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Vertical Route or Under Pressure:

Aeration Analysis for EBNR

OWEA2017

Hazen

Presentation Overview

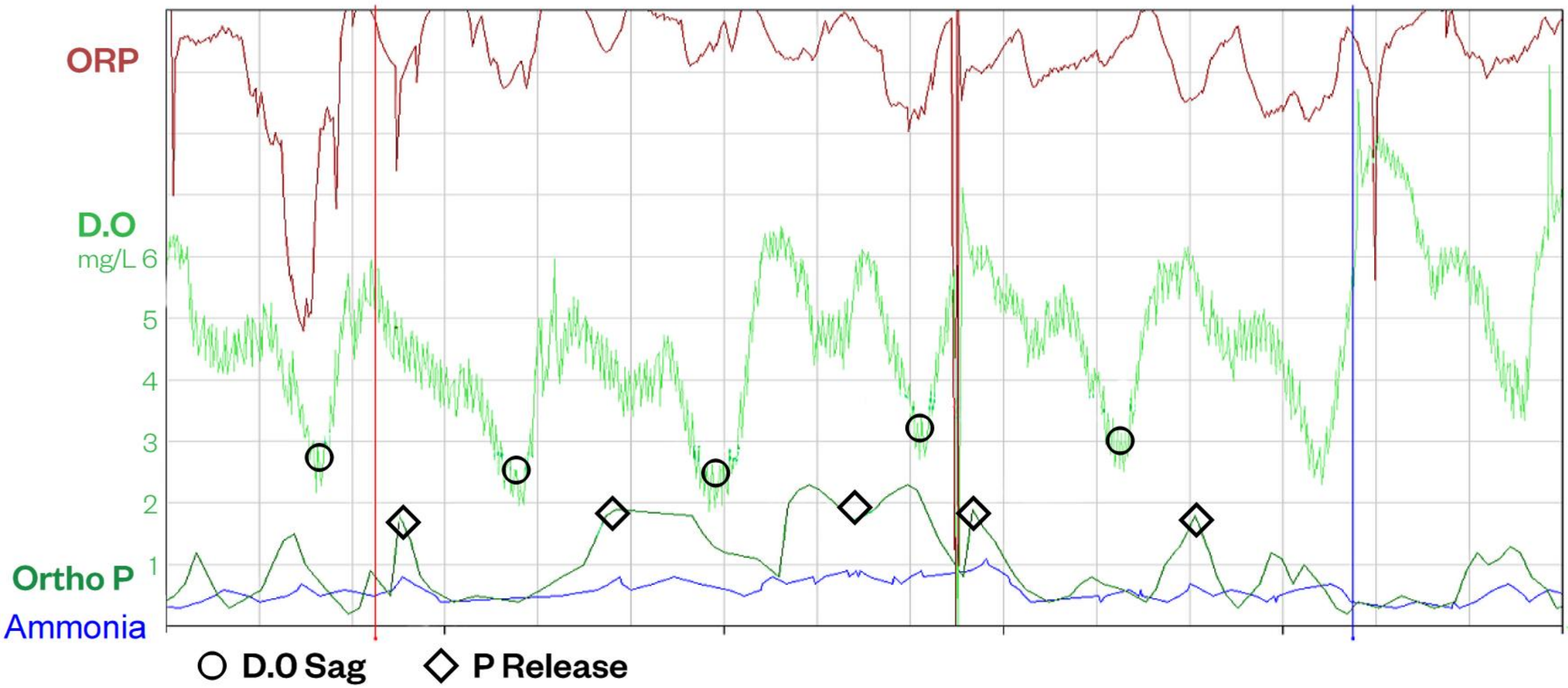
- Project Background
- Aeration Alternatives Development
- Process Modeling
- Aeration Demand
- Alternatives Analysis
- Recommendations

Project Background

Project Background – UMC Operational Challenges

- Significant spikes of TP and TSS in effluent 2009-2011
  - Accompanied by spikes in CBOD and TSS in influent
- High number of industrial users
- 2012-2014
  - Operations support
  - Evaluation of nutrient instability and process performance
  - Developed calibrated process model for optimization

