Process Considerations for Changing Times:
Process optimization and doing more with less

Ron Latimer, PE
Hazen
Process Optimization Approach

Extensive field work to thoroughly investigate and understand plants and operations issues

Calibrate whole plant process model
Whole Plant Process Simulators

Whole Plant Simulations – BioWin, GPS-X

Steady State and Dynamic Modeling

Powerful tool with PROPER CALIBRATION and APPLICATION
Mason Farm WWTP, OWASA North Carolina

<table>
<thead>
<tr>
<th></th>
<th>Nov 2008 – May 2010</th>
<th>June 2010 – Oct 2012</th>
<th>% Reduced</th>
<th>Cost ($/gallon)</th>
<th>Annual Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>48% Alum (gpd)</td>
<td>915</td>
<td>671</td>
<td>27%</td>
<td>$0.66</td>
<td>$59,000</td>
</tr>
<tr>
<td>25% Sodium Hydroxide (gpd)</td>
<td>1,360</td>
<td>535</td>
<td>61%</td>
<td>$0.74</td>
<td>$223,000</td>
</tr>
<tr>
<td>20% Acetic Acid (gpd)</td>
<td>622</td>
<td>438</td>
<td>30%</td>
<td>$1.08</td>
<td>$73,000</td>
</tr>
<tr>
<td>Total Annual Savings</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>$355,000</td>
</tr>
</tbody>
</table>

Effluent TN Concentration (mg/L)

[Graph showing effluent TN concentration over time]
Challenge: Increase Plant Capacity by 25% with No New Basins and Meet TN of 5.6 mg/L

Existing 20 mgd secondary treatment facility

Project Goals:

- Plant rerate to 25 mgd AADF
- Effluent total nitrogen (TN) goal = 5.6 mg/L
  
  TMDL based

- NO NEW BASINS
  
  Minimize capital and operating costs

- Existing plant to remain in service
Approach: Model Calibration, Full Scale Pilot, Model Verified and Design Further Optimized

Special sampling, BioWin model calibration

Full scale test different nitrogen removal configurations determined using model

Model further calibrated from pilot, used model to further optimize design
Solution: Innovative Hybrid Step Feed Design with Internal Recycle

Zone DO Control – maximize nitrification, minimize carryover

Internal Recycle Pump – fully utilize anoxic capacity

Step Feed – optimize influent carbon use, wet weather

Zone 1B (Aerated) 4,000 mg/L
Zone 2 (Aerated) 3,600 mg/L
Zone 1A (Anoxic) 40%Q
Zone 2 Swing (Anoxic) 60%Q
Zone 4 Swing (Aerated)
Zone 5B Swing (Aerated)
Zone 5A (Aerated)
Solution: Modified Aeration Basins
Results: TN < 4 mg/L, Exceeds the 5.6 mg/L Goal

Arlington East WRF - Secondary Effluent Nitrogen

Monthly Avg TN: June 2010 - 3.8 mg/L
July 2010 - 3.9 mg/L
August 2010 - 3.4 mg/L
September 2010 - 3.9 mg/L
Lesson Learned: Modeling and Full Scale Testing Allows Optimization of Existing Infrastructure

An innovative and cost effective solution

Achieved rerating from 20 to 25 mgd and TN removal to 5.6 mg/L with no additional basin volume

Estimated savings versus more conventional approach – $10 million
Neuse River WWTP Uses Process Models to Improve Effectiveness of Design

New Requirements
- Expansion to from 60 to 75 mgd
- TN = 2.7 mg/L
- TP = 1 mg/L

Challenges
- Rerate existing bioreactors
- No new aeration basin volume
- Energy and chemical cost reduction
Existing Plant Rated to 75 mgd

Extensive Special Sampling and BioWin Model Calibration

Full Scale Verification

Secondary Clarifier Stress Testing

CFD Model Calibration
Solution

Modeling verified rerate feasible

Optimized seasonal swing zone operations
Optimized zone DO control and NH3 based DO control
Deoxygenation zone for NRCY and 2nd anoxic zone
Full scale testing verified

Existing BNR Basins OK for 75 mgd

Saves $20 Million

Combined BioWin Modeling, Stress Testing, Secondary Clarifier CFD Modeling and Full Scale Verification
### F. Wayne Hill WRC, Gwinnett Co, GA

