Optimization Programs for Enhanced Drinking Water Quality

West Fargo, ND

April 22, 2025

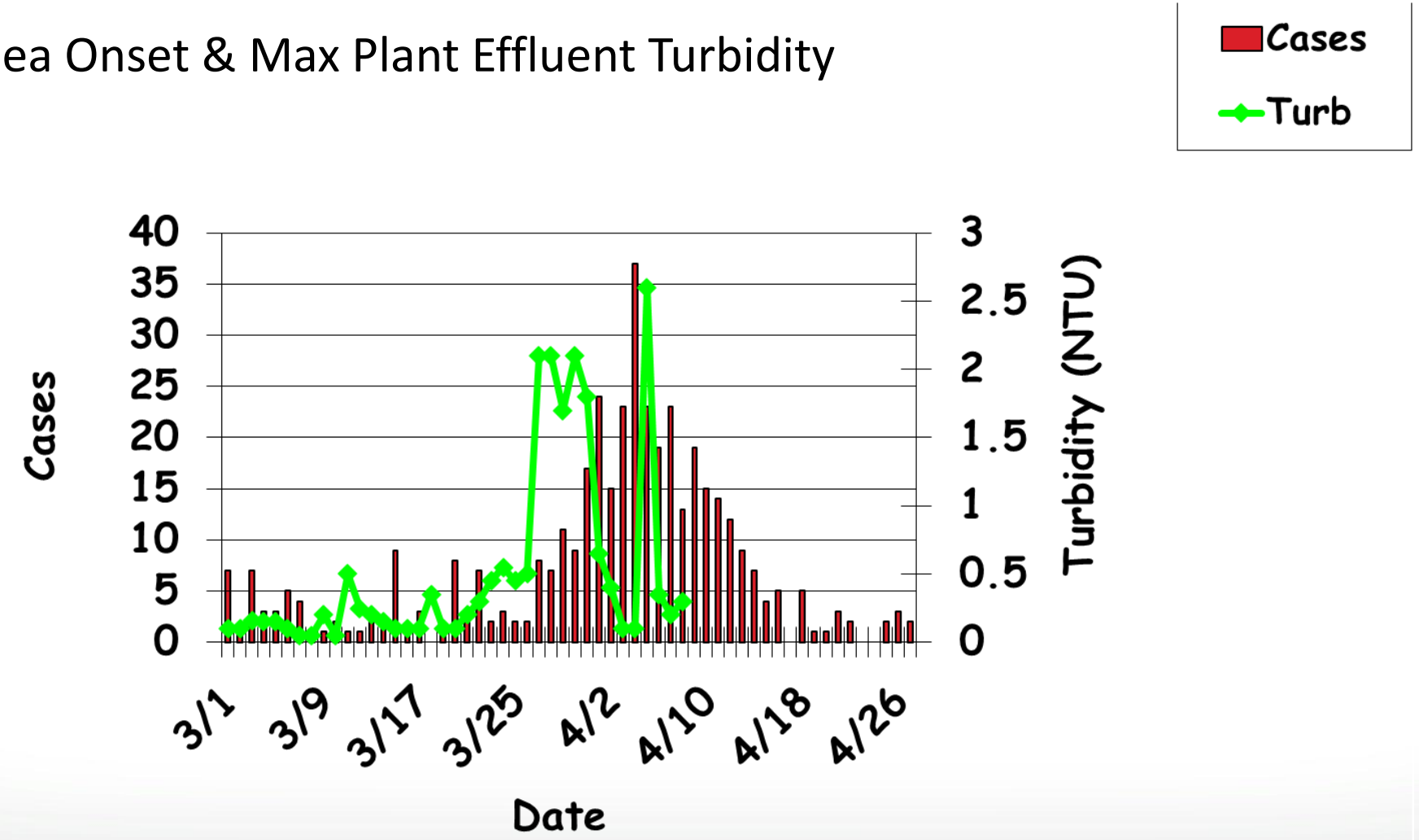
Agenda

- Overview of two established national drinking water optimization programs
  - Area-Wide Optimization Program (AWOP)
  - Partnership for Safe Water (PSW)
- Minnesota DOH experiences: Comprehensive Performance Evaluations
- Workshop introduction: Turbidity data interpretation and data integrity
- Tabletop exercise: Turbidity data evaluation and interpretation

PROCESS APPLICATIONS, INC.

1993 Milwaukee Outbreak

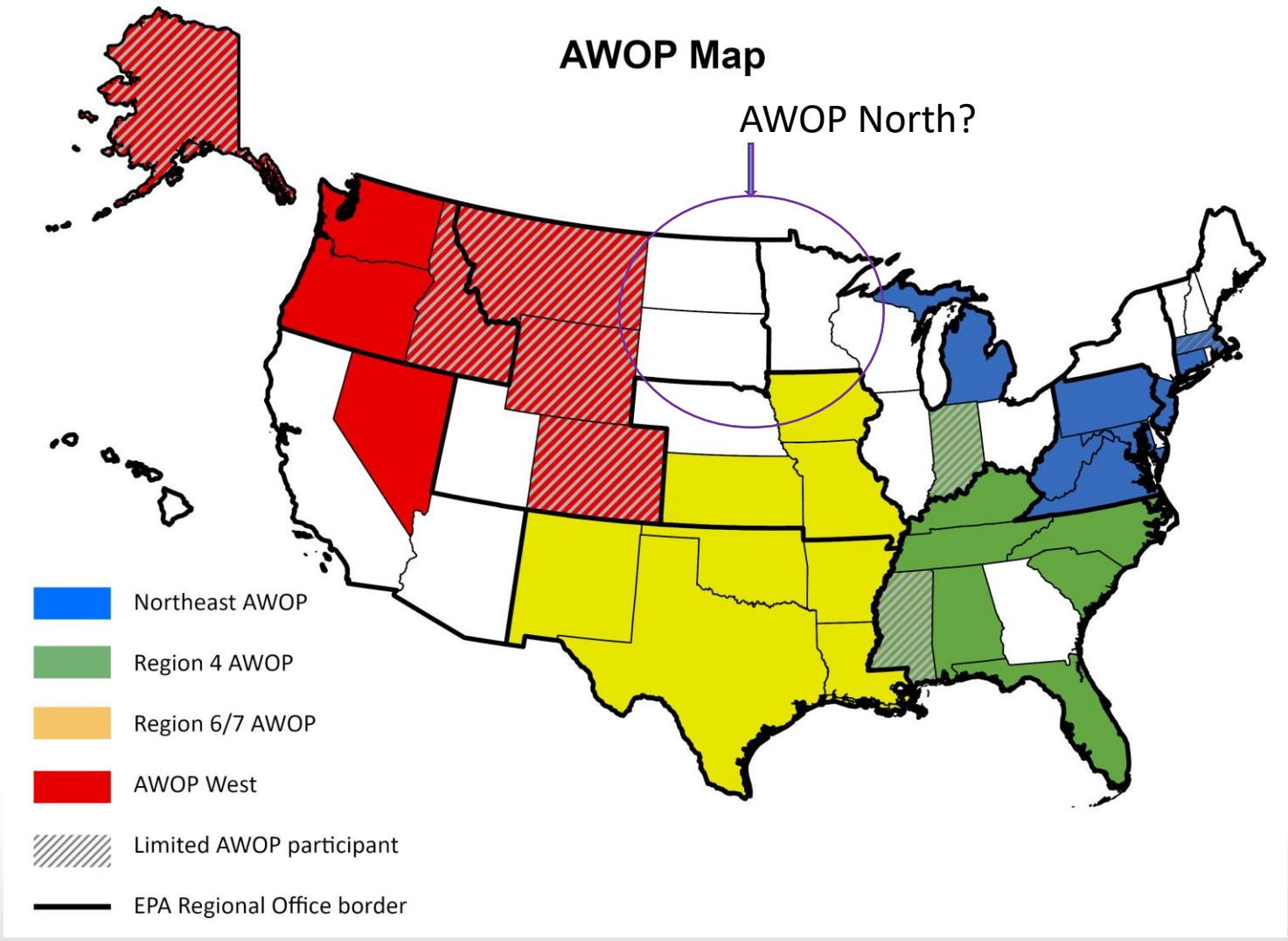
Diarrhea Onset & Max Plant Effluent Turbidity



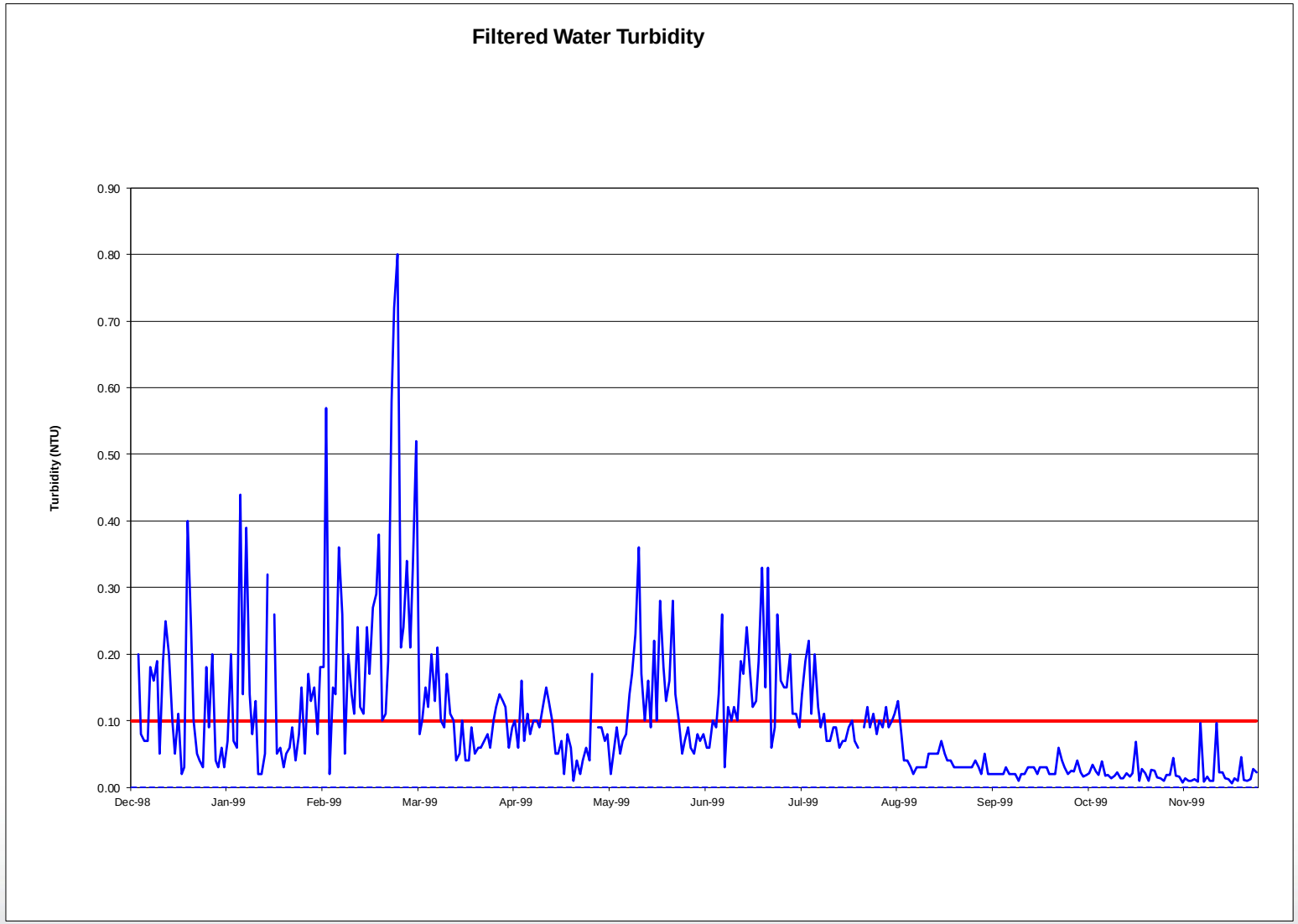
AWOP

The **Area-Wide Optimization Program**, referred to as **AWOP**, was developed utilizing the foundation of the EPA Composite Correction Program (CCP), an optimization program that was developed for drinking water treatment plants in the 1980s through a pilot project with the State of Montana drinking water program and Process Applications, Inc.

AWOP Map


AWOP Map
AWOP North?
Northeast AWOP
Region 4 AWOP
Region 6/7 AWOP
AWOP West
Limited AWOP participant
EPA Regional Office border

Ultimate Goal of AWOP



PROCESS APPLICATIONS, INC.

Partnership for Safe Water

American Water Works Association

EPA

Water Research Foundation

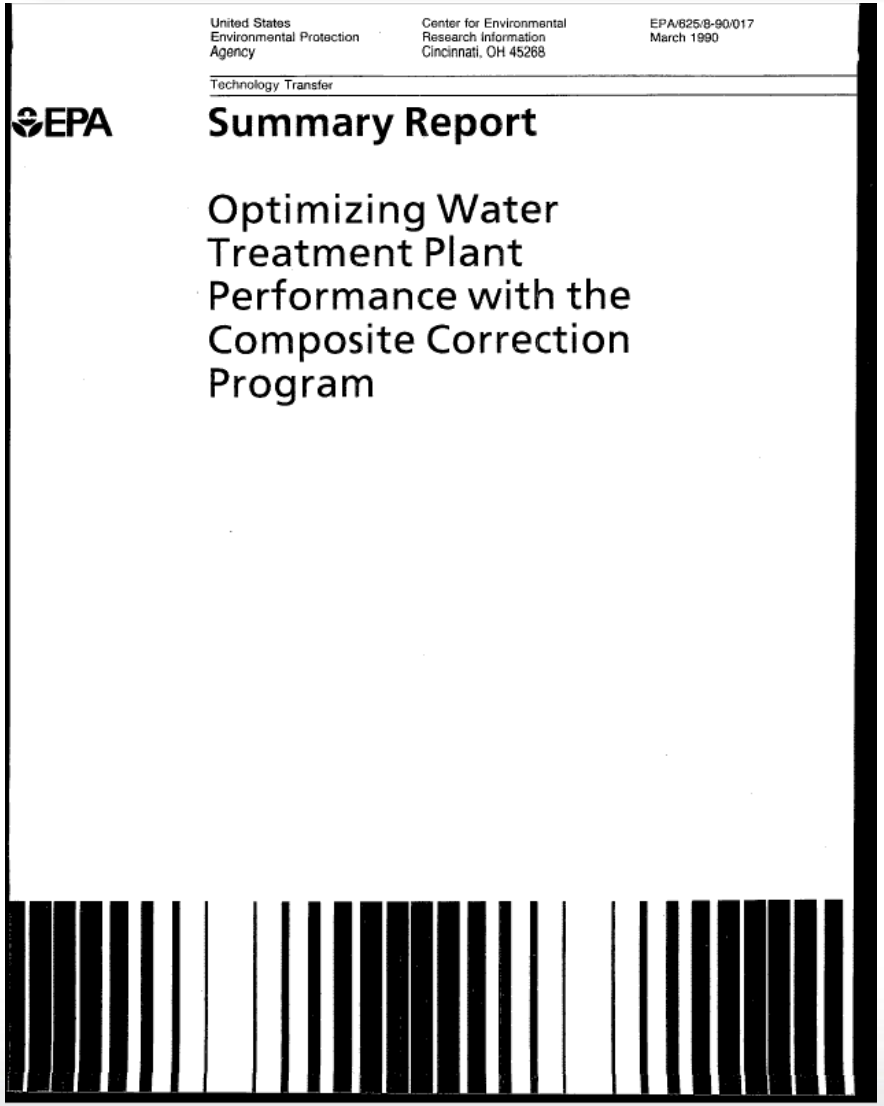
ASDWA
Association of State Drinking Water Administrators

NAWC
National Association of Water Companies

Association of Metropolitan Water Agencies

Composition Correction Program

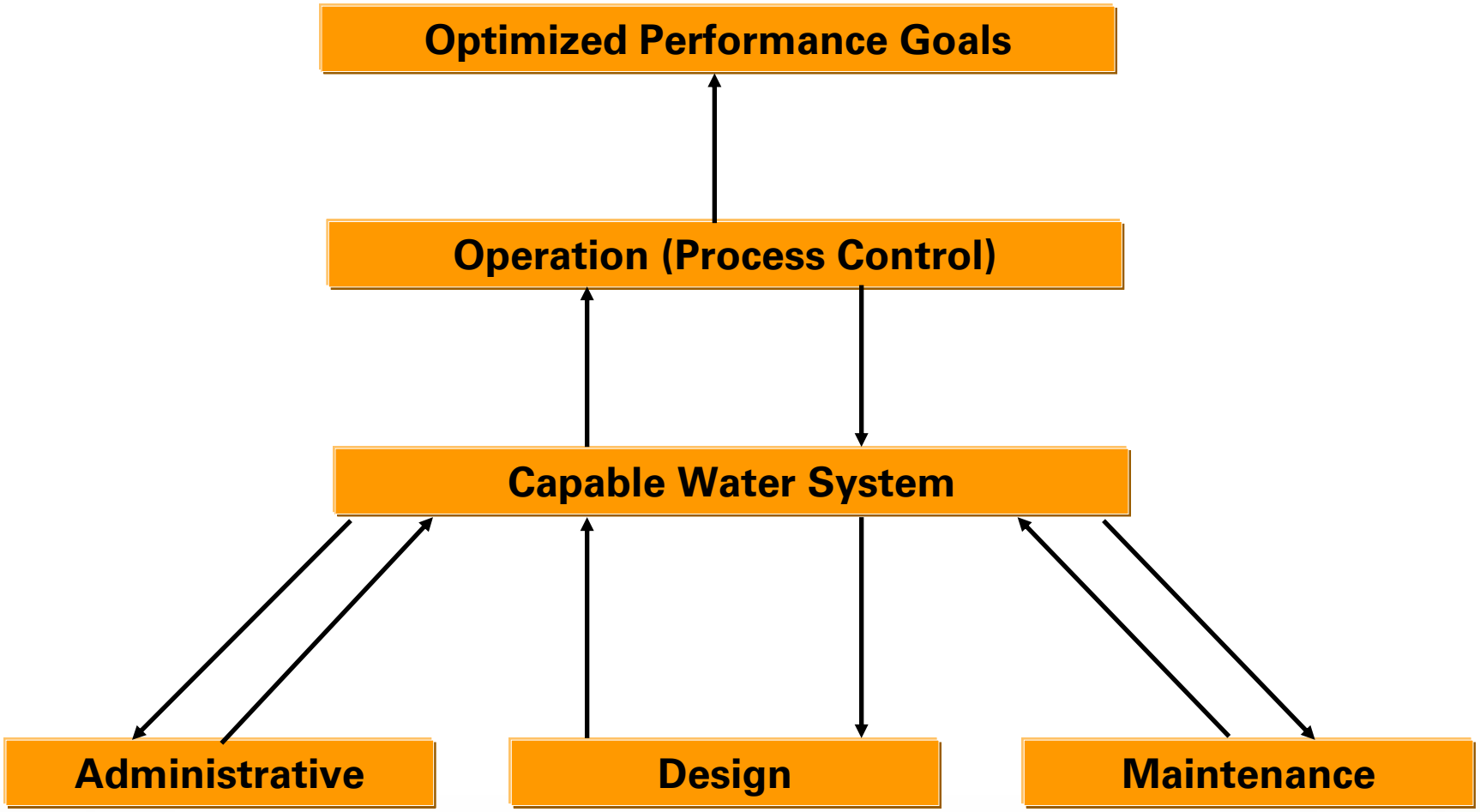
Drinking Water Treatment optimization was developed and documented in 1990.



