SCHREIBER
Pure Ingenuity

Continuously Sequencing Reactor (CSR) Process

Part I – Design and Operations

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Presentation Topics

- Historical Process Development
- CSR Process Description
- CSR System Description

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Pasveer Oxidation Ditch

- Aeration devices placed in the channel to propel water and provide aeration
- Mixed liquor is recirculated many times with small portion discharged from the channel

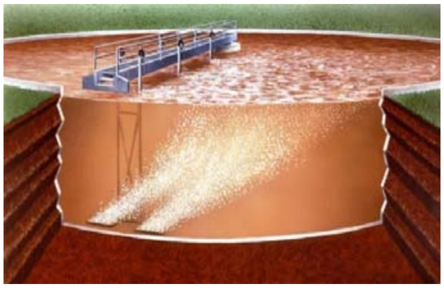
Oxidation Ditch

- Oxidation ditch mechanical aerators (disk rotors, vertical turbines) are used for mixing and aeration

- High energy consumption: minimum 70 HP/MG is required for solids suspension

Schreiber Counter Current Aeration

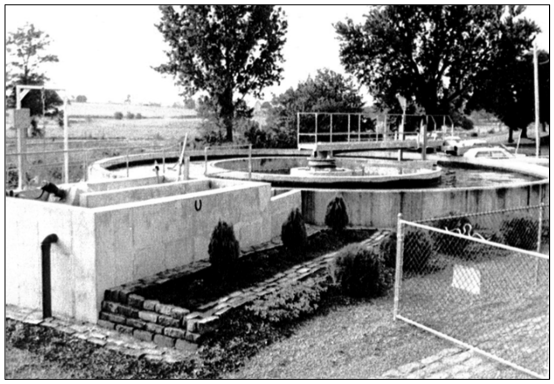
- Developed in Germany in 1960s based on observation that when propelling water over fixed fine bubble diffusers in ditch configuration, oxygen transfer efficiency is doubled
- Rotating fine bubble diffusers suspended from a bridge and submerged in mixed liquor became the preferred energy efficient option to oxidation ditch



Counter Current Aeration

- Horizontal component to the bubbles path will reduce bubble coalescence and increase residence time resulting in higher SOTE
- EPA considered counter current aeration an innovative energy efficient technology for medium and small communities

First USA Installation in 1979



College Hills, PA

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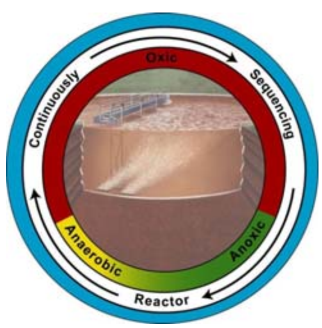
Schreiber Continuously Sequencing Reactor (CSR) Process



- Continuous flow activated Sludge process
- Cyclic aeration allows biological nutrient removal in single basin

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Hampden Township's Roth Lane WWTP
Mechanicsburg, PA

CSR Rotating Bridge

- Provides Aeration & Mixing
- Two rotating parts:
  - Center bearing
  - Drive assembly
- Mixing provided by:
  - Rotating diffuser assemblies
  - Mixing plates

Essence of CSR Process

- Rotating bridge which provides both aeration and mixing
- Functions of mixing and aeration are completely separated
- Aeration system designed based on process oxygen requirements

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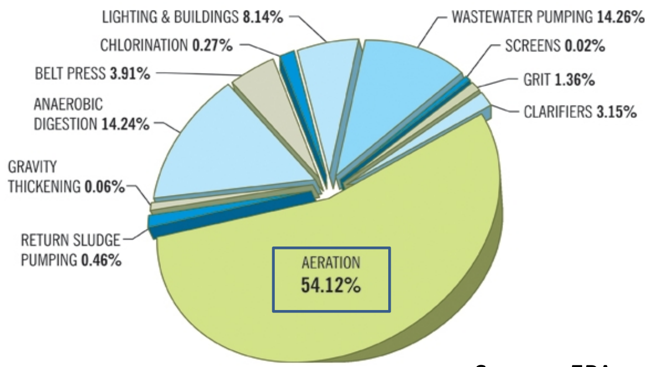
WWT is Energy Demanding Process



Source: EPA

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Aeration & Mixing Energy

- Sizing of aeration equipment in activated sludge systems is dictated by mixing
- Volumetric power input is used to compare mixing energy of different processes
- Defined as the power required for mixing biomass divided by reactor volume

