Utilization and Practical Approach of Ammonia-Based Aeration Control (ABAC) at Bonnybrook Wastewater Treatment Plant, Canada

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INTRODUCTION

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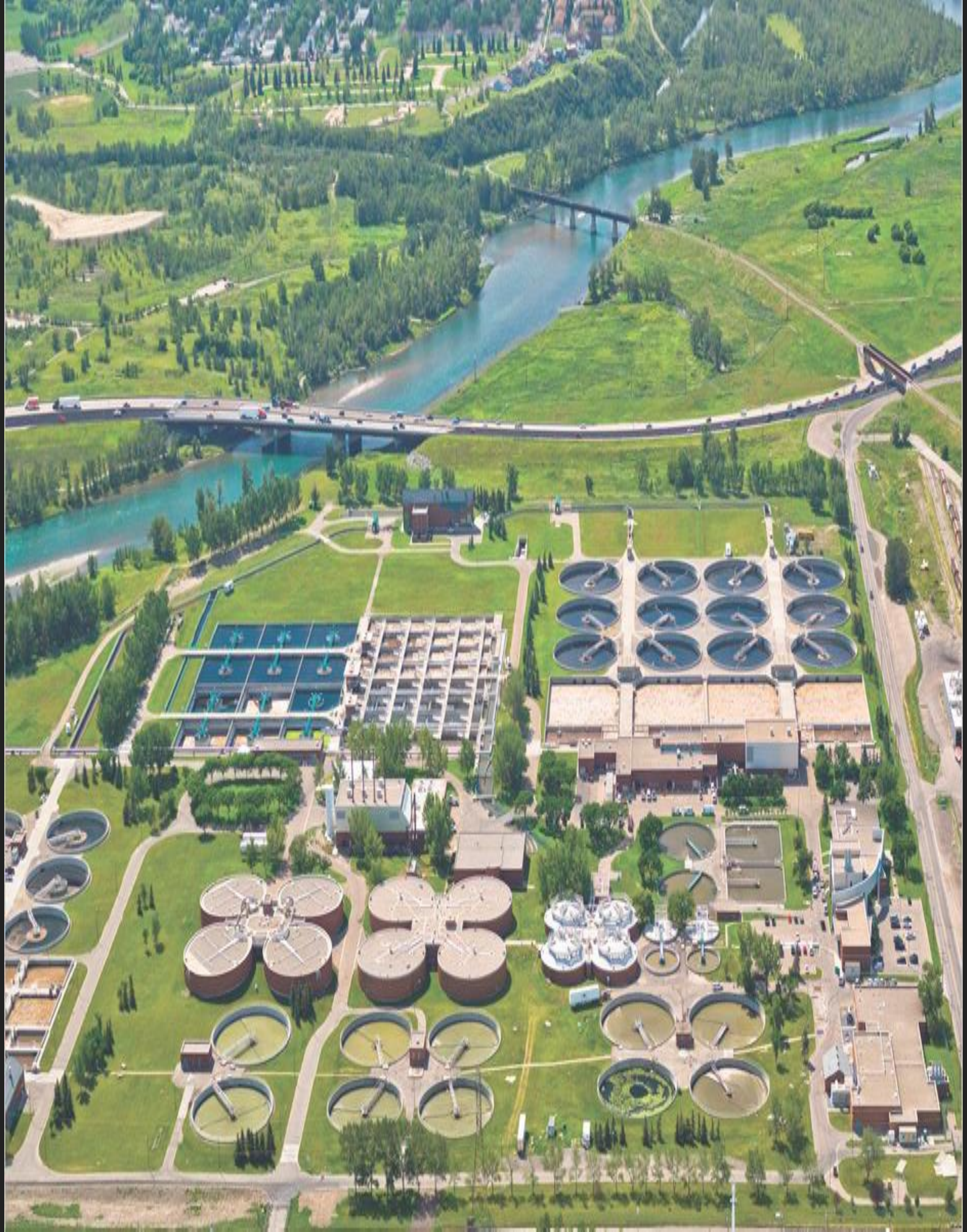