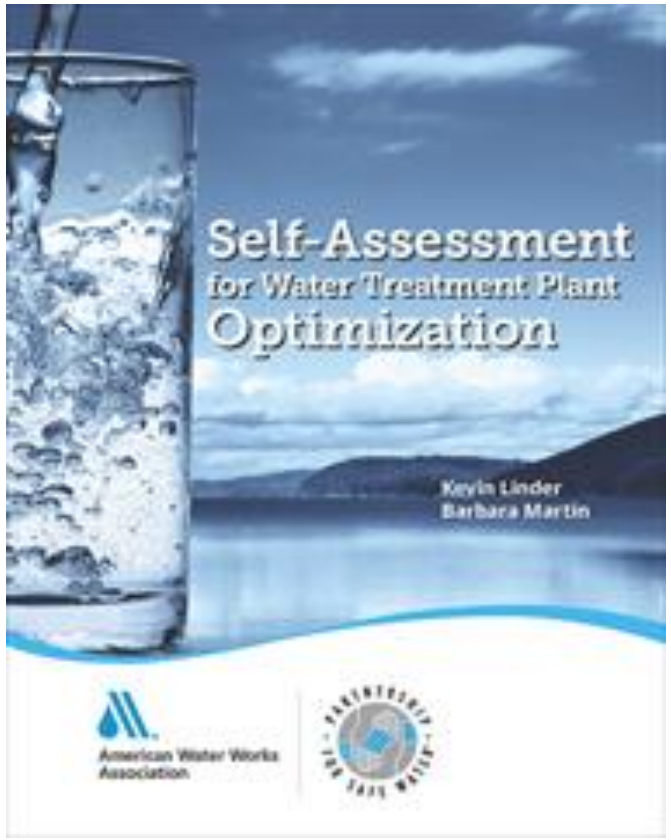
Composite Correction Program

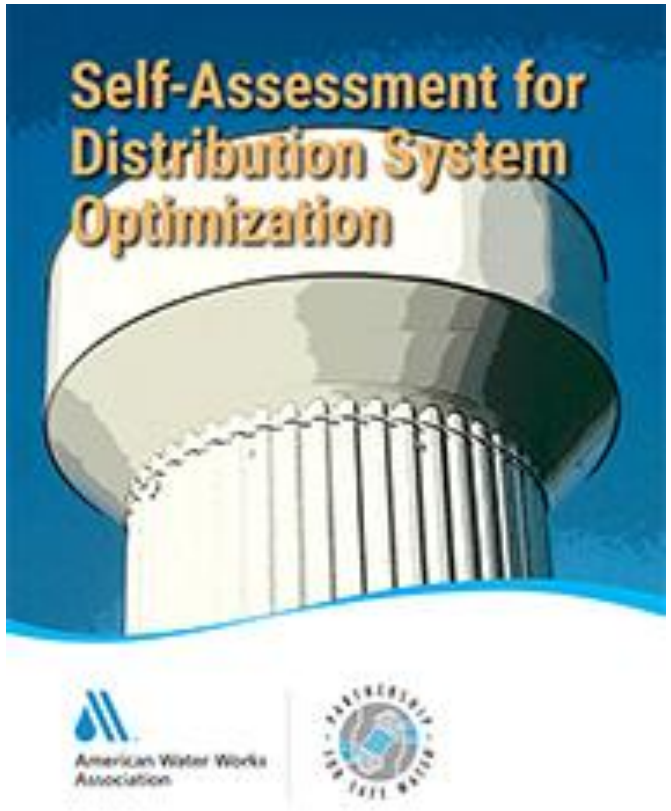
- CCP
  - Comprehensive Performance Evaluation (CPE)
    - Assess Performance
    - Identify Performance Limiting Factors (PLFs) Related to Administration, Design, Maintenance and Operations
  - Comprehensive Technical Assistance (CTA)
    - Address PLFs
    - Continue Measuring Performance

Program Approach



PSW Self-Assessment Guides





Converting facilitated optimization tools to a Self-Assessment Approach

AWOP Development

- CPE training (CO, KY, MA, MD, MT, PA, RI, TX, WV)
  - States generally comfortable with performance evaluation portion, recognizing that the resource commitment > typical plant inspection
  - Many trained state CPE teams disbanded over time
    - Inspections required of all water systems, optimization efforts were not
    - No organizational structure to maintain CPE capability
  - States less comfortable with technical assistance portion of program
    - Resource commitment perceived as too great
    - Technical assistance role not embraced by all states
- Multistate approach (1997)

AWOP Development

Lessons Learned: we needed a strategy, not just a toolbox

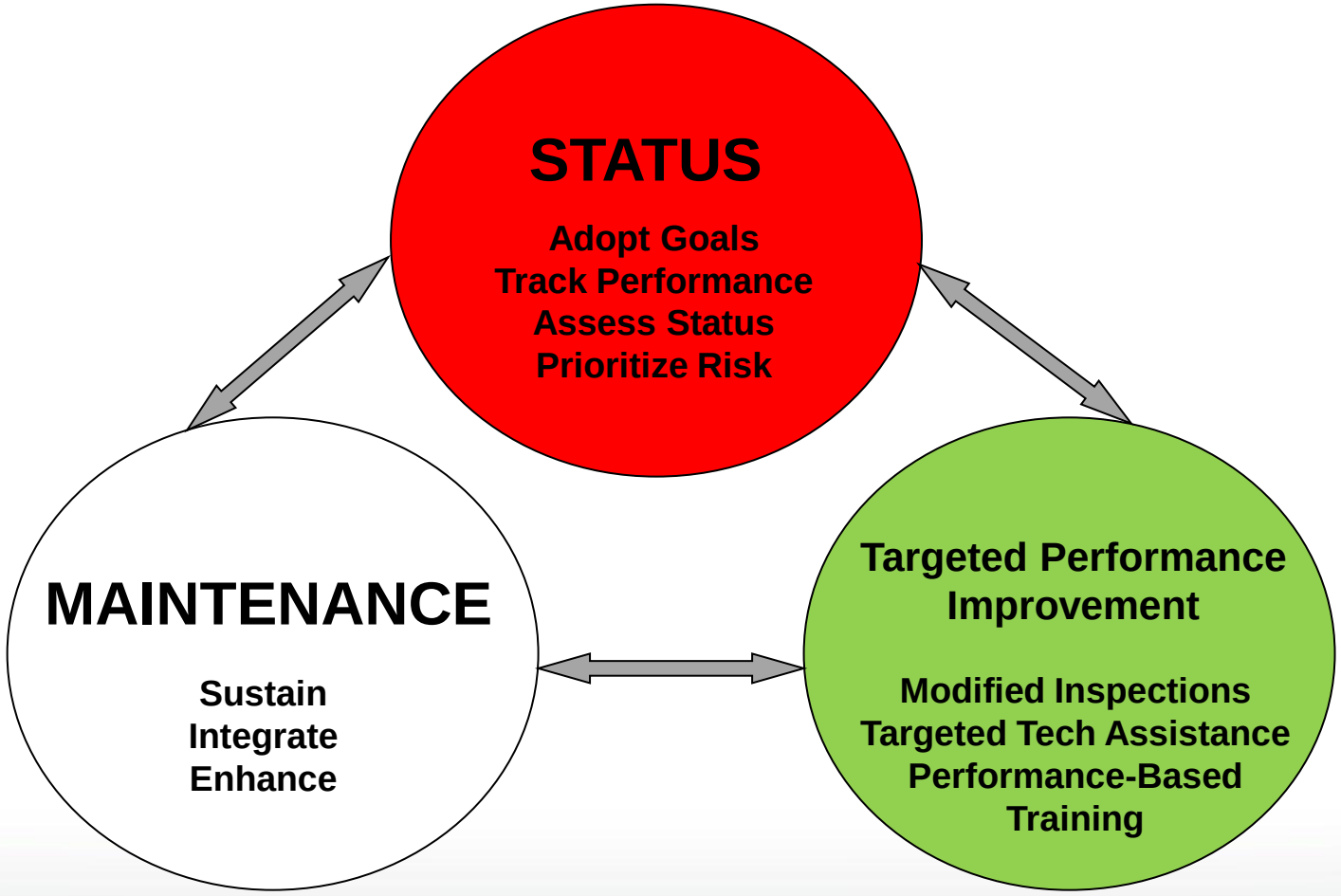
Stage 1: EMERGENCY
- Meet immediate needs with compassion
- Create clear, accurate information

Stage 2: TRUST
- Slow down and listen
- Build relationships throughout the community

Stage 3: COLLABORATE
- Create collaborative formats to identify and meet longer term needs
- Keep showing up, keep listening, trust the community

Stage 4: MAINTAIN
- Support community efforts to move forward
- Keep showing up, keep listening

AWOP Model


STATUS
Adopt Goals
Track Performance
Assess Status
Prioritize Risk
MAINTENANCE
Sustain
Integrate
Enhance
Targeted Performance Improvement
Modified Inspections
Targeted Tech Assistance
Performance-Based Training

Optimization Goals

- Developed and Endorsed by the NOLT
- Monitoring Goals
  - Sampling Locations
  - Sampling Frequency
  - Modified to keep up with technology improvements in monitoring instrumentation
- Performance Goals
  - Enhance public health protection
  - Implementable

Area-Wide Optimization Program Disinfection By-Product and Distribution System Optimization Goals and Guidelines

Monitoring & Operating Goals Summary

Category	Goal/Guideline	Status	Description	References
Disinfection By-Product	Plant Effluent Monitoring Goal	Adopted	• Collect quarterly total trihalomethane (TTHM) and haloacetic acid (HAA5) samples at the plant effluent with distribution system compliance sites.	
Disinfection By-Product	Enhanced Coagulation Monitoring Goal[1]	Adopted	• Collect monthly raw and treated water total organic carbon (TOC) samples (only applies to parent systems).	
Disinfection By-Product	Disinfection Monitoring Goal	Adopted	• Record disinfectant residual, temperature, and pH at maximum daily flow in the treatment plant for CT calculations.	
Distribution System	Disinfection By-Product Monitoring Goal	Adopted	• Collect quarterly DBP samples at all compliance locations at systems in compliance with the Stage 2 D/DBP Rule. • Collect monthly DBP samples at all compliance locations at system *not* in compliance with the Stage 2 D/DBP Rule.	
Distribution System	Disinfectant Residual Monitoring Goal	Adopted	• Monitor disinfectant residual at bacteriological and DBP compliance sites, all active distribution system entry points, all storage tanks (preferably while draining), and at a minimum of four critical sites (one in each quadrant of the system) identified by investigative sampling. • Conduct monitoring at least monthly and more frequently during warmer weather.	
Distribution System	Chloramination Process Monitoring Goal	Adopted	• Monitor free ammonia in raw water, prior to the addition of chlorine in the treatment plant, and in the plant effluent on a routine basis. Raw water should be monitored at least weekly and other locations should be monitored at least daily. The frequency of analysis at each location should be adjusted based on variability	American Water Works Association, 2013

Area-Wide Optimization Program Disinfection By-Product and Distribution System Optimization Goals and Guidelines

Performance Goals & Guidelines Summary

Category	Goal/Guideline	Status	Description	References
Disinfection By-Product	Plant Effluent Performance Goal	Adopted	• Adopt System Specific Targets: Discrete value or range based on a running annual average (RAA). Recommended goal should be 30% to 50% of long-term locational running annual average (LRAA) goals (e.g., 20-30 ppb for TTHM, 15-20 ppb for HAA5).	
Disinfection By-Product	Enhanced Coagulation Performance Goal[1]	Adopted	• Meet Stage 1 D/DBP Rule TOC removal requirements for enhanced coagulation, which are based on source water alkalinity and TOC levels, or an alternative compliance criteria, as a RAA of the performance ratio (PR) (actual/required removal) plus a factor of safety of 10% (or PR ≥ 1.1).	
Disinfection By-Product	Disinfection Performance Goal	Adopted	• Meet CT requirements to achieve inactivation of Giardia and viruses plus a system-specific factor of safety.	
Disinfection By-Product	Disinfection By-Products Performance Goals	Adopted	• Individual Site Goal: Quarterly maximum LRAA TTHM/HAA5 values not to exceed 70/50 ppb. • Long-Term System Goal: Average of maximum LRAA TTHM/HAA5 values not to exceed 60/40 ppb (the average of the last 8 quarters cannot exceed 60/40 ppb).	
Distribution System	Disinfection Performance Goals	Adopted	• Maintain ≥ 0.20 mg/L free chlorine residual at all monitoring sites in the distribution system, at all times in systems that use free chlorine as a secondary disinfectant. • Maintain ≥ 1.50 mg/L monochloramine residual at all monitoring sites in the distribution system, at all times. In systems that use chloramines as a secondary disinfectant.	American Water Works Association, 2013 American Water Works Association, 2017
Distribution System	Storage Tank Operational Guideline	Adopted	• Maintain an average turnover time < 5 days; or establish and maintain an acceptable water turnover rate at each storage facility to maintain water quality. • Maintain good mixing (i.e., $PR^2 \geq 1$) at all times; for tanks where the PR cannot be calculated, adequate mixing (i.e., uniform water quality) should be confirmed by alternate means (e.g., tank profiling/water quality sampling).	

Status Component

Table 2. 2022 Microbial Status, Prioritized Facilities

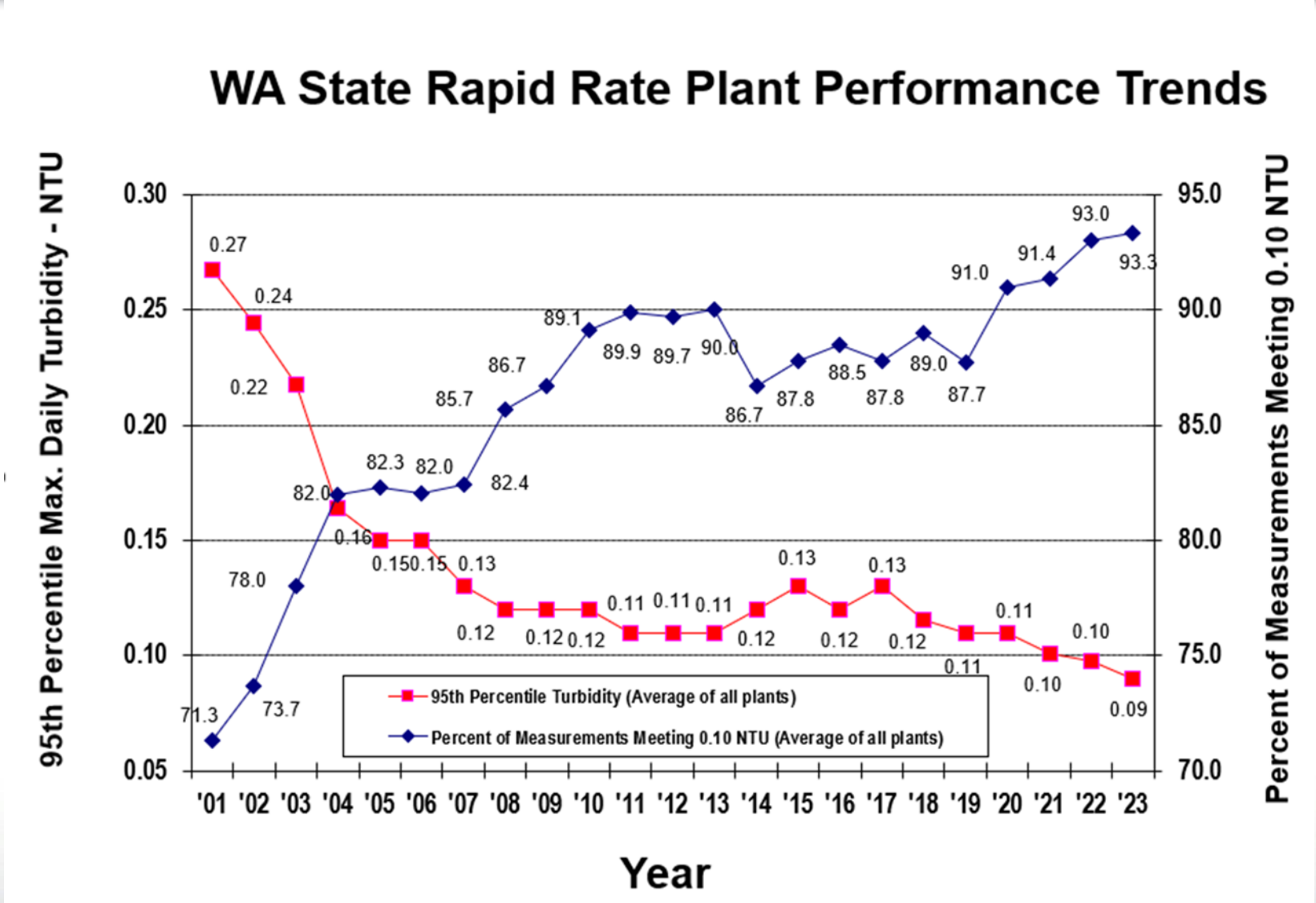
System Name	2022 Score	#>1.0 NTU	#>0.30 NTU	#>0.10 NTU
SOUTHERN WATER & SEWER DISTRICT	2090	0	0	2090
CARLISLE WATER DEPARTMENT	1341	0	1	1338
MOUNTAIN WATER DIST	1228	0	0	1228
ALBANY WATER WORKS	1145	0	0	1145
WOODSON BEND PROPERTY OWNERS ASSOC	1050	0	0	1050
EDMONSON CO WATER DISTRICT	972	0	0	972
CAMPBELLSVILLE MUNICIPAL WATER	938	0	0	938
CAWOOD WATER DISTRICT	904	0	0	904
PIKEVILLE WATER DEPARTMENT	616	0	0	616
PINE MT SETTLEMENT SCHOOL	567	0	0	567
TOMPKINSVILLE WATER WORKS	562	0	1	559
BARDSTOWN MUNICIPAL WATER DEPT	502	0	5	487
HAZARD WATER DEPARTMENT	463	0	0	463
SPRINGFIELD WATER WORKS				
MT VERNON WATER WORKS				
EDMONSON CO WATER DISTRICT				
LANCASTER WATER WORKS				
MARION WATER DEPARTMENT				
ASHLAND WATER WORKS				
SALYERSVILLE MUNICIPAL WATER				
ALBANY WATER WORKS				
NORTHERN KENTUCKY WATER DISTRICT				
KUTTAWA WATER DEPARTMENT				
DAWSON SPRINGS WATER & SEWER				
CORBIN UTILITIES COMMISSION				
FRANKFORT PLANT BOARD				
MOREHEAD UTILITY PLANT BOARD				
RUSSELL WATER COMPANY				
WINCHESTER MUNICIPAL UTILITIES	118	0	0	118
GREENVILLE UTILITIES COMMISSION	112	0	0	112

Data-based Assessment and Prioritization

Community Surface Water Systems with Conventional Treatment
2020 West Virginia Microbial "Public Health Risk" category ranking.