Volumetric Power Input

Oxidation ditch with Mechanical Aerators

70 Hp/MG

CSR Process with Rotating Bridge

3-4 Hp/MG

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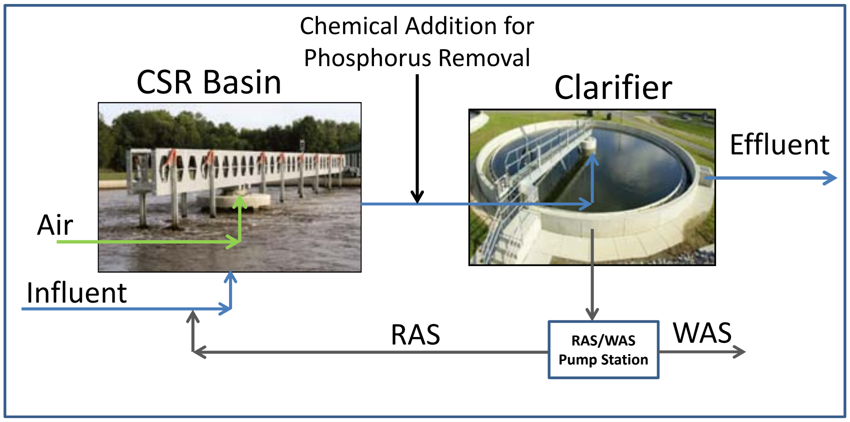
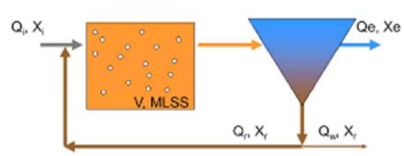
CSR Process Flow Diagram



Solids Retention Time (SRT)

When Wasting Sludge form Recycle

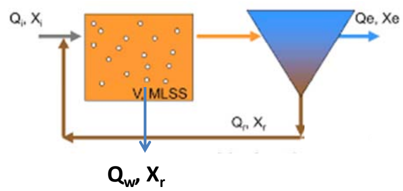


$$SRT = \frac{Inventory}{Wastage} = \frac{(V)\ x\ (MLSS)}{(Q_W\ x\ X_r) + (Q_e\ x\ X_e)}$$

$$SRT = \frac{(V)\ x\ (MLSS)}{(Q_W\ x\ X_r)}$$

Solids Retention Time (SRT)

When Wasting Sludge form Reactor

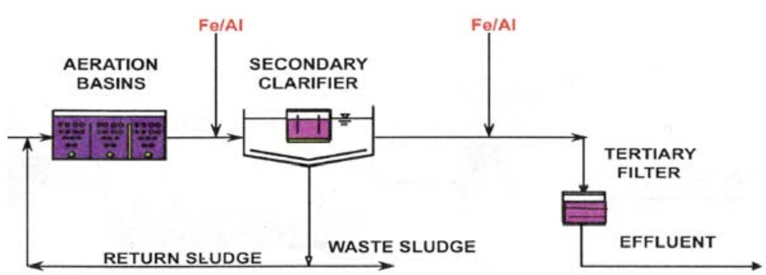


$$MLSS = X_r$$

$$SRT = \frac{V}{Q_w}$$

If desired SRT = 10 days then Q_w (gpd) = 10% x V

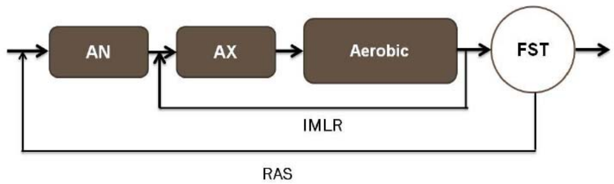
Combining Chemical and Bio-P Removal



- Most reliable for low effluent P limits
- Lowers operational costs (less chemicals)
- Dose depends on effluent P limit:
  - For Alum: 20-30 mg/L (0.5 to 0.1 mg/L P)

Conventional Biological N and P Removal

- Example A^2/O requires defined anaerobic, anoxic and aerobic zones with internal mixed liquor recycle



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Simultaneous Biological Nutrient Removal (SBNR)

- Defined as occurrence of BNR in systems without defined anoxic and anaerobic zones and does not required internal mixed liquor recycle

Orbal™ Oxidation Ditch

Schreiber® CSR

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Why are we interested in SBNR?

- Lower capital and energy costs
- Mechanically simple
- Achieved by simply changing operation
- Implementation requires better understanding of design and control

Key Mechanisms Responsible for SBNR

- Mixing Pattern (Macro-Environment)
- Floc Micro-Environment
- Novel Microorganisms

Mixing Pattern (Macro-Environment)

- Informal anaerobic and anoxic zones form in reactors

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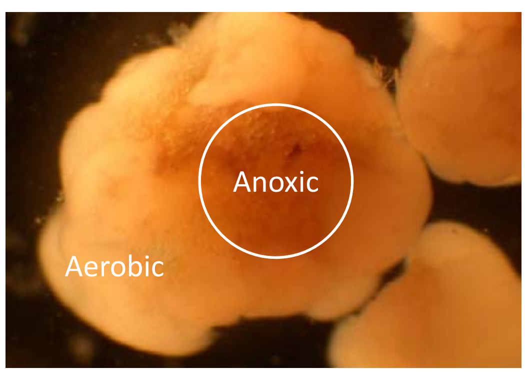
Floc Micro-Environment