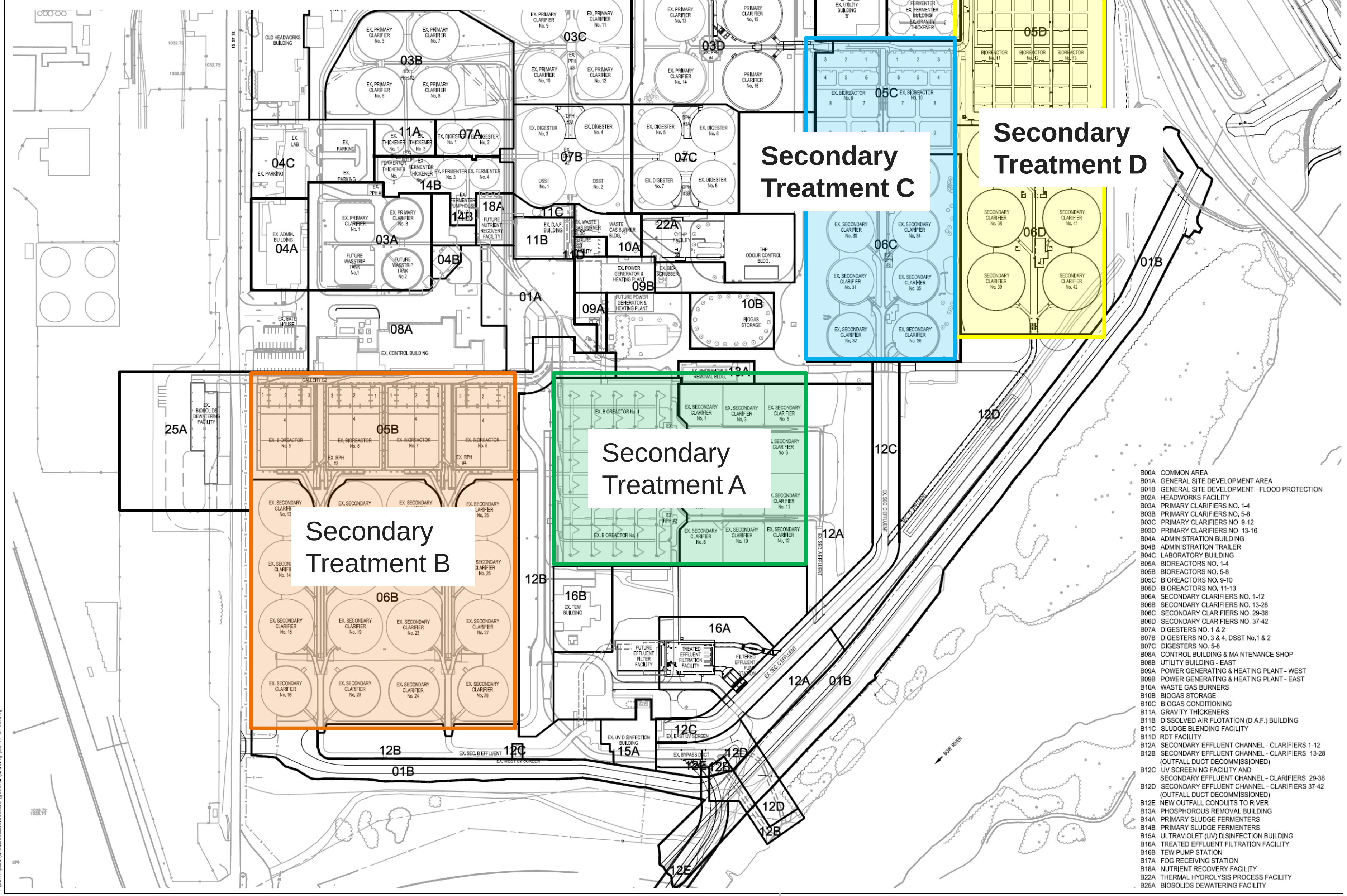
Agenda

1. Plant Background
2. ABAC Introduction
3. Case Study 1
4. Case Study 2
5. Case Study 3
6. Conclusions and Next Steps

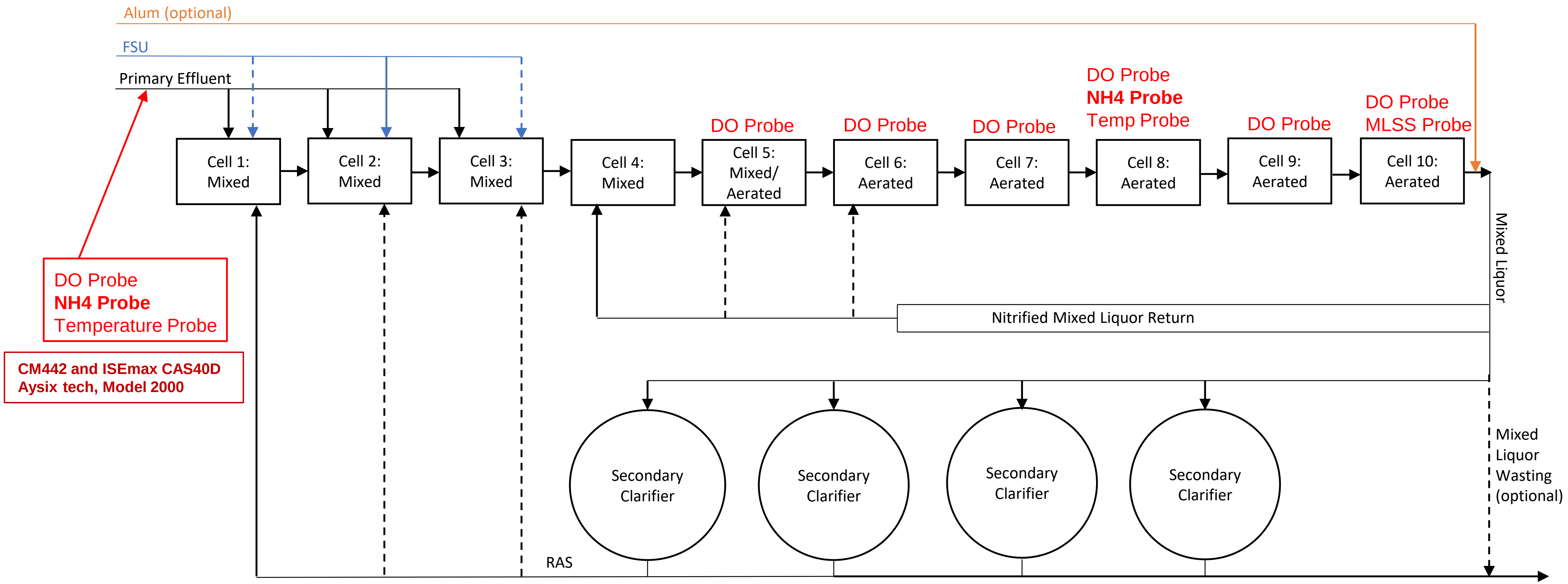
City of Calgary Plant Background

City of Calgary Plant Background

Bonnybrook Wastewater Treatment Plant



Secondary Treatment C - Trains 9 & 10

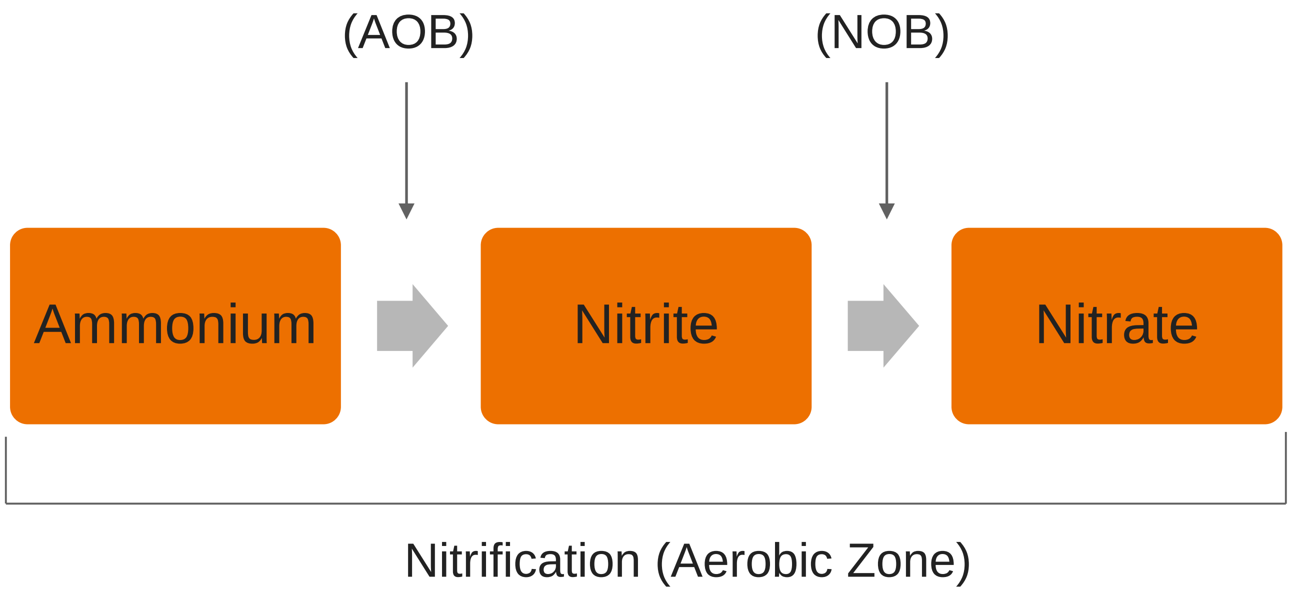


Bonnybrook WWTP Monthly Approval Limits

Parameter	Limit
CBOD	≤ 15 mg/L monthly arithmetic mean of daily composite sample
TSS	≤ 20 mg/L monthly arithmetic mean of daily composite sample
Phosphorus	≤ 1.0 mg/L monthly arithmetic mean of daily composite sample
Ammonia-Nitrogen (October 1 to June 30)	**≤ 10 mg/L monthly arithmetic mean of daily composite sample**
Ammonia-Nitrogen (July 1 to September 30)	**≤ 5 mg/L monthly arithmetic mean of daily composite sample**
Fecal Coliform Counts	≤ 200 MPN or CFU per 100 mL/monthly geometric mean of daily grab samples

Nitrification Basics

