# Nutrient Reduction

## Nitrogen & Phosphorus Removal

## Using Existing Wastewater Treatment Equipment Differently

## Part 1 of 4

Grant Weaver, PE & wastewater operator

Fleming Training Center

Murfreesboro, Tennessee

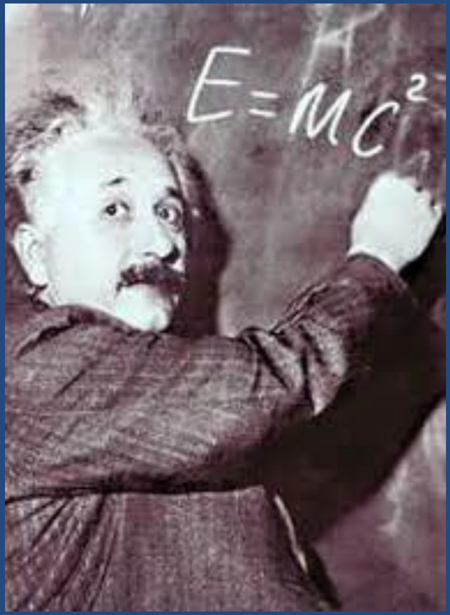
November 13, 2014

THE WATER PLANET COMPANY

www.cleanwaterops.com

*Nutrient Reduction*

*N&P Removal using existing equipment*




**What Might Optimization do for YOU?**

Compare & Contrast w/ Facility Upgrades

Case Studies – Overview

**Science & Technology**

N&P Removal for Operators

Technology for Operators

**Case Studies**

Nitrogen Removal

Phosphorus Removal

# *Operations First: an unconventional approach to permit compliance*

Conventional Thinking:

Wastewater treatment plants require Facility Upgrades to meet new permit limits.

Operations First Approach:

Most any treatment plant can be ***operated differently*** to provide better treatment, generally at lower cost.

*Traditional Approach*



*As an analogy, let's assume ...*

*I have an eight year old car that squeaks and sputters.*
*I'm looking for advice.*

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*I have an eight year old car that squeaks and sputters. I'm looking for advice.*

# *Optimize First Approach*


*The Right Equipment?*

*Empowered, Effective Operations?*

*Kitchen?*

*Chef?*

*Golf clubs?*

*Golfer?*

*Car …*


*… and …*


*Driver!*

*Facility Upgrade?*

*Best Possible Operations!*

## *The Big Picture Story*

Why do municipalities have wastewater treatment plants?

What are the top job responsibilities for plant staff?

- Clean Environment
  - Water
  - Energy Efficiency & Sustainability
- Community Development

Clean Environment:

- The cleaner the water, the better.
- The more sustainable, the better.

Community Development:

- The cheaper, the better.

## *The Good News is this …*

Don’t much need to balance environmental considerations and cost

- because -

Most optimization efforts

- Reduce Operational Costs (lower O&M)
- Reduce Scope of Facility Upgrades (lower capital costs)
- Improve Sustainability
  - Less Chemicals
  - Less Electricity
  - Less Sludge Production

## *Making the Treatment Plant a Good Home for the Bacteria that Live there*


By understanding what makes bacteria thrive…

Knowing a bit about technology…

And, being willing to experiment…

It isn't all that difficult to make any treatment plant work better: BOD, TSS, Nitrogen & Phosphorus Removal.

And, at little to no cost: monetary (capital, O&M) or environment.

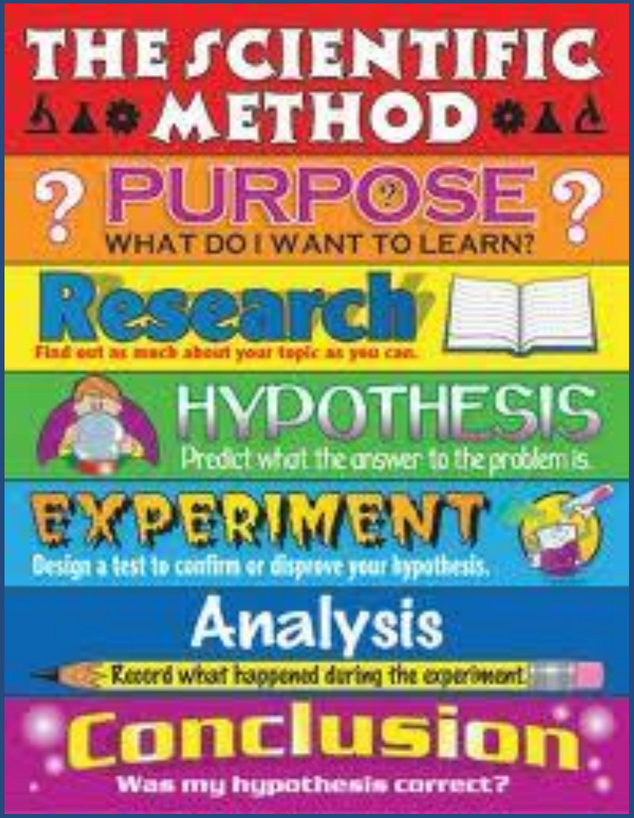
*July 2014 TPO Magazine*
*"Judge this Book by its Cover" … Willis, Texas*

*$1 Million O&M Savings*
*Nutrient Removal*

Westfield, Massachusetts

Montague, Massachusetts

Palmer, Massachusetts



## *Westfield, Massachusetts (population 41,000)*
## *6.1 MGD*

New Phosphorus Limits:
- Old limit.  Summer only: 1.0 mg/L
- New limits.  Summer: 0.46 mg/L   -and-  Winter: 1.0 mg/L

Chemical treatment only:
- Poly-aluminum chloride
- Sodium aluminate

Biological treatment supplemented with sodium aluminate:
- Chemical Savings
  - Sodium aluminate - $130,000/yr
  - Caustic soda - $40,000/yr
- Sludge Disposal - $175,000/yr
- Electricity - $20,000/yr

**O&M Savings: $365,000 per year**

*Montague, Massachusetts (population 8,500)*
*1.8 MGD*

Cost-Effective Operations of 1.8 MGD wastewater treatment plant

- $385,000/yr additional revenues from trucked-in waste
- $250,000/yr sludge disposal savings
- Electrical savings: 40 HP vs 100 HP blower

Sustainable Nutrient Removal by Changing Operations

- $75,000 vs. $4.5 million upgrade
- t-N: 5 mg/L
- t-P: 0.75 mg/L

Sludge Reduction

- Mixed liquor volatile solids: 20-25%

**O&M Savings: $635,000 per year**

## *Palmer, Massachusetts (population 12,000)*
## *5.6 MGD*

Experimentation with Nitrogen removal and biological Phosphorus removal

Raise mixed liquor concentration from 2000 mg/L to 3500 mg/L
Use two of four aeration tanks: cycle air on and off
Use one of two primary clarifiers as fermenter

Sludge disposal savings - $50,000/yr
Chemical savings - $15,000/yr
Increased electrical costs - $15,000/yr

**O&M Savings: $50,000 per year**

## *N&P Removal and $1,000,000 per year Operations & Maintenance Cost Savings*

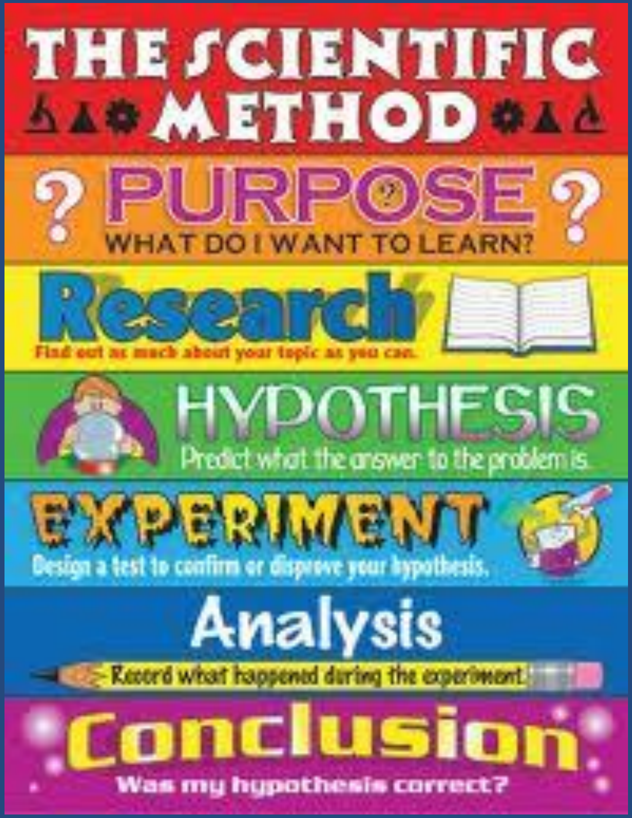
Combined Population: 61,500
Total Design Capacity: 13.5 MGD

| | total-N (mg/L) | total-P (mg/L) |
|---|---|---|
| Westfield, Massachusetts | | 4.0/0.5 to 1.0/0.4 |
| Montague, Massachusetts | 10 to 5 | 3.0 to 0.8 |
| Palmer, Massachusetts | 20 to 6 | 0.8 |

**O&M Cost Savings**

| | |
|---|---|
| Westfield, MA | $365,000/yr |
| Montague, MA | $635,000/yr |
| Palmer, MA | $50,000/yr |
| | $1,050,000/yr |

*$100 Million Facility Upgrade Savings*
*Nutrient Removal*




Amherst, Massachusetts

Keene, New Hampshire

Plainfield, Connecticut

## *Amherst, Massachusetts (population 38,000)*
## *7.2 MGD*

New Nitrogen Limit: 546.5 pounds/day, approximately 15 mg/L

2008 BioWin modeling results:

> *"The existing facility has half of the necessary volume at the current flows ...*
> *... there are no operational or minor modifications/retrofits that could be implemented at this facility to consistently achieve nitrogen removal. "*

Instead, by cycling air on and off, the facility is meeting its limit.

Facility Upgrade cost estimate: $48,000,000
Cost of compliance . . . . . . . . . . . . $100,000

**Facility Upgrade Savings: $47,000,000+**

*Keene, New Hampshire (population 23,000)*
*6.0 MGD*

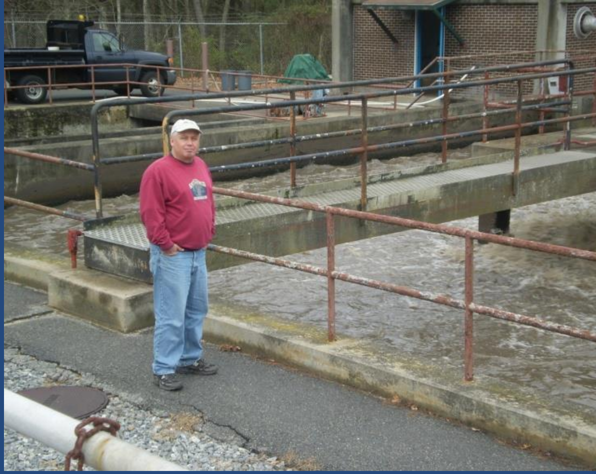
New Phosphorus Limit: 0.2 mg/L

BioWin modeling determined new equipment needed.

Instead, by fermenting wastewater in an existing tank, biological phosphorus removal has cut chemical usage in half while meeting a restrictive effluent limit.

Facility Upgrade budget: $16,000,000
Revised project . . . . . . . . . $4,500,000

**Facility Upgrade Savings: $11,000,000+**



## *Plainfield, Connecticut (population 15,000)*
## *1.5 MGD (two plants)*

Nitrogen Targets: ~6 mg/L
Phosphorus Limit for Village Plant: 0.7 mg/L

Facility Plan: Build one new plant and demolish existing facilities.

Instead, a 2-year optimization effort and $10,000 in equipment …
improved TSS & BOD removal, 50% less nitrogen & 75% less phosphorus at Village Plant

Facility Plan Proposal: $55,000,000
New Facility Upgrade: $6,000,000

**Facility Upgrade Savings: $49,000,000**

## *N&P Removal with $100 million Facility Upgrade savings*

Combined Population: 76,000
Total Design Capacity: 14.7 MGD

| | total-N (mg/L) | total-P (mg/L) |
|---|---|---|
| Amherst, Massachusetts | 25 to 10 | |
| Keene, New Hampshire | | 3.0 to 0.2 |
| Plainfield, Connecticut | | |
| North Plant | 15 to 8 | |
| Village Plant | 20 to 8 | 3.0 to 0.8 |

**Facility Upgrade Savings**

| | |
|---|---|
| Amherst, MA | $47,000,000 |
| Keene, NH | $11,000,000 |
| Plainfield, CT | $49,000,000 |
| | **$107,000,000** |

# *A Preview of what Might be Possible at YOUR plant …*


Greater than 50% Nitrogen Reduction

Greater than 50% Phosphorus Reduction

Capital Cost: as little as ZERO

- No New Tanks

O&M: generally, a cost SAVINGS

- No Chemicals
- Less Electricity

Carbon Footprint: REDUCED

# *"Proven Technology"*
# *Facilities where this has been done*

*Amherst, Massachusetts*
*Chinook , Montana*
*Colchester-East Hampton, Connecticut*
*Columbia Falls,  Montana*
*Conrad, Montana*
*East Haddam, Connecticut*
*East Helena, Montana*
*Easthampton, Massachusetts*
*Farmington, Connecticut*
*Greenfield, Massachusetts*
*Keene, New Hampshire*
*Lolo, Montana*
*Manhattan, Montana*
*Montague, Massachusetts*
*Northfield, Massachusetts*
*Palmer, Massachusetts*
*Plainfield North, Connecticut*
*Plainfield Village, Connecticut*
*South Deerfield, Massachusetts*
*Suffield, Connecticut*
*Sunderland, Massachusetts*
*Upton, Massachusetts*
*Westfield, Massachusetts*

# *Nitrogen Removal without Facility Upgrades*

| | t-N Before | t-N After |
|---|---|---|
| Suffield, CT | 7 | 1 |
| Windsor Locks, CT | 7 | 5 |
| Conrad, MT | 26 | 5 |
| East Hampton, CT | 11 | 6 |
| Palmer, MA | 20 | 6 |
| Manhattan, MT | 11 | 7 |
| Montague, MA | 20 | 7 |
| Plainfield North, CT | 15 | 8 |
| Plainfield Village, CT | 20 | 8 |
| Farmington, CT | 12 | 8 |
| Amherst, MA | 25 | 10 |
| Chinook, MT | 25 | 13 |

*Phosphorus Removal without Facility Upgrades*

| | t-P Before | t-P After |
|---|---|---|
| Keene, NH | 3.0 | 0.2 |
| East Haddam, CT | 3.5 | 0.4 |
| Montague, MA | 5.5 | 0.6 |
| Suffield, CT | 3.0 | 0.7 |
| Plainfield Village, CT | 3.0 | 0.8 |

## *Summation*

Two Approaches for Achieving Permit Compliance

- Traditional: Facility Planning (assumes new equipment required)
- Operations First: Experiment with new ways of using existing equipment

A small Investment in Wastewater Operations can provide BIG Paybacks

- Improved Water Quality
- Financial Savings
  - Capital
  - O&M
- Sustainable, Energy Efficient

THE WATER PLANET COMPANY

Making clean water affordable

www.cleanwaterops.com

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## Using Existing Wastewater Treatment Equipment Differently

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Part 2 of 4

The Water Planet Company

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# *Nitrogen Removal*

## *Grant Weaver, Your Presenter*

*g.weaver@cleanwaterops.com*

President
The Water Planet Company

Licensing

Professional Engineer

Wastewater Operator

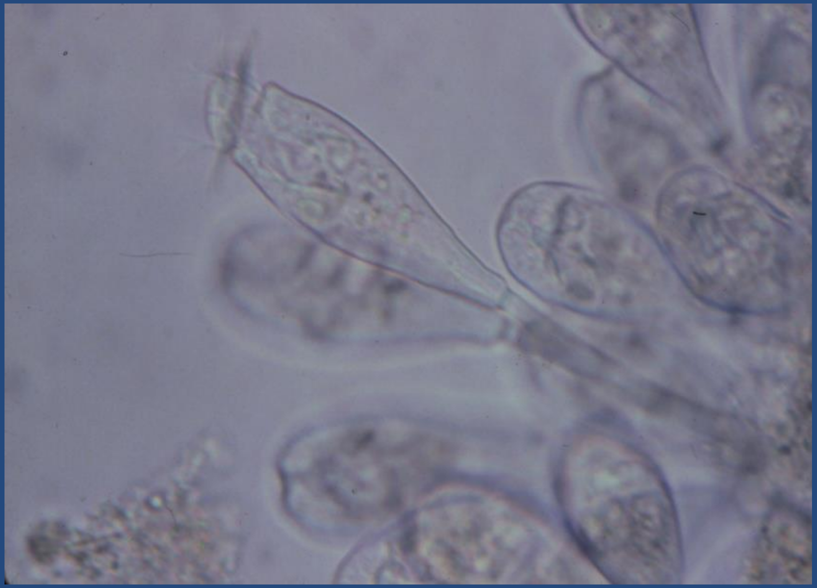
Education

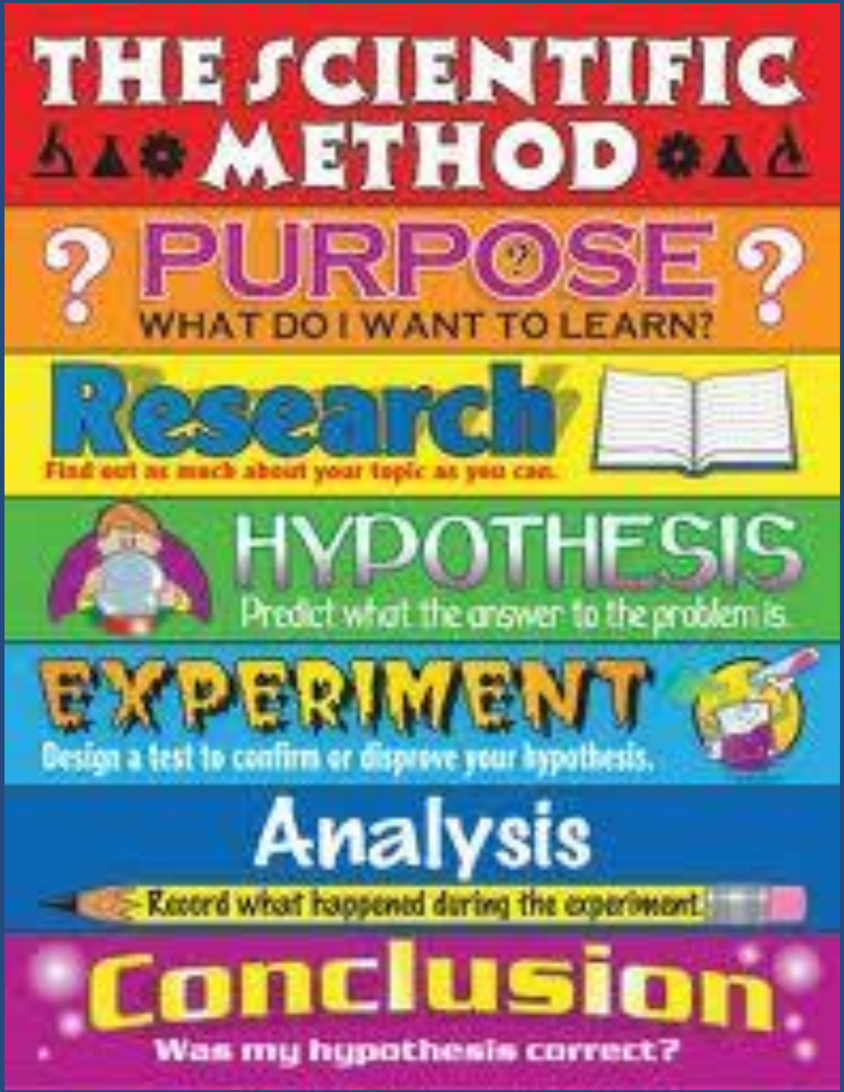
Massachusetts Institute of Technology (MIT):
*Post-Graduate Studies in Environmental Toxicology*

Oklahoma State University (OSU):
*MS Bio-Environmental Engineering*

Kansas State University (KSU):
*BS Biology*

# *Creating Optimal Habitats*


THE SCIENTIFIC METHOD
PURPOSE
WHAT DO I WANT TO LEARN?
Research
Find out as much about your topic as you can.
HYPOTHESIS
Predict what the answer to the problem is.
EXPERIMENT
Design a test to confirm or disprove your hypothesis.
Analysis
Record what happened during the experiment.
Conclusion
Was my hypothesis correct?

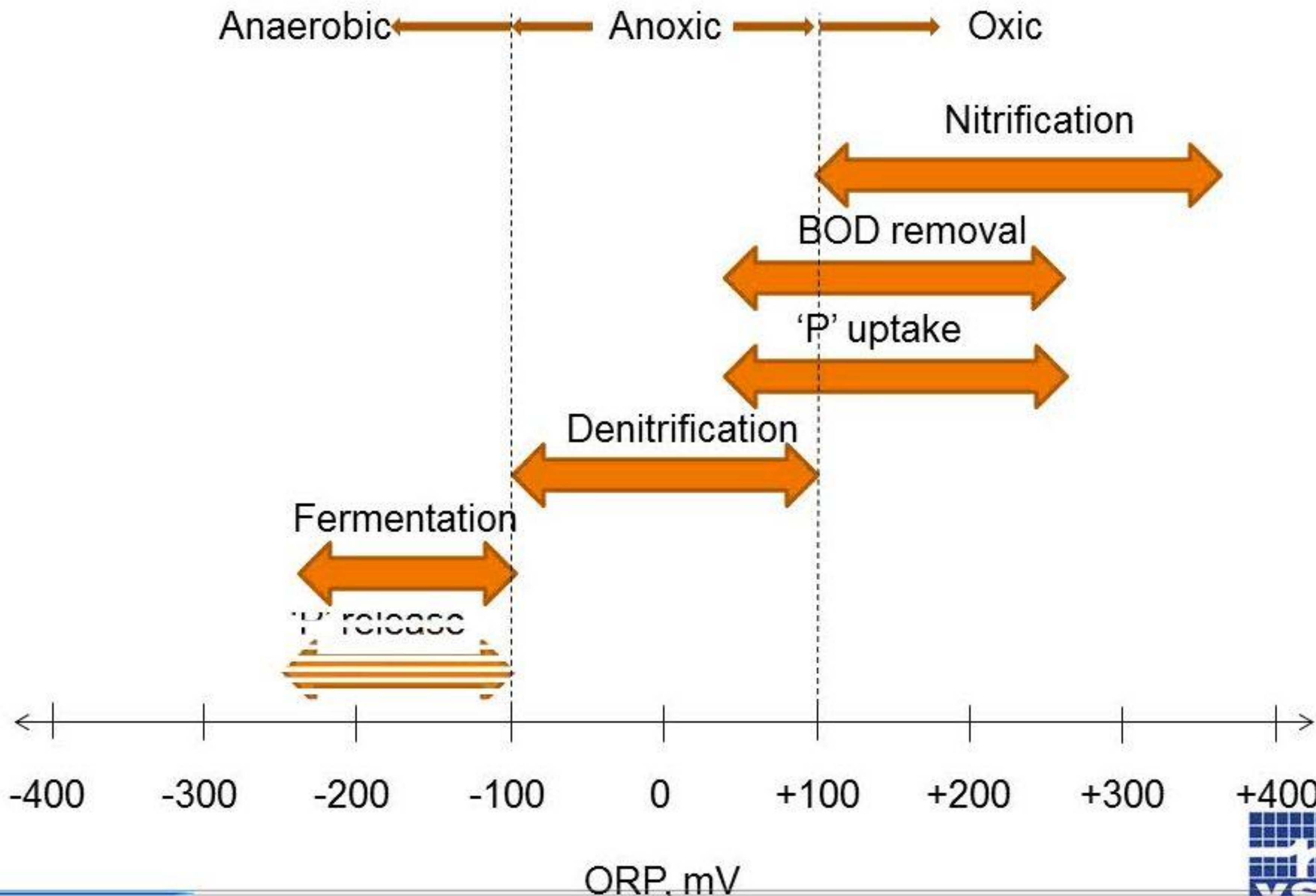
*Wastewater Science*

*Alkalinity and pH*

*Wastewater Science*

*DO and ORP*

# What does ORP tell us about our process?



7

# N

Nitrogen

## *Ammonia Removal*

Oxygen

Oxygen

**Ammonia ($NH_4$)** → **Nitrite ($NO_2$)** → **Nitrate ($NO_3$)**

Alkalinity

Nitrification Habitat:

- High DO / +ORP
- Low BOD
- High MLSS/MCRT
- High HRT

Consumes oxygen

Consumes alkalinity: lowers pH

## *Nitrification:*
## *Ammonia ($NH_4$) is converted to Nitrate ($NO_3$)*

Oxygen Rich Habitat

MLSS* of 2500+ mg/L (High Sludge Age / MCRT / low F:M)
ORP* of +100 to +150 mV (High DO)
Time* (high HRT … 24 hr, 12 hr, 6 hr, 4 hr)
Low BOD

Consumes Oxygen
Adds acid - Consumes 7 mg/L alkalinity per mg/L of $NH_4 \rightarrow NO_3$

*Approximate, each facility is different.