Project Background – UMC Operational Challenges



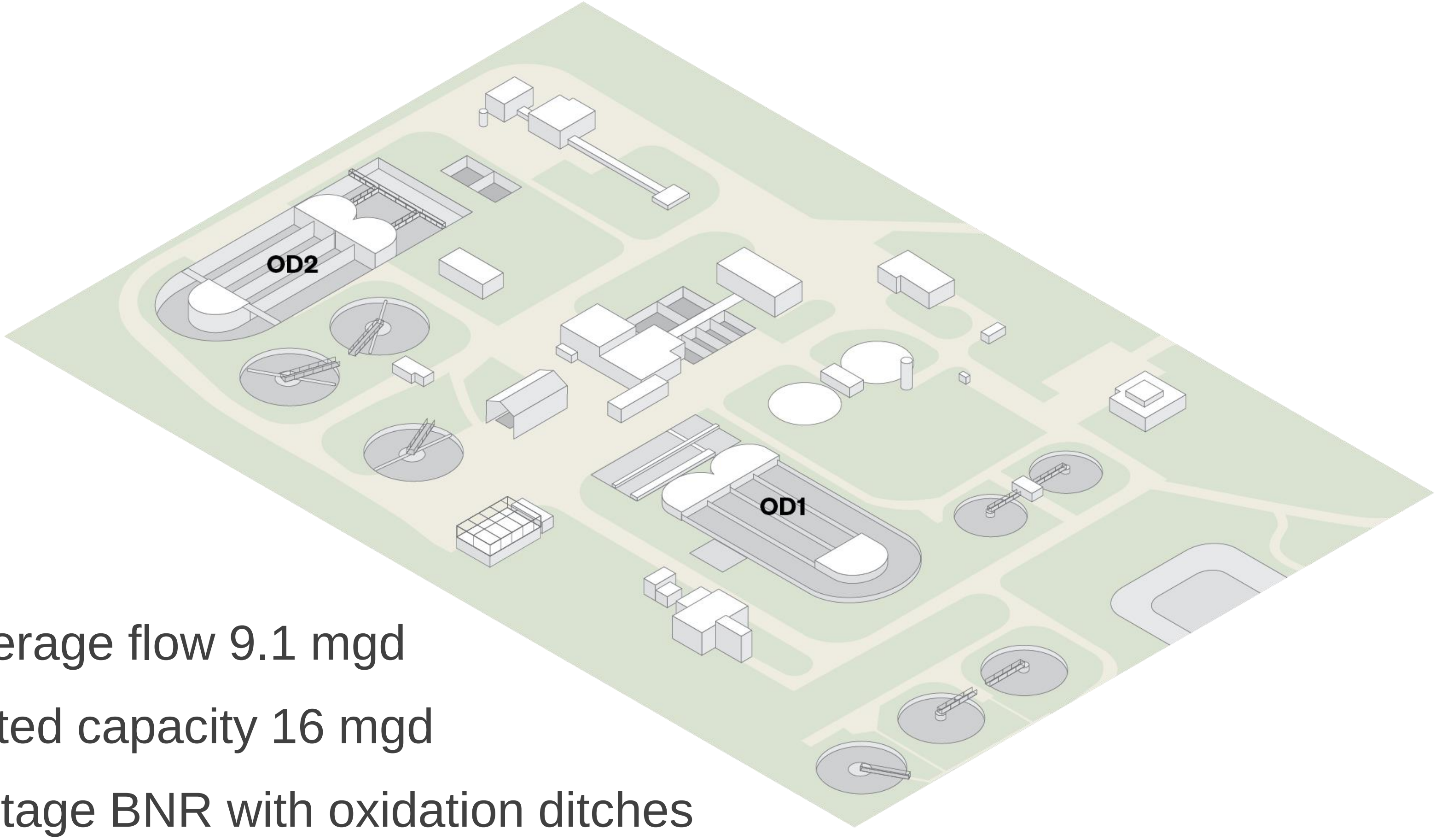
Objective of Project

Evaluate alternatives for aeration to improve treatment process performance and reliability and reduce O&M costs.

