# Nitrogen Removal

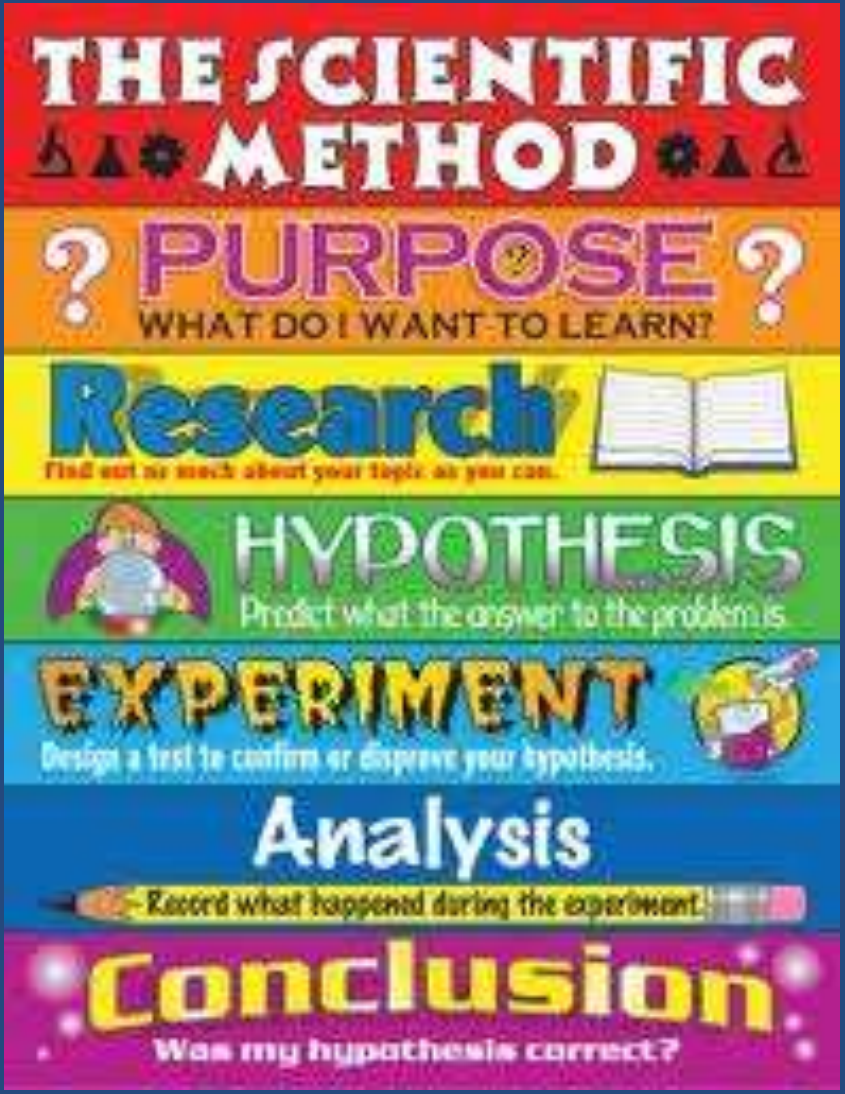
Grant Weaver, PE & WWTP Operator
President
The Water Planet Company

The Water Planet Company

*www.cleanwaterops.com*

*Creating Optimal Habitats*

# *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?

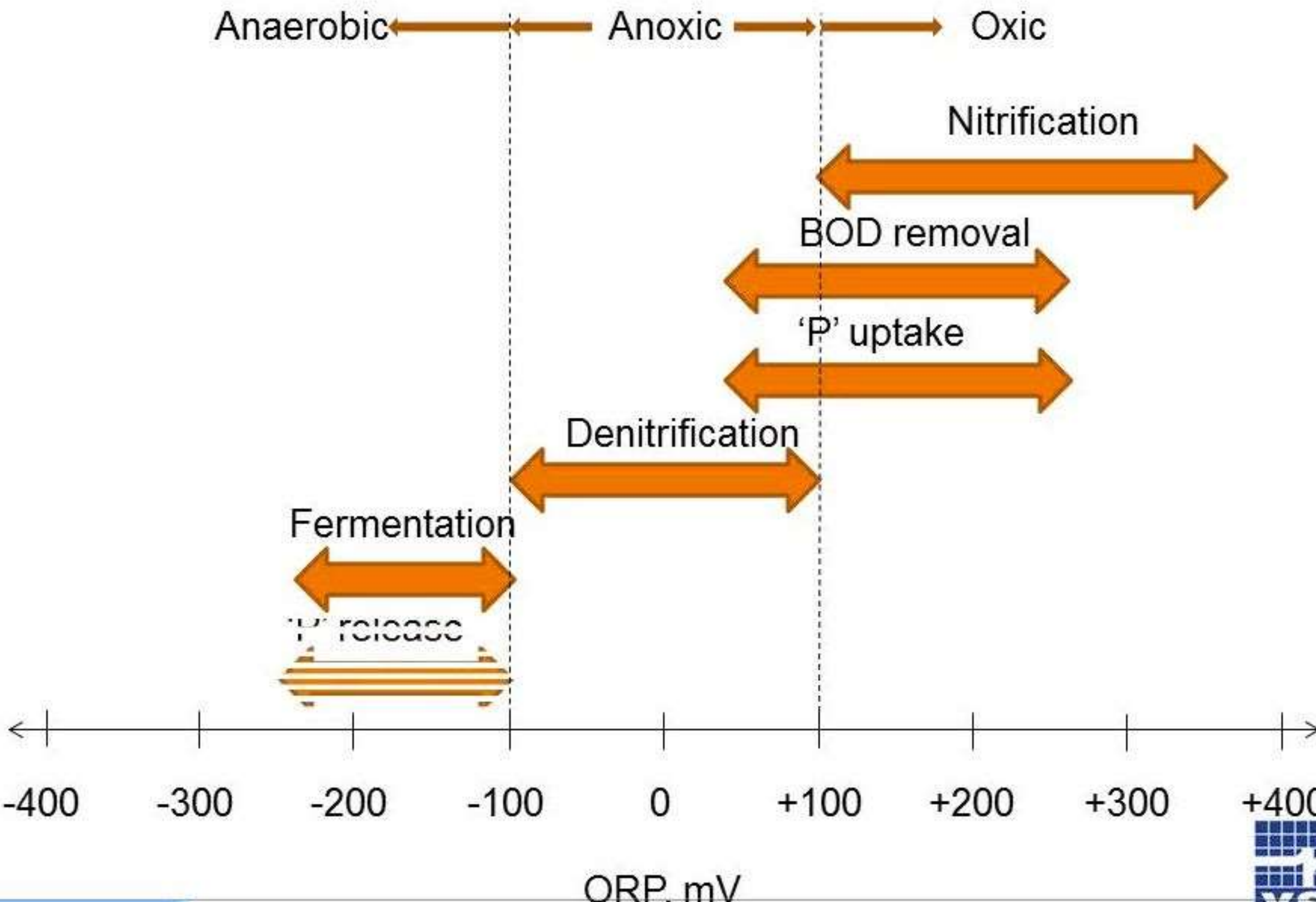
*Wastewater Science*

*Alkalinity and pH*

*Wastewater Science*

*DO and ORP*

# What does ORP tell us about our process?



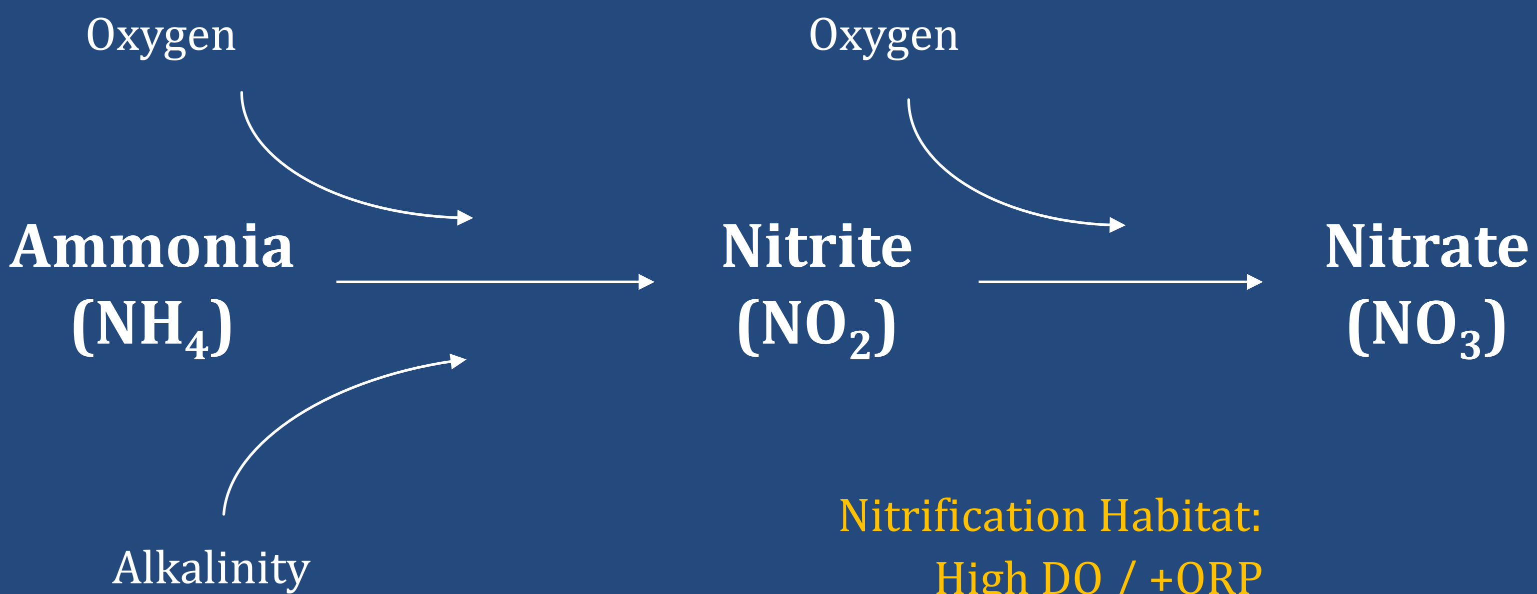
N

7

Nitrogen

*Biological Nitrogen Removal:*
*Convert liquid to gas …*

# *Ammonia Removal*




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 ($NO_3$)*

<u>Oxygen Rich Habitat</u>

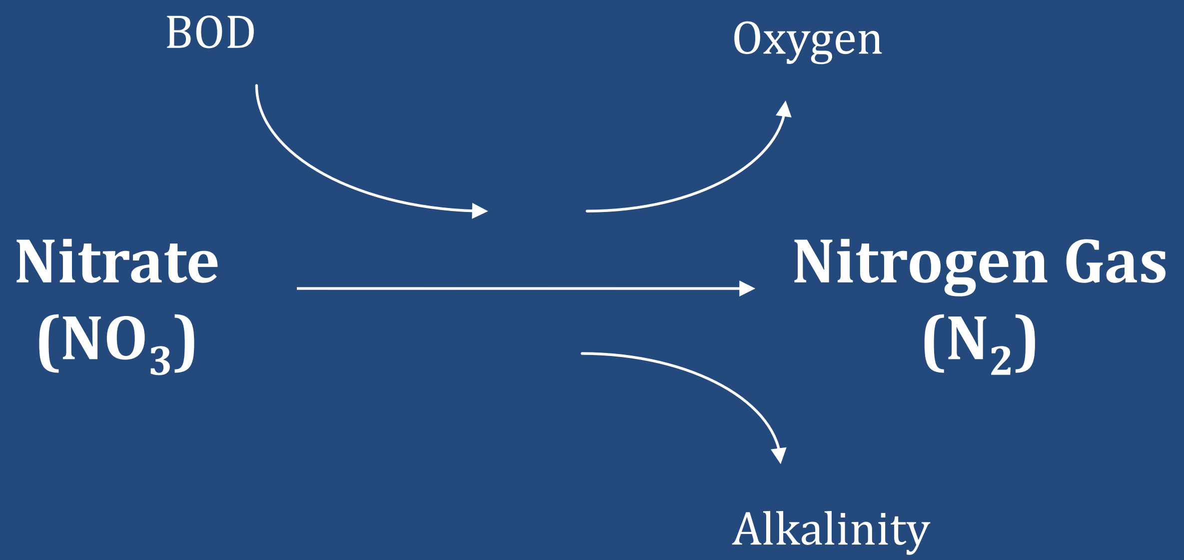
MLSS* of 2500+ mg/L (High Sludge Age / MCRT / low F:M)
ORP* of +100 to +150 mV (High DO)
Time* (high HRT … 24 hr, 12 hr, 6 hr, 4 hr)
Low BOD

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 ($N_2$)*

<u>Oxygen Poor Habitat</u>

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.

