

# Automation of Nitrogen Removal in Mukilteo's Big Gulch WWTF

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## Background



Excess nitrogen released by wastewater treatment facilities (WWTF) leads to harmful algal blooms, decreased dissolved oxygen, and less diverse ecosystems

WWTFs fall under strict regulations to control nitrogen in their effluent

Available oxygen can be controlled to transform aqueous nitrogen into gaseous  $N_2$ , reducing the environmental impact of wastewater

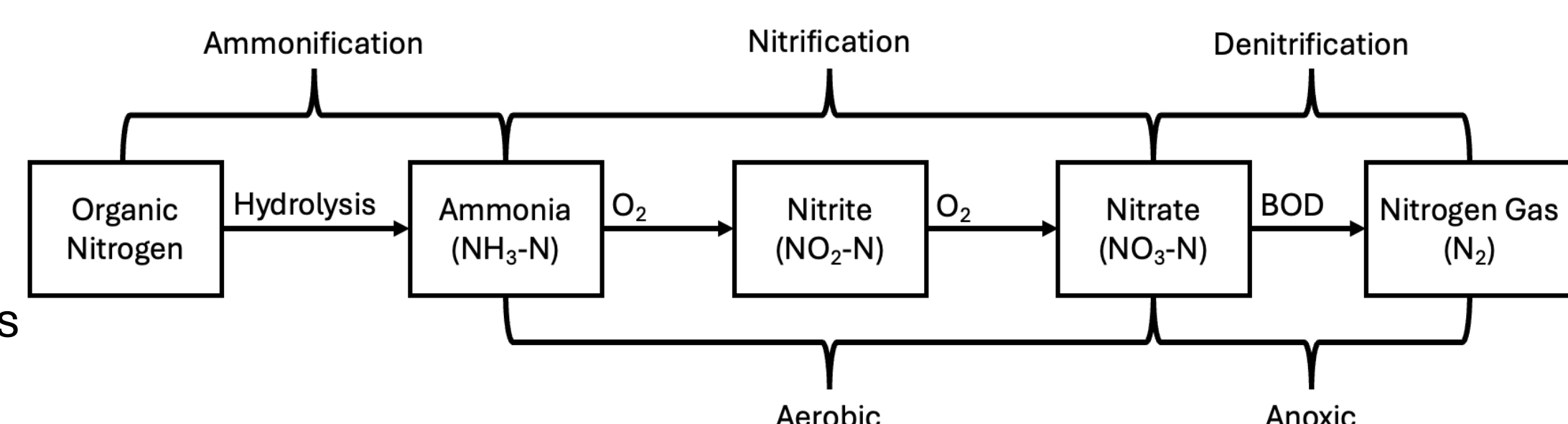


Figure: Nitrogen Removal Process Using Aerobic and Anoxic Periods [2]

Mukilteo Wastewater Treatment Facility is working to reduce total nitrogen in effluent to limits of 3 mg/L in the summer and 8 mg/L in the winter