11	13	8	13	19	19	18	12	8	12	7	15	8	3	6	←number of zero points WTPs per year		Risk To Public Health			
18 RK	17 RK	16 RK	15 RK	14 RK	13 RK	12 RK	11 RK	10 RK	09 RK	08 RK	07 RK	06 RK	05 RK	*04 RK	System Name	PWSID #	DIST R	Overall Score	Risk	95%tile CFE
1	14	9	1	1	1	1	1	1	1	3	1.2	1 tie	13	121	Putnam PSD (12 tzp), 3 fltr (1.6 MGD 24/7) DW36Ex12'	WV3304011	2	0	L	0.07
12	1	1	14	1	20	1	1	9	17	13	29	55	29	100	WVAWC-BLUEFIELD DISTRICT, 4 fltr (1.3 MGD 24/7)	WV3302835	1	0	L	0.04
44	1	1	1	1	1	1	1	1	13	10	7	4	5	113	WVAWC-BLUESTONE PLANT, 4 fltr (2.2 MGD 24/7)	WV3304513	1	0	L	0.02
44	1	1	1	1	1	1	1	1	1	2	9	11	23	118	WVAWC-NEW R REG WTP (11 tzp) 3 fltr (2.2 MGD 24/	WV3301046	1	0	L	0.04
1	1	40	1	1	1	1	1	1	1	1	1.3	5 tie	2	123	WVAWC-WESTON (15 tzp) 4 fltr(1 MGD 24/7)	WV3302104	6	0	L	0.06
1	14	9	14	20	20	55	12	32	34	11	14	28	36	115	Morgantown (Evo 0.04-µm uF) Hyb 8 flt (9.5 MGD 24/7)	WV3303111	6	0	L	0.02
1	14	9	1	1	1	1	1	1	1	6	11	9	53	91	HURRICANE TOWN OF (9 tzp) 2 fltr	WV3304005	2	0	L	0.07
1	14	19	67	60	1	1	1	1	1	5	15	17	48	82	WVAWC-Hunt'n(7 tms 0 pts)12 fltr(9.3 MGD 24/7)	WV3300608	2	0	L	0.07

Status Component



Targeted Performance Improvement

Performance Limiting Factors Summary

- A - Major Effect on a long-term repetitive basis
- B - Moderate effect on a routine basis or a major effect on a periodic basis
- C - Minor effect

Example Performance Limiting Factors

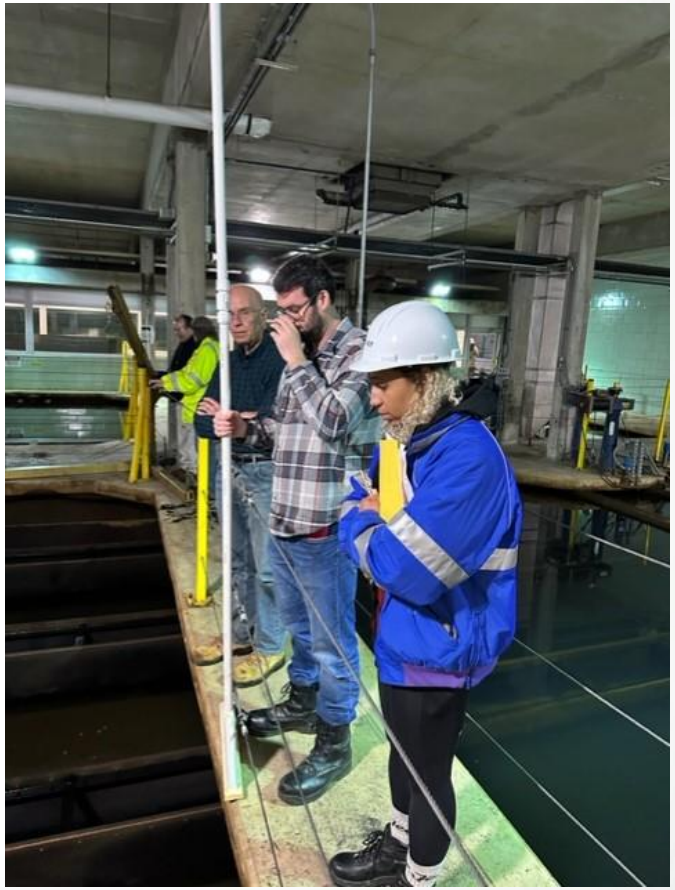
- **A** – Design (Sedimentation)
- **A** – Operations (Representative Sampling)
- **A** – Design (Process Controllability)
- **A** – Administration (Reliability)
- **B** – Administration (Policies)
- **B** – Design (Filtration)
- **C** – Design (Pre-sedimentation Basin)

Targeted Performance Improvement

Addressing Performance Limitations

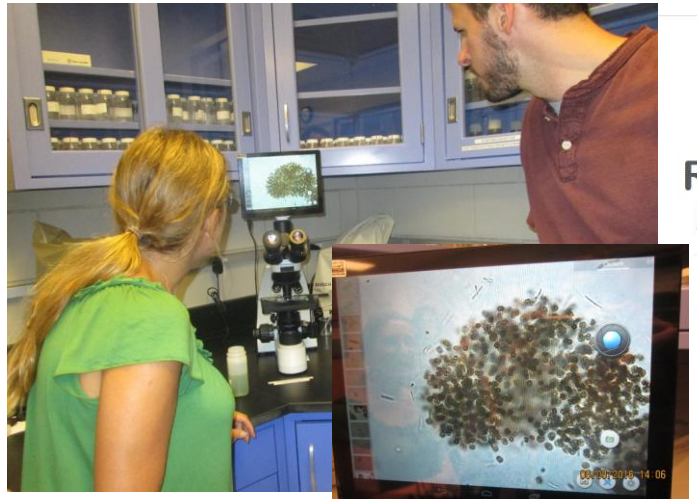
PBT in NC

Mn Demand Testing



New State CPE Demonstration

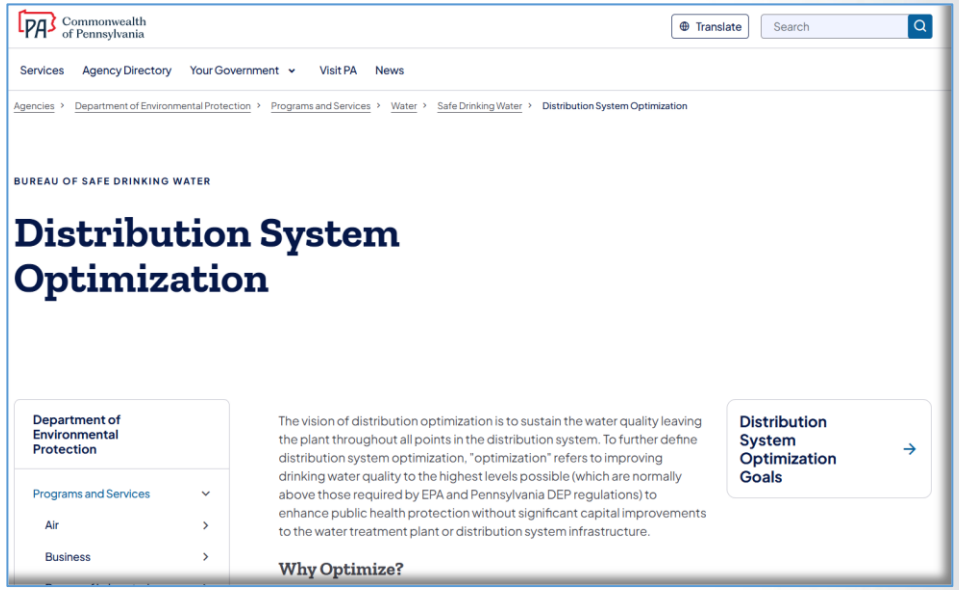
Maintenance



- Enhance the AWOP continuously using data-based evaluation and adjustments.
- Integrate AWOP principles into all aspects of the drinking water program.
- Sustain AWOP within the organization.

AWOP Strategy

- Primacy Agency Implementation
  - State Public Water System Supervision Program personnel adopt, promote and implement the optimization of drinking water treatment and distribution processes.
- National Program Implementation
  - Managed by EPA-OGWDW.
  - National Optimization Leadership Team (NOLT) advises OGWDW
    - Comprised of ASDWA & EPA Regions.
  - Participation is voluntary.



PSW & AWOP Information

- PSW: https://www.awwa.org/programs/partnership-for-safe-water/

- EPA: https://www.epa.gov/sdwa/drinking-water-optimization-program
- ASDWA: https://www.asdwa.org/awop/
- Content to be found on these websites
  - AWOP Overview
  - Goals & Guidelines
  - AWOP Tool descriptions, including recordings
  - Water Quality Impacts
  - Interactive map of State Agency AWOP webpages

Agenda

- Overview of two established national drinking water optimization programs
  - Area-Wide Optimization Program (AWOP)
  - Partnership for Safe Water (PSW)
- **Minnesota DOH experiences: Comprehensive Performance Evaluations**
- Workshop introduction: Turbidity data interpretation and data integrity
- Tabletop exercise: Turbidity data evaluation and interpretation

Turbidity Data Interpretation and Integrity

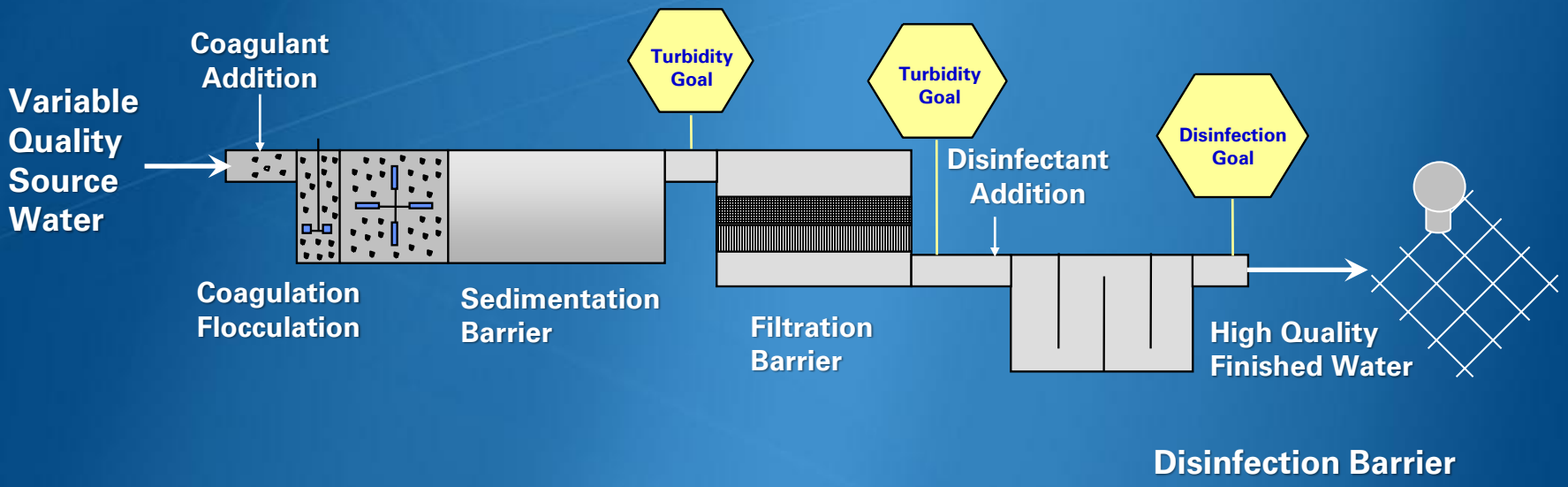
West Fargo, North Dakota
April 22, 2025

Background for Turbidity Optimization Performance Goals

- Public Health Protection Challenge
  - Waterborne disease outbreaks are commonly linked with protozoan parasites:
    - *Giardia* and *Cryptosporidium* are routinely detected in North American water supplies
    - 0.2 log or less inactivation of *Cryptosporidium* with free chlorine at 5 - 15 mg/L for 60 - 240 minutes
      (Finch, 1995)
  - Meeting existing compliance levels not always effective in preventing disease.

Optimized Performance Reduces Risk

- Optimization requires treatment beyond regulatory levels.
- Focus on multiple barrier strategy to enhance plant performance:
  - Particle removal (i.e., turbidity).
    - Coagulation/flocculation + sedimentation + filtration
  - Disinfection



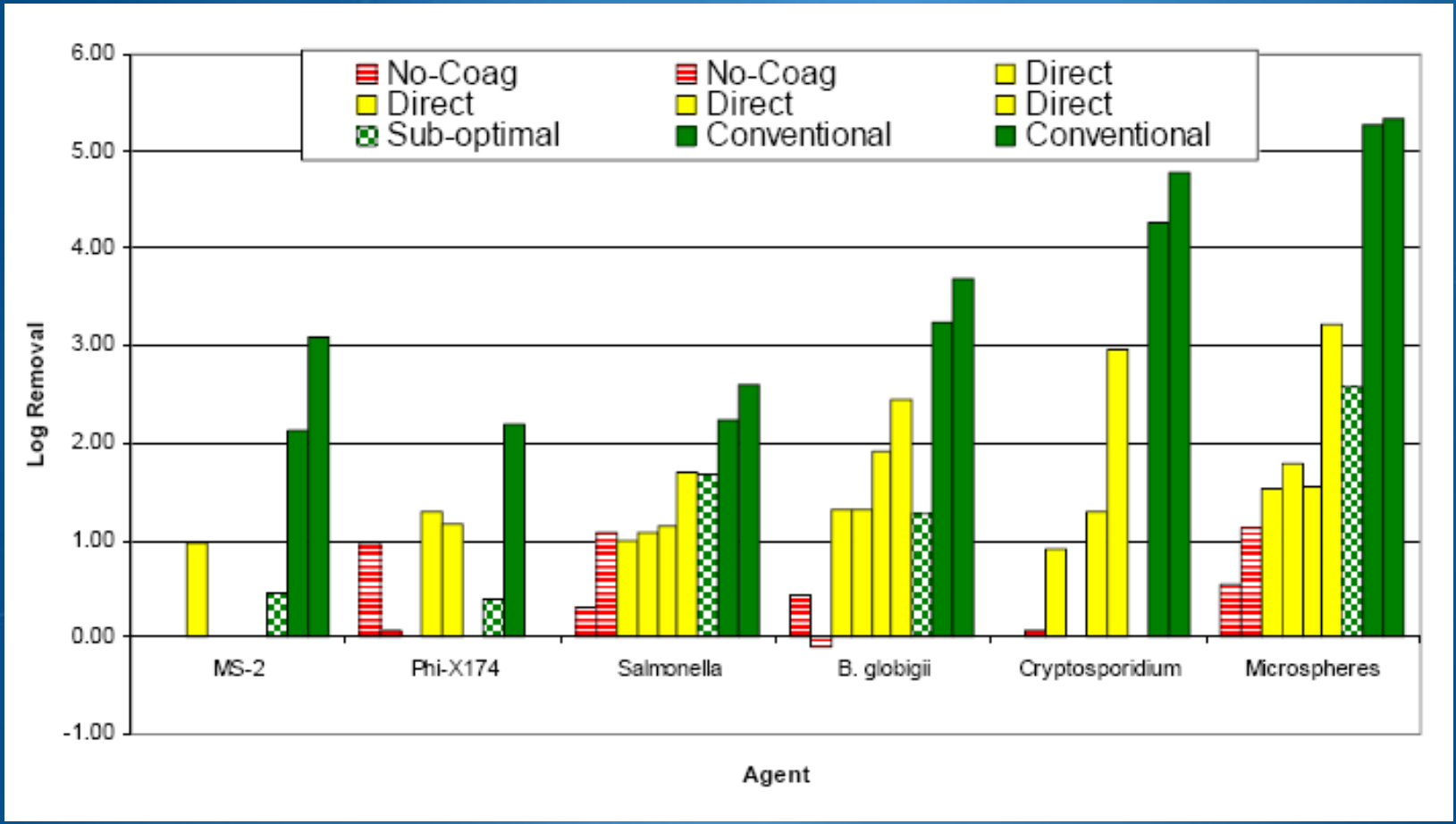
Basis For Sedimentation Basin Goals

- Dugan (2001) – Pilot scale work to assess *Cryptosporidium* removal through conventional sedimentation (USEPA):
  - Sedimentation removal under sub-optimal coagulation averaged 0.2 log *Crypto*.
  - Sedimentation removal under optimal coagulation averaged 1.3 log *Crypto*.
  - Removals positively correlated with turbidity removal.

Basis For Filtered Water Turbidity Goals

- Emelko (2000) – Pilot scale work to assess *Cryptosporidium* removal through filtration *(University of Waterloo):*
  - Stable operation: 5 to 6 log (turbidity ~ 0.04 NTU)
  - End-of-run: 2 to 3 log (turbidity increase to 0.10 NTU)
  - Breakthrough: 1.5 to 2 log (turbidity increase to 0.3 NTU)

Removal of Organisms Based on Treatment Type and Conditions



(Ref. Amburgey 2007 WQTC.)

