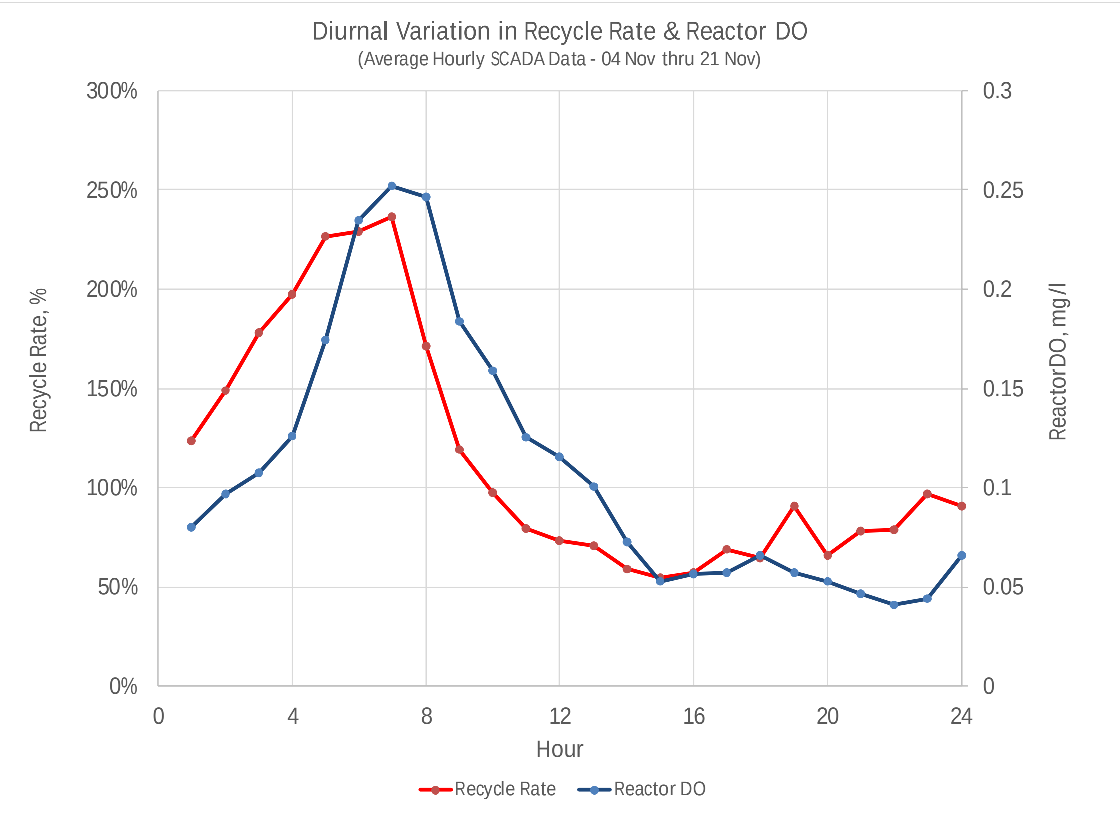
# Pilot Results – Process Performance

– Diurnal Variation in Recycle Rate & Reactor DO




– DO trends harder to spot "by eye" but