Figure: Aerial View of Big Gulch WWTF

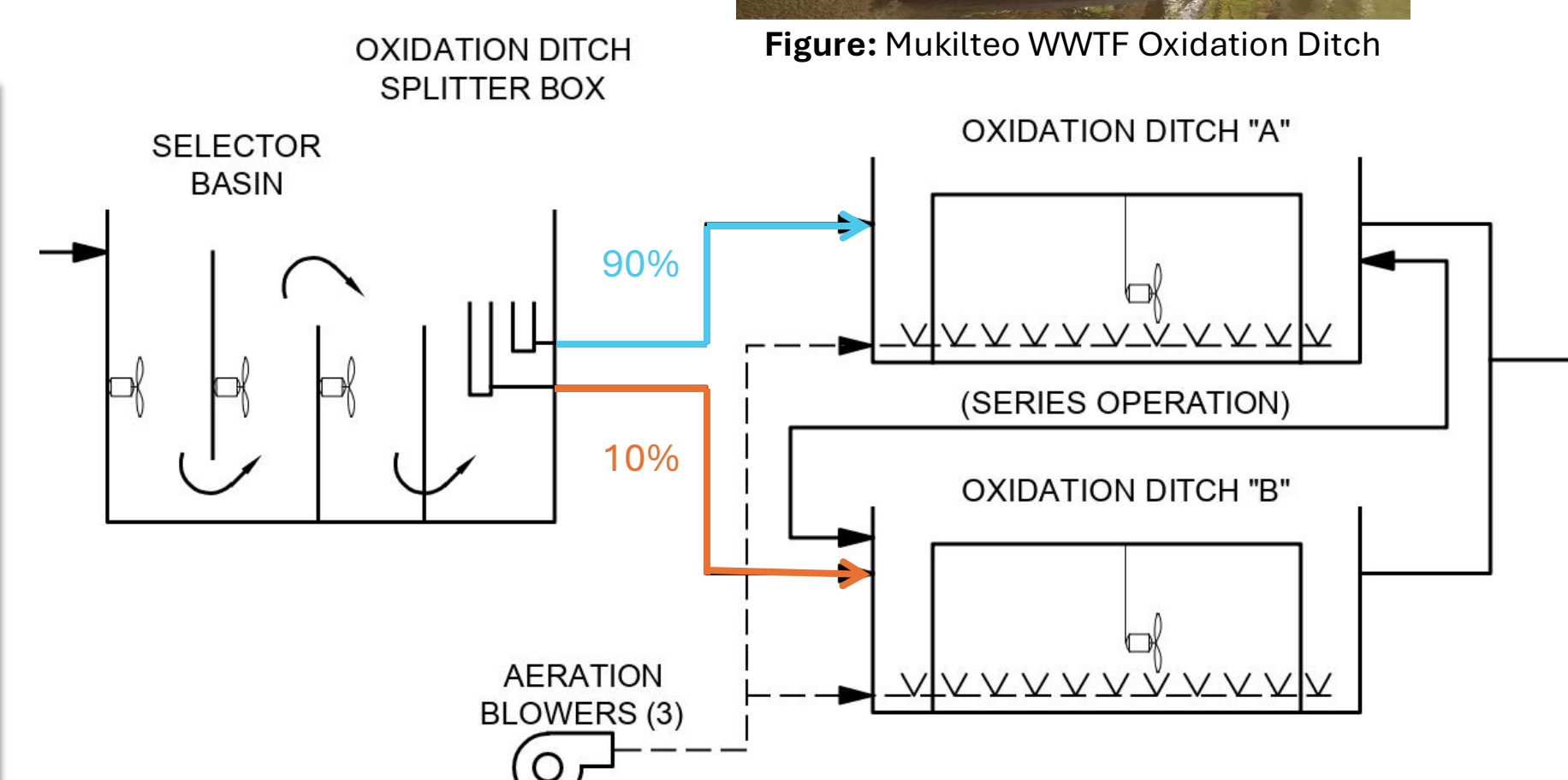


Figure: Process Diagram of Oxidation Ditches

## Objective

Bring effluent nitrogen concentration below projected limits by applying controls to current infrastructure

- Determine optimal aeration control strategies to reduce power usage within tighter limits
- Identify costs of needed resources to implement large-scale controls system