- Zones within flocs due to Low DO and/or High F/M



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Schreiber SBNR System

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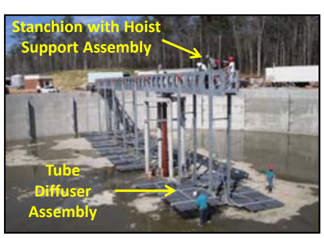
CSR Rotating Aeration Bridge



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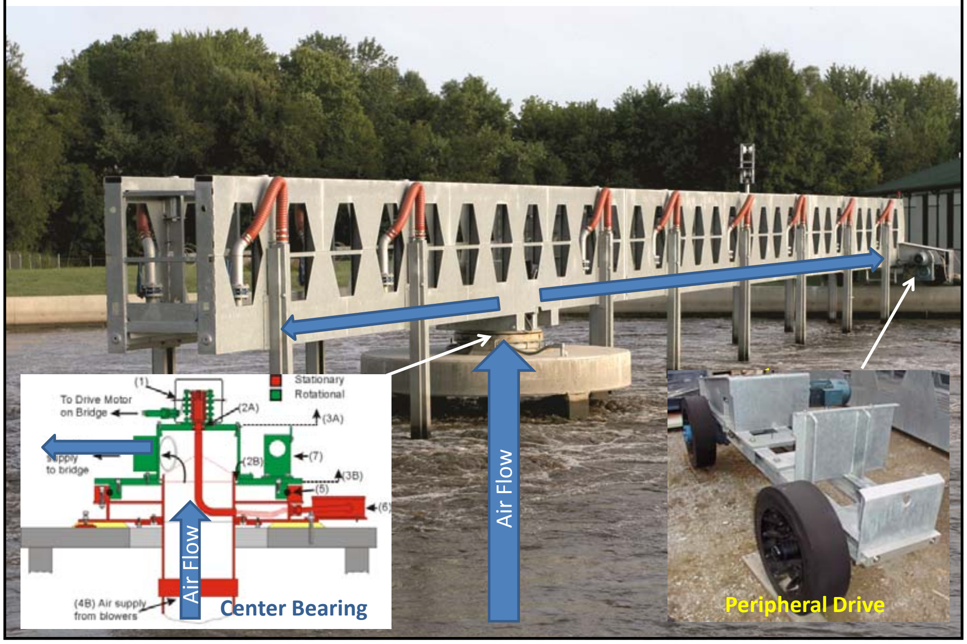
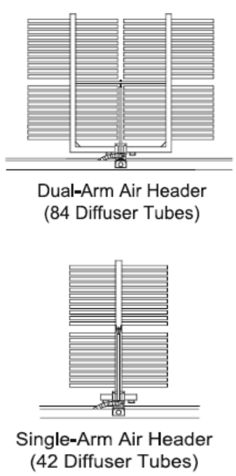
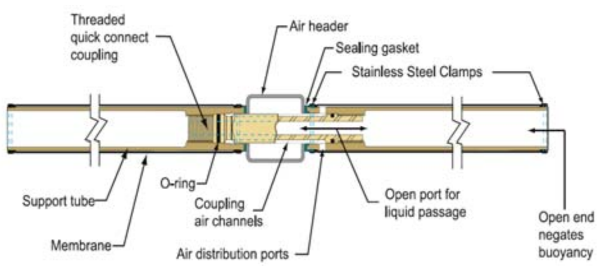
Rotating Bridge Center Bearing & Drive



Fine Bubble Diffuser Assembly





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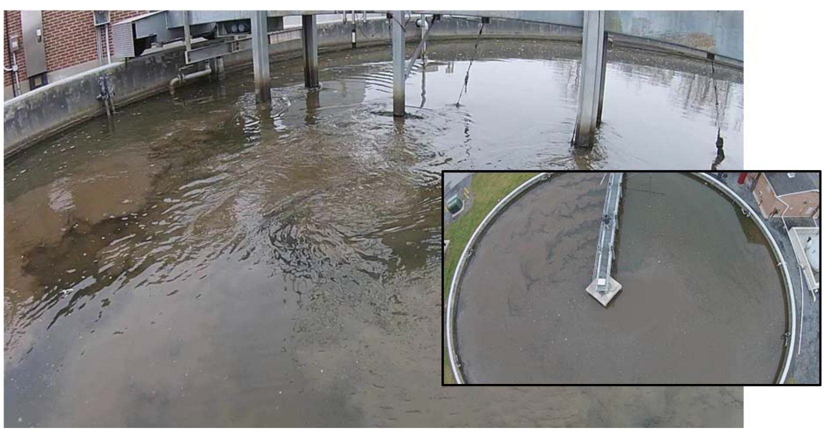
Stationary Diffusers

Mixing with Rotating Bridge



Videos showing Mixing Patterns caused by the rotating bridge (air blowers OFF)

CSR Process Configurations

CSR Basin + Clarifier

ADF up to 3.0 MGD

CSR-Clarifier Concentric Basin

ADF up to 1.5 MGD

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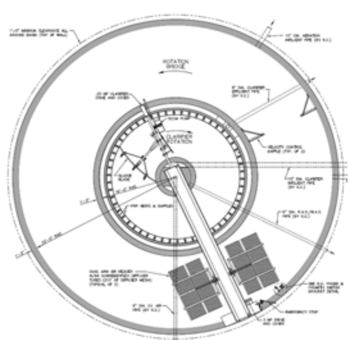
Aerobic Digester/Thickener