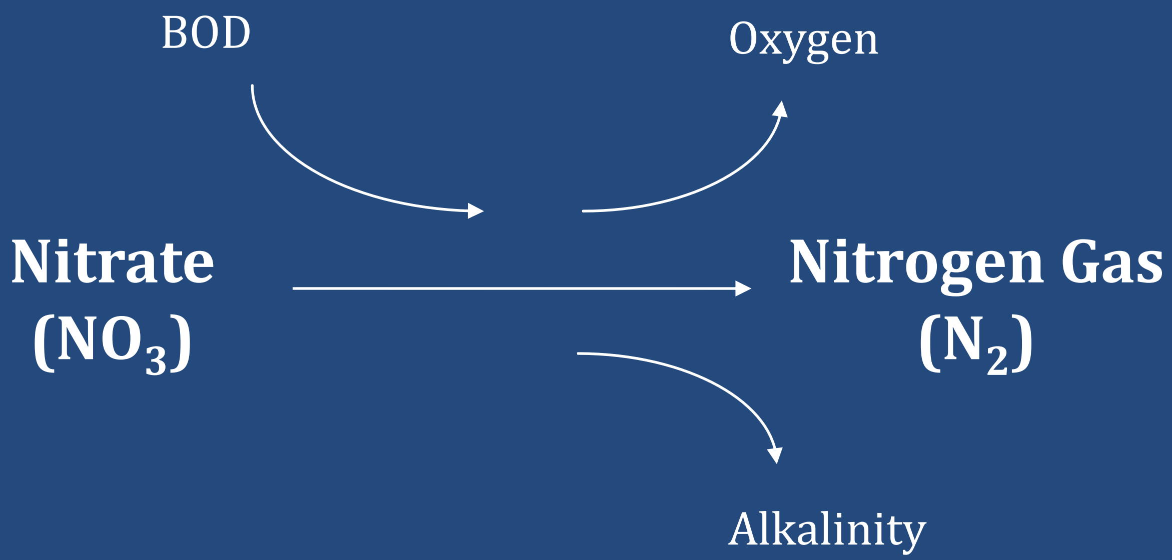
*Biological Nitrogen Removal:*

*Next,*

*The Nitrate ($NO_3$) created during Nitrification …*

*is converted to Nitrogen Gas ($N_2$)*

## *Nitrate Removal*




Denitrification Habitat:

- Low DO / -ORP
- High BOD

Adds DO
Gives back ½ the alkalinity: beneficially raises pH

## *Denitrification:*
## *Nitrate ($NO_3$) is converted to Nitrogen Gas ($N_2$)*

Oxygen Poor Habitat

ORP* of -100 mV or less (DO < 0.3 mg/L)

Surplus BOD* (100-250 mg/L: 5-10 times as much as $NO_3$)

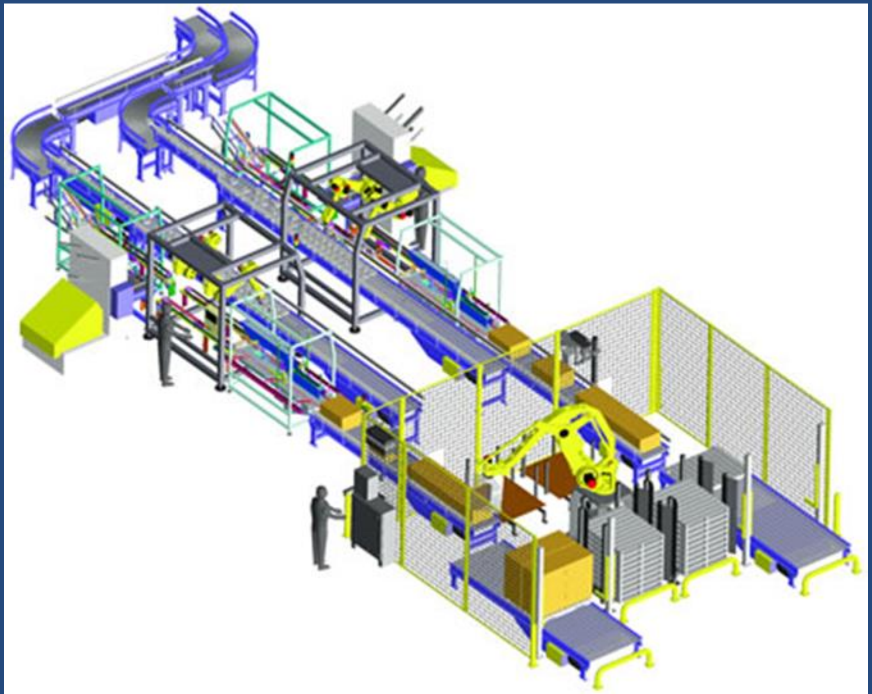
Retention Time* of 45-90 minutes

Gives back Oxygen

Gives back Alkalinity (3.5 mg/L per mg/L of $NO_3 \rightarrow N_2$)

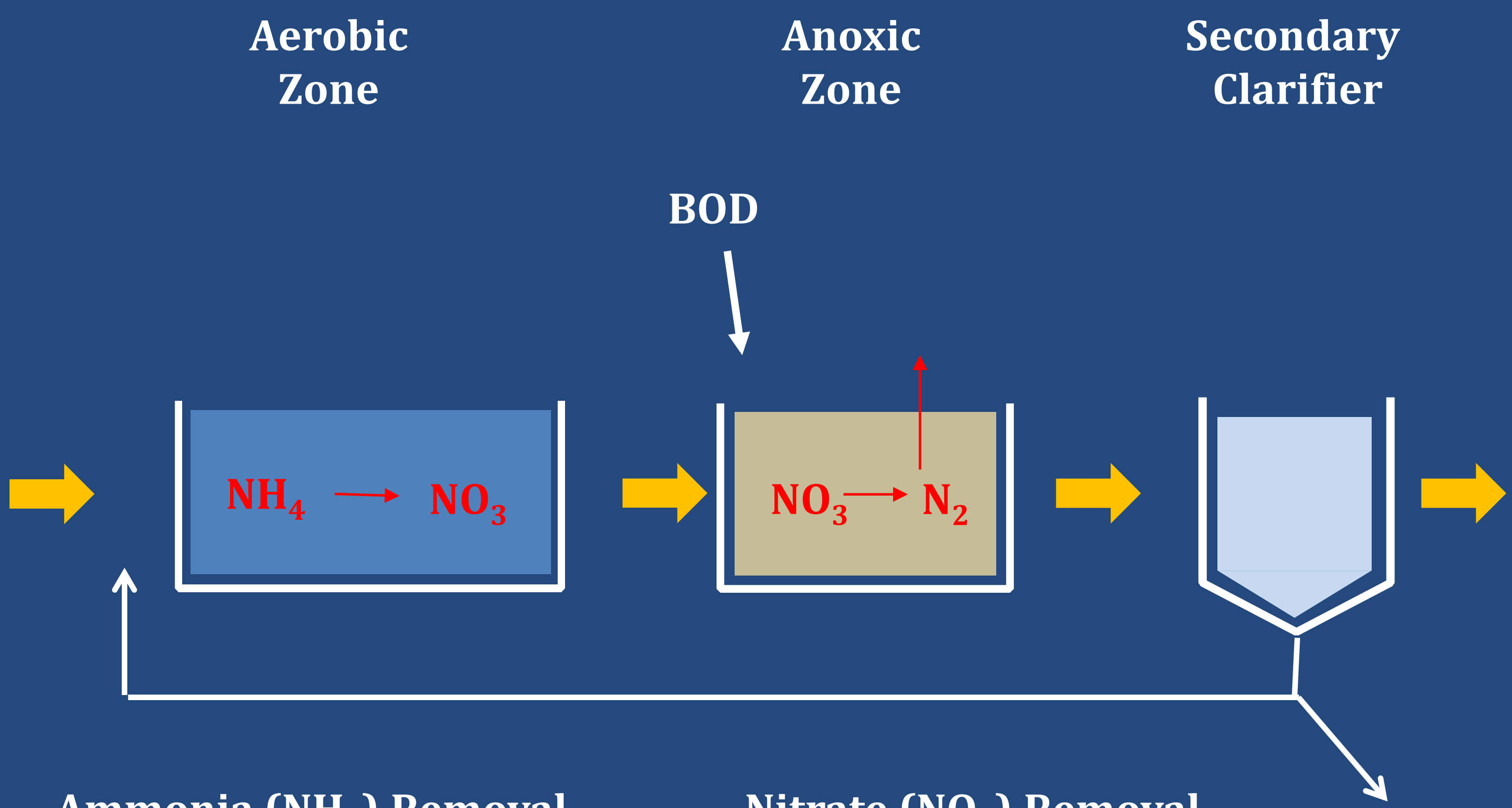
*Approximate, each facility is different.

*Technology!*




Post Denitrification

# Post-Anoxic Denitrification




**Ammonia ($NH_4$) Removal**

Target: $NH_4 < 0.5$ mg/L

**Nitrate ($NO_3$) Removal**

Target $NO_3$ in Anoxic Tank: 0.5-2 mg/L


MLE (Modified Ludzack-Ettinger) Process

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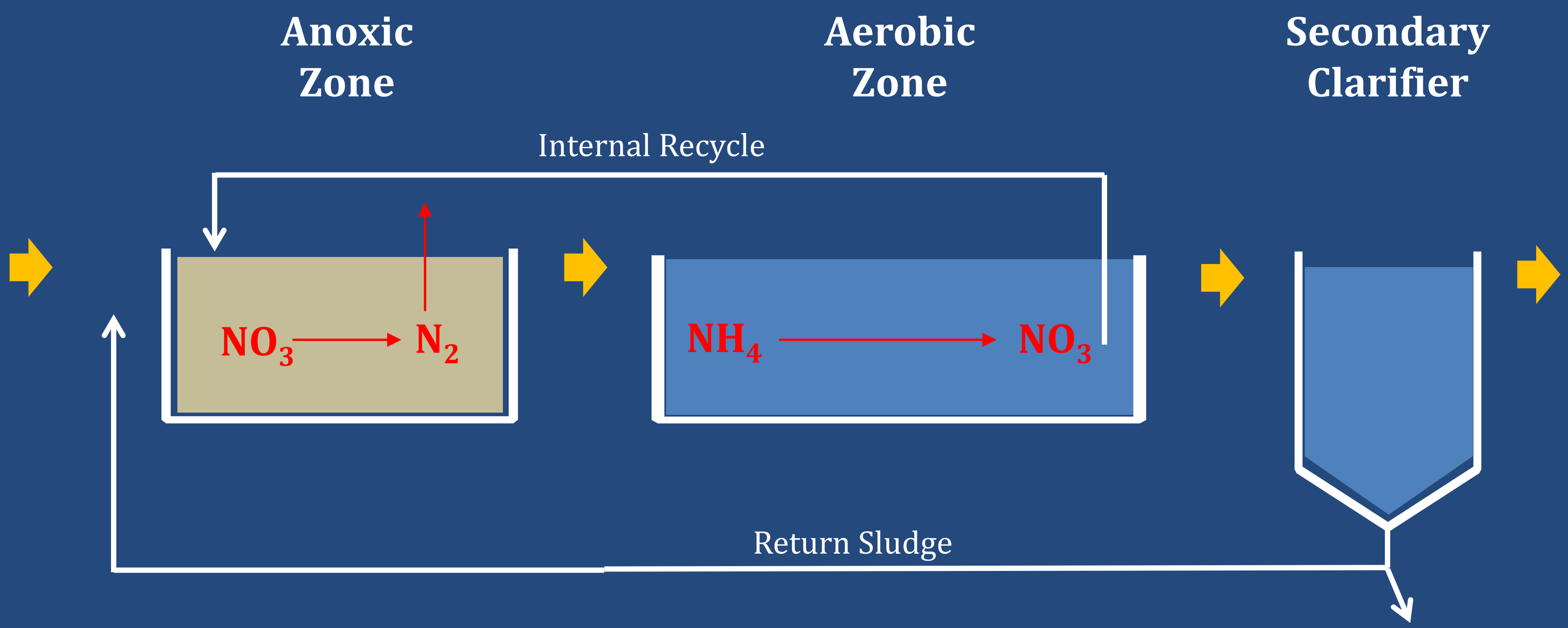


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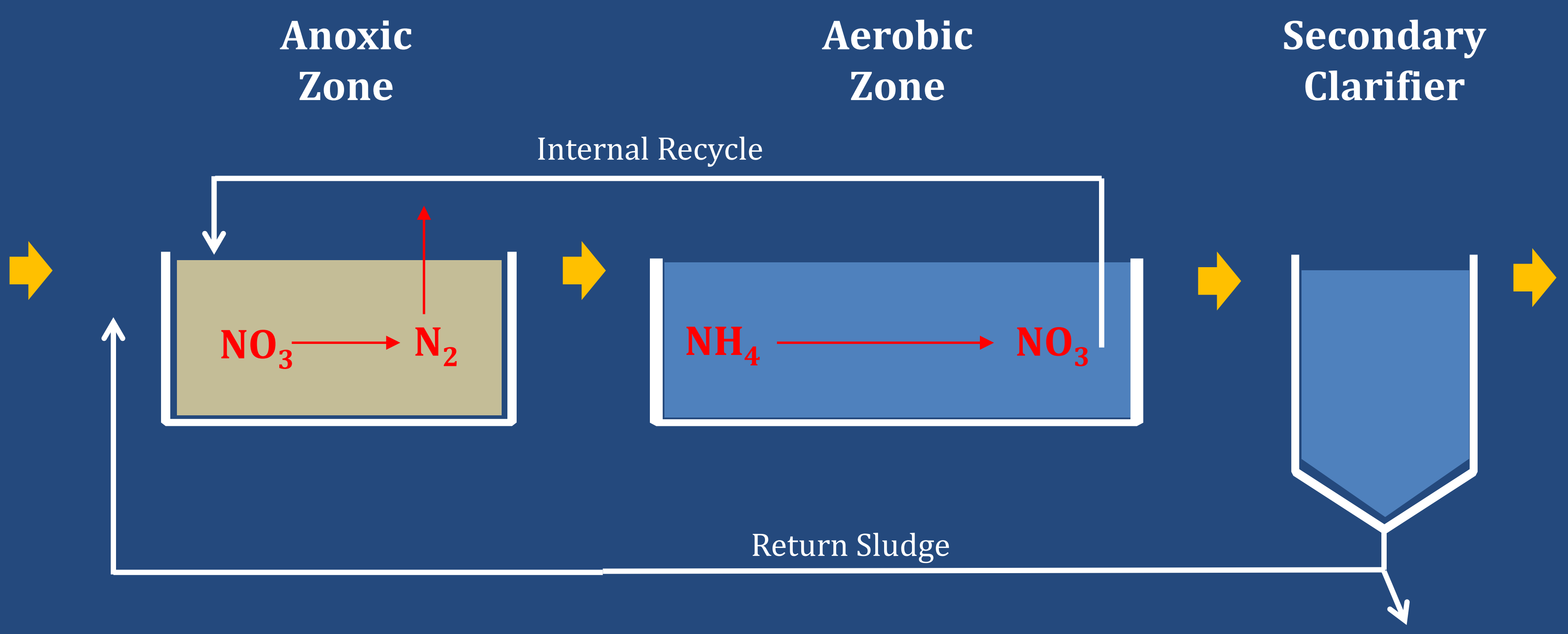
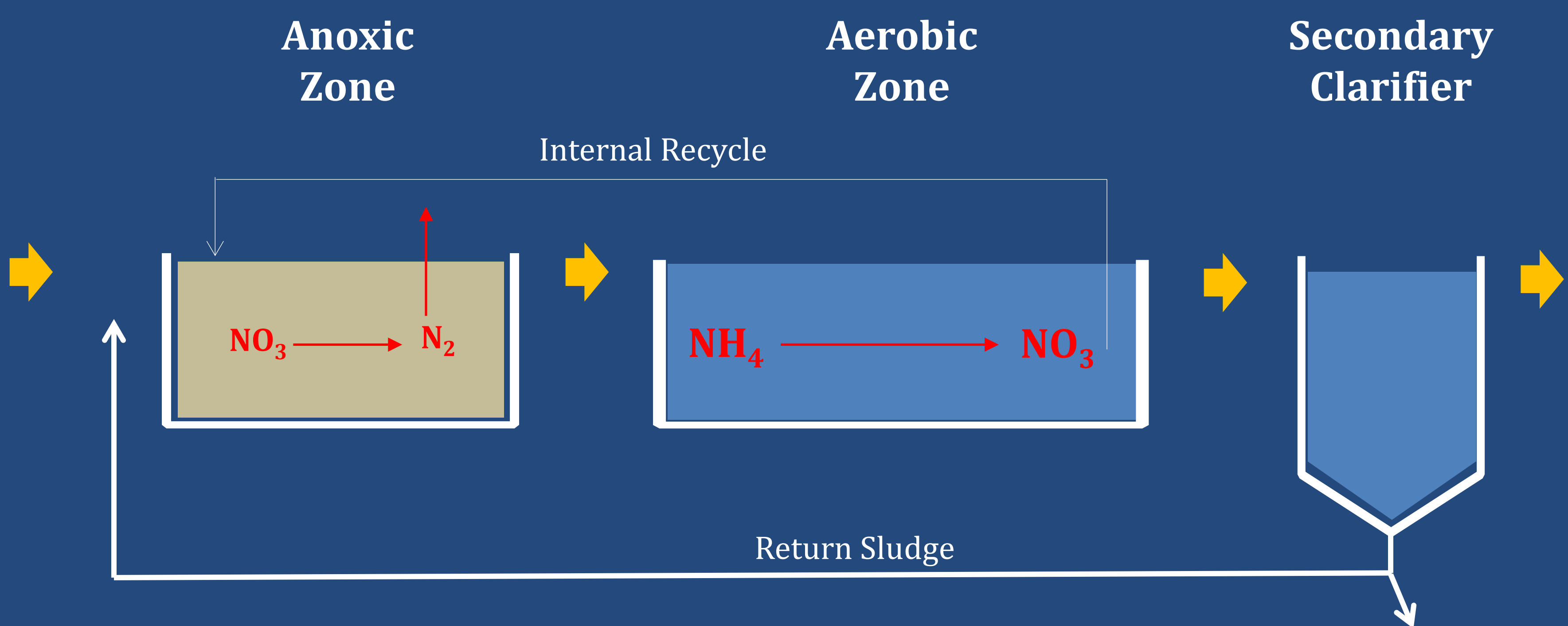
# MLE (Modified Ludzack-Ettinger) Process




MLE Process Control:

Proper Internal Recycle Rate; not too much / not too little.
ORP of +100 mV in Aerobic Zone for Ammonia ($NH_4$) Removal.
ORP of -75 to -150 mV in Anoxic Zone for Nitrate ($NO_3$) Removal.
Enough BOD to support Nitrate ($NO_3$) Removal.

# MLE with not enough Internal Recycle




**Ammonia ($NH_4$) Removal**

Excellent Aerobic Habitat: ORP +150 mV

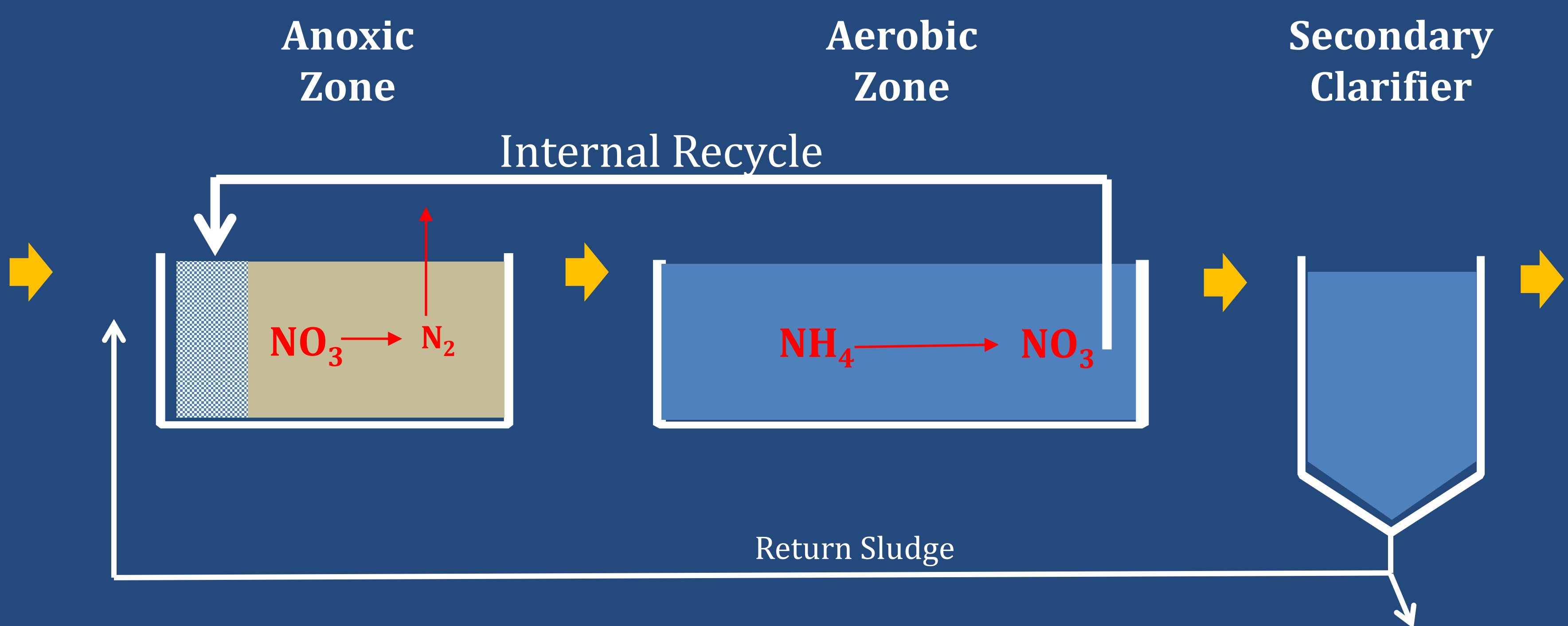
$NH_4 < 0.5$ mg/L

**Nitrate ($NO_3$) Removal**

Great Anoxic Habitat: ORP -150 mV or lower

$NO_3 > 4$ mg/L because too little $NO_3$ is returned to Anoxic Zone

# MLE with too much Internal Recycle




**Ammonia ($NH_4$) Removal**

Good Aerobic Habitat: ORP +100 mV

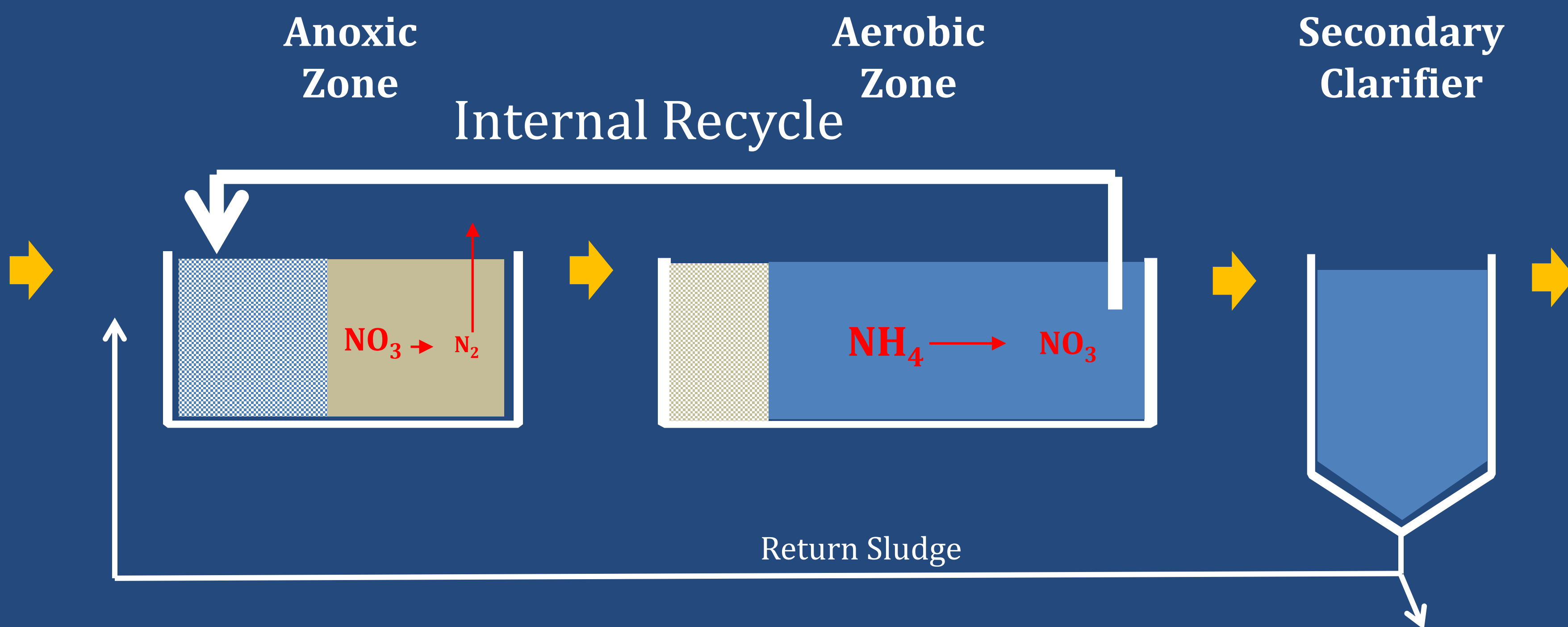
$NH_4$ < 0.5 mg/L

**Nitrate ($NO_3$) Removal**

Stressed Anoxic Habitat: ORP 0 to -100 mV

$NO_3$ > 4 mg/L: bacteria will not convert Ammonia ($NH_4$) to Nitrate ($NO_3$)