## Results

### Calibration

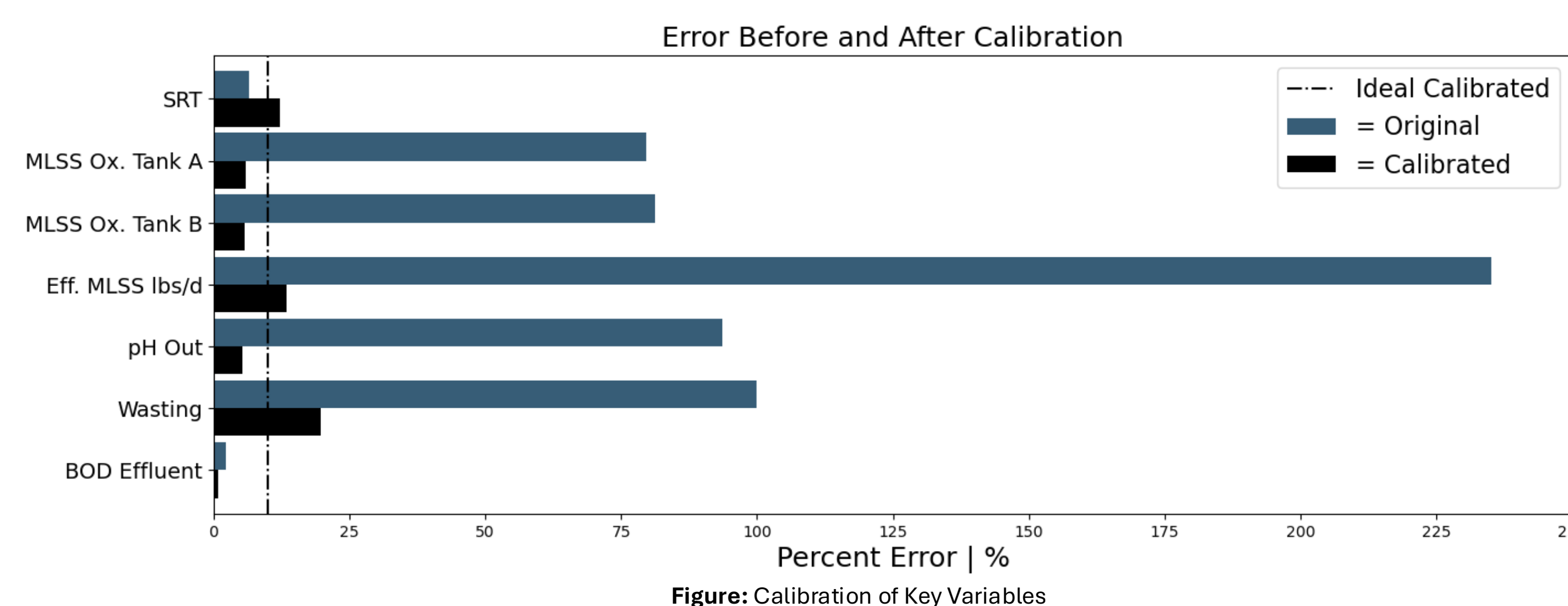
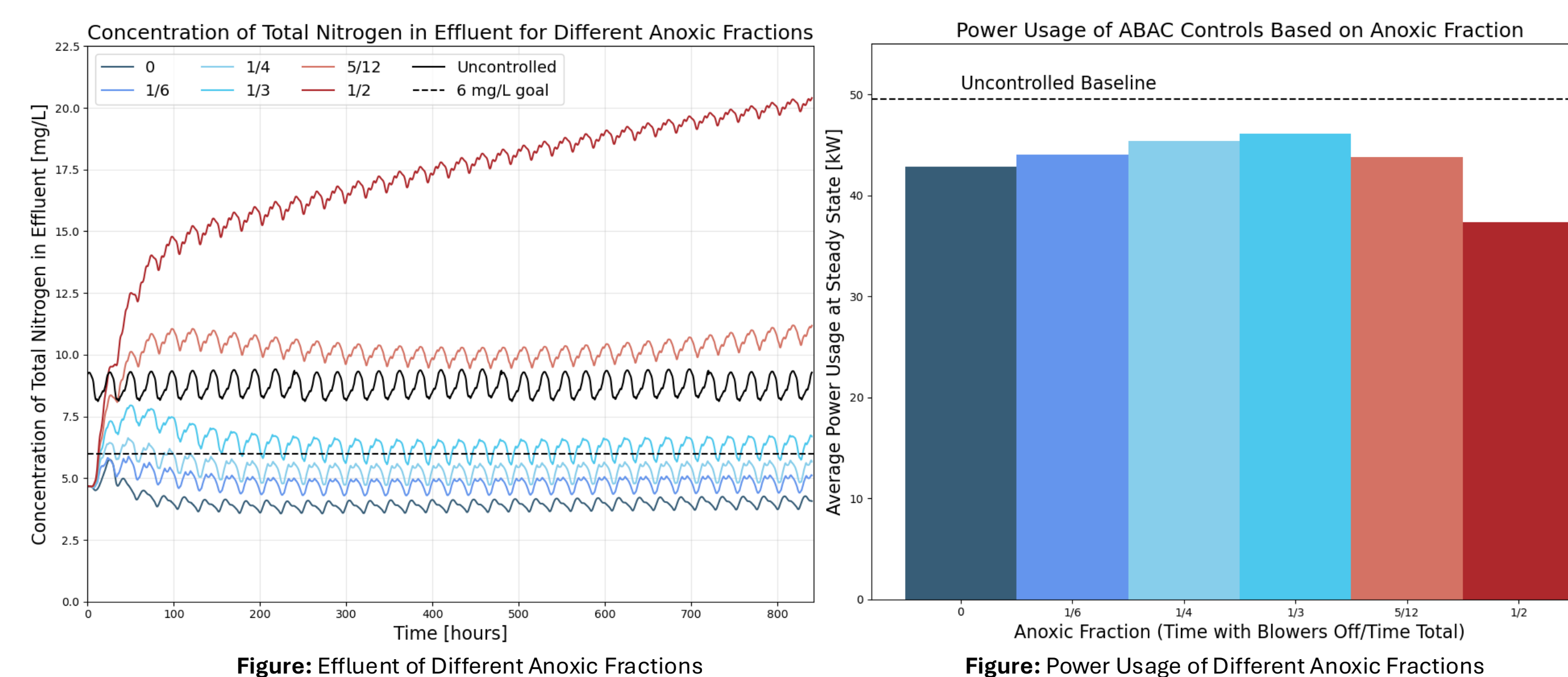


