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Operational Assistance & Training to Enhance Nitrogen Removal

Massachusetts Water Pollution Control Association
Quarterly Meeting
Log Cabin, Holyoke, MA
June 16, 2010

Paul Dombrowski, P.E., BCEE
Vice President
Woodard & Curran

COMMITMENT & INTEGRITY DRIVE RESULTS

Acknowledgements

- Connecticut DEP & Nitrogen Credit Advisory Board
- NEIWPCC
- Project Team
  - Chuck Conway
  - Roy Fredricksen
  - Art Enderle
- WPCF Superintendents & Staff

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Nitrogen Limits in Connecticut

- Water quality problems in Long Island Sound
  - Hypoxia
  - Low dissolved oxygen in Western Sound
  - Nitrogen limiting nutrient
- Long Island Sound Study
  - 1985 – LISS initiated
  - 1990 – No Net Increase Policy (Ph. I)
  - 1990's – Interim upgrades at 15 coastal plants (Ph. II)
  - 2002 – General Permit for Nitrogen Discharges (Ph. III)
  - Now – Looking Upstream (Phase IV)

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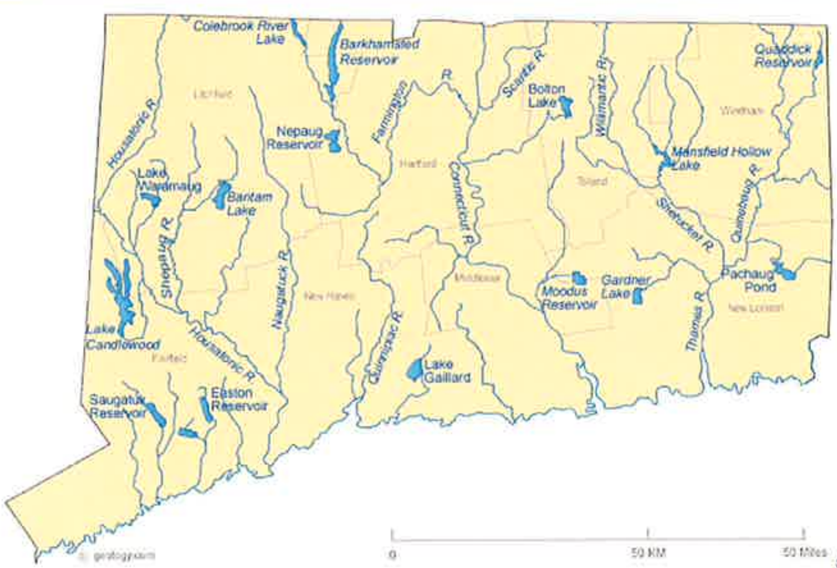
Connecticut Rivers



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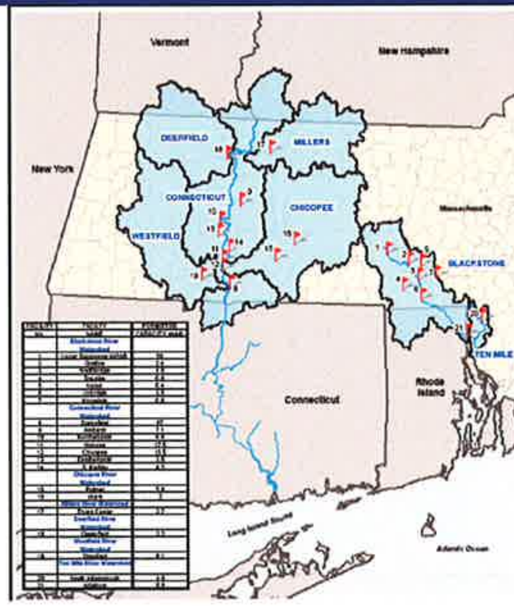
Massachusetts WWTPs Studied (2008)



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General Permit for Nitrogen

- Separate from NPDES Permits
- Requires 79 plants to achieve 64% Removal by 2014
  - Mass based, annual average limits
  - Pollutant trading program (adjusted for location)
  - Limits phased –in over 12 years
- Credit Payments – 2006
  - $3,828,000 paid to DEP, $2,395,000 paid to Plants **(NET $1,433,000)**
- Credit Payments – 2007
  - $3,087,000 paid to DEP, $ 2,072,000 paid to Plants **(NET $1,015,000)**
- Credit Payments – 2008
  - $3,488,000 paid to DEP, $2,660,000 paid to Plants **(NET $828,000)**

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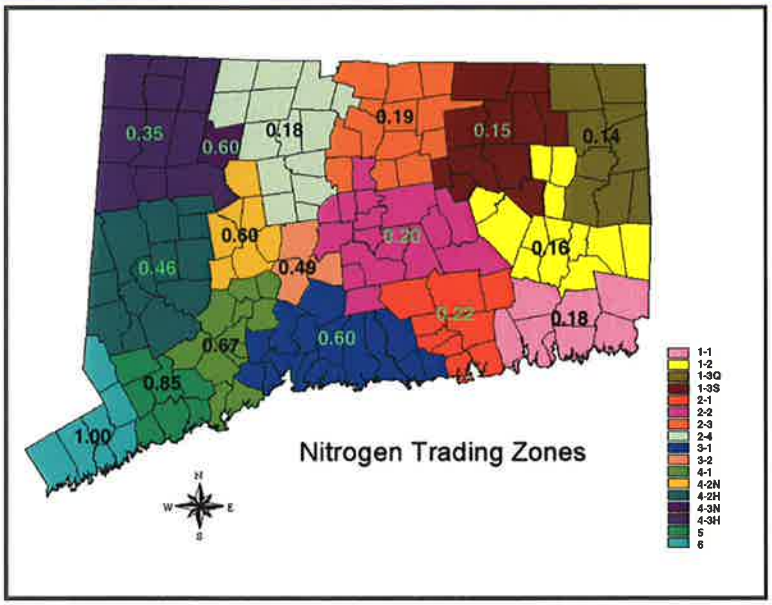
Connecticut Nitrogen Trading Zones