Project Scope

- Review data and existing equipment to evaluate performance
- Develop design criteria for aeration system
- Process model simulations to confirm improvements
- Evaluate and recommend most effective option for meeting aeration demand and permit requirements

Upper Mill Creek WRF Overview



Average flow 9.1 mgd

Rated capacity 16 mgd

5-stage BNR with oxidation ditches

Existing Aeration System

- 2 Oxidation Ditches – 2 Treatment Trains
  - 3 – 150 HP Vertical Surface Aerators (2 speed)
  - 6 – Retractable Diffuser Grids
  - 4 – Rotary Lobe Blowers

Oxidation Ditch 1

Oxidation Ditch 2

UMC WRF Select NPDES Permit Limits (Monthly Average)

Season	Total CBOD	TSS	Ammonia	Nitrite + Nitrate	Total P
Summer Limit (mg/L)	10	12	1.0	5.0	1.0
Winter Limit (mg/L)	10	12	3.0	5.0	1.0

Aeration Alternatives Development

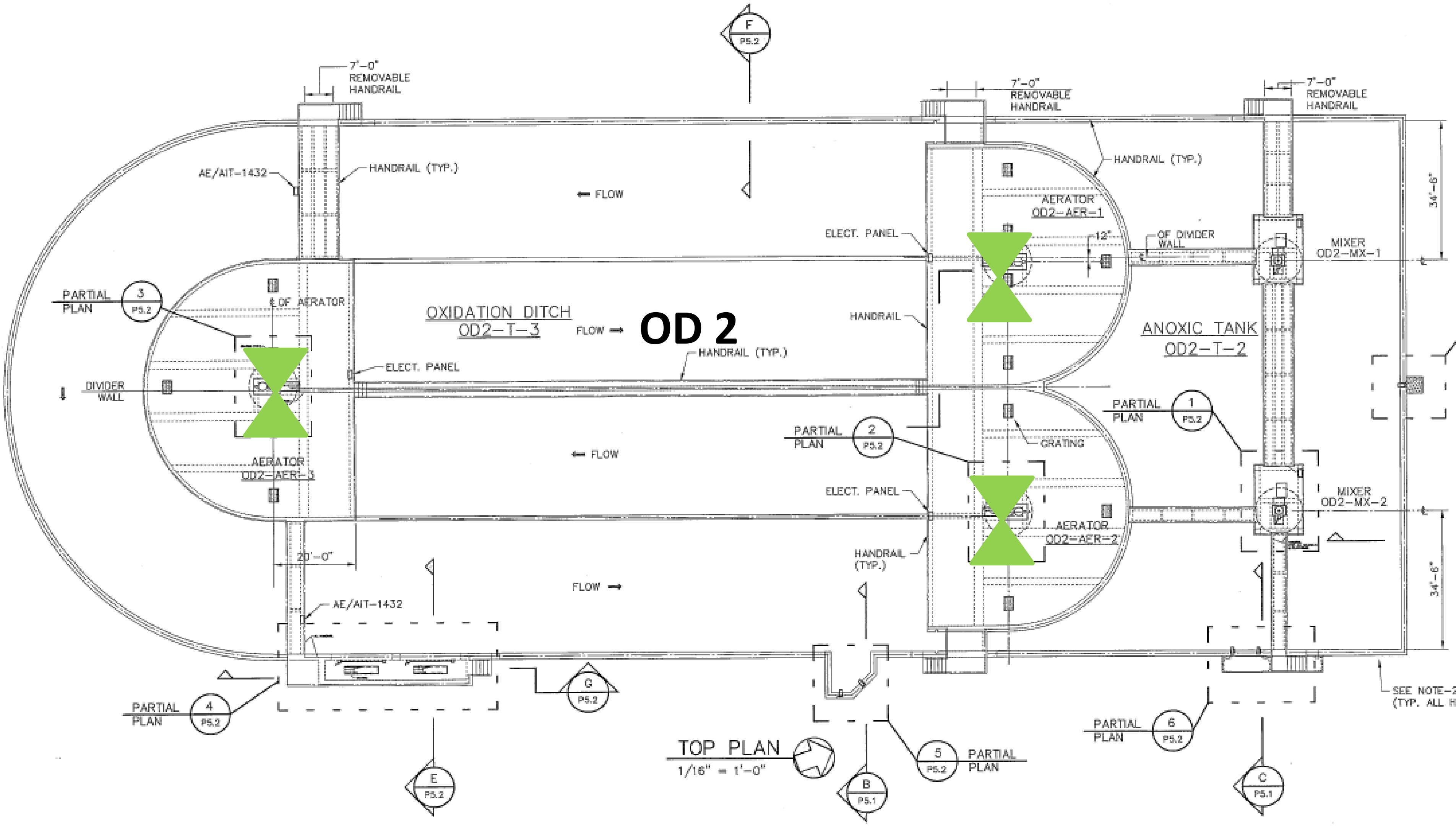
Technology Alternatives

- New vertical surface aerators with VFDs
  - More efficient, better turndown, better mixing, more air than existing
- Conventional fine bubble diffusers, high speed blowers and submersible mixers.
  - Decouple aeration and mixing
  - Moves away from traditional OD configuration