graph of averages shows similar pattern

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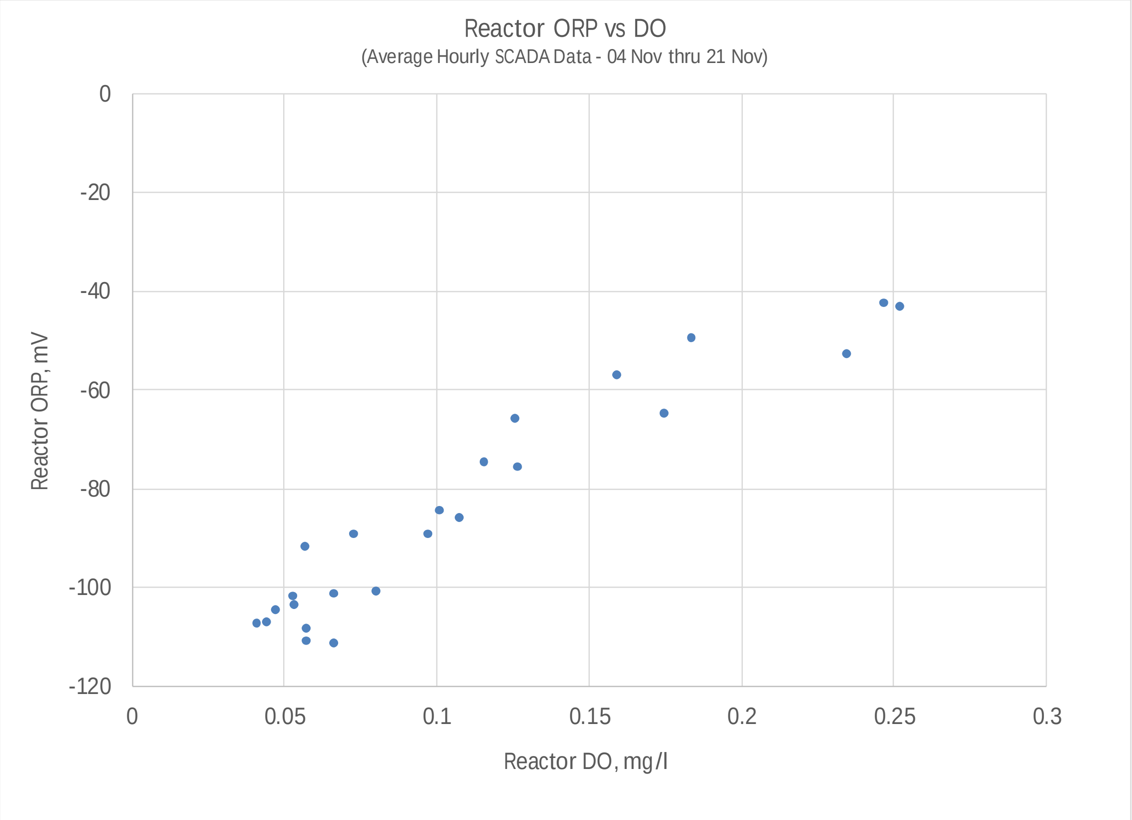
# Pilot Results – Process Performance