Program Components

- Nitrogen Removal Seminars
  - DEP Training Center – Old Lyme
  - MDC Training Center - Hartford
- Plant Assessments – 10 Plants
  - Bristol, East Hampton, East Hartford, Greenwich, Manchester, New Haven, New London, Norwich, Wallingford and Waterbury
- Workshops – Four 2-day sessions
  - New Haven, Norwich, Stamford and Waterbury
- Plant Specific Training

Technical Approach-Assessments

- Various plant configurations & sizes
- Examined "Cause & Effect" relationships to demonstrate applicability
  - Influent Wastewater Characteristics
  - Overall Plant Configuration
  - Solids Processing
  - Secondary Treatment Performance
  - Secondary Clarifier Capacity
  - Nitrification
  - Denitrification

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Secondary Clarifier Impacts on BNR

- Effluent TSS contains nutrients:
  - 6-12% Nitrogen
  - 1-3% Phosphorus (5%+ in EBPR and Chem-P plants)
- Secondary Clarifiers define allowable reactor MLSS
  - Nitrification requires higher aerobic MCRT
  - As MCRT↑ - MLSS↑ (for any given reactor volume)
  - As a result, allowable MLSS limits MCRT

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Clarifier Operating Evaluation

- Based State Point Analysis (Solids Flux)
- Using two graphs based on a series of SPA :
  - PHF surface overflow rate vs. MLSS & SVI
  - Minimum RAS % to prevent overload condition
- Compared to operating data
  - Using clarifier blanket depth as indicator

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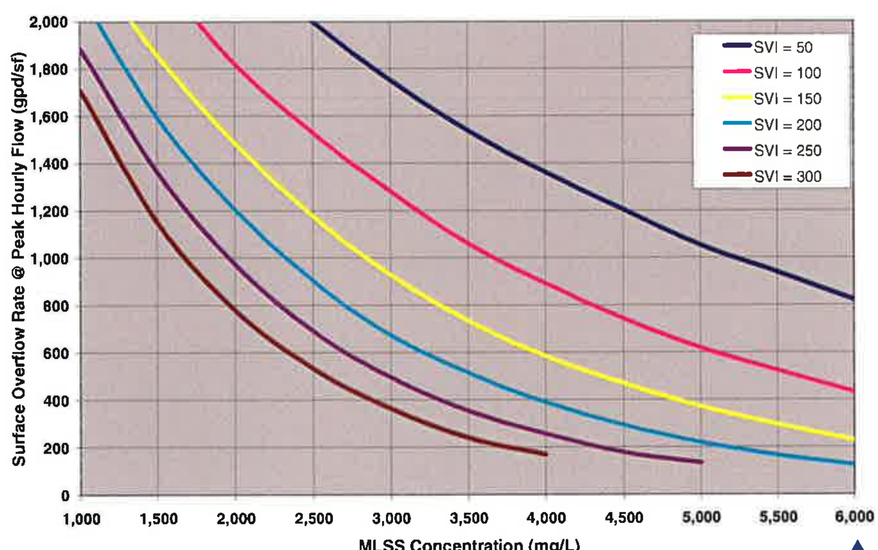
Secondary Clarifier Peak Hourly Flow SOR vs. MLSS Conc & SVI
Modified Daigger & Roper Equation - Non-RAS Rate Limiting Conditions



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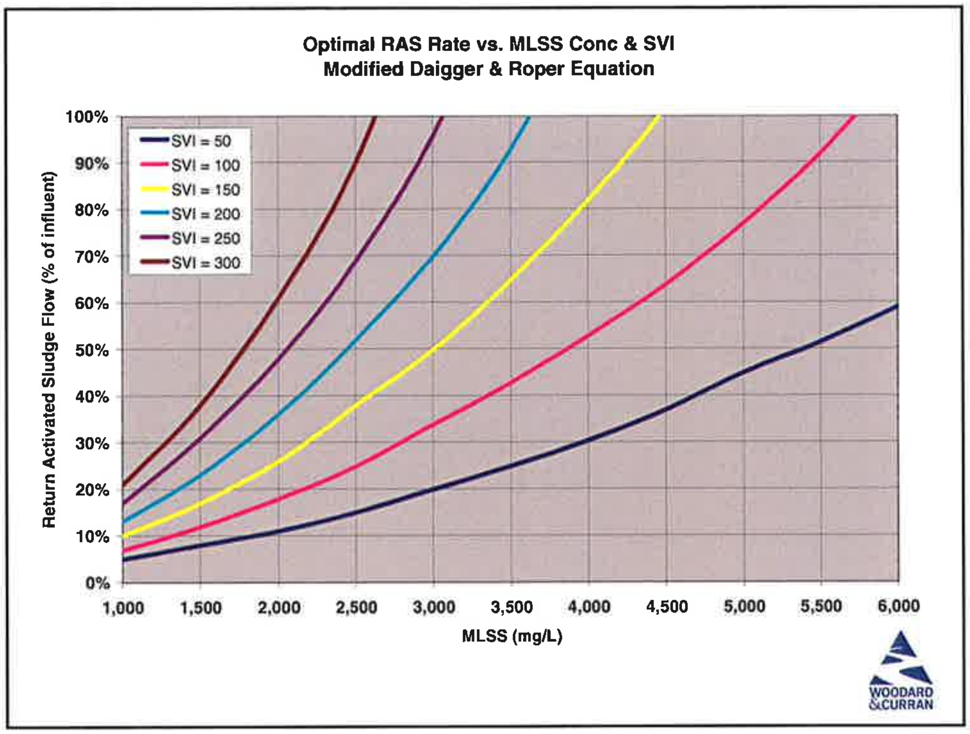

