Pilot-Scale Evaluation of Manganese Removal Treatment Approaches for a Surface Water Source in Coos Bay, OR

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COOS BAY • NORTH BEND WATER BOARD

AMERICAN WATERWORKS ASSOCIATION
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Presentation Topics

1. Background / Source Water Management
2. Conceptual Design Expansion Approach
3. Pilot Plant Study (PPS) Approach
4. PPS Key Outcomes and Results

Upper Pony Creek
Reservoir & Dam
Merritt Lake
Pony Creek
Treatment Plan

Source Water Management Approach:

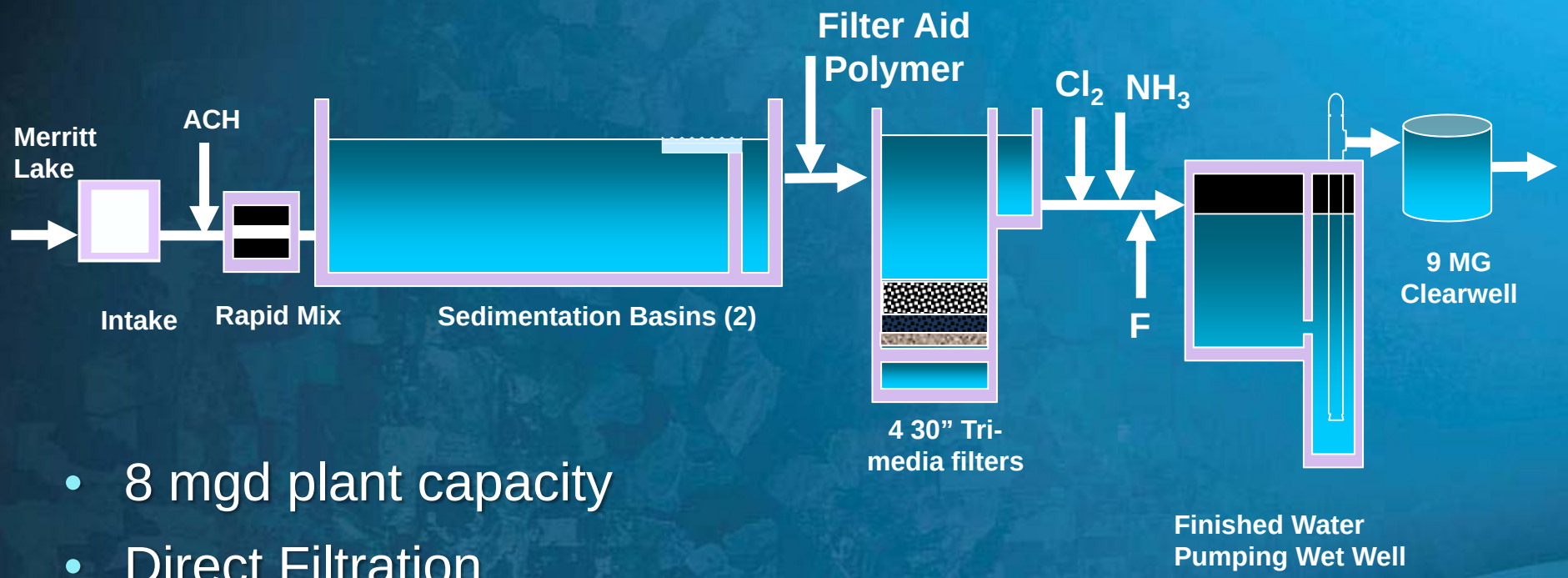
SolarBee® mixer installed in September ’09 at UPC Reservoir

30-in siphon pipe draws water from upper depth of UPC Reservoir to avoid Mn-laden water

Seasonal Raw Water Quality

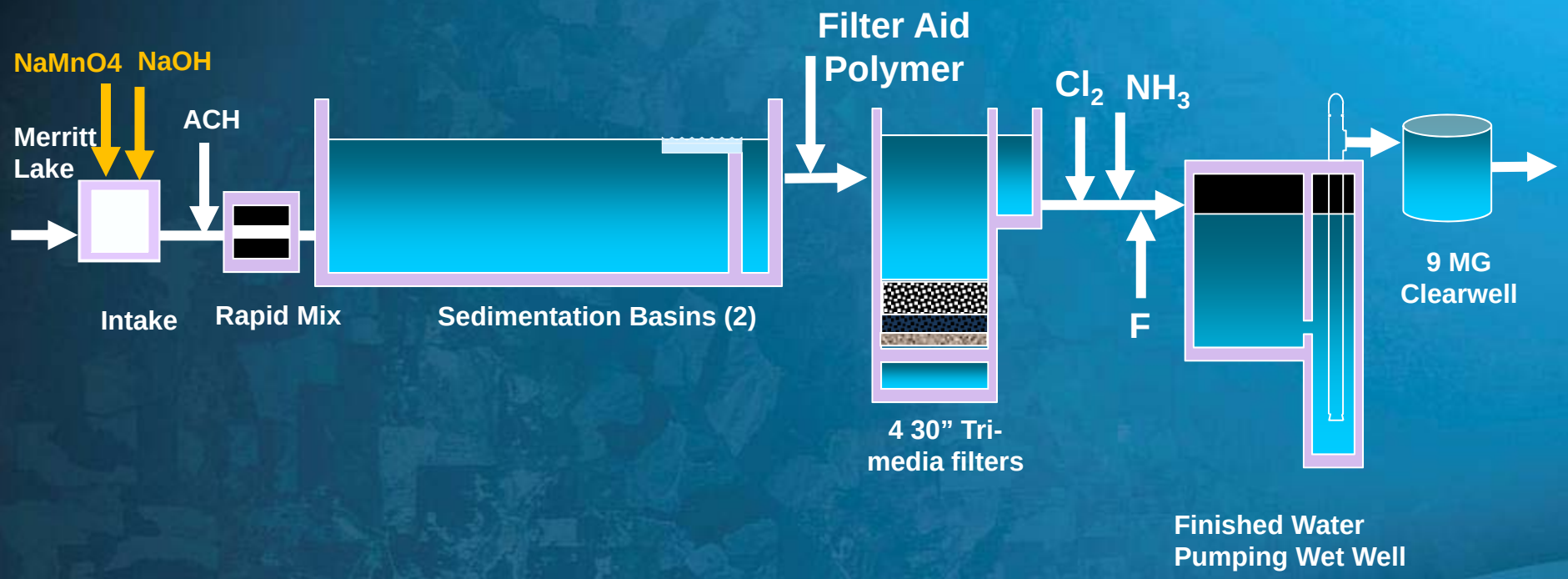
WQ Parameter	Winter Average	Summer Average
Turbidity (NTU)	1.6	2.3
Temperature (deg C)	13	19
pH	6.5	6.6
Alkalinity (mg/L-CaCO3)	7.3	8.1
Iron (mg/L)	0.6	0.8
Manganese (mg/L)	0.03	0.07
TOC (mg/L)	2 - 5	4 - 10
Color (CU)	60	75

Existing Treatment Process



- 8 mgd plant capacity
- Direct Filtration
- Operated in "batch" at rated flowrate
- Short filter runs (8-12 hr filter runs = ~2-4,000 gal/sf UFRV)
- No ability to remove manganese
- Chloramines are used for *Giardia* inactivation credit (1-log)

