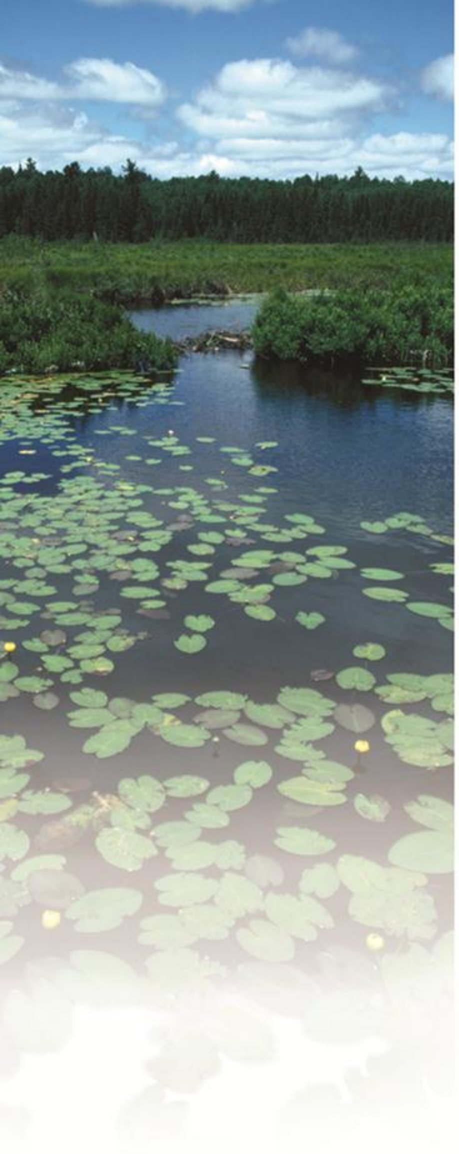

General Operational Considerations in Nutrient and Wet Weather Flow Management for Wastewater Treatment Facilities

Part II

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CH2MHILL

Ohio WEA Plant Operations Workshop
September 28, 2011

Presentation Outline

- Why Remove Nutrients?
- Overview of Wastewater Treatment
- Nutrient Removal Fundamentals
  - Phosphorus Removal

Part I

  - Nitrogen Removal
- Sustainability Considerations
- Design & Operational Considerations

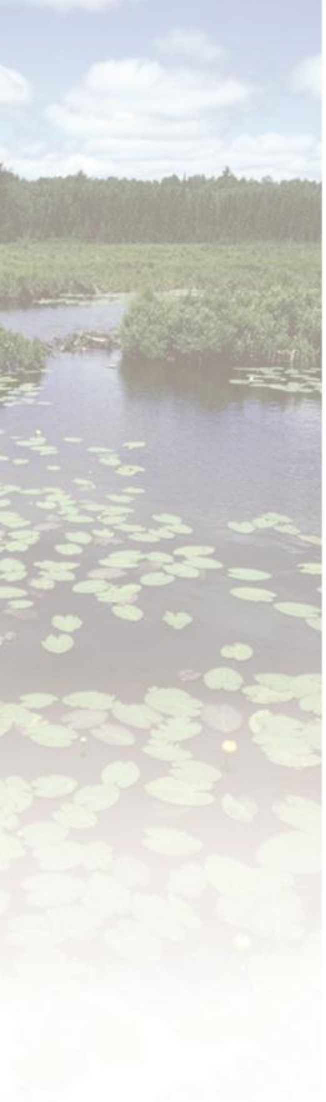
Part II

- Managing Wet Weather Flows in Nutrient Removal Facilities

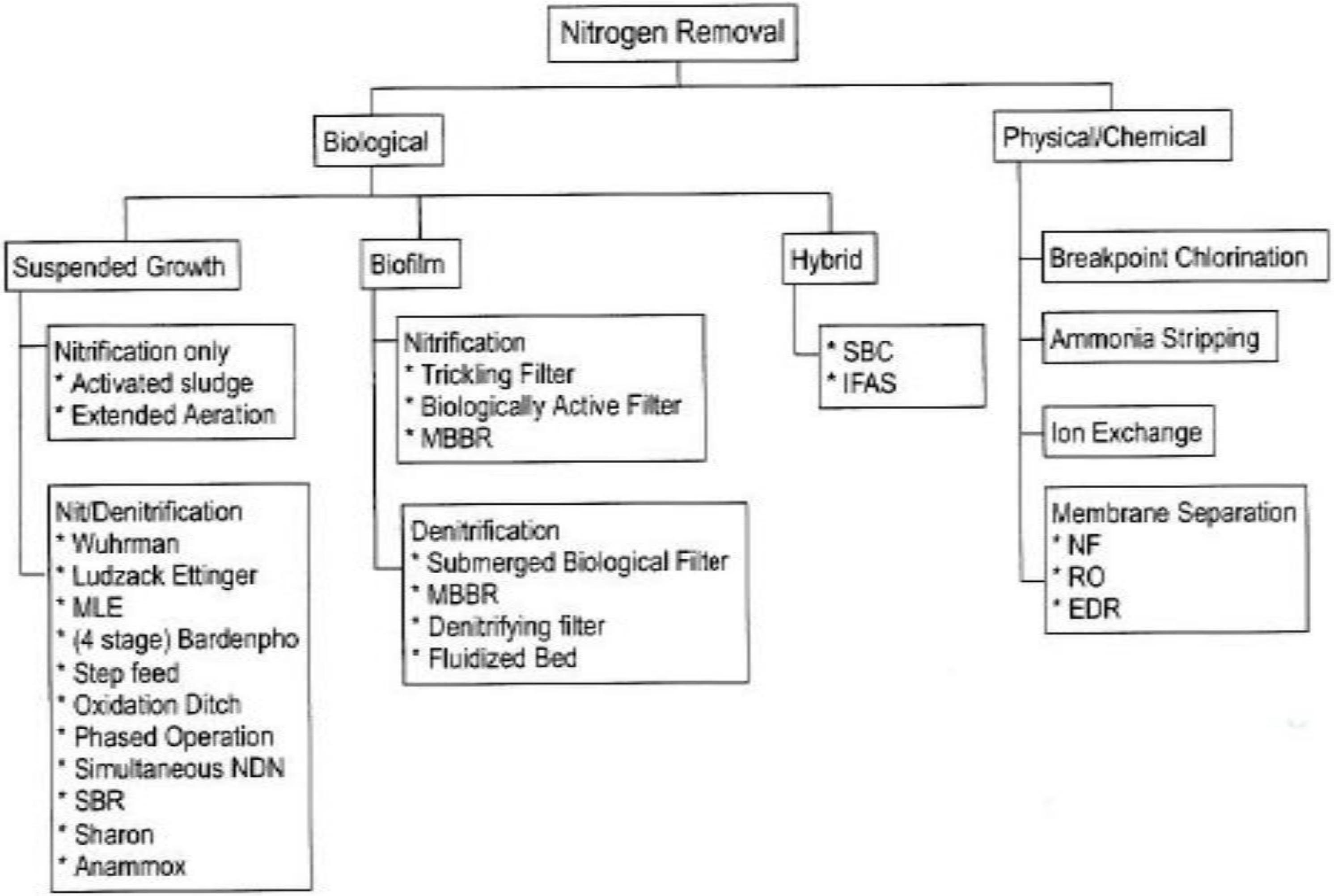
Part III

Presentation Outline

- Why Remove Nutrients?
- Overview of Wastewater Treatment
- **Nutrient Removal**
  - Phosphorus Removal
  - **Nitrogen Removal**
- **Sustainability Considerations**
- **Design & Operational Considerations**
- Managing Wet Weather Flows in Nutrient Removal Facilities