- Nitrification is a microbial process where ammonia is oxidized to nitrite and then nitrate
- Nitrification DO supplementation is between 50 to 60% of the total supplied oxygen demand.



- DO
- SRT
- Nutrient

Ammonia Based Aeration Control Introduction

ABAC Introduction

ABAC Control Strategies

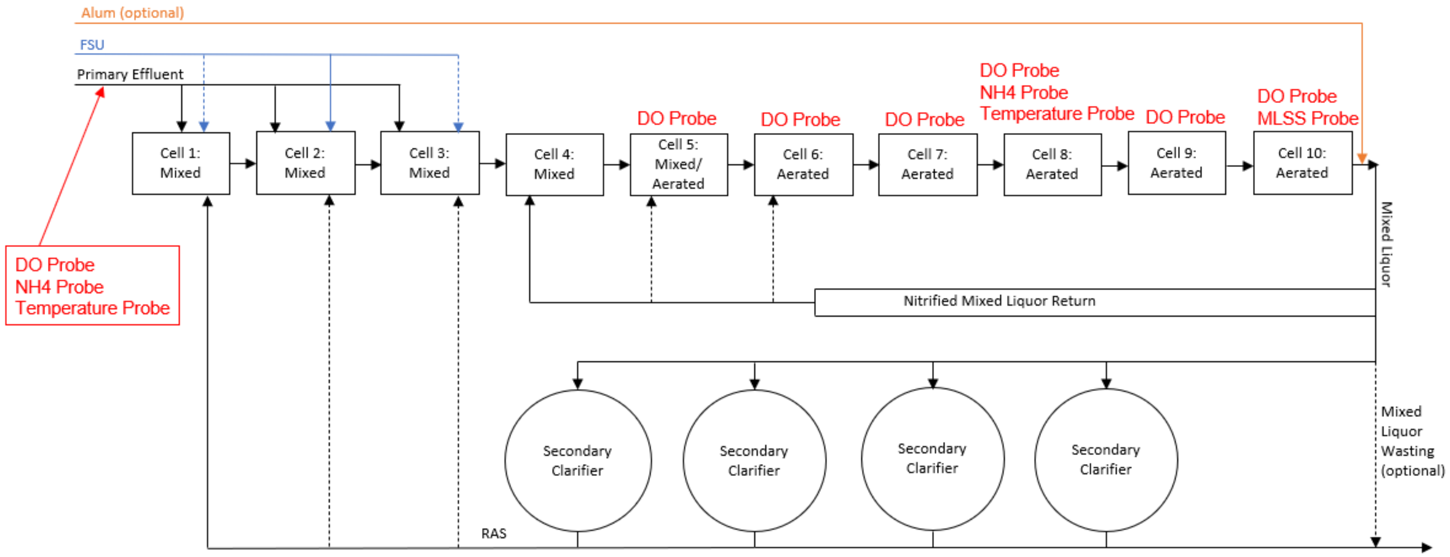
	Description	Advantages	Disadvantages
Feedback	• Measured process variable that is input to the controller. • Control action is based on difference of measured and desired value.	• Does not require a model of the controlled system.	• An error must exist before a control action can be taken. • Slow reactions to control actions.
Feedforward	• Measures a process disturbance and uses a model to predict the behavior of the controlled system.	• Fast response to ammonium load peaks. • Adequate for conditions where no “above the limit” discharge is allowed.	• More complexity due to more sensors. • Requires an accurate process model description. • Low control authority in dry weather flow and ammonium peaks.