# MLE with way too much Internal Recycle




**Ammonia ($NH_4$) Removal**

Poor Aerobic Habitat: ORP +50 mV

$NH_4$ > 0.5 mg/L

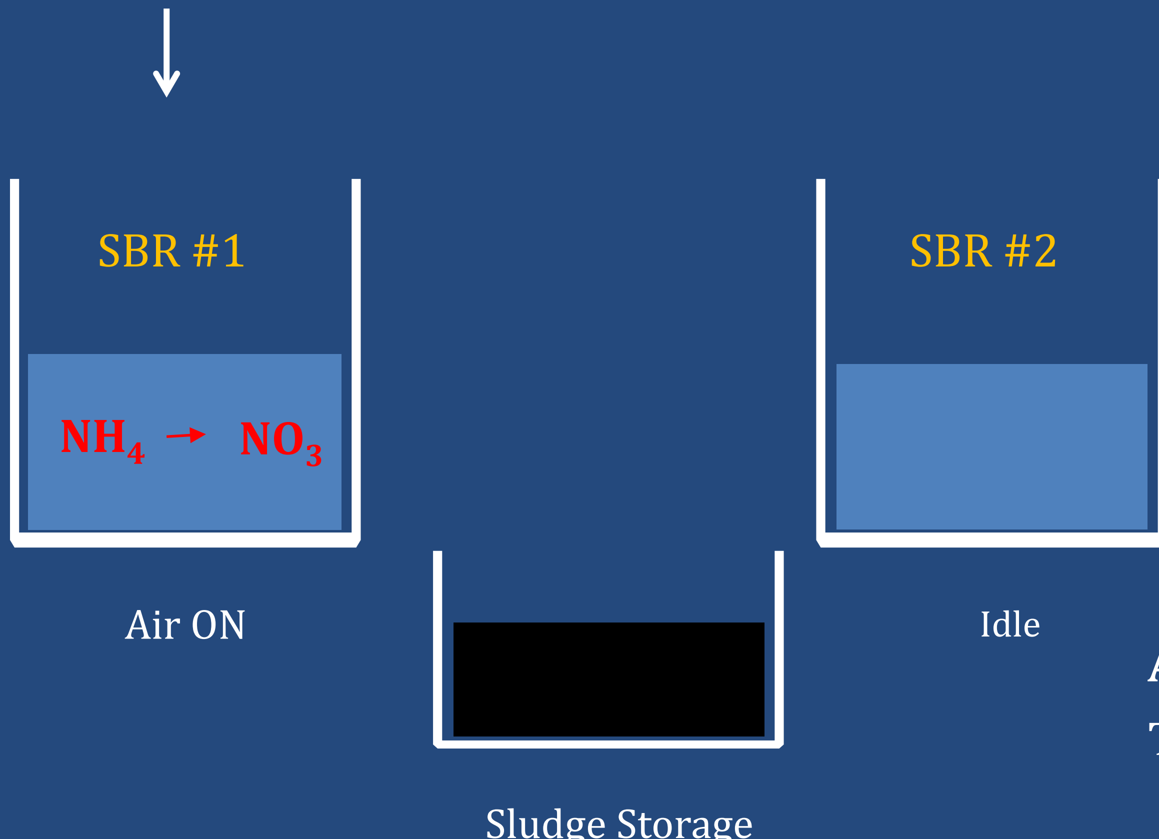
**Nitrate ($NO_3$) Removal**

Poor Anoxic Habitat: ORP 0 mV or higher

$NO_3$ > 4 mg/L

# Sequencing Batch Reactor
# SBR

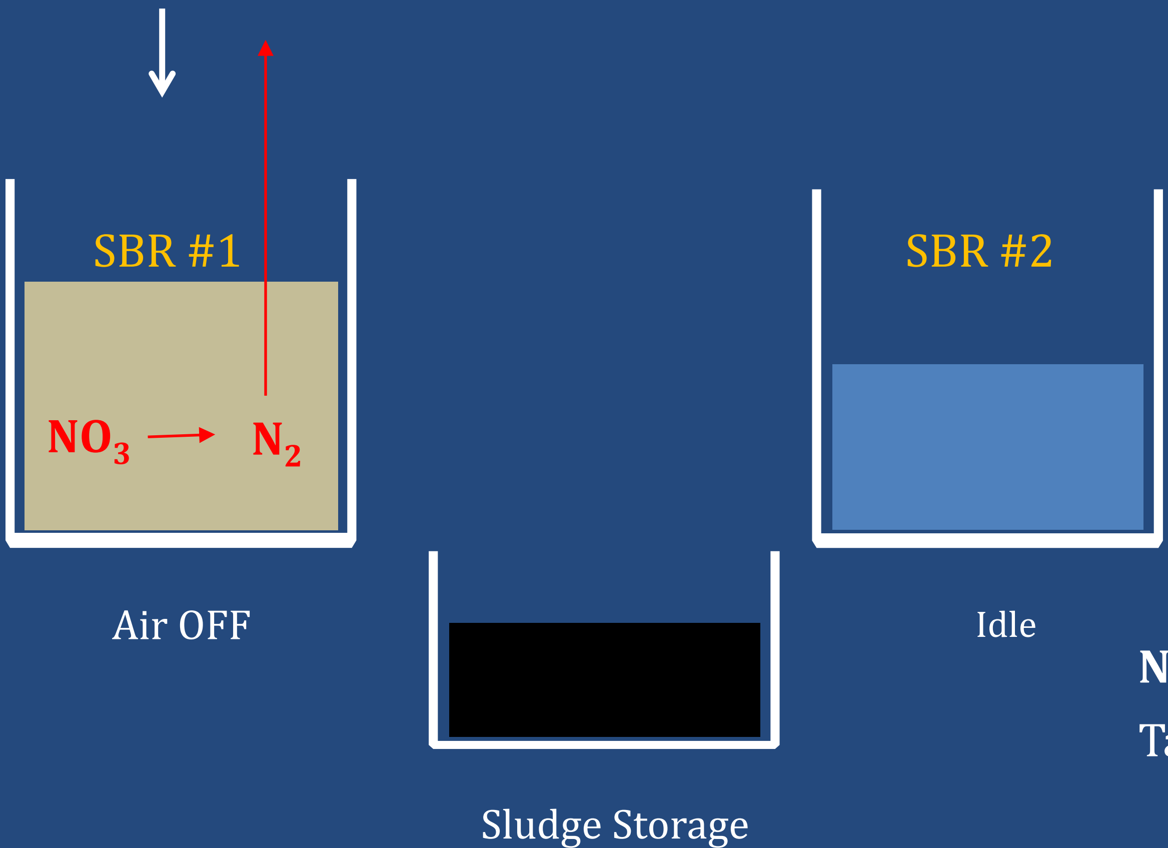
# Sequencing Batch Reactor (SBR)
# Ammonia ($NH_4$) Removal: Nitrification




**Ammonia ($NH_4$) Removal**

Target: $NH_4 < 0.5$ mg/L

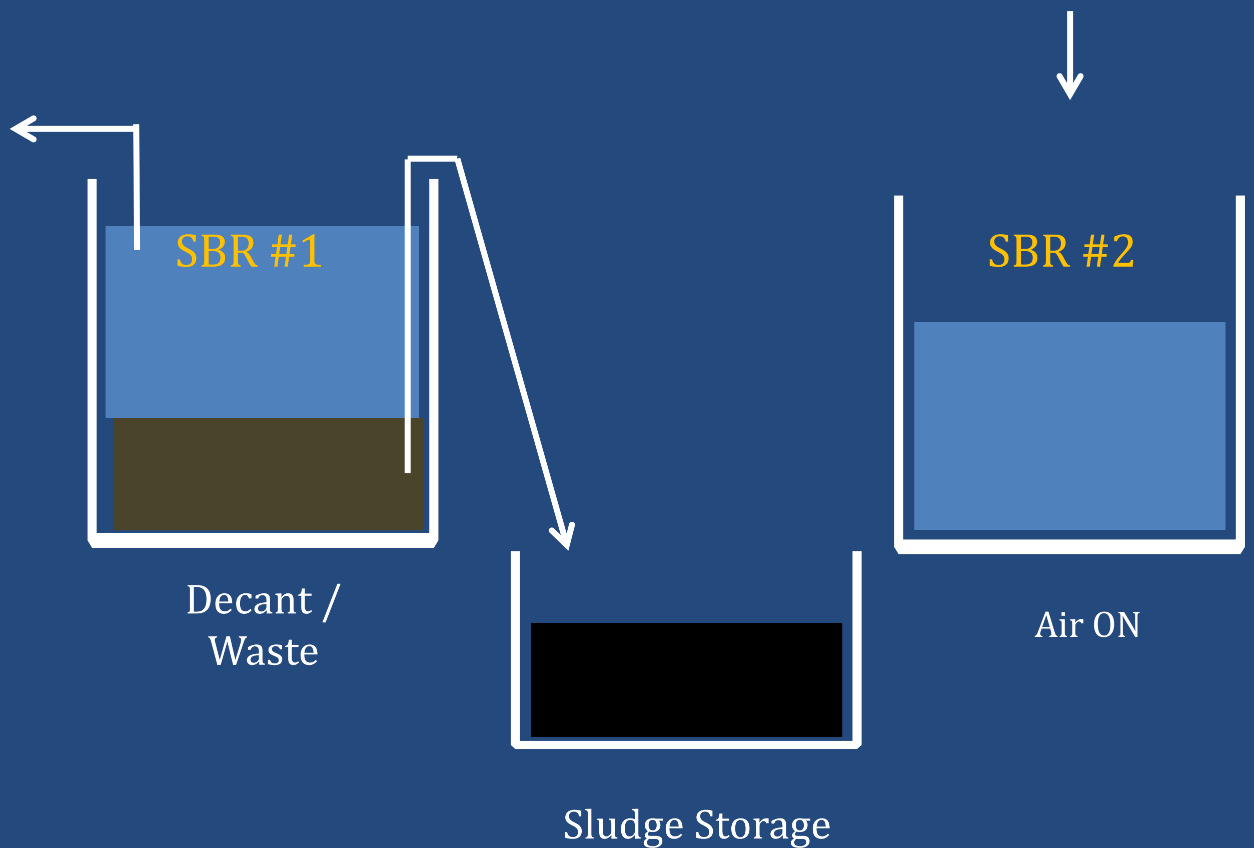
# Sequencing Batch Reactor (SBR)
# Nitrate ($NO_3$) Removal: Denitrification




**Nitrate ($NO_3$) Removal**

Target: $NO_3 < 4$ mg/L

# Sequencing Batch Reactor (SBR)
# Settle, Decant & Waste Sludge




SBR Process Control:

Establish cycle times that are long enough to provide optimal habitats.

And, short enough to allow all of the flow to be nitrified and denitrified.

# *Optimizing SBR cycle time*

Too short

Will not reach +100 mV for Ammonia ($NH_4$) Removal.

Will not reach -100 mV for Nitrate ($NO_3$) Removal.

Note: Temperature and BOD affect Air OFF cycle.

Too long

Wastewater will pass through tank before all Ammonia ($NH_4$) converted to Nitrate ($NO_3$).

And, before all Nitrate ($NO_3$) is converted to Nitrogen Gas ($N_2$).

Just right

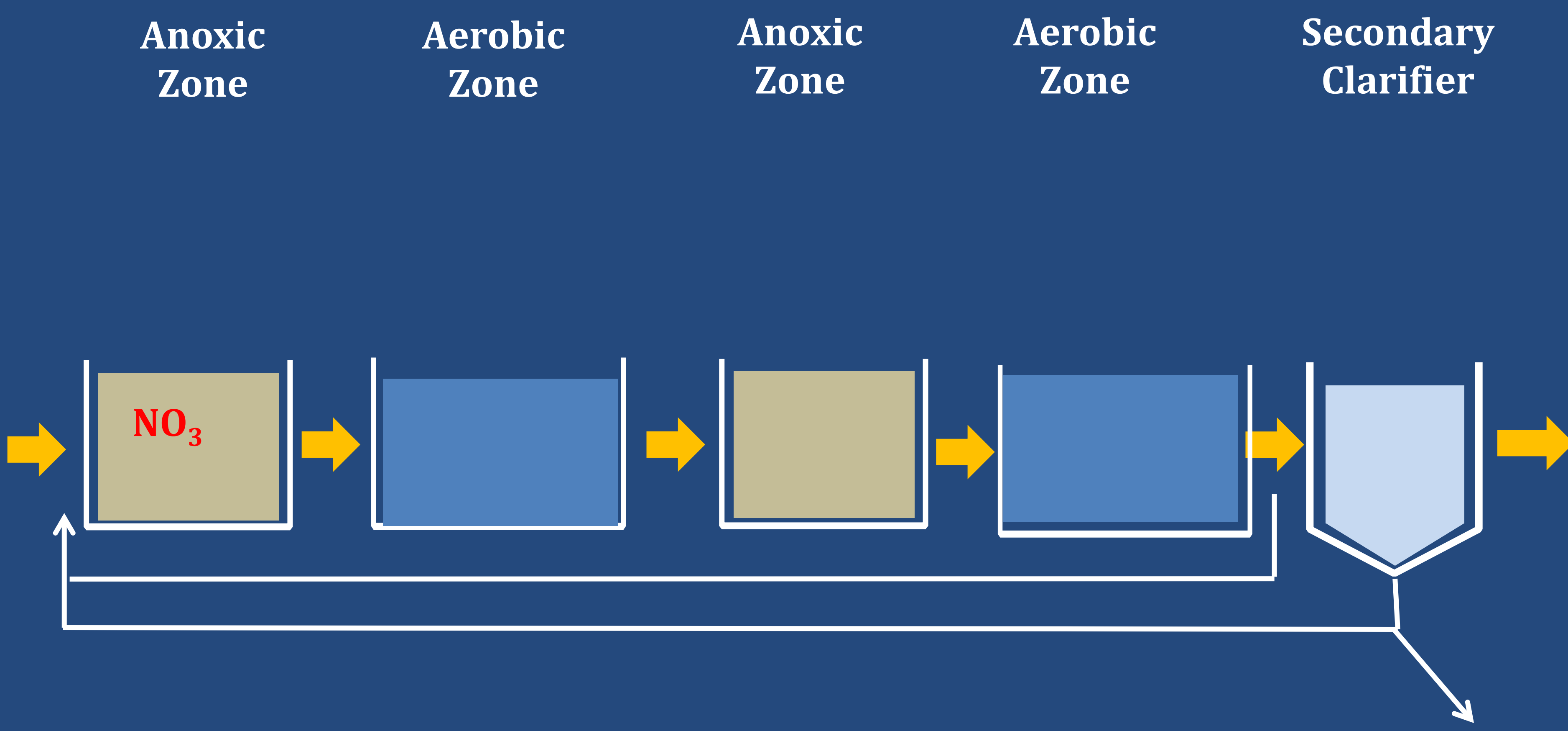
Good habitats …

- ORP of +100 mV for 60 minutes
- And, ORP of -100 mV for 30 minutes.

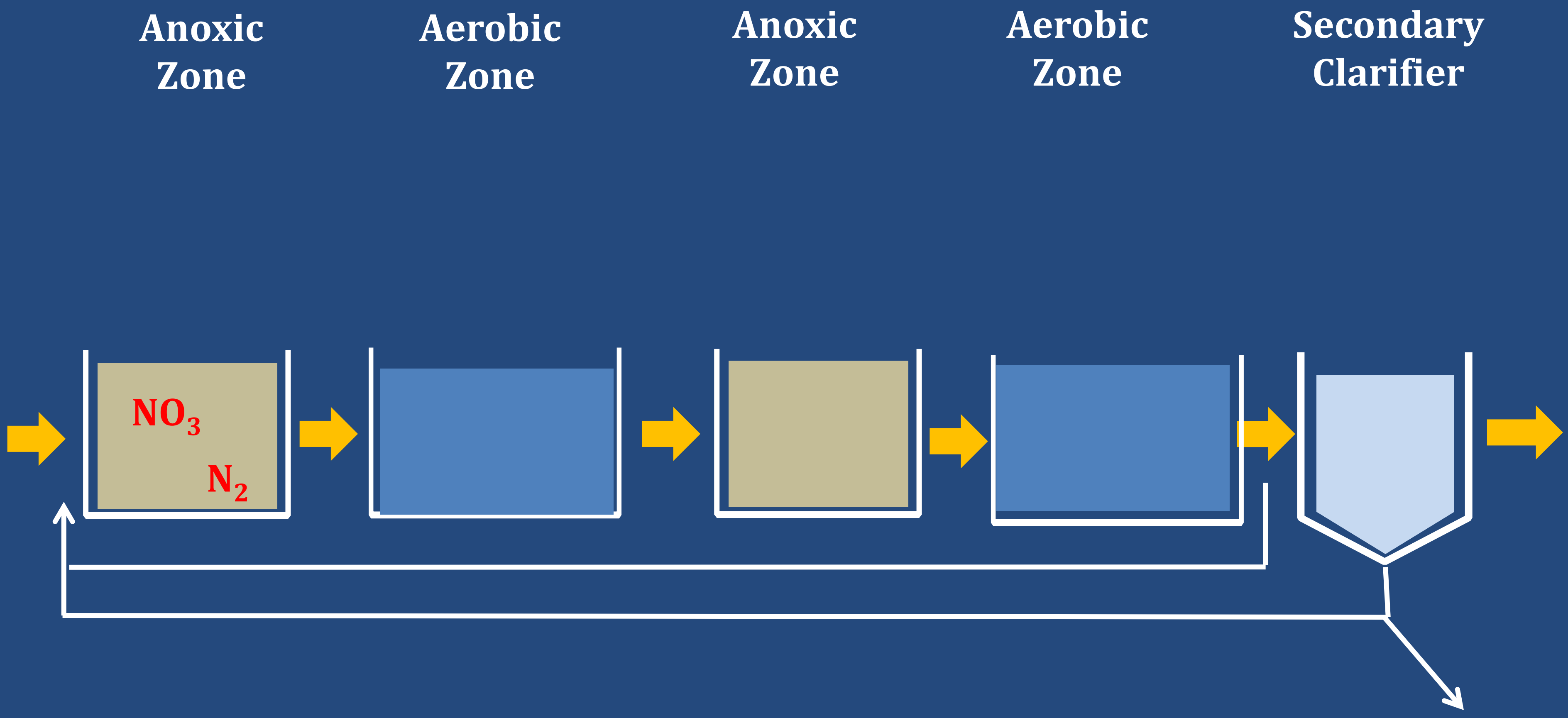
Bonus: Changing conditions will serve as a selector.