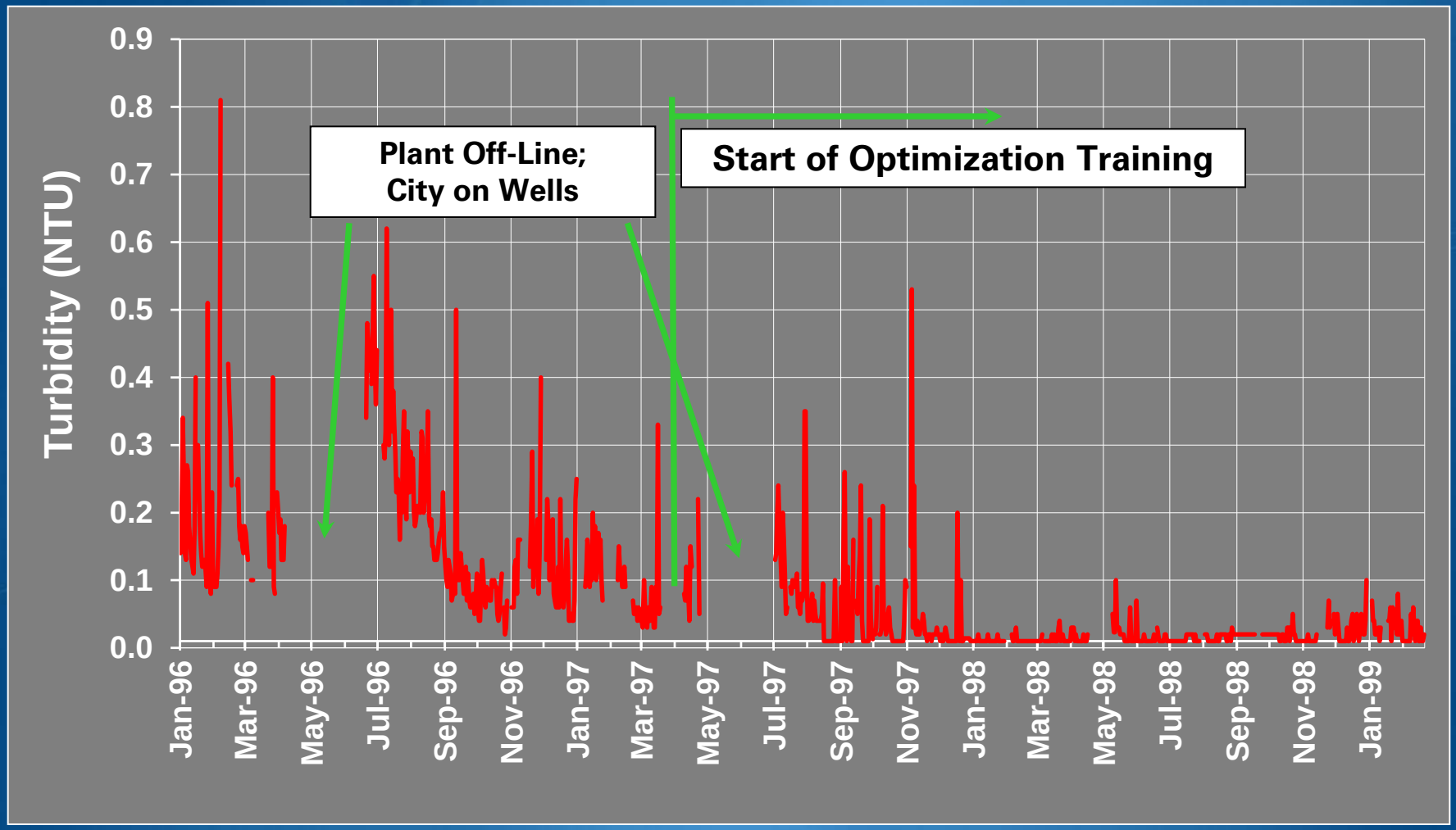
Sedimentation Performance Goals

- Max Daily Turbidity:
  ≤ 2 NTU 95% time when source turbidity >10 NTU
- Max Daily Turbidity:
  ≤ 1 NTU 95% time when source turbidity ≤ 10 NTU
- Frequency of sampling:
  - Grab – every 4 hours
  - Continuous – capture highest value per day from SCADA

Filtration Performance Goals for Conventional Rapid Rate Filters

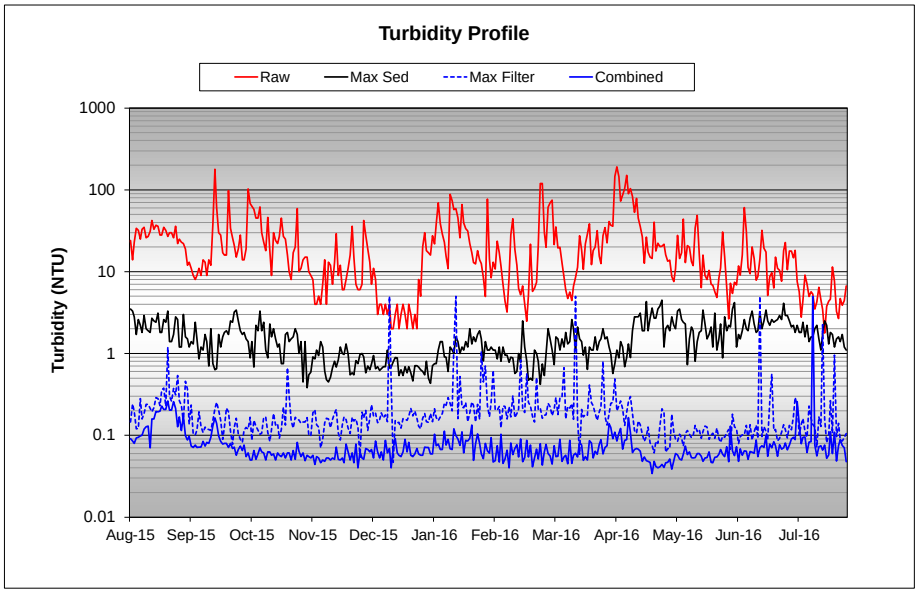
- Max Daily Turbidity Individual Filter and Combined Filter Effluent: $\leq$ 0.10 NTU 95% of the time
- Maximum Turbidity: $\leq$ 0.30 NTU
- Continuous monitoring for IFE and CFE (capture highest value per day from SCADA)

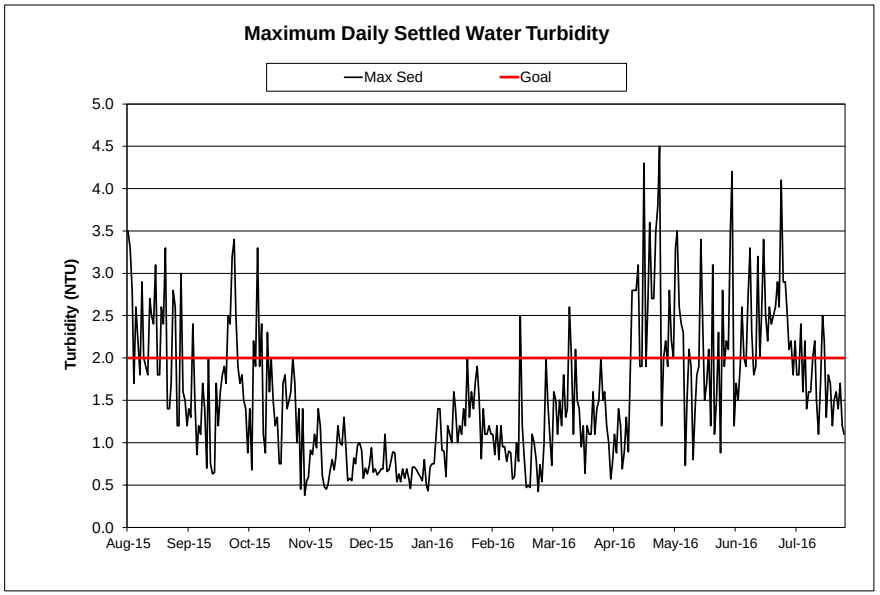
Optimization Approach – Draw the Graph!



A Tool to Manage Performance Data

- Optimization Assessment Spreadsheet
  - Allows for viewing trends over 3 years
    - Most analyses are done using a specified 12-month period of time.
  - Software for direct filtration, conventional, and membrane plants
  - Provides graphs, charts and tables allowing strategic insights into plant performance.





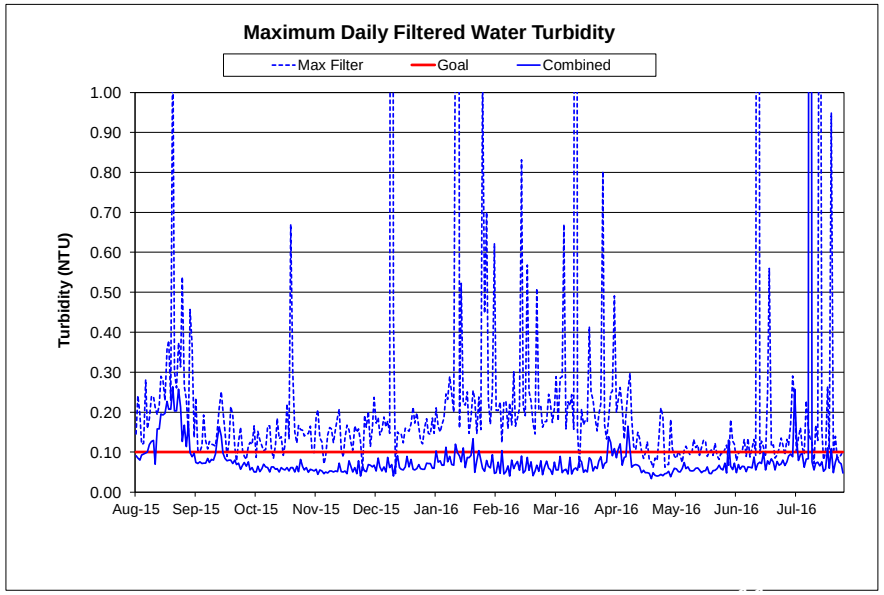
ANNUAL DATA	Avg	Min	Max	RSQ	95%	Opt. Goal	Reg.
	NTU	NTU	NTU		NTU	% Values	% Values
Raw Turbidity	23.0	1.8	191.4	n/a	73.1	n/a	n/a
Max. Settled Turbidity	1.6	0.4	4.5	0.00	3.2	76	n/a
Max. Filtered Turbidity	0.25	0.05	5.00	0.00	0.52	15	n/a
Combined Filtered Turbidity	0.09	0.03	5.00	0.00	0.15	88	100

RSQ = Correlation Coefficient for two selected data sets (> ~ 0.25 suggests correlation)

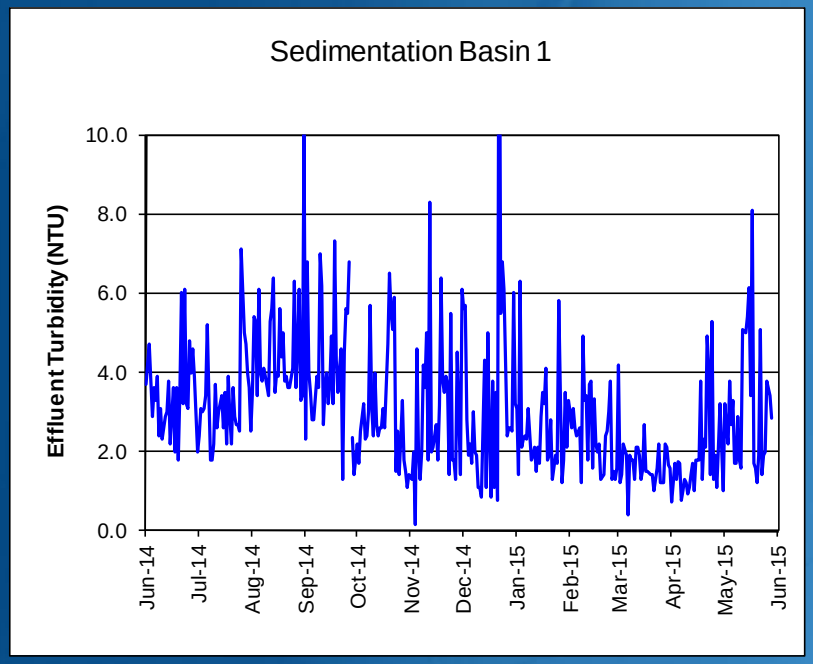
95% = 95th Percentile value for data set

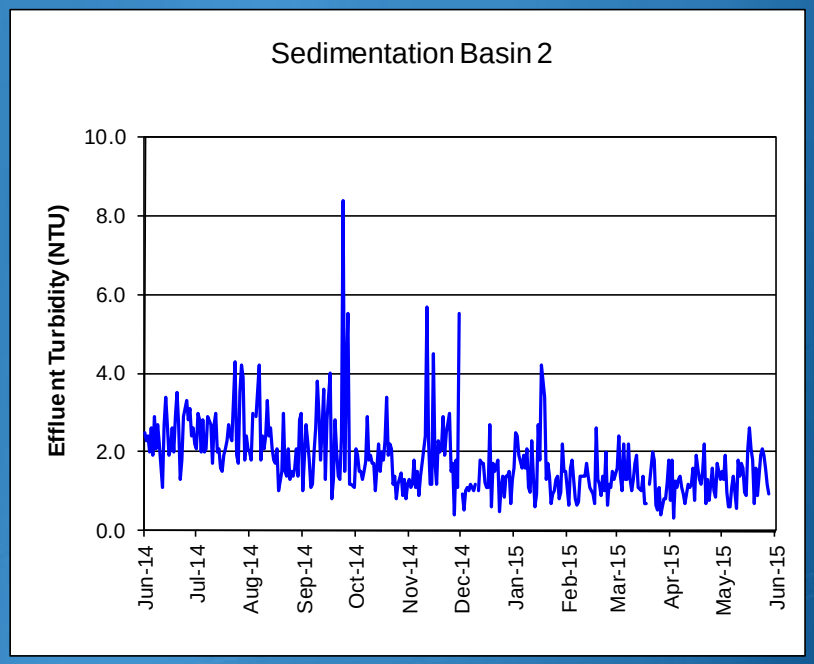
Opt. Goal = % of values in data set that are less than or equal to the selected optimization turbidity goal

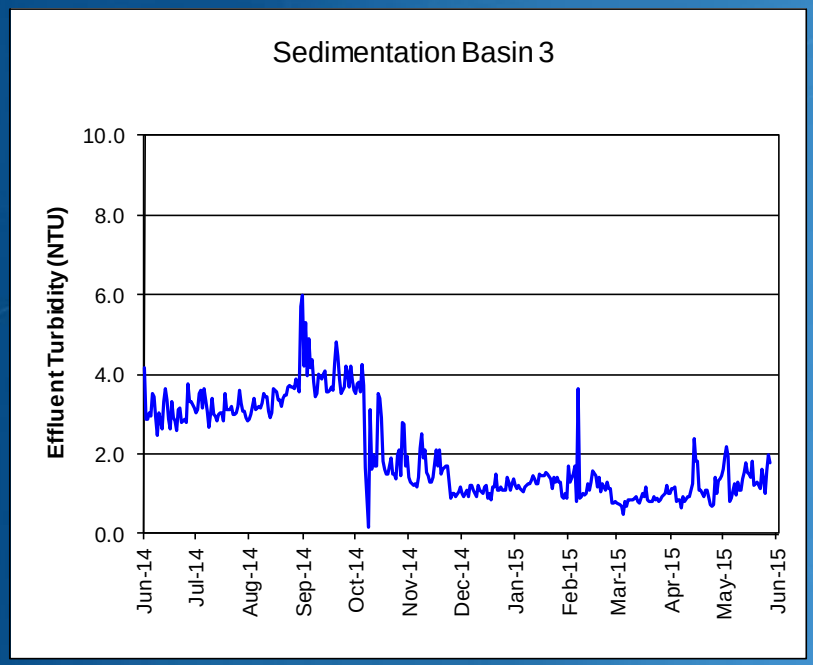
Reg. = % of values in data set that are less than or equal to the regulated turbidity requirement