# *Nitrogen Terms for Operators*

**organic-Nitrogen** (org-N or $N_{org}$)

**Ammonia** ($NH_3$)
Ammonium ($NH_4$ or $NH_4^+$)

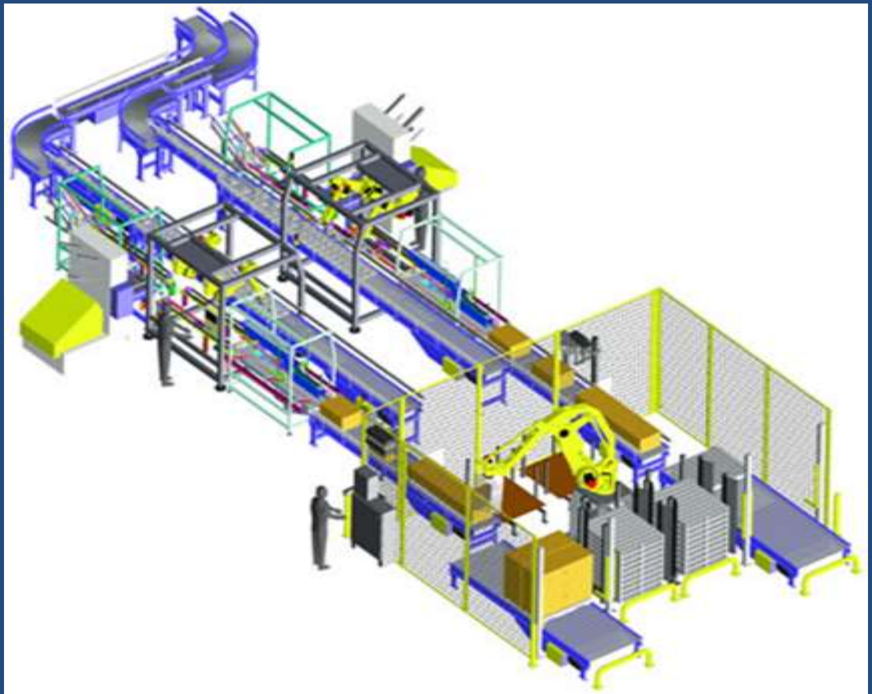
**TKN** (Total Kjeldahl Nitrogen)
= organic-Nitrogen + Ammonia

**Nitrate** ($NO_3$ or $NO_3^-$)

**Nitrite** ($NO_2$ or $NO_2^-$)

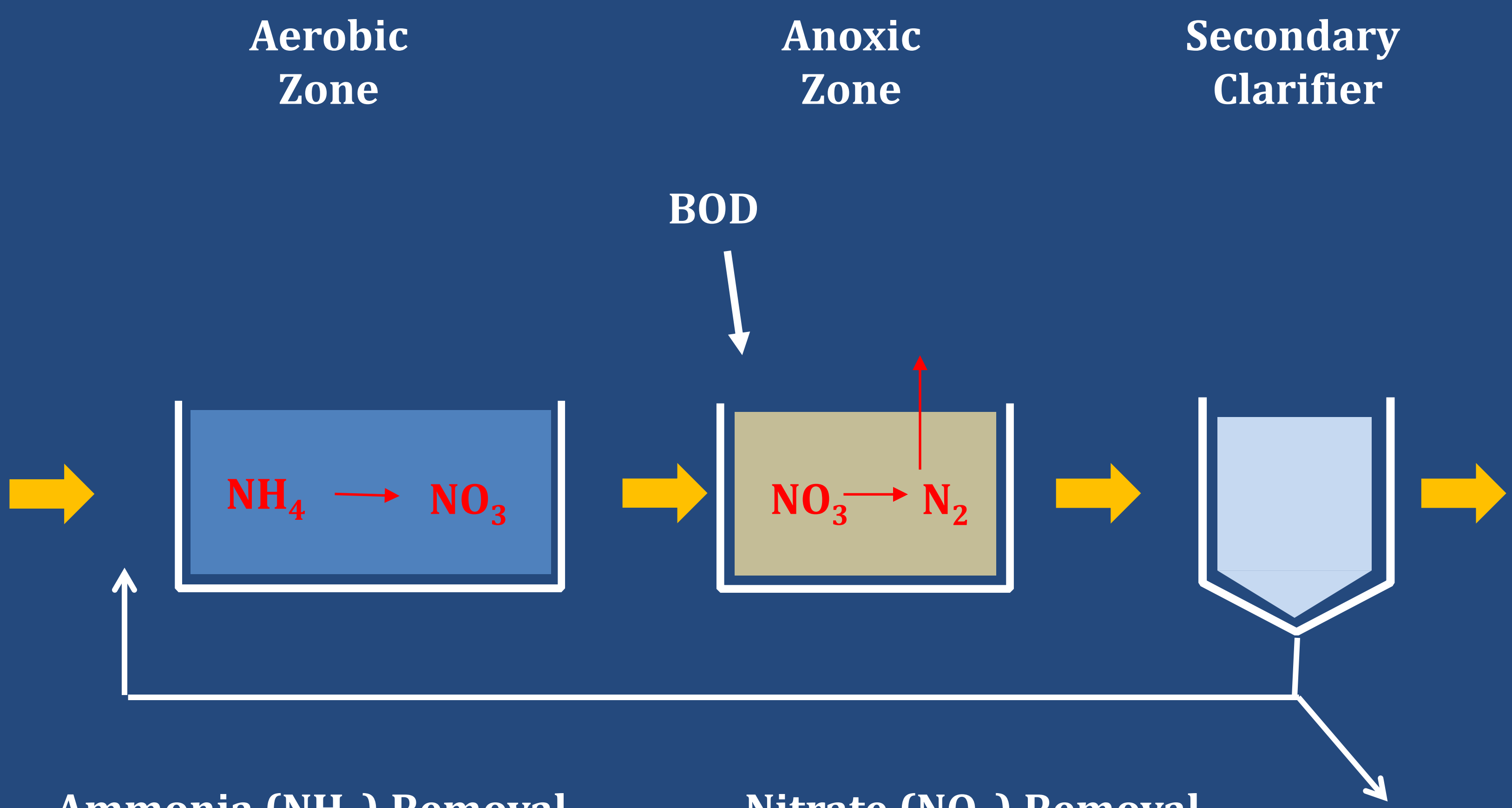
**total Nitrogen** (total-N, N, TN, tN, or $N_{total}$)
= TKN + Nitrate + Nitrite

*Technology!*




Post Denitrification

# Post-Anoxic Denitrification




**Ammonia ($NH_4$) Removal**

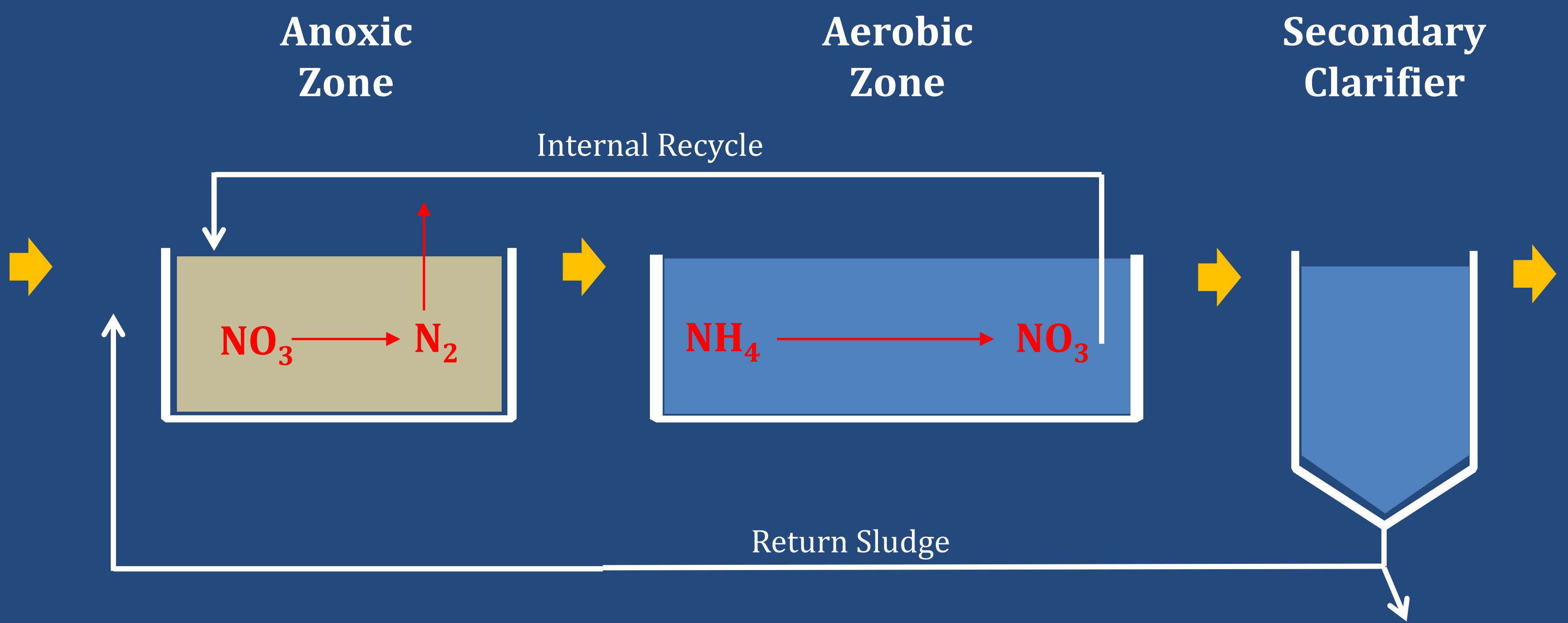
Target: $NH_4 < 0.5$ mg/L

**Nitrate ($NO_3$) Removal**

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

# *MLE (Modified Ludzack-Ettinger) Process*

# MLE (Modified Ludzack-Ettinger) Process




MLE Process Control:

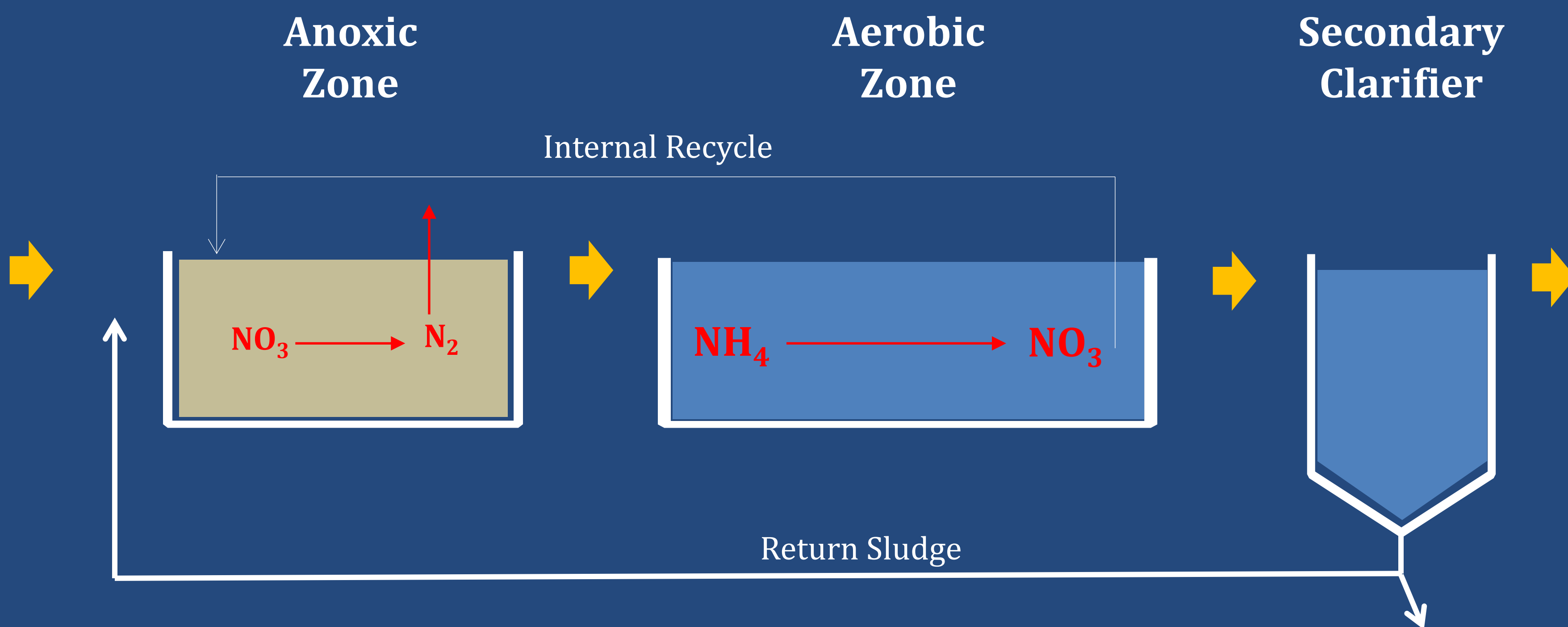
Proper Internal Recycle Rate; not too much / not too little.