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>F. Wayne Hill Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow</td>
<td>mgd</td>
<td>60</td>
</tr>
<tr>
<td>cBOD5</td>
<td>mg/L</td>
<td>--</td>
</tr>
<tr>
<td>TSS</td>
<td>mg/L</td>
<td>3</td>
</tr>
<tr>
<td>COD</td>
<td>mg/L</td>
<td>18</td>
</tr>
<tr>
<td>Ammonia-N</td>
<td>mg/L</td>
<td>0.4</td>
</tr>
<tr>
<td>Total Phosphorus</td>
<td>mg/L</td>
<td>0.08</td>
</tr>
<tr>
<td>Turbidity</td>
<td>ntu</td>
<td>0.5</td>
</tr>
<tr>
<td>DO</td>
<td>mg/L</td>
<td>7</td>
</tr>
<tr>
<td>Fecal Coliform</td>
<td>#/100</td>
<td>2</td>
</tr>
</tbody>
</table>
Capacity Crisis – Consultant – Your 60 mgd Plant is Really Only a 30 mgd Plant

Individual Unit Process Capacity - Maximum Month With Yellow River Sludge

<table>
<thead>
<tr>
<th>Unit Process / Scenario</th>
<th>Year</th>
<th>cBOD, mg/L</th>
<th>COD, mg/L</th>
<th>TSS, mg/L</th>
<th>NH3, mg/L</th>
<th>TP, mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>2004</td>
<td>182</td>
<td>609</td>
<td>430</td>
<td>24.8</td>
<td>7.6</td>
</tr>
<tr>
<td></td>
<td>2005</td>
<td>237</td>
<td>1021</td>
<td>940</td>
<td>25.6</td>
<td>7.3</td>
</tr>
<tr>
<td></td>
<td>2006</td>
<td>252</td>
<td>715</td>
<td>575</td>
<td>25.6</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>2007</td>
<td>297</td>
<td>1170</td>
<td>1391</td>
<td>28.6</td>
<td>9.6</td>
</tr>
<tr>
<td></td>
<td>2008</td>
<td>277</td>
<td>1211</td>
<td>1186</td>
<td>30.6</td>
<td>9.4</td>
</tr>
</tbody>
</table>
Detailed Process Study

Detailed field work, sampling, and BioWin calibration

Extremely poor historical sampling

Loads far overestimated

Primary clarifiers that “don’t work”

Simple operational changes

Low cost canopy baffle installed

– Now work
Installed Canopy Baffle Drastically Improves Performance in Side By Side

<table>
<thead>
<tr>
<th>Primary Clarifier</th>
<th>% TSS Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary 9 – Baffle Installed</td>
<td>48%</td>
</tr>
<tr>
<td>Primary 10 – As Is</td>
<td>31%</td>
</tr>
</tbody>
</table>
Primary Clarifier Optimization for capacity

2015 = 65%
4 blowers to 2 blowers
Primary Clarifier optimization for increased gas
Modified Sampling and Whole Plant BioWin Model Calibration Confirms True Loadings

Poor influent sampling and FOG/grease
Historical loads far overestimated

BioWin calibration and special sampling verified “true” loadings much lower

Primary clarifiers now working well - Plant capacity maintained

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Original Design</th>
<th>Historical Avg. (Prior to Data Reconciliation)</th>
<th>Recommended Values (After Data Reconciliation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD, mg/L</td>
<td>476</td>
<td>1,030</td>
<td>635</td>
</tr>
<tr>
<td>BOD₅, mg/L</td>
<td>200</td>
<td>266</td>
<td>284</td>
</tr>
<tr>
<td>TSS, mg/L</td>
<td>230</td>
<td>1,023</td>
<td>365</td>
</tr>
</tbody>
</table>
Ammonia Based DO Control

• Concept – use aerobic zone ammonia (online probe/analyzer) concentration to determine DO setpoints
  • Benefits: Minimize airflow/energy, reduce supplemental carbon
  • Allows stricter control of DO entering anoxic zones and simultaneous nitrification/denitrification (SNDN)
  • Take advantage of extra aerobic volume to do SNDN as well as endogenous denitrification
Overview of Simultaneous Nitrification and Denitrification (SNDN)

- SNDN is operating at low DO conditions to achieve nitrification and denitrification in the same zone.
- Denitrification can occur at low DO conditions in aerobic zone.
  - Overall reduced need for purchased carbon/lower TN.
- Requires higher SRTs and solids inventories.
  - Nitrification slows down at lower DO.
- 20 mgd plant operating at a low DO concentration would save ~ $80,000/year with diffused aeration.