Recommended Process Improvements



- NaOH and NaMnO4 added for pre-oxidation of Mn during summer peak events

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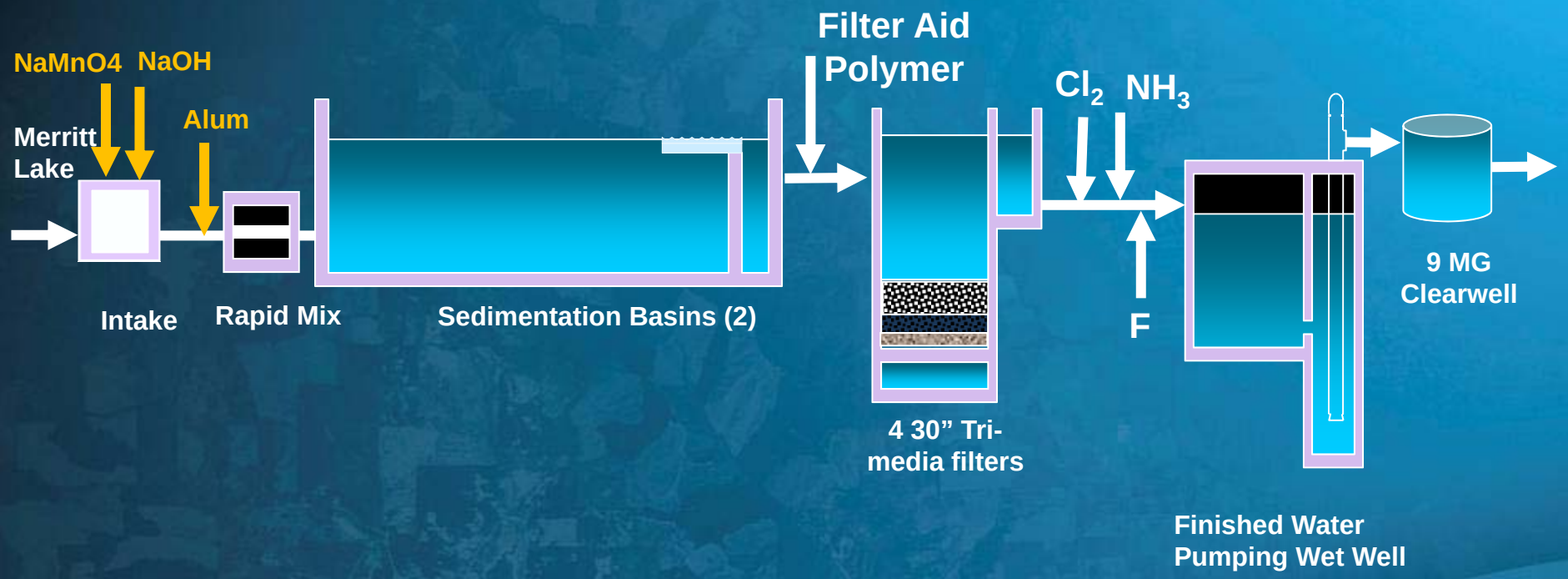
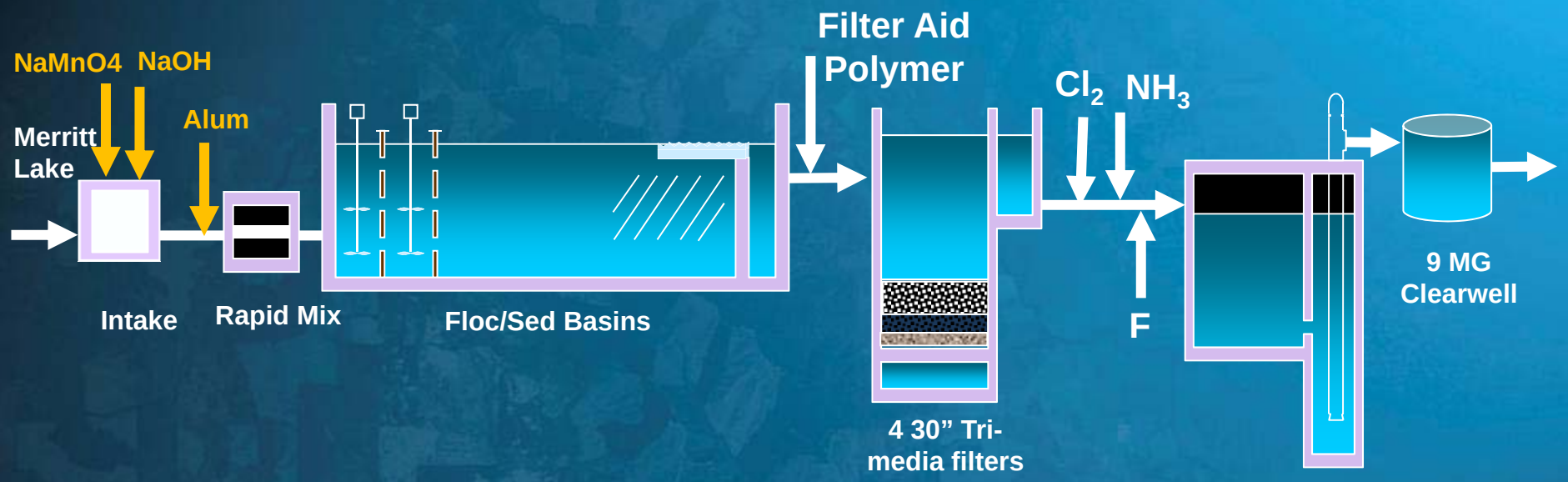


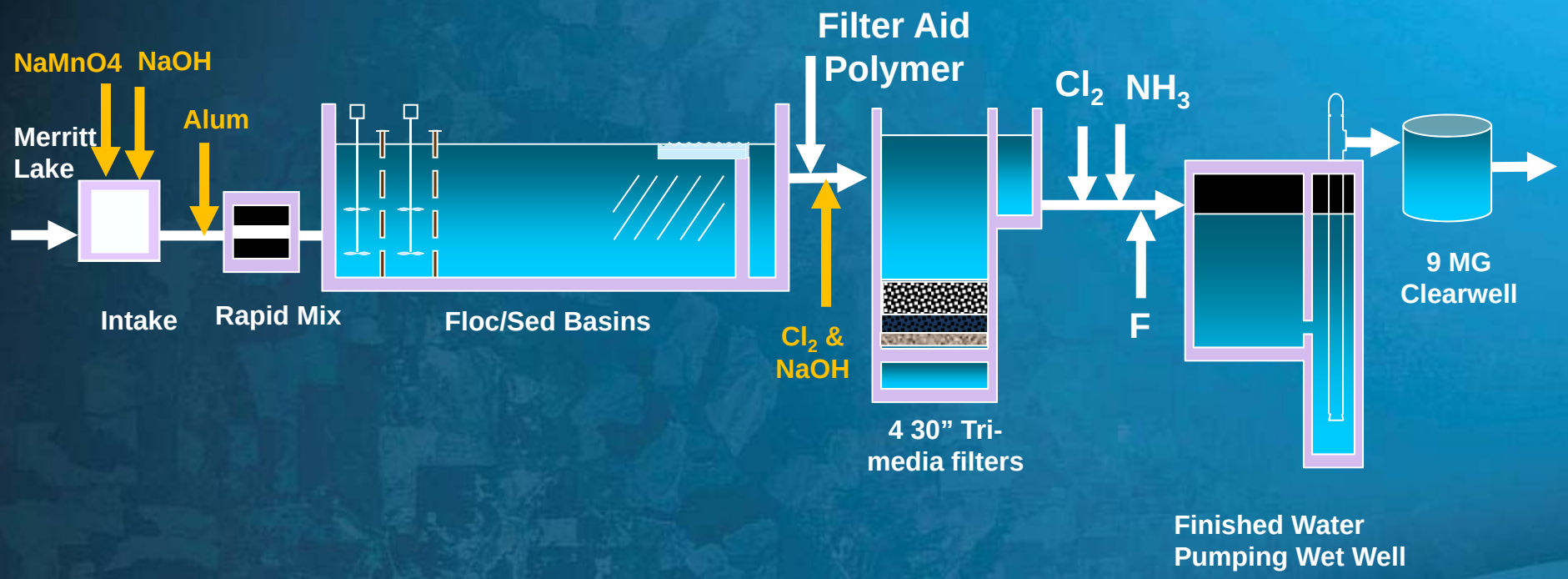
- NaOH and NaMnO4 added for pre-oxidation of Mn during summer peak events
- Coagulant changed from ACH to alum