– Direct Comparison of DO and ORP



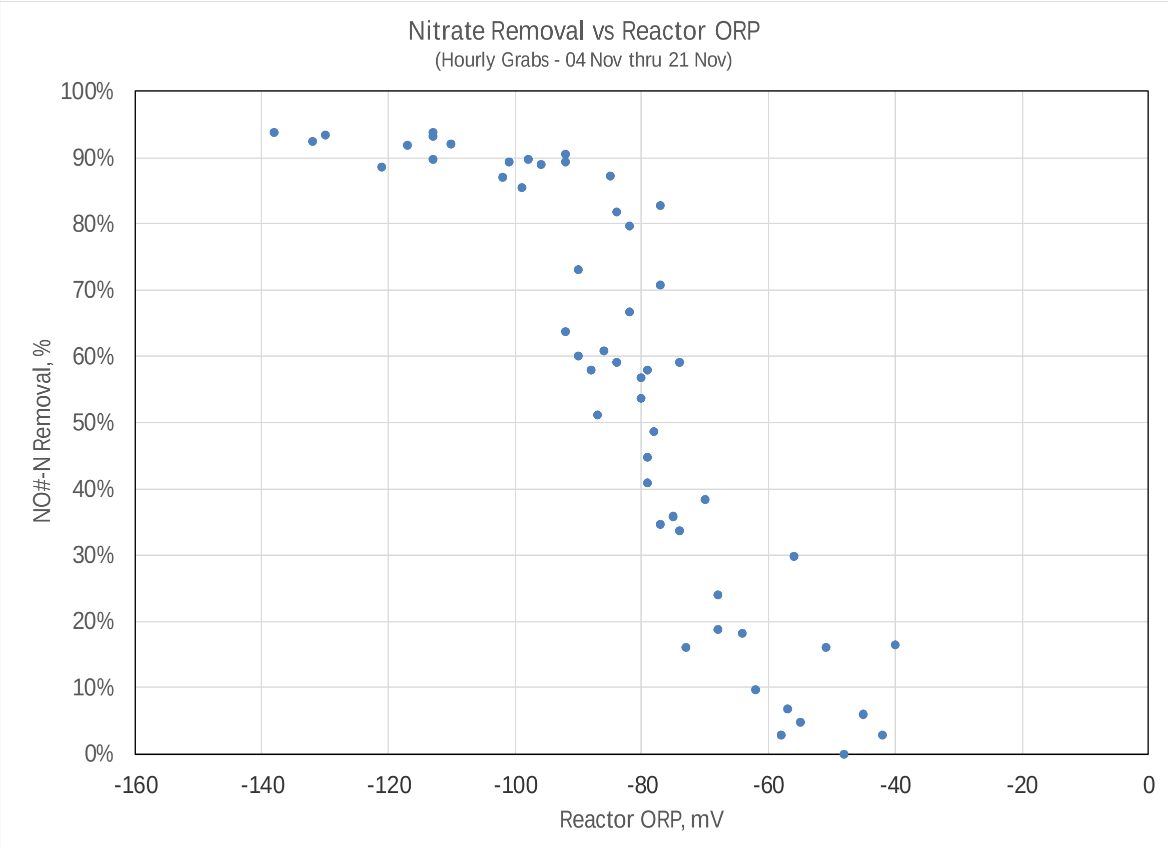

– Direct comparison of DO and ORP illustrates strong correlation

– Elevated DO = Elevated ORP

– To be expected, but ORP changes much easier to observe

# Pilot Results – Process Performance

– Nitrate Removal and ORP




– Strong correlation between ORP and $NO_3$-N removal

– Conclusions

- Degradation of $NO_3$-N removal is caused by ORP elevation
- ORP elevation caused by excessive reactor DO
- Excessive reactor DO caused by high recycle rates
- Nothing we didn't know, but…
  - o Impact much sharper than anticipated
  - o Has implications for suspended growth as well as fixed film processes

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# Summary of Pilot Conditions & Results

– Daily average conditions and results

| Parameter | Daily Averages | Comments |
|---|---|---|
| Reactor HRT, hrs | 1 to 3 | No real impact on NO3 removal observed. |
| Media SALR, g NOx/m2-d | 0.2 to 0.9 | Marginal improvement at lower SALRs, but not enough to justify large impact on capital cost. |
| Recycle Rate, % | 65 to 130 | Sharp drop off in removal over 100 % recycle |
| Average MBBR NO3-N Removal, % | 65 | Data at elevated recycle rates excluded. |

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# Preliminary MBBR Design Criteria & Sizing

– Design Criteria

| | |
|---|---|
| • Annual Average Influent Flow: | 2.3 mgd |
| • Trickling Filter Recycle Rate: | 100% |
| • Peak MBBR Flow: | 7.5 mgd |
| • Combined Primary Effluent/Recycle NOx-N: | 6.4 mg/l |
| • Minimum Month Operating Temperature: | 10 degrees C |
| • Design Surface Area Loading Rate: | 0.8 g NOx-N/m2-d |
| • Design HRT at Average Flow: | 1.5 hours |

– Design Summary

| | |
|---|---|
| • Quantity of Tanks: | 2 |
| • Tank Dimensions | |
| o Length | 30 ft |
| o Width | 30 ft |
| o SWD | 21 ft |
| • Tank Volume | |
| o Each | 142,000 gals |
| o Total | 284,000 gals |
| • Media Fill | 26% |

<u>Ancillary MBBR Equipment</u>

– Twenty (10/tank) media sieves
– Two (1/tank) drain sieves
– Two (1/tank) sparge manifolds
– Two (1 duty/1 assist) 5HP blowers
– Two (1/tank) 20 HP mixers
– DO/ORP Probes
– Level instrumentation
– Control panels
– 280 m3 of MBBR media

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# MBBR Process Control Considerations - Full Scale

– Improve nitrification rate in trickling filters
  - TF media replacement in both tanks with higher density media
  - Reduced carbon loading to trickling filters
  - Improved capacity with hydraulic improvements

– Flow Control/Bypass Provisions

– Overflow Protection/Media Retention
  - Overflow provisions and ability to return to Primary Effluent wet well
  - Level instrumentation and alarm (2 levels)
  - Redirect flow to TF only upon HWL