Feedforward Control

Initial DO setpoint based on influent loadings to bioreactor

$$Ammonia\ Load\ \left(\frac{Ton}{d}\right) = Influent\ Flow\ (MGD)x\ Influent\ NH3\ concentration\ (\frac{Ton}{MG})$$

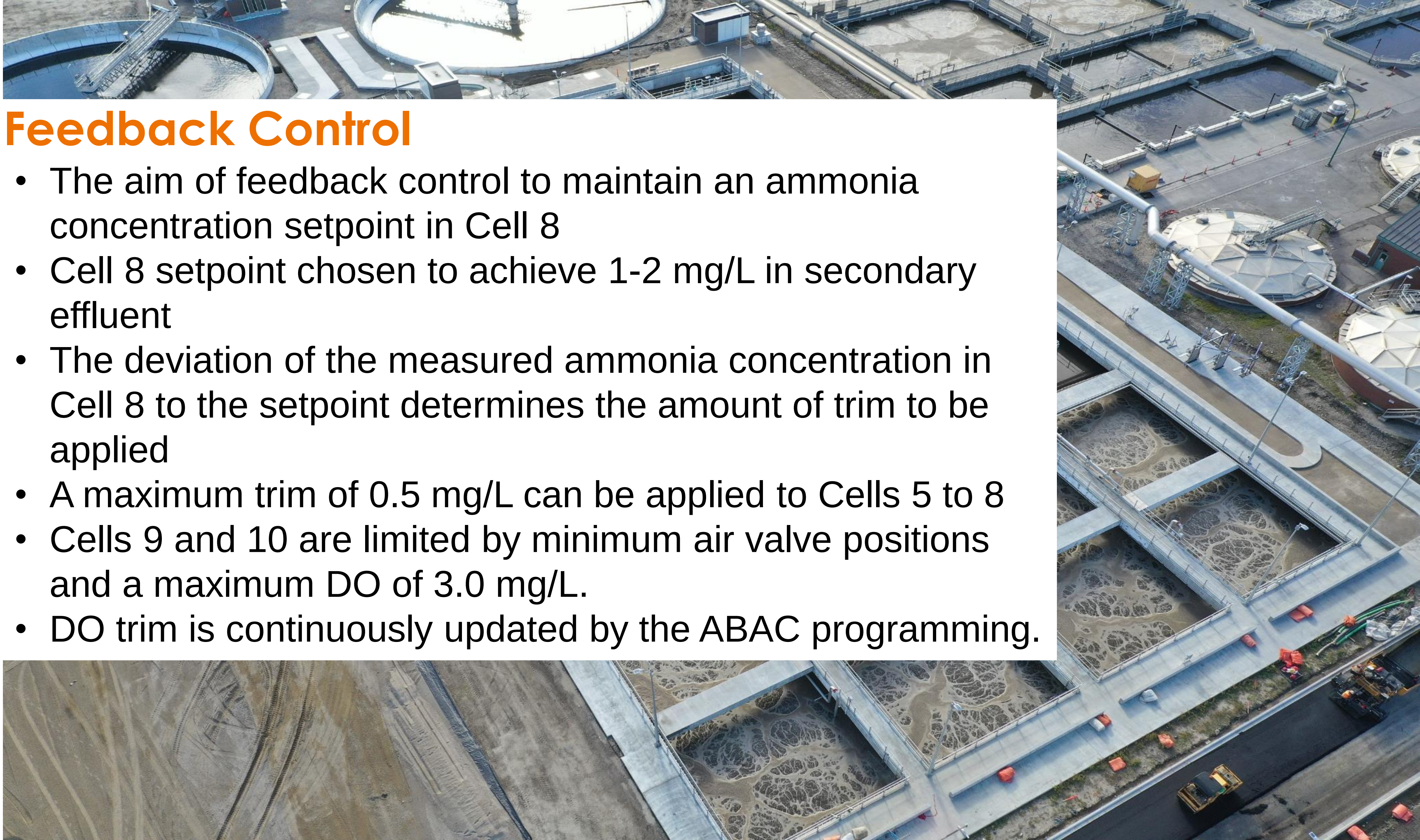
- Summer and Winter DO setpoint Matrices developed based on operational experience
- Base DO setpoint adjusted every 10 minutes to avoid system hunting



Feedforward Control DO Setpoints

$$Ammonia\ Load\ \left(\frac{Ton}{d}\right) = Influent\ Flow\ (MGD) x\ Influent\ NH3\ concentration\ (\frac{Ton}{MG})$$

Primary Effluent Ammonium Loads (Ton/d)	DO (mg/L)					
	Cell 5*	Cell 6	Cell 7	Cell 8	Cell 9	Cell 10
Summer Mode DO Setpoints						
<0.5	1.50	1.50	1.20	1.00	0.50	0.50
=>0.5 and <1	1.70	1.70	1.40	1.10	0.75	0.50
=>1and <1.5	1.90	1.90	1.70	1.30	0.90	0.50
=>1.5 and <1.75	2.00	2.00	2.00	1.50	1.00	0.50
=>1.75 and <2	2.25	2.25	2.25	1.75	1.25	0.75
=> 2	2.50	2.50	2.50	2.25	1.50	1.50



Feedback Control

- The aim of feedback control to maintain an ammonia concentration setpoint in Cell 8
- Cell 8 setpoint chosen to achieve 1-2 mg/L in secondary effluent
- The deviation of the measured ammonia concentration in Cell 8 to the setpoint determines the amount of trim to be applied
- A maximum trim of 0.5 mg/L can be applied to Cells 5 to 8
- Cells 9 and 10 are limited by minimum air valve positions and a maximum DO of 3.0 mg/L.
- DO trim is continuously updated by the ABAC programming.