Recommended Process Improvements



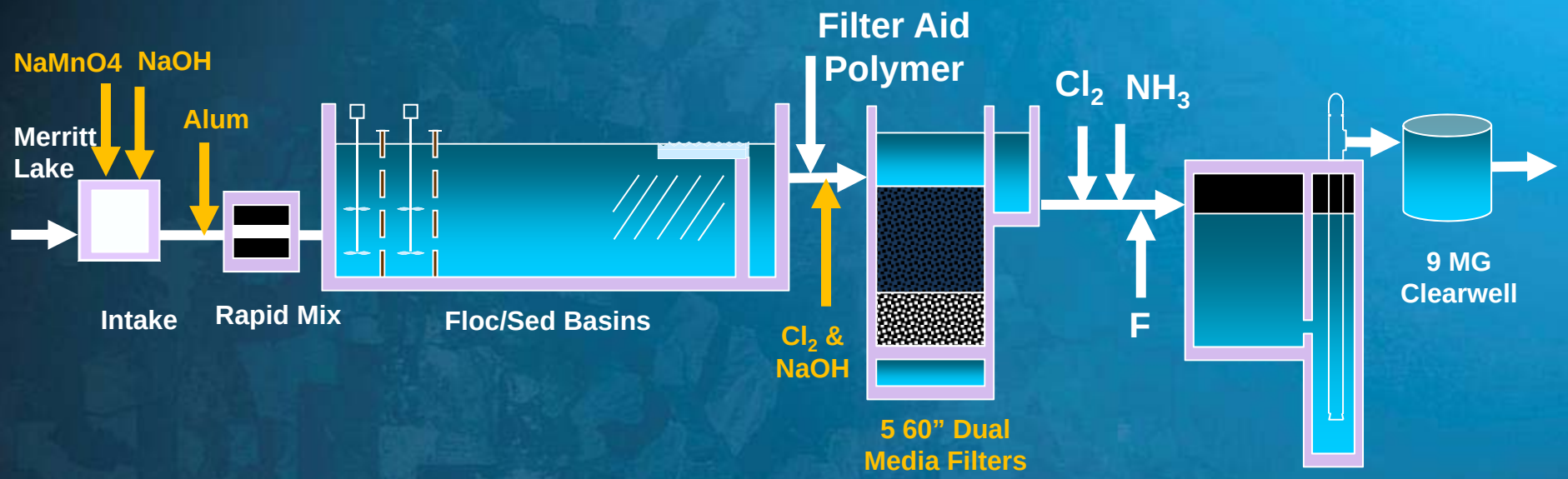
- Basins retrofitted with flocculation and plate settlers to improve pretreatment
- Increase capacity from 4 mgd to 6 mgd (each basin)

Recommended Process Improvements



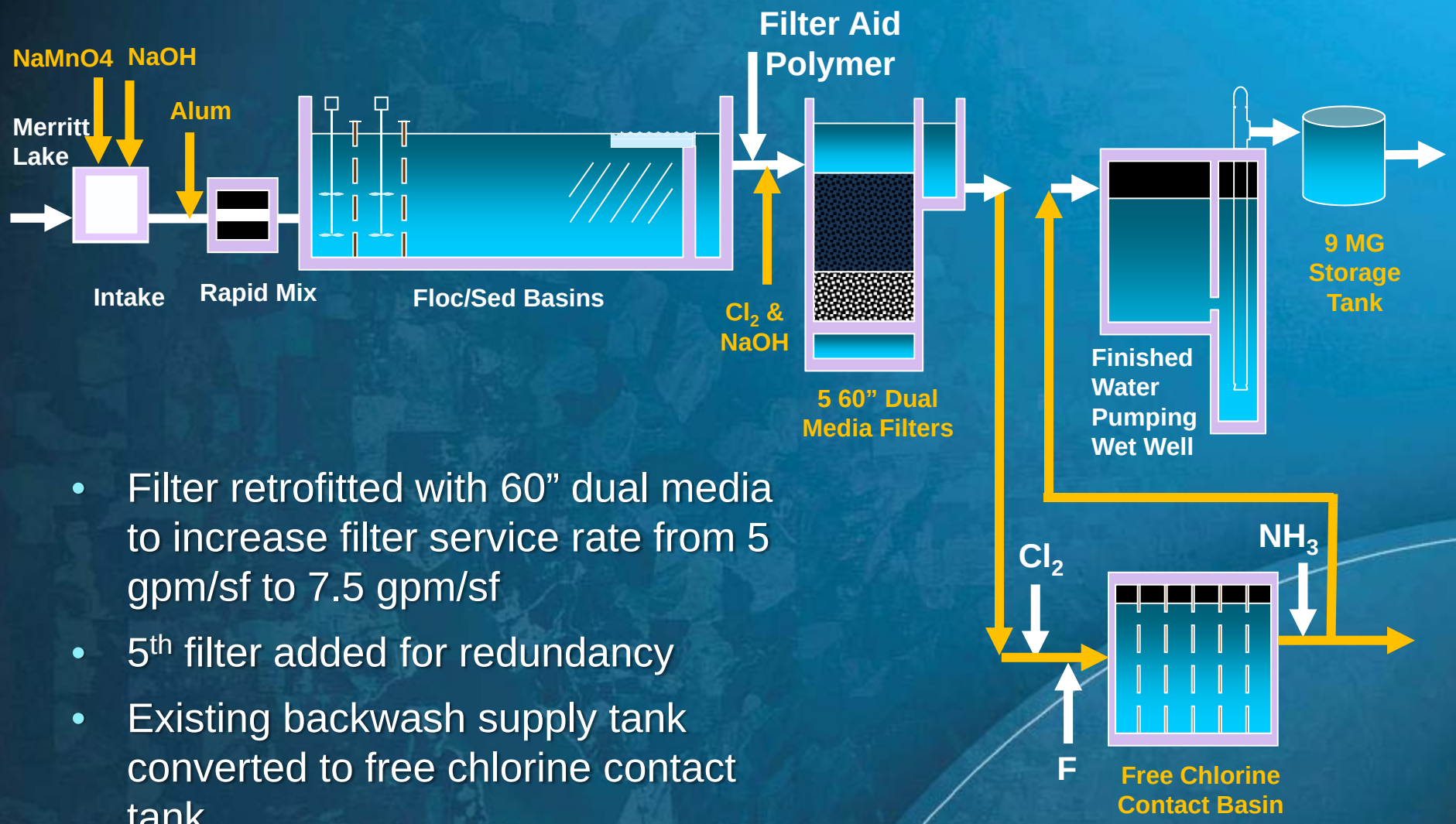
- Chlorine and NaOH feed points added to filter influent for catalytic oxidation/adsorption of Mn

Recommended Process Improvements



- Filter retrofitted with 60" dual media to increase filter service rate from 5 gpm/sf to 7.5 gpm/sf
- 5th filter added for redundancy