Figure: Calibration of Key Variables

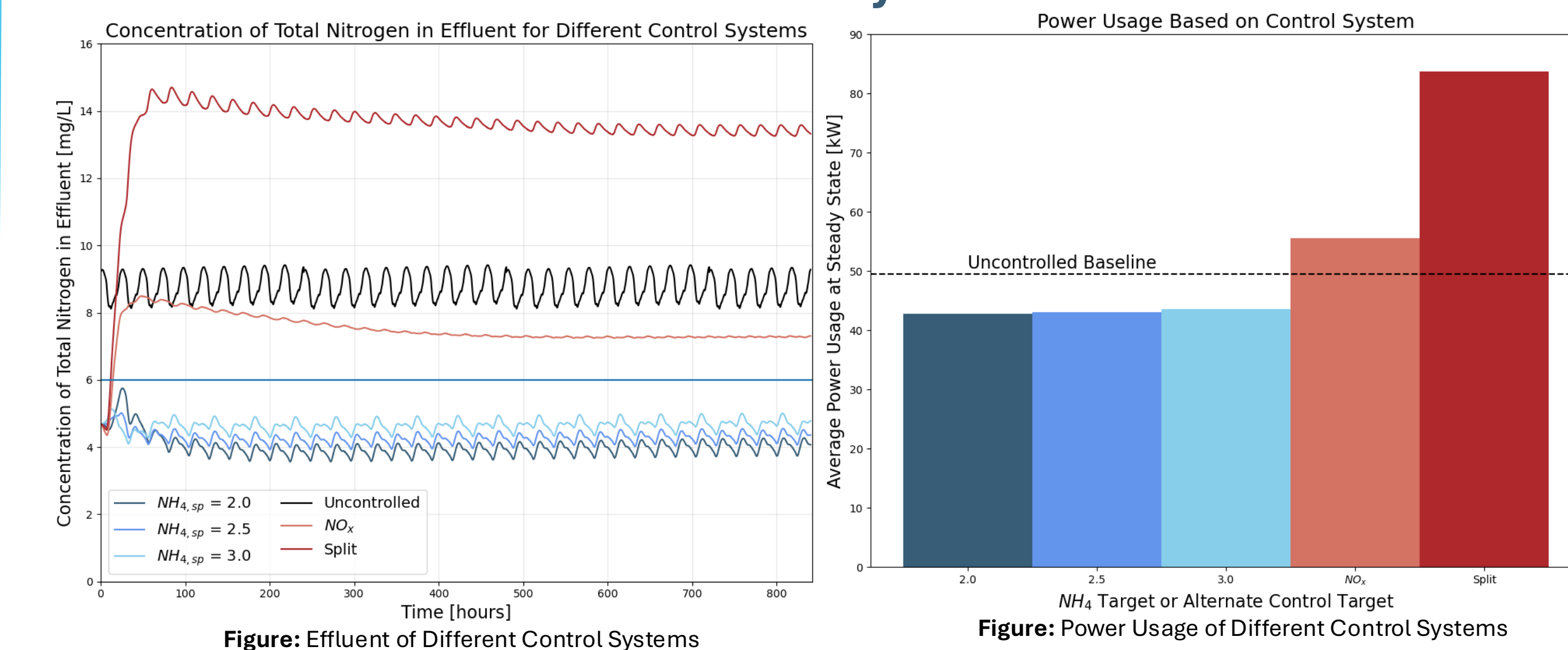
Ideal Uncontrolled Oxidation Ditch System		Modeled System
Unit Process	Design Goal	Measured
Ammonia Oxidation Ditch A [mg/L]	14.7	16.175
Ammonia Oxidation Ditch B [mg/L]	1.09	7.795
Peak Air Requirement [scfm]	2580	2550