<table>
<thead>
<tr>
<th></th>
<th>DO = 2 mg/L</th>
<th>DO = 0.5 mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diffused Aeration</td>
<td>$270,000</td>
<td>$190,000</td>
</tr>
</tbody>
</table>

Assumes $0.06/kW-hr
Ammonia Based DO/aeration control

Example control concept at Tallahassee, FL Advanced Wastewater Treatment Plant

- 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
Ammonia Based DO Control for SNDN shows high savings potential

24 mgd VA plant
- Goal is to save on supplemental carbon costs and aeration
- Savings up to $280,000/yr

75 mgd VA plant
- Goal is to save on supplemental carbon costs and aeration
- 40% reduction in supplemental carbon ($400K/yr)

30 mgd VA plant
- 47% reduction in supplemental carbon, 10% reduction in energy
Example SNDN Pilot Using Ammonia-Based DO Control to Reduce Carbon Demand

Cell 5 aerated
Ammonia setpoint 1.5 mg/L

Control Basin
Four Individual MOVs Control Airflow to SND Pilot – Each Has Separate DO Setpoints

Legend:
- D.O. Probe
- FE/PDIT
- MOV

Four Individual MOVs Control Airflow to SND Pilot – Each Has Separate DO Setpoints
Optimized DO Control Strategy

- **Zone 1 Cells 5-6**
  - Low DO – 0.5 mg/L
  - High DO – 1.0 mg/L

- **Zone 2 Cells 7-9**
  - Low DO – 0.75 mg/L
  - High DO – 3.0 mg/L

- **Zone 3 Cell 1**
  - Low DO – 1.9 mg/L
  - High DO – 2.1 mg/L

- **Zone 4 Cell 13**
  - 2.0 mg/L setpoint
Nitrification is Maintained and SNDN Tank Performing Similarly Using 40% Less Carbon
DO Profile in SNDN Train
Ammonia At End of Cell 9 Drops when Setpoint is Lowered from 2.5 to 1.5 mg/L (as Expected)
Diffused aeration/mixing considerations

Diffused aeration also provides mixing of MLSS. The energy required to mix may exceed the process oxygen demand. Results in excessive aeration, DO carryover to unaerated zones and increased power costs. Inadequate mixing can lead to short circuiting, solids settling, secondary P release, etc.
Poor Diffuser Taper and Underloaded Basins result in Mixing Limited Conditions

~ $100,000/yr additional aeration at $0.10/kW-hr
# Comparison of Mixing Technologies Evaluated for a 56 mgd BNR Facility

<table>
<thead>
<tr>
<th>Mixing Technology</th>
<th>HP/1,000 CF</th>
<th>Total HP&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Annual Cost@ $0.10/kW-hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Mixers</td>
<td>0.15 – 0.20</td>
<td>143 – 191</td>
<td>$93,000 – $125,000</td>
</tr>
<tr>
<td>Hyperboloid Mixers</td>
<td>0.10 – 0.15</td>
<td>96 – 143</td>
<td>$63,000 – $93,000</td>
</tr>
<tr>
<td>Jet Mixing</td>
<td>0.60</td>
<td>574</td>
<td>$375,000</td>
</tr>
<tr>
<td>Large - Bubble Mixing</td>
<td>0.10 – 0.15</td>
<td>96 – 143</td>
<td>$63,000 – $93,000</td>
</tr>
<tr>
<td>Fine Bubble Diffusers</td>
<td>0.30&lt;sup&gt;2&lt;/sup&gt; – 0.5&lt;sup&gt;2&lt;/sup&gt;</td>
<td>287 – 487</td>
<td>$188,000 – $313,000</td>
</tr>
</tbody>
</table>

<sup>1</sup>Based on 956,000 CF of mixed volume  
<sup>2</sup>Based on 0.12 scfm/SF, 20 scfm/hp, 12 to 20 ft depth

**Conclusion –** We want to limit the occurrence of mixing limited conditions in aerobic zones since it is expensive to mix with diffused air.
Case Study – 15 mgd AWRRF Recently Converted to ENR

Needs to meet TN < 5 and TP < 0.3 mg/L

Mixed zone provided just prior to post-anoxic zone to reduce oxygen in NRCY and post anoxic zone.
The Mixed Zone Provides Substantial Denitrification prior to the Post-Anoxic

2.6 mg/L decrease in NO3-N prior to post-anoxic zone
Providing a Mixed Zone upfront of the Post Anoxic Zone Saves Money

Additional 1.5 mg/L TN reduction

- 230 gpd of supplemental carbon saved
- $150,000 carbon savings, $17,000 additional energy

$300,000 additional construction cost to provide mixers in 5 basins

Simple payback just over two years
Decoupling aeration and mixing for reduced energy and effluent TN