Recommended Process Improvements



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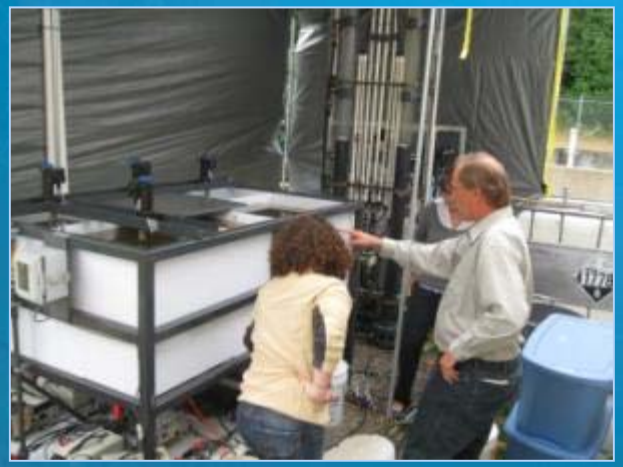
- 5th filter added for redundancy
- Existing backwash supply tank converted to free chlorine contact tank

Pilot Plant Study Objectives

- Demonstrate conversion of direct filtration to conventional; benefit of pre-treatment
- Evaluate free chlorine contact time and pre-filter chlorine addition on DBP formation
- Evaluate removal of Mn employing pre-oxidation and catalytic adsorption
- Demonstrate filter performance: increased filter service rate and UFRV > 10,000 gal/sf
- Evaluate backwash water (BWW) recycle on process performance, Mn fate



Proposed Water Quality and Treatment Goals

Parameter	Location	Goal	Condition	Hist'l Finished Water Quality (2006 - 08)	Comments
Solids/Metals					
Turbidity	Settled Water	≤ 2.0 ntu	95% of time		Only if conventional process
	Settled Water	≤ 5.0 ntu	99% of time		Only if conventional process
	IFE	≤ 0.15 ntu	95% of time		LT2 microbial toolbox credit
	CFE	≤ 0.15 ntu	99% of time		LT2 microbial toolbox credit
Total Iron	Entry Point	≤ 0.05 mg/L		<0.11 mg/L (95% of time)	EPA SMCL: 0.3 mg/L
Total Manganese	Entry Point	≤ 0.01 mg/L		<0.03 mg/L (95% of time)	EPA SMCL: 0.05 mg/L
Total Aluminum	Entry Point	≤ 0.05 mg/L			EPA SMCL: 0.05 - 0.2 mg/L
Aesthetics					
Apparent Color	Entry Point	≤ 3.0 CU		<19 CU (95% of time)	
Taste and Odor	Entry Point	≤ 2 TON			
Organics/DBPs					
TOC	Plant Removal	≥ 50%	95% of time		
	Entry Point	≤ 3.0 mg/L	95% of time		
TTHM	Dist. System	≤ 64 µg/L	7-day SDS		80% of MCL
HAA5	Dist. System	≤ 48 µg/L	7-day SDS		80% of MCL
Bromate					Only if ozone applied (EPA MCL: 0.010 mg/L Bromate)
Chlorite					Only if chlorine dioxide applied (EPA MCL: 1.0 mg/L Chlorite)
Disinfection/Residuals					
Chloramine Residual	Entry Point	≤ 3.0 mg/L Cl2	95% of time	<4.1 mg/L (95% of time)	EPA MRDL: 4 mg/L
	Entry Point	≤ 4.0 mg/L Cl2	99% of time	<4.4 mg/L (99% of time)	
	Dist. System	≥ 0.5 mg/L Cl2	95% of time		
	Dist. System	≥ 0.2 mg/L Cl2	99% of time		
Free Ammonia Conc.	Entry Point	≤ 0.1 mg/L N		<0.2 mg/L (95% of time)	
Nitrite+Nitrate Conc.	Dist. System	≤ 0.8 mg/L N			80% of MCL
Corrosion Control					
pH	Entry Point	8.5 to 9.0		>7.4 (95% of time)	
Alkalinity	Entry Point	30 to 50 mg/L		>12 mg/L (95% of time)	

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Total Alumin					5 - 0.2 mg/L
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TOC	Plant Removal	≥ 50%	
	Entry Point	≤ 3.0 mg/L	
TTHM	Dist. System	≤ 64 µg/L	
HAA5	Dist. System	≤ 48 µg/L	

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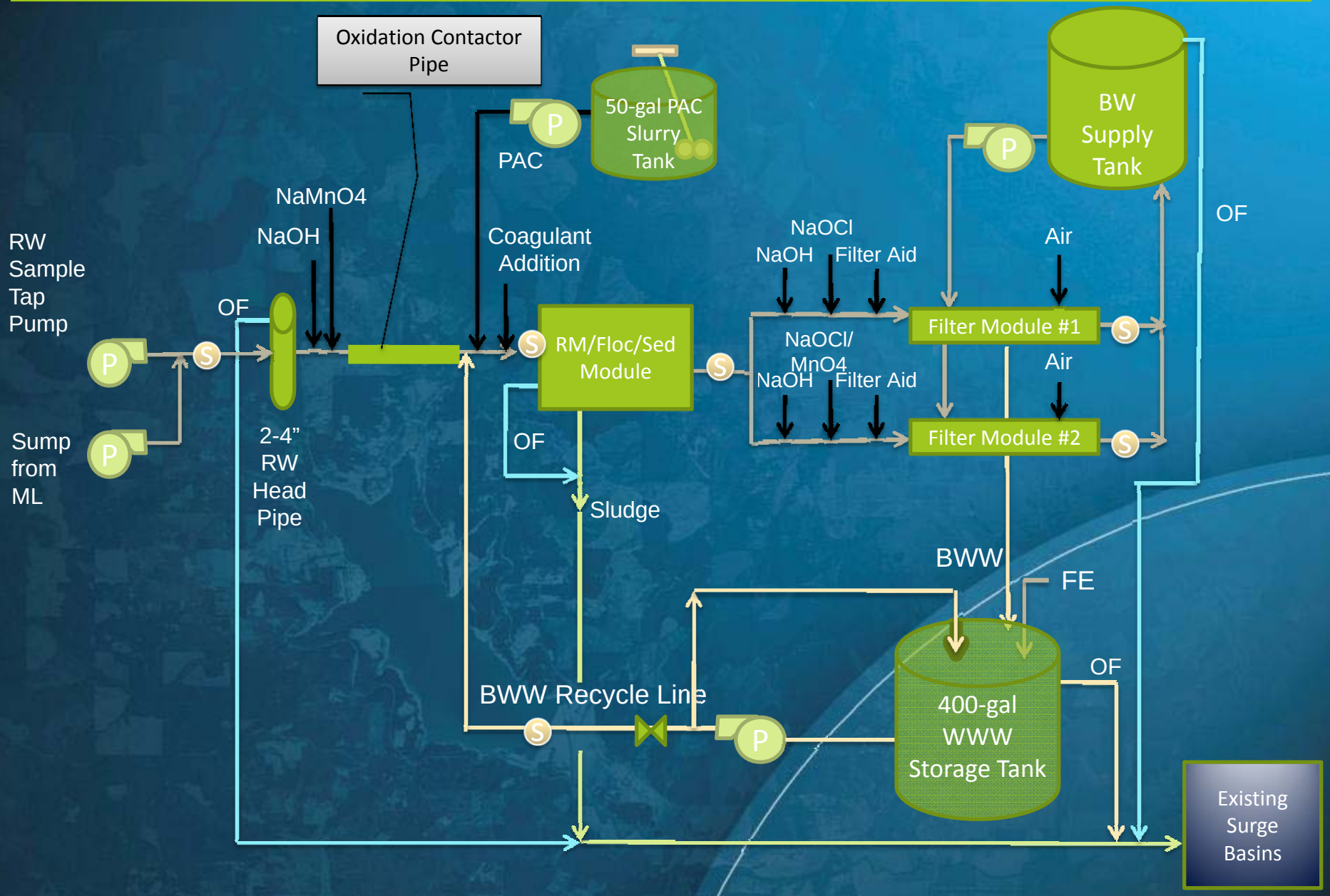
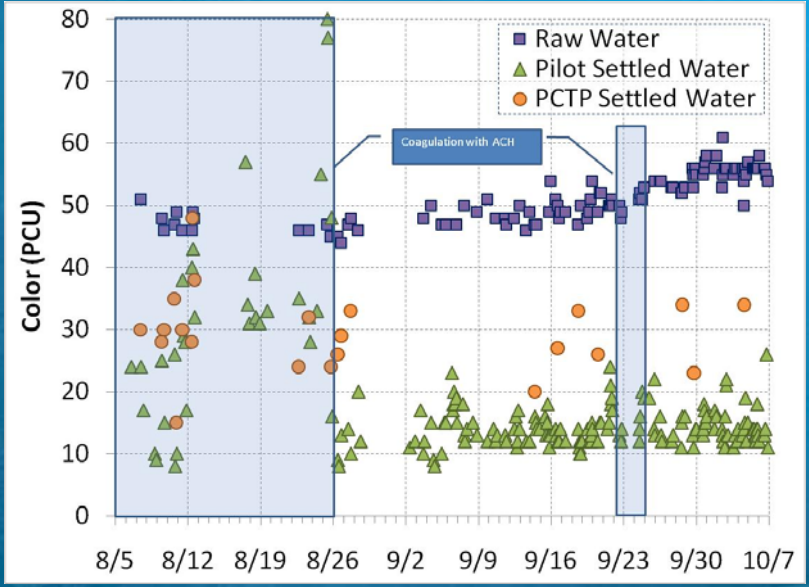
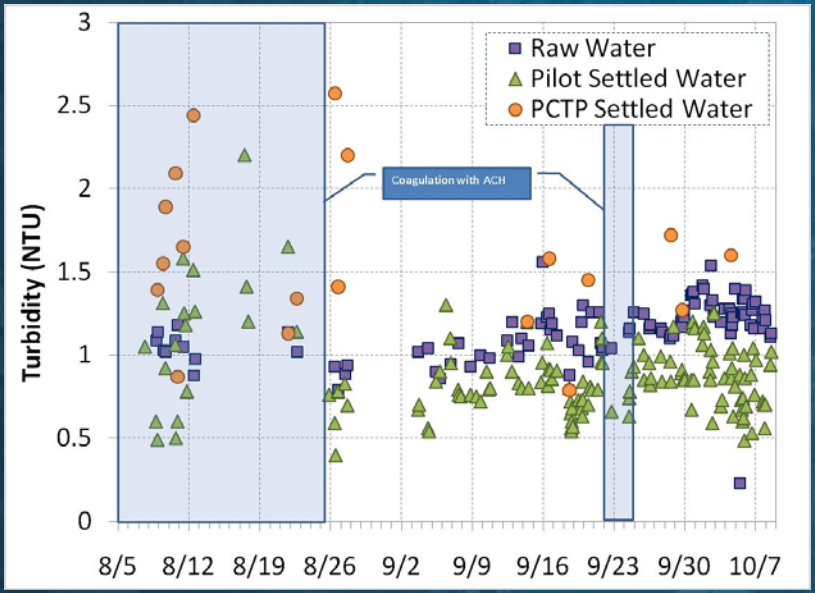
Pilot Plant Process Schematic