Sequencing and Implementation Methodology

Case 1: Existing ABAC logic applied in Secondary C. Feedforward-feedback control based on the ammonia loading and Cell 8 Ammonia setpoint. Reviewed for control and energy savings available

Case 2: BioWin® model of Feedforward-feedback logic as described, based on existing hourly plant data and available ammonia profile. Existing model calibration and optimization

Case 3: Calibrated BioWin® model used to develop new feedforward control logic dependent on microbial kinetics to maintain ammonia setpoint of desired cell. Reviewed for control and additional energy savings

ABAC Case Study 1

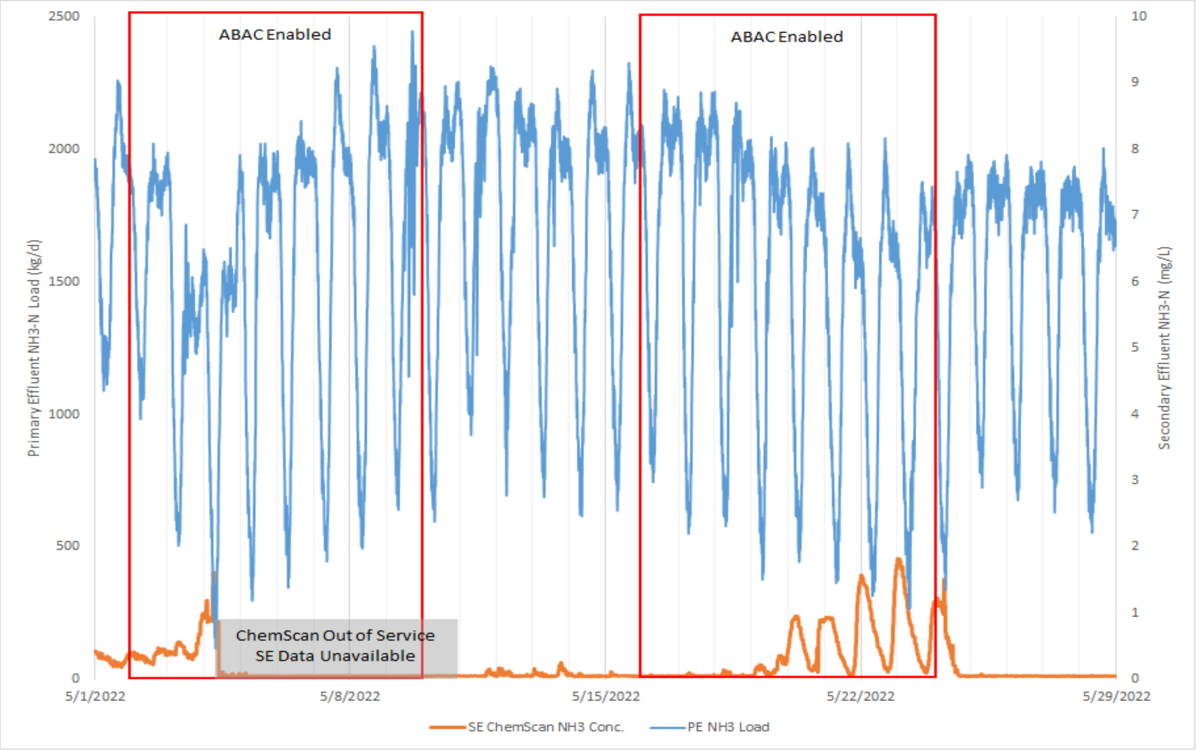
Case Study 1

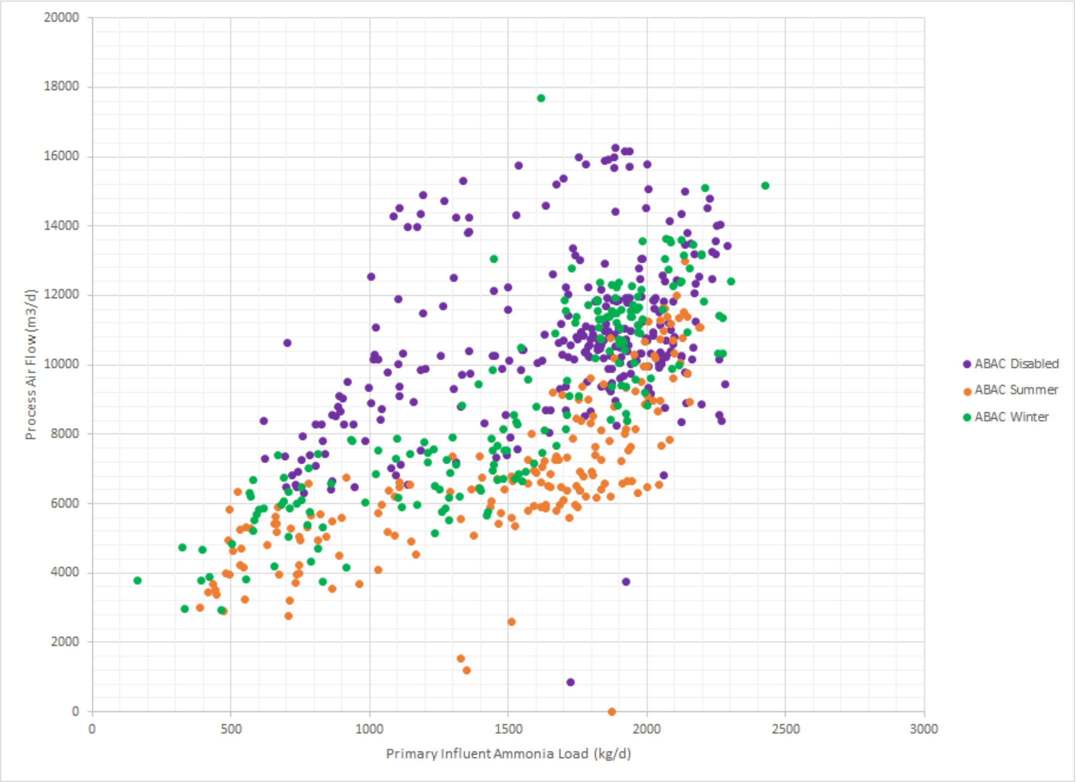
Case 1: ABAC Testing Bioreactor 10

Dates	Aeration Mode	Influent Temperature (F)	Influent Flow (MGD)	Average PE TKN Concentration (mg/L)	DO Setpoints (mg/L)				
					Cell 6	Cell 7	Cell 8	Cell 9	Cell 10