Optimal RAS Rate vs. MLSS Conc & SVI
Modified Daigger & Roper Equation
Return Activated Sludge Flow (% of influent)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
5,500
6,000
MLSS (mg/L)
SVI = 50
SVI = 100
SVI = 150
SVI = 200
SVI = 250
SVI = 300
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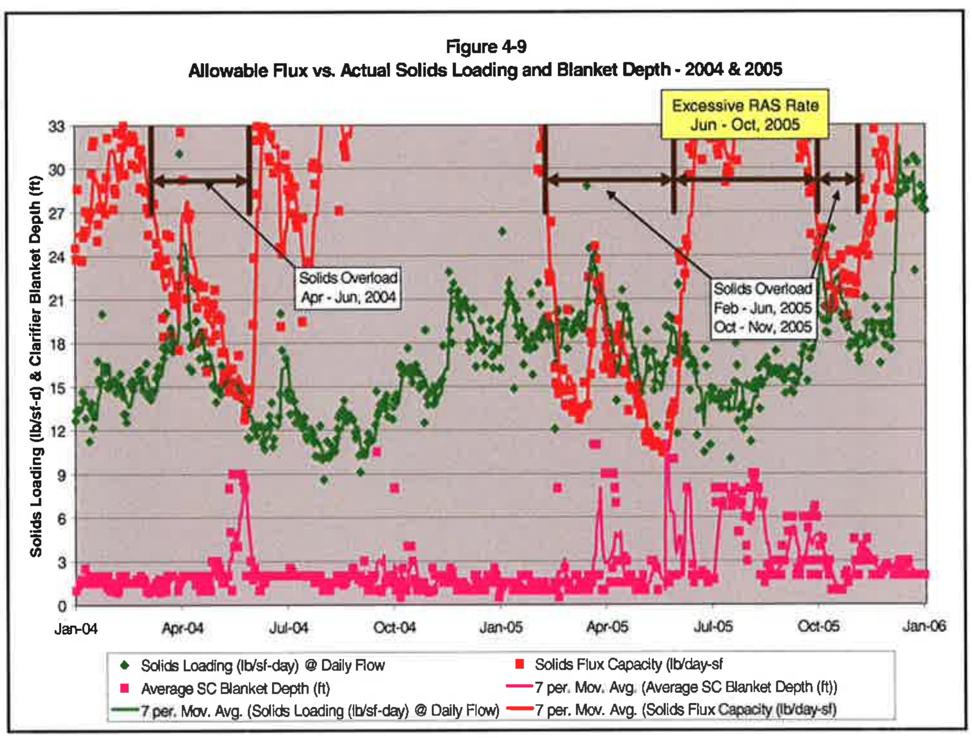
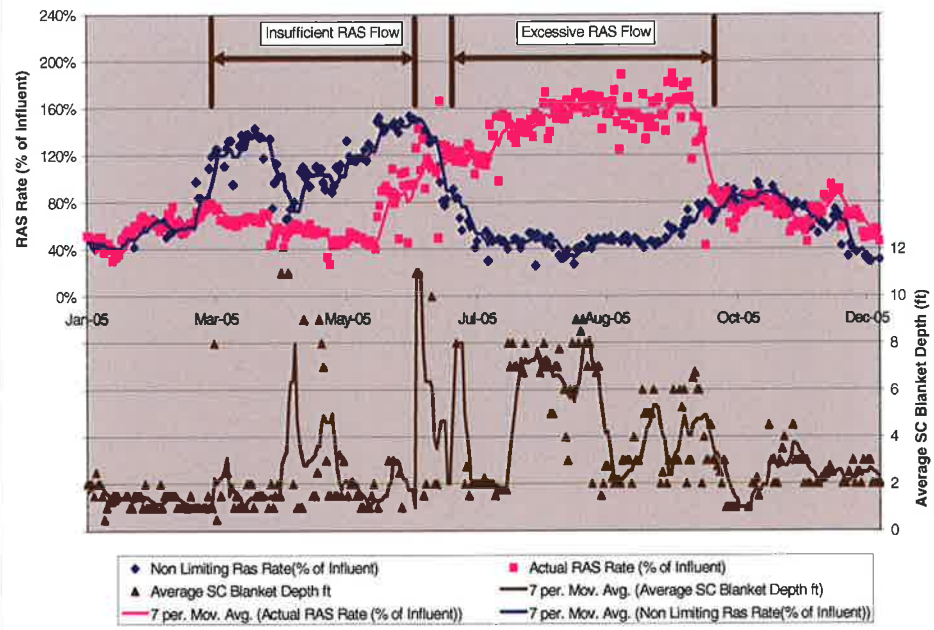