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

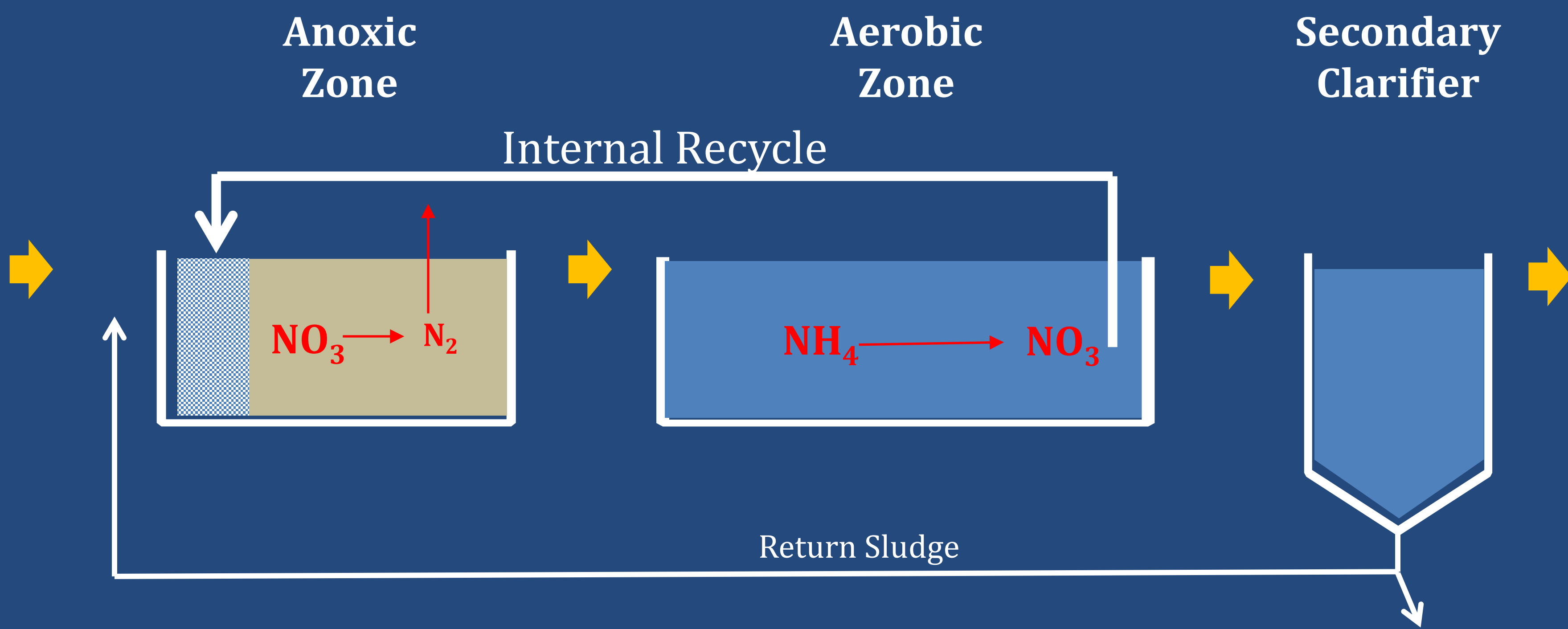
$NH_4$ < 0.5 mg/L

**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

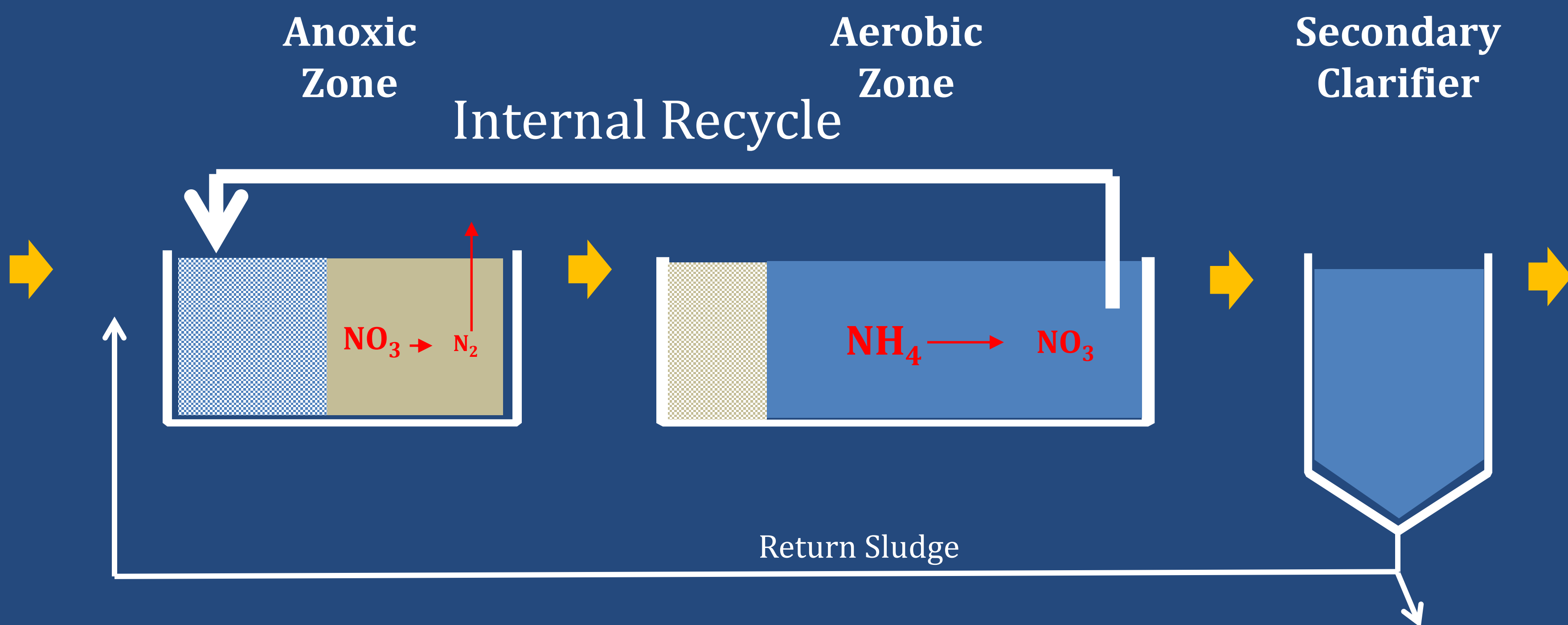
$NH_4$ < 0.5 mg/L

**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

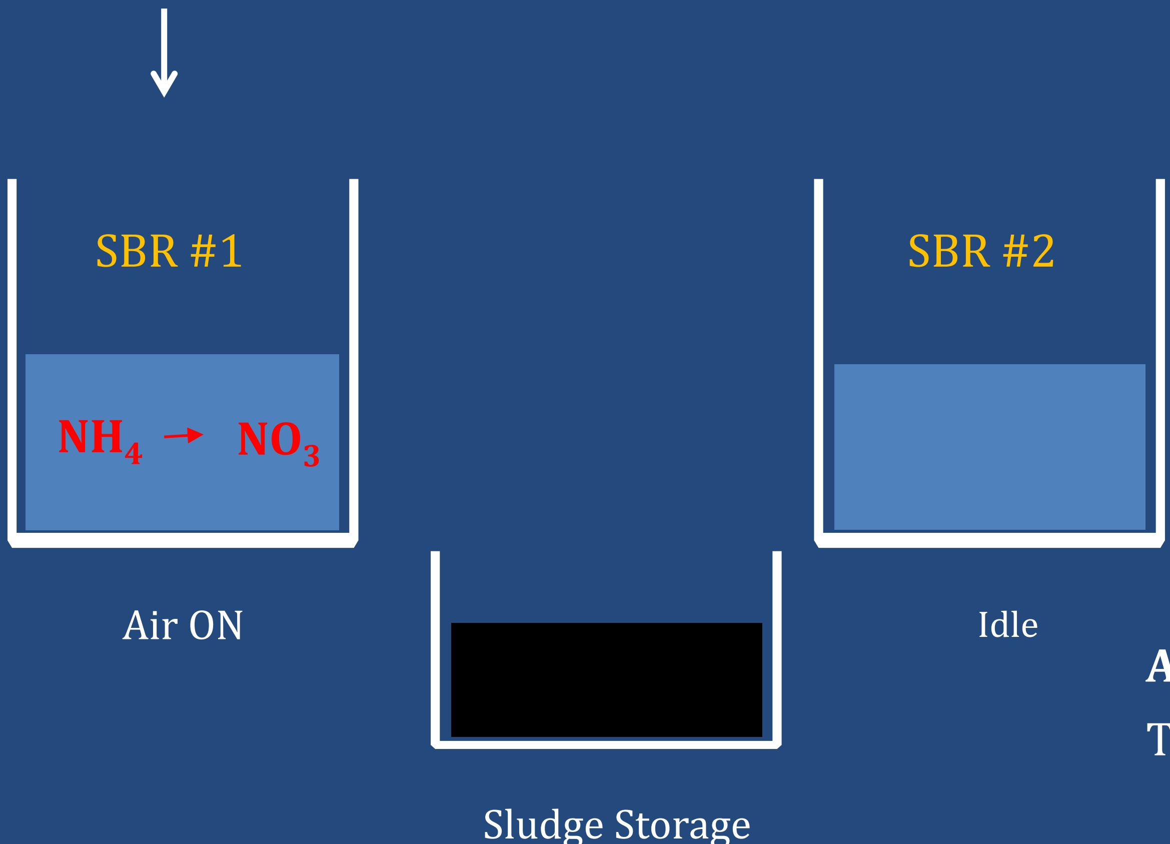
**Nitrate ($NO_3$) Removal**

Poor Anoxic Habitat: ORP 0 mV or higher

$NO_3$ > 4 mg/L


Sequencing Batch Reactor
SBR

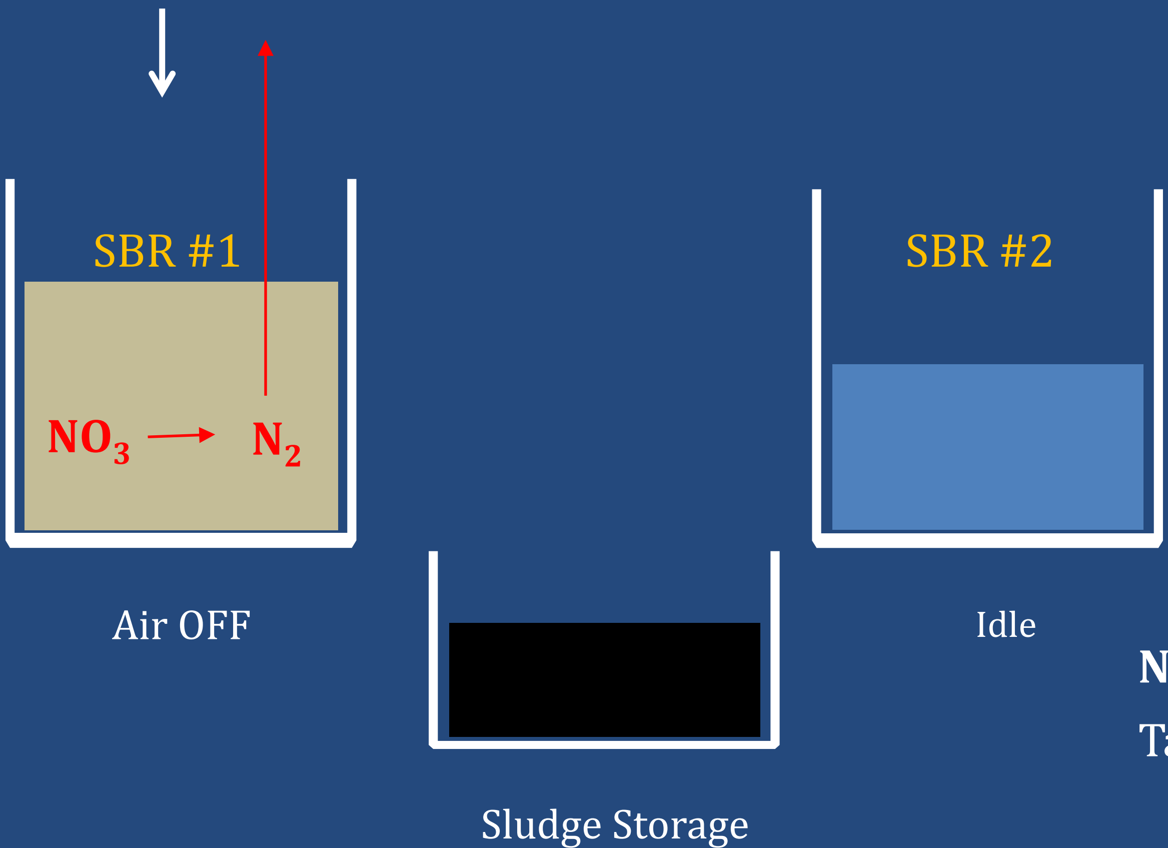