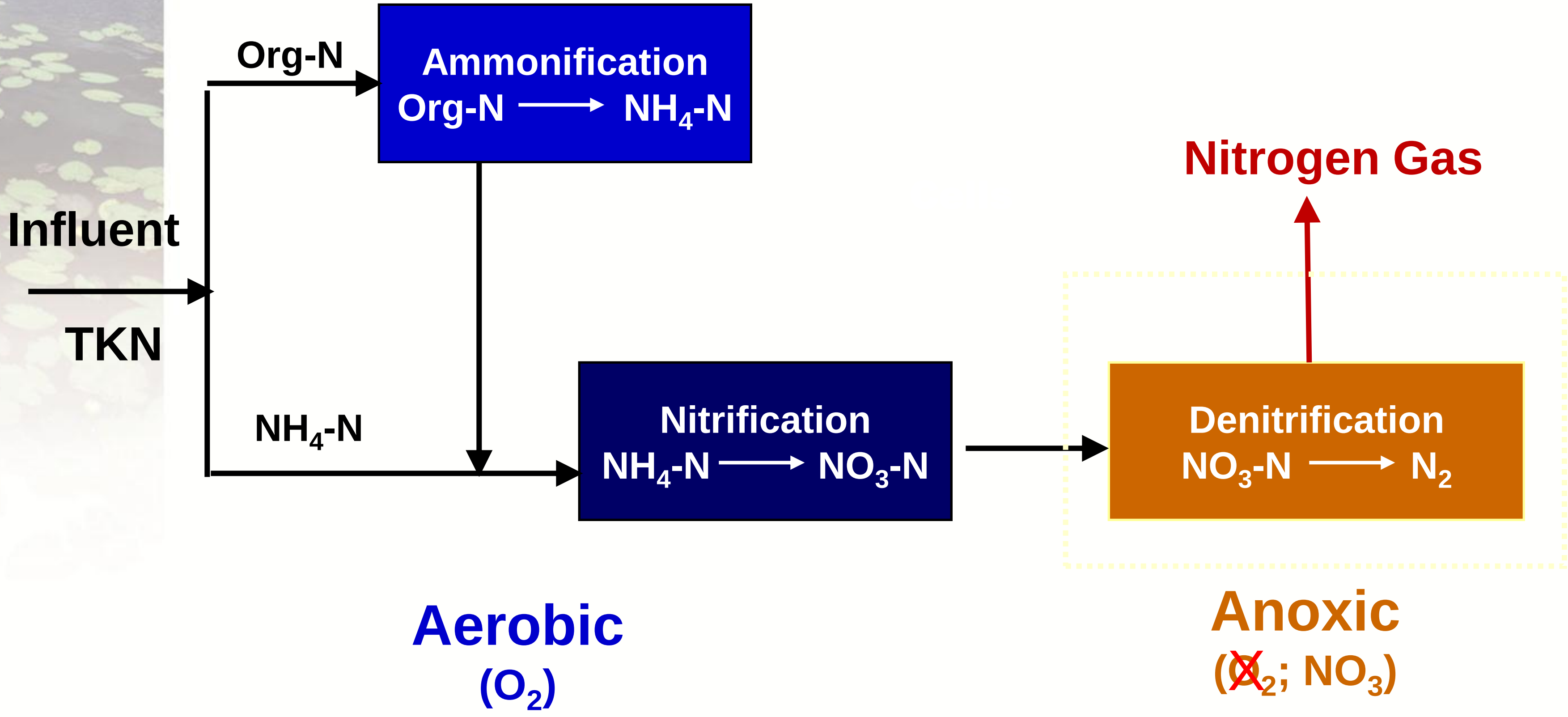


Nitrogen Removal Alternatives



- Nitrogen Removal
  - Biological
    - Suspended Growth
      - Nitrification only
        - * Activated sludge
        - * Extended Aeration
      - Nit/Denitrification
        - * Wuhrman
        - * Ludzack Ettinger
        - * MLE
        - * (4 stage) Bardenpho
        - * Step feed
        - * Oxidation Ditch
        - * Phased Operation
        - * Simultaneous NDN
        - * SBR
        - * Sharon
        - * Anammox
    - Biofilm
      - Nitrification
        - * Trickling Filter
        - * Biologically Active Filter
        - * MBBR
      - Denitrification
        - * Submerged Biological Filter
        - * MBBR
        - * Denitrifying filter
        - * Fluidized Bed
    - Hybrid
      - * SBC
      - * IFAS
  - Physical/Chemical
    - Breakpoint Chlorination
    - Ammonia Stripping
    - Ion Exchange
    - Membrane Separation
      - * NF
      - * RO
      - * EDR

Nitrogen Removal Processes



Influent

TKN

Org-N

NH$_4$-N

Ammonification
Org-N $\longrightarrow$ NH$_4$-N

Nitrification
NH$_4$-N $\longrightarrow$ NO$_3$-N

Denitrification
NO$_3$-N $\longrightarrow$ N$_2$

Nitrogen Gas

Aerobic
(O$_2$)