Figure 4-9
Allowable Flux vs. Actual Solids Loading and Blanket Depth - 2004 & 2005
Excessive RAS Rate
Jun - Oct, 2005
Solids Overload
Apr - Jun, 2004
Solids Overload
Feb - Jun, 2005
Oct - Nov, 2005
Solids Loading (lb/sf-d) & Clarifier Blanket Depth (ft)
33
30
27
24
21
18
15
12
9
6
3
0
Jan-04
Apr-04
Jul-04
Oct-04
Jan-05
Apr-05
Jul-05
Oct-05
Jan-06
Solids Loading (lb/sf-day) @ Daily Flow
Solids Flux Capacity (lb/day-sf)
Average SC Blanket Depth (ft)
7 per. Mov. Avg. (Average SC Blanket Depth (ft))
7 per. Mov. Avg. (Solids Loading (lb/sf-day) @ Daily Flow)
7 per. Mov. Avg. (Solids Flux Capacity (lb/day-sf))

Figure 4-10
Actual vs. Optimal RAS Rate - 2005



Biological Nitrogen Removal

- Assimilation
  - Incorporation of nitrogen into cell mass, typically 5% of BOD removed (7-10% of VSS formed)
- Ammonification
  - Conversion of organic nitrogen into ammonia
- Nitrification
  - Oxidation of ammonia to nitrite then nitrate
- Denitrification
  - Reduction of nitrate to nitrogen gas

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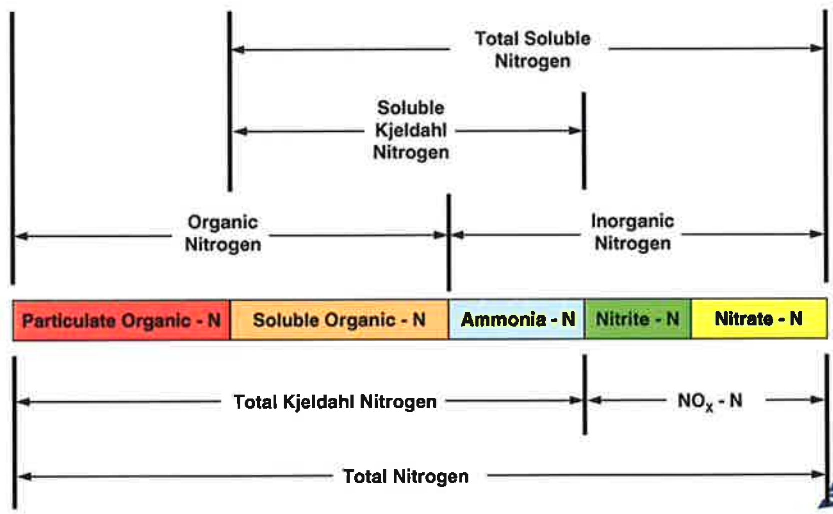
Forms of Nitrogen in Wastewater



Nitrification Basics

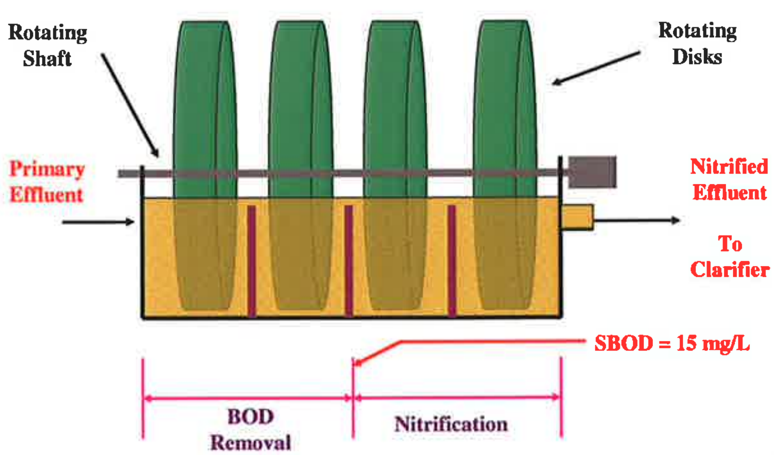
- NH_4^+-N + 2 O_2 ⟶ NO_3^--N + 2 H^+ + H_2O + Bacteria
- Autotrophic Bacteria - Nitrosomonas & Nitrobacter
  - Energy from Oxidation of NH_4^+-N
  - Carbon from HCO_3^- (BiCarbonate)
  - Aerobic Organisms – DO Sensitive (4.6 lb oxygen required / lb NH_4)
  - Low Growth Rate – Temperature Sensitive
  - Produces Acid – Consumes Alkalinity (7.2 lb alkalinity ($CaCo_3$) / lb NH_4)
  - pH Sensitive – Acclimation
  - Sensitive to Toxics
- MUST BE RELATIVELY COMPLETE FOR TN REMOVAL
- MUST PRECEDE DENITRIFICATION !