Oxidation Ditch
4-Stage Bardenpho

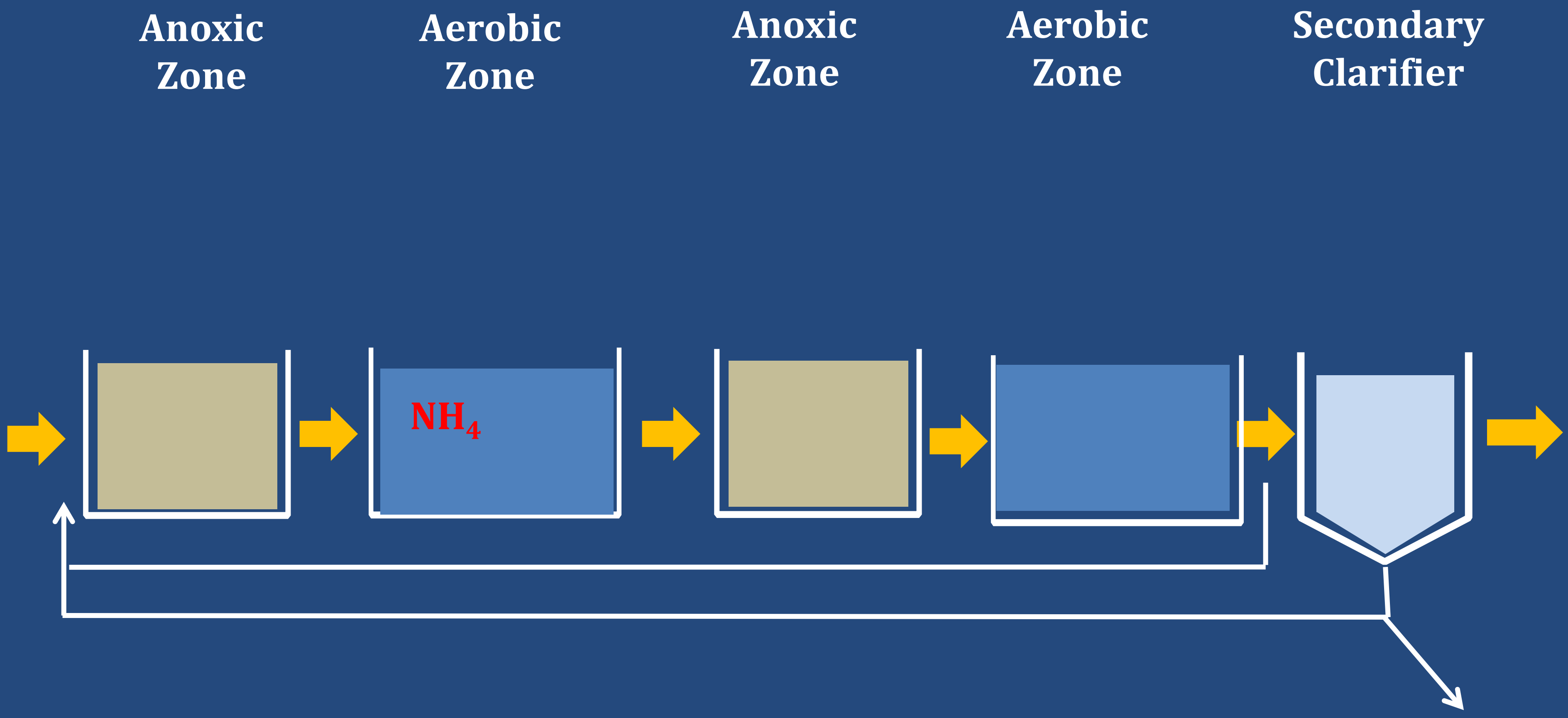
# Oxidation Ditch – 4-Stage Bardenpho



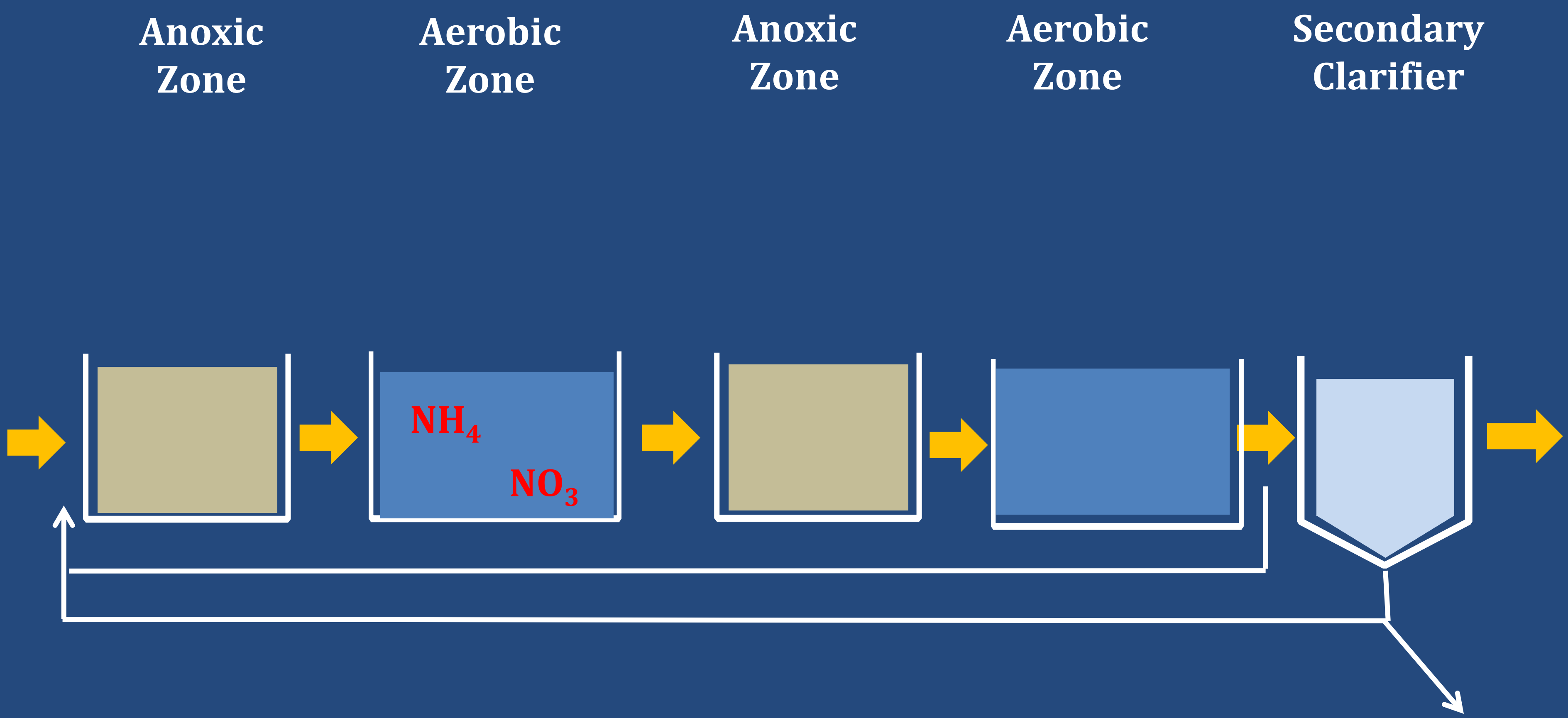
# Oxidation Ditch – 4-Stage Bardenpho



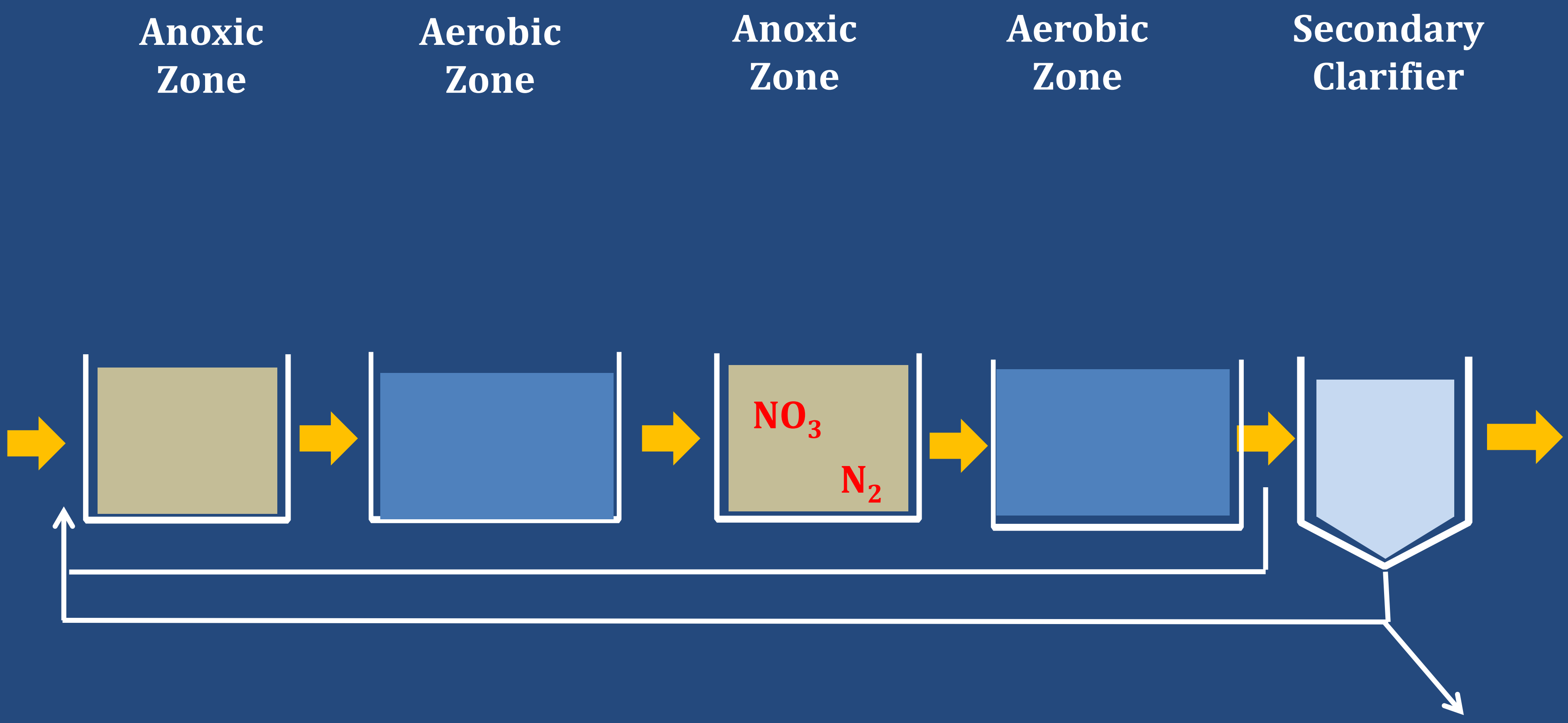
# Oxidation Ditch – 4-Stage Bardenpho



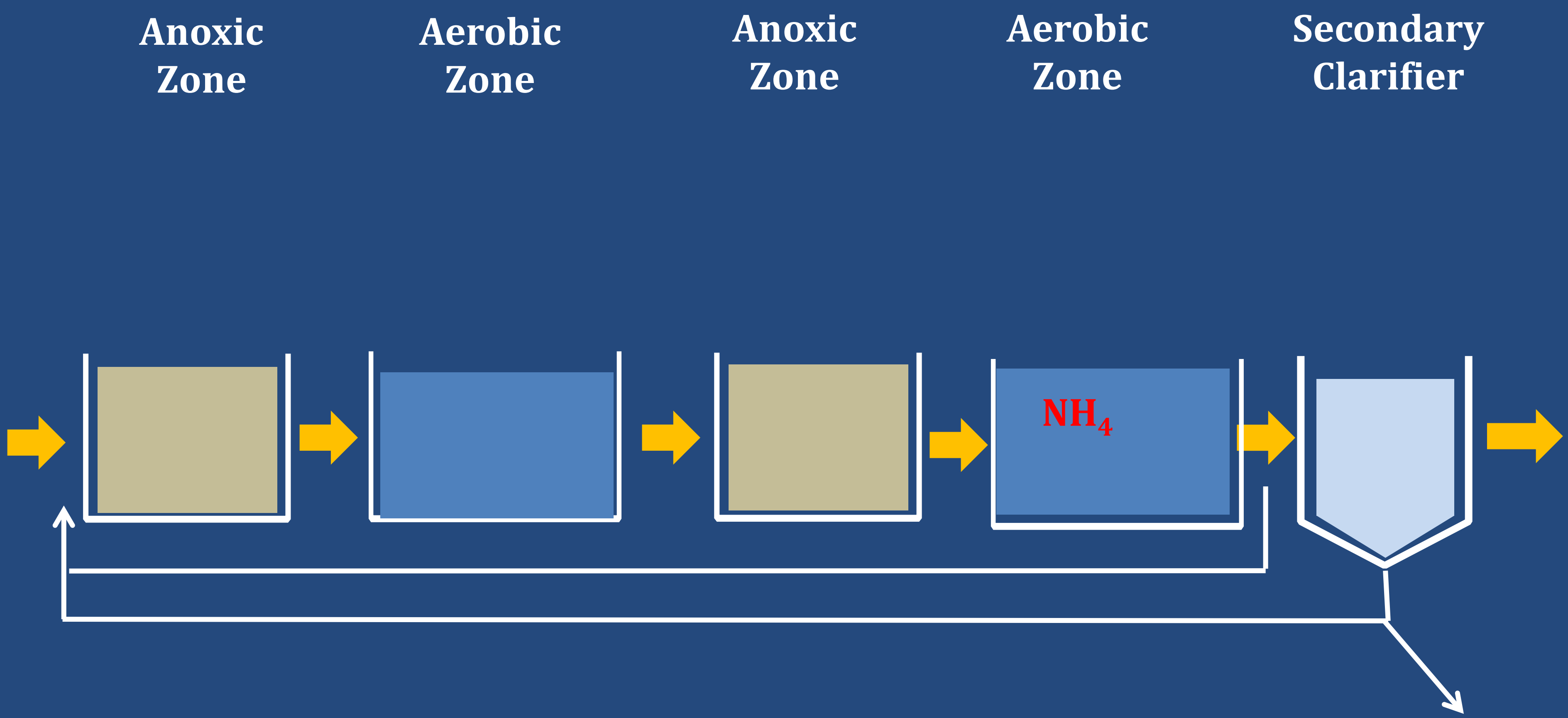
# Oxidation Ditch – 4-Stage Bardenpho



# Oxidation Ditch – 4-Stage Bardenpho



# Oxidation Ditch – 4-Stage Bardenpho



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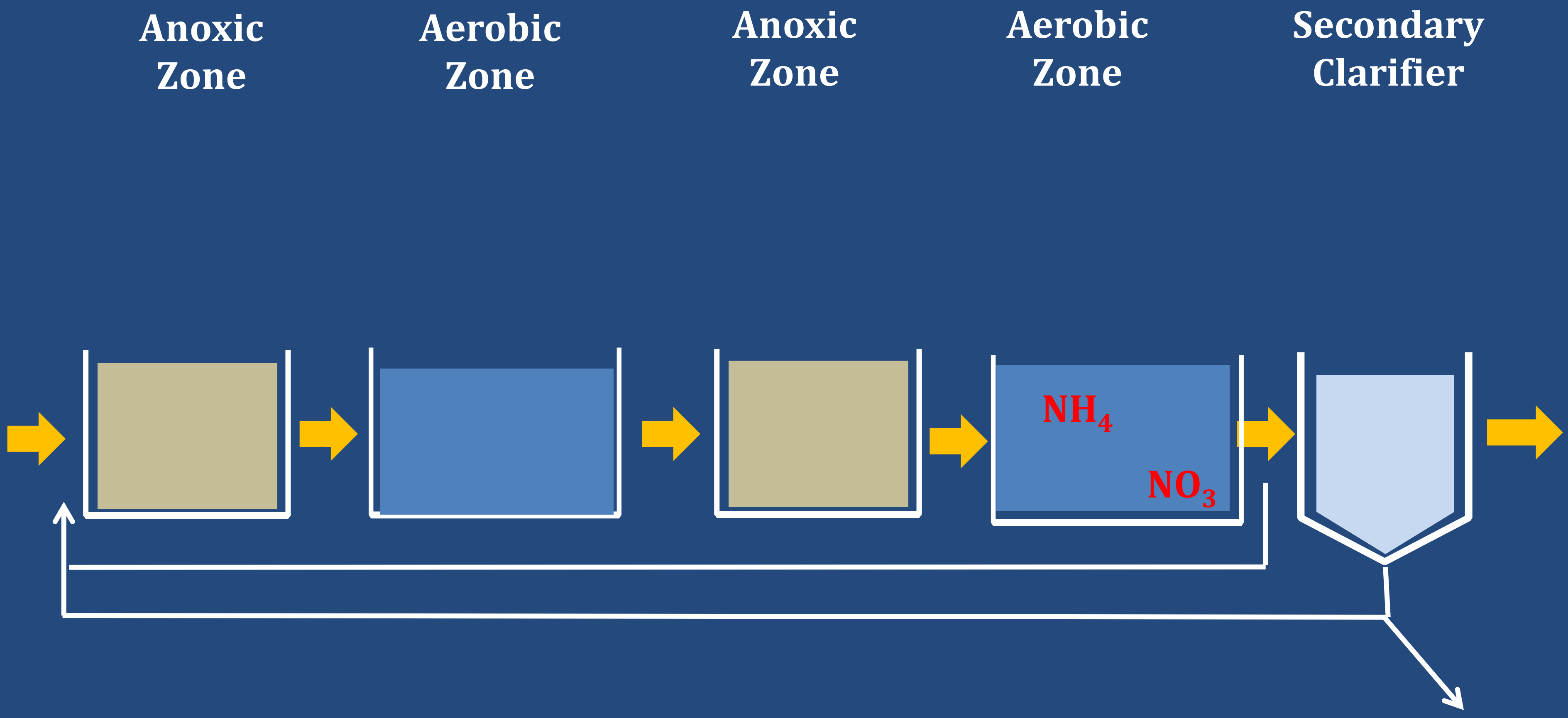
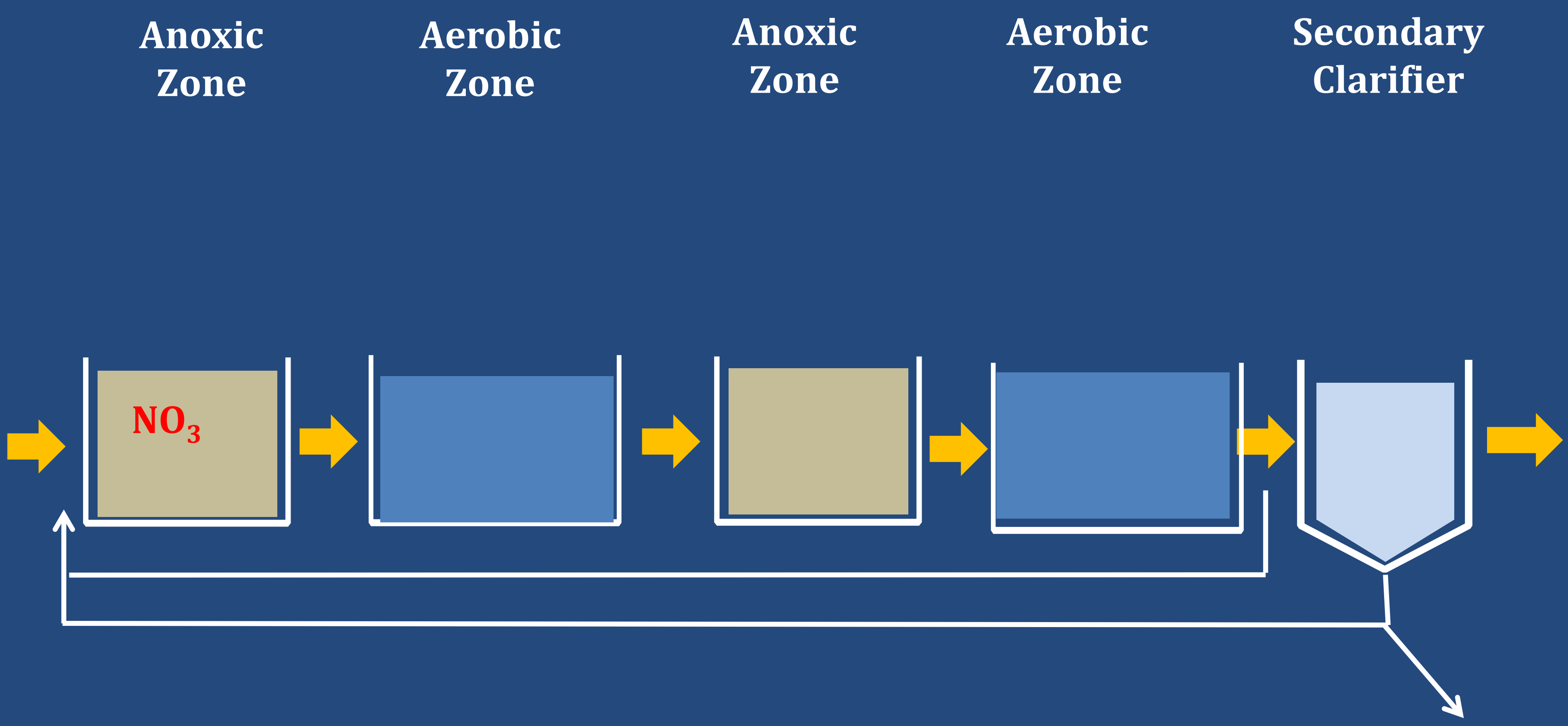


# Oxidation Ditch – 4-Stage Bardenpho




BACKGROUND
INFORMATION


COMPLETED
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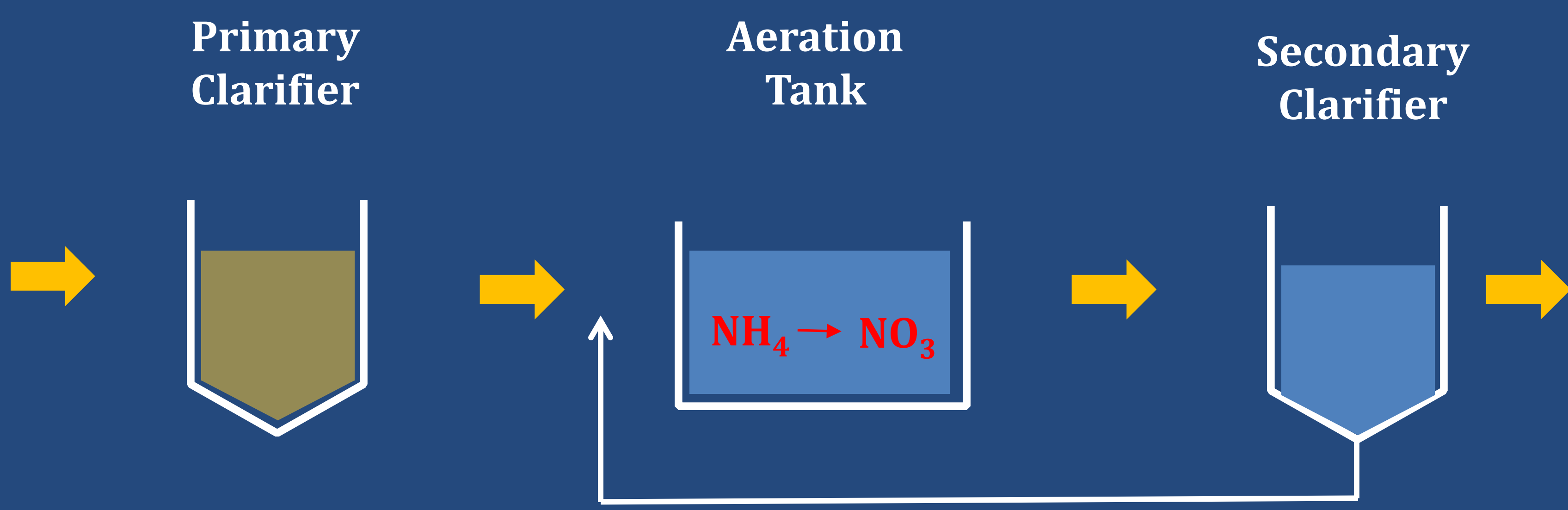
*Experimenting with YOUR plant:*
*Finding the "Right" Process Control Strategy*


*… and, Optimizing Nitrogen Removal*

# Step 1

*Optimize Ammonia ($NH_4$) Removal*

# *Conventional Activated Sludge Plant*




**Ammonia ($NH_4$) Removal**

**Target: less than 0.5 mg/L**

Raise mixed liquor

… the higher the better for N-Removal.

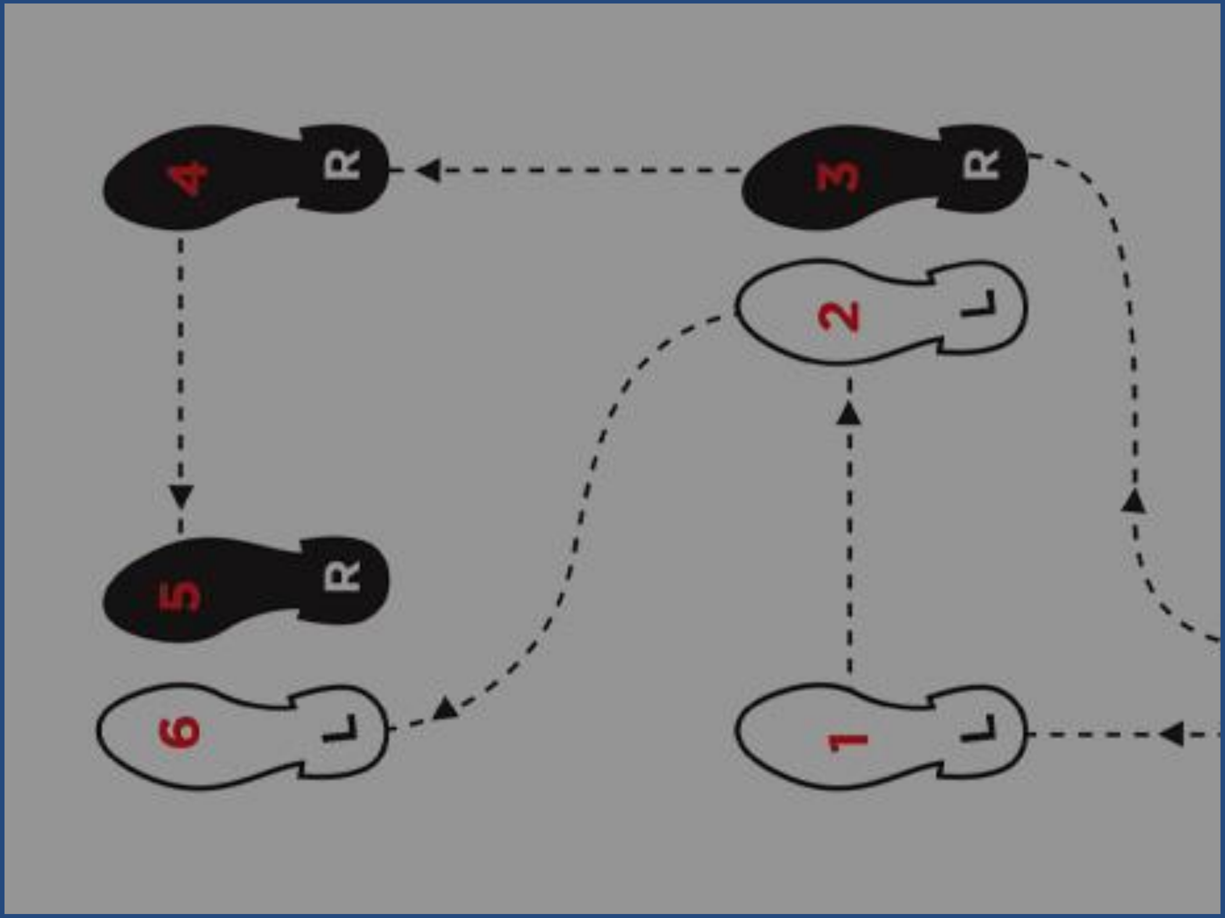
Keep ORP at +100 mV (or higher) by adjusting DO settings until …

… enough DO & ORP to reduce $NH_4$ to 0.5 mg/L …

… but not so much as to move too much DO into Anoxic or waste electricity.

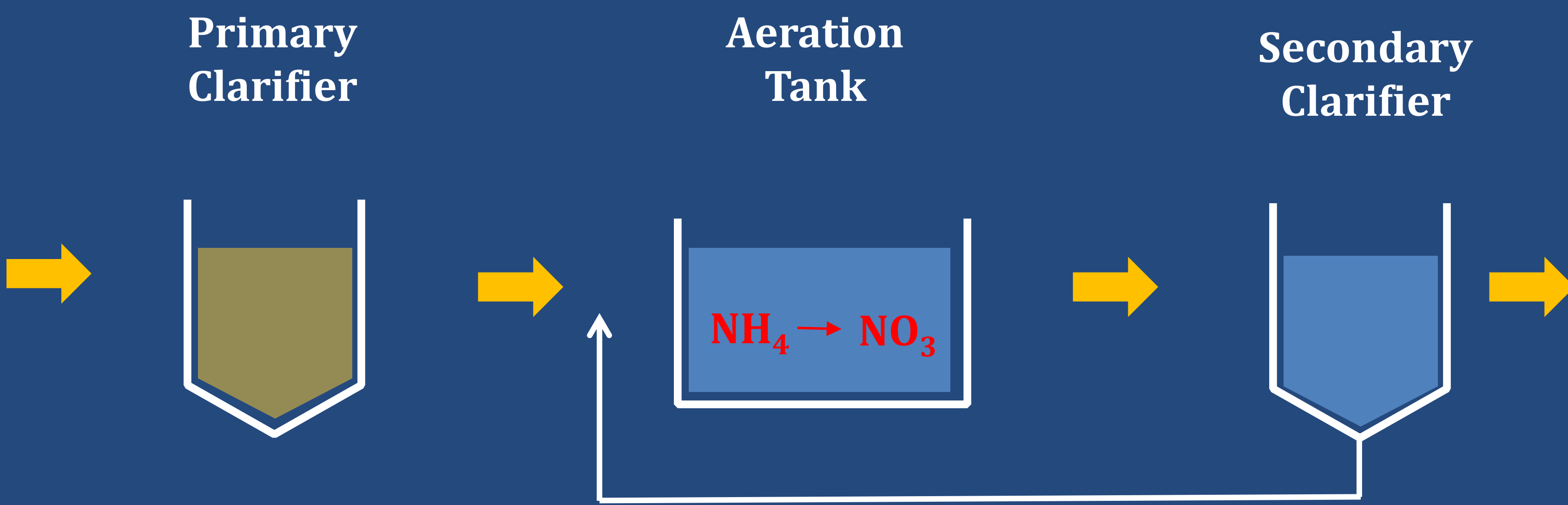
Warning: pH and Nitrite ($NO_2$)

## *Step 2: Optimize Nitrate ($NO_3$) Removal*



*Operate Aeration Tank as SBR*

# *Conventional Activated Sludge operated as SBR*

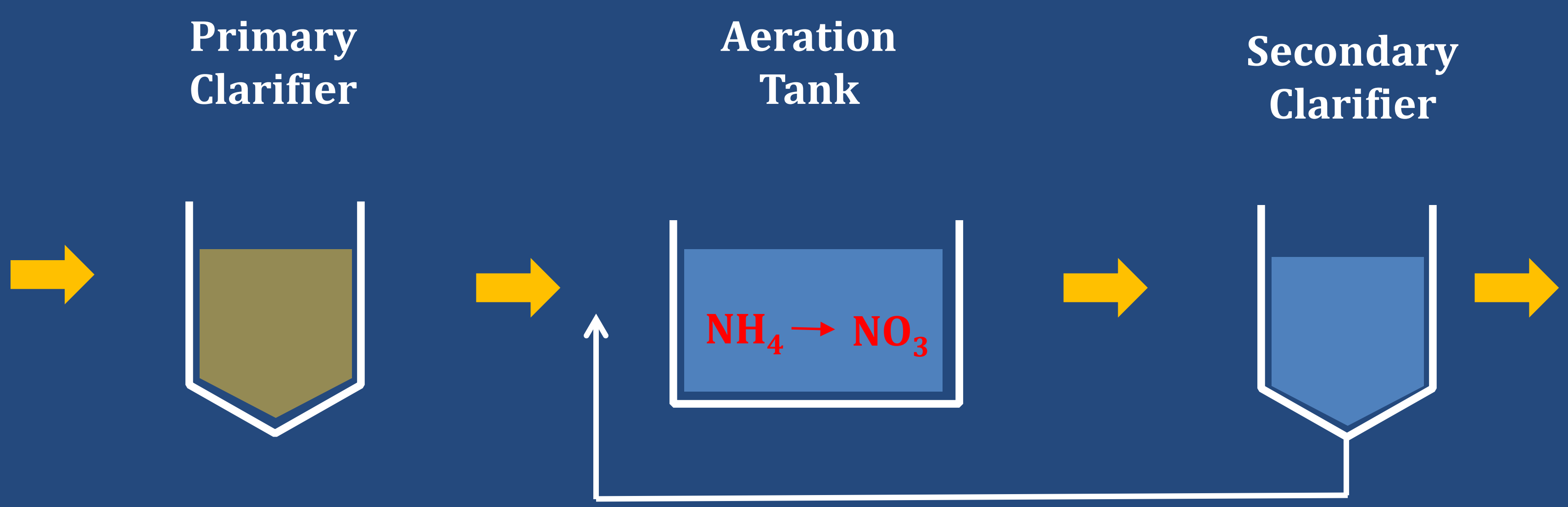


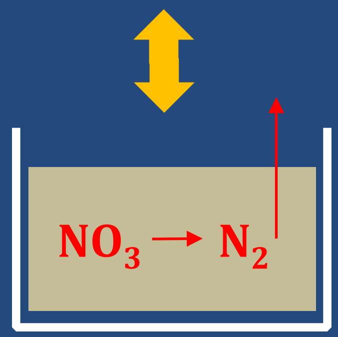

**Maintain Ammonia ($NH_4$) Removal**

Target: $NH_4 < 0.5$ mg/L

ORP: +100 mV long enough (60 minutes)

# *Conventional Activated Sludge operated as SBR*




**Maintain Ammonia ($NH_4$) Removal**

Target: $NH_4 < 0.5$ mg/L

ORP: +100 mV long enough (60 minutes)

**Nitrate ($NO_3$) Removal**

Target: $NO_3 < 4$ mg/L

ORP: -100 mV long enough (30 minutes)

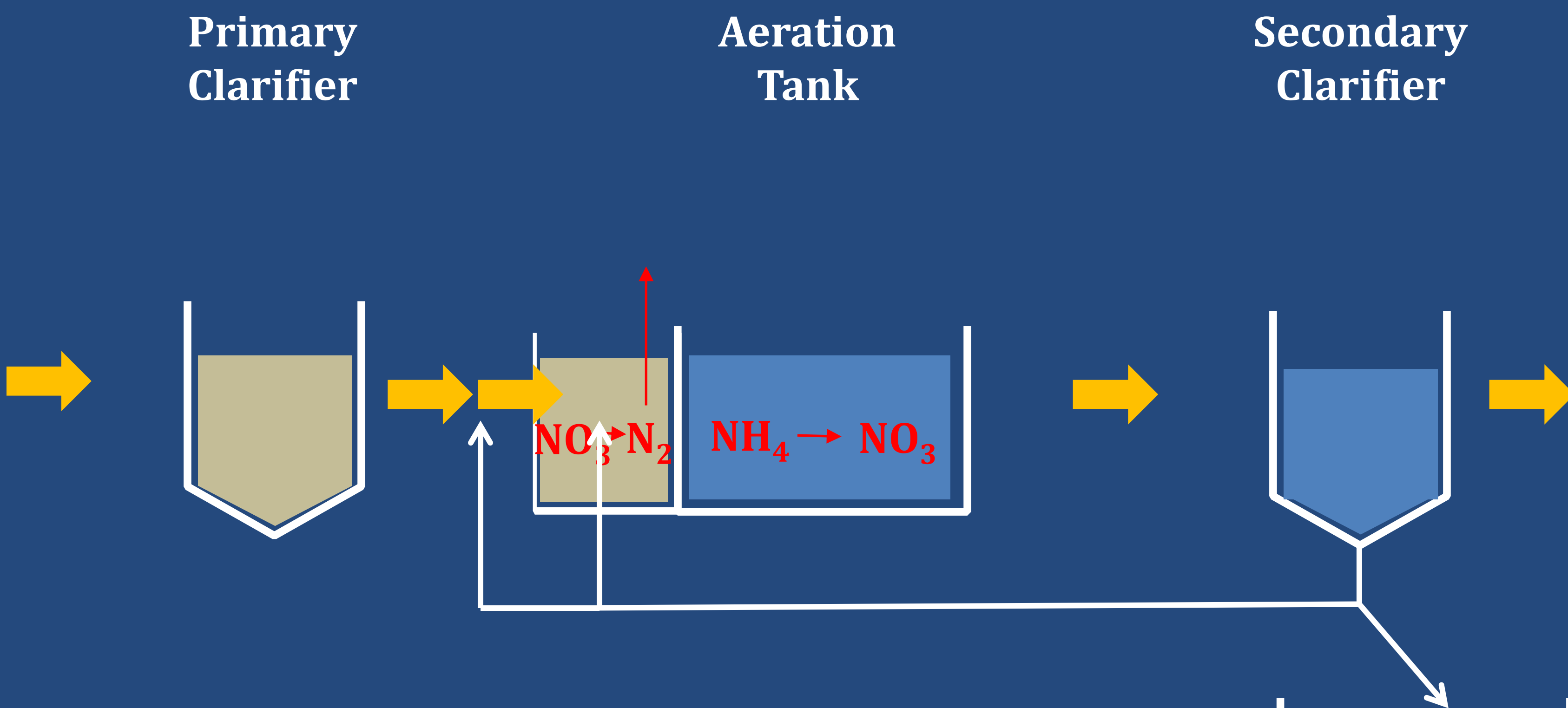
If habitats are good and $NO_3$ remains high, likely not enough BOD.