### Anoxic Periods



Anoxic periods did **not** improve power usage and effluent nitrogen concentration  
→ The system is near operational capacity for MMF and would require additional infrastructure to allow anoxic periods without falling behind

### Control System



ABAC Control had the least power usage with the best output results  
Ammonia setpoint of 2.0 in oxidation ditch B had the lowest nitrogen output and the lowest power cost  
**Best: ABAC Control with  $NH_4$  setpoint of 2.0 in Oxidation ditch B**

Setpoint:	Operation of Different Setpoints				
	1.0	1.5	2.0	2.5	3.0
Power [kW]	44.94	43.48	42.06	43.04	43.61
Nitrogen [mg/L]	4.9	4.06	4.01	4.31	4.69

### Final Controller

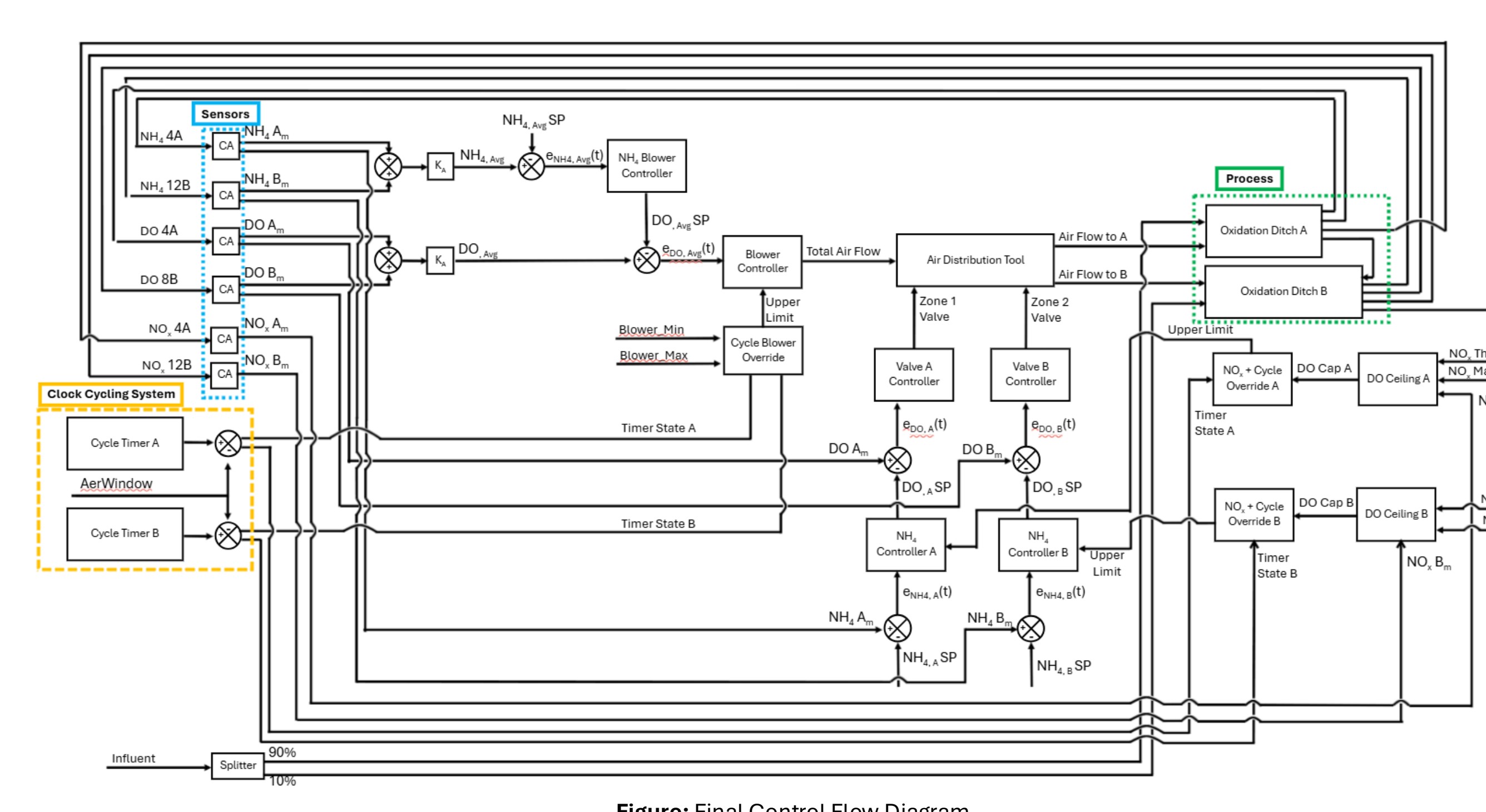