Fixed Film Nitrification

- Fixed Film
  - Biomass Attached to Media
  - Must Occur Following BOD Removal
  - Organics Removal to <15 mg/L $SBOD_5$
  - Performance may be limited by diffusion into biomass

- Trickling Filters
- Packed Towers
- Rotating Biological Contactors (RBC)
- Biological Aerated Filters (BAF)

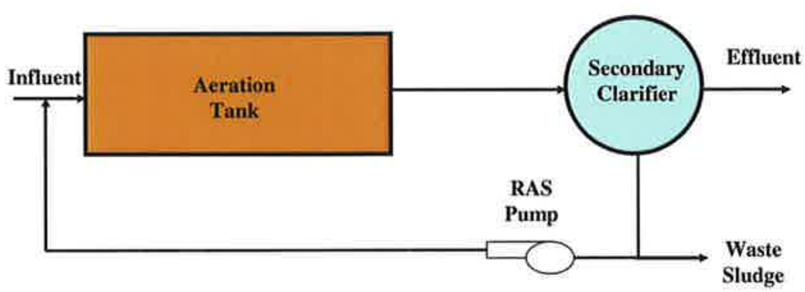
Fixed Film (RBC) Nitrification



Activated Sludge Nitrification

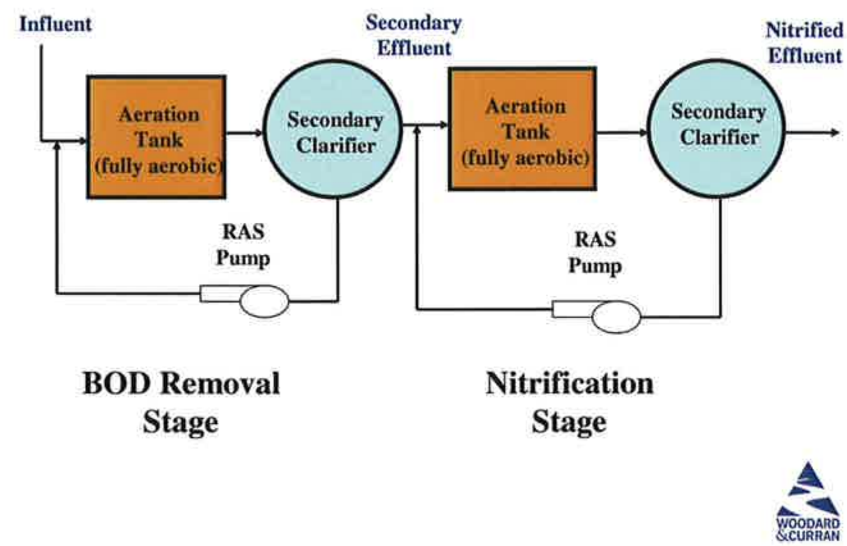
- System Microbiology
  - Can Occur Concurrent or Following BOD Removal
  - Heterotrophs grow faster than Nitrifiers, so must reduce overall system growth rate
  - Depends on Aerobic SRT
- Single Sludge Nitrification
  - Continuous Flow Systems
  - Sequencing Batch Reactors (SBR)
  - Membrane Bioreactors (MBR)
- Separate Sludge Nitrification

