Utilization of Dynamic Modeling to Evaluate and Design Secondary Clarifiers for the Muddy Creek WWTP

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Presented by Joe Rohrbacher, PE
Agenda

- Project Background
- Dynamic Modeling Approach
- Secondary Clarifier Modeling Results
- Project Summary
City/County Utilities Commission (CCUC) Muddy Creek WWTP

- 21 mgd rated capacity
  - Current average flows ~ 15 mgd

- Monthly/weekly limits with seasonal ammonia limit
  - BOD – 25/40 mg/L
  - TSS – 30/45 mg/L
  - NH3-N – 14/35 mg/L
    April-October
Muddy Creek WWTP Unit Process Summary

Four Rectangular Primary Clarifiers
- 7,000 sf each
- 750 gpd/sf at 21 mgd

Three Aeration Basins
- Provided with RAS step feed capability
- Fully aerated for nitrification
- No current nutrient removal processes

Four Secondary Clarifiers
- 110’ Diameter
- 550 gpd/sf at 21 mgd
- Inset launders
Existing Secondary Clarifiers
Occasional High ESS is Observed during Peak Flow Events
Variable Settleability Impacts Performance
Secondary Clarifier Improvements Project

Objectives

- Evaluate upgrades to existing secondary clarifiers
  - Increase center well sizing

- Evaluate need to construct a fifth secondary clarifier
  - 110-ft diameter to match existing
  - Larger secondary clarifier to improve performance

- Evaluate future secondary process requirements
  - Future 30 mgd capacity
  - Potential nutrient limits in the Yadkin River basin
    - Total nitrogen (TN)
    - Total phosphorus (TP)
Dynamic Modeling Approach
Whole Plant Simulator Models such as BioWin use Idealized 1-Dimensional Clarifier Models

- Idealized solids flux (ex. state point analysis)
- Does not account for hydrodynamics, flocculation, environmental impacts
2-Dimensional Clarifier Models Address many of these Limitations

- Utilizes Computational Fluid Dynamics
- Models:
  - Hydrodynamics
  - Flocculation
  - Turbulence
  - Temperature
- Limitations
  - Wind
  - Complex inlets
  - Cannot model biological reactions
- Simulates mechanical/structural features
  - Center wells, baffles, launder position, inlets
Calibrated Biological Process and Clarifier CFD Models were Developed

- BioWin process model and Clarifier 2DC CFD models were linked through iterative dynamic simulation
  - Predict plant performance (solids production, MLSS, and effluent quality) at current and design conditions
  - Assess SC performance at design and peak wet weather flows
  - Assess potential for implementing BNR to meet future TN and TP limits
Intensive Site-Specific Sampling was Performed for Model Calibration

- Plant historical influent and operational data analysis

- Site specific sampling by CCUC/H&S to supplement data for process model calibration
  - Influent wastewater speciation
  - Carbon / nitrogen / phosphorus profiles through treatment process
  - Recycle stream impacts
Column Testing was Performed to Understand Sludge Settleability Characteristics

\[ V_s (\text{ft/h}) = 31.0 \times e^{-0.523x} \text{ (g/L)} \]

\[ R^2 = 0.9799 \]
Clarifier Stress Testing was Performed to Determine Performance under Variable Loading

![Graph showing stress testing period with 3, 2, and 1 SCs]
Clariﬁer CFD Model Calibration

[Graph showing sludge blanket depth vs. time for Day 2 June 7th, 2011. The graph includes the following data points:
- Blanket - SC No. 1
- Blanket - SC No. 2
- Blanket - SC No. 3
- Blanket - SC No. 4
- Blanket + Dispersed Zone - SC No. 2
- Blanket + Dispersed Zone - SC No. 4
- Model Blanket
- Model Blanket + Dispersed]
A Design Storm Hydrograph was Developed for Wet Weather Modeling

Muddy Creek WWTP Design Storm Hydrograph

- Longest duration storm event based on several years of data
- Peak flow of ~56 mgd coincided with a 30-day rolling average flow of 21.4 mgd
- Representative of sustained peak flow at rated capacity
Secondary Clarifier Modeling Results
Secondary Clarifier Performance was Evaluated for Maximum Month Conditions