Anoxic
$(\cancel{O_2}; NO_3)$

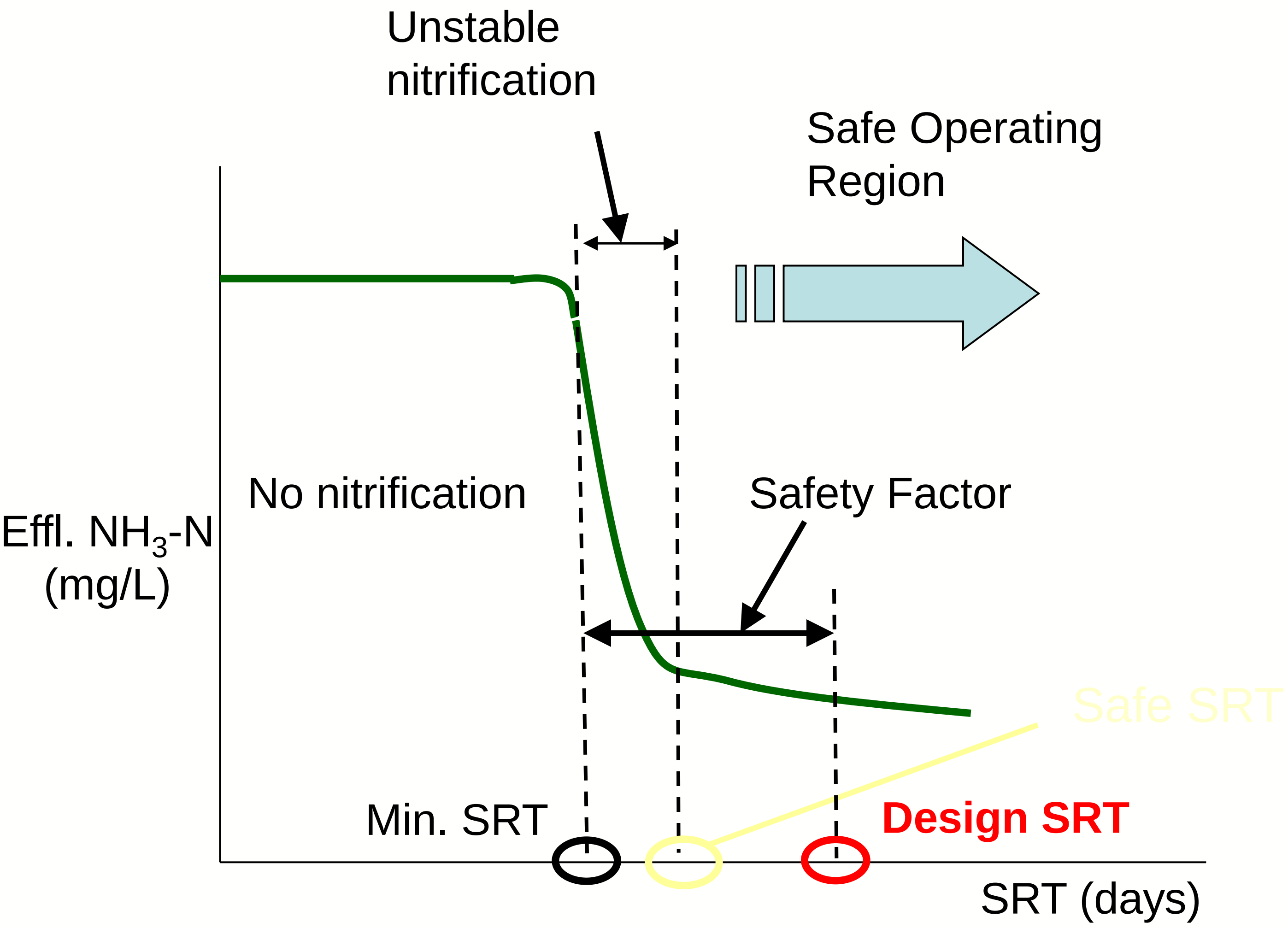
Nitrification

- Mediated by *Autotrophs*
- Conversion (oxidation) of ammonia to nitrate
- Does not result in significant nitrogen removal

Factors that impact nitrification

- Solids Retention Time (SRT)
- pH (Optimum: 6.5 - 8.0)
- DO (Optimum: 1.0 – 2.0 mg/L)
- Absence of inhibitory compounds
- Recycle load

Adequate SRT is Crucial for Reliable Nitrification



Unstable nitrification

Safe Operating Region

No nitrification

Safety Factor

Effl. NH_3-N (mg/L)

Safe SRT

Min. SRT

Design SRT

SRT (days)

Denitrification

- Denitrification: Conversion (reduction) of nitrate to nitrogen gas

$$NO_3 \rightarrow N_2\ (g)$$

- Facultative heterotrophic organisms
- Results in nitrogen removal

Factors impacting denitrification

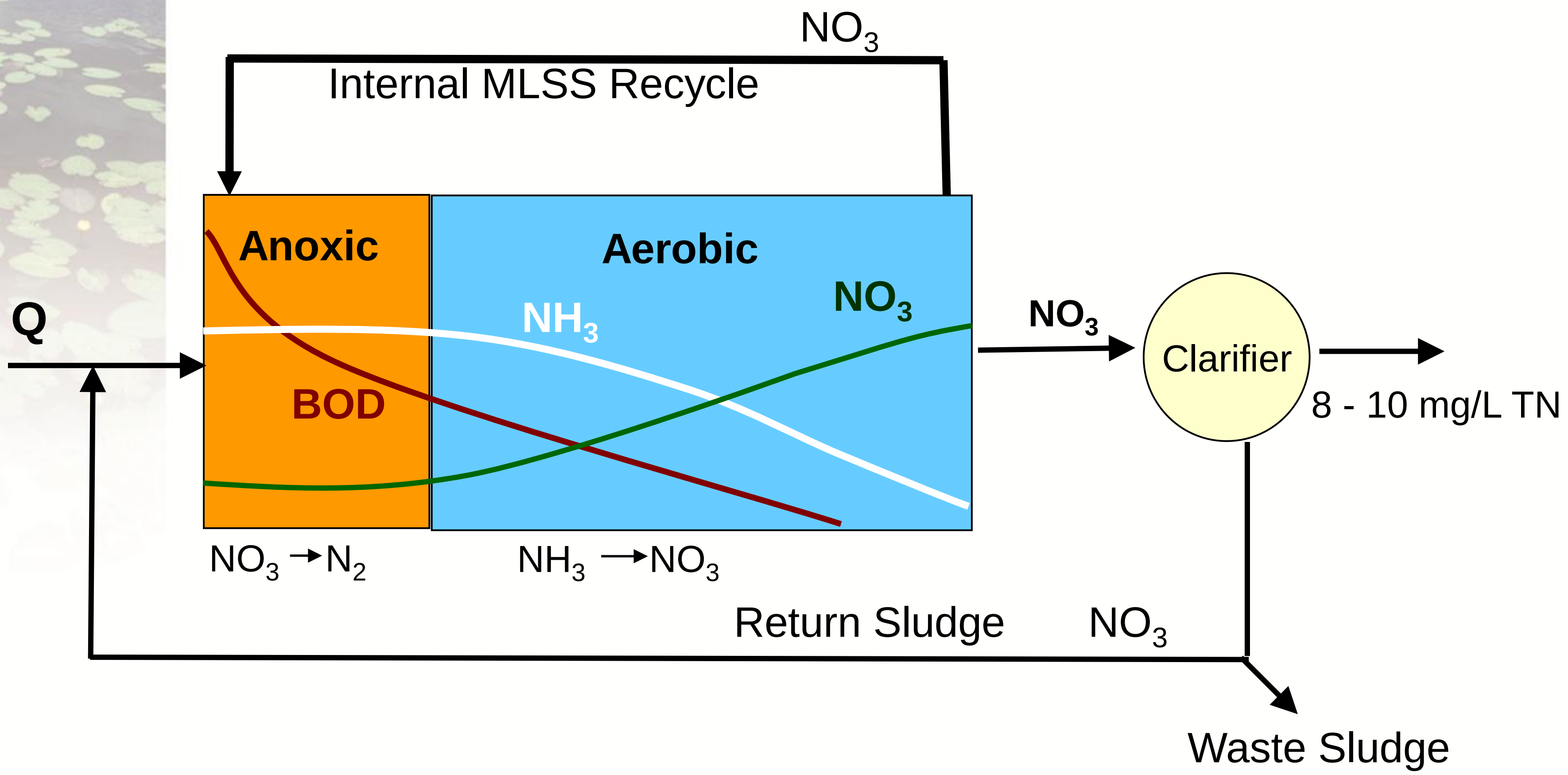
- Anoxic condition (Sufficient NO_3)
- Carbon source
- Adequate anoxic SRT
- Temperature

Nitrification vs. Denitrification

Factor	Nitrification	Denitrification
Environment	Aerobic	Anoxic
Oxygen source (Electron Acceptor)	Dissolved oxygen (DO)	Combined Oxygen (NO_3)
Type of Organism	Autotrophs	Heterotrophs
Energy (food) source Electron Donner)	Ammonia-N	Organic Matter
Carbon Source	Organic Matter	Inorganic (CO_2)
Oxygen	Demand (4.6 lb O_2 / lb NH_4 oxidized)	Credit (2.9 lb O_2 / lb NO_3 reduced)
Alkalinity (as $CaCO_3$)	Consumed (7.1 lb /lb NH_4 oxidized)	Produced (3.6 lb /lb NO_3 reduced)

How is Nitrogen Removal Achieved in Practice?