Single Sludge Nitrification

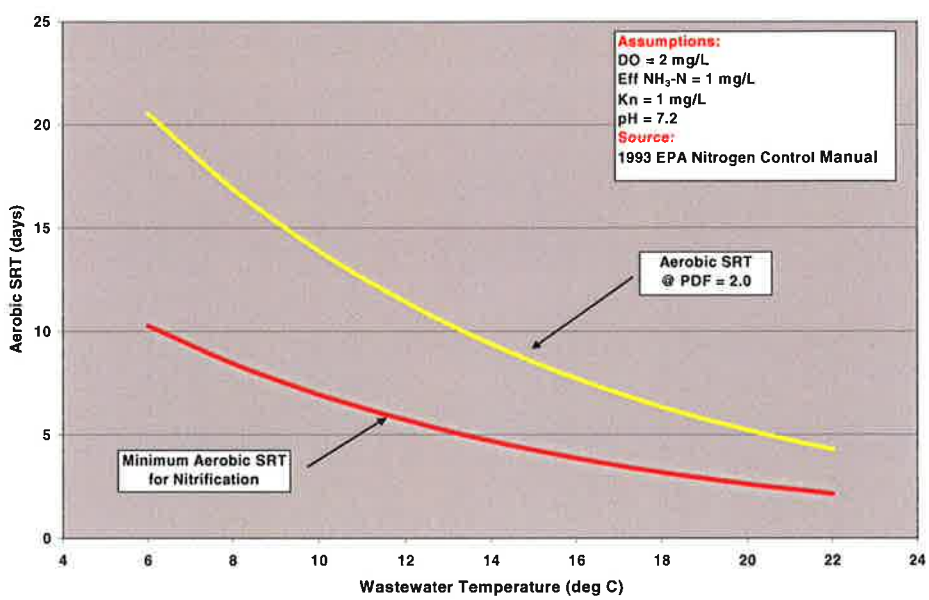


BOD Removal & Nitrification

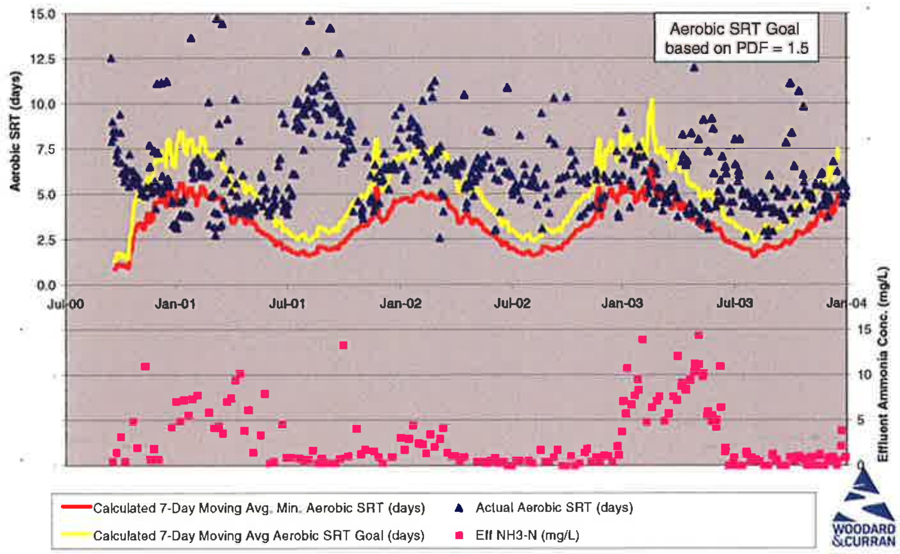
Separate Sludge Nitrification



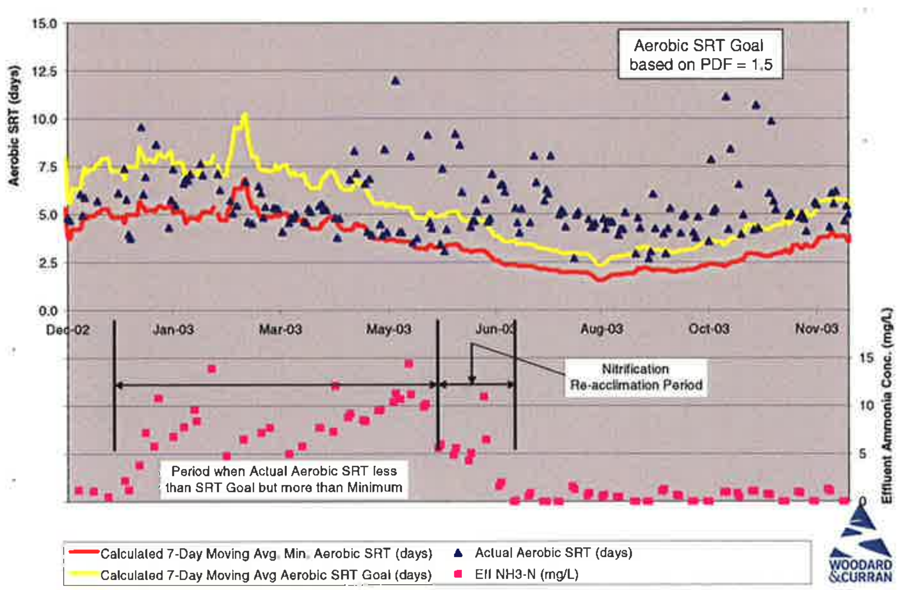
Aerobic SRT for Nitrification



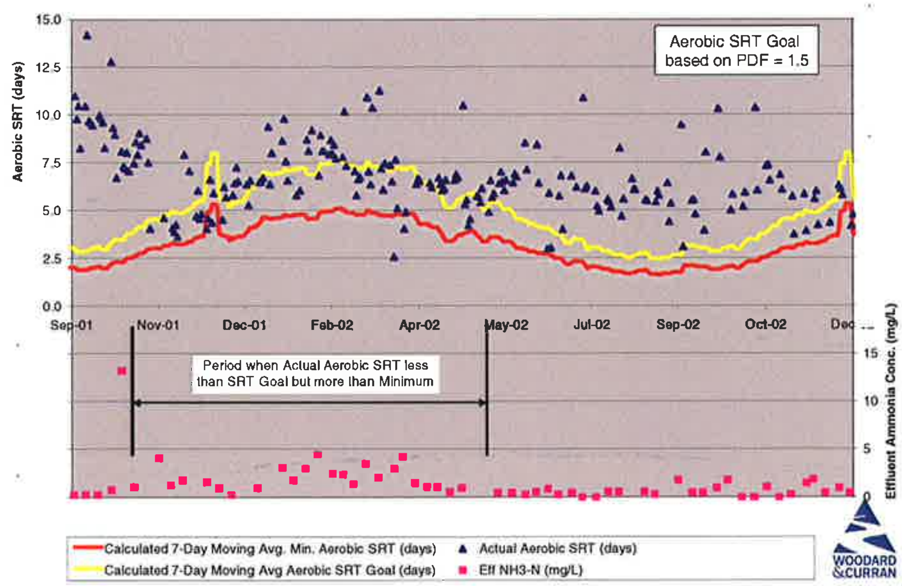
Plant 1 - Nitrification Performance

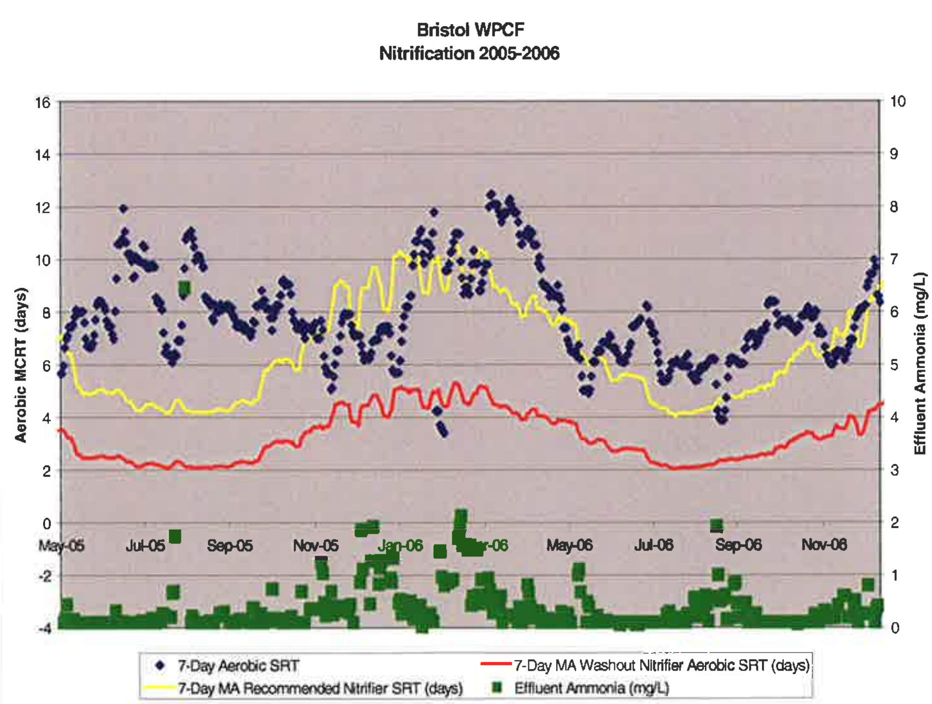


Plant 1 - Nitrification Performance



Plant 1 - Nitrification Performance



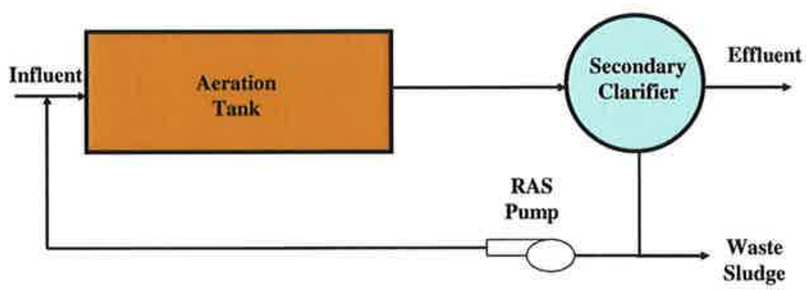


Denitrification Basics

- $2\ NO_3^-\text{-}N + 12\ H^+ + 2.9\ BOD \longrightarrow N_2 + 6\ H_2O + \text{Bacteria}$