- oxygen required is small since low load activated sludge is already fairly stabilized

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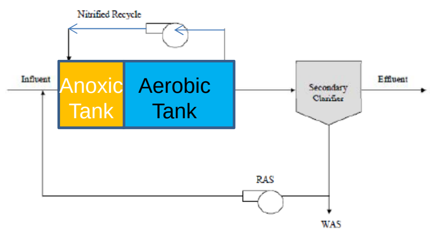
CSR as MLE Process

MLE Process



Little Falls Run WWTF - Stafford County, VA

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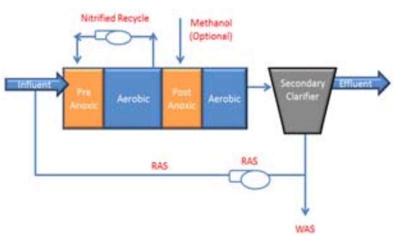
CSR as 4-Stage Bardenpho

4-Stage Bardenpho



Aquia WWTF - Stafford County, VA

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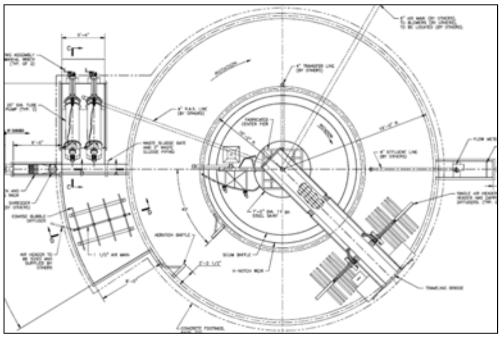
Schreiber SBNR Package Plant

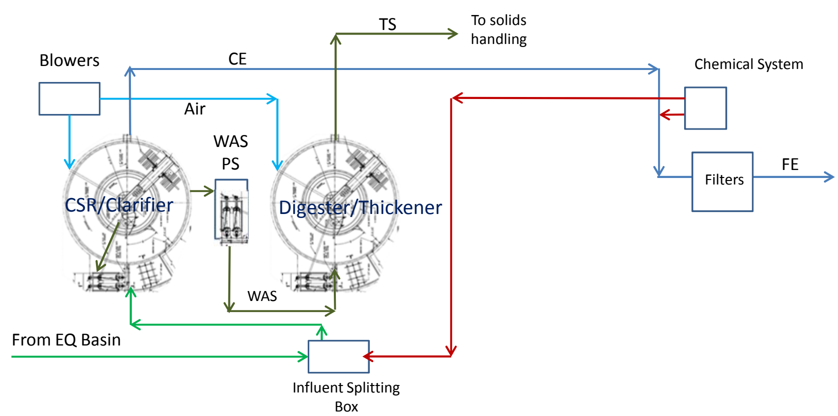


CSR Package System at Parish Alabama (ADF 50,000 gpd)

Lake Areas Cass County, MI
(ADF 0.125 MGD)

- 1st basin serves as CSR and clarifier
- 2nd basin serves as digester and thickener
- 2nd basin can be changed to CSR and clarifier

Phase 1 – Normal Operations



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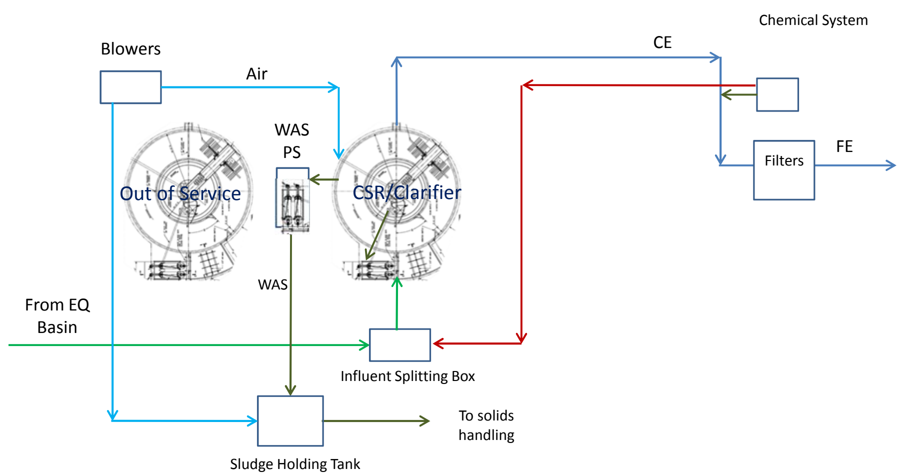
Phase 1 – CSR/Clarifier Out of Service



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Instrumentation & Control System