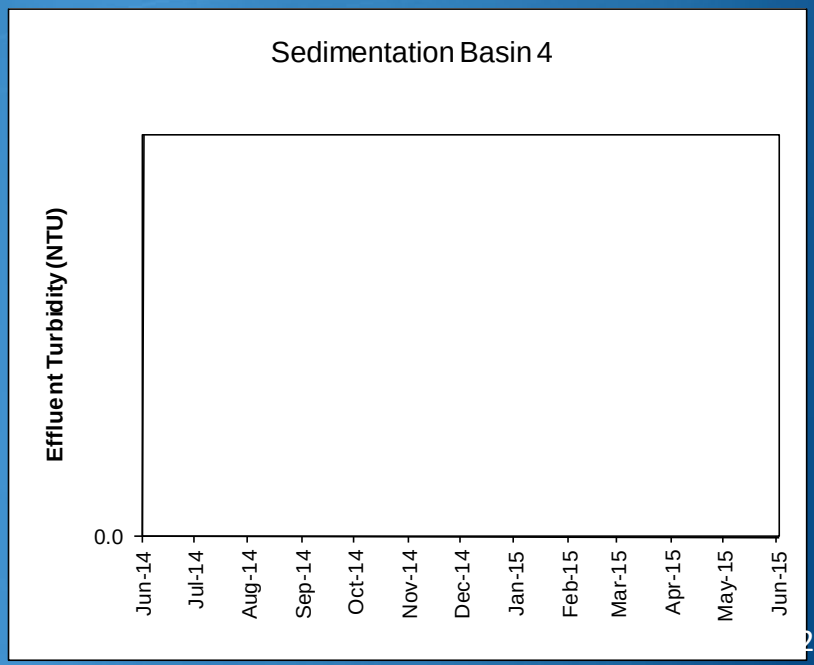


Sedimentation Performance Summary

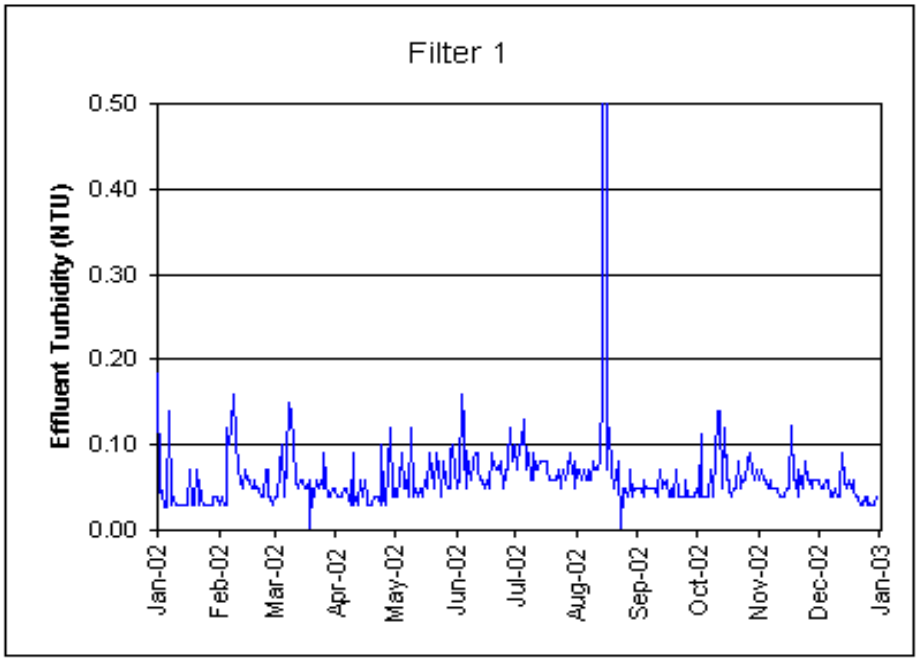


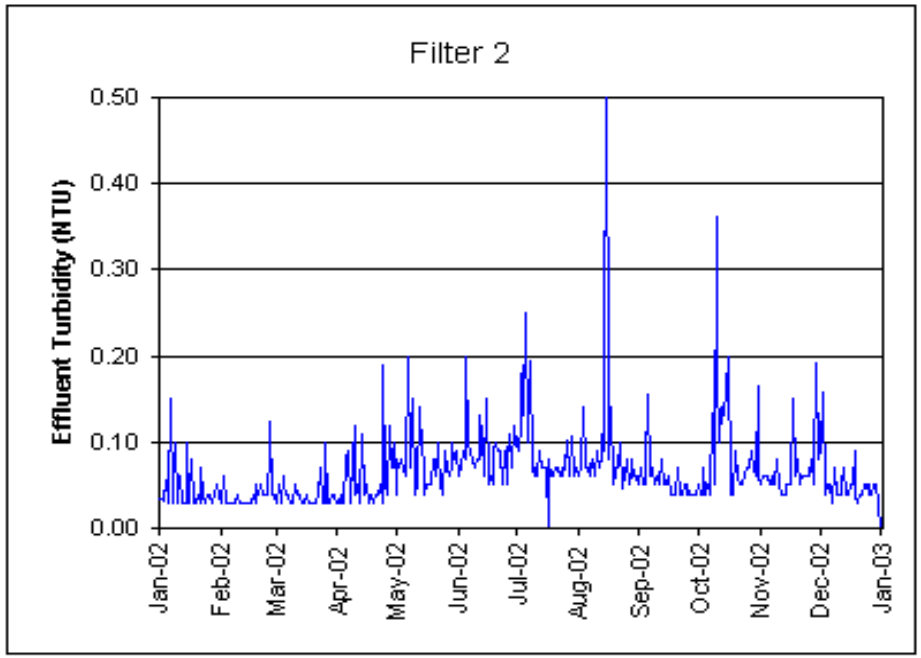


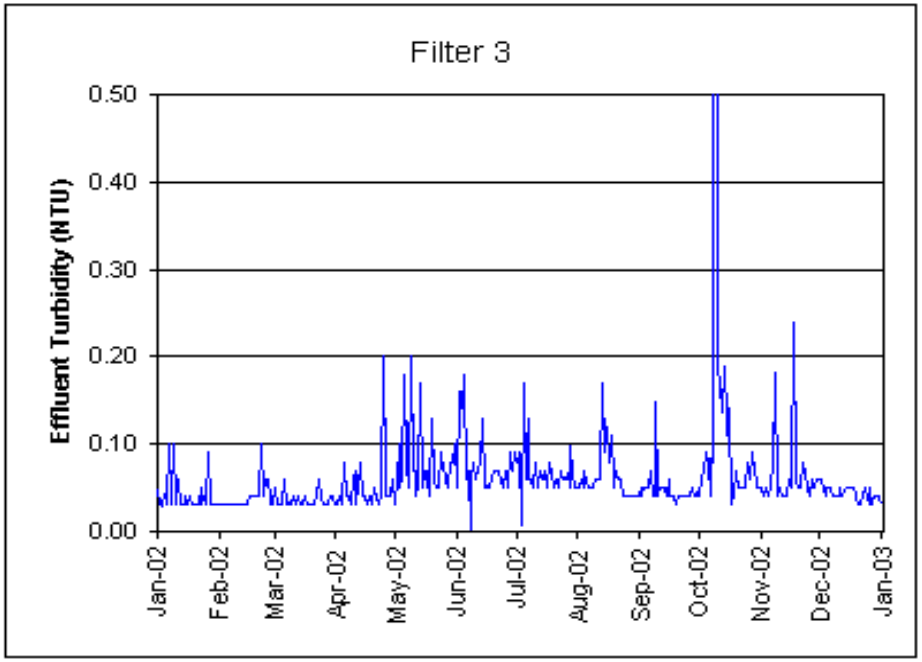


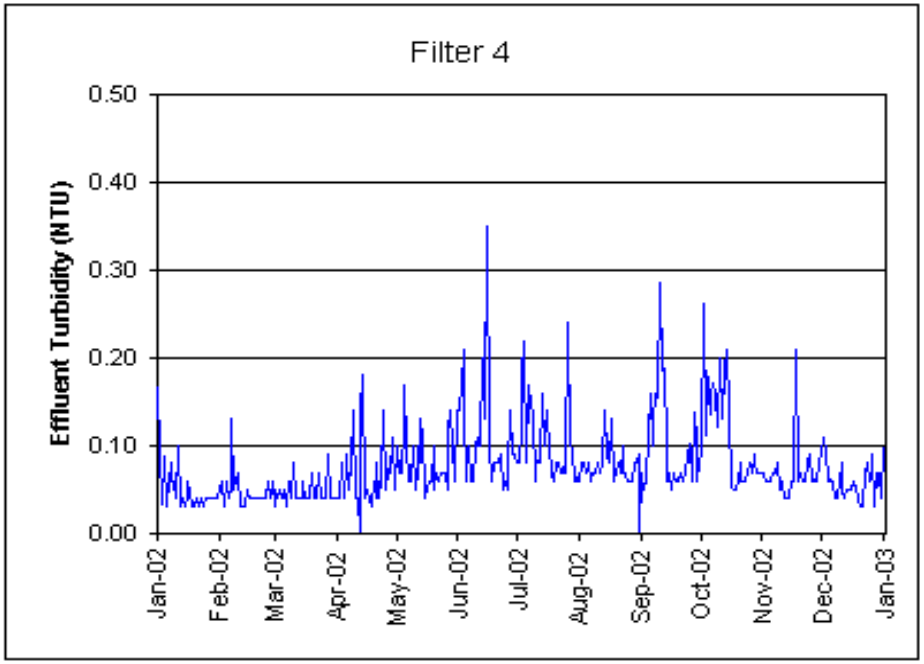


Filtration Performance Summary (Filters 1 - 4)









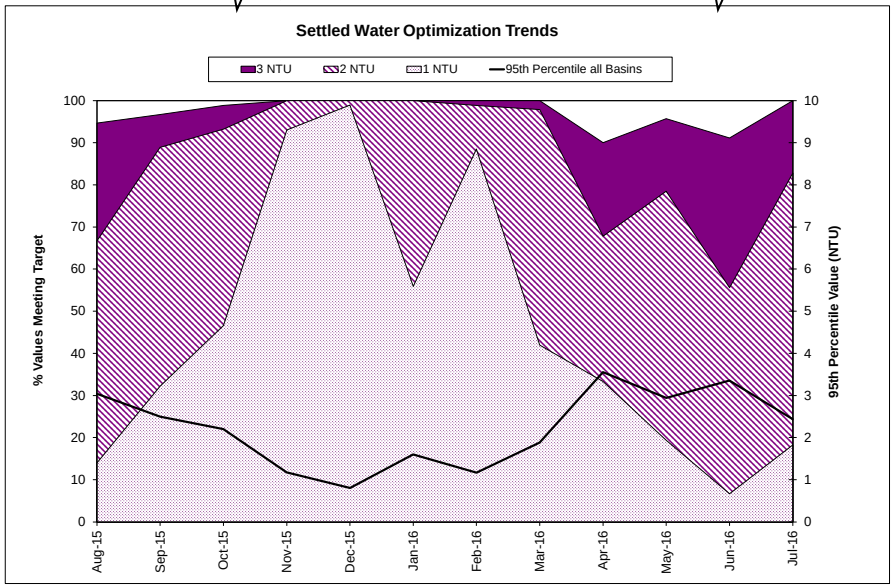
	Settled Water Turbidity								Filtered Water Turbidity																
	95th Percentile Values (NTU)					% Values Meeting Goal			95th Percentile Values (NTU)														% Values Meeting Goal All Filters		
	Sed 1	Sed 2	Sed 3	Sed 4	All Sed	3 NTU	2 NTU	1 NTU	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter 9	Filter 10	Filter 11	Filter 12	Combined	All Filters	0.3	0.2	0.1
Aug-15	2.95	2.95	3.10					14.0	0.27	0.32	0.26					0.34					0.24	0.30	95.16	63.31	19.4
Sep-15	2.89	2.28	2.18					32.2	0.18	0.22	0.13					0.21					0.14	0.19	100.00	96.67	69.6
Oct-15	2.37	2.20	1.50					46.6	0.14	0.16	0.13					0.15					0.07	0.15	99.19	98.79	83.9
Nov-15	1.26	1.00	0.88					93.0	0.12	0.18	0.12					0.18					0.08	0.16	100.00	98.75	86.3
Dec-15	0.92	0.69	0.71		0.81	100.00	100.00	98.9	0.18	0.19	0.14	0.15	0.13	0.21	0.16	0.16					0.09	0.17	99.19	98.39	81.5
Jan-16	1.80	1.60	1.40		1.60	100.00	100.00	55.9	0.25	0.72	0.34	0.67	0.17	0.21	0.19	0.21					0.12	0.25	95.97	87.90	72.6
Feb-16	1.06	1.16	1.16		1.17	100.00	98.85	88.5	0.15	0.22	0.22	0.20	0.20	0.22	0.22	0.43					0.09	0.22	97.84	91.38	78.4
Mar-16	1.50	1.85	1.90		1.88	100.00	97.85	41.9	0.15	0.29	0.17	0.35	0.17								0.09	0.23	97.98	90.73	78.6
Apr-16	2.97	3.11	4.08		3.56	90.00	67.78	33.3	0.19	0.15	0.21	0.19	0.14								0.13	0.20	99.58	95.00	82.5
May-16	2.40	2.85	3.35					.4	0.10	0.10	0.09	0.09	0.10								0.07	0.11	100.00	100.00	92.7
Jun-16	3.36	3.11	3.37					.7	0.21	0.10	0.10	0.12	0.10	0.12	0.10	0.13					0.09	0.13	98.33	96.67	88.8
Jul-16	2.50	2.20	2.45		2.44	100.00	82.80	18.3	0.16	0.14	0.20	0.62	0.08	0.15	0.10	0.12					0.20	0.16	97.98	95.97	85.9
Yr. 95%	2.60	2.70	2.80						0.21	0.24	0.23	0.24	0.19	0.21	0.21	0.22					0.15				
Yr. Goal	86.5%	86.5%	84.3%						78.1%	72.7%	77.5%	73.5%	80.6%	77.0%	80.6%	73.0%					88.3%				

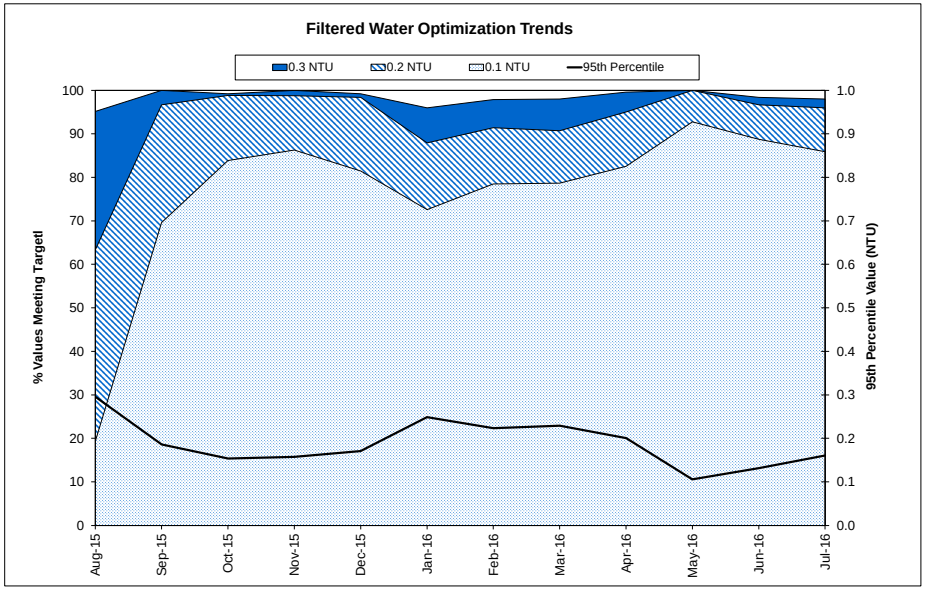
Worst Sed Basin For Month

Worst Filter For Month

Highest Value, All Sed Basins

Highest Value, All Filters

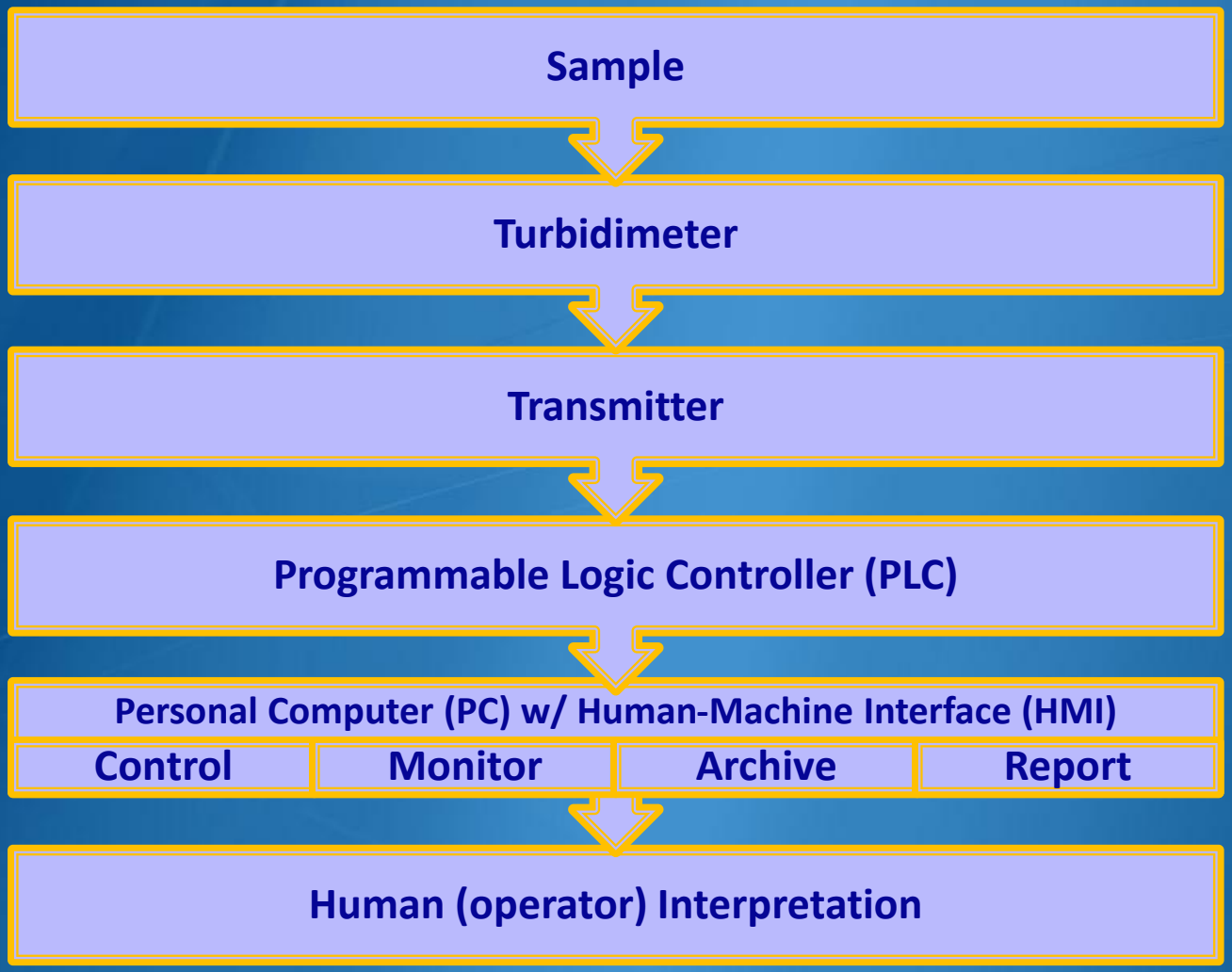




Data Integrity

A process to maintain and assure the accuracy and consistency of data over its entire life cycle.

Based on Turbidity Data Life Cycle



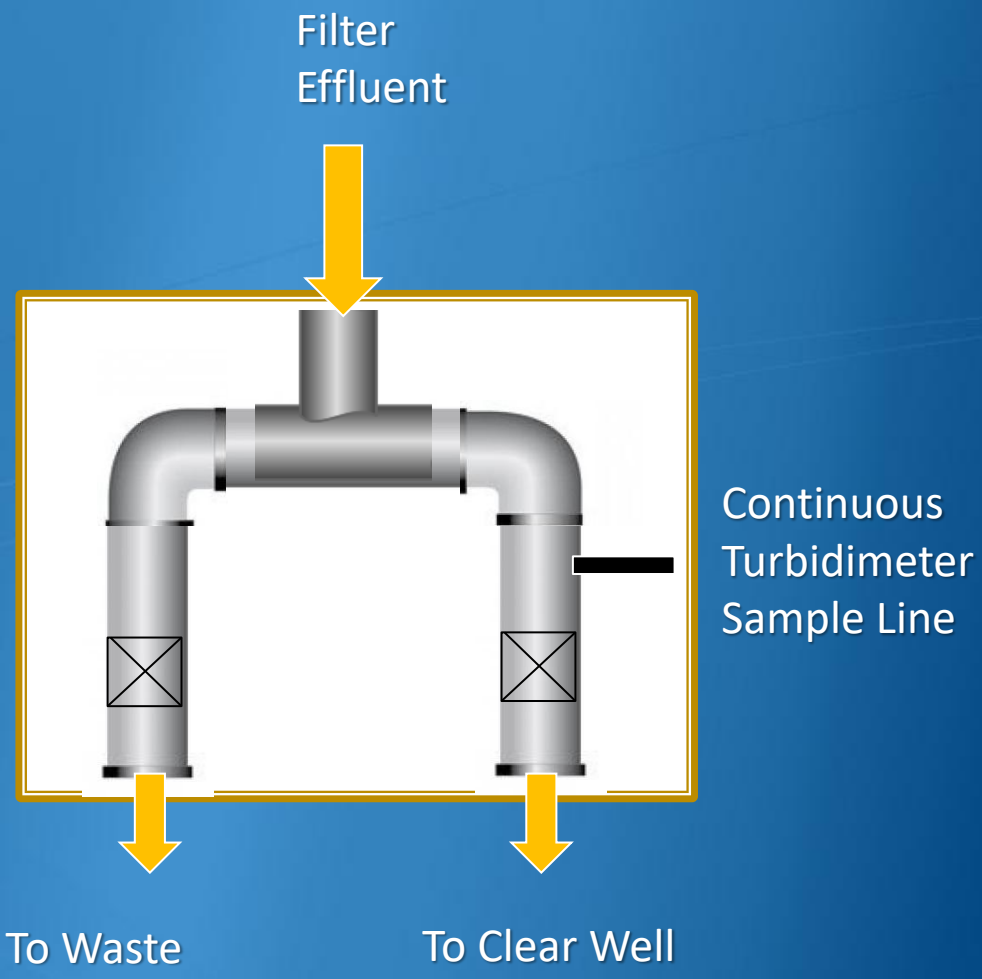
Settled Water Sample Considerations

- Consider location, length of sample line, and sample flow rate to turbidimeter(s).
- Check sample line condition and turbidimeter cleaning frequency.
  - Solids deposition in line and meter often contributes to turbidity spikes.
- Check for delayed start of sampling (e.g., solenoid that opens sample line 15 minutes after start-up).

Case study – ~ 75 feet 1-inch line to turbidimeter

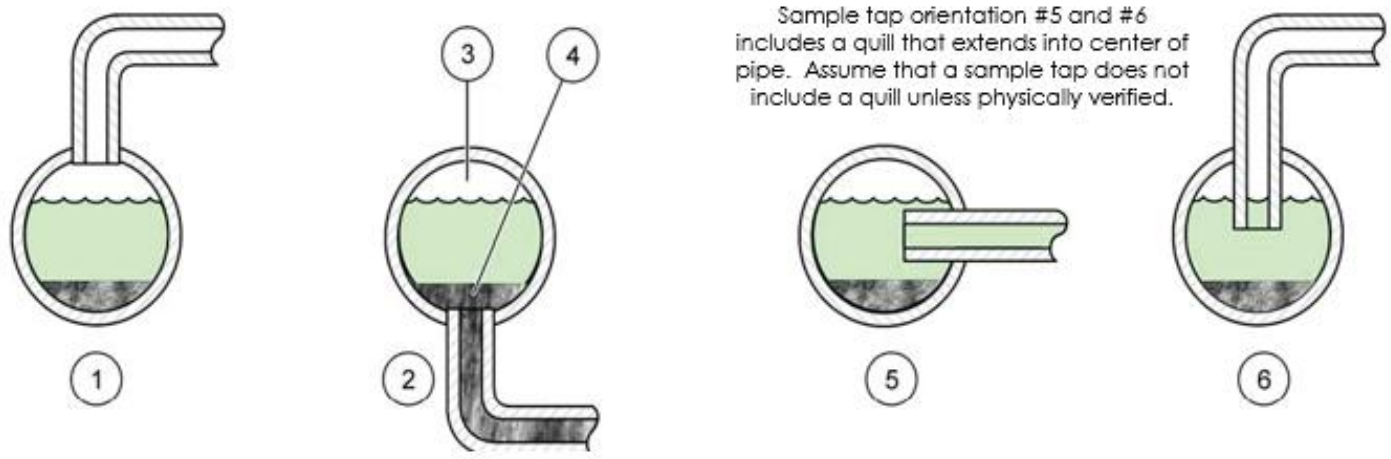
Individual Filter Effluent Sampling

- Sample tap location issues:
  - Should be able to accurately measure turbidity during both filter-to-waste and filter-to-clear well periods.
  - The graphic shows a stagnant zone at the monitoring location during filter-to-waste.