Modified Ludzack-Ettinger (MLE) Process



NO_3

Internal MLSS Recycle

Q

Anoxic

BOD

Aerobic

NH_3

NO_3

NO_3

Clarifier

8 - 10 mg/L TN

$NO_3 \rightarrow N_2$

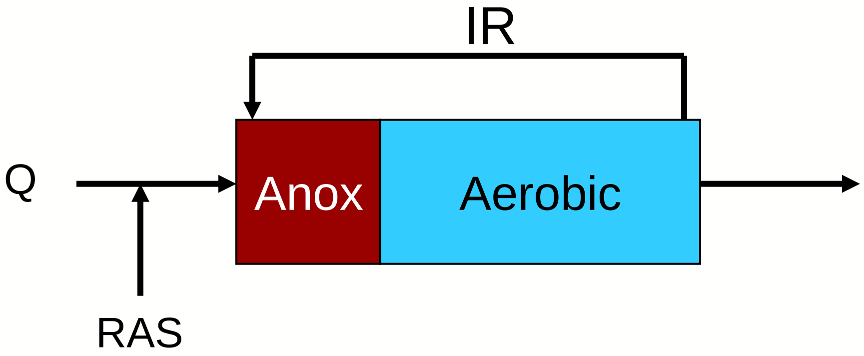
$NH_3 \longrightarrow NO_3$

Return Sludge NO_3

Waste Sludge

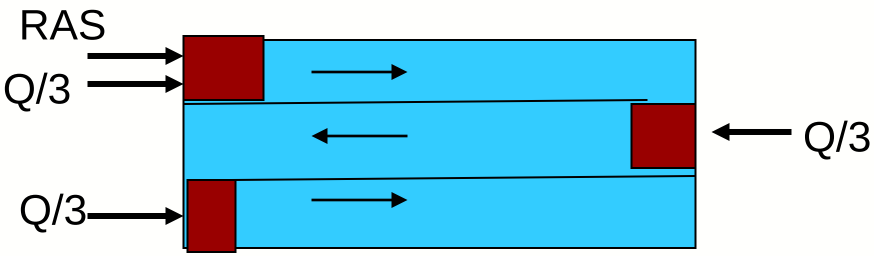
Nitrogen Removal Capability of Various Processes

MLE Process
TN = 8 - 10 mg/L



IR
Q
Anox
Aerobic
RAS

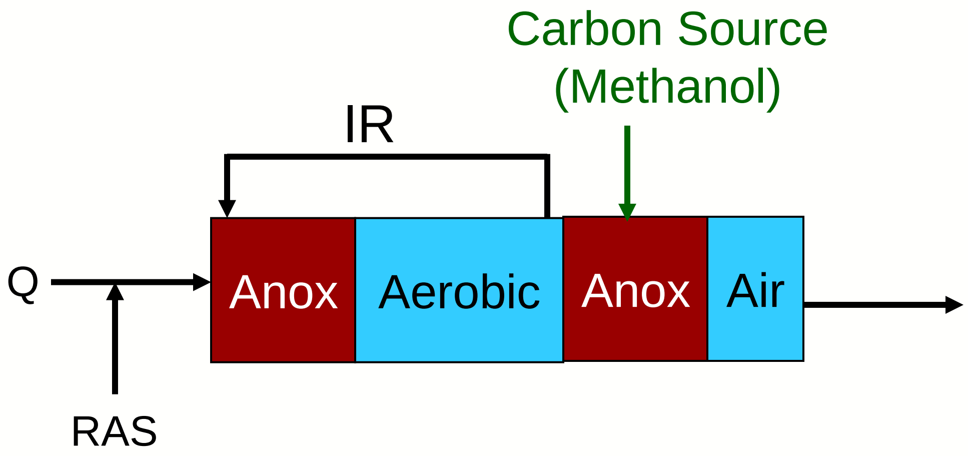
Step-Feed
TN = 8-10 mg/L



RAS
Q/3
Q/3
Q/3

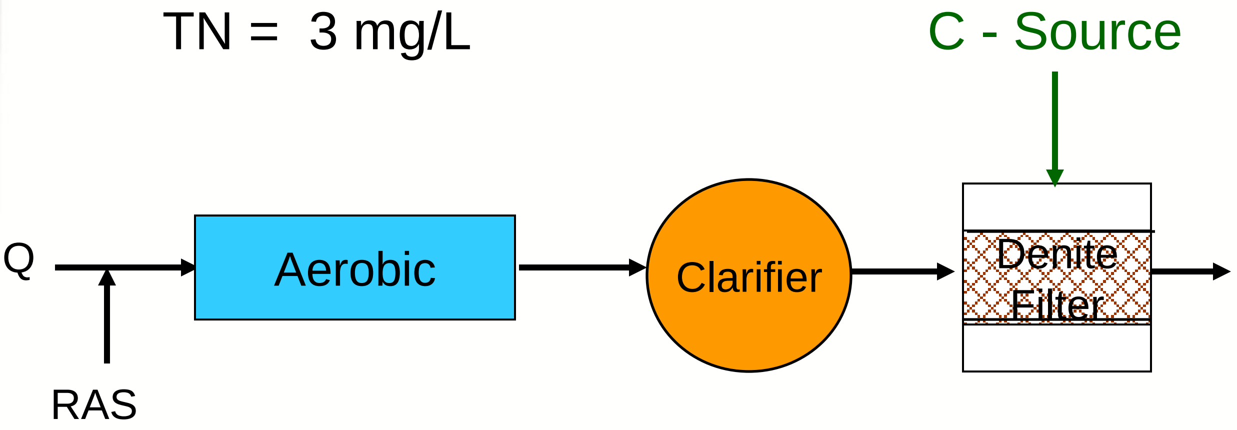
Nitrogen Removal Capability of Various Processes