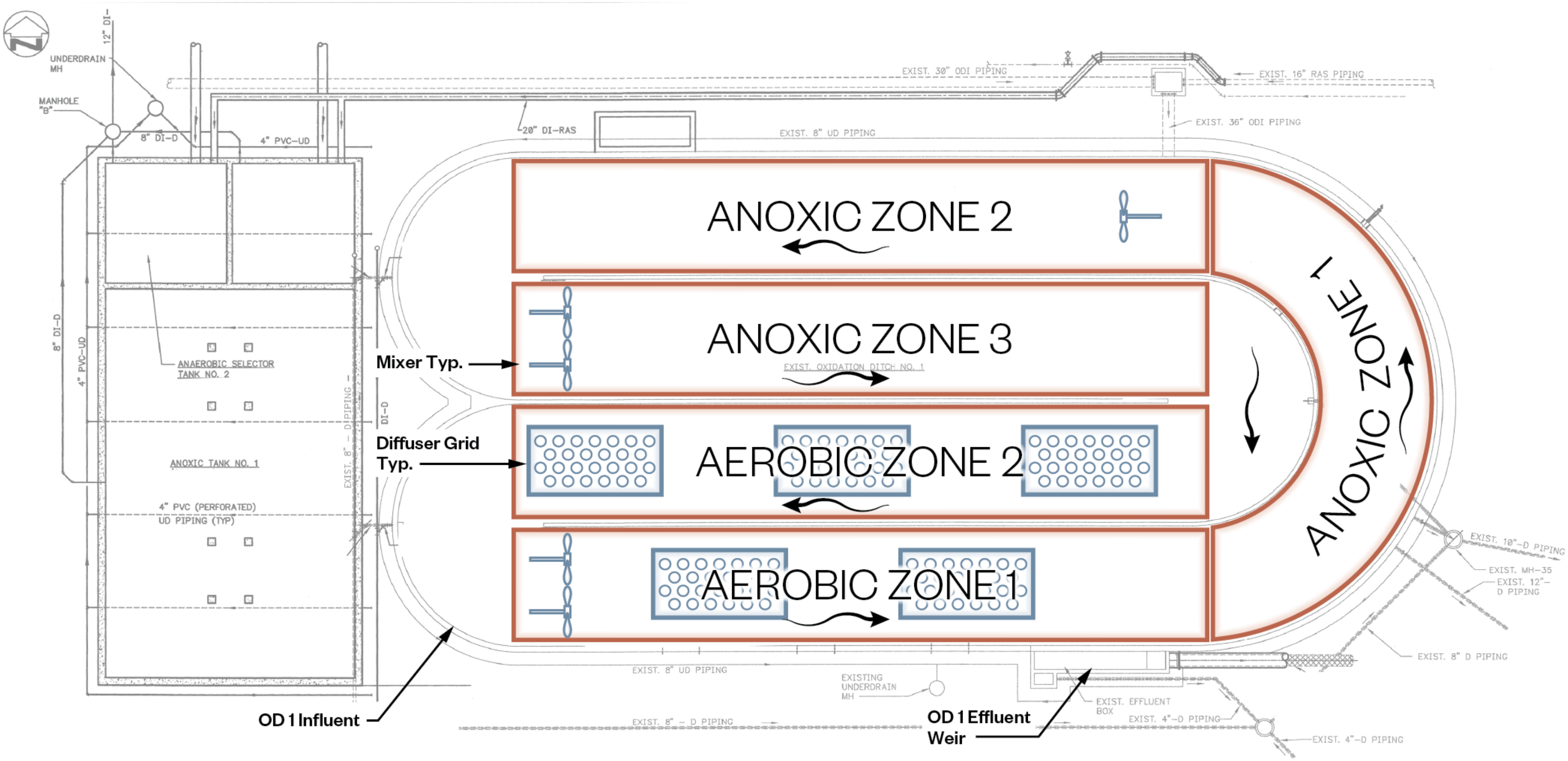
Alternatives List

1. New vertical surface aerators with VFDs
2. Conventional fine bubble diffusers, high speed blowers and submersible mixers
3. Alt 1 plus post aeration tank
4. Alt 2 plus post aeration tank