Sample Tap Location for Turbidimeters

- Sample tap location: Best location is the side of the pipe or a quill that allows sample to be taken from the pipe center.



Source: Hach Company (2014)

1	Poor	4	Sediment (typical)
2	Poor	5	Good
3	Air (typical)	6	Best

Figure 1: Sample Line Location in Process Stream (Hach Company)

Sample Line Integrity

IFE Sample Tap Relocation Project

What the Operators Found!

CFE Sample Considerations

- Location of CFE sample line.
  - Is CFE representative of all filters?
  - Post clear well locations can be problematic:
    - Floc due to pH changes and chemical addition
    - Turbulence from high service pumps
- Length of sample line to turbidimeter and flow rate.

Case study – ~ 30 feet 1-inch line to 1720E turbidimeter

Sample Line pumps can add error

- Individual filter effluent turbidity samples pumped to remote turbidity location.
- Operators experienced frequent problems with air and turbulence causing turbidity spikes.
- Access to IFE sample tap and line is through confined space ~ 20 feet below access hatch (plant < 10 years old).

Turbidimeter Considerations

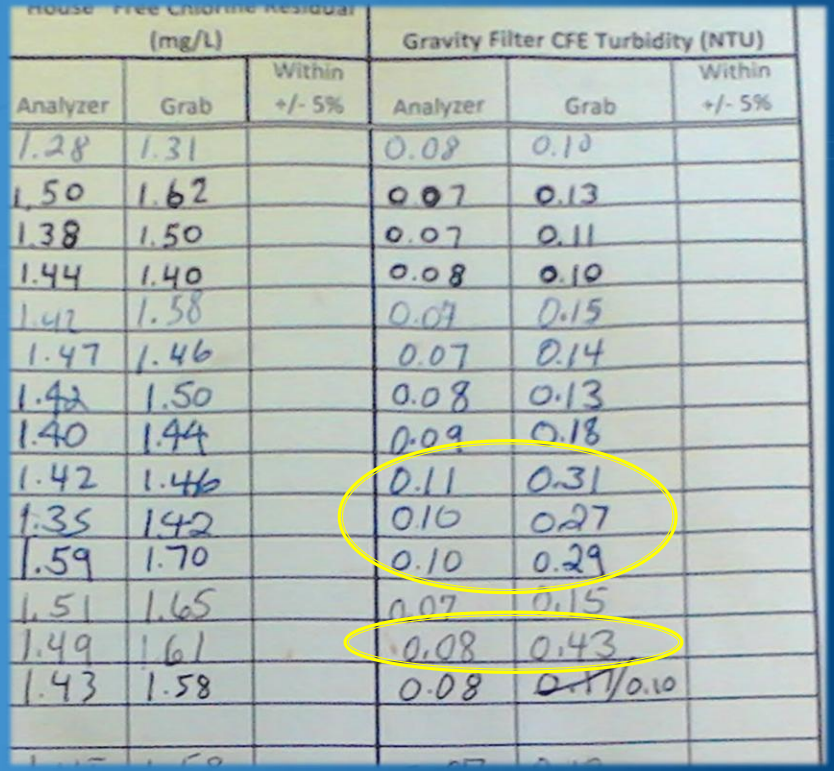
- Bench top vs continuous instruments
  - Using a benchtop introduces additional potential error, due to sample handling and sample cell integrity.
- Newer technologies are more accurate/reliable
  - Laser technology.
- Continuous readings from one manufacturer to another may be slightly different.

Turbidimeter Verifications and Calibrations

- Verifications
  - Usually done at least weekly
  - Compare measured result to known standard (primary or secondary) or to another instrument.
  - If instrument reading is our of range, conduct a calibration
- Calibrations
  - Usually done at least quarterly
  - Adjusts the reading according to a primary standard.

Turbidity Verification Procedures

- Common perception that portable and bench turbidimeters are not accurate for comparing to online instruments when measuring low turbidity water (i.e., IFE, CFE).



(mg/L)			Gravity Filter CFE Turbidity (NTU)		
Analyzer	Grab	Within +/- 5%	Analyzer	Grab	Within +/- 5%
1.28	1.31		0.08	0.10	
1.50	1.62		0.07	0.13	
1.38	1.50		0.07	0.11	
1.44	1.40		0.08	0.10	
1.42	1.58		0.09	0.15	
1.47	1.46		0.07	0.14	
1.42	1.50		0.08	0.13	
1.40	1.44		0.09	0.18	
1.42	1.46		0.11	0.31	
1.35	1.42		0.16	0.27	
1.59	1.70		0.10	0.29	
1.51	1.65		0.07	0.15	
1.49	1.61		0.08	0.43	
1.43	1.58		0.08	0.11/0.10	

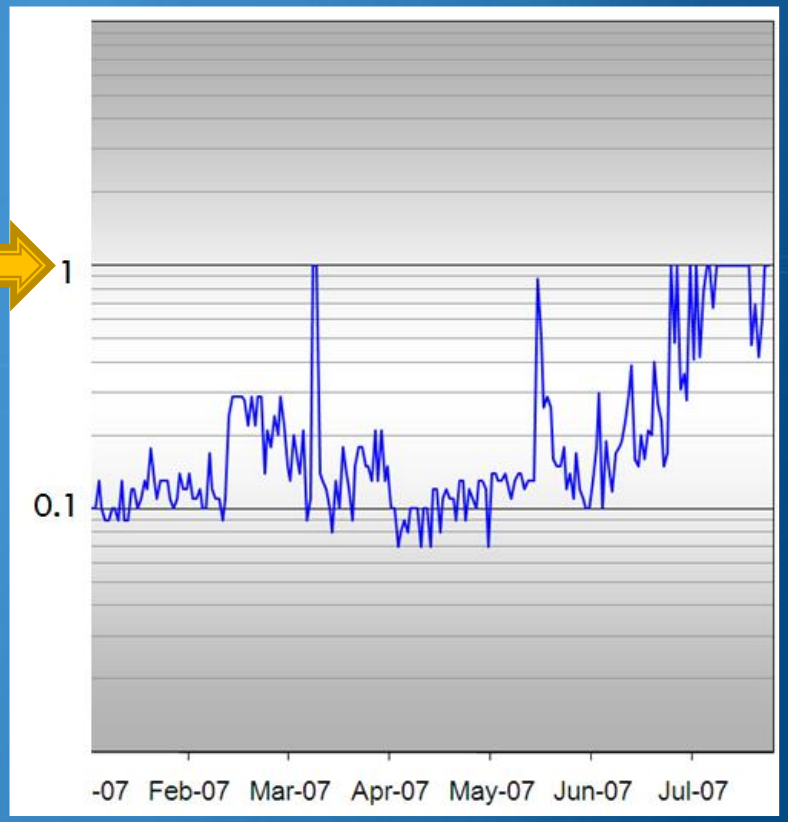
Online Turbidimeter O&M and Configuration (settings) Assessment

Online Turbidimeter O&M and Configuration (settings)

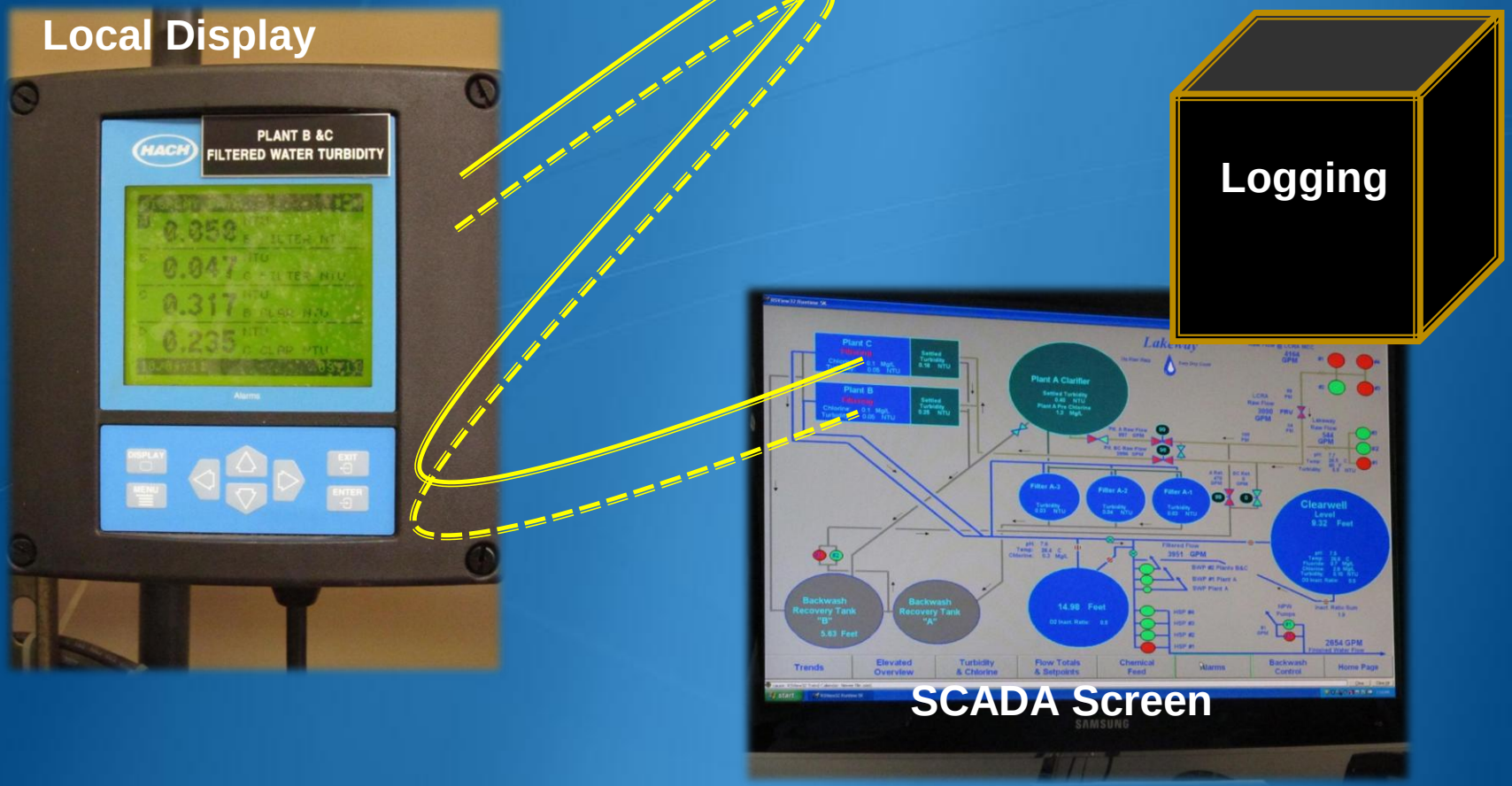
- Turbidimeter O&M:
  - Calibration practices
  - Verification practices
  - Photocell inspection and cleaning
  - Bulb replacement frequency
  - Flow rate check frequency
  - Availability of maintenance logs
- Turbidimeter settings:
  - Signal averaging
  - Bubble reject
  - Error hold mode
  - Output span

Online Turbidimeter O&M and Configuration (settings)

- Signal output range – 0 to 1 NTU common finding for IFE but will result in *"capping"* of data during filter upsets.
  - Potential compliance issue with determining the daily max. value.
- Check controller response to loss of communication with sensor – default is to report last known value.
  - Occurred in a large plant, and *"last known value"* was sent to SCADA for > 24 hours before operator aware of problem.



Turbidimeter Signal Verification and Data Logging



Data Transmission: Analog to PLC Scenario

Digital data display is showing the value coming from the sensor, before it has been converted to analog.

At the controller the signal is converted from digital to analog.

The PLC converts the analog signal back to a digital signal for communication with the SCADA system.

Controller (SC 200)

Digital

Sensor

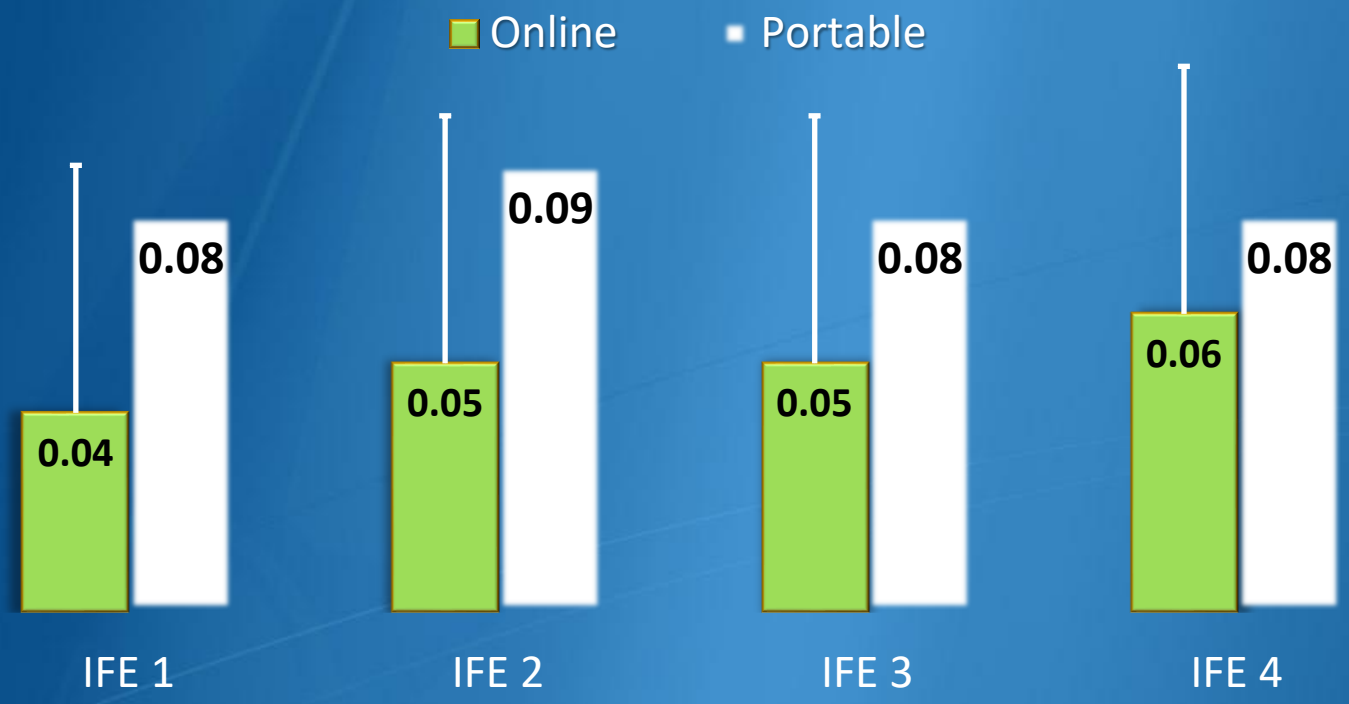
Analog

PLC

Digital

SCADA Data Storage

Turbidity Verification Procedures



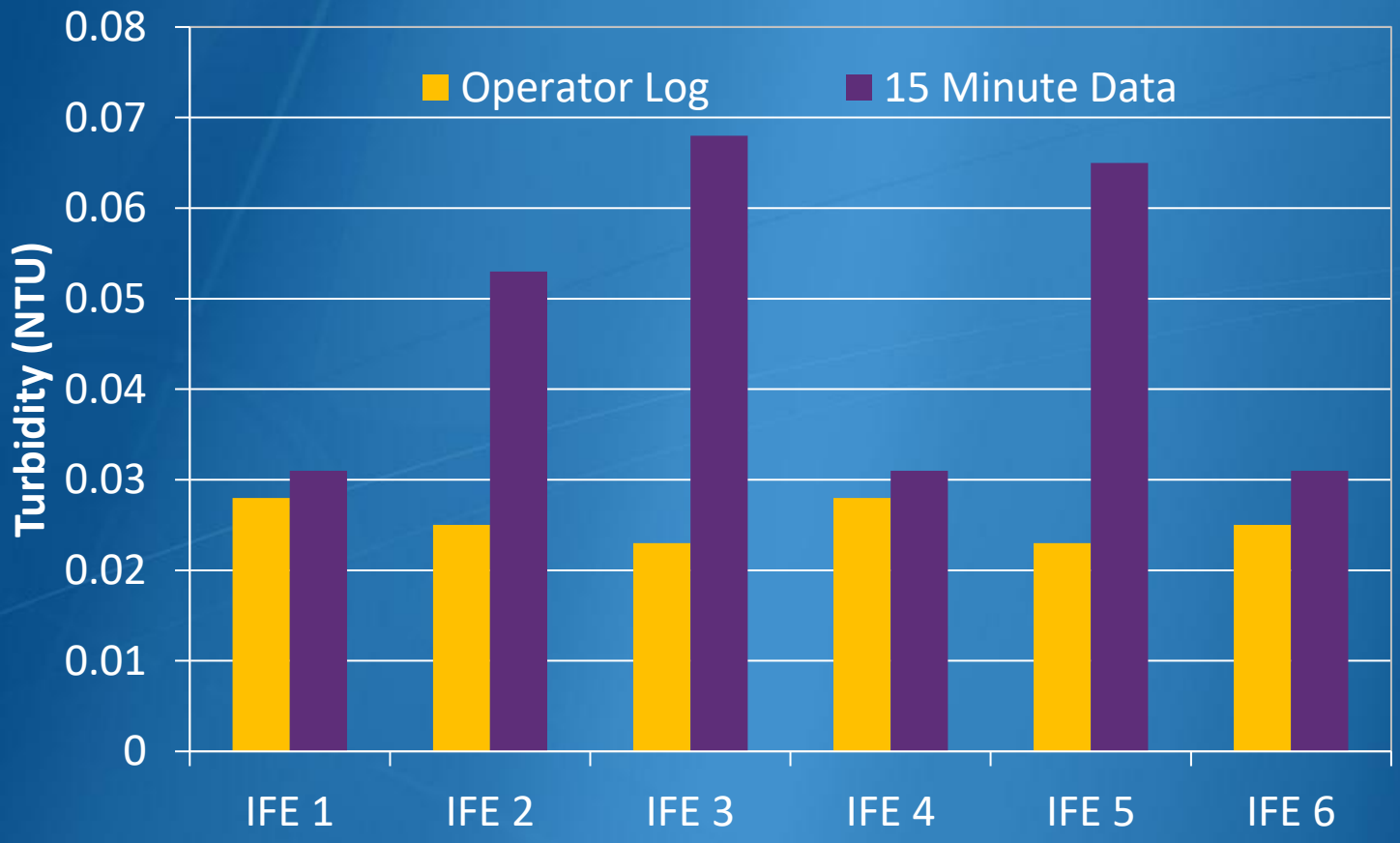
- Using proper techniques and calibrated meters results in acceptable verification.
  - Grab sample results should be within 0.05 NTU of online instrument.
  - Requires awareness of sample cell integrity, cell indexing, de-gassing sample, access to representative turbidimeter sample location.