May 2 to May 9	ABAC Winter	55.58	9.47	56.6	ABAC Controlled with Cell 8 ammonia setpoint of 7.0 mg/L				
May 10 to 12	ABAC Disabled	55.76	9.64	55.0	2.5	2.5	2.5	2.0	1.5
May 13 to 15					2.0	2.0	2.0	2.0	1.5
May 16 to May 23	ABAC Summer	55.94	8.28	51.1	ABAC Controlled with Cell 8 ammonia setpoint of 4.5 mg/L (May 16 to 18th) and 5.5 mg/L (May 19th to 23rd)				
May 24 to May 28	ABAC Disabled	57.02	8.78	52.7	2.0	2.0	2.0	2.0	1.5

CASE STUDY 1

Case 1: Results





Case 1: Results and Savings

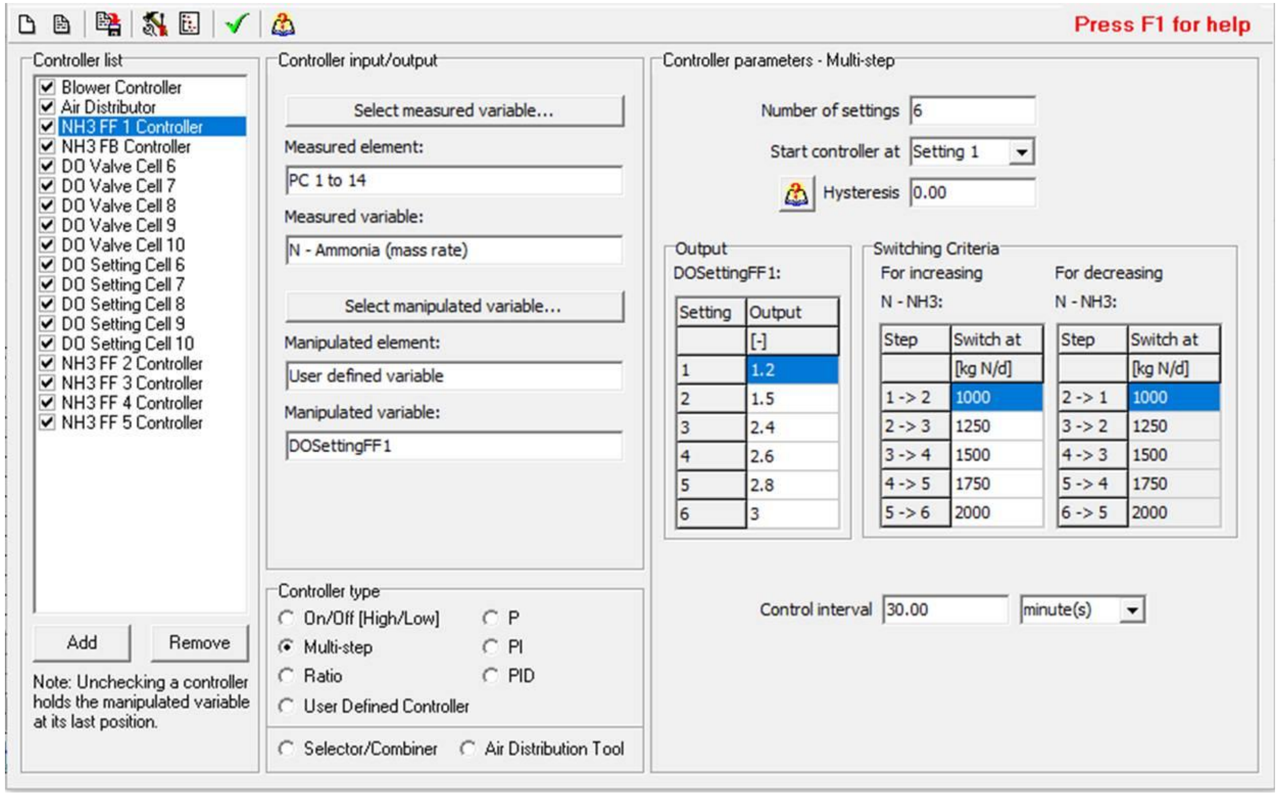
- ABAC summer mode: 26% process air savings/mass of ammonia-N
- ABAC winter mode: 7% process air savings/mass of ammonia-N
- Overall, ABAC control achievable 17% savings

Aeration Mode	Process Air per kg Ammonia-N ($m^3/kgNH_3$-N)	Process air per Influent Flow (m^3/MGD)	Power savings (MWhr)	Annual savings (US$)
ABAC Avg.	**5.7**	**67.4**	*~1136*	*~121k*
Summer	*5.1*	*63.2*	*~1738*	*~185k*
Winter	*6.4*	*71.9*	*~468*	*~50k*
ABAC Disabled	**6.9**	**82.5**	-	-