Diffused aeration is an expensive way to mix reactors

Proper design, control & operation should limit the frequency of occurrence

The ability to decouple mixing from aeration can result in:

- Decreased energy consumption
- Decreased chemical usage
- Decreased effluent nutrients
Decoupling aeration and mixing for reduced energy and effluent TN

Providing separate mixing equipment in aerobic zones (especially towards the end) can be cost-effective

Vertical, hyperboloid and big-bubble mixers can be cost effective and installed with diffused air

At a minimum, develop control strategies to allow airflows to drop below minimum mixing requirements, with occasional re-suspend cycles
Real-time Control of Nitrified Recycle Rate to Optimize Denitrification

What is the nitrate concentration leaving 1st anoxic zone?

If > 1 mg/L, reduce NRCY; if < 0.5 mg/L increase NRCY
Sidestream treatment can provide cost effective N and P reduction

Sidestreams contribute:
- ≥15 to 20% of the influent TN
- ≥30% P load

Can often reuse existing infrastructure to reduce costs
Sidestream N treatment - Anammox/Deammonification

- Ammonia oxidizing bacteria (AOB)
  - Oxygen: ~63% theoretical savings
  - Carbon: ~100% theoretical savings
  - Achieve 80-90% TIN removal
  - Sustainable, green technology

- Nitritation
  - $\text{NO}_2^-\text{-N}$
  - $\text{NO}_3^-\text{-N}$
  - $\text{NH}_3^-\text{-N}$

- Anaerobic Ammonia Oxidation
  - $\text{N}_2$-Gas

- Anammox bacteria
## Recent Sidestream N Project Example

<table>
<thead>
<tr>
<th>Technology</th>
<th>$/lb N Removed</th>
<th>Breakeven Compared to Mainstream (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demon New Tank</td>
<td>$ 0.54</td>
<td>9</td>
</tr>
<tr>
<td>Kruger MBBR New Tank</td>
<td>$ 0.63</td>
<td>11</td>
</tr>
<tr>
<td>Kruger IFAS New Tank</td>
<td>$ 0.50</td>
<td>8</td>
</tr>
<tr>
<td>BNR Mainstream N Removal</td>
<td>$ 1.03</td>
<td>-</td>
</tr>
</tbody>
</table>

Cost in $/lbs N removed for SNR processes ranges from $0.50-0.63 / lb N removed

Cost to remove nitrogen in the mainstream is about double
Sidestream P treatment: Nutrient recovery helps minimize nuisance struvite formation and reduce P recycle

- Fluidized bed reactor or CSTR used for struvite recovery
- High quality, slow release fertilizer – revenue offsets costs
- Reduction in ferric/alum – payback on capital
F. Wayne Hill WRC – Nutrient Recovery Project

- Gwinnett County DWR
- 60 MGD advanced WWTP
- 0.08 mg/L TP effluent limit
- Bio-P and chemical trim for P-removal
- Influent TP ~ 9 mg/L
Implementation of WASSTRIP™ concept at FWH to minimize nuisance struvite production

Influent → Primary Clarification → 3 Stage BNR → Secondary Clarification → To Tertiary Treatment

Influent → Primary Clarification → 3 Stage BNR → Secondary Clarification

- Primary Clarification → 3 Stage BNR
- Secondary Clarification → To Tertiary Treatment

- P-Release Tank
  - P-Release Tank → Rotary Drum Thickening
  - Rotary Drum Thickening → Anaerobic Digestion
  - Anaerobic Digestion → Dewatering Centrifuges
  - Dewatering Centrifuges → Nutrient Recovery Facility

- Nutrient Recovery Facility
  - Nutrient Recovery Facility → Filtrate EQ
  - Filtrate EQ → Centrate EQ
  - Centrate EQ → Struvite Pellets

- Nutrient Recovery Facility
  - Nutrient Recovery Facility → MgCl₂, NaOH

- Release P and Mg from sludge
- Lower P and Mg content of sludge minimizes nuisance struvite formation from digester onwards

- Influent → P-Release Tank
- P-Release Tank → Centrate EQ

- Centrate Pump Station
- Filtrate / Centrate

- Send P, Mg rich sidestream to recovery process

- WAS
- RAS
Observations from last 4 months

- Producing about 1 ton per day of slow release fertilizer product
- Reduced main plant chemical use
- Dewatered cake increase from 22 to 24%
- 22 wet ton decrease in sludge mass leaving plant
Thank You!
Questions and Contact Information

Ron Latimer
Hazen and Sawyer
rlatimer@hazenandsawyer.com