	New CSR Process Control Options
Simple Controls & Less Stringent Limits	DO Control (Basic Control)
	DO Control + Nitrate Control
	DO Control + Ammonia Control
	DO control + Nitrate control + CS Dosing *CS = Carbon Source (e.g. Methanol)*
	DO control + Nitrate control + Ammonia Control + CS Dosing
Advanced Controls & more Stringent Limits	DO Control + Nitrate Control + Ammonia Control + Phosphate + MS Dosing *MS = Metal Source (e.g. alum)*
	DO Control + Nitrate Control + Ammonia Control + Phosphate + MS Dosing + CS Dosing

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Modular Control System Design

- As higher degrees of nutrient removal are required, more elaborate CSR control system can be implemented
- Recent improvement in instrumentation technologies resulted in reliable LDO and ion-specific electrode (ISE) sensors
- They allow online real-time measurement of mixed liquor's DO, NH_3, NO_3 & ORP
- Based on online measurements, the operator can optimize the length of oxic & anoxic cycles

DO Probe with LDO Sensor

AN-ISE Combination Sensor for NH4 and NO3

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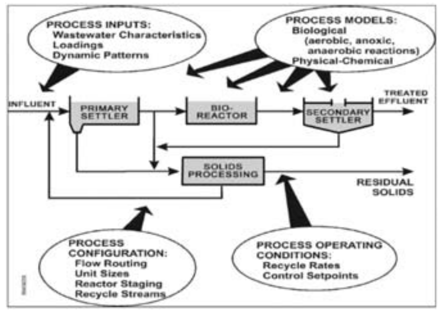
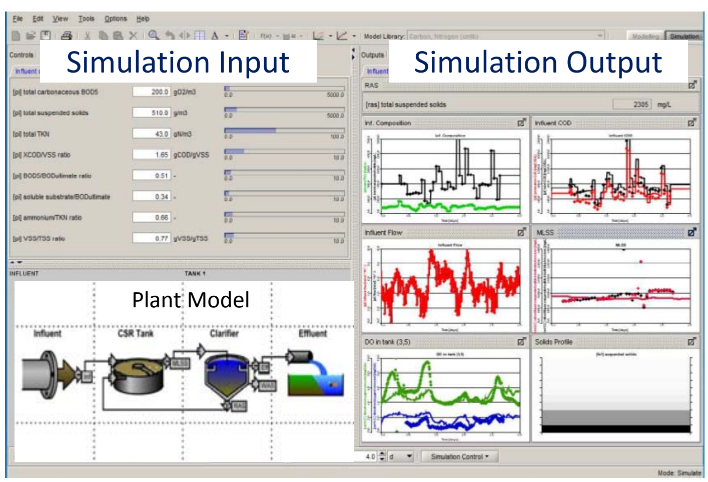
BNR Modeling & Simulation

- Setting up simulation of BNR system requires:
  - Wastewater characteristics
  - Influent loadings
  - Biological, physical and chemical models
  - Flow routing, reactor sizes
  - Control setpoints, RAS



- Process simulator specify facility processes, select model and solve to predict plant performance

CSR Modeling and Simulation



GPS-X Process Simulations

- Determine power consumption and effluent TN for the following operational conditions:

Operation Condition	Aeration Mode	Aeration Time	DO Setpoint
1	Continuous	24 h/day	2.0 mg/L
2	Cyclic	16 h/day	2.0 mg/L
3	Cyclic	16 h/day	1.0 mg/L

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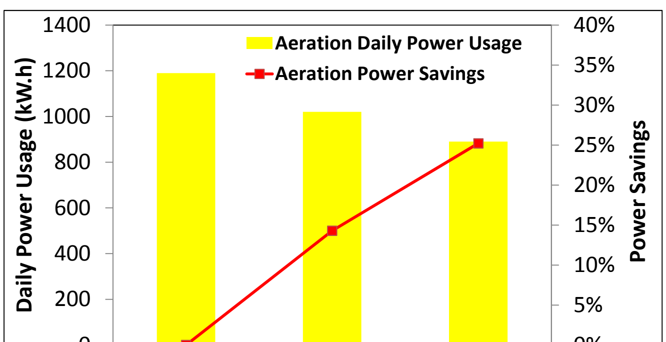
Optimization of CSR Aeration



	Simulation 1	Simulation 2	Simulation 3
Aeration Mode	Continuous	Cyclic	Cyclic
DO Setpoint	2 mg/L	2 mg/L	1 mg/L
Power Usage (Kw.h)	1190	1020	890
TN (mg/L)	28	12.2	8.6

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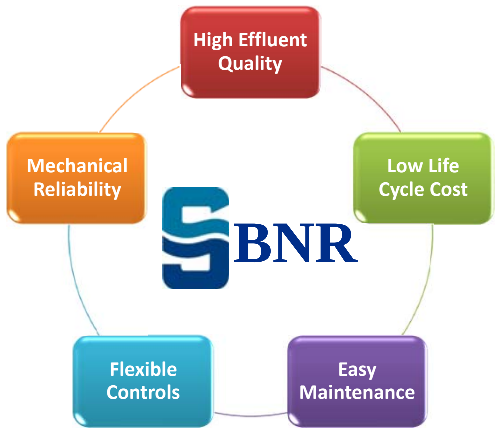
Benefits of Schreiber SBNR System



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Thank you

Questions?