Search for additional BOD.

Cycle air ON to remove $NH_4$ & OFF to remove $NO_3$

Use ORP to adjust AirON/AirOFF times

*Operate Aeration Tank as MLE*




**Maintain Ammonia ($NH_4$) Removal**

Target: $NH_4$ < 0.5 mg/L

ORP: +100 mV

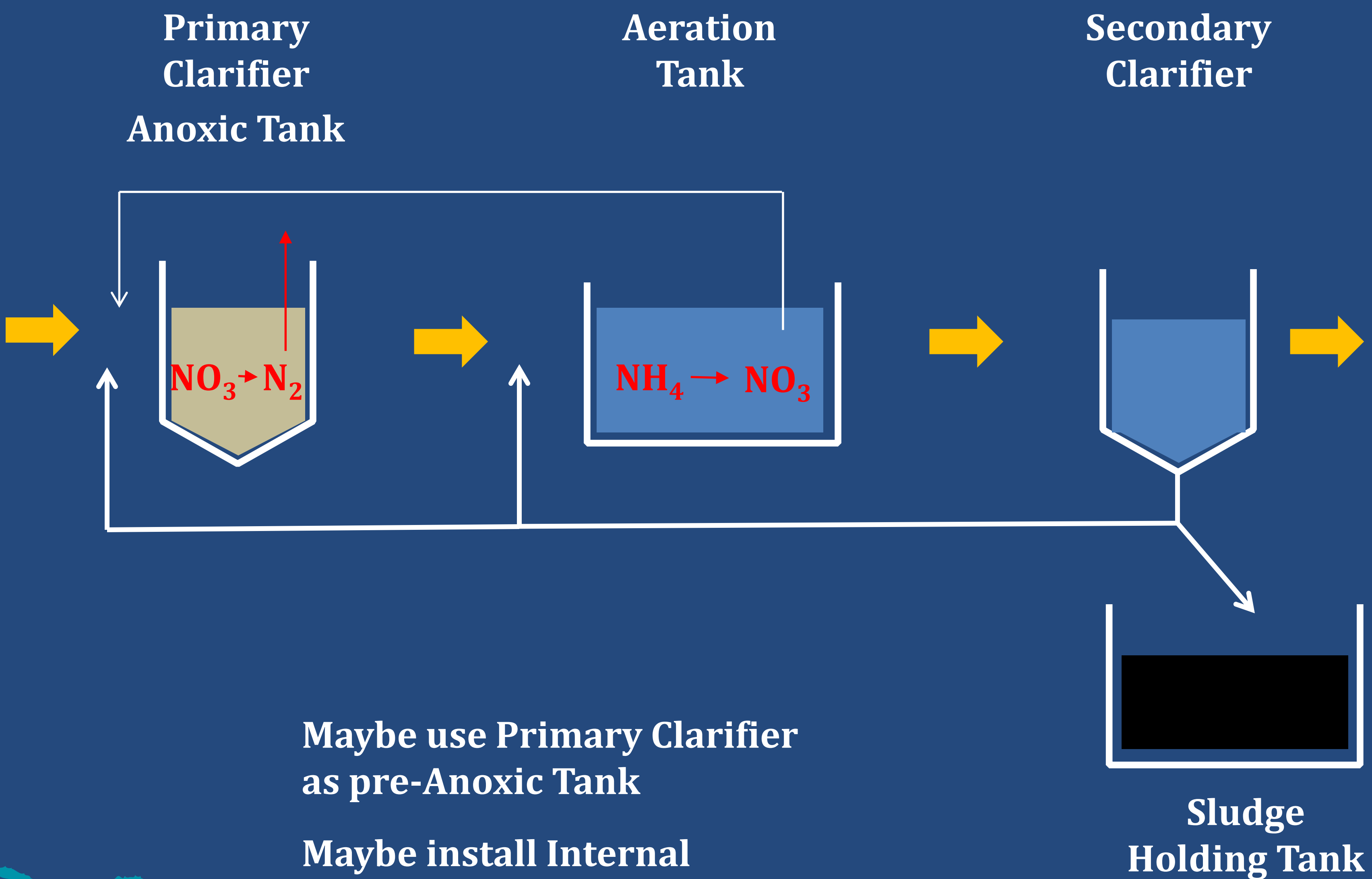
**Nitrate ($NO_3$) Removal**

Target: $NO_3$ < 4 mg/L

ORP: -100 mV

Unless RAS can be increased to 200% or more, $NO_3$ target of 4 mg/L will be hard to achieve

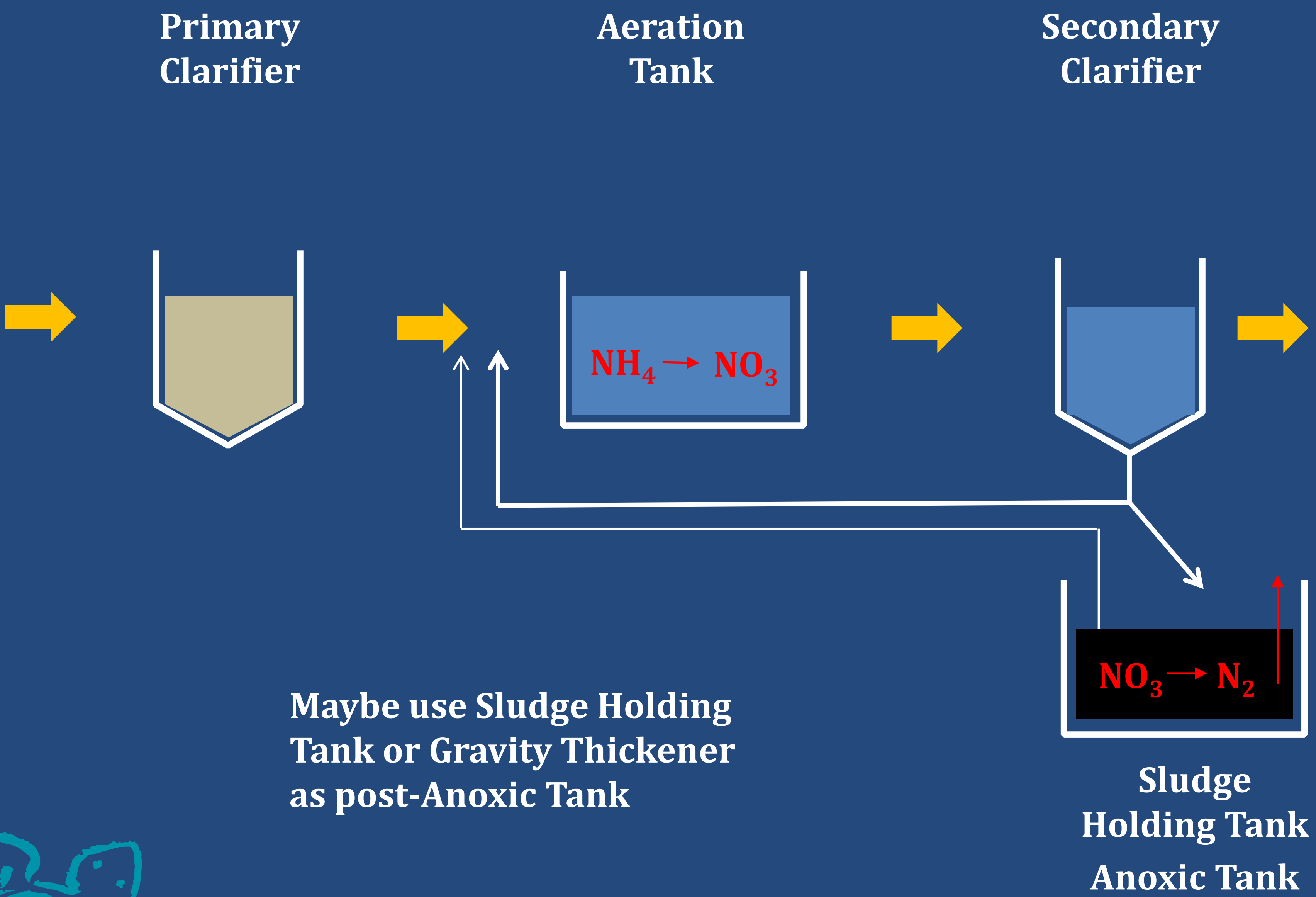

*MLE Process Modification of Conventional AS Plant*



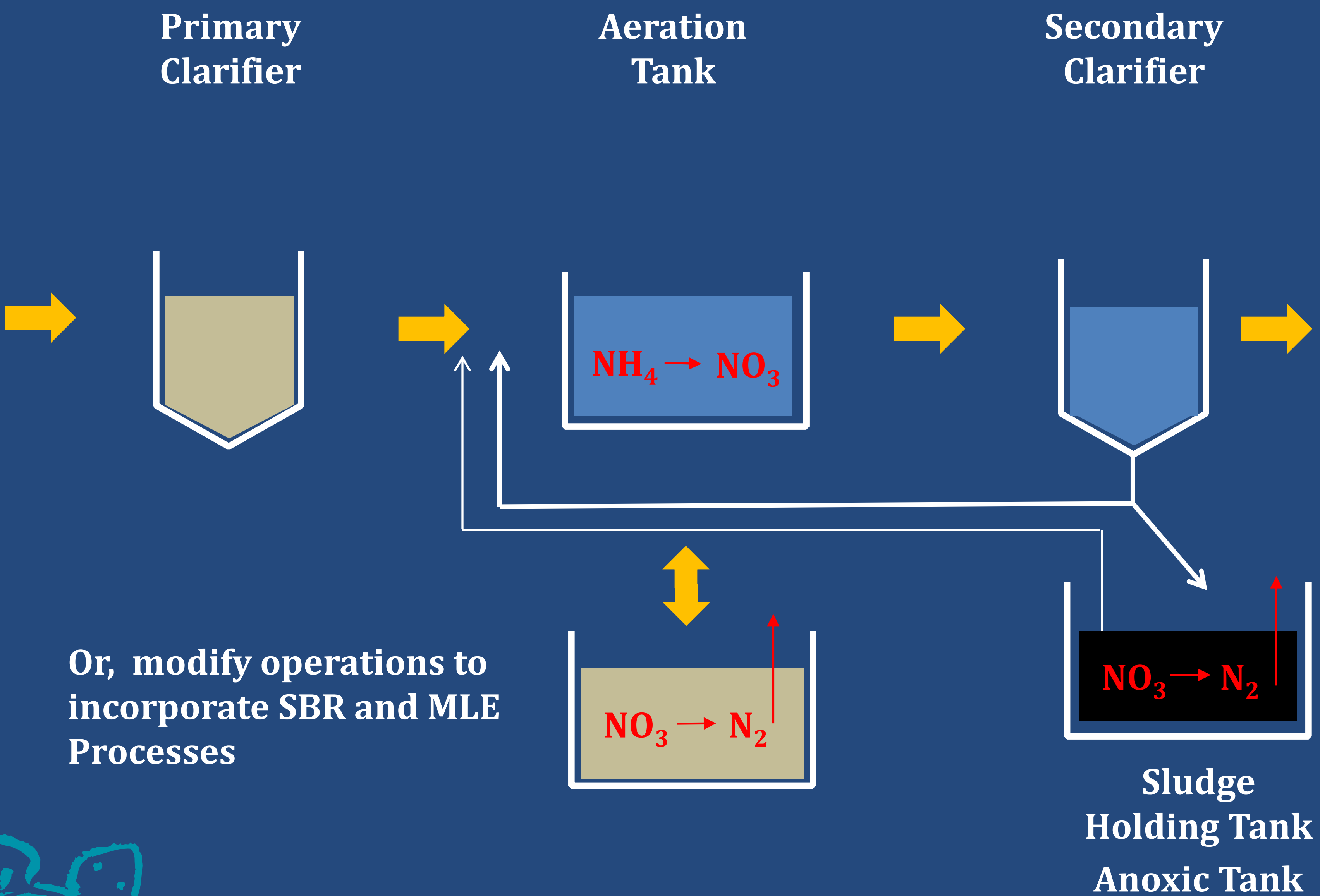

**Maybe use Primary Clarifier as pre-Anoxic Tank**

**Maybe install Internal Recycle Pump(s)**

## *MLE Process Modification of Conventional AS Plant*




# *MLE Process Modification of Conventional AS Plant*




Or, modify operations to incorporate SBR and MLE Processes

# *MLE & SBR Modification of Conventional AS Plant*

# *Monitor and Control the Process*


Review and Analyze Data every day

- Maintain Optimized Habitats
- Monitor Treatment Efficiency

Be Prepared to make Process Changes every day

- Preemptive changes to keep Habitats Ideal
- Reactive changes to meet Treatment Requirements

## *Monitoring* ***HABITAT CONDITIONS***


Daily testing of …

- Process control parameters
  - SVI
  - MLSS
  - DO
- ORP
- Alkalinity

## *Monitoring* ***TREATMENT***

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# Phosphorus Removal

## Nitrogen & Phosphorus Removal
## Using Existing Wastewater Treatment Equipment Differently

Grant Weaver, PE & wastewater operator
Fleming Training Center
Murfreesboro, Tennessee
November 13, 2014

Part 3 of 4

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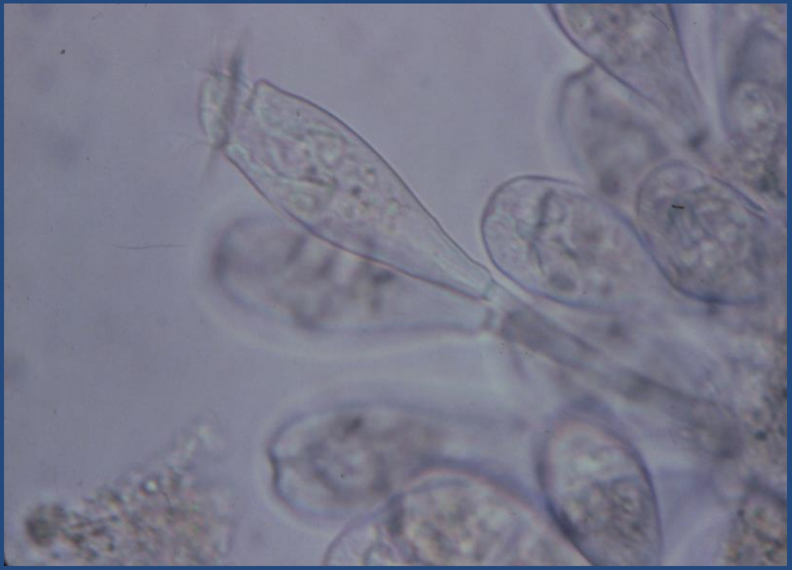
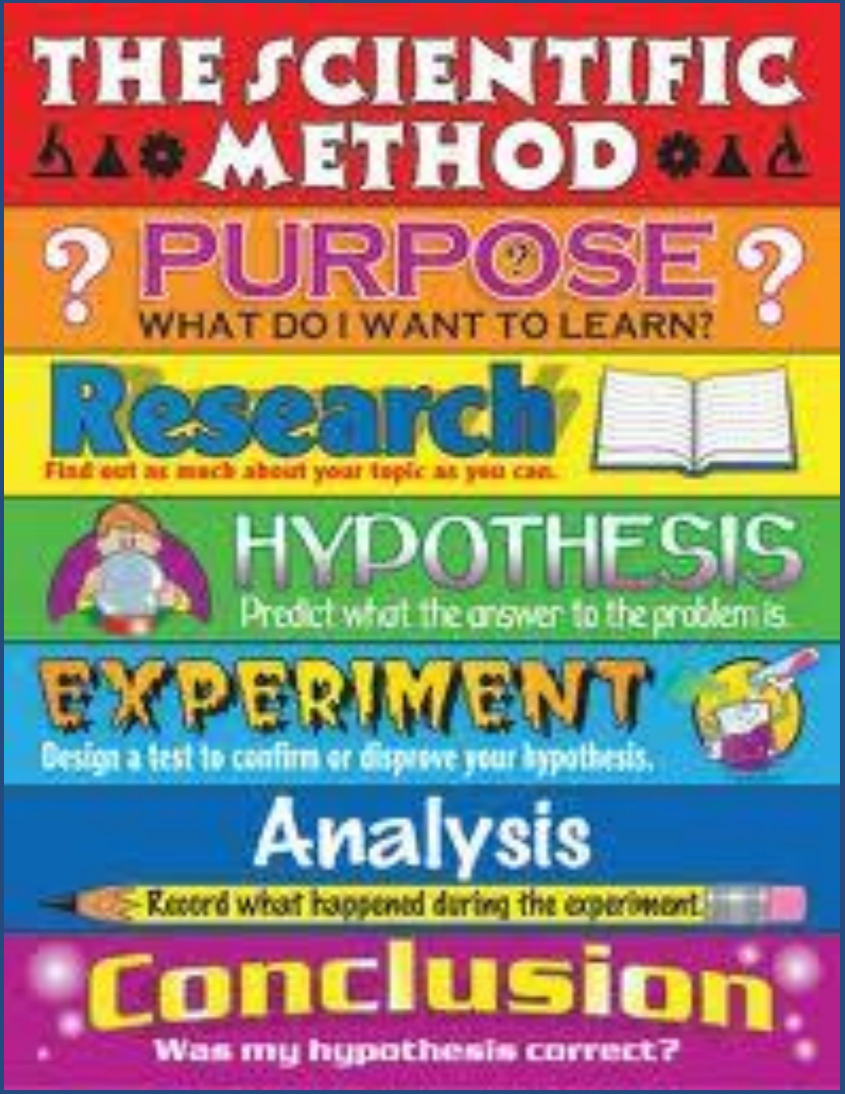
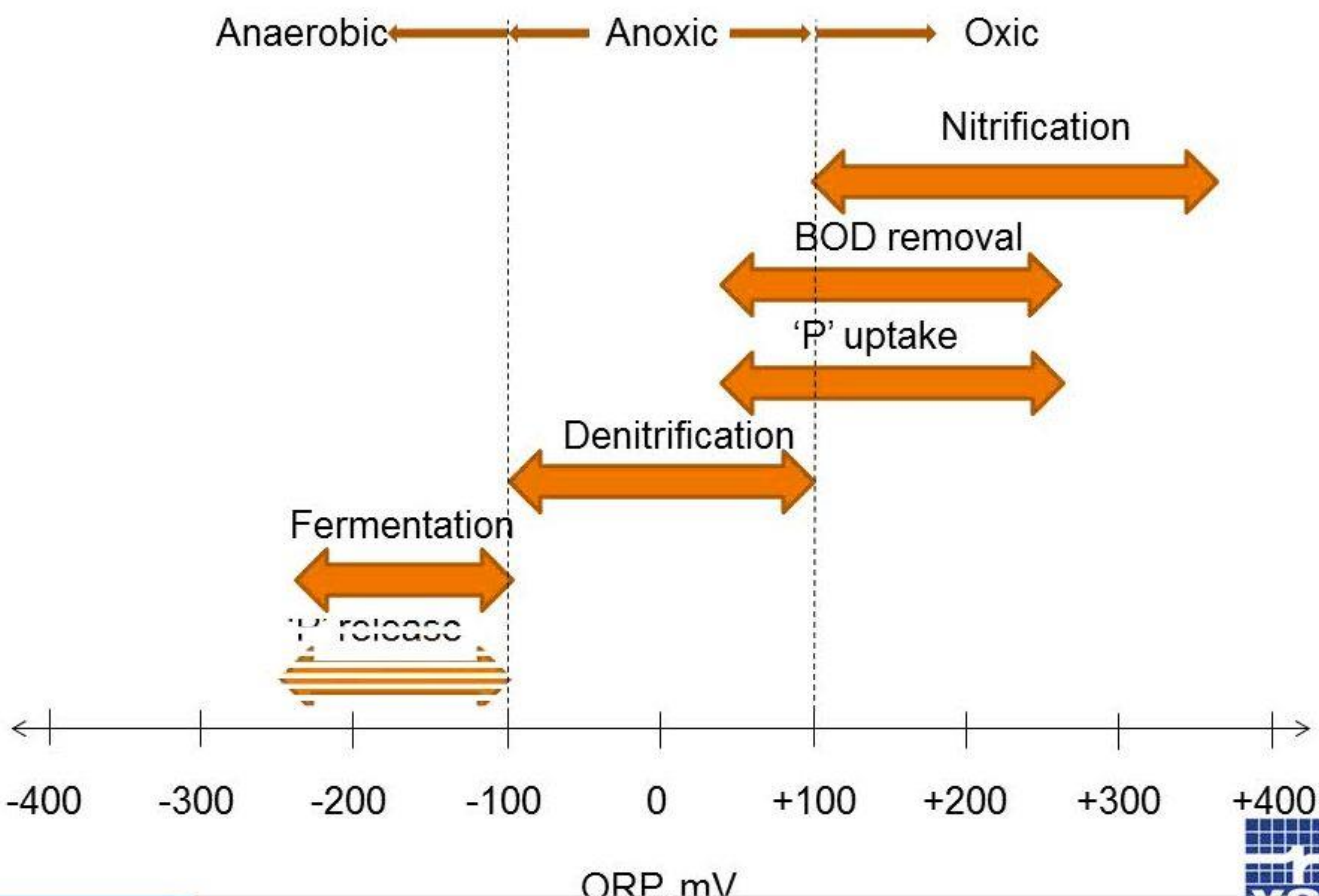
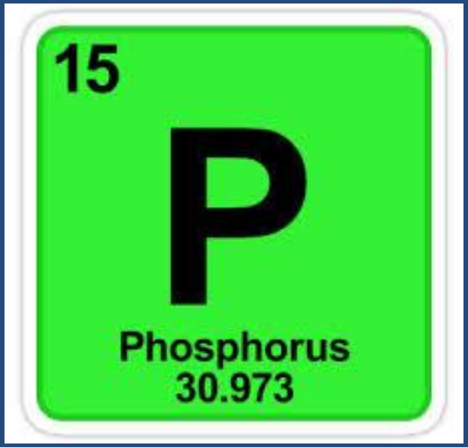
*Creating Optimal Habitats*


THE SCIENTIFIC METHOD
PURPOSE
WHAT DO I WANT TO LEARN?
Research
Find out as much about your topic as you can.
HYPOTHESIS
Predict what the answer to the problem is.
EXPERIMENT
Design a test to confirm or disprove your hypothesis.
Analysis
Record what happened during the experiment.
Conclusion
Was my hypothesis correct?

# What does ORP tell us about our process?




15
P
Phosphorus
30.973

## *Phosphorus Removal:*
## *What an Operator needs to know*


ONE. Convert soluble phosphorus to TSS …

- Biologically
- Chemically

TWO. Remove TSS

Rules of Thumb:

0.05 mg/L of soluble phosphorus (ortho-P) remains after treatment

Each 1 mg/L TSS contains up to 0.05 mg/L total-P

## *TSS Removal Requirements*

Since all but 0.05 mg/L of the soluble Phosphorus can be converted to TSS Phosphorus (Biologically and/or Chemically)

And, because approximately 5% of Effluent TSS is Phosphorus

… To meet a total-P limit, the effluent TSS needs to be kept to the max TSS number shown in the table.

| P Limit | max TSS |
|---|---|
| 0.1 | 1 |
| 0.2 | 3 |
| 0.3 | 5 |
| 0.4 | 7 |
| **0.5** | **9** |
| 0.6 | 11 |
| 0.7 | 13 |
| 0.8 | 15 |
| 0.9 | 17 |
| **1.0** | **19** |
| 1.1 | 21 |
| 1.2 | 23 |
| 1.3 | 25 |
| 1.4 | 27 |
| 1.5 | 29 |

## *Biological Phosphorus Removal: Converting liquid phosphorus to solid phosphorus*

Zero Oxygen Habitat (Fermentation)

Bacteria break down BOD to create volatile fatty acids (VFAs)

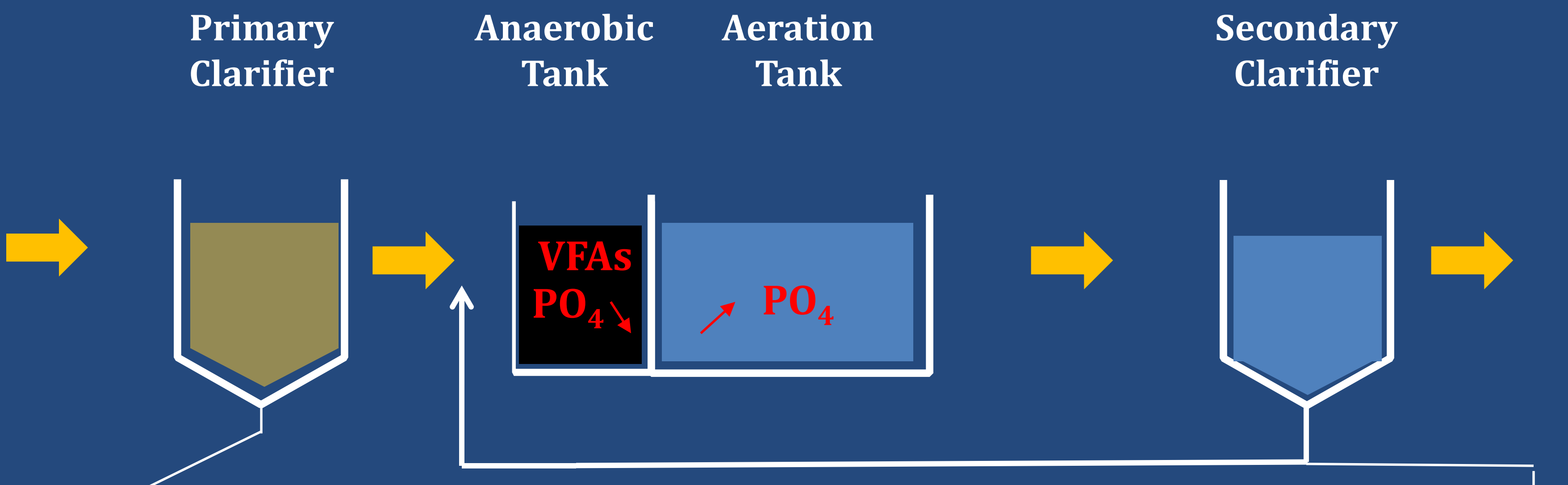
Other bacteria (PAOs) take in the VFAs as an energy source and temporarily release more ortho-P into solution

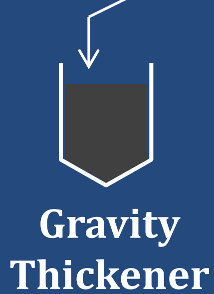
Oxygen Rich Habitat (Aeration Tank)

PAO bacteria use the stored energy to “bulk up” on ortho-P

# *Biological Phosphorus Removal: Mainstream Flow Fermentation Processes*

# *Bio-P Removal: Mainstream Fermentation Process*





In **Anaerobic Tank** …

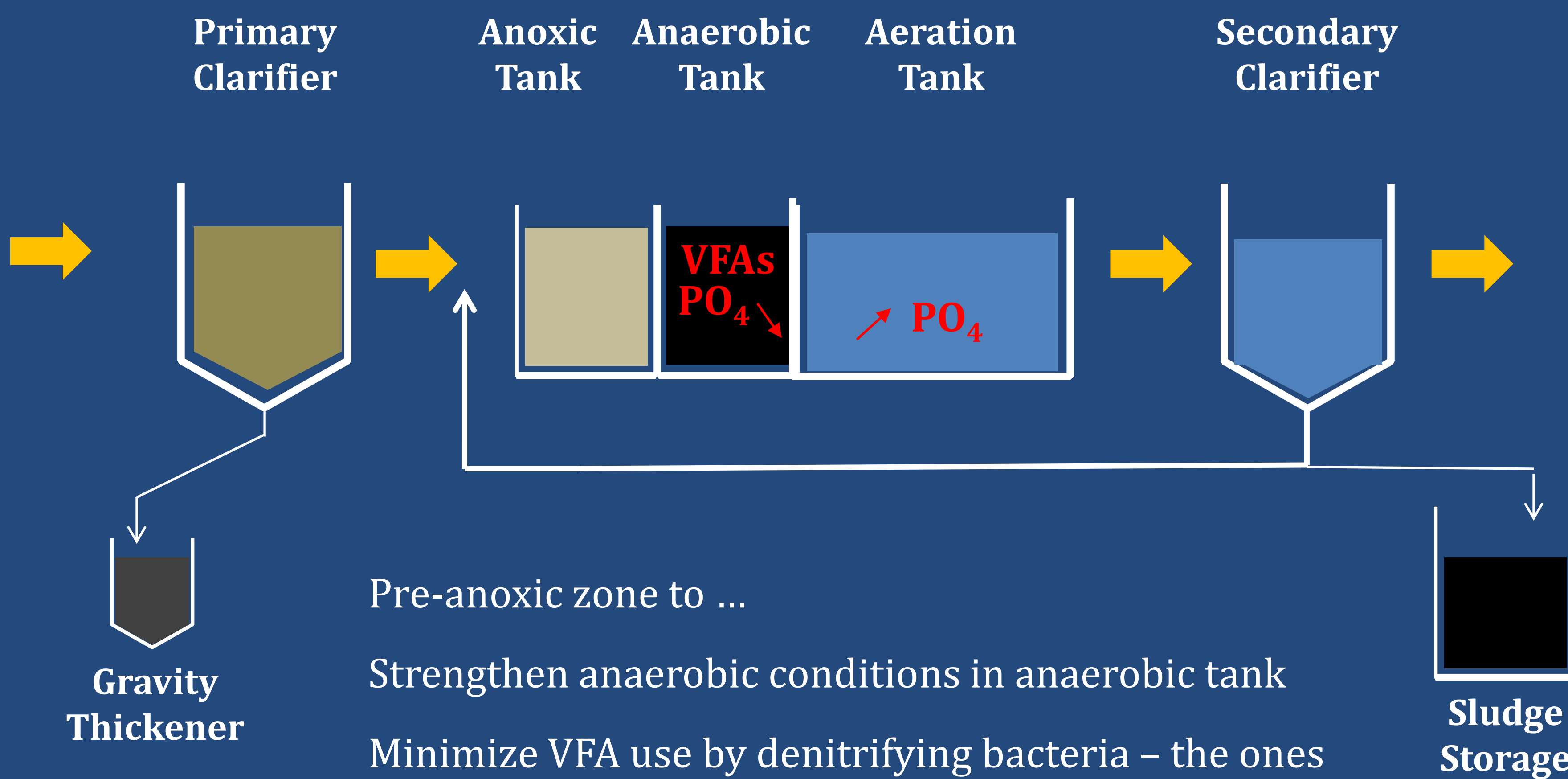
Bacteria break down complex BOD into more digestible VFAs.