# Sequencing Batch Reactor (SBR)
# Ammonia ($NH_4$) Removal: Nitrification




**Ammonia ($NH_4$) Removal**

Target: $NH_4 < 0.5$ mg/L

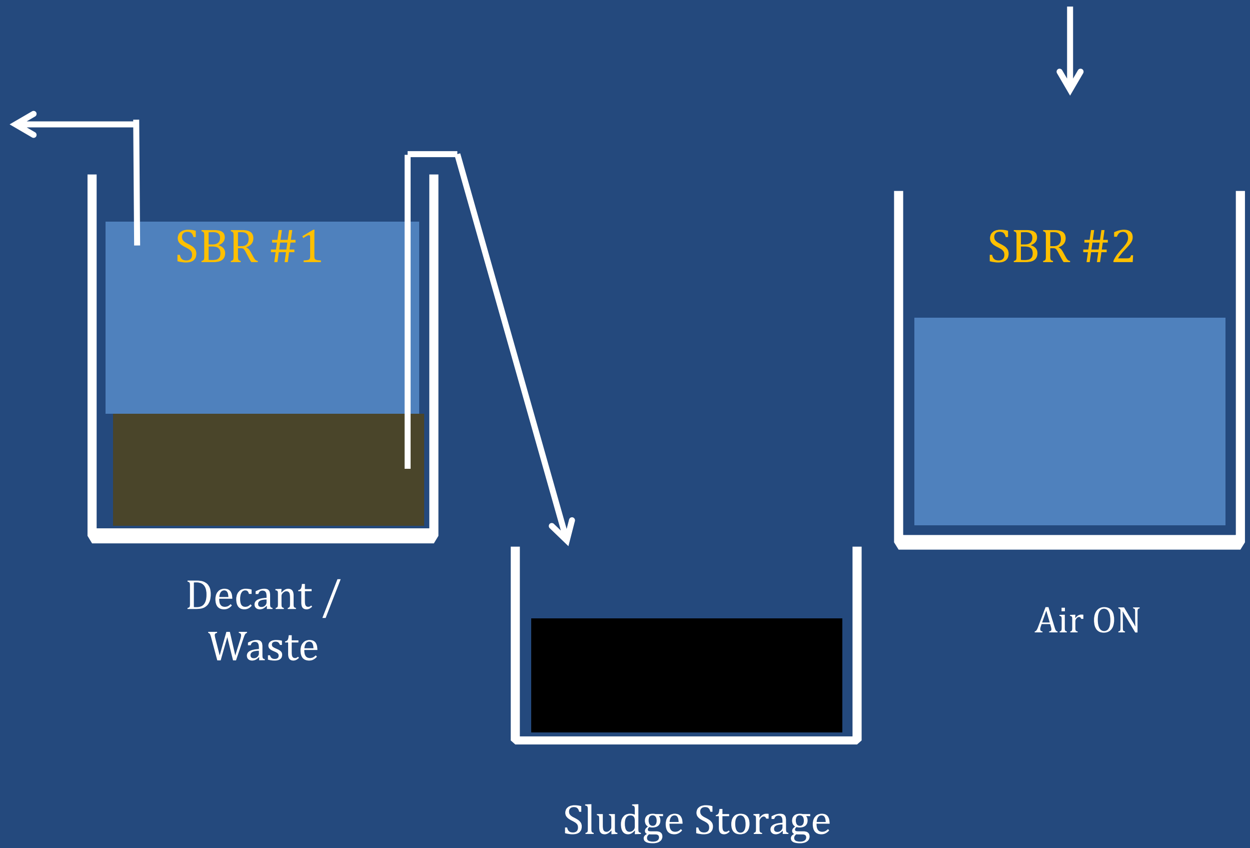
# Sequencing Batch Reactor (SBR)
# Nitrate ($NO_3$) Removal: Denitrification




**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

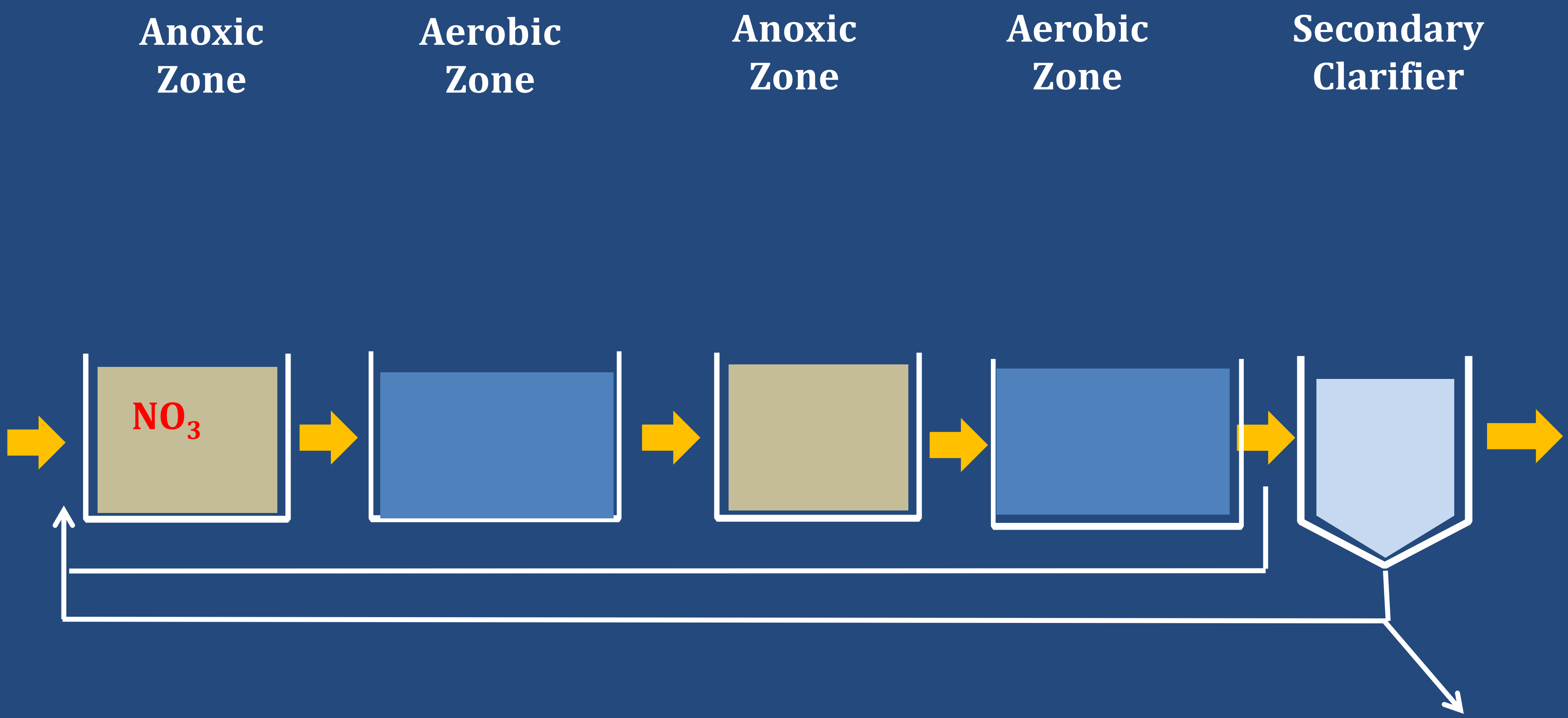
Good habitats …

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

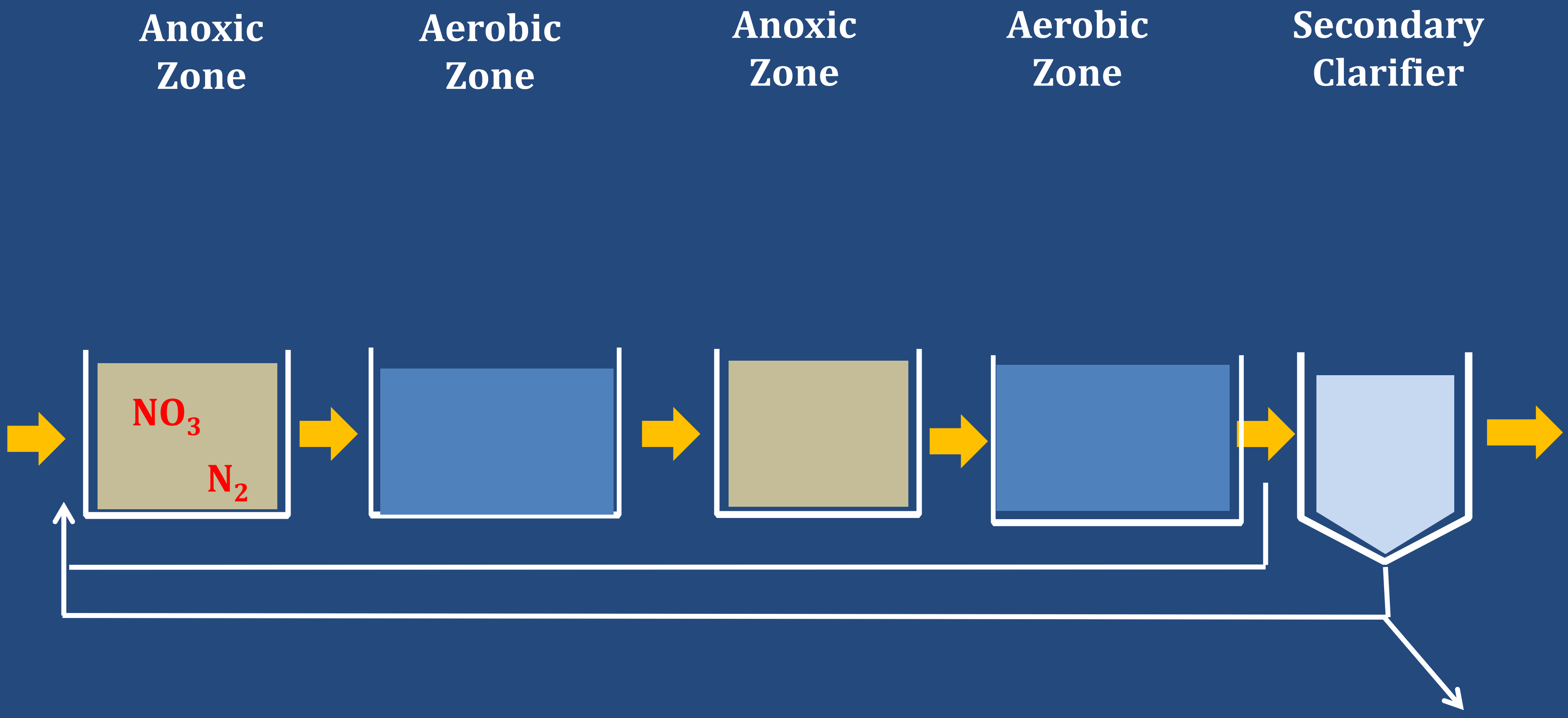
Bonus: Changing conditions will serve as a selector.