4-Stage Bardenpho
TN = 3 mg/L



Carbon Source
(Methanol)
IR
Q
Anox
Aerobic
Anox
Air
RAS

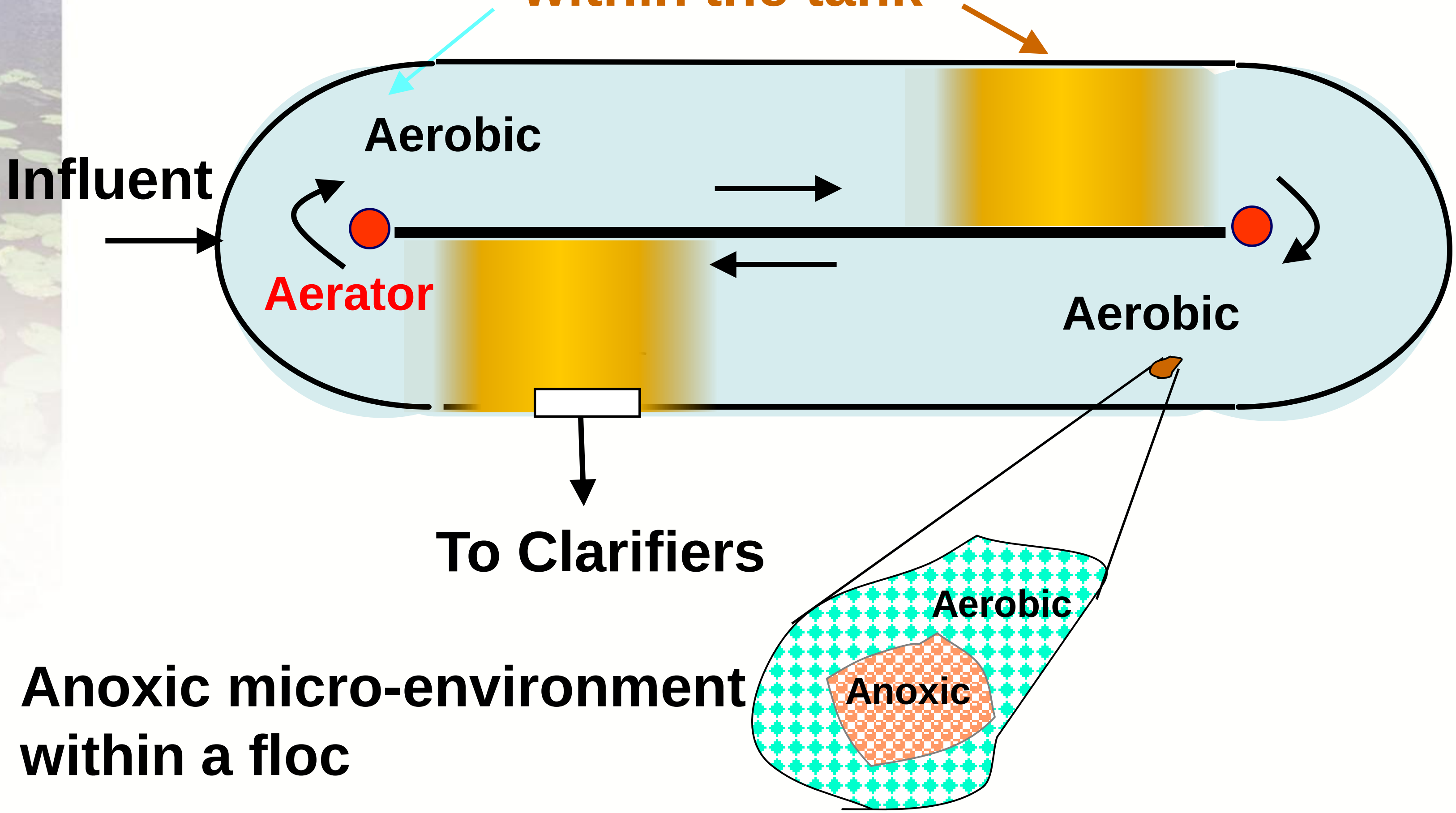
Denitrification Filter
TN = 3 mg/L



C - Source
Q
Aerobic
Clarifier
Denite
Filter
RAS

Informal Anoxic Zones Cause Simultaneous Nitrification/Denitrification

Anoxic macro-environment within the tank



Anoxic micro-environment within a floc

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Striking a Balance

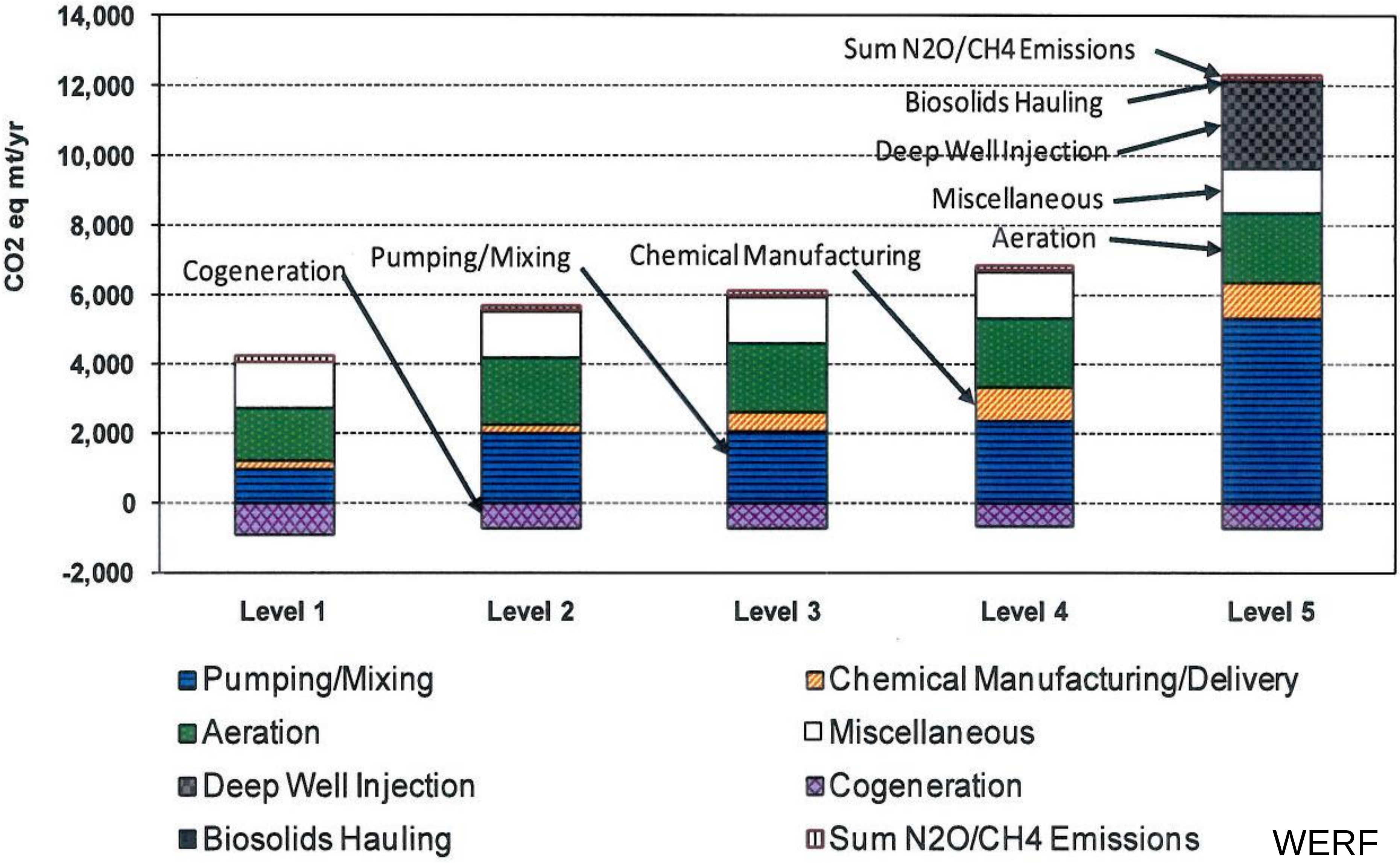
- Removing nutrients to very low levels:
  - Incur significant capital and O&M costs
  - Have larger carbon footprint
    - Increased use of chemicals & energy
    - Increased GHG emissions
  - Can result in lower ‘net’ environmental benefits - meaningless