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Continuously Sequencing Reactor (CSR) Process

Part II – BNR & ENR Applications

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Presentation Topics

- BNR Application at Hampden Township, PA
- BNR & ENR Application at Stafford County, VA
- EBPR Application at Green County, OH

Hampden Township Roth Lane Facility

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Roth Lane NPDES Permit

Parameter	Average monthly concentration (mg/L)	Mass load (lb/yr)
Total suspended solids	30	-
Carbonaceous biochemical oxygen demand	15	-
Ammonia (5/1 to 10/31)	1.8	-
Ammonia (11/1 to 4/30)	5.4	-
Total phosphorus	2.0	12,359
Total nitrogen	-	101,997

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Roth Lane WWTP Basis of Design

Parameter	Unit	Design Value
Raw Wastewater Flow and Loadings		
Annual average daily flow	MGD	4.82
Peak instantaneous wet weather flow	MGD	33.0
Biochemical oxygen demand (BOD)	mg/L	148
Ammonia	mg/L	19.1
Biological Reactor System (CSR) Design Criteria		
CSR average daily flow	MGD	5.05
CSR hydraulic detention time @ AADF	hr	12

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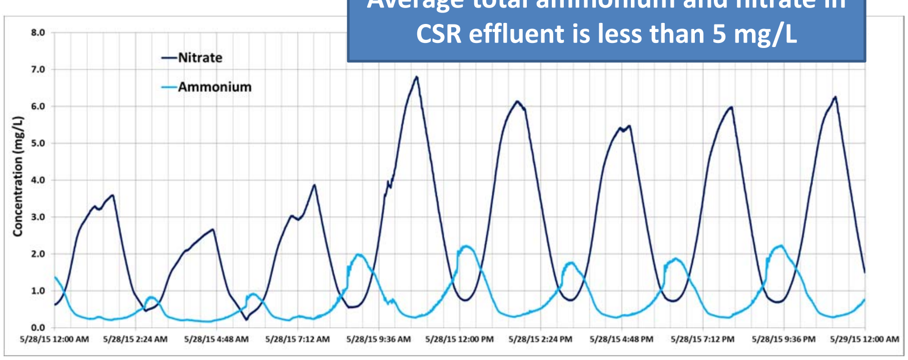
NH_4-N & NO_3-N Concentration Profile in CSR Mixed Liquor

Average total ammonium and nitrate in CSR effluent is less than 5 mg/L



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Roth Lane Actual Performance

Annual Average concentrations for calendar year 2012			
Parameter	Influent	Effluent	% Removal
CBOD (mg/L)	157	2.7	98.3%
TSS (mg/L)	167	4.0	97.6%
Ammonia (mg/L)	21.3	0.46	97.8%
TP (mg/L)	3.4	0.76	77.6%

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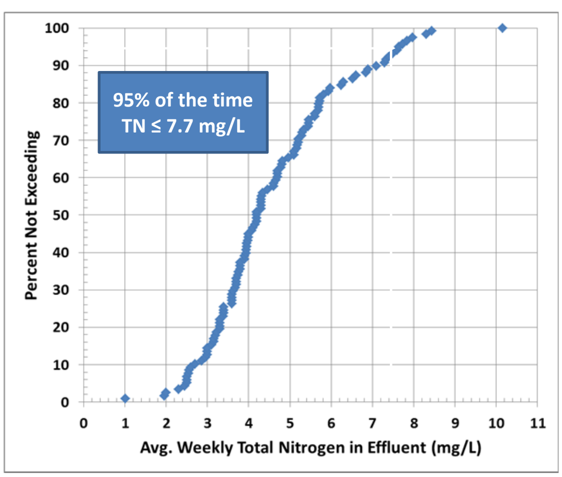
Plant Performance – Frequency and Reliability Approach



EPA Approach: Performance should not be expressed in terms of a single numeric value. Rather in terms of its **Frequency** and **Reliability**

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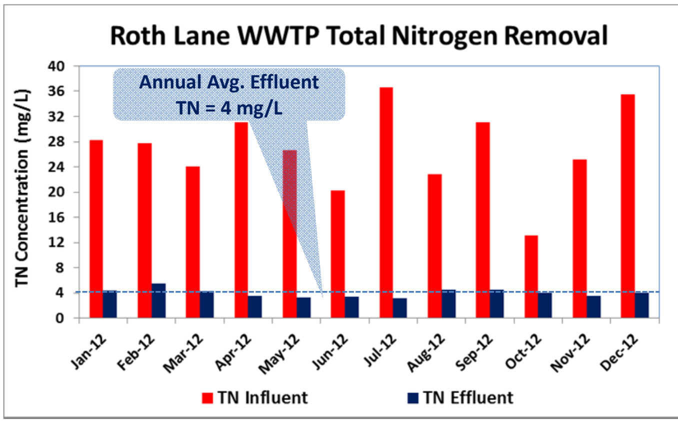
Excellent Plant Performance