New Aerators – Layout



New Fine Bubble Diffusers – Layout



Process Modeling

Influent Characterization

- Three years of data

  Year 1 – August 2011 – July 2012

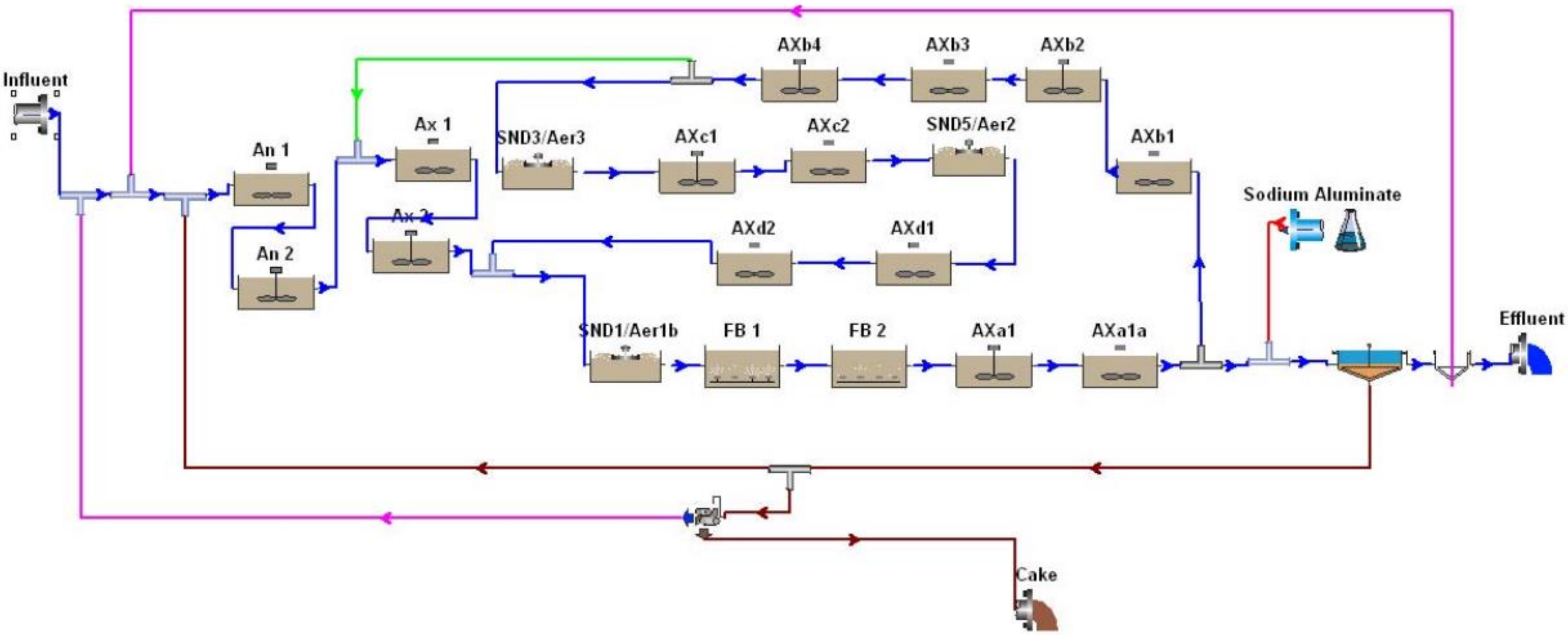
  Year 2 – August 2012 – July 2013

  Year 3 – August 2014 – July 2015

- Influent inputs – based on three-year average of Max 30-Day Average for each parameter

Process Simulations

- Oxidation Ditch 1 BioWin Configuration



Process Simulations – Evaluations

- Maximum sustainable treatment capacity of a single OD while meeting permit
- Verify expected performance of oxidation ditches with upgraded aeration systems
- Verify SND needed to meet N limits

Season	Total CBOD	TSS	Ammonia	Nitrite + Nitrate	Total P
Summer Limit (mg/L)	10	12	1.0	5.0	1.0
Winter Limit (mg/L)	10	12	3.0	5.0	1.0

Evaluation of Post Aeration

- SND required for current and future N limits – increases risk of P release at low DO
- Preventing DO sag can be difficult in large volume ODs (UMC high soluble organic loads at times)
- If P release occurs – more chemical feed is required and increases risk of unstable Bio-P due to excess chemical
- Evaluated use of post aeration tanks to improve process stability for both N and P removal

Process Simulations for Alternatives