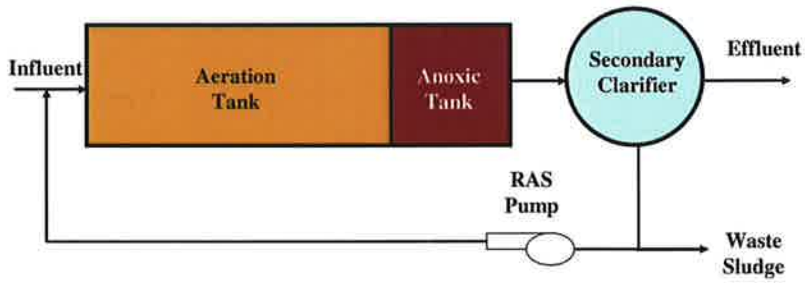
- Heterotrophic Bacteria – "BOD Removers"
  - Anoxic Conditions Req'd – No or Low DO
  - Energy from Organic Carbon (BOD) (2.9 lbs BOD /lb NO_3-N)
  - Produces Alkalinity (3.6 lbs $CaCO_3$ / lb NH_4-N)
  - BOTH NITRIFICATION AND DENITRIFICATION ARE REQUIRED TO ACHIEVE TN REMOVAL

Activated Sludge Process



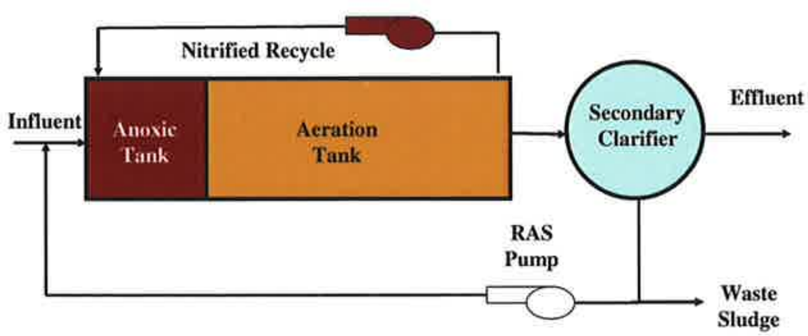
BOD Removal & Nitrification

Wuhrman Process



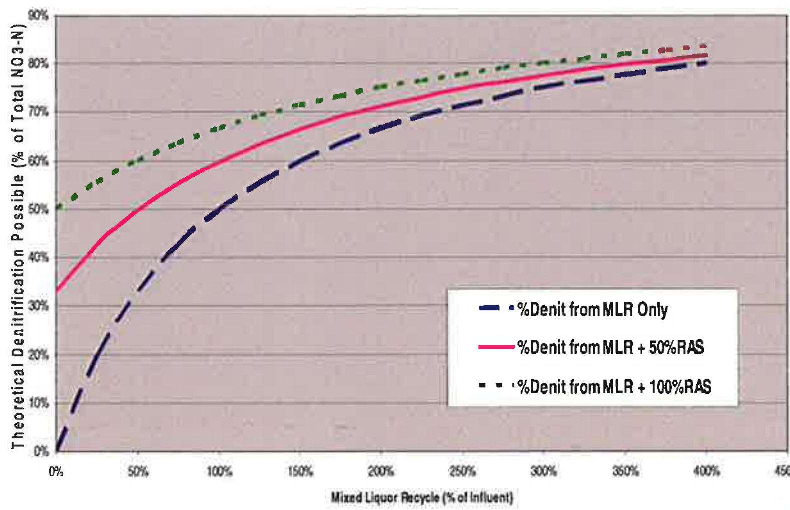
BOD Removal, Nitrification & Denitrification