Fact:
Annual Avg. TN Effluent conc. is well below the Equivalent TN Effluent conc. limit of 6.7 mg/L

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Annual Nutrient Mass Loadings

Parameter	NPDES Limit (lbs/Year)	Effluent Mass Load (lbs/Year)	Mass Load Credit (lbs/year)
Total Nitrogen	101,997	43,187	58,810
Total Phosphorus	12,359	7,888	4,471

Hampden Township can sell TN &TP credits to other municipal WWTPs on the Nutrient Trading Market

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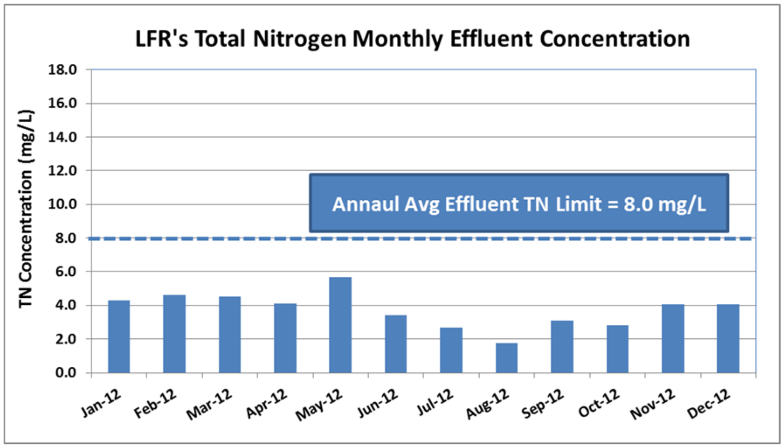
Stafford County Little Falls Run WWTF

LFR Nutrient Discharge Requirements

- Concentration-based limits:
  - Monthly average effluent limit of 2 mg/L TP
- Load-based limits at 4 MGD:
  - Annual WLA of 97,458 lb/yr TN (8 mg/L)
  - Annual WLA of 7,309 lb/yr TP (0.6 mg/L)

Little Falls Run Performance



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Stafford County Aquia WWTP

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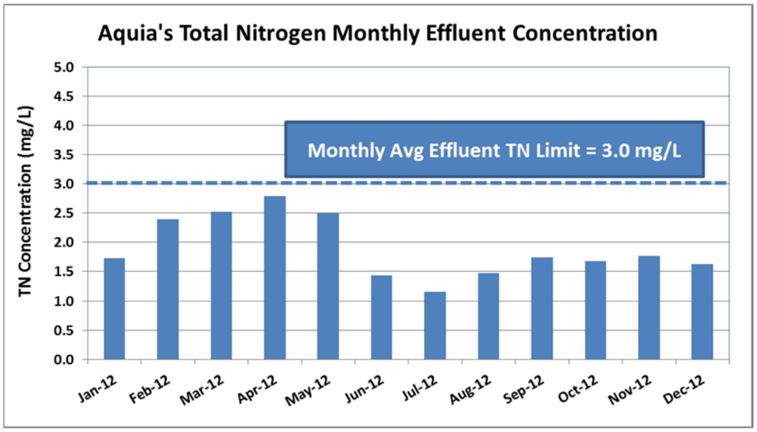
Aquia Plant Performance



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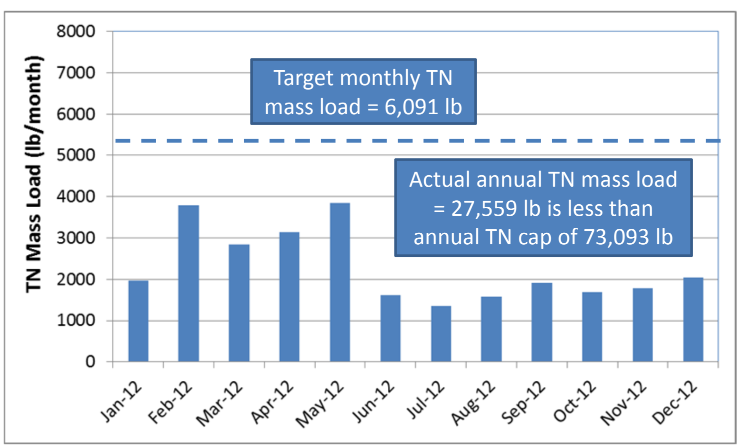
Aquia's Monthly TN Mass Load