Figure: Final Control Flow Diagram

## Methods

**Data:** PARIS (Permit and Reporting Information System)

System modeled around the max month flow (MMF)

### Calibration:

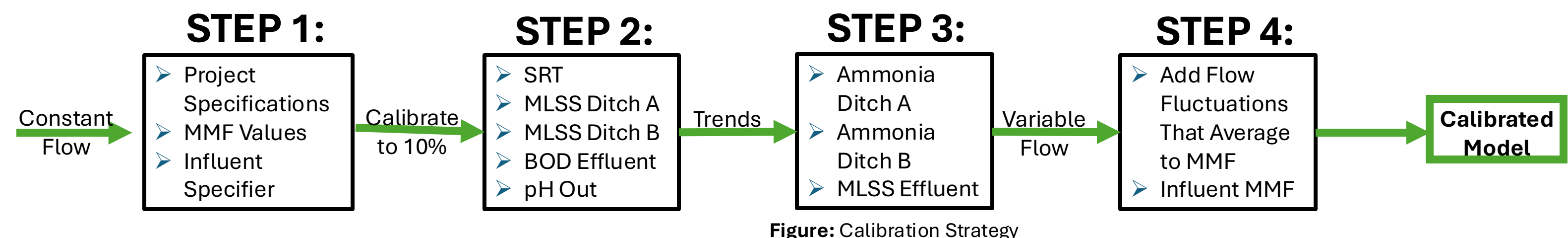


Figure: Calibration Strategy

### Limitations:

The model does not account for settling behavior, temperature impact, or chemical oxygen demand (COD) fractions

### Controls:

- Available Inputs:
- $NO_x$  Concentration
  - $NH_4$  Concentration
  - Dissolved Oxygen (DO) concentration



Figure: Probe in Oxidation Ditch [3]

Calibrated Airflow	
Ditch A Calibrated Airflow	Ditch B Calibrated Airflow
375 scfm per aerated section	450 scfm per aerated section
Total: 2550 scfm	