Summary of WERF Sustainability Study

- 10 mgd plant with following effluent objectives

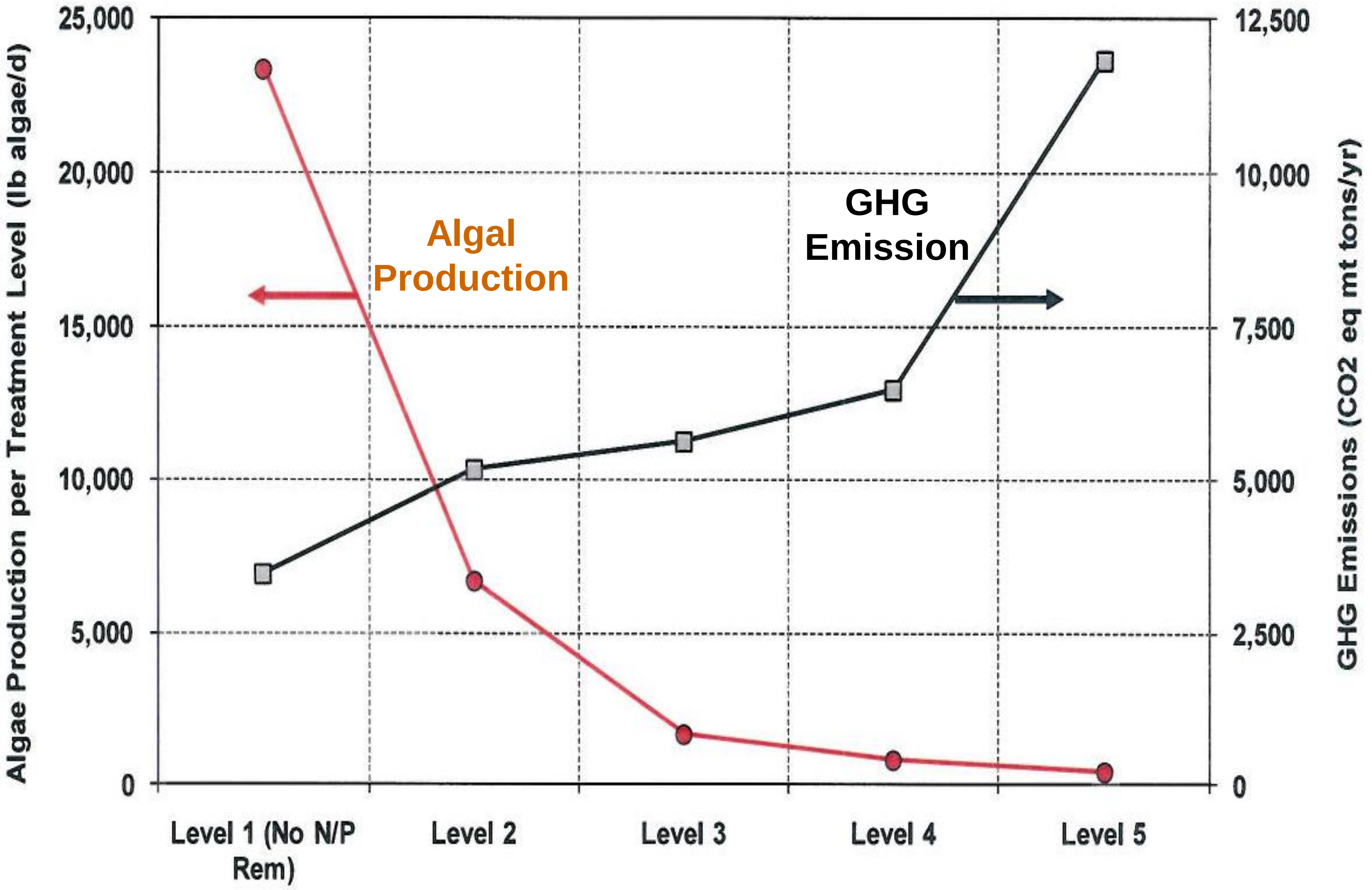
Level	BOD (mg/L)	TSS (mg/L)	TN (mg/L)	TP (mg/L)
1 (Secondary)	**30**	**30**	**-**	**-**
2	**-**	**-**	**8**	**1**
3	**-**	**-**	**4-8**	**0.1 – 0.3**
4	**-**	**-**	**3**	**0.1**
5	**-**	**-**	**<2**	**<0.05**

Total GHG Emission Burden



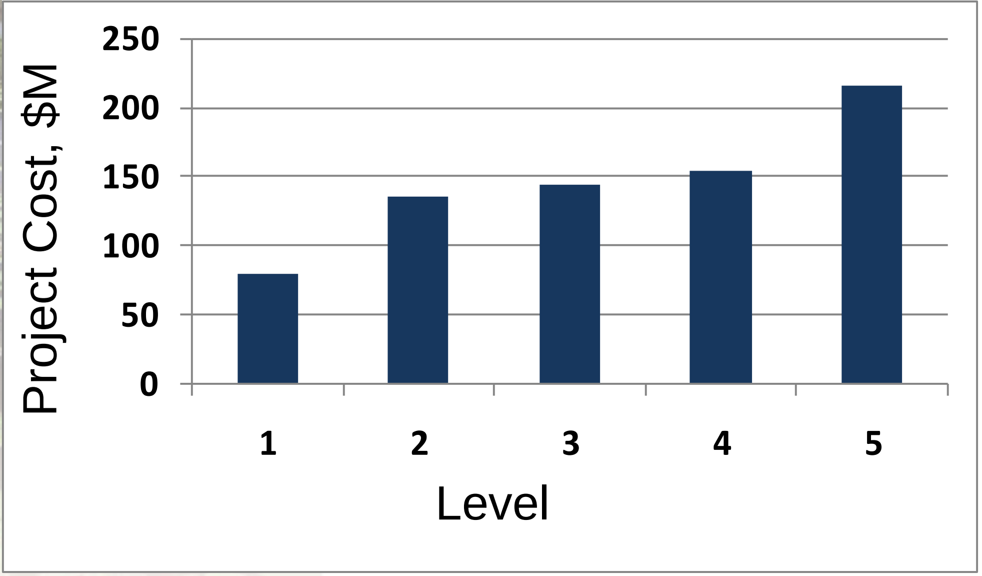
WERF

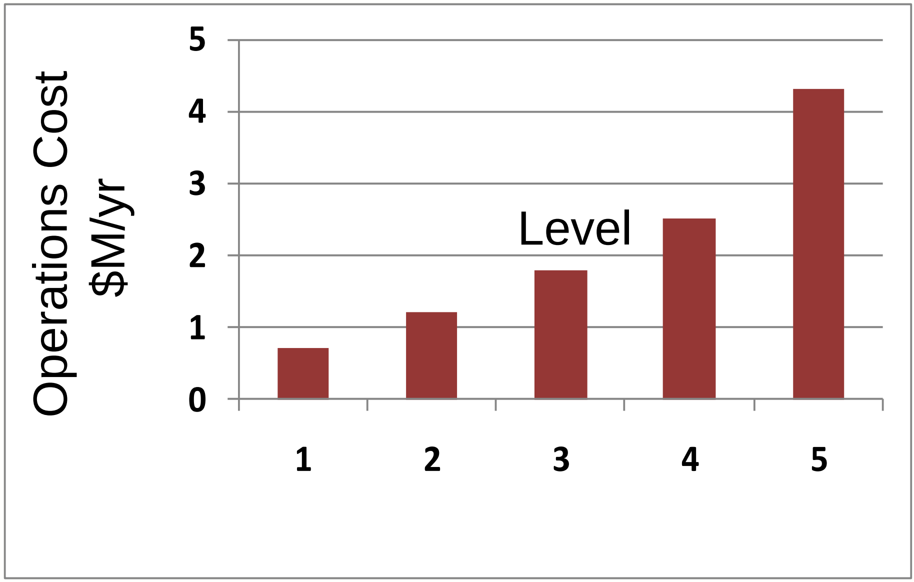
GHGs versus Algal Production



WERF

Capital & Operations Costs



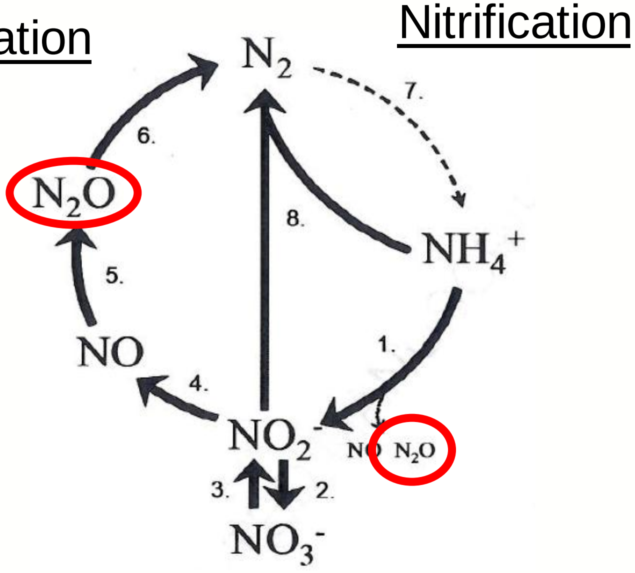


Excludes labor, maintenance, & membrane replacement costs

WERF

New Information on Nitrous Oxide Generation at WWTPs

- N_2O potentially produced during nitrification & always during denitrification.
- Potentially more during nitrification. Occurs due to:
  - Intermittent or incomplete nitrification
  - Repeated switching between aerobic & anoxic + high DO & NH_3-N
- But lower N_2O production in ox. ditches due to more uniform spatial DO profile