- Full year-round nitrification
  - Initial MLSS = 2,300 mg/L
  - Average SVI = 117 mL/g
  - 75th percentile SVI = 138 mL/g
  - 90th percentile SVI – 183 mL/g

- Biological Nutrient Removal
  - Initial MLSS = 3,200 mg/L
  - Average SVI = 117 mL/g
  - 75th percentile SVI = 138 mL/g
  - 90th percentile SVI – 150 mL/g

- The impacts of wet weather step feed operation were also evaluated
4 vs. 5 Clarifier Operation with Step Feed
MLSS = 2,300 mg/L, SVI = 180

4 clarifiers in operation
TSS > 100 mg/L, clarifier failure

5 clarifiers in operation
TSS < 20mg/L, clarifier performance excellent
Predicted Effluent TSS at MLSS = 2,300 mg/L

SVI = 138 mL/g

TSS < 20 mg/L with step feed or 5th clarifier

SVI = 183 mL/g

Failure with 4 clarifiers in service regardless of step feed

Five clarifiers required
# Summary of Secondary Clarifier Modeling Results at 2,300 mg/L MLSS

<table>
<thead>
<tr>
<th>SVI</th>
<th>No. of SCs</th>
<th>Step Feed Used?</th>
<th>Average Effluent TSS</th>
<th>Maximum Effluent TSS</th>
<th>Sludge Blanket Depth?</th>
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<tr>
<td>180</td>
<td>4</td>
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<td>High/Failure</td>
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<td>&lt; 20</td>
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## Summary of Secondary Clarifier Modeling Results at 3,200 mg/L MLSS (BNR)

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<td>4 / 110-ft</td>
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<td>&gt; 50</td>
<td>&gt; 100</td>
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<td>5 / 110-ft</td>
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<td>High</td>
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<td>138</td>
<td>5 / 110-ft</td>
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<td>High/Failure</td>
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<td></td>
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<td>&gt; 50</td>
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<td>High/Failure</td>
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<tr>
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<td>2/125-ft</td>
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Secondary Clarifier Modeling Conclusions

- Current permit limits – MLSS limited to 2,300 mg/L
  - One new 110-ft diameter clarifier required to treat peak flows under poor settling conditions

- Future potential BNR limits – MLSS increase
  - Risk of failure under 75th percentile settling conditions with five 110-ft secondary clarifiers
  - Two new 125-ft secondary clarifiers may be required under future BNR scenario

- Construction of one new 125-ft secondary clarifier was recommended
  - Plan for second 125-ft clarifier if BNR is implemented in the future
Dynamic Modeling was used to Optimize Fifth Secondary Clarifier Design

Relationship between effluent TSS and clarifier depth
- Existing clarifiers 14-ft SWD
- New clarifier 17-ft SWD

Relationship between effluent TSS and effluent launder distance to end wall for inset launders
- Minimum distance of 4-feet required
- Diminishing improvement beyond 10-feet
- Inset launders not designed for 5th clarifier
Dynamic Modeling was used to Optimize Fifth Secondary Clarifier Design

Relationship between effluent TSS and center well diameter
- Existing clarifiers 14%
- New clarifier 25%

Relationship between effluent TSS and center well submergence
- Existing clarifiers 34.5%
- New clarifier 45%
Project Summary
The Secondary Clarifier Improvements are Currently Under Construction

- The fifth clarifier has been placed in service
- Existing clarifiers are being refurbished and mechanisms are being replaced
- RAS pumping improvements
- MLSS distribution improvements
Dynamic Modeling is a Powerful Tool in Optimizing Secondary Process Designs

- Dynamic modeling can simulate multiple operational and design scenarios
  - Results in optimized designs

- Integrating CFD and process models can introduce better confidence in simulated performance
  - Significant optimization/cost savings achievable

- Dynamic modeling can be used to justify deferment of improvements and allow capacity rerates

- There is a need in the WW industry for single-package integration of CFD with whole plant process models
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Questions?

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