Interpreting and Reporting Turbidity Data

Turbidity Data Tracking and Reporting

- Establish the current data recording protocol.
  - Include raw through CFE turbidity sample locations.
- Consider all data sources (e.g., operator logs, SCADA downloads).
  - Determine which data source is used for recorded turbidity values.
  - How are maximum daily IFE and CFE values determined?

Example IFE Max Day Verification



Summary

- Optimized performance of the settling and filtration barriers protect public health
  - Performance goals can be used to measure performance.
- OAS spreadsheet can be used to interpret performance data.
- Data integrity is an important aspect of interpreting performance.
  - Accurate data can bring about important operational decisions.

CPE Overview in MN

Indran Kamalanathan | SWTR Compliance Engineer

CPEs in Minnesota

- MN has completed three CPEs since 2022
  - Thief River Falls, Ely, and International Falls

- Provides the plant and state staff with a deep understanding of CPE focus areas
  - Design – Plant unit process capabilities
  - Operations – Plant staff and how the plant is run day to day
  - Admin – Plant management and planning

Optimization Goals

- Enhanced treatment targets with the goals of improved public health outcomes and compliance
- Multiple barriers operating effectively can produce the highest quality water
- Turbidity:
  - Daily Maximum Sedimentation Turbidity does not exceed 2 NTU (based on raw >10 NTU)
  - Daily Maximum Filter Turbidity does not exceed 0.1 NTU in IFE and CFE measurements
  - Filter Backwash Spike does not exceed 0.3 NTU and returns to 0.1 NTU within 15 minutes

CPE Process

- Pre-meeting and planning with PAI and systems
- On-site evaluation
  - Day 1 – Kickoff and Plant Tour | Project Team Breakout
  - Day 2 – Special Studies and Project Team Work
  - Day 3 – Wrap-up Studies | Factor Deliberation
  - Day 4 – Exit Meeting Presentation
- Report Generation
- Regular Check-In with District Engineer and SWTR Team

Figure 16. Filter No. 1 surface wash arm.

Figure 17. Filter expansion measurement tool.

CPE Activities and Plant Studies

Baseline Studies

- Admin Interviews
- Operation Interviews
- Major Unit Process Analysis
- Historical Data Analysis

Special Studies

- Filter Bed Study
- Backwash Performance Study
- UV/TOC Removal Study
- Chemical Feed Verification
- Plant Meter Verification
- Turbidity Data Analysis
- Chloramination Study

Factor Determination

- Plant Performance Limiting Factor List is generated and categorized based on effect
  - A – Major long-term
  - B – Moderate routine or Major Periodic
  - C – Minor
- Provides the plant with a key prioritized list that leads them naturally to optimization

Rank	Rating	Performance-Limiting Factor (Category)
1	A	Administration/Plant Administrators/Policies
2	A	Administration/Plant Administrators/Supervision
3	A	Operation/Process Control/Water Treatment Understanding
4	A	Operation/Testing/Process Control Testing
5	A	Operation/Process Control/Application of Concepts and Testing to Process Control
6	A	Design/Unit Process Adequacy/Process Controllability
7	B	Administration/Plant Staff/Number
8	B	Operation/Process Control/Operational Guidelines/Procedures
9	B	Maintenance/Maintenance Program/Maintenance Resources/Materials and Equipment

Example Factor Description

Process Control Testing – Operations (A)

Strategic process control testing and representative sampling of each treatment process is necessary to make sound process control decisions related to the ability of each treatment barrier to prevent contamination.

- Operators currently do not test daily for raw turbidity, temperature, or pH. If a raw water quality change were to suddenly occur, response time may be delayed as a result.

- Operators are not testing settled water turbidity, free ammonia, or monochloramine in finished water. These analyses are necessary for optimizing the clarification and chloramination processes.

Common Findings So Far

- Admin – Policies: Plants need clear optimization goals to produce the best quality water
- Admin – Plant Coverage/Staffing: Plants need staff with sufficient time to perform optimization work
- Design – Process Controllability: Limited ability to modify processes to improve water quality (chemical feed location, filter backwashing settings)
- Design – Unit Process Adequacy – Disinfection: Disinfection taking place in plant does not sufficiently meet CT
- Operation – Water Treatment Understanding/Application: Lack of surface water focused knowledge and minimal in plant studies to help guide operation
- Operation – Process Control Testing: Insufficient data collection to fully understand plant operation

Benefits for Water Plants

- Helps building understanding at all levels of limitations and needs
- Provides water operators with deeper understanding of their process
- Builds rapport with state staff for questions and concerns
- Helps limit and address violations preemptively and direct plant improvements
- Leads to more confidence in plant operation

Benefits for State Program

- Builds deeper technical knowledge of water treatment principles
- Engages staff in challenging work
- Builds knowledge of water treatment plant for compliance and technical assistance work
- Helps determine program wide needs
- Develops connections with broader AWOP community

Thank You!

Indran Kamalanathan

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Surface Water Treatment Optimization Training
West Fargo, North Dakota
April 22, 2025

AWOP Workshop

Prepared by:

Process Applications, Inc.
2627 Redwing Road, Suite 340
Fort Collins, CO 80526

and

U.S. Environmental Protection Agency
Office of Ground Water and Drinking Water
Technical Support Branch
26 W. Martin Luther King Drive
Cincinnati, Ohio 45268

AWOP Workshop

Instructions:

Collecting and assessing plant performance data is an important step to establish the status of a plant relative to achieving optimized performance goals. The purpose of this workshop is for the participants to explore methods for summarizing and evaluating a plant's historical performance data and to develop interpretation skills.

Below are the optimization performance goals for the sedimentation barrier and the filtration barrier.

Barrier	Performance Goals
Sedimentation	• Max Daily Turbidity: o 2 NTU 95% time when source turbidity >10 NTU • Max Daily Turbidity: o 1 NTU 95% time when source turbidity ≤ 10 NTU • Frequency of sampling: o Grab – every 4 hours o Continuous – capture highest value per day from SCADA
Filtration	• Max Daily Turbidity: ≤ 0.10 NTU 95% time • Maximum turbidity:≤ 0.30 NTU • Continuous monitoring for IFE and CFE (capture highest value per day from SCADA)

Attached are plant summary reports from Optimization Assessment for a surface water treatment plant. Within your small group, review and evaluate the performance data. Be prepared to discuss your answers to the questions.

Plant 1:

1) What are the turbidity goals for this plant? How is it performing relative to each specific goal?

The average of the maximum daily raw water turbidities over the year was 3.5 NTU, which is below 10 NTU so the goal would be 1.0 NTU for maximum daily settled water turbidity.

The plant met the 1.0 settled water turbidity goal only on about 56% of the days and the 95th percentile of the maximum daily settled water turbidity was 3.6 NTU, slightly above the 1.0 NTU optimization goal. There is some room for performance improvement related to the settled water turbidity goal.

The plant met the individual filter turbidity goal on about 59% of the days and the 95th percentile of the individual filter maximum daily turbidity was 0.63 NTU, quite a bit higher than the optimization goal of 0.10 NTU.

The plant met the combined filtered water turbidity goal on about 94% of the days and the 95th percentile of the combined filtered maximum daily turbidity was 0.21 NTU, above the goal of 0.10 NTU. There is some room for improvement in the combined filtered water turbidity removal plant performance.

2) Identified areas for performance improvement (i.e., if this were your plant, where would you focus your optimization efforts?).

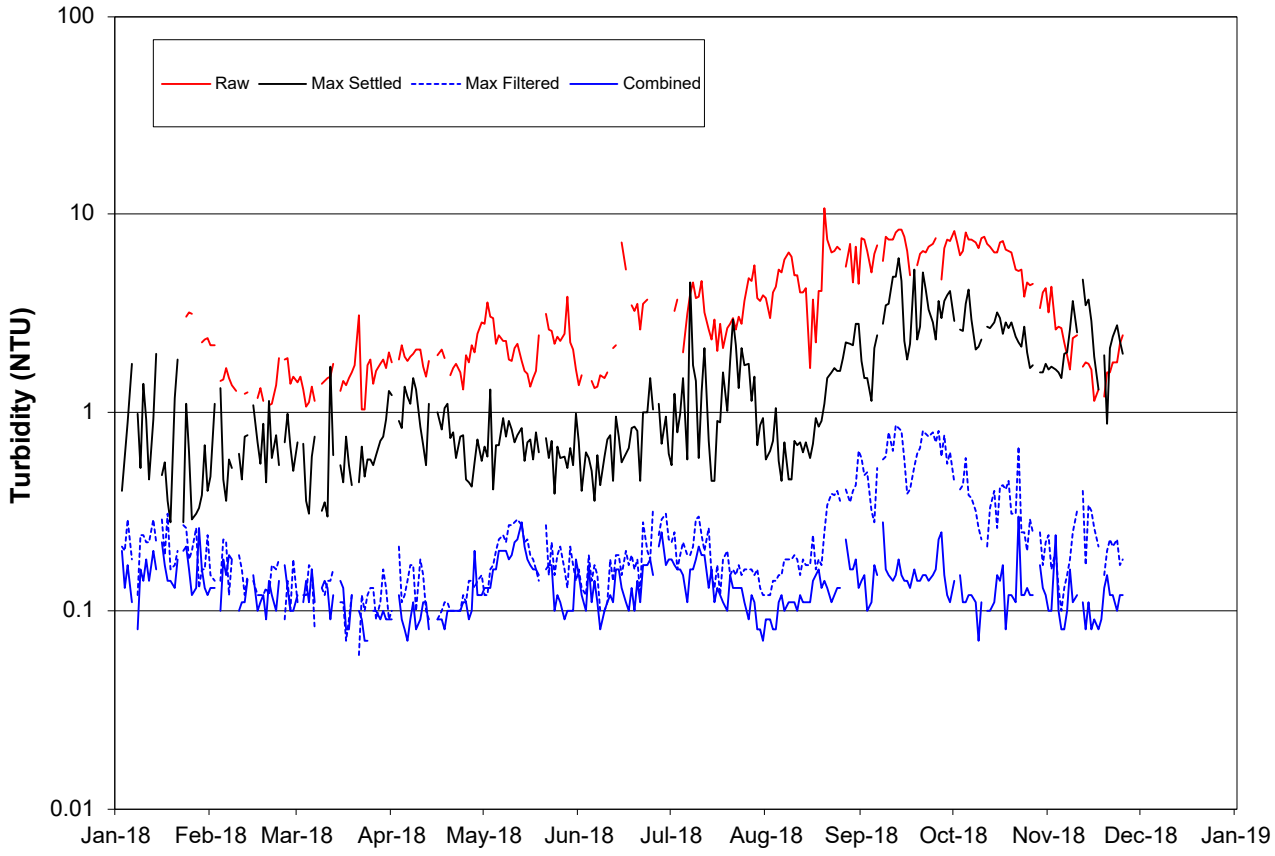
In the months near the end of the performance period, increasing raw water turbidity seemed to pass through the plant, demonstrated by higher settled water maximum daily turbidity values and higher individual filter maximum daily turbidity values. The operators could try to improve their clarification process, and in turn may reduce filter loading and may also improve filter performance. Filter 4 had a 95th percentile maximum daily turbidity of 0.77 NTU for the year,

significantly higher than the other filters. The annual 95th percentile for filters 1, 2 and 3 were also significantly higher than filters 5 through 8. It would be worth investigating why one half of the filters in the plant seem to perform better than the other half.

3) Are there any possible data integrity issues that might be evident from the data summaries?

The maximum of the maximum daily combined filter turbidity readings is 0.30 NTU. This could be due to a control system automatic shut off if the turbidity reaches that value, but it could also be a data capping situation. It should be investigated.

The maximum daily settled water turbidity data are all from one sample location (Sed 1). If there are multiple trains in the plant, the data are most likely collected on top of the filters, representing combined flow from the multiple trains. The situation should be investigated, and the operators should adopt a policy of collecting data at least every 4 hours from each individual train to be able to assess the performance of each basin separately.



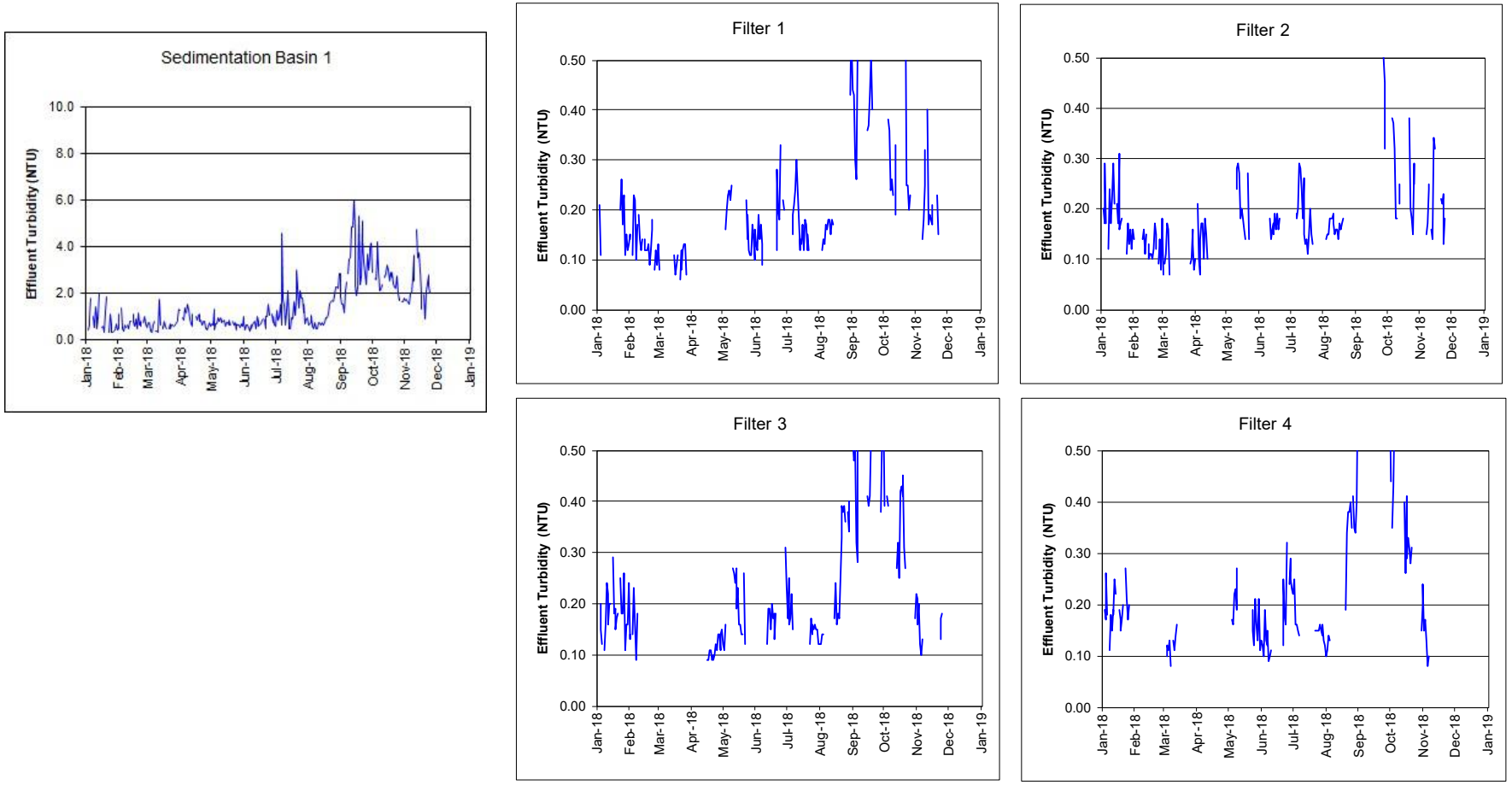
Plant 1 Turbidity Profile Trend

ANNUAL DATA	Avg	Min	Max	95%	Opt. Goal
	NTU	NTU	NTU	NTU	% Values
Raw Turbidity	3.5	1.0	10.8	7.5	n/a
Max. Settled Turbidity	1.4	0.3	6.0	3.6	56
Max. Filtered Turbidity	0.24	0.06	0.86	0.63	59
Combined Filtered Turbidity	0.13	0.07	0.30	0.21	94

Plant 1 Summary

	Settled Water Turbidity					Filtered Water Turbidity								
	95th Percentile Values (NTU)					95th Percentile Values (NTU)								
	Sed 1	Sed 2	Sed 3	Sed 4	All Sed	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Combined
Jan-18	1.81				1.81	0.26	0.29	0.26	0.26	0.17	0.18	0.12	0.14	0.25
Feb-18	1.13				1.13	0.22	0.17	0.22		0.14		0.10		0.18
Mar-18	1.17				1.17	0.13	0.17		0.15	0.12				0.14
Apr-18	1.33				1.33		0.20	0.14		0.13	0.10			0.12
May-18	0.96				0.96	0.24	0.28	0.27	0.24	0.21	0.22	0.19		0.23
Jun-18	1.07				1.07	0.30	0.19	0.27	0.29	0.19	0.19			0.20
Jul-18	2.57				2.57	0.25	0.28	0.23	0.23	0.20	0.20	0.23		0.19
Aug-18	2.52				2.52	0.50	0.18	0.39	0.48	0.20	0.22	0.20		0.17
Sep-18	5.20				5.20	0.53	0.77	0.63	0.84		0.27	0.32	0.20	0.24
Oct-18	3.42				3.42	0.48	0.38	0.44	0.49	0.09	0.20	0.20		0.17
Nov-18	3.70				3.70	0.35	0.33	0.21	0.25		0.18	0.20		0.16
Dec-18														
Yr. 95%	3.61					0.43	0.59	0.50	0.77	0.19	0.23	0.27	0.19	0.21
Yr. Goal	55.6%					67.3%	68.9%	61.1%	54.7%	97.4%	87.4%	82.3%	100.0%	94.4%

Plant 1 Monthly Performance by Basin and Filter



Plant 1 Max Daily Settled Water Turbidity Trend and Individual Filter Max Daily Turbidity Trend

Surface Water Treatment Optimization Training
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AWOP Workshop:
Performance Data Interpretation and Assessment

Prepared by:

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Performance Data Interpretation and Assessment

Instructions:

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Below are the optimization performance goals for the sedimentation barrier and the filtration barrier.

Barrier	Performance Goals
Sedimentation	• Max Daily Turbidity: o 2 NTU 95% time when source turbidity >10 NTU • Max Daily Turbidity: o 1 NTU 95% time when source turbidity ≤ 10 NTU • Frequency of sampling: o Grab – every 4 hours o Continuous – capture highest value per day from SCADA

Filtration	• Max Daily Turbidity: ≤ 0.10 NTU 95% time • Maximum turbidity:≤ 0.30 NTU • Continuous monitoring for IFE and CFE (capture highest value per day from SCADA)

Attached are plant summary reports from Optimization Assessment for a surface water treatment plant. Within your small group, review and evaluate the performance data. Be prepared to discuss your answers to the questions.

Plant 2:

1) What are the turbidity goals for this plant? How is it performing relative to each specific goal?

The average of the maximum daily raw water turbidities over the year was 2.8 NTU, which is below 10 NTU so the goal would be 1.0 NTU for maximum daily settled water turbidity.

The plant met the 1.0 settled water turbidity goal only on about 18.6% of the days and the 95th percentile of the maximum daily settled water turbidity was 2.4 NTU, slightly below the average daily maximum raw water turbidity and above the optimization goal. There is room for performance improvement related to the settled water turbidity goal.