Modified Ludzack-Ettinger Process



BOD Removal, Nitrification & Denitrification

MLE Recycle Relationship



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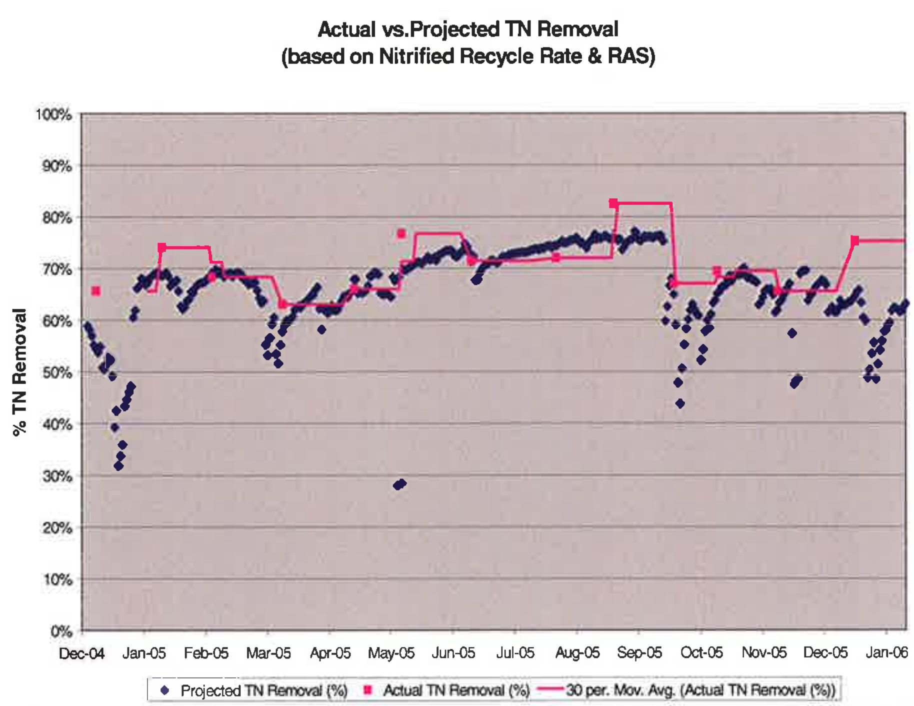

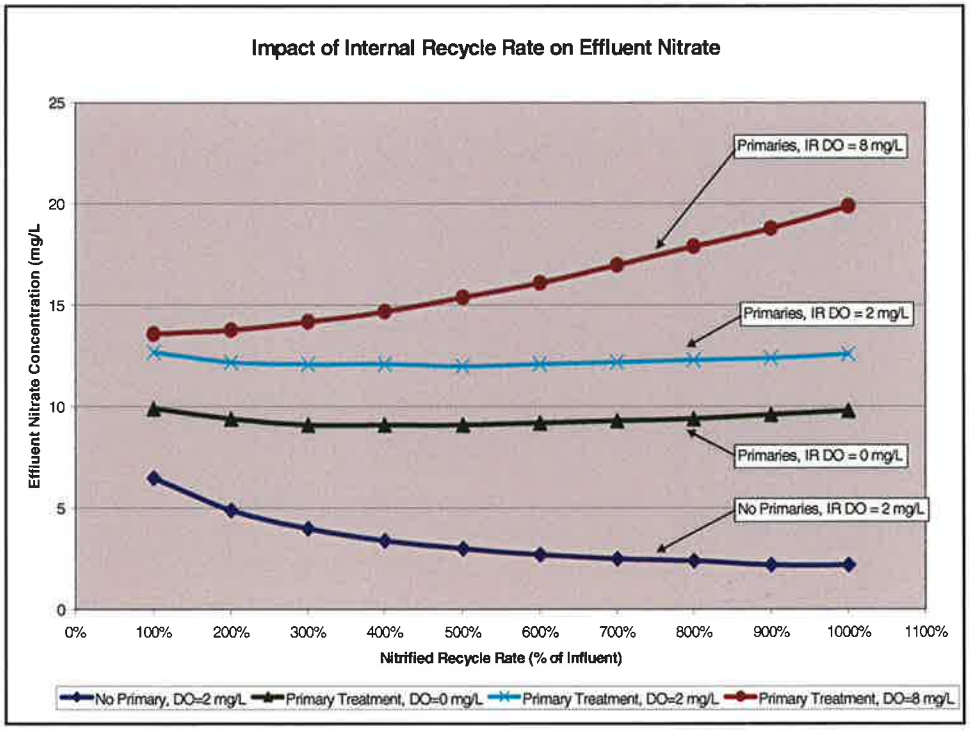

Common Challenges

- Secondary Clarifiers
  - Inventory management, filaments, wet weather operation
- Nitrification
  - Variable aerobic SRT, low alkalinity, "nitrite lock"
- Denitrification
  - High D.O., unmanaged nitrified recycle, low BOD/N Ratio
- Solids Management
  - Nutrient recycles from digestion

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Summary

- Developing "Cause & Effect" operating relationships can illustrate impacts of changing conditions on plant performance
- Collaborative training provides a fresh perspective both from trainers and operators

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