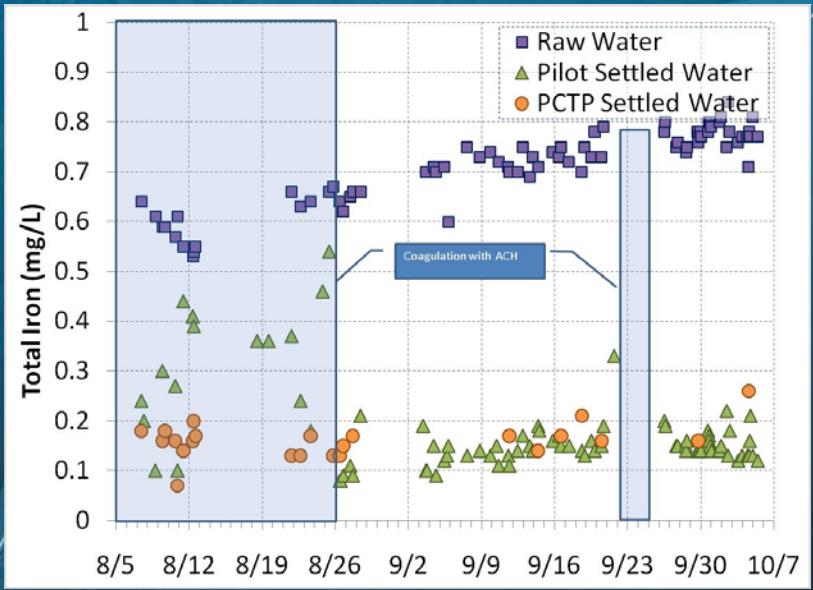


Results: Demonstration of Pre-treatment/ Filter Performance

- Coagulant was switched to alum because of improved floc formation, settling performance, and effect on filter performance

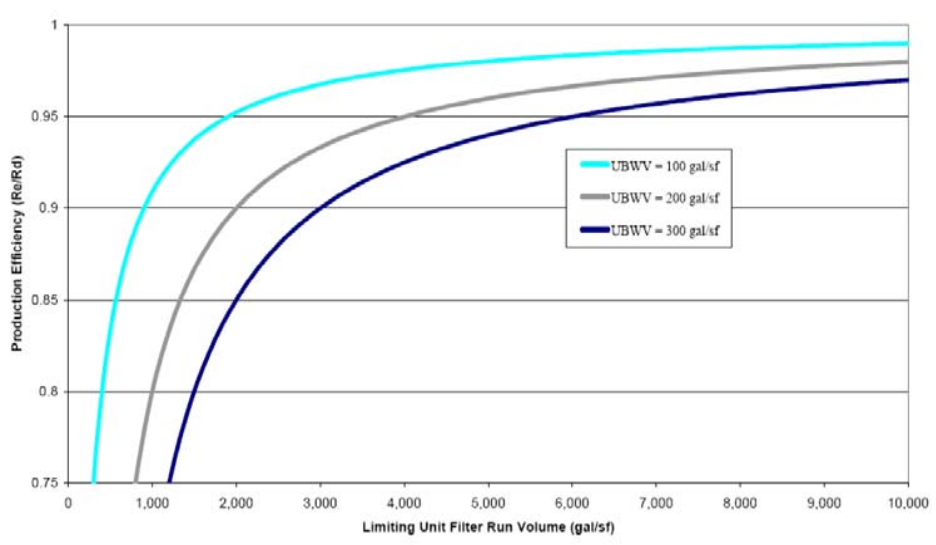






Results: Demonstration of Pre-treatment/ Filter Performance

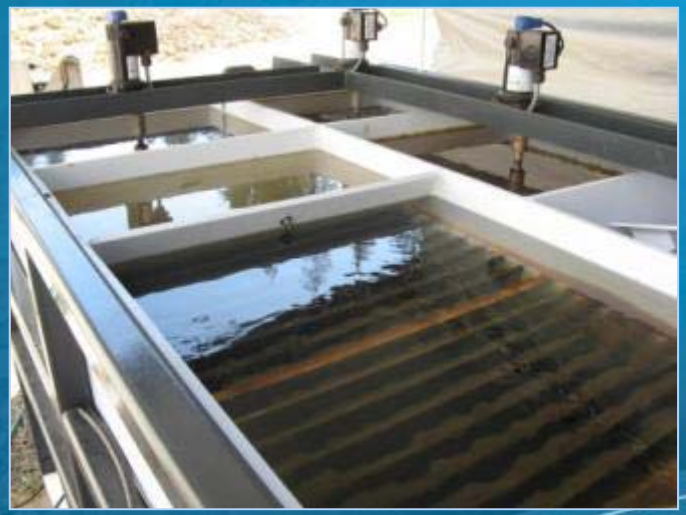
- Coagulant was switched to alum because of improved floc formation, settling performance, and effect on filter performance
- Filter run duration increased to > 24 hours @ 7.5 gpm/sf, UFRV > 10,000 gal/sf