ABAC Case Study 2

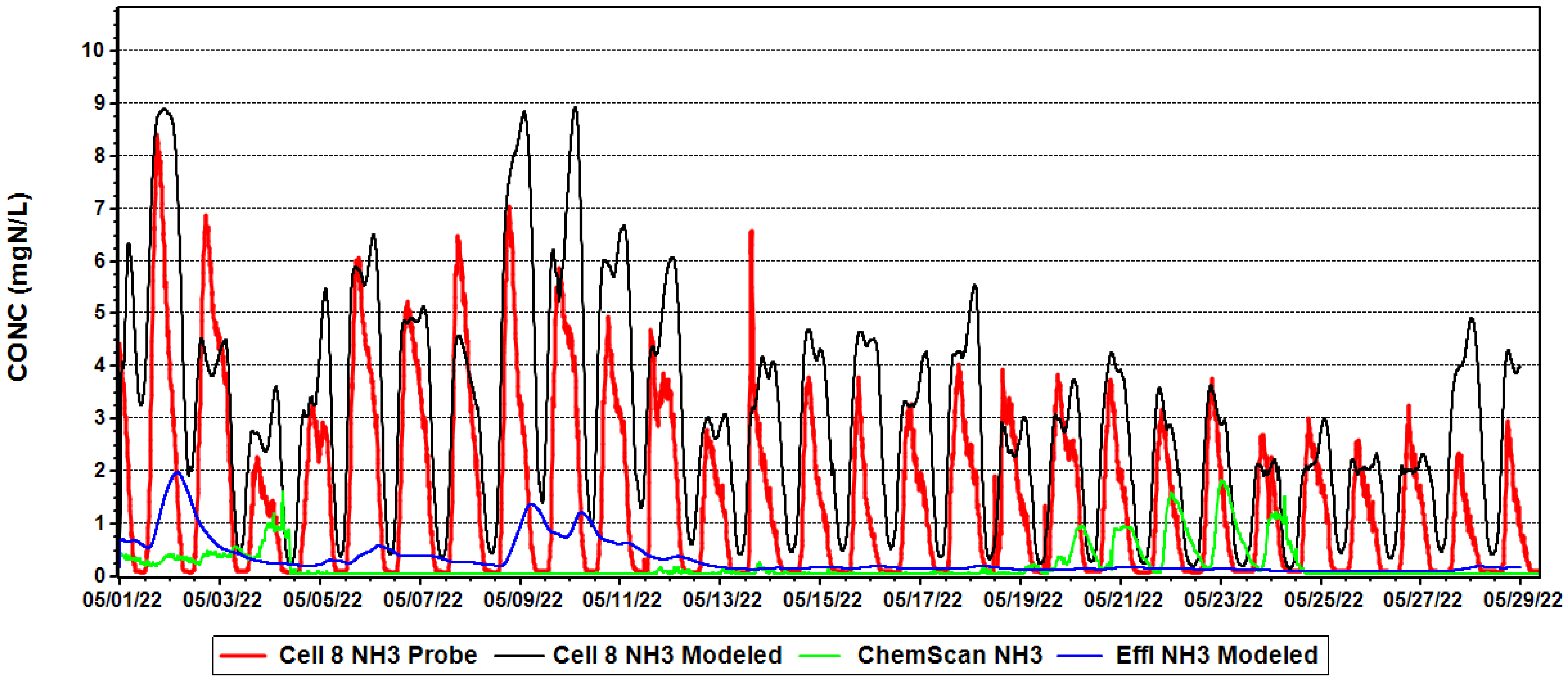
Case Study 2

Case 2: Existing BioWin® Simulation



- Existing control logic was simulated in BioWin® and BioWin Controller®
- Feedforward with Feedback trim, adjusting a floating DO setpoint at a similar time interval
- 28-day simulation was completed
- The input highlights that as the ammonia load changes the DO setpoint also changes