PAO bacteria take in VFAs as energy source & temporarily release $PO_4$ into solution.

In **Aeration Tank** …

PAO bacteria use VFAs to take $PO_4$ out of solution.

# *Bio-P Removal: Mainstream Fermentation Process*



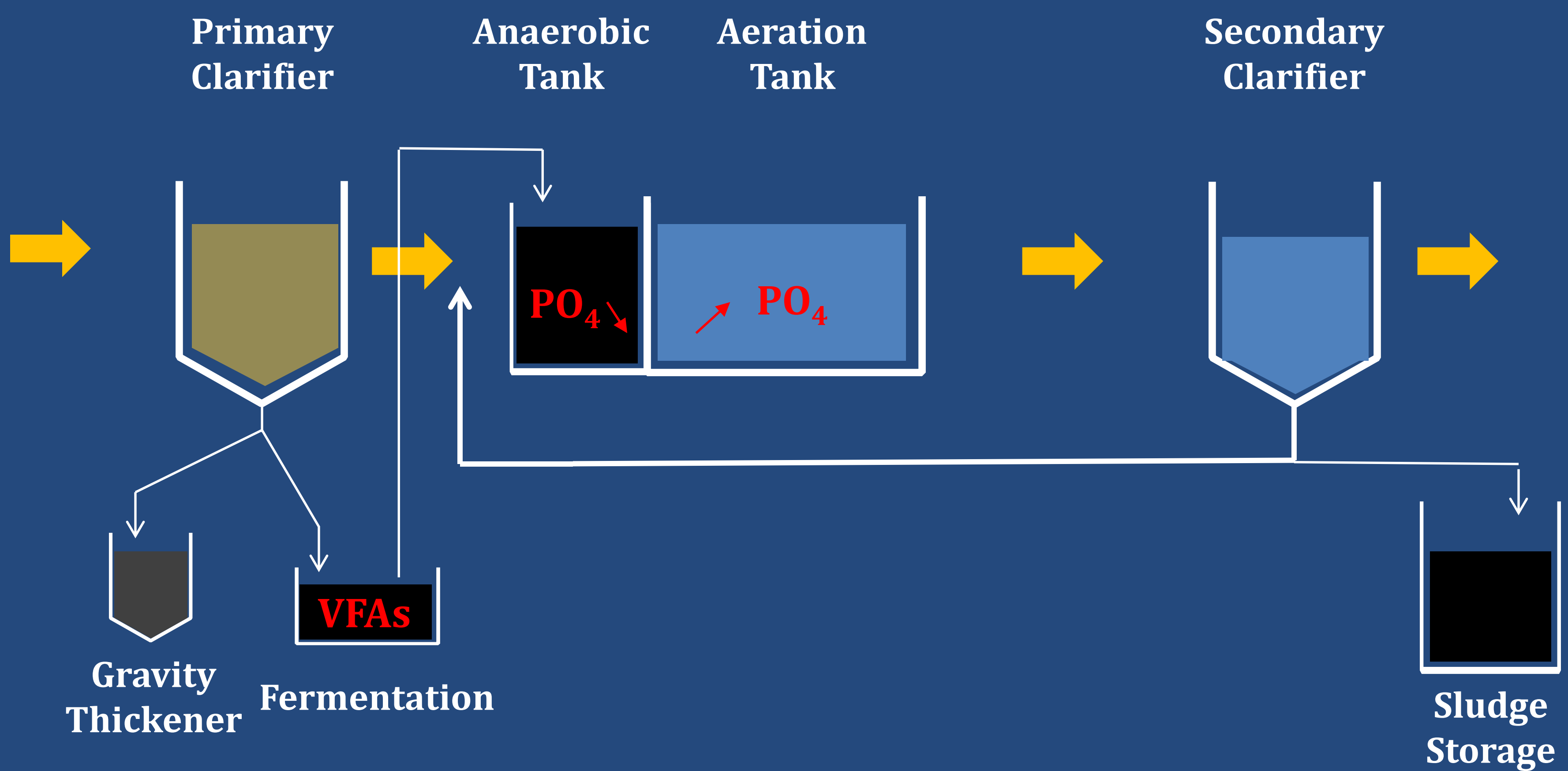

Pre-anoxic zone to …

Strengthen anaerobic conditions in anaerobic tank

Minimize VFA use by denitrifying bacteria – the ones that convert Nitrate ($NO_3$) to Nitrogen Gas ($N_2$) – by "feeding" influent to the denitrifiers.

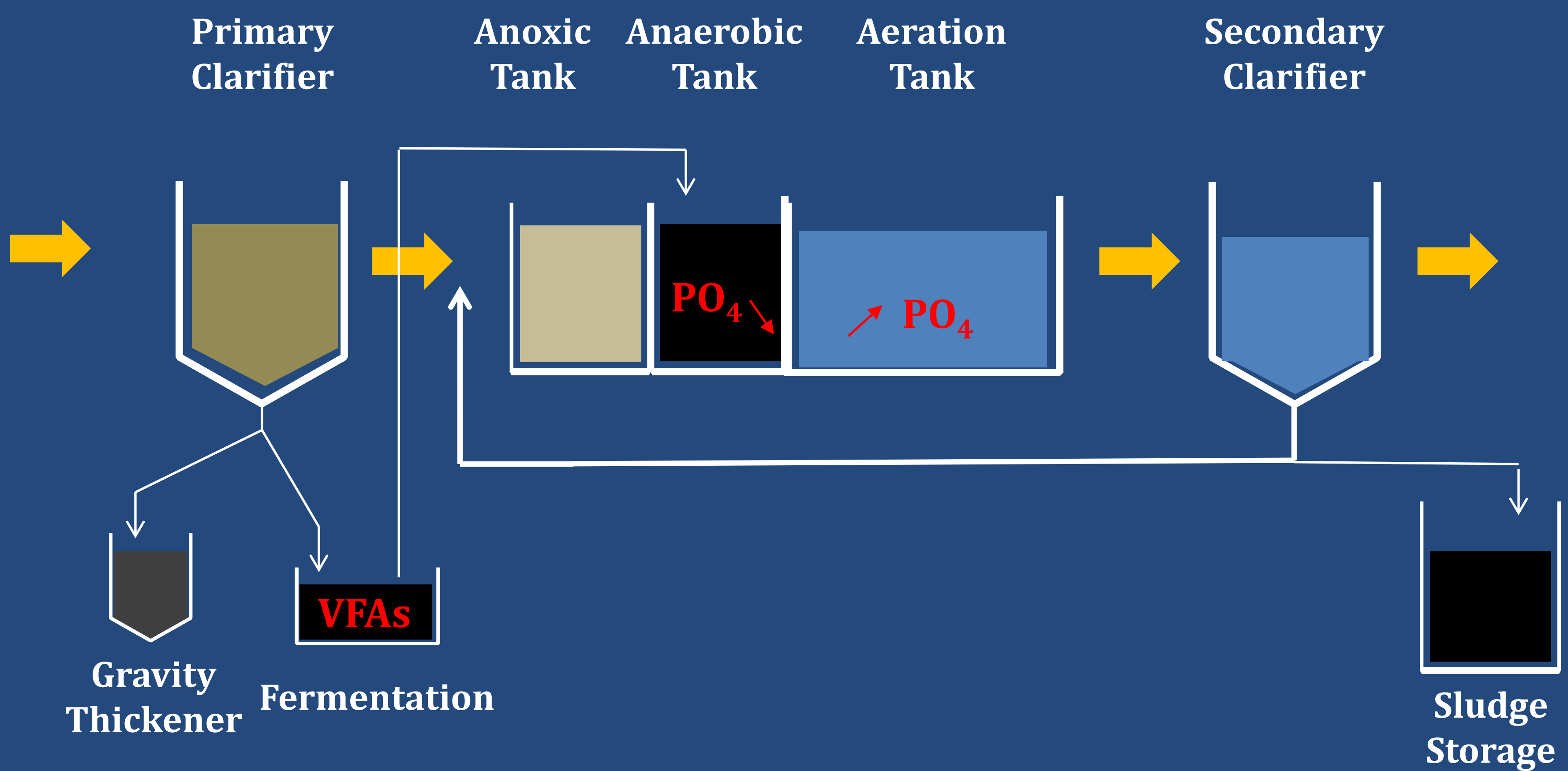
# *Biological Phosphorus Removal: Combined Sidestream & Mainstream Fermentation*

# *Bio-P Removal: Sidestream Fermentation Process*




**Nitrogen Interference**: Nitrate ($NO_3$) will consume VFAs

# *Bio-P Removal: Sidestream Fermentation Process*




**No Nitrogen Interference**

# *Optimizing Bio-P Removal: Mainstream or Sidestream Fermentation*

Anaerobic Tank

~1 hour HRT*
ORP of -200 mV*
25 times as much BOD as influent ortho-P*
Ortho-P release (3-4 times influent ortho-P)*