Coagulant Type	Filter Service Rate (gpm/sf)	Media Configuration	Maximum UFRV (gal/sf)	Filter Run Duration (hours)	Terminal Headloss (inches)	Terminal Turbidity (ntu)
ACH	6.0	Fine	1,500	4	33	0.122
		Coarse	4,140	11	28	0.100
	7.5	Fine	4,125	9	74	0.105
		Coarse	4,725	11	68	0.103
Alum	6.0	Fine	13,380	37	74	0.102
		Coarse	9,360	26	40	0.117
	7.5	Fine	11,550	26	117	0.014
		Coarse	13,275	29	89	0.100

Results: Demonstration of Pre-treatment/ Filter Performance

- Coagulant was switched to alum because of improved floc formation, settling performance, and effect on filter performance
- Filter run duration increased to > 24 hours @ 7.5 gpm/sf, UFRV > 10,000 gal/sf
- TOC removal consistently > 50%
- Coagulation pH maintained ~ 5.8 for optimal DBP precursor removal



Baseline Mn Treatment Strategy:
Evaluation of Catalytic Mn Adsorption using Pre-filter Chlorine Addition

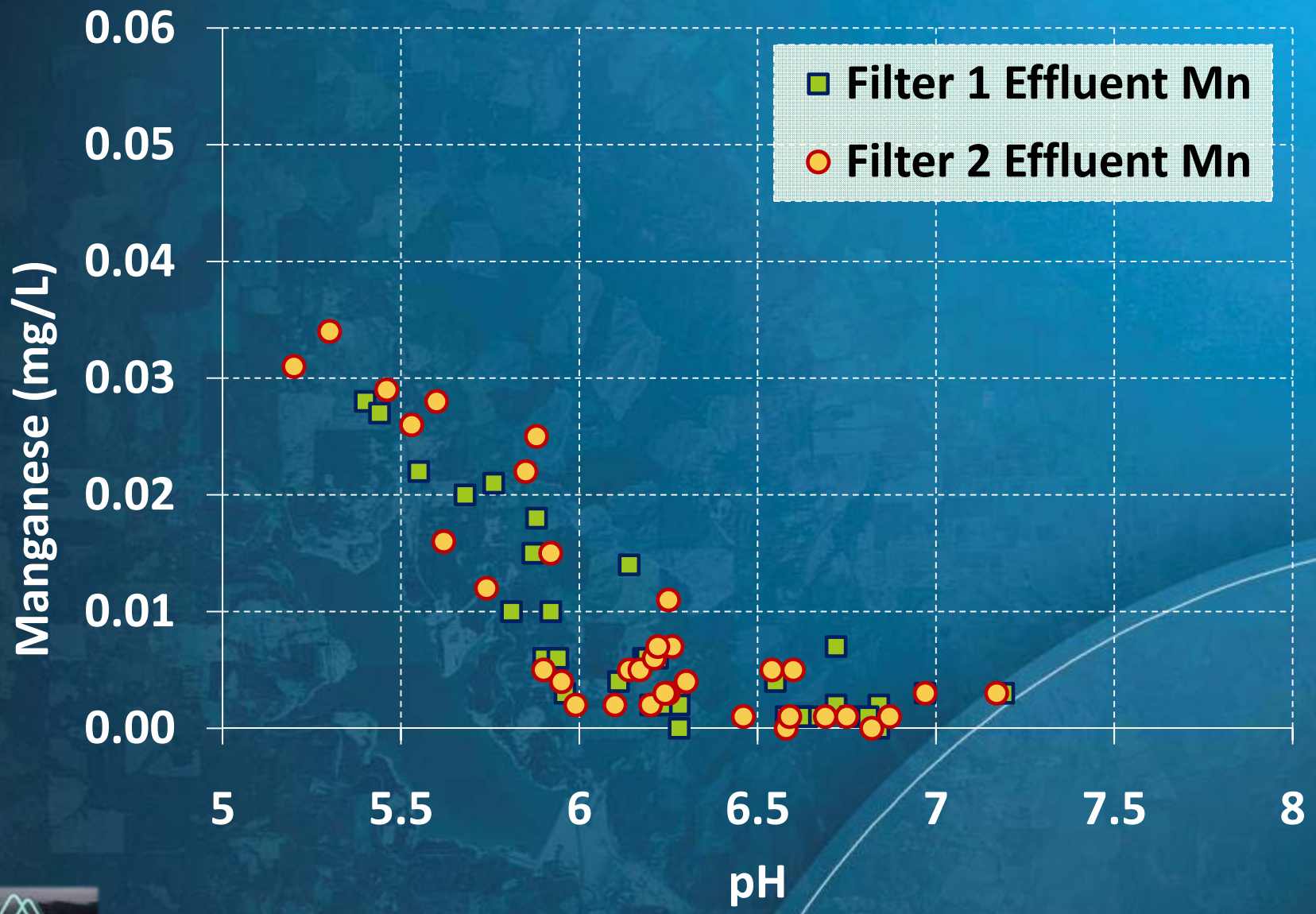
- Overview of pre-filter chlorine addition for Mn removal
- Effect of pH on Mn adsorption
- Effect of chlorine dose / filter effluent chlorine residual
- Evaluation of DBP production

Results: Evaluation of Catalytic Mn Adsorption via pre-filter chlorine addition

- Filter media was soaked in a high strength sodium permanganate solution to facilitate development of MnO_x coating
- Mn removal via pre-filter chlorine addition was not effective until after "seasoning" procedure water performed
- Following "seasoning," Mn removal instantly effective
- Requires continuous pre-filter chlorine addition to maintain MnOx coating
- Affected by filtration pH and chlorine residual