WERF

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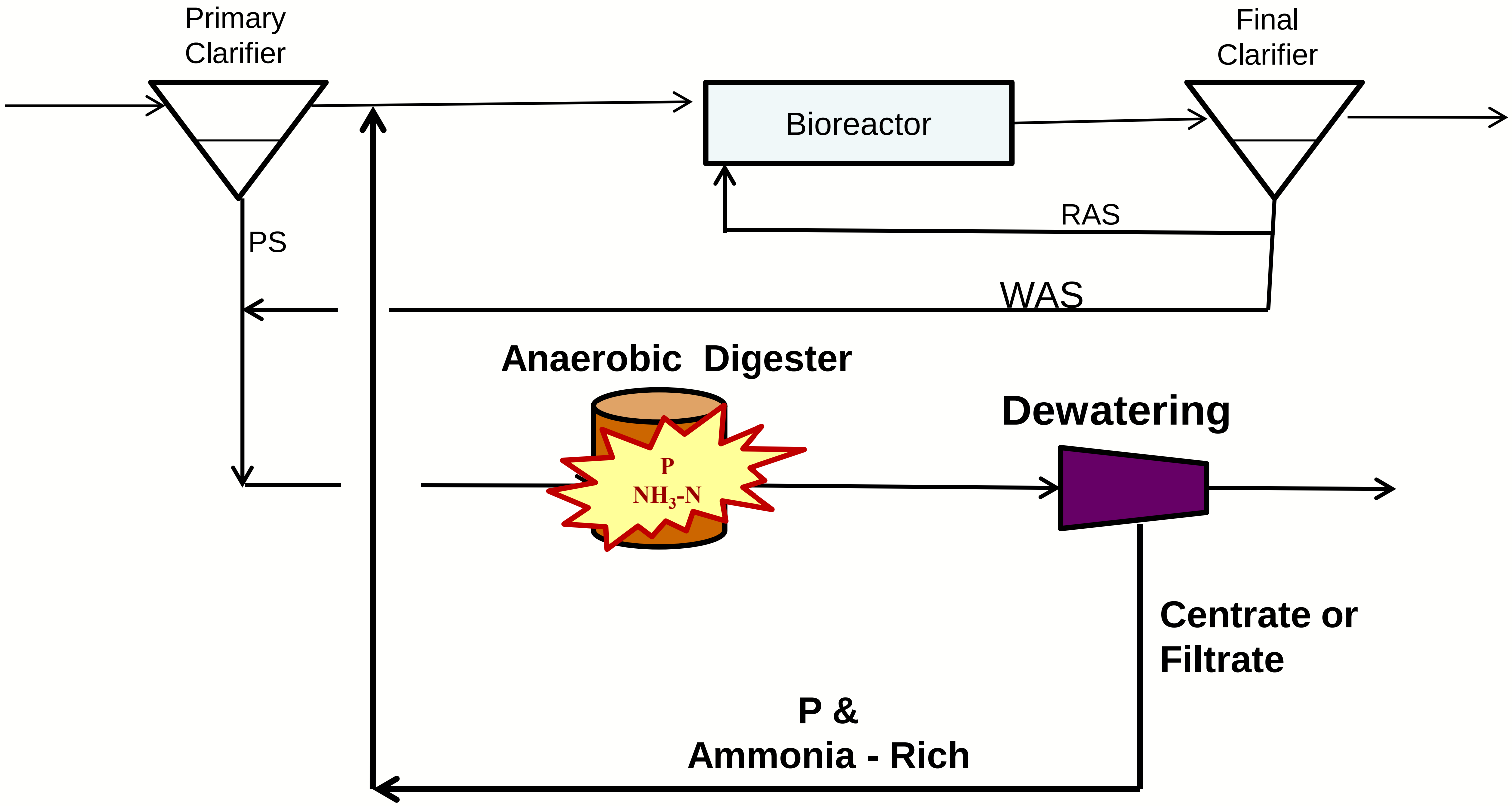
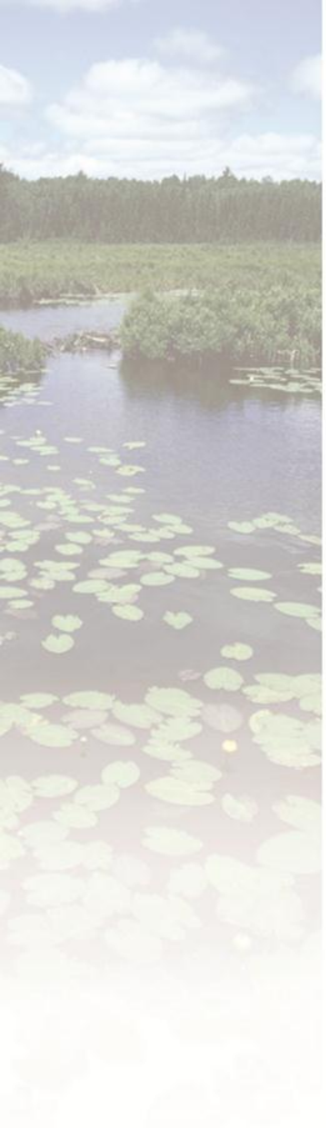
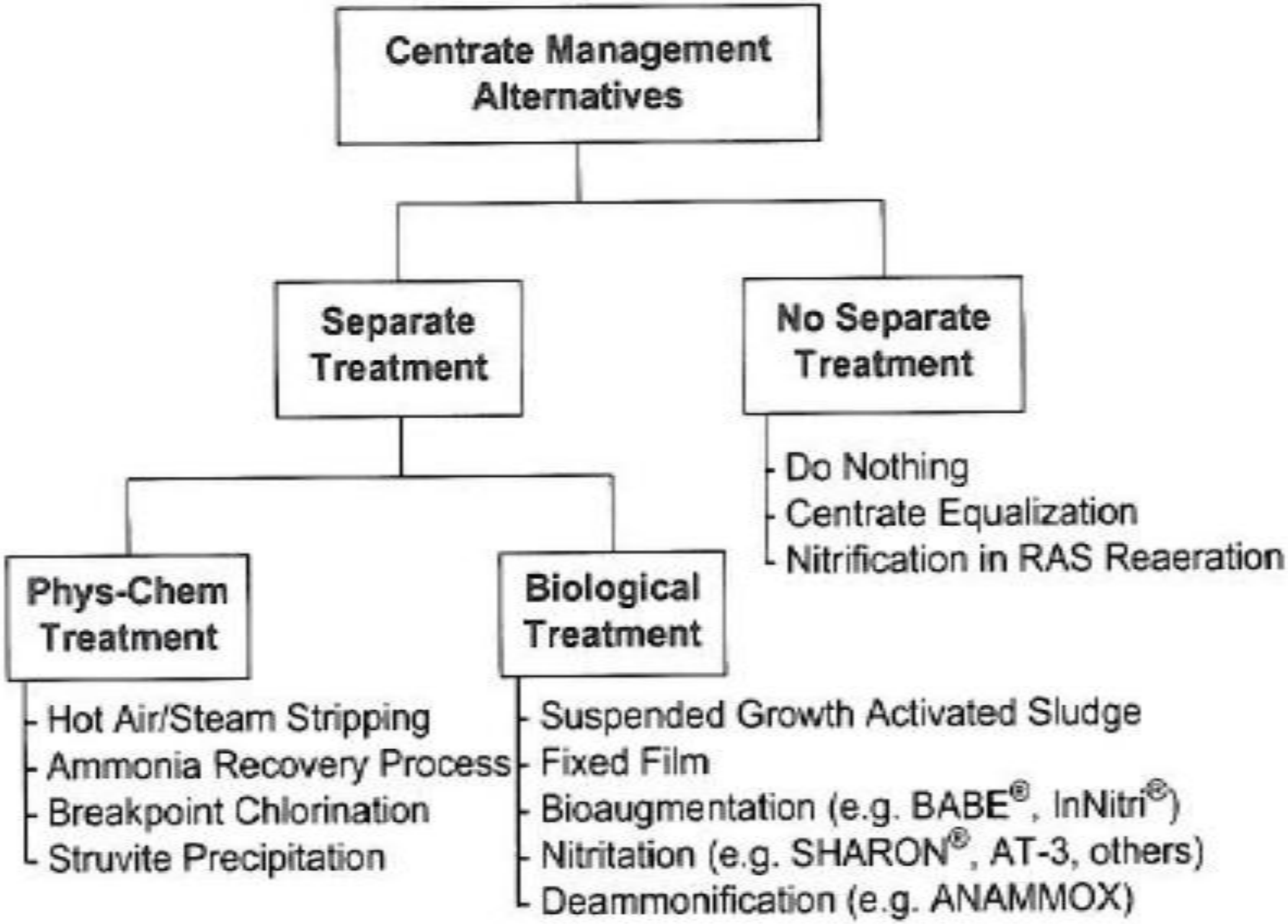
Recycle Management is Crucial for Meeting TP & TN Limits