The plant met the individual filter turbidity goal on about 100% of the days and the 95th percentile of the individual filter maximum daily turbidity was 0.04 NTU, indicating optimized performance of the filtration barrier.

The plant met the combined filtered water turbidity goal 100% of the days also, and the 95th percentile of the combined filtered maximum daily turbidity was 0.06 NTU, within the goal of 0.10 NTU. Together with the individual filter performance data, the combined filtered water performance indicates the plant filtration barrier is optimized.

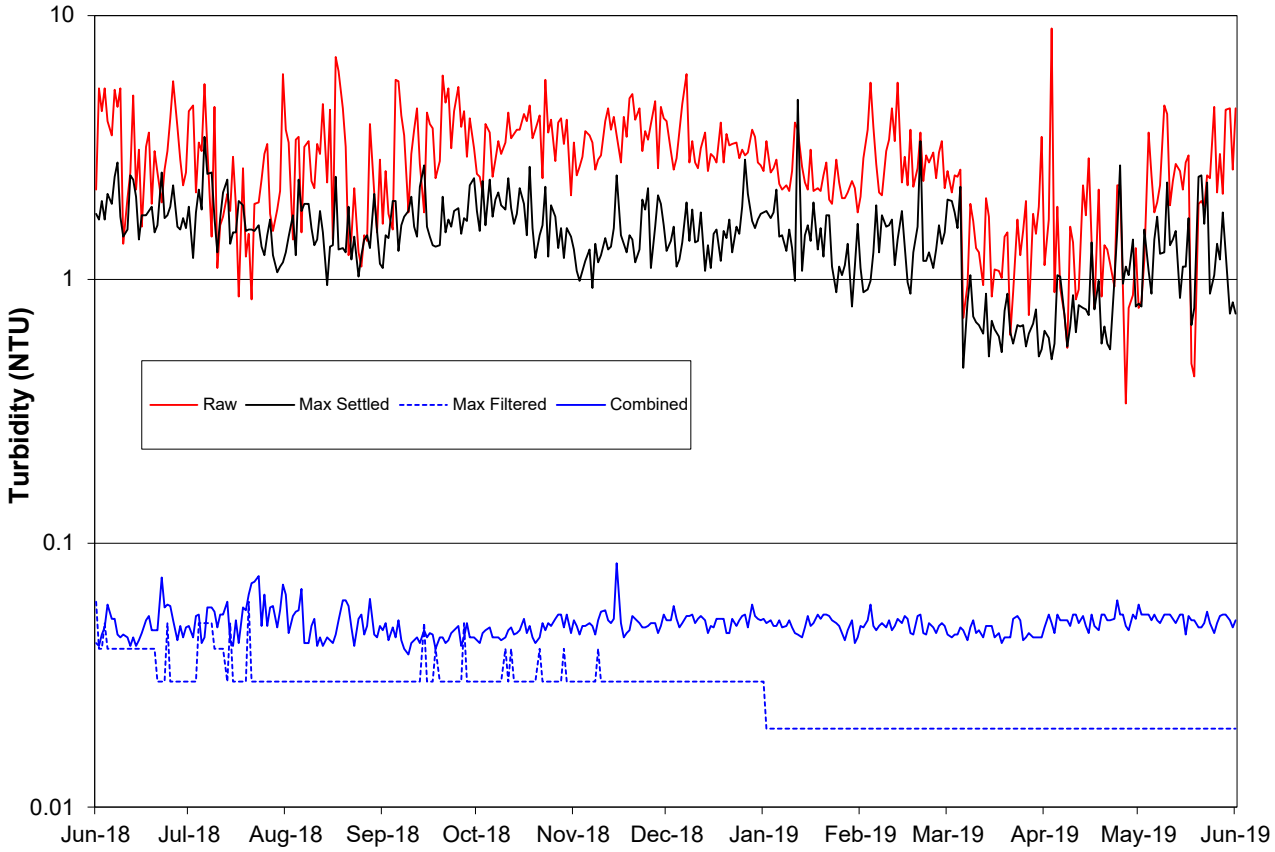
2) Identified areas for performance improvement (i.e., if this were your plant, where would you focus your optimization efforts?).

The operators of Plant 2 would look to optimize their sedimentation performance. In reviewing the performance of each basin individually, the performance seems to be better from Sed 2 (1.75 NTU max daily turbidity 95th percentile) vs. basin 1 (2.42 NTU max daily turbidity 95th percentile). Operators should investigate the operational differences between the basins.

3) Are there any possible data integrity issues that might be evident from the data summaries?

There is only one month of data from Sed 3 and incomplete annual data from Sed 2. Are Sed two and Sed 3 available and not operated part of the year or is the data set incomplete? Either way the

operators should find a way to operate all basins or collect at least 4-hour settled water turbidity samples from all active trains.



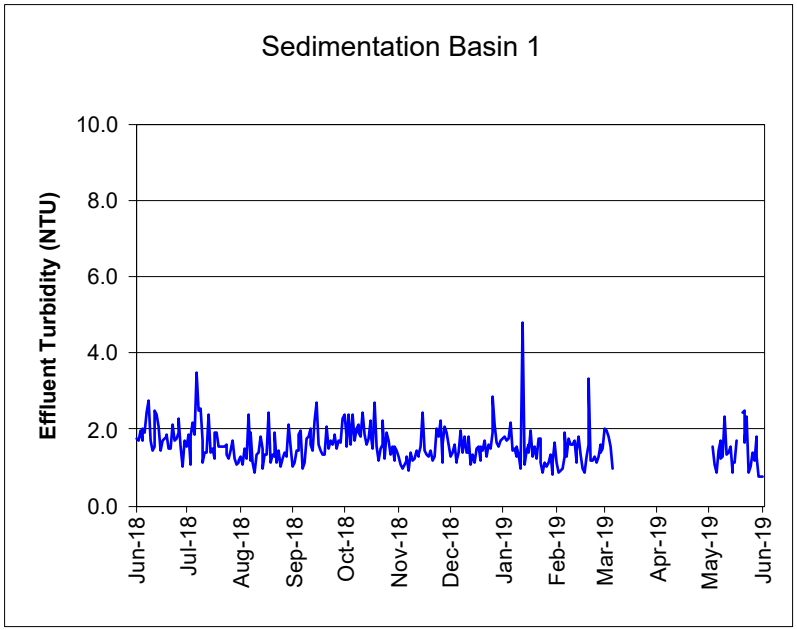
Plant 2 Turbidity Profile Trend

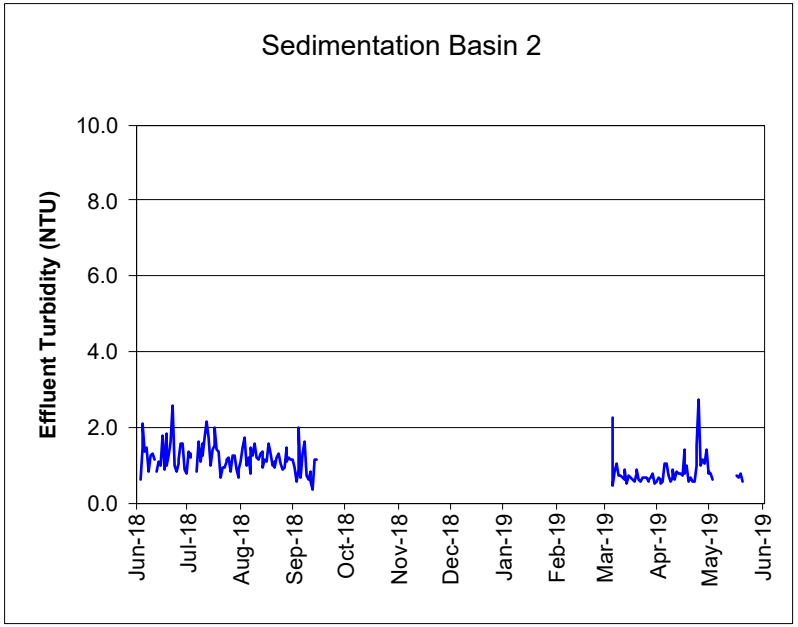
ANNUAL DATA	Avg	Min	Max	95%	Opt. Goal
	NTU	NTU	NTU	NTU	% Values
Raw Turbidity	2.8	0.3	8.9	5.2	n/a
Max. Settled Turbidity	1.5	0.5	4.8	2.4	18.6
Max. Filtered Turbidity	0.03	0.02	0.06	0.04	100.0
Combined Filtered Turbidity	0.05	0.04	0.08	0.06	100.0

Plant 2 Summary

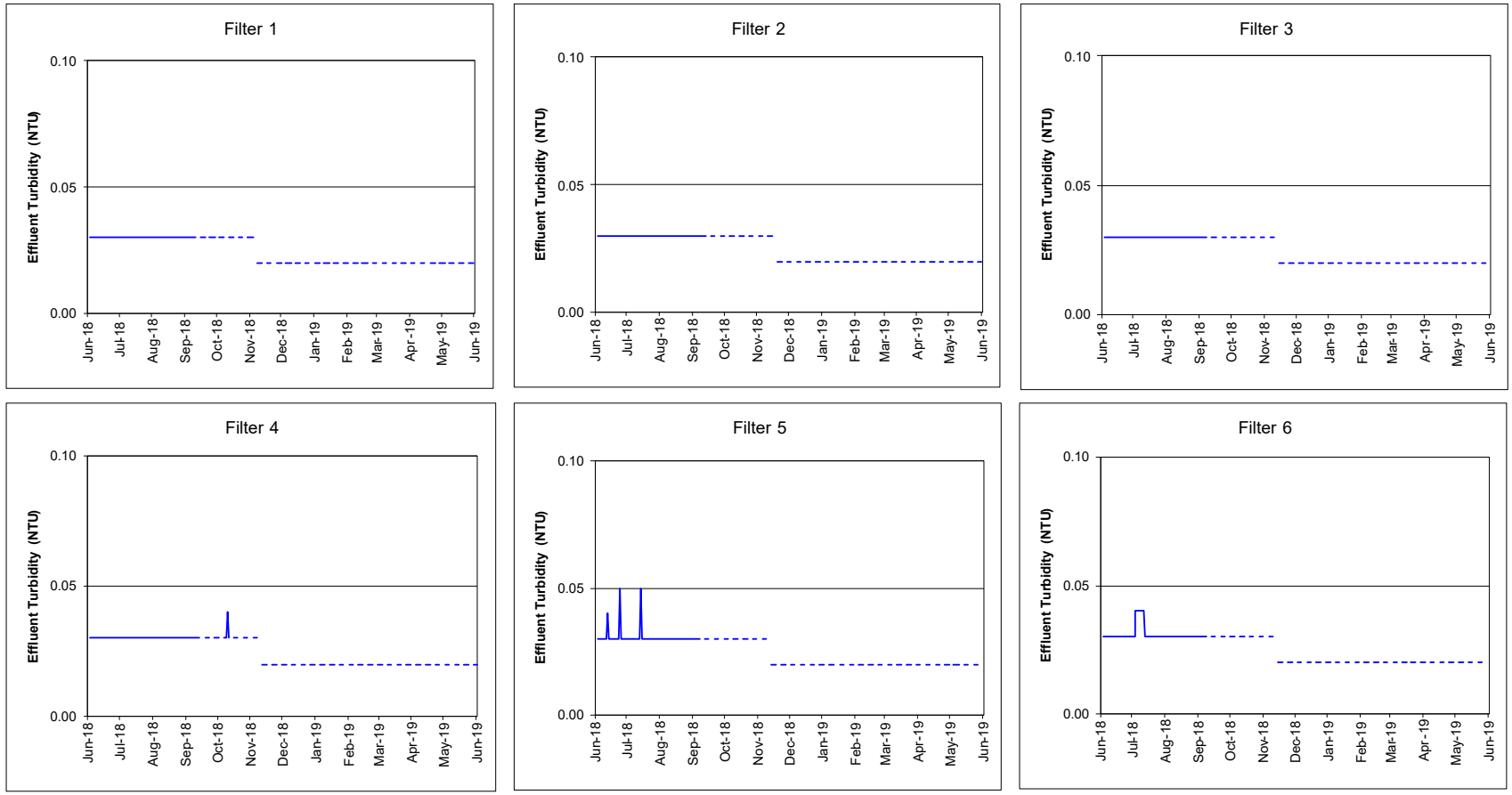
	Settled Water Turbidity							Filtered Water Turbidity														
	95th Percentile Values (NTU)					% Values Meeting Goal		95th Percentile Values (NTU)														
	Sed 1	Sed 2	Sed 3	Sed 4	All Sed	2 NTU	1 NTU	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter 9	Filter 10	Filter 11	Filter 12	Filter 13	Filter 14	Combined
Jun-18	2.47	2.00			2.45	82.76	17.2	0.03	0.03	0.03	0.03	0.04	0.03	0.04	0.03	0.05	0.03	0.03	0.03	0.03	0.03	0.06
Jul-18	2.52	1.88			2.39	90.00	15.0	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.05	0.03	0.03	0.03	0.03	0.03	0.07
Aug-18	2.24	1.56	1.89		1.93	95.77	21.1	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.06
Sep-18	2.35	1.70			2.27	86.96	26.1	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.05
Oct-18	2.40				2.40	77.42		0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.05
Nov-18	2.16				2.16	86.67	6.7	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.06
Dec-18	2.03				2.03	93.55		0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.06
Jan-19	2.06				2.06	93.55	9.7	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.05
Feb-19	1.87				1.87	96.43	17.9	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.05
Mar-19	1.99	0.99			1.98	96.88	81.3	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.05
Apr-19		1.48			1.48	96.67	73.3	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.05
May-19	2.41	0.82			2.37	88.57	37.1	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.05
Yr. 95%	2.42	1.75	1.89					0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03
Yr. Goal	6.5%	54.4%	66.7%					100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Plant 2 Monthly Performance by Basin and Filter

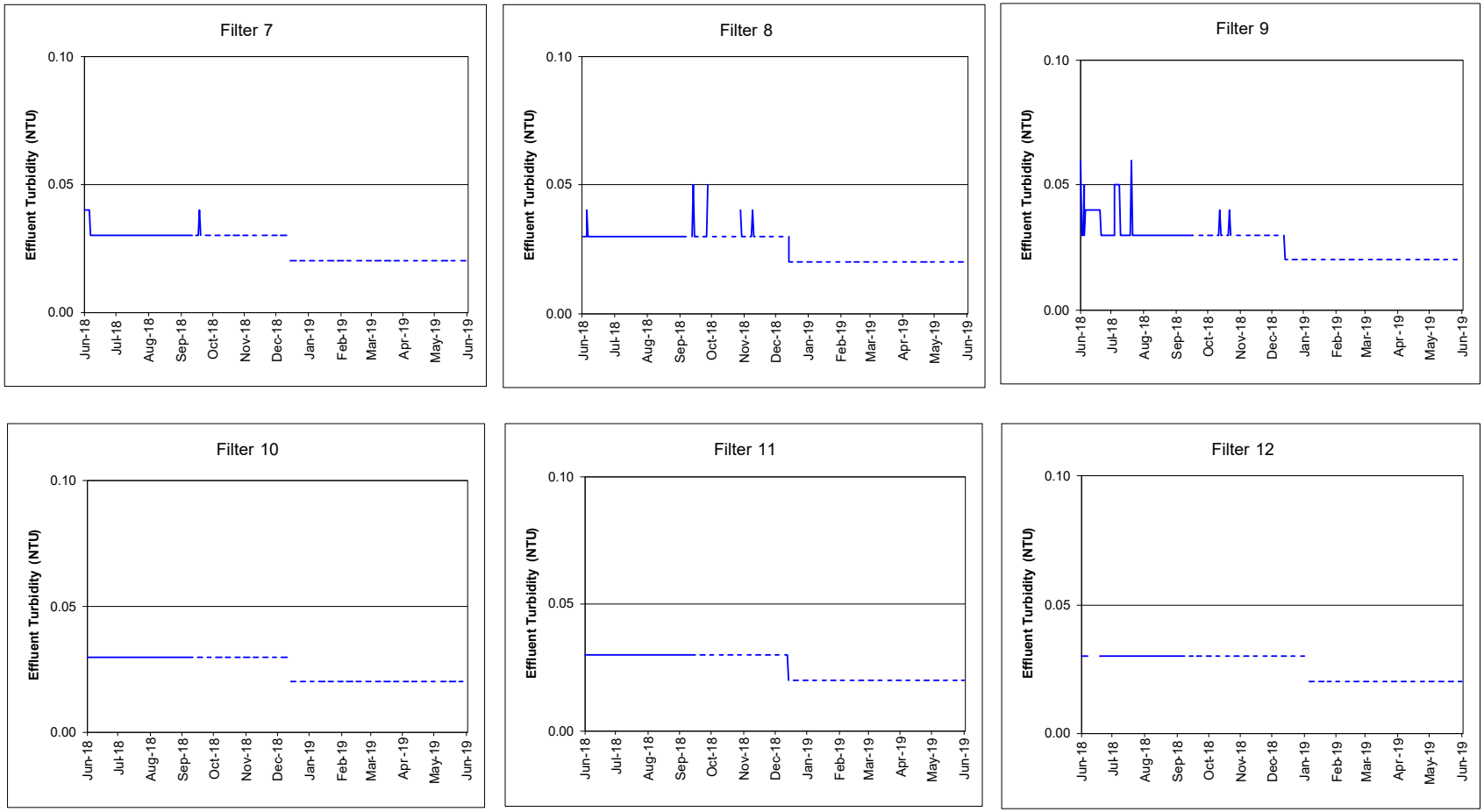




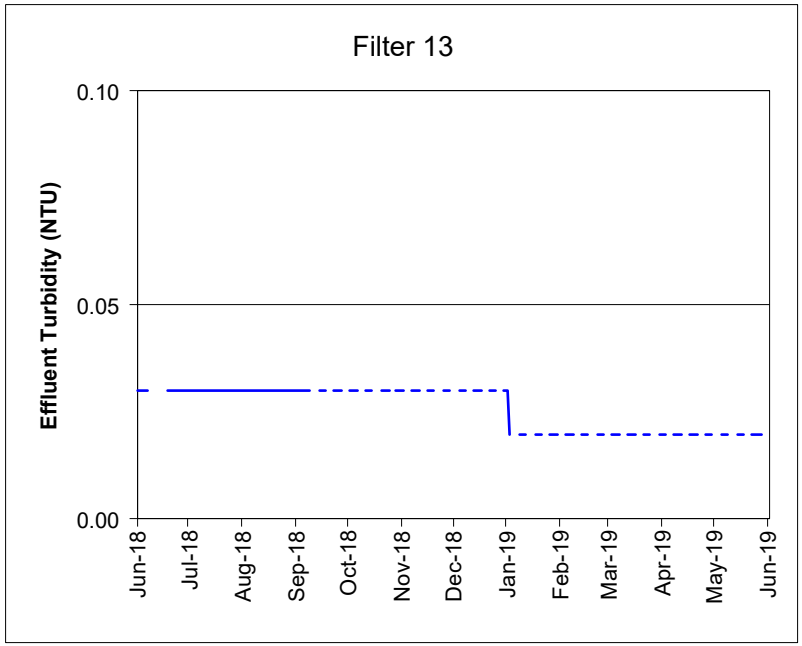
Plant 2 Max Daily Individual Sedimentation Basin Settled Water Turbidity Trend