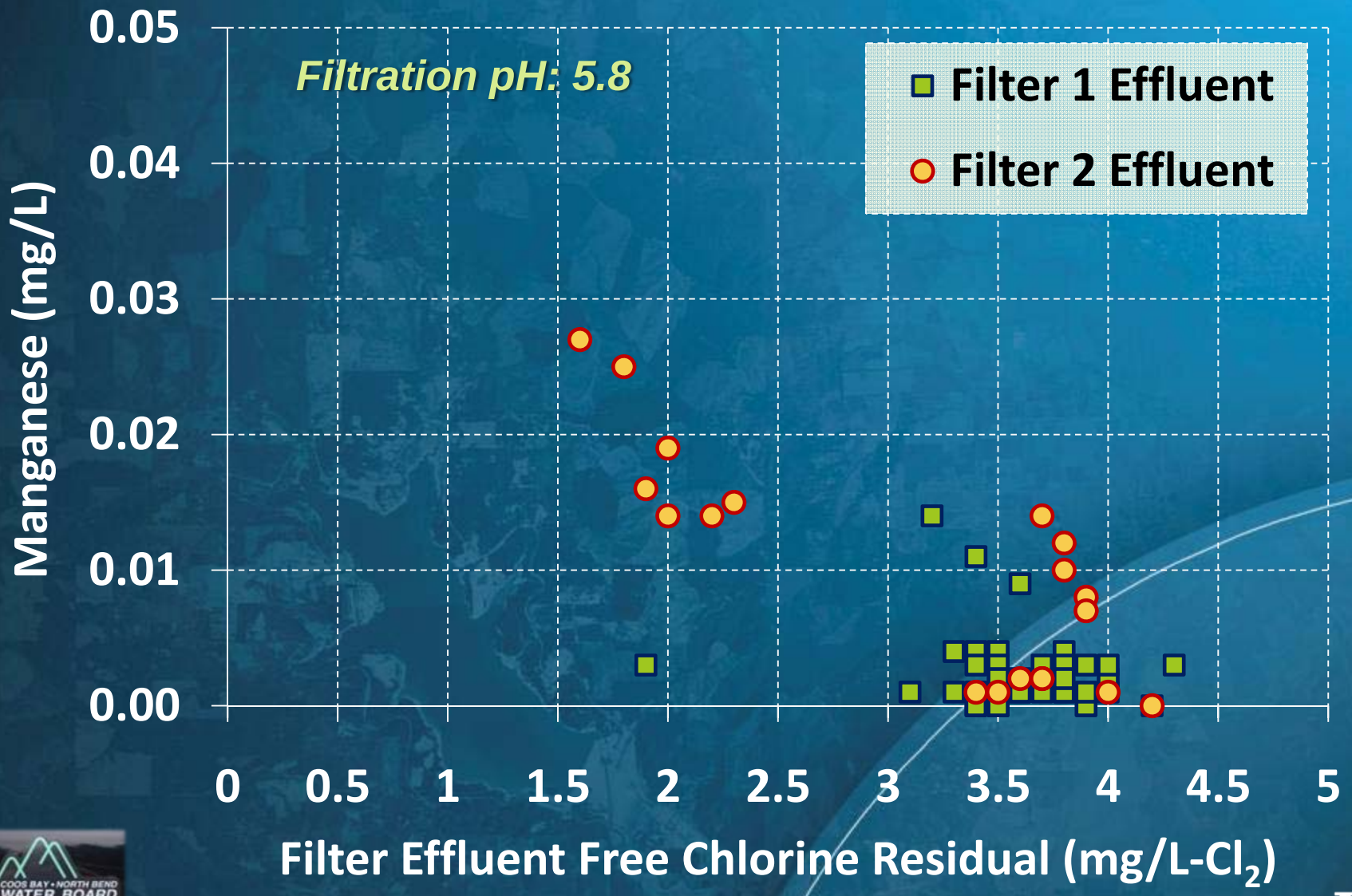
Filters are "seasoned" with 100 mg/L NaMnO4 to "jump start" MnO_x coating and Mn adsorption

Effect of pH on Catalytic Mn Removal



Catalytic Mn removal highly effective at pH as low as 5.8

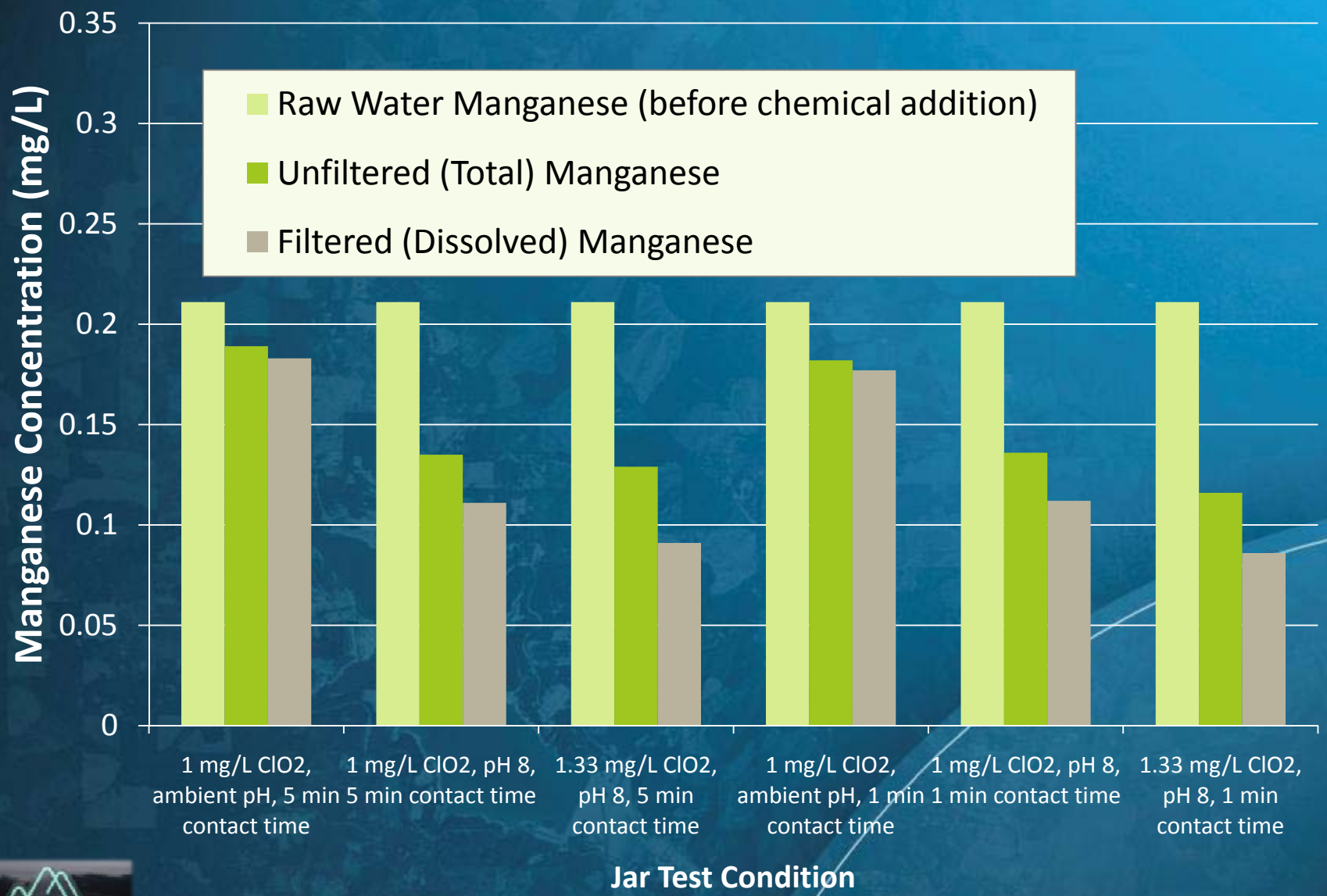
Effect of Filter Effluent Chlorine Concentration on Catalytic Mn Removal



Peak Mn Treatment Strategy:
Evaluation of Pre-oxidation Alternatives in Bench Testing