- Anaerobic digestion releases P & ammonia.
- Dewatering centrate/filtrate can impose additional load on the main process

Sidestream Management Alternatives





Centrate Management Alternatives

Separate Treatment

No Separate Treatment
- Do Nothing
- Centrate Equalization
- Nitrification in RAS Reaeration

Phys-Chem Treatment
- Hot Air/Steam Stripping
- Ammonia Recovery Process
- Breakpoint Chlorination
- Struvite Precipitation

Biological Treatment
- Suspended Growth Activated Sludge
- Fixed Film
- Bioaugmentation (e.g. BABE®, InNitri®)
- Nitritation (e.g. SHARON®, AT-3, others)
- Deammonification (e.g. ANAMMOX)

The Dreaded Foam

It's a balancing act!

Most Common Filaments in Wastewater Treatment in the US

Dominant Filament	Percentage of the Plants
Nocardioforms	31
Type 1701*	29
Type 021N *	19
Type 0041*	16
Thiotrix spp	12
S. natans	12
Microthrix parvicella *	10

525 samples from 270 plants
* Also commonly found in other countries

Jenkins et al & WERF

Factors Impacting Filamentous Growth

- Wastewater Characteristics
- Process Configuration (design)
- Operational Conditions

Wastewater Characteristics Associated with Some of the Common Filaments

Dominant Filament	rbCOD	sbCOD	Sulfide	Nutrient Deficiency
Nocardioforms	√	√		
Type 1701*	√			
Type 021N *	√		√	√ (N)
Type 0041*		√		
Thiotrix spp	√		√	√ (N)
S. natans	√			√ (P)
Microthrix parvicella *		√		

rbCOD – Rapidly Biodegradable COD (VFAs)
sbCOD – Slowly Biodegradable COD (LCVA)

Summary of Operational Conditions Associated with Some of the Common Filaments

Dominant Filament	Low DO	Long MCRT	Modest MCRT	Short MCRT
Nocardioforms		√	√	
Type 1701*	√		√	
Type 021N *		√	√	
Type 0041*		√		
Thiotrix spp			√	√
S. natans	√		√	√
Microthrix parvicella *	√	√		

WERF

More Design & Operational Considerations

- General design approach:
  - Influent characteristics
  - Effluent limits
  - The box in-between
  - SRT is paramount

- General process optimization approach:
  - First, nitrification & denitrification
  - Then, EBPR; add supplemental chemical, if required
- Judicious use of automation
- Data is not information

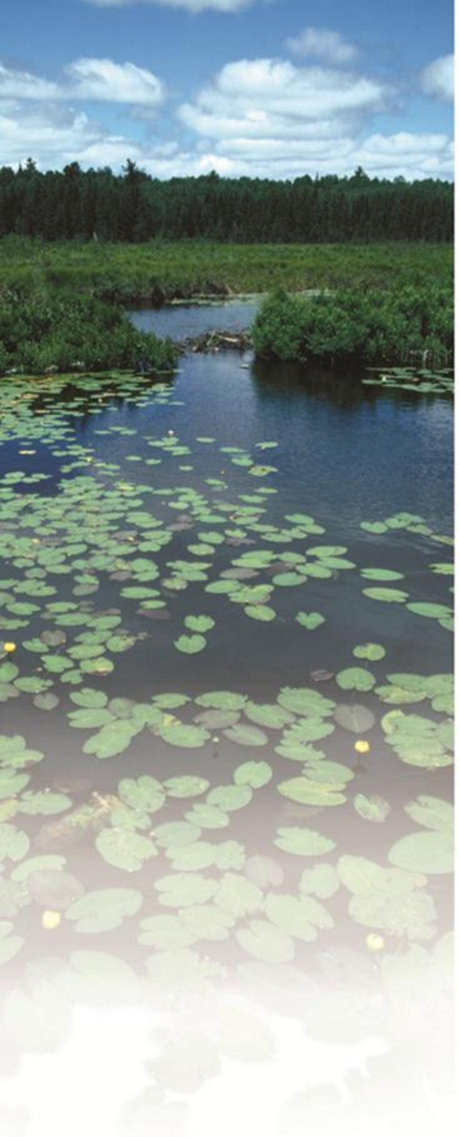
More Design & Operational Considerations

- Even flow splitting
  - ➢ Underloaded units often can not compensate for overloaded units
- Provision to control problem children of the activated sludge system - filaments
- Keep the bugs in the aeration basin- maintain low sludge blanket
- Maintain close as possible to SRT required for process reliability.
- It takes two to tango!
  - ➢ Designers: provide operational flexibility.
  - ➢ Operators: use operational flexibility provided.

Life with Nutrient Removal Requirements Will be more “Exciting”

- Little time left for crossword puzzles and/or web surfing!
- Dust your microbiology books
- Buy lunch for your lab tech: they will be running many more tests
- Provide tighter DO control for both N & P removal systems
- High flow conditions (RAS; IMLR) often result in higher DO; keep as low as possible
- DO & Nitrates are the enemy in BioP anaerobic zones
- Readily biodegradable carbon sources are your friend in unaerated zones
- Consider early retirement….

Questions?



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