Oxidation Ditch
4-Stage Bardenpho

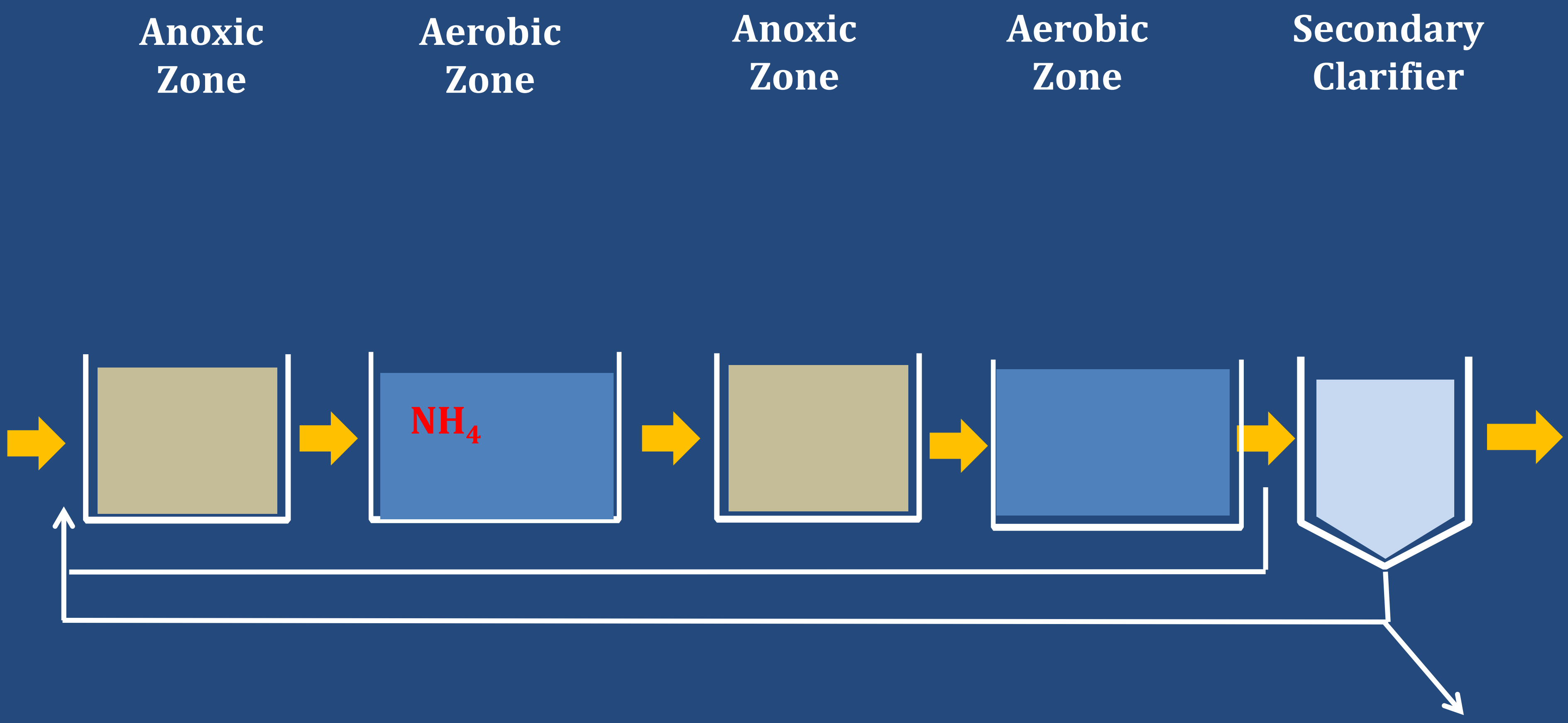
# Oxidation Ditch – 4-Stage Bardenpho



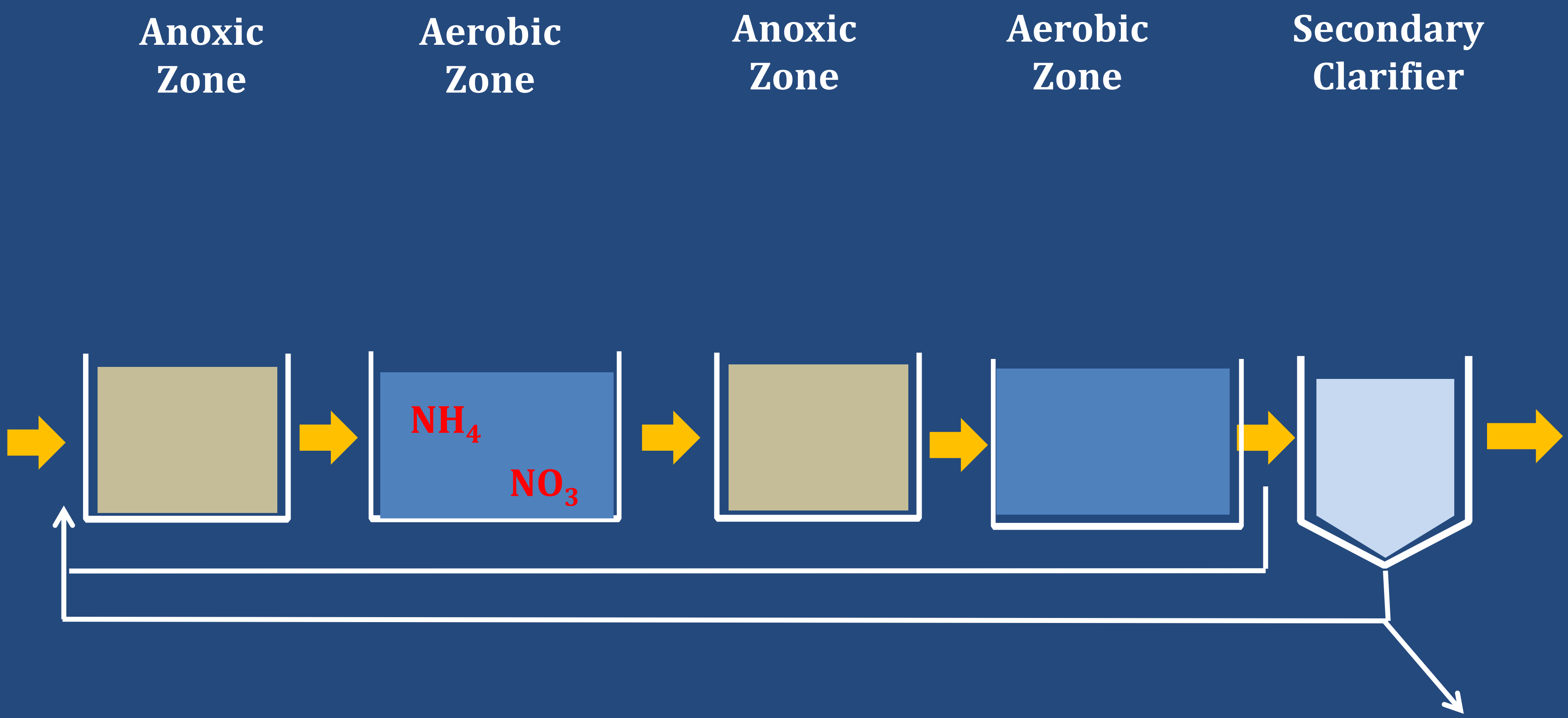
# Oxidation Ditch – 4-Stage Bardenpho



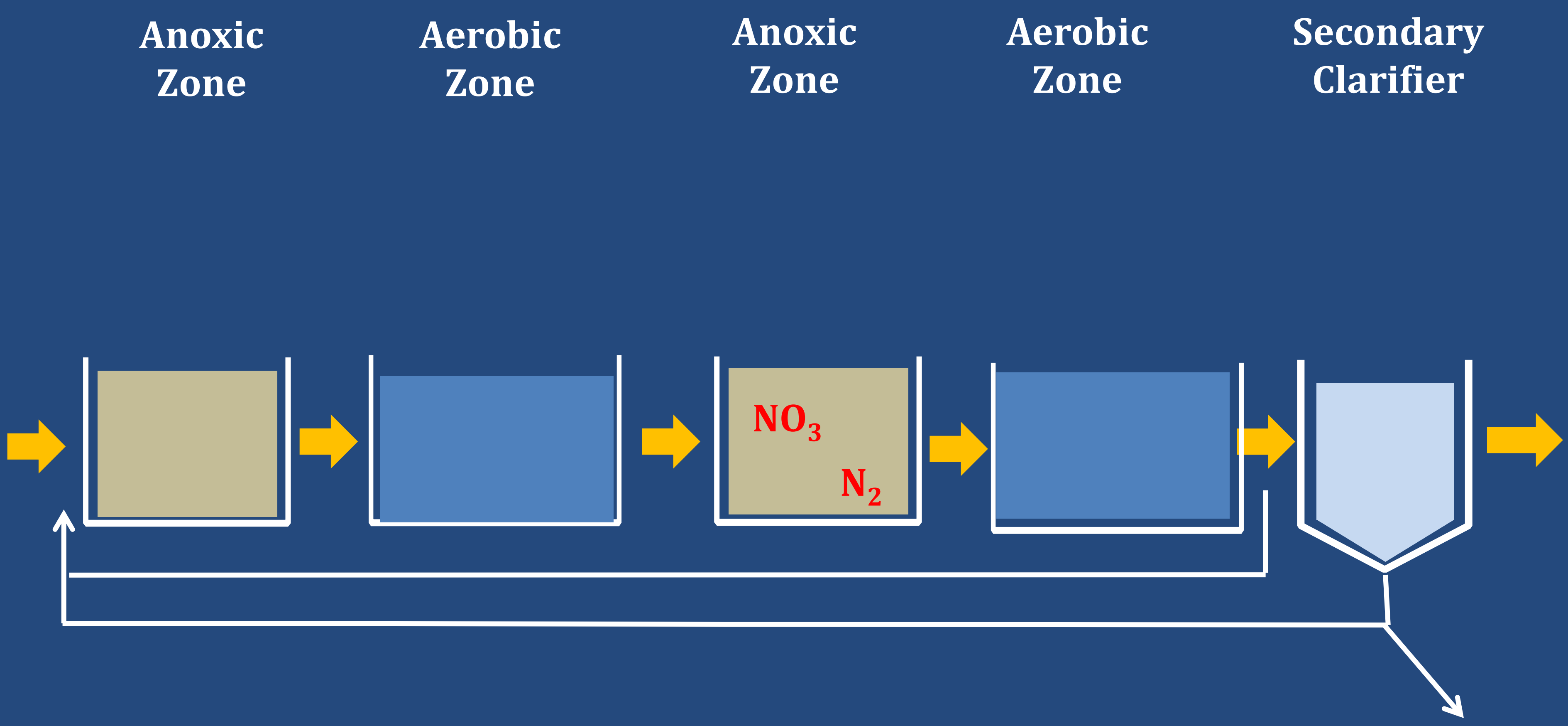
# Oxidation Ditch – 4-Stage Bardenpho



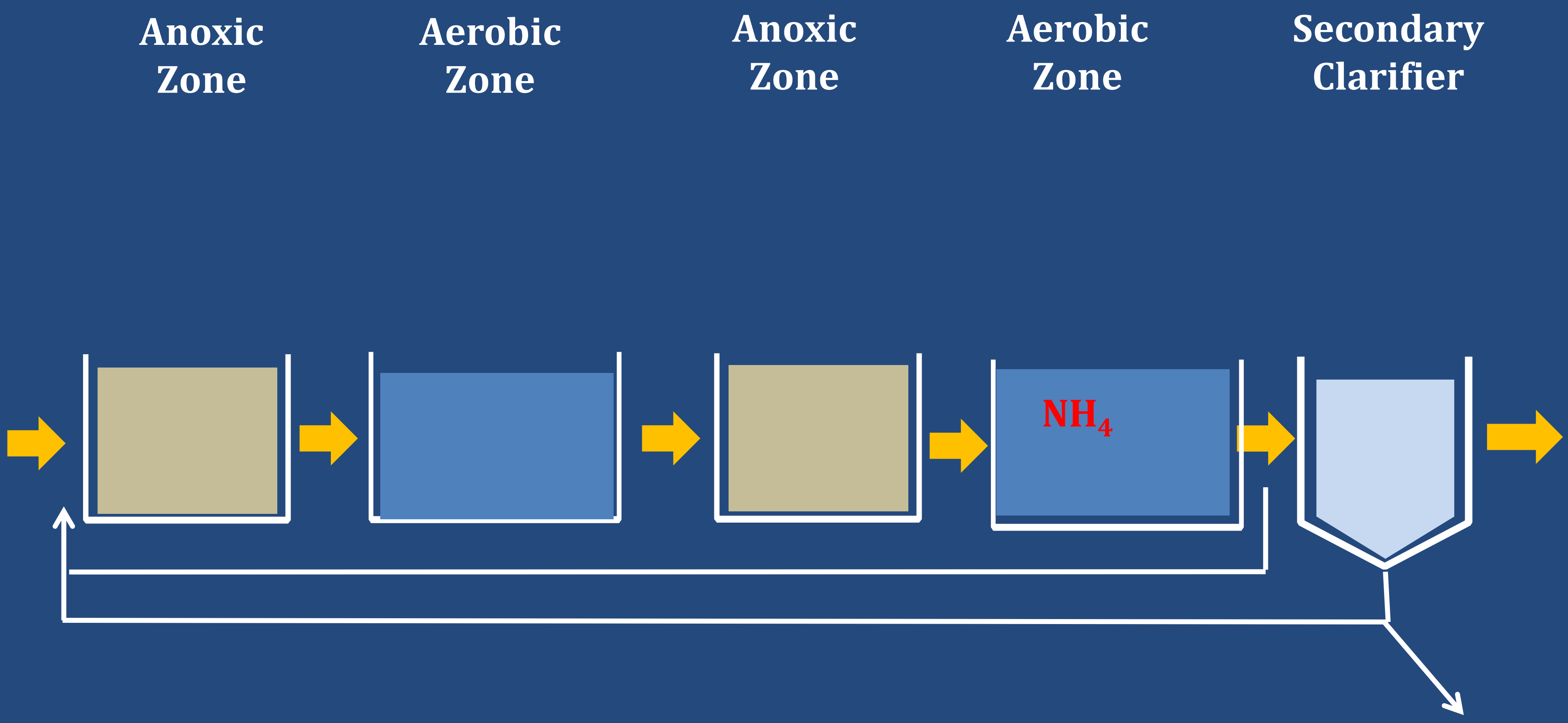
# Oxidation Ditch – 4-Stage Bardenpho



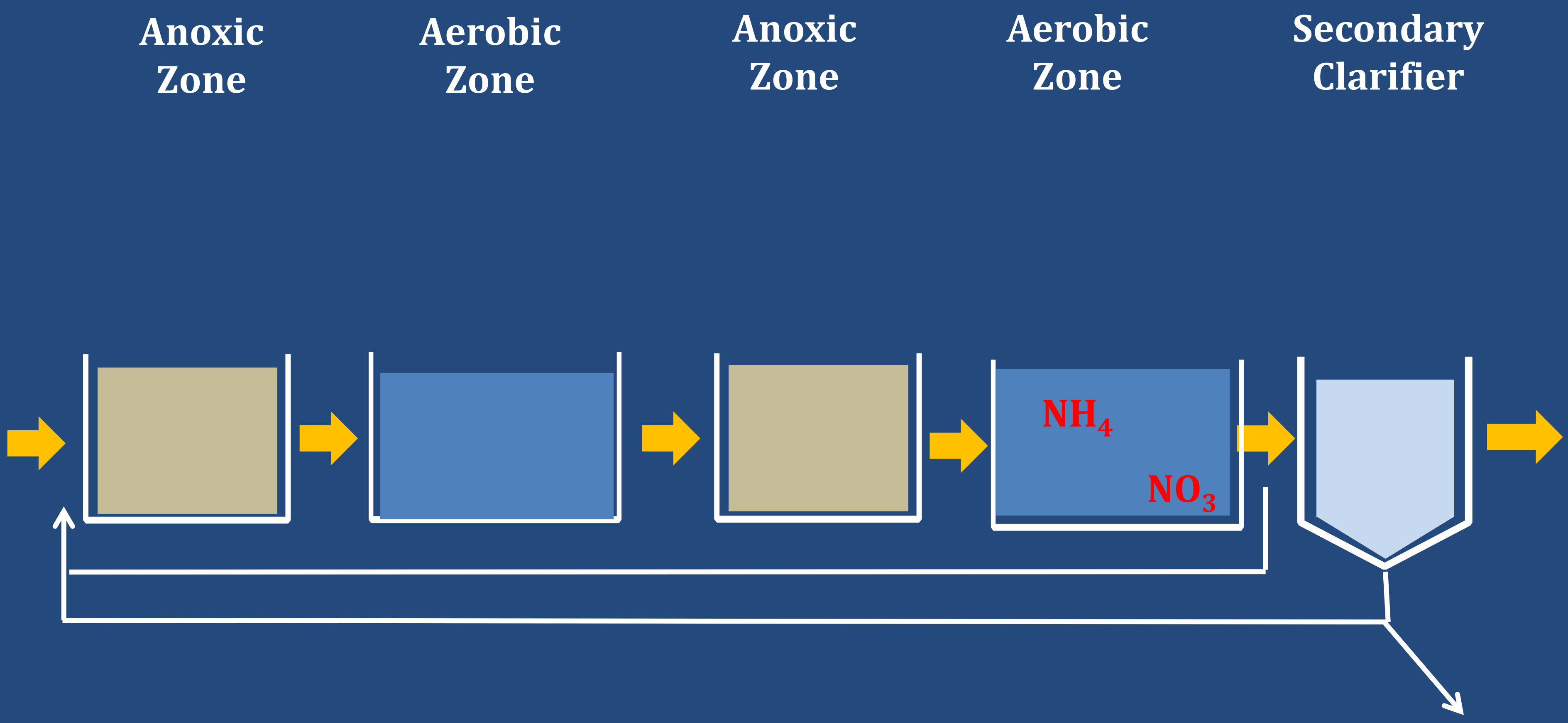
# Oxidation Ditch – 4-Stage Bardenpho



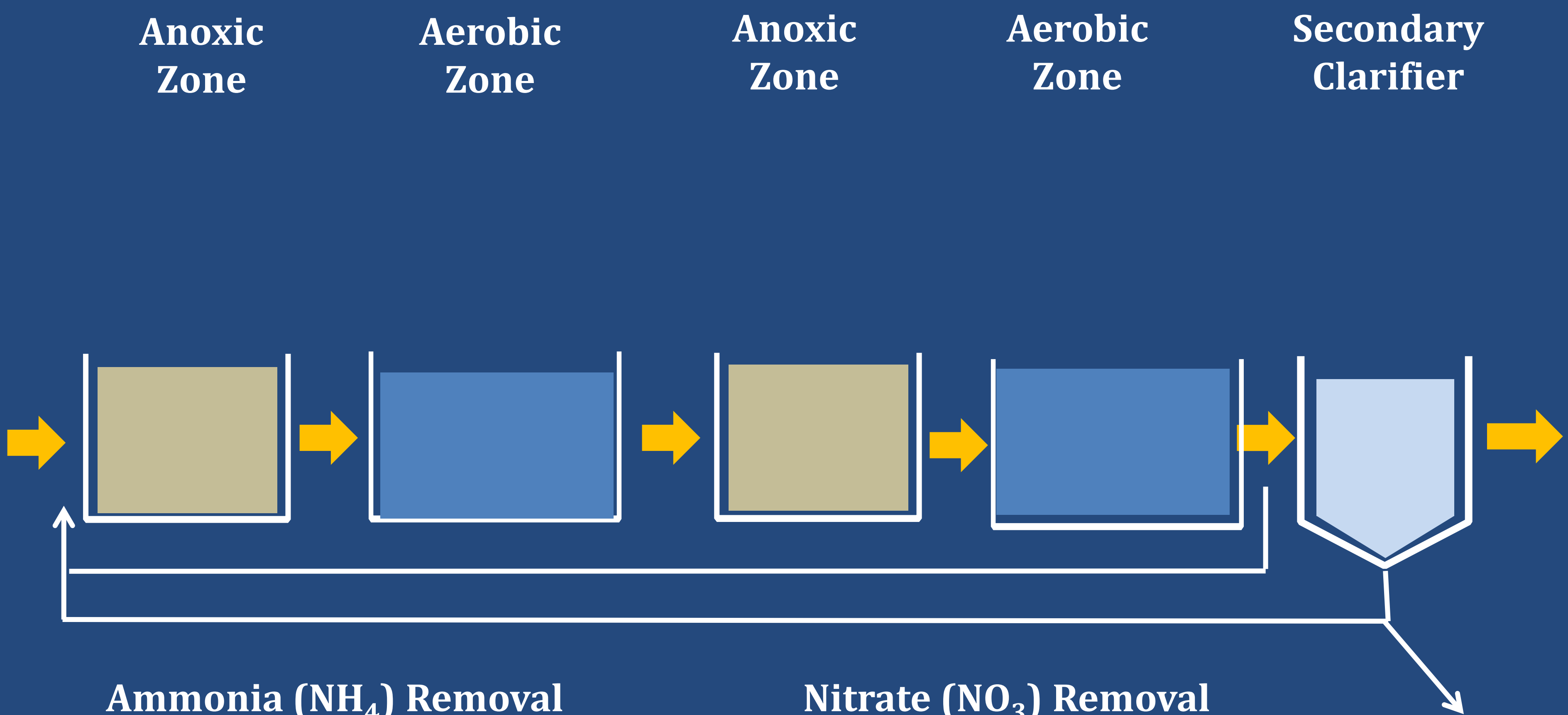