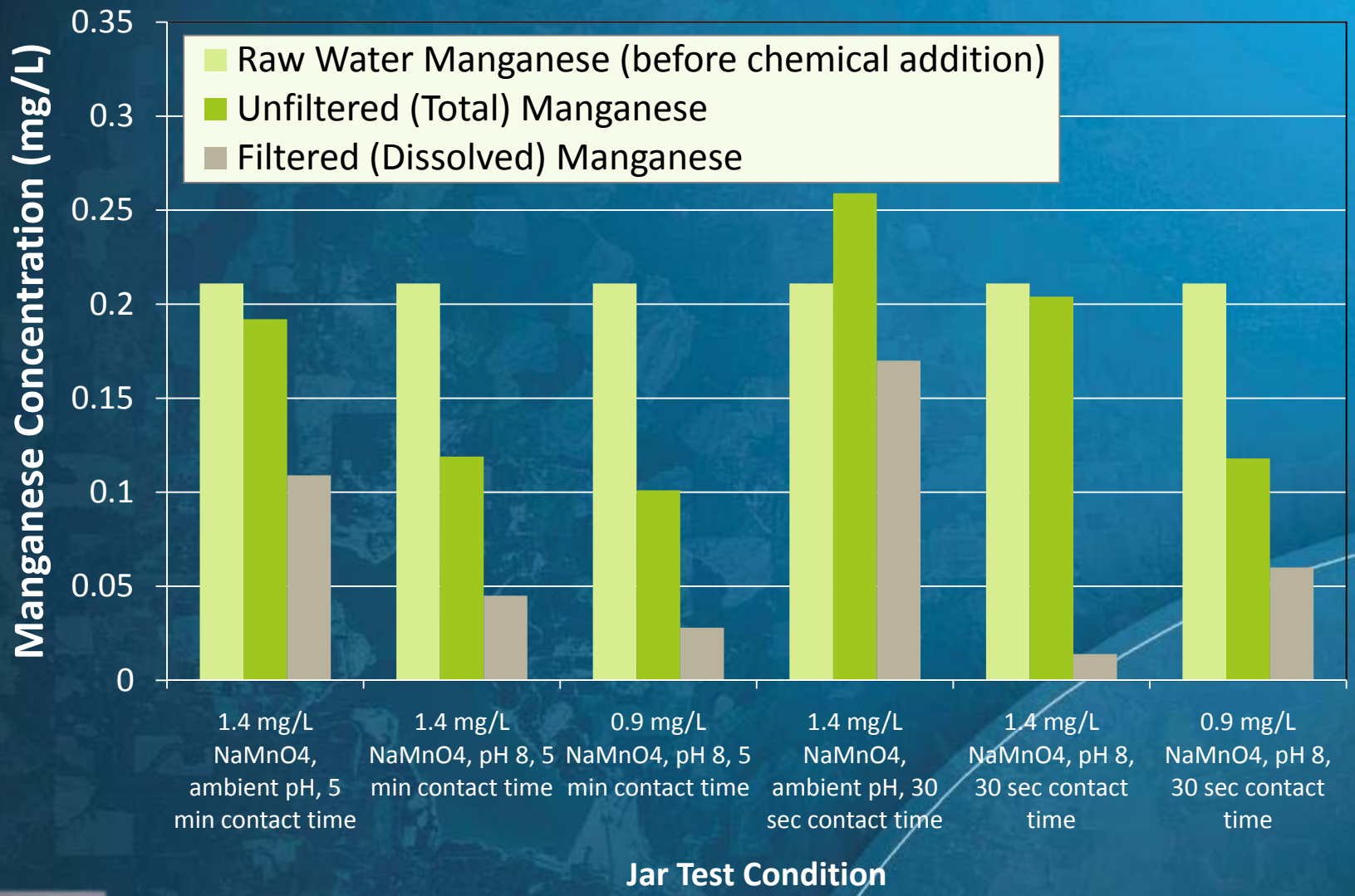
- Comparison of chlorine dioxide (ClO_2) and Sodium Permanganate ($NaMnO_4$) pre-oxidants
- Effect of oxidant contact time before coagulant addition
- Effect of pH (ambient vs. upward adjustment)

Comparison of $NaMnO_4$ and ClO_2 Pre-oxidation



Higher chlorine dioxide dose needed to oxidize Mn

Comparison of $NaMnO_4$ and ClO_2 Pre-oxidation



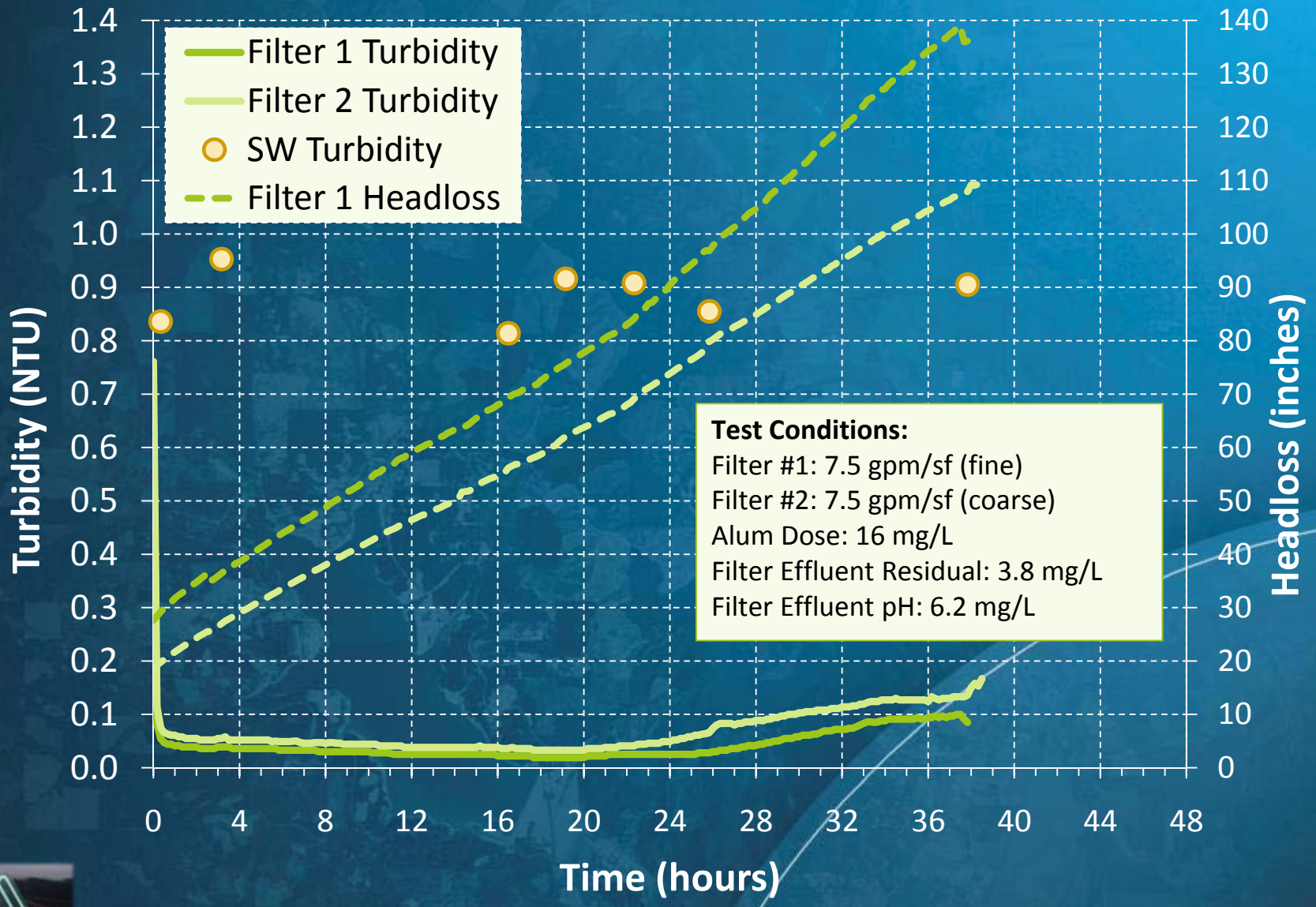
NaMnO4 highly effective at RW Mn > 1 mg/L and at contact time of 30 seconds when pH adjusted

Conclusions

- Switch back to alum needed to meet pre-treatment and filtration performance objectives
- Baseline Mn treatment strategy (pre-filter chlorine addition) highly effective; though for pH, chlorine dose, and DBP formation must be considered
- Sodium permanganate selected for pre-oxidation when catalytic treatment process overwhelmed; pH adjustment needed
- Clarification of BWW not required to guarantee treatment performance as long as BWW is chlorinated and maintained above pH 7

Acknowledgements

- Coos Bay-North Bend Water Board staff
- MWH ARD
- Al Vetrovs, Tom Visosky, Andy Hill, Yujung Chang
- Dr. William Knocke (Virginia Tech)

Extra slides

Results: Filter Run Results