– Look for opportunities to reduce DO carry-over to MBBR

– Improve recycle control
  - Implement ORP control on recycle

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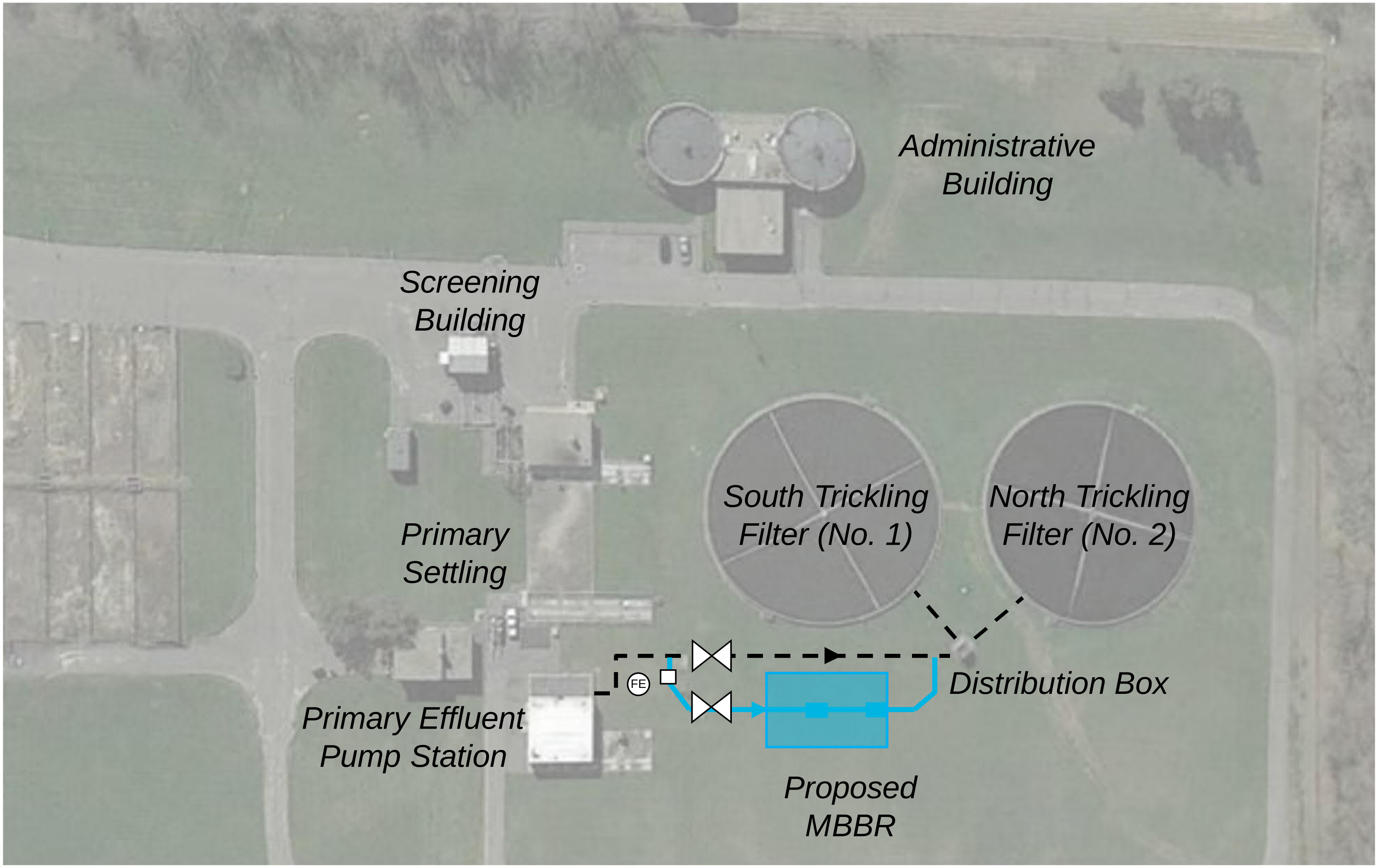
# Other Project Needs

- Fine Screening
  - Provide 6 mm screens and washer/compactors to replace current screen
- Trickling Filters
  - Replace media in both trickling filters
  - Correct hydraulic problems in the south Trickling Filter by increasing influent pipe size to 20-inch diameter
  - Replace south Trickling Filter rotary distributor
- Convert solids handling from anaerobic digestion to storage and removal
- Electrical improvements


Administrative
Building
Screening
Building
South Trickling
Filter (No. 1)
North Trickling
Filter (No. 2)
Primary
Settling
FE
Distribution Box
Primary Effluent
Pump Station
Proposed
MBBR



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