Item	Flow (MGD)	CBOD (mg/L	TSS (mg/L)	Ammonia (mg/L)	Nitrite + Nitrate (mg/L)	Total P (mg/L)	Sodium Aluminate (gal/d)
Permit Limits	**-**	**10**	**12**	**1.0**	**5.0**	**1.0**	**-**
Alternative 1 New Aerators	10	1.6	1.7	0.8	4.2	0.7	55
Alternative 2 New Fine Bubble Diffusers with Submerged Mixers	10	2.1	1.9	1.8	0.9	0.8	15
Alternative 3 New Aerators with Post Aeration	10	1.6	1.7	0.1	3.0	0.5	0
Alternative 4 New Fine Bubble Diffusers with Submerged Mixers with Post Aeration	10	1.9	1.9	0.4	2.4	0.2	0

Aeration Demand

Aeration Demand

- Determine oxygen demand based on influent BOD and TKN
  - 1.2 lb O_2 per lb BOD
  - 4.57 lb O_2 per lb TKN
- Denitrification credit
  - 2.86 lb O_2 per lb $N_{2\ gas}$ ($TKN_{oxidizable}$ – NO_3 eff)
- AOR = 1.2 * BOD + 4.57 * TKN – 2.86 * $N_{2\ gas}$
  - Actual Oxygen Requirement, lb O_2/d

Aeration Demand

- Convert AOR to SOR
- Surface Aerators versus Fine Bubble Diffusers

Same Same

$$AOR = SOR * \alpha F * \theta^{T-20} * \left(\frac{\tau * \beta * \Omega * C_{sat\,20} - C}{C_{sat\,20}} \right)$$

Aeration Demand – Design Alpha-F

- Alpha Factor (α)
- Fouling Factor (F)
- Wastewater Correction Factor for Oxygen Transfer
- Impacted by a number of factors, including type of aeration device
- For UMC:
  - αF for fine bubble diffusers = 0.5
  - αF for surface aerators = 0.85