Aeration Tank

High DO / High ORP
pH of 6.8+*
Ortho-P concentration of 0.05 mg/L*

*Approximate: Every Plant is Different


BACKGROUND
INFORMATION

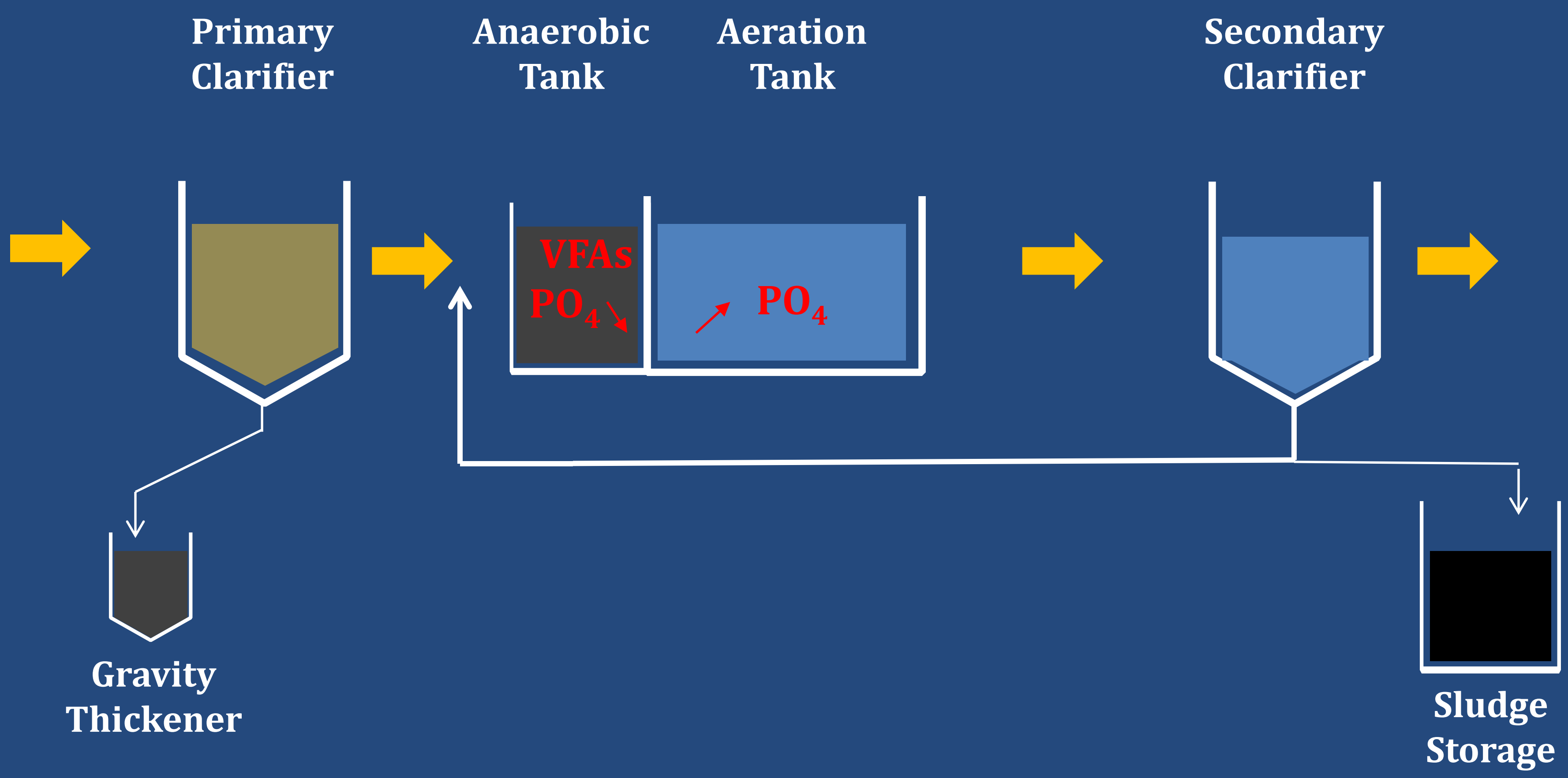

COMPLETED
dreamstime.com

*Experimenting with YOUR plant:*
*Finding the “Right” Process Control Strategy*


*… and, Optimizing Phosphorus Removal*

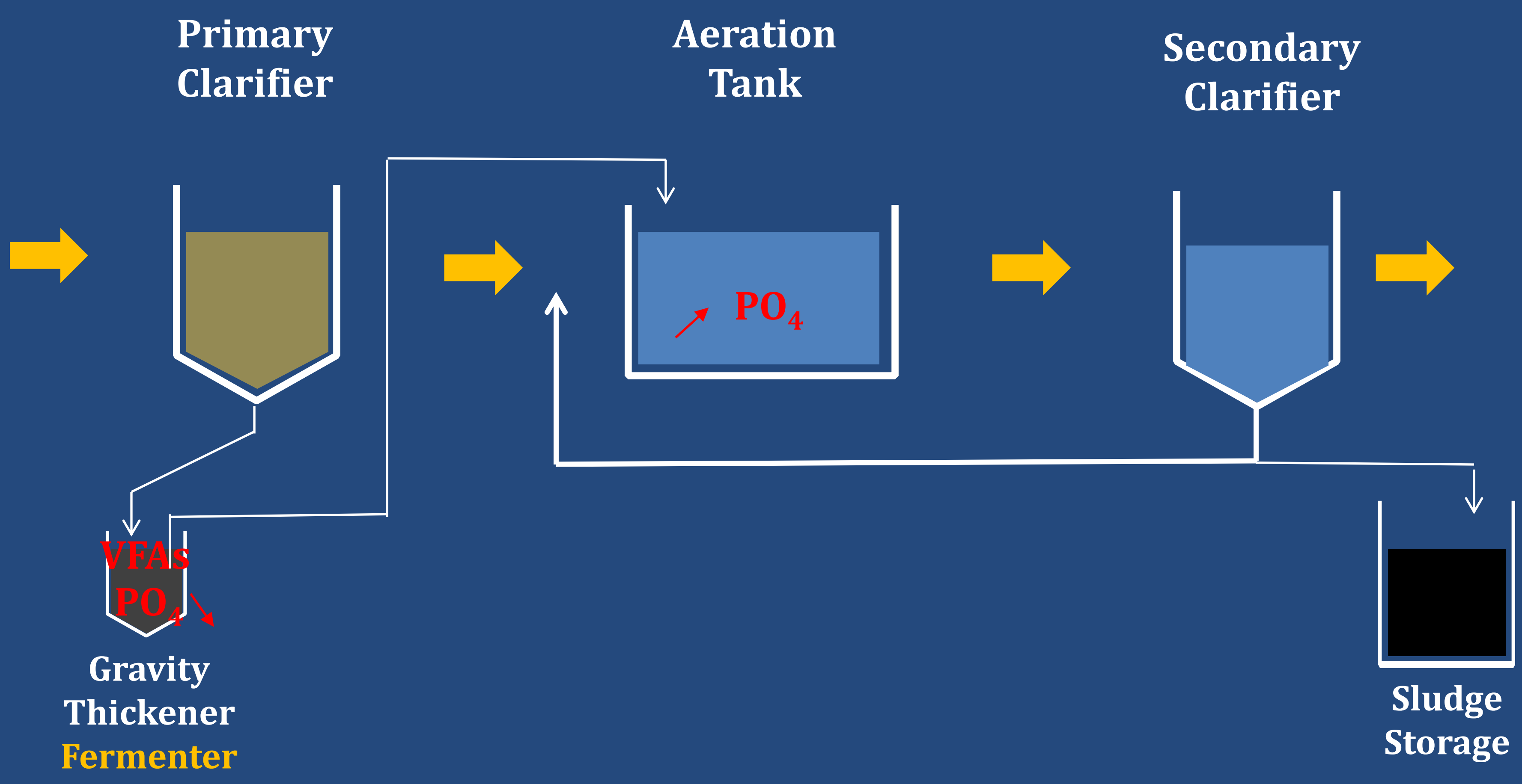
*Create a Mainstream Fermentation Zone*

# *Mainstream Bio-P Removal in Conventional AS Plant*

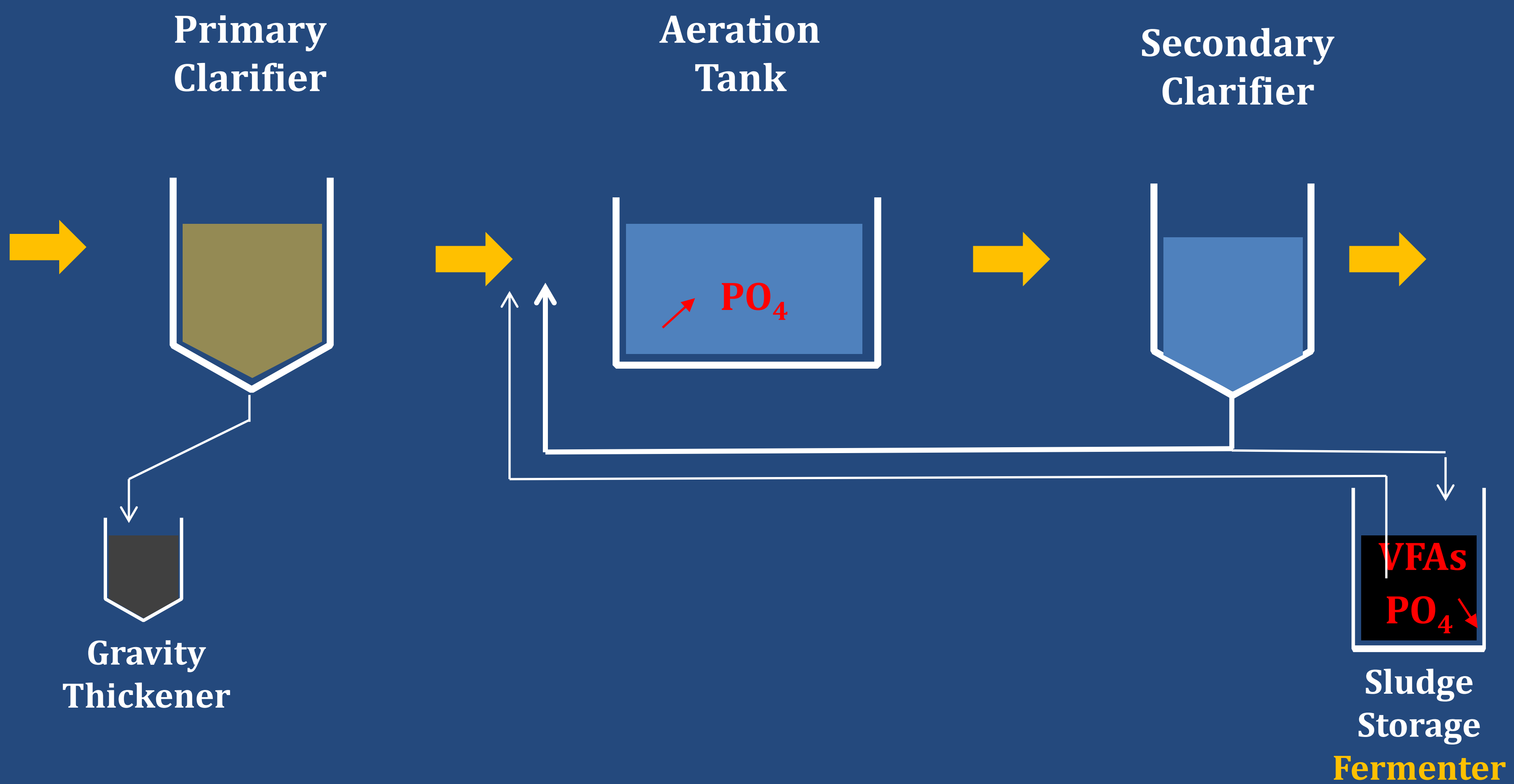


*Create a Sidestream Fermentation Zone*

# *Sidestream Biological-P Removal: Gravity Thickener*

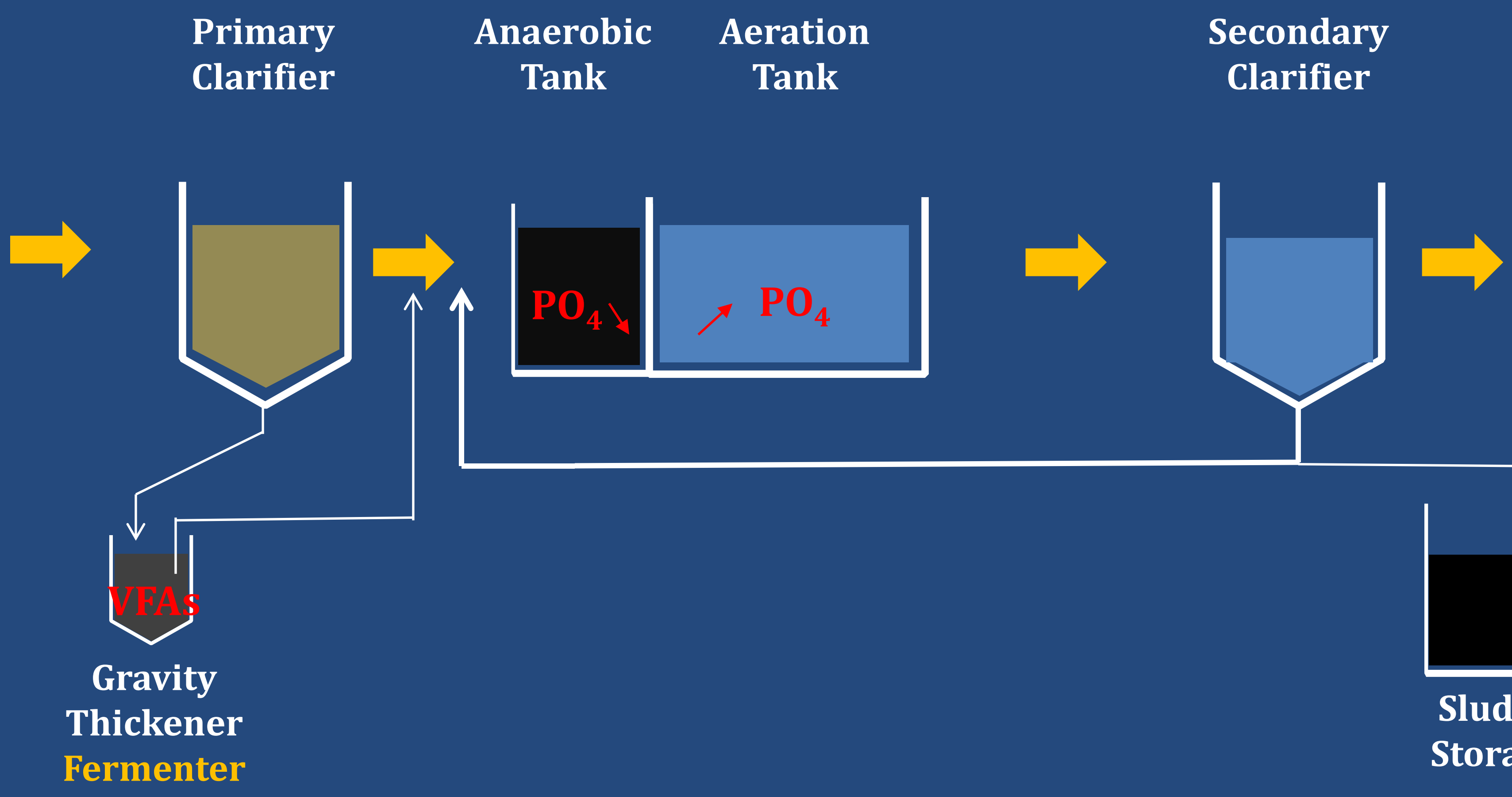


# *Sidestream Biological-P Removal: Sludge Storage*

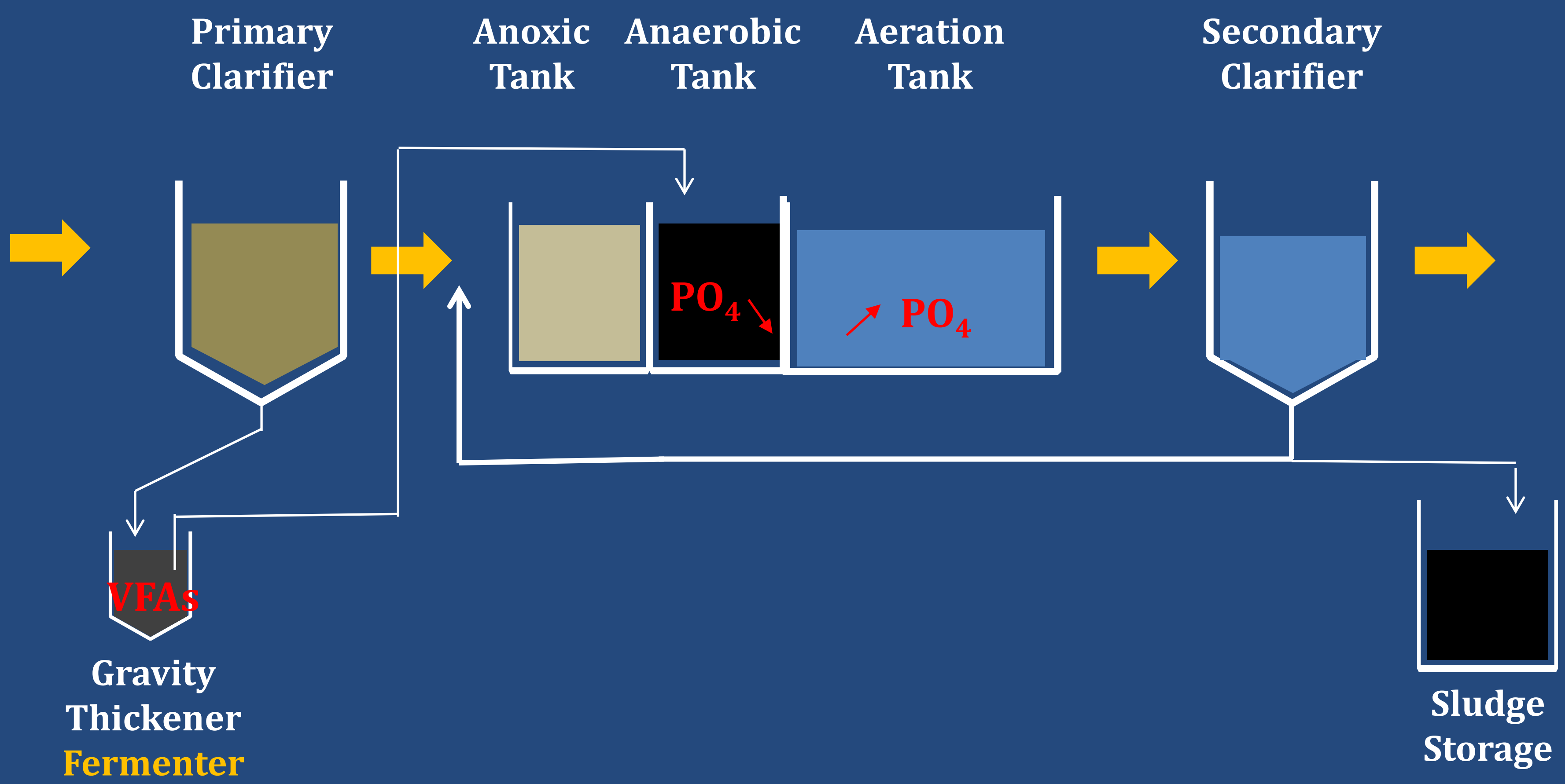


*Create Both Mainstream & Sidestream Fermentation Zones*

# *Sidestream & Mainstream Bio-P Removal*

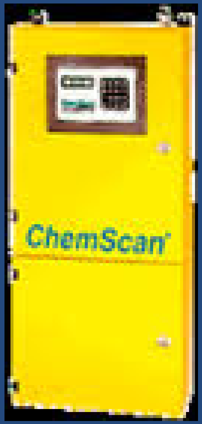


# *Sidestream & Mainstream Bio-P Removal*




**No Nitrogen Interference**

# *Optimizing Fermentation: Mainstream or Sidestream*




Anaerobic Tank

~1 hour HRT*
ORP of -200 mV*
25* times as much BOD as influent ortho-P
ortho-P release (3-4 times influent ortho-P)*

Aeration Tank

DO of 2.0 mg/L*
pH of 6.8+*
ortho-P concentration of 0.05 mg/L*

*Approximate: Every Plant is Different

# *Dialing In Biological N&P Removal*

Denitrifiers outcompete PAOs for volatile fatty acids (VFAs)

*03-Optimizing both Nitrogen and Phosphorus Removal in Activated Sludge Treatment Facilities*

# *Summary*


Operational changes allow many (most) Activated Sludge Plants to biologically remove phosphorus - and - as a bonus create a biological selector for filament control.

Find opportunities for mainstream as well as sidestream fermentation zones.

Recognize that two things occur in the anaerobic tanks:

- VFA formation (hard to digest compounds converted to easy-to-eat molecules)
- PAOs use volatile fatty acids as an energy source (food)

Aeration Tank habitat is important: DO & pH

Bio-P converts soluble-P to an effluent TSS rich in P …

- TSS control is critical!

Minimize VFA use by Nitrate ($NO_3$)

Monitor and Adjust DAILY for the rest of your life!

**Options for Monitoring Nitrogen and Phosphorus Removal**

| | Cheapest | Good | Better | Best | Ideal |
|---|---|---|---|---|---|
| **Environmental conditions** | | | | | |
| **DO** | hand held membrane DO meter | hand held LDO meter | hand held LDO with thumb drive | in-line DO probe | in-line connected to SCADA |
| **ORP** | pen/stick measure | hand held ORP meter | hand held ORP meter with thumb drive | in-line ORP probe | in-line connected to SCADA |
| **pH** | test strips | pen/stick measure | benchtop pH | in-line pH probe | in-line connected to SCADA |
| **Alkalinity** | test strips | test strips | spectrophotometer | benchtop pH w/ titration | benchtop pH w/ titration |
| **Nitrogen** | | | | | |
| **TKN** | estimate: Ammonia + 2.0 mg/L | estimate: Ammonia + 2.0 mg/L | spectrophotometer | spectrophotometer | spectrophotometer |
| **Ammonia** | test strips | test strips | spectrophotometer | in-line instrument ($$) | in-line connected to SCADA ($$) |
| **Nitrate** | test strips | test strips | spectrophotometer | in-line instrument ($$) | in-line connected to SCADA ($$) |
| **Nitrite** | test strips | test strips | spectrophotometer | spectrophotometer | spectrophotometer |
| **Phosphorus** | | | | | |
| **total-P** | estimate: TSSx0.05 + test strips | estimate: TSSx0.05 + test strips | spectrophotometer | spectrophotometer | spectrophotometer |
| **ortho-P** | test strips | test strips | spectrophotometer | in-line instrument ($$) | in-line connected to SCADA ($$) |

## Options for Monitoring Nitrogen and Phosphorus Removal: Small Plants – Less than 1.0 MGD

**Environmental conditions**

| | Cheapest | Good | Better | Best | Ideal |
|---|---|---|---|---|---|
| **DO** | hand held membrane DO meter | **hand held LDO meter** | hand held LDO with thumb drive | in-line DO probe | in-line connected to SCADA |
| **ORP** | pen/stick measure | **hand held ORP meter** | hand held ORP meter with thumb drive | in-line ORP probe | in-line connected to SCADA |
| **pH** | test strips | **pen/stick measure** | benchtop pH | in-line pH probe | in-line connected to SCADA |
| **Alkalinity** | test strips | **test strips** | spectrophotometer | benchtop pH w/ titration | benchtop pH w/ titration |

**Nitrogen**

| | Cheapest | Good | Better | Best | Ideal |
|---|---|---|---|---|---|
| **TKN** | estimate: Ammonia + 2.0 mg/L | **estimate: Ammonia + 2.0 mg/L** | spectrophotometer | spectrophotometer | spectrophotometer |
| **Ammonia** | test strips | **test strips** | spectrophotometer | in-line instrument ($$) | in-line connected to SCADA ($$) |
| **Nitrate** | test strips | **test strips** | spectrophotometer | in-line instrument ($$) | in-line connected to SCADA ($$) |
| **Nitrite** | test strips | **test strips** | spectrophotometer | spectrophotometer | spectrophotometer |

**Phosphorus**

| | Cheapest | Good | Better | Best | Ideal |
|---|---|---|---|---|---|
| **total-P** | estimate: TSSx0.05 + test strips | **estimate: TSSx0.05 + test strips** | spectrophotometer | spectrophotometer | spectrophotometer |
| **ortho-P** | test strips | **test strips** | spectrophotometer | in-line instrument ($$) | in-line connected to SCADA ($$) |

## Options for Monitoring Nitrogen and Phosphorus Removal: 2-5 MGD

| | Cheapest | Good | Better | Best | Ideal |
|---|---|---|---|---|---|
| **Environmental conditions** | | | | | |
| **DO** | hand held membrane DO meter | hand held LDO meter | hand held LDO with thumb drive | in-line DO probe | in-line connected to SCADA |
| **ORP** | pen/stick measure | hand held ORP meter | hand held ORP meter with thumb drive | in-line ORP probe | in-line connected to SCADA |
| **pH** | test strips | pen/stick measure | benchtop pH | in-line pH probe | in-line connected to SCADA |
| **Alkalinity** | test strips | test strips | spectrophotometer | benchtop pH w/ titration | benchtop pH w/ titration |
| **Nitrogen** | | | | | |
| **TKN** | estimate: Ammonia + 2.0 mg/L | estimate: Ammonia + 2.0 mg/L | spectrophotometer | spectrophotometer | spectrophotometer |
| **Ammonia** | test strips | test strips | spectrophotometer | in-line instrument ($$) | in-line connected to SCADA ($$) |
| **Nitrate** | test strips | test strips | spectrophotometer | in-line instrument ($$) | in-line connected to SCADA ($$) |
| **Nitrite** | test strips | test strips | spectrophotometer | spectrophotometer | spectrophotometer |
| **Phosphorus** | | | | | |
| **total-P** | estimate: TSSx0.05 + test strips | estimate: TSSx0.05 + test strips | spectrophotometer | spectrophotometer | spectrophotometer |
| **ortho-P** | test strips | test strips | spectrophotometer | in-line instrument ($$) | in-line connected to SCADA ($$) |

## Options for Monitoring Nitrogen and Phosphorus Removal: 5+ MGD … or, 6 mg/L tN limit or 0.5 mg/L tP limit

| | Cheapest | Good | Better | Best | Ideal |
|---|---|---|---|---|---|
| **Environmental conditions** | | | | | |
| **DO** | hand held membrane DO meter | hand held LDO meter | hand held LDO with thumb drive | in-line DO probe | in-line connected to SCADA |
| **ORP** | pen/stick measure | hand held ORP meter | hand held ORP meter with thumb drive | in-line ORP probe | in-line connected to SCADA |
| **pH** | test strips | pen/stick measure | benchtop pH | in-line pH probe | in-line connected to SCADA |
| **Alkalinity** | test strips | test strips | spectrophotometer | benchtop pH w/ titration | benchtop pH w/ titration |
| **Nitrogen** | | | | | |
| **TKN** | estimate: Ammonia + 2.0 mg/L | estimate: Ammonia + 2.0 mg/L | spectrophotometer | spectrophotometer | spectrophotometer |
| **Ammonia** | test strips | test strips | spectrophotometer | in-line instrument ($$) | in-line connected to SCADA ($$) |
| **Nitrate** | test strips | test strips | spectrophotometer | in-line instrument ($$) | in-line connected to SCADA ($$) |
| **Nitrite** | test strips | test strips | spectrophotometer | spectrophotometer | spectrophotometer |
| **Phosphorus** | | | | | |
| **total-P** | estimate: TSSx0.05 + test strips | estimate: TSSx0.05 + test strips | spectrophotometer | spectrophotometer | spectrophotometer |
| **ortho-P** | test strips | test strips | spectrophotometer | in-line instrument ($$) | in-line connected to SCADA ($$) |

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# Case Studies

## Nitrogen & Phosphorus Removal

## Using Existing Wastewater Treatment Equipment Differently

Grant Weaver, PE & wastewater operator

Fleming Training Center

Murfreesboro, Tennessee

November 13, 2014

Part 4 of 4

The Water Planet Company

# *Case Studies*


<u>Montana</u>
- Conrad

<u>Massachusetts</u>
- Upton
- Amherst
- Palmer
- Westfield

<u>New Hampshire</u>
- Keene

<u>Connecticut</u>
- East Haddam
- Suffield
- Plainfield

## *Montana Department of Environmental Services*

**Two Day Classroom Seminar (2012)**

| | t-N Before (mg/L) | t-N After (mg/L) |
|---|---|---|
| Chinook | 25 | 13 |
| Conrad | 26 | 5 |
| Manhattan | 11 | 7 |


Conrad, Montana
(0.5 MGD: 2,600)

## *Conrad, Montana (0.5 MGD: 2,600)*

After a two-day training class Operator Keith Thaut began cycling aeration ON and OFF.
Effluent nitrogen dropped 82% from 26 mg/L to under 5 mg/L.

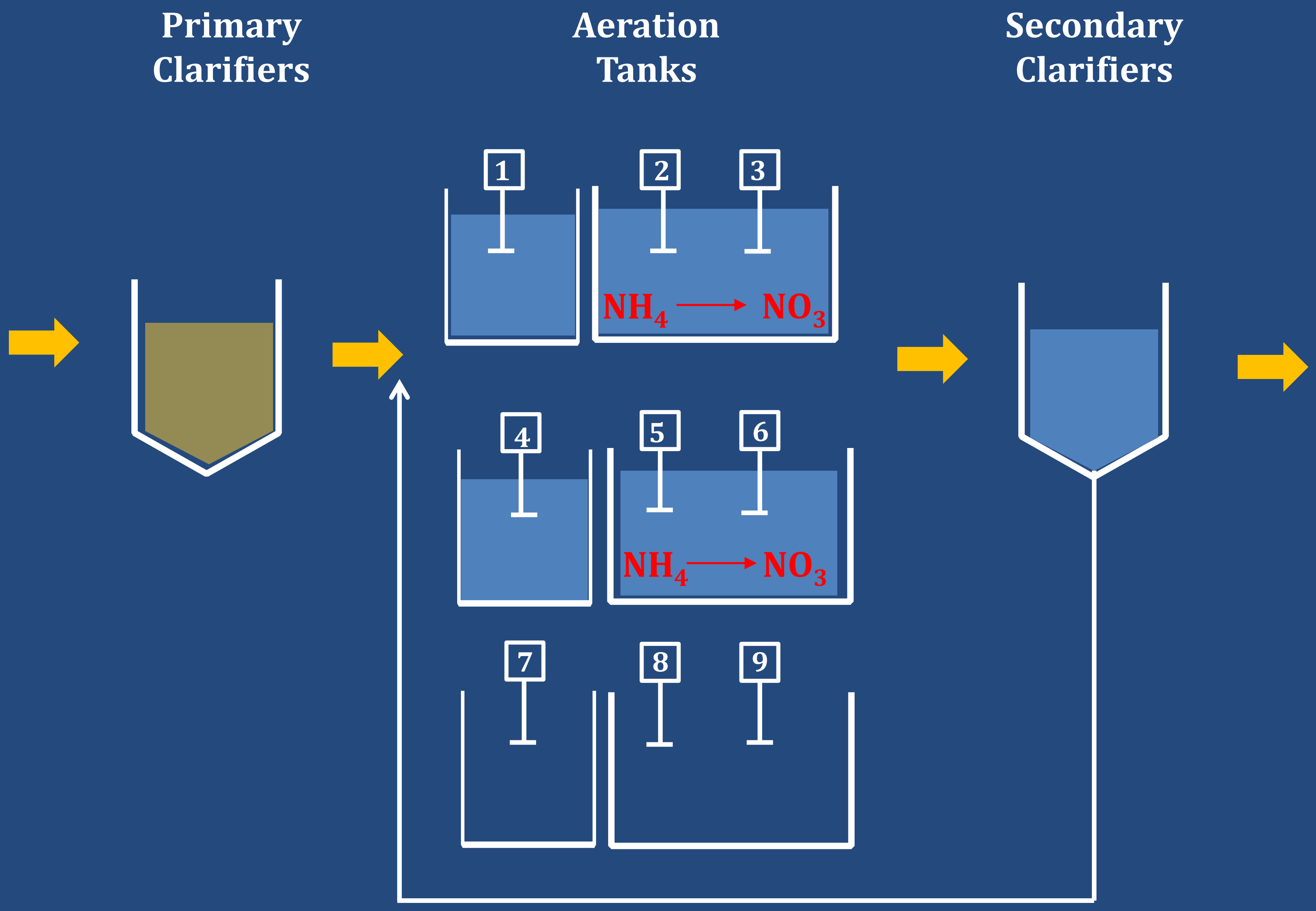
During the summer: air ON for 3 hours followed by 2 hours air OFF.
During the winter: air ON for 2 hours followed by 1½ hours air OFF.

By returning sludge from digestion tank to aeration tank, sludge production has declined by more than 50%.

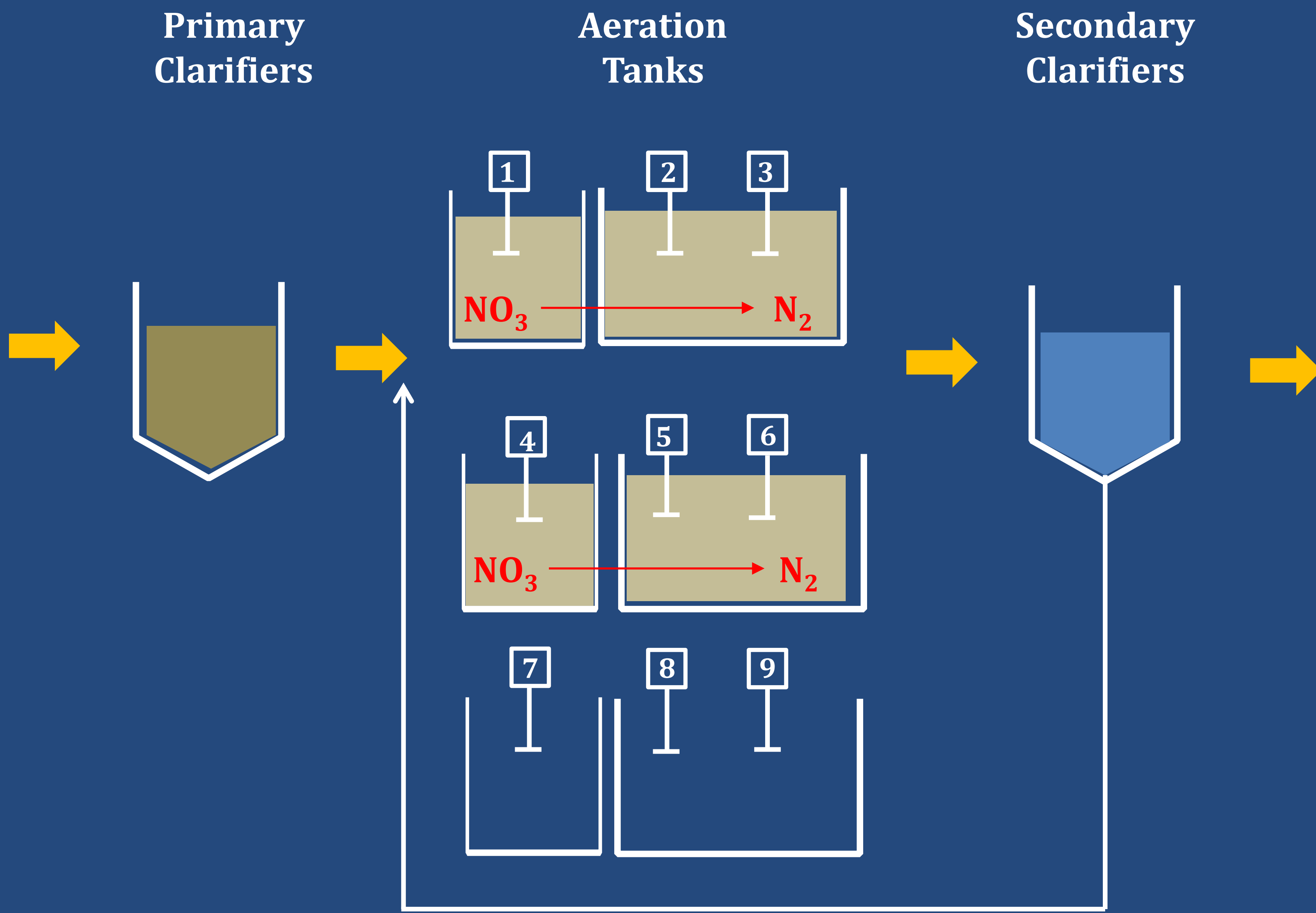
To optimize phosphorus removal, Conrad is experimenting with turning air OFF in the sludge digestion tank.


Upton, Massachusetts
(0.4 MGD: 5,600)


Amherst,
Massachusetts
(7.2 MGD: 38,000)




Amherst, Massachusetts

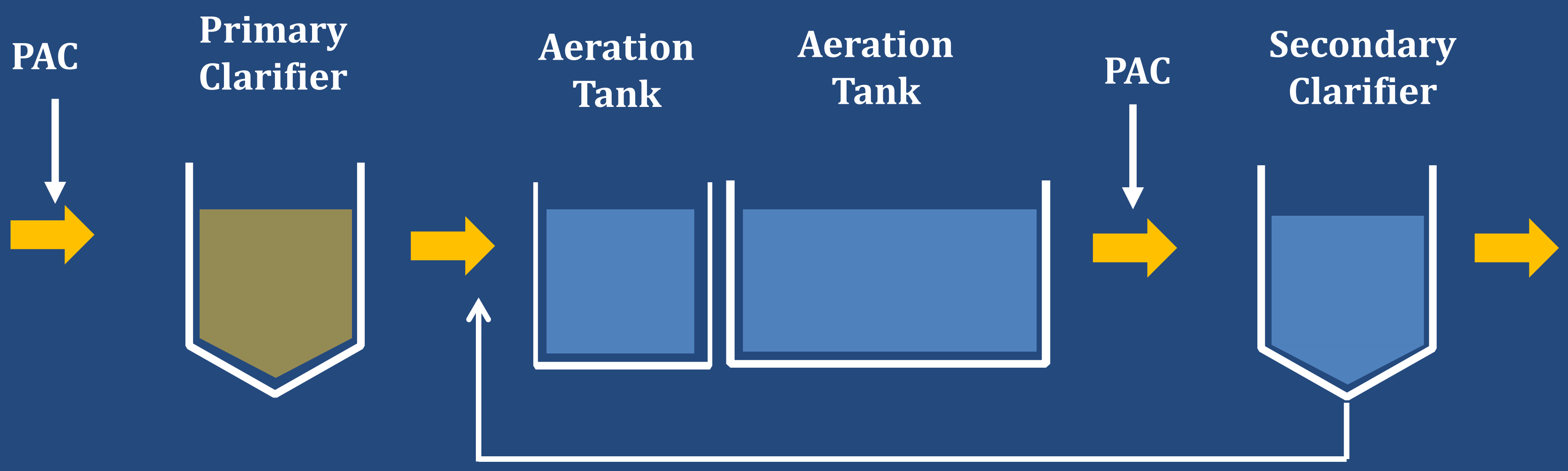



Amherst, Massachusetts


Palmer, Massachusetts
(5.6 MGD: 12,000)
Wastewater Treatment Plant

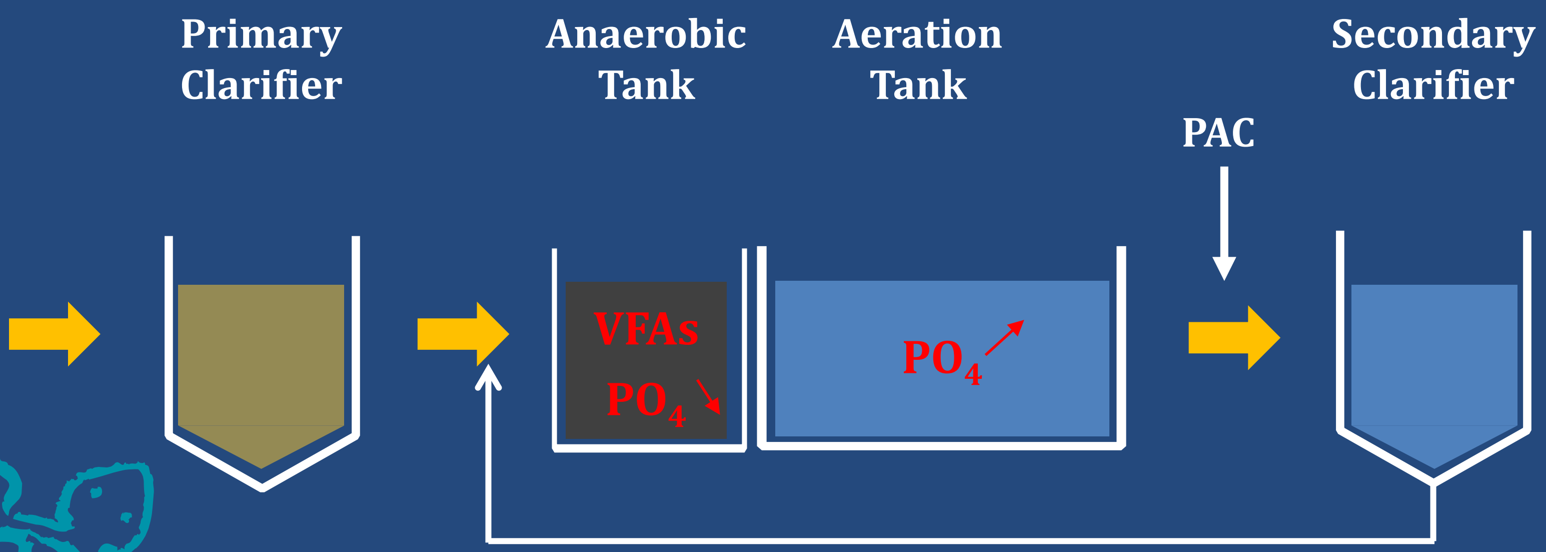

Westfield, Massachusetts
(6.1 MGD: 41,000)