# Oxidation Ditch – 4-Stage Bardenpho



# Oxidation Ditch – 4-Stage Bardenpho



# Oxidation Ditch – 4-Stage Bardenpho




**Ammonia ($NH_4$) Removal**

Target: $NH_4 < 0.5$ mg/L

**Nitrate ($NO_3$) Removal**

Target: $NO_3$ of 1-4 mg/L


BACKGROUND
INFORMATION


COMPLETED

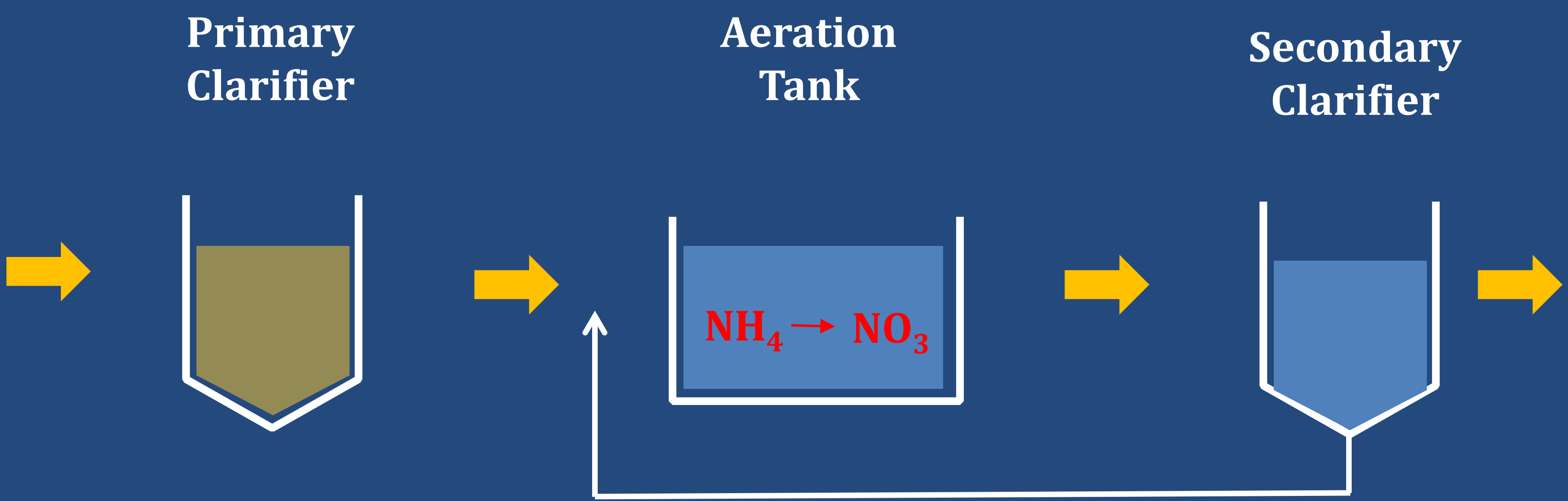
*Experimenting with YOUR plant:*
*Finding the "Right" Process Control Strategy*


*... 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.