Aeration Demand – Assumptions

- Determine oxygen demand based on influent CBOD and TKN
- Dissolved oxygen of 2.5 mg/L in first aeration passes to meet ammonia limit based on modeling
- No denitrification credit
- Summer conditions (worst case for O_2 transfer)
- Current and future conditions (increased flow, maintain same influent concentrations)

Aeration Demand

Condition	Current Average Annual	Max Treatment Capacity per Ditch	Max 30-Day Running Average	Future Average Annual	Future Max 30-Day Running Average
Influent Flow per Basin (mgd)	9.11	10.00	6.40	8.00	11.24
Influent CBOD5 (mg/L)	150	150	127	150	127
Influent TKN (mg/L)	45.9	45.9	38.0	45.9	38.0
Design Alpha Factor (αF) - Surface Aeration	0.85	0.85	0.85	0.85	0.85
Design Alpha Factor (αF) - Diffused Aeration	0.5	0.5	0.5	0.5	0.5
SOR per Ditch (lb O_2/day) - Surface Aeration	48,000	53,000	28,200	42,100	49,500
SOR per Ditch (lb O_2/day) - Diffused Aeration	81,600	90,000	47,900	71,900	84,000

Existing Aeration Capacity

Oxygen Supply	Existing SOR
Aerators Total Per Basin (lb O_2/d)	36,000
Diffusers Total per Basin (lb O_2/d)	9,000
Total per Basin (lb O_2/d)	45,000

- Max required 53,000 lb/d O_2 required (surface aeration)

Alternatives Analysis

Alternatives Evaluation – OPCC

Item	Description	OPCC
Alternative 1	New 200 HP Vertical Surface Aerators	**$2,940,000**
Alternative 2A	New 200 HP Blowers, Diffusers, and Mixers	$6,220,000
Alternative 2B	New 300 HP Blowers, Diffusers, and Mixers	$6,200,000
Alternative 3	New 200 HP Vertical Surface Aerators and Post Aeration Tank	**$4,620,000**
Alternative 4A	New 200 HP Blowers, Diffusers, Mixers, and Post Aeration Tank	$7,380,000
Alternative 4B	New 300 HP Blowers, Diffusers, Mixers, and Post Aeration Tank	$7,360,000

Alternatives Evaluation – LCCA

Alternative	Description	OPCC	20-Year Present Worth of Electrical Cost	20-Year Present Worth of Chemical Cost	20-Year Present Worth of Maintenance Cost	Total 20-Year Present Worth
Alternative 1	200 HP Aerators	$2,940,000	$3,230,000	$340,000	$180,000	**$6,350,000**
Alternative 2A	200 HP Blowers, Diffusers, and Mixers	$6,220,000	$3,150,000	$120,000	$520,000	$9,890,000
Alternative 2B	300 HP Blowers, Diffusers, and Mixers	$6,200,000	$3,080,000	$120,000	$480,000	$9,760,000
Alternative 3	200 HP Aerators with Post Aeration	$4,620,000	$2,950,000	$50,000	$180,000	**$7,750,000**
Alternative 4A	200 HP Blowers, Diffusers, Mixers, with Post Aeration	$7,380,000	$2,600,000	$50,000	$470,000	$10,450,000
Alternative 4B	300 HP Blowers, Diffusers, Mixers, with Post Aeration	$7,360,000	$2,550,000	$50,000	$430,000	$10,340,000

Recommendations

Conclusions

- Lowest construction and life cycle cost – Aerators with VFDs
- Many diffused air/mixer systems have been retrofitted in ODs
  - Few with SND/nutrient removal
- Replacement of surface aerators will have less impact on the plant operations, shorter construction period

Recommended Improvements

- New 200 HP surface aerators with VFDs for turndown capability
- Future post aeration tanks for optimization of biological nutrient removal (when more stringent limits are in effect)

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