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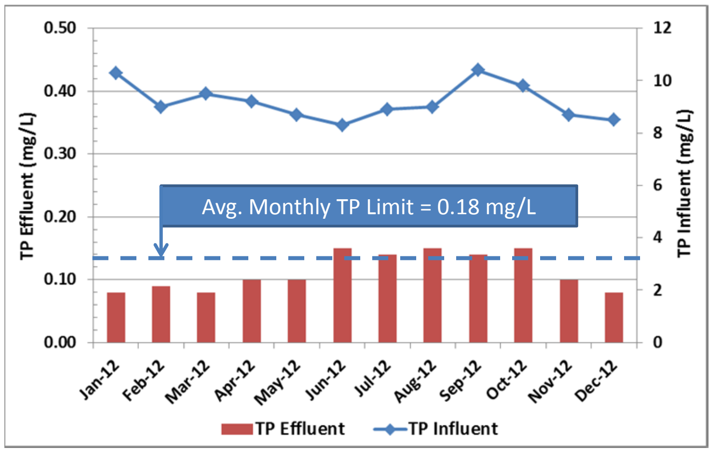
Aquia Total Phosphorus Removal



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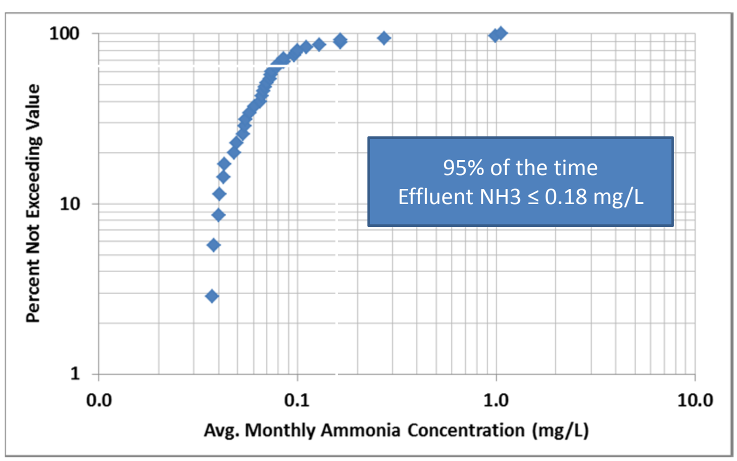
Aquia Process Reliability NH3 Removal



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Green County Sugarcreek WRRF

Green County Sugarcreek WRRF

NPDES Discharge Permit		
Parameter	Monthly Average Concentration (mg/L)	Annual Mass Loading (lbs/year)
CBOD	10	-
TSS	16	-
NH3 (5/1-9/30)	1.25	-
NH3 (10/1-4/30)	7.5	-
TP	1.0	74,679

Green County Sugarcreek WRRF

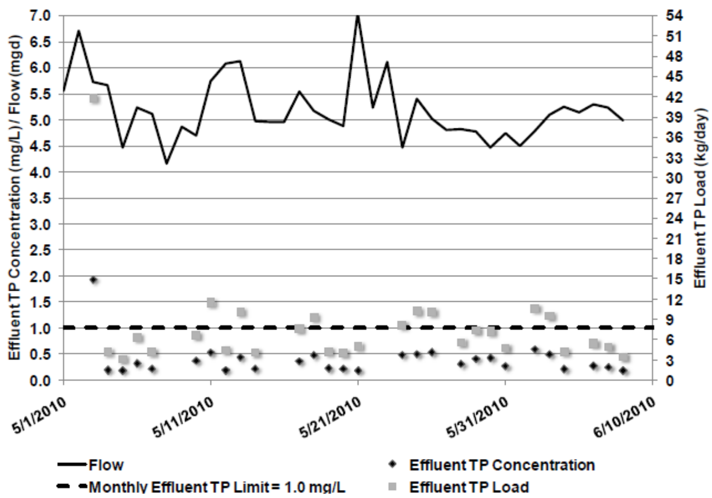
Design Parameters	
Design Flow	9.9 MGD
Number of CSR	Three Full Rotating Bridge Reactors
Volume (each)	2.0 MG
SRT	18 to 20 days
MLSS	2000 mg/L
F/M Ratio	0.07 – 0.1
Type of blowers	Two single-stage Turblex Centrifugal blowers

Green County Sugarcreek WRRF

Operating Parameters

Operating Parameter	Target
Max ORP Setpoint (switch from Oxic to Anoxic)	+100 mV
Min ORP Setpoint (switch from Oxic to Anaerobic)	-100 mV
Anaerobic timer Setpoint (switch from Anaerobic to Oxic)	40 min
DO Setpoint	2.2 mg/L

Green County Sugarcreek WRRF



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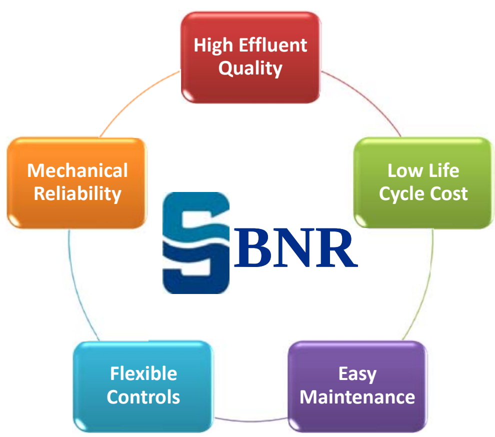
Benefits of Schreiber SBNR System



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Questions?

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