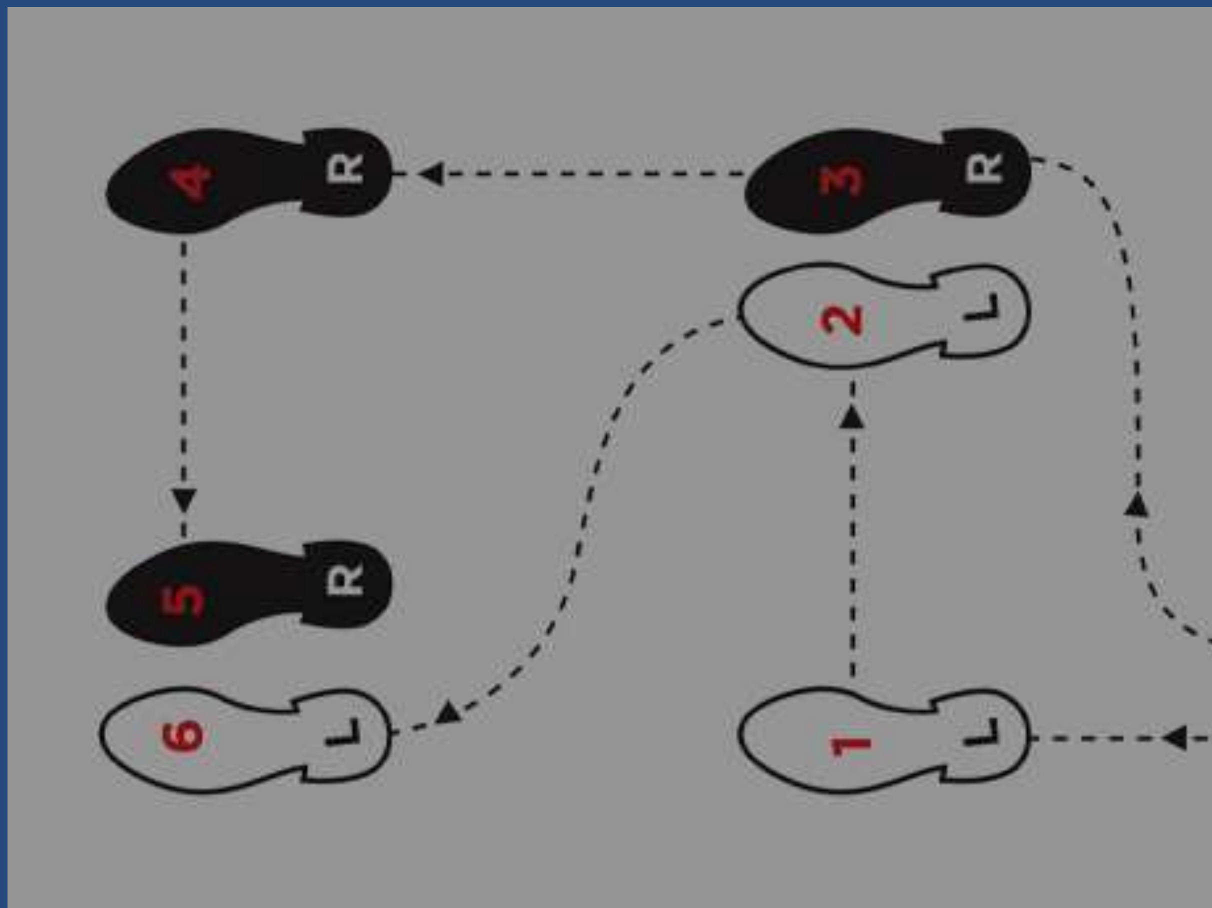
Keep ORP at +100 mV (or higher) by adjusting DO settings until ...

... 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.

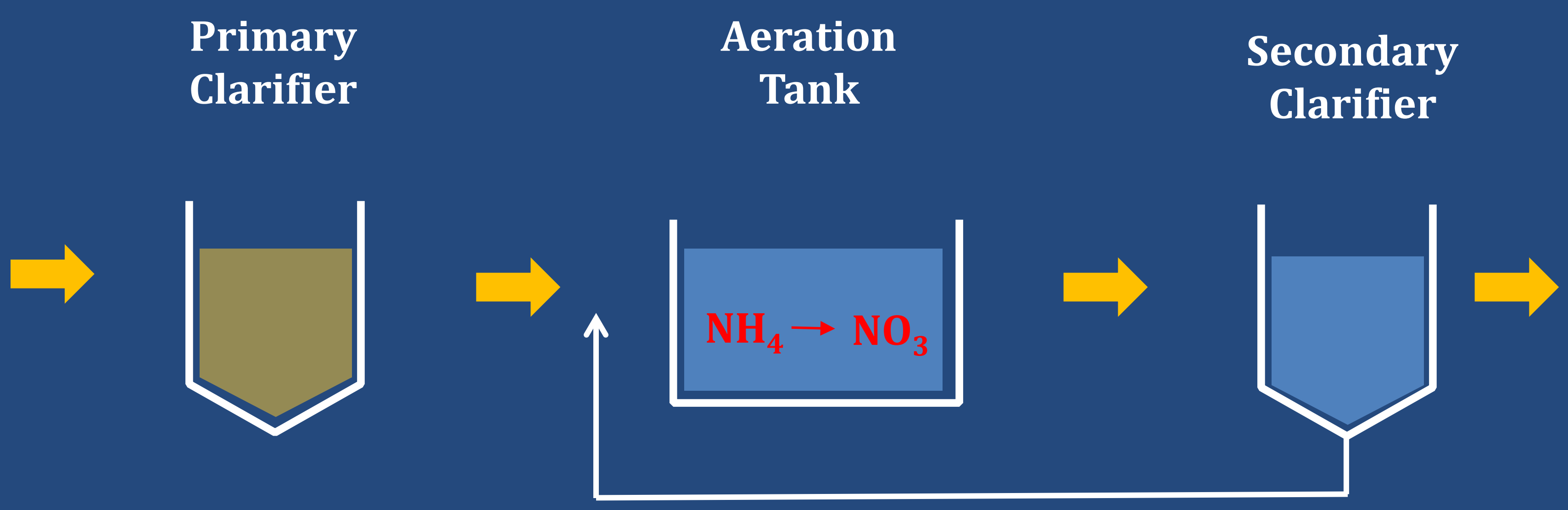
Warning: pH and Nitrite ($NO_2$)

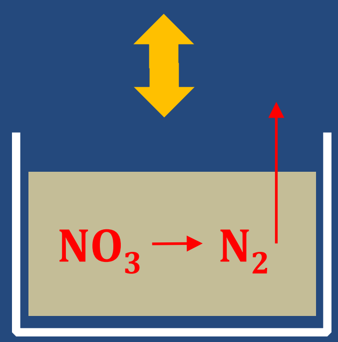
# *Step 2: Optimize Nitrate ($NO_3$) Removal*



*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)

**Nitrate ($NO_3$) Removal**

Target: $NO_3$ < 4 mg/L

ORP: -100 mV long enough (30 minutes)

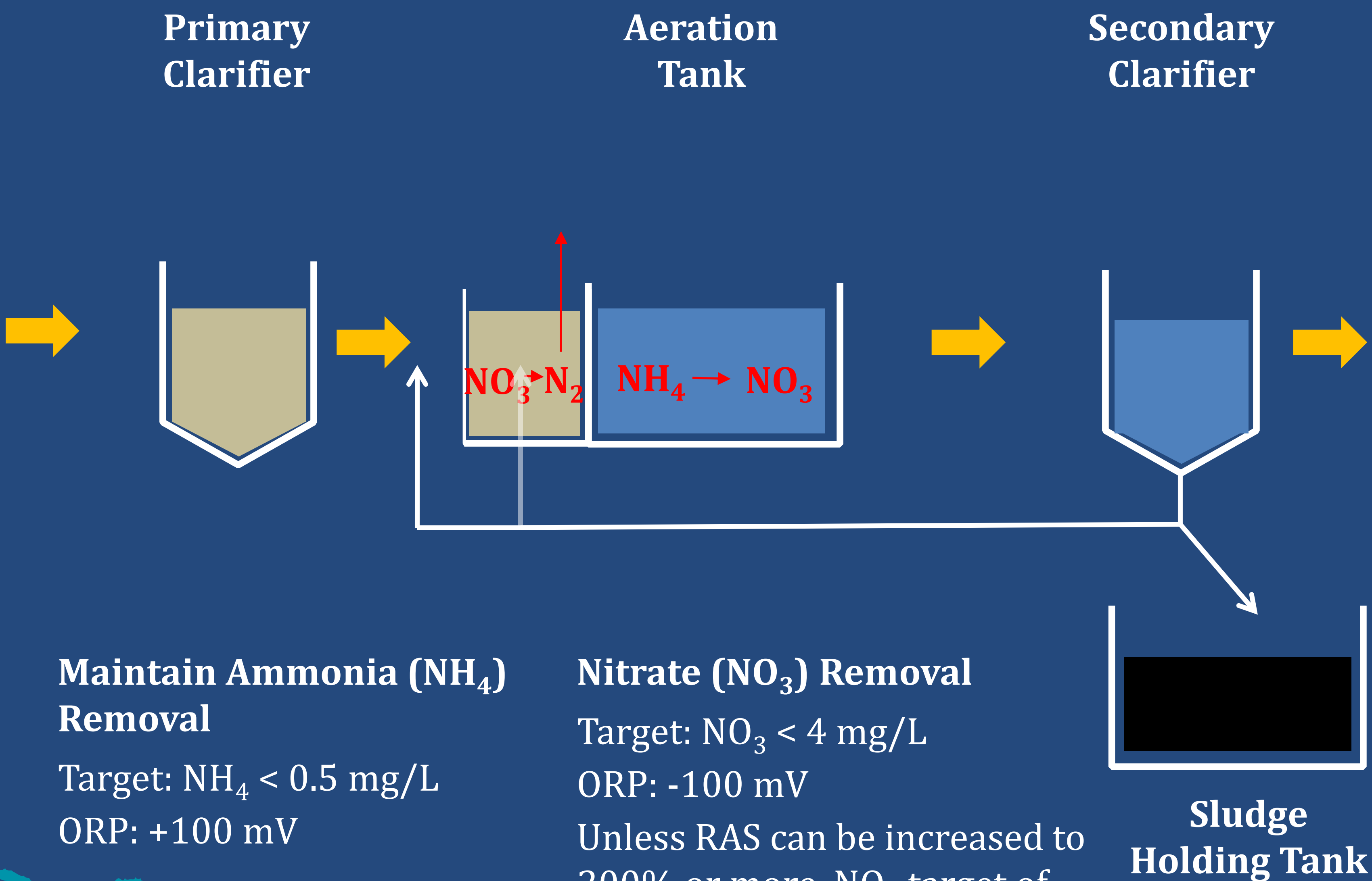
If habitats are good and $NO_3$ remains high, likely not enough BOD.