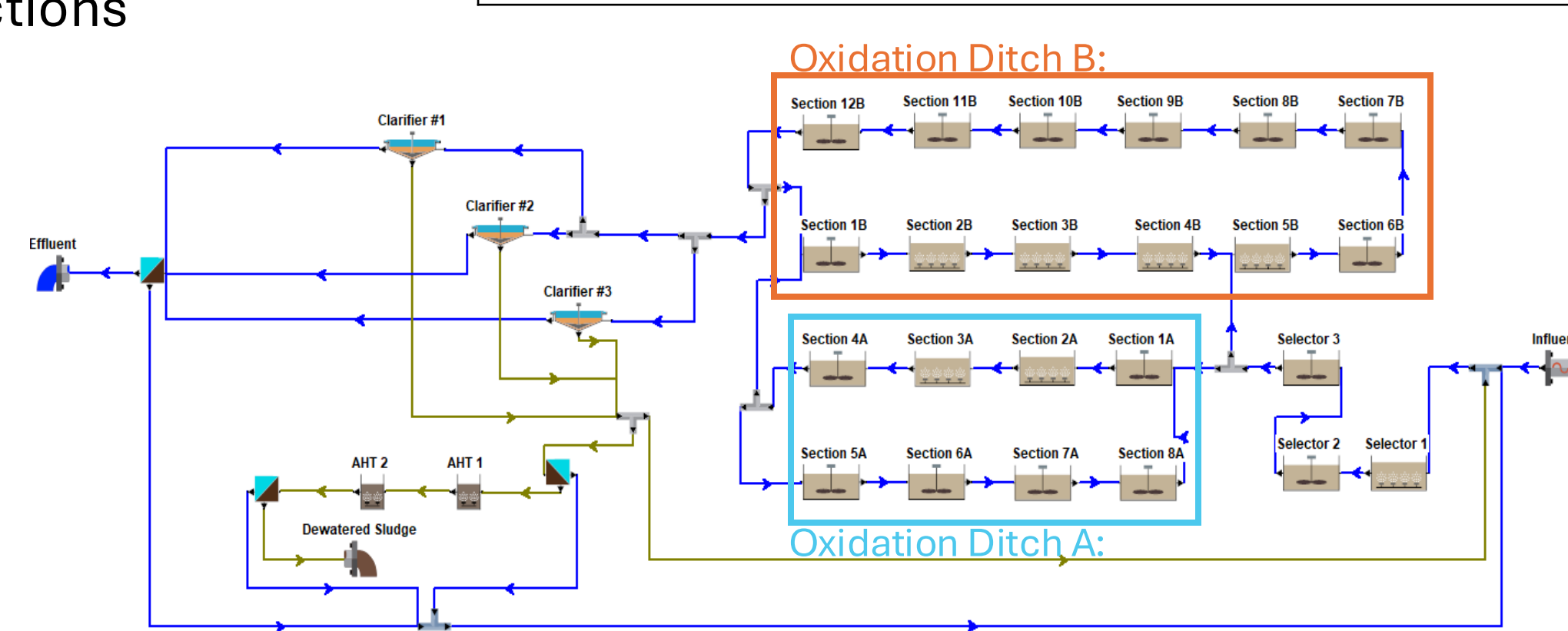


Figure: Biowin Model Flowsheet

**ABAC:** Ammonia Based Aeration Control  
 $[NH_4] \rightarrow [DO]_{sp} \rightarrow$  Airflow requirement  
**NOX:** Nitrite + Nitrate Based Aeration Control  
 $[NO_x] \rightarrow [DO]_{sp} \rightarrow$  Airflow requirement

**Split:** ABAC for Ditch B, NOX for Ditch A

Anoxic periods: blowers are forced to turn off to allow denitrification

## Costs

Item	Total Capital Expenses	
	A Tank	B Tank
SC1000 Probe Module	\$5,031.00	\$5,031.00
Electrical cable	\$91.00	\$91.00
Extension cable	\$59.98	\$74.98
Ethernet cable	\$19.55	\$22.78
PLC integration and Updates	\$5,000.00	\$5,000.00
<b>Subtotal</b>	<b>\$10,201.53</b>	<b>\$10,219.76</b>
Labor costs (50%)	\$2,600.77	\$2,609.88
Operations (15%)	\$780.23	\$782.96
<b>Total</b>	<b>\$13,582.52</b>	<b>\$13,612.60</b>

Description	Operational Costs	
	Unit	Amount
Power	kW	49.55
Energy rates [4]	\$/kWh	0.08635
Daily energy cost	\$/day	\$102.69
<b>Annual energy cost</b>	<b>\$/year</b>	<b>\$37,481</b>

Description	Proposed Controls: ABAC B Tank 2.0 SP	
	Unit	Amount
Power	kW	42.06
Energy rates [4]	\$/kWh	0.08635
Daily energy cost	\$/day	\$87.20
<b>Annual energy cost</b>	<b>\$/year</b>	<b>\$31,828</b>

## Acknowledgements



## References

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