Keene, New Hampshire
(6.0 MGD: 23,000)




*Keene, New Hampshire*

# *Keene, New Hampshire*



*Case Study – Phosphorus Removal*
*East Haddam, Connecticut*

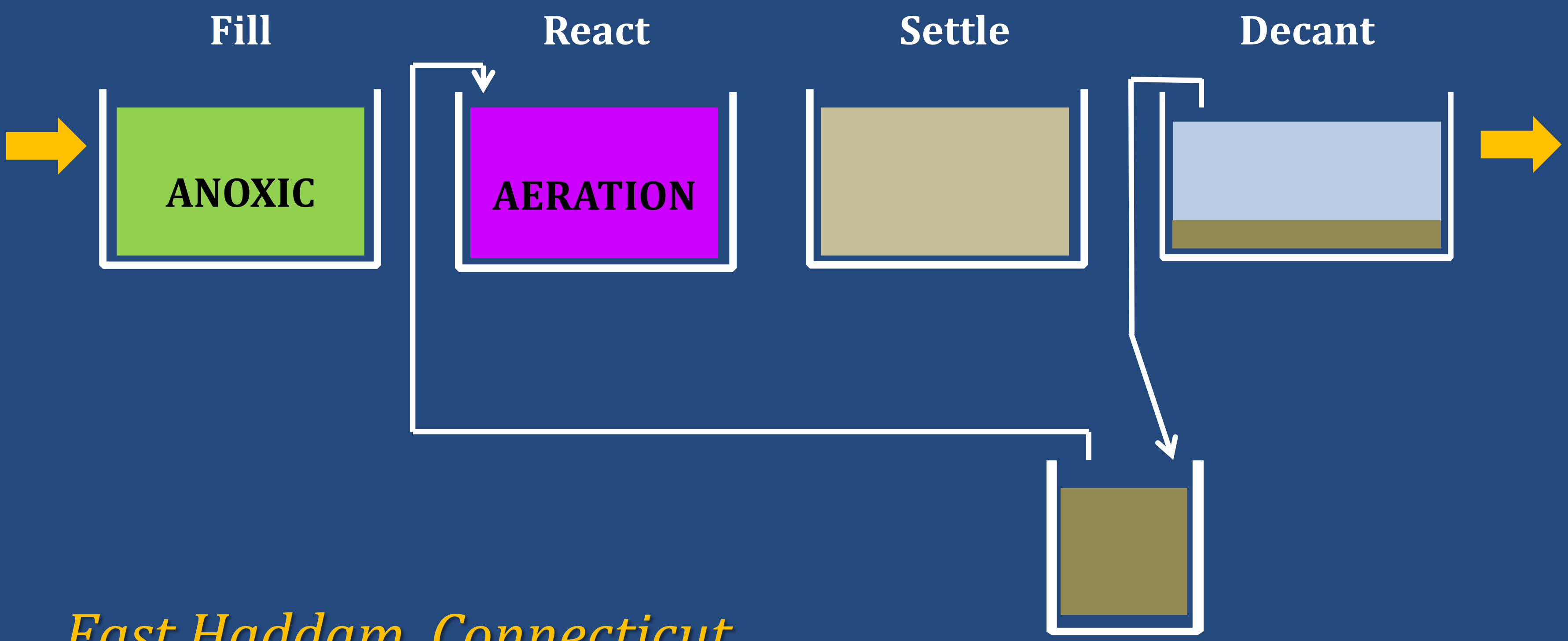
Design Flow: 0.055 MGD
Actual: 0.015 MGD

Effluent total-N

Before & After: 6.5 mg/L
(2 TKN, 0.5 Ammonia, 3.5 Nitrite + Nitrate)

Effluent total-P

Before Changes: 3-4 mg/L
After Changes: 0.35 mg/L




*East Haddam, Connecticut*

*East Haddam, Connecticut*

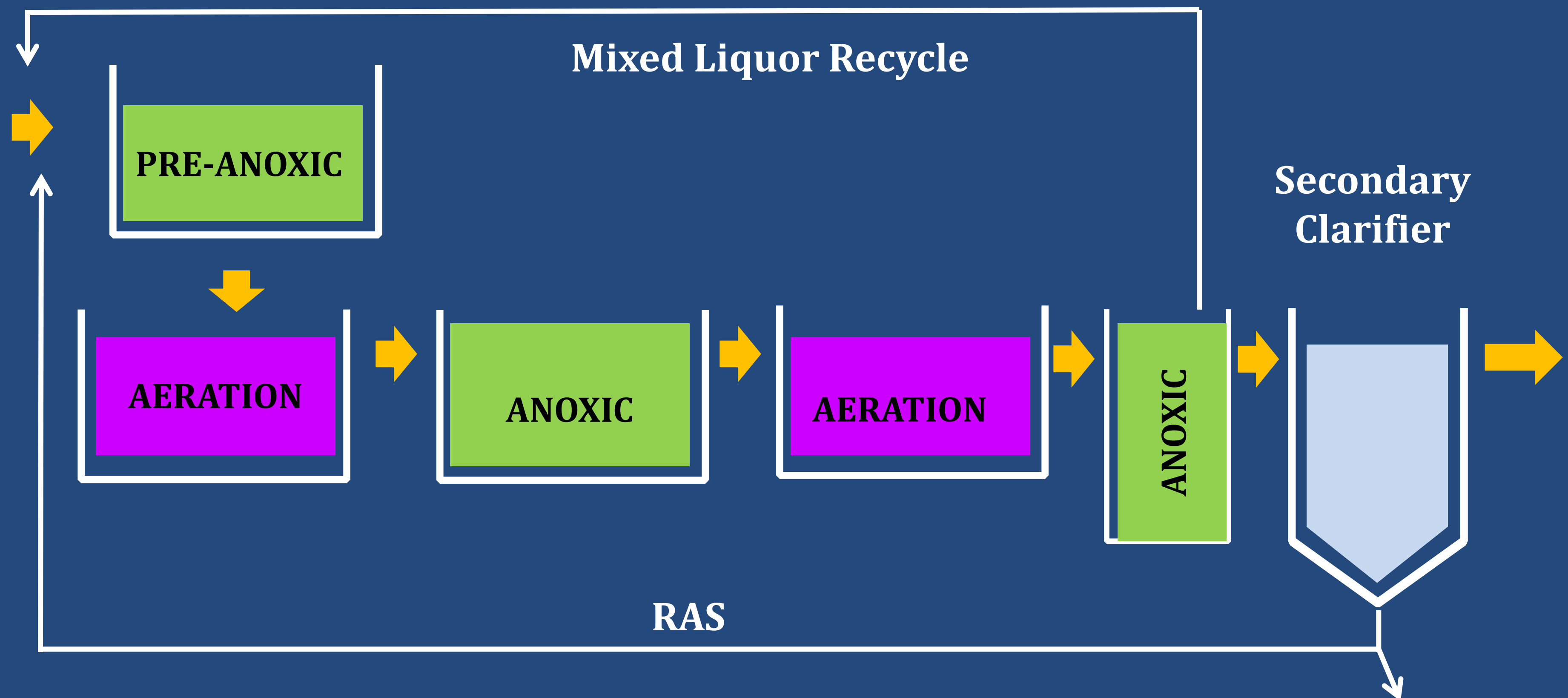

Suffield, Connecticut
(2.0 MGD: 16,000)

## *Suffield, Connecticut*

Design Flow: 2.0 MGD
Actual: 1.0 MGD

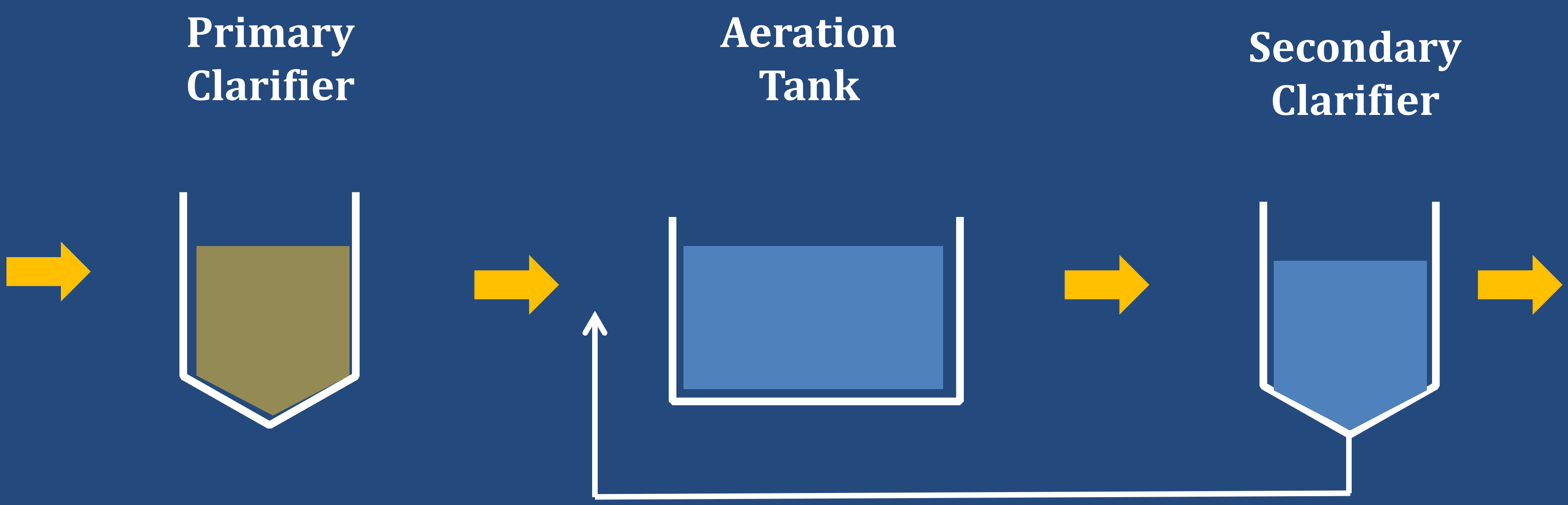
Effluent total-N
- Before Changes: 7 mg/L
  (3 TKN, 0.5 Ammonia, 4 Nitrite + Nitrate)
- After Changes: 1.0-2.0 mg/L
  (1 TKN, 0.1 Ammonia, 1 Nitrite + Nitrate)

Effluent total-P
- Before Changes: 3.0 mg/L
- After Changes: 0.7 mg/L

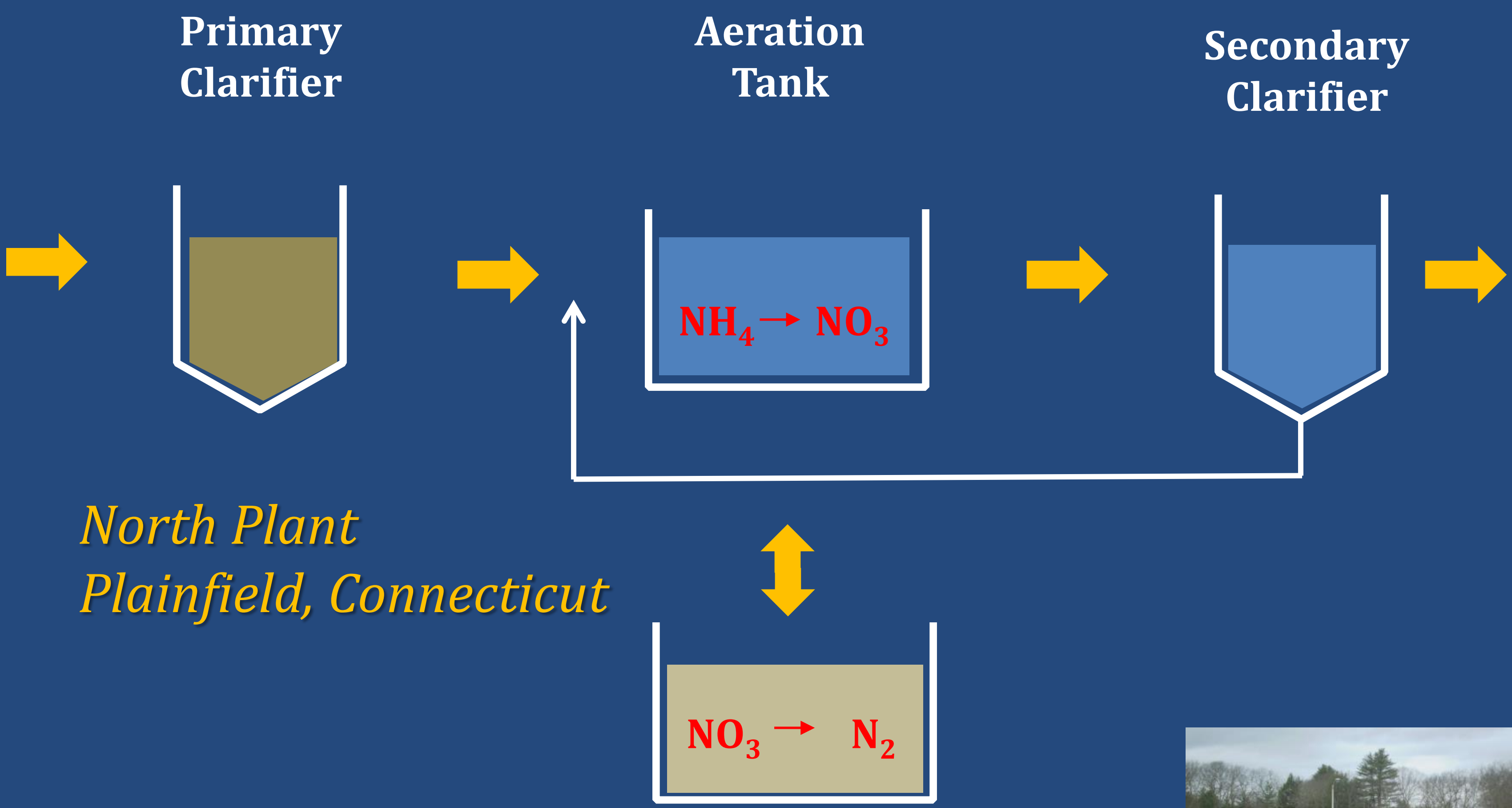



*Suffield, Connecticut*


Plainfield, Connecticut – North Plant
(1.0 MGD: 15,000)




*North Plant*
*Plainfield, Connecticut*

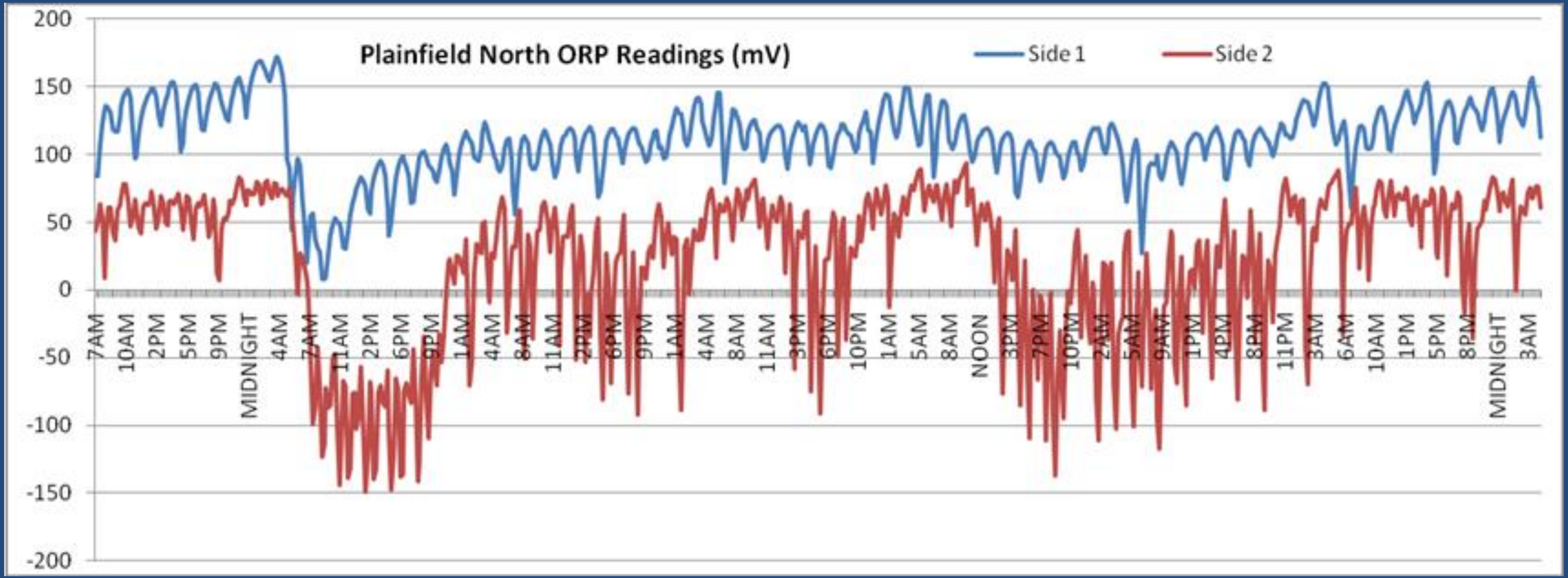



*North Plant*
*Plainfield, Connecticut*


Plainfield North Plant

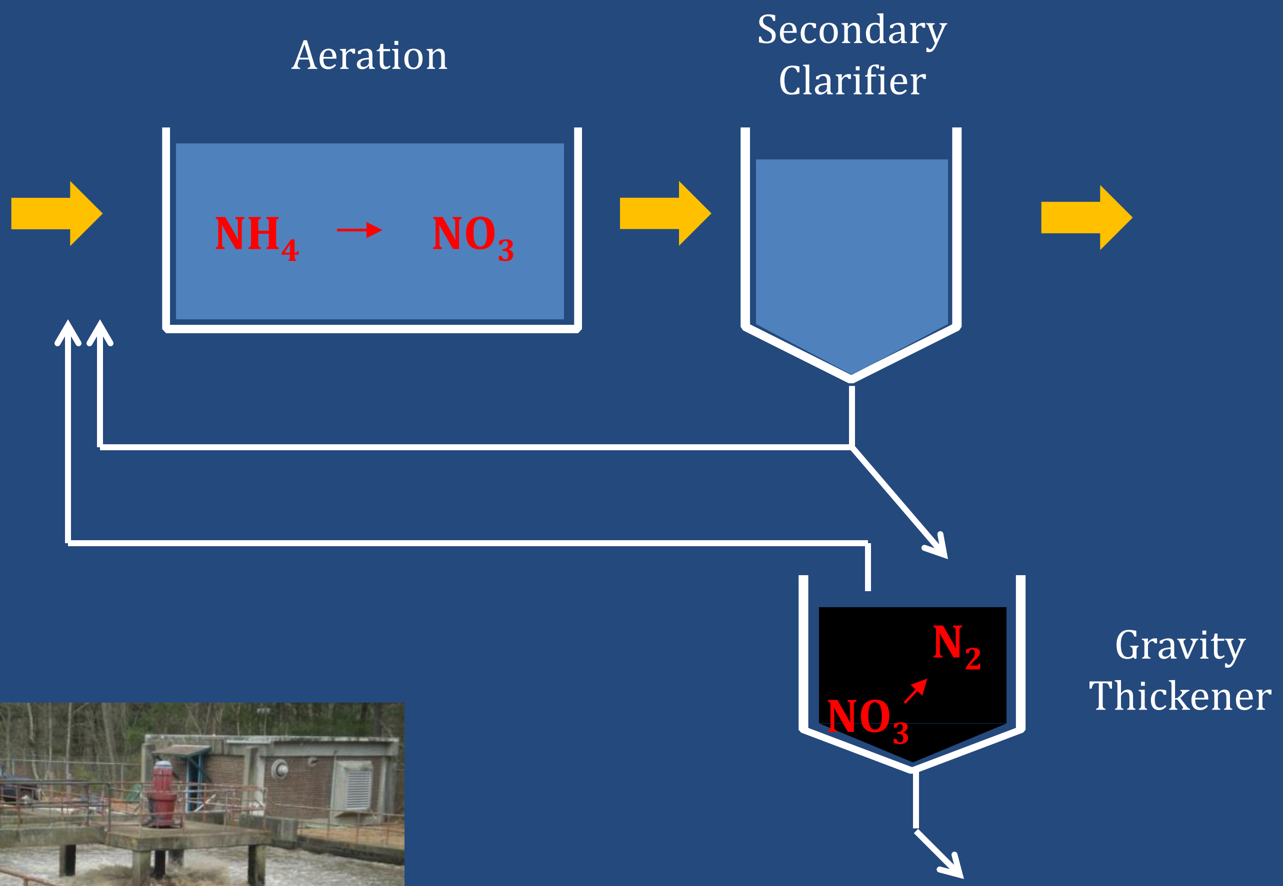
## *ORP Readings*

## *Cycling Aeration to create ideal habitats for Ammonia and Nitrate removal*



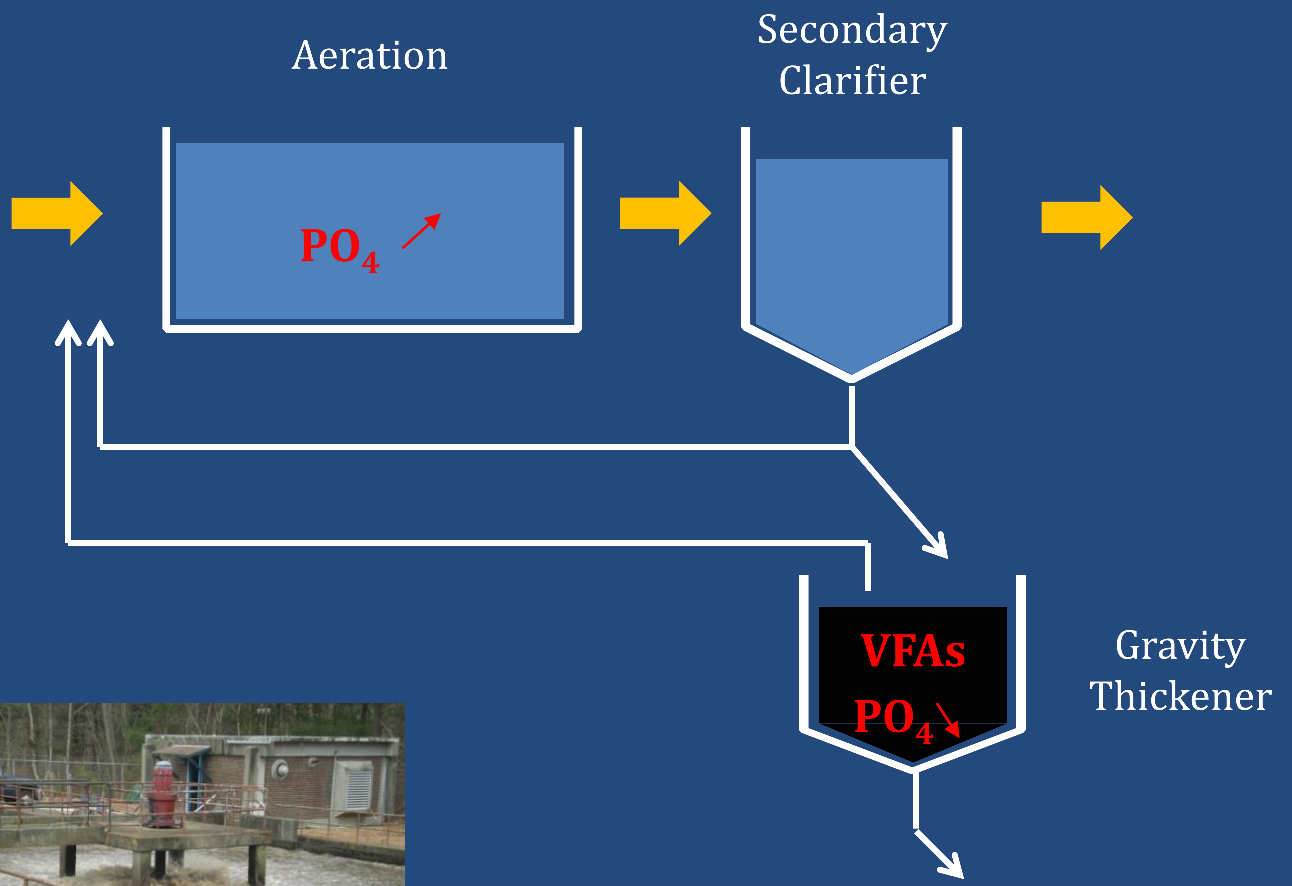

Plainfield, Connecticut – Village Plant
(0.5 MGD: 15,000)

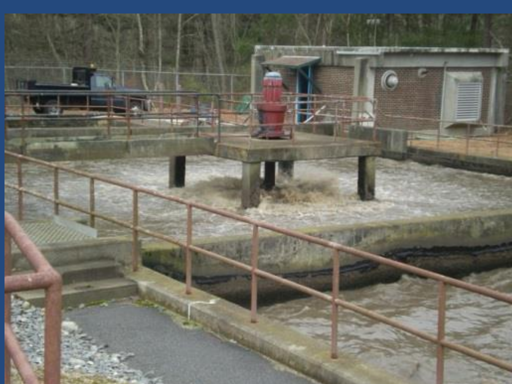
## *Plainfield Village*




## *Nitrogen Removal*

# *Plainfield Village*



*Phosphorus Removal*

# *Case Studies: these are not isolated examples*

**Personal Experience**:
20+ Wastewater Treatment Plants

**2008 MA DEP Study**:
*11 of 21 studied can be "operated to remove Nitrogen"*

**2014 NEIWPCC Study** (*Preliminary Findings*):
*24 of 29 plants studied can remove Nitrogen with "minor" upgrade*

## *Summary*

Notwithstanding a lack of reference documentation …

Many wastewater treatment plants can be operated differently to meet new permit limits w/o Facility Upgrades

… at fantastic savings

Operator expertise / support is required

Instrumentation and computer controls are cost-effective; but, rarely installed:

- Clean Water Funds not practical
- Local funds (O&M budgets) are tight

THE WATER PLANET COMPANY

Making clean water affordable

g.weaver@cleanwaterops.com