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

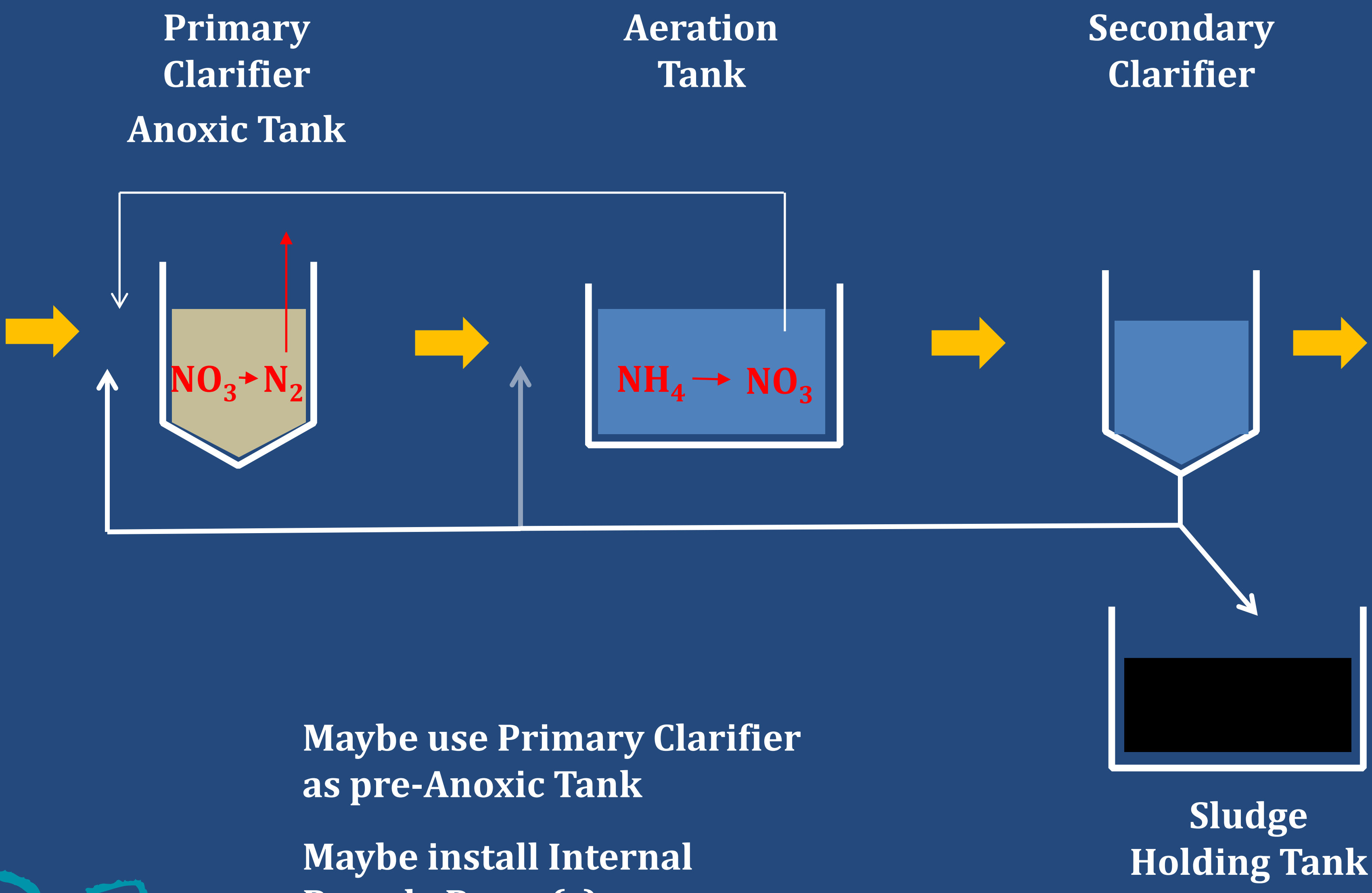
**Nitrate ($NO_3$) Removal**

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

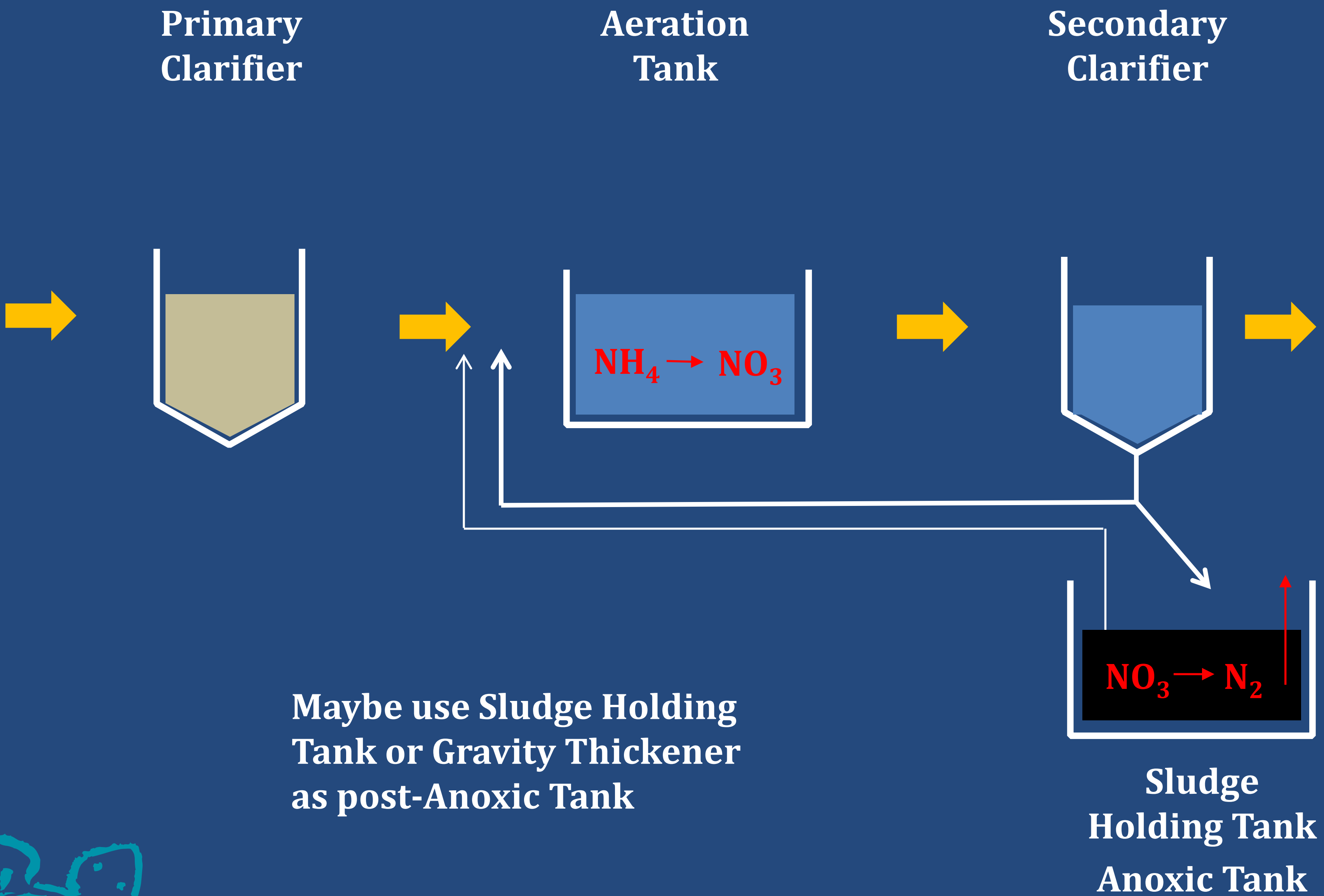
## *MLE Process Modification of Conventional AS Plant*




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

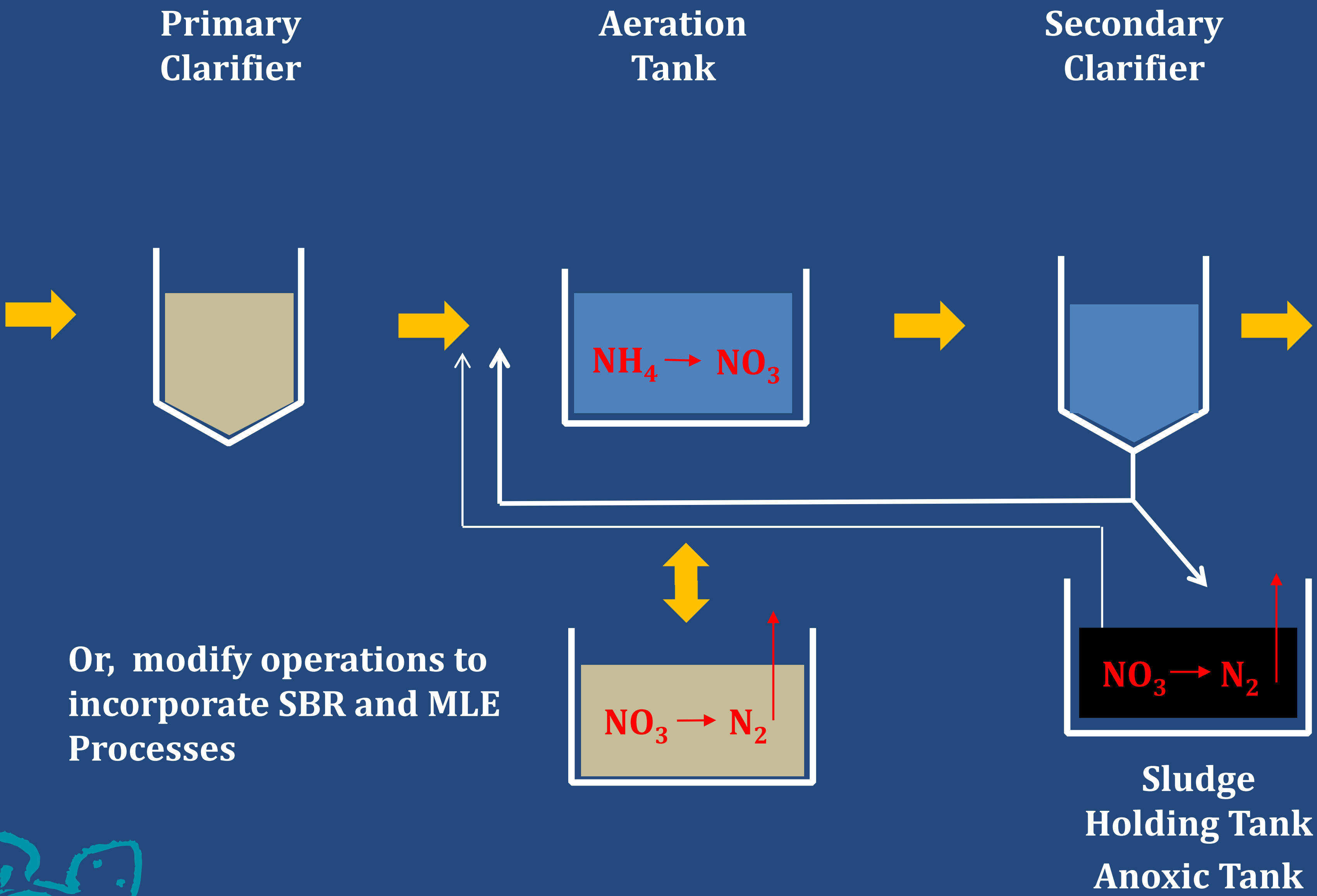
**Maybe install Internal Recycle Pump(s)**

## *MLE Process Modification of Conventional AS Plant*




**Maybe use Sludge Holding Tank or Gravity Thickener as post-Anoxic Tank**

## *MLE Process Modification of Conventional AS Plant*




*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 Nitrogen

# *Monitoring **HABITAT CONDITIONS***


Daily testing of …

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

*DO and ORP*


# *Probes*

*Portable Analyzers*


*pH and Alkalinity*

# *Monitoring* ***TREATMENT***

*Monitoring Nitrogen*


Daily testing of …

Ammonia

Nitrate

Nitrite

# *Lab Spectrophotometer*

Daily testing of …

- Ammonia
- Nitrate
- Nitrite

# *In-Line Nitrogen Probes*


Ammonia

Nitrate

THE WATER PLANET COMPANY

Making clean water affordable

www.cleanwaterops.com