Case 2: Simulation Results



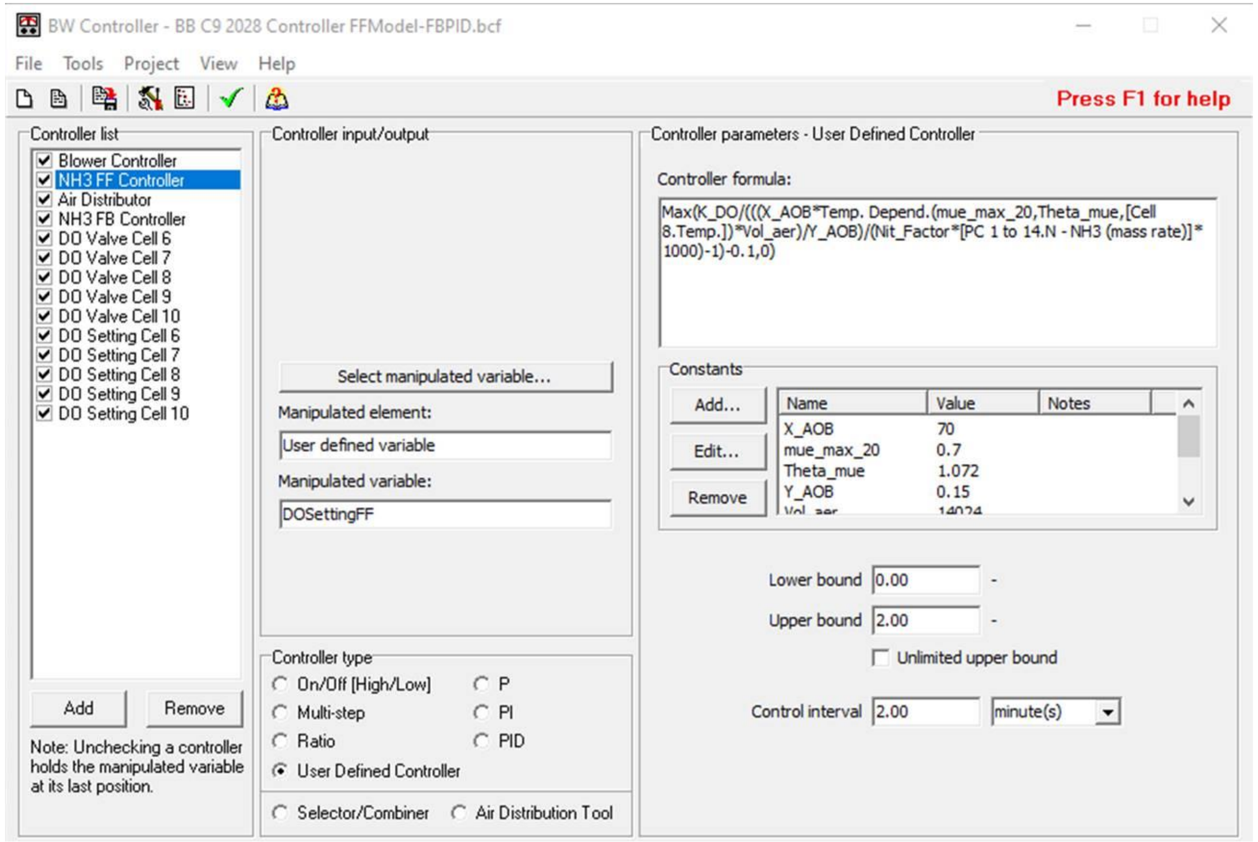
ABAC Case Study 3

Case Study 3

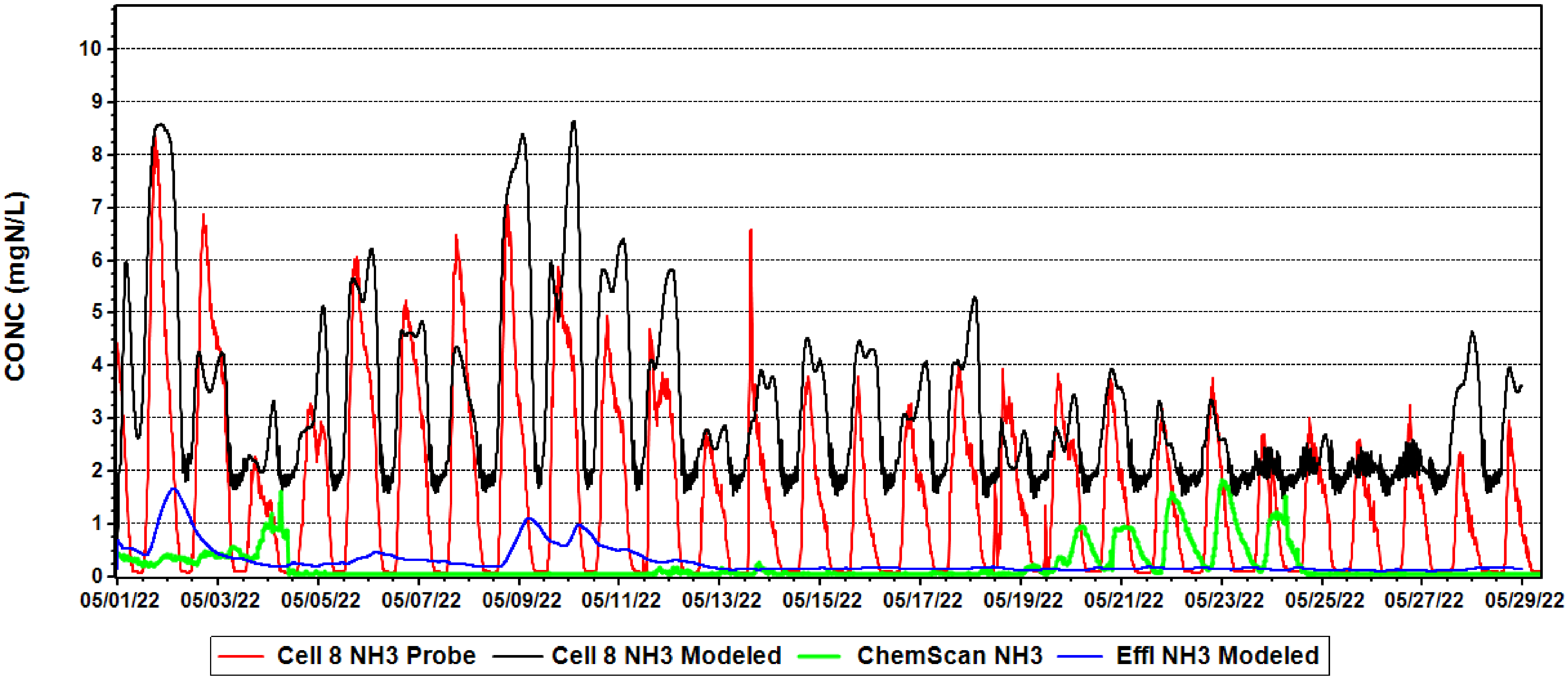
Case 3: Modified ABAC Control Logic

- Modified control logic was developed
- Controllers maintains a desired ammonia objective by considering microbial kinetics, total mass load of nitrifiers, and the incoming ammonia load

$$\frac{K_{DO}}{\left(\frac{\left(X_{AOB}\cdot\mu_{max@20}\cdot\theta^{T-20}\cdot Vol_{Aer[m3]}\right)/Y_{AOB}}{NitFac\cdot\frac{kgNH3N\ INF}{d}\cdot 1000}-1\right)}-0.1$$



Case 3: Simulation Results



Conclusion and Next Steps

Next Steps

Conclusion

- ABAC has been widely applied in WWTP but not optimized
- Any advance control optimization may result in investing time, labor and possible disruption to system
- Optimized simulation yield to time and capitol savings and operation disturbance protection

Next Steps

- Program a second modified controller for testing
- Implement in Secondary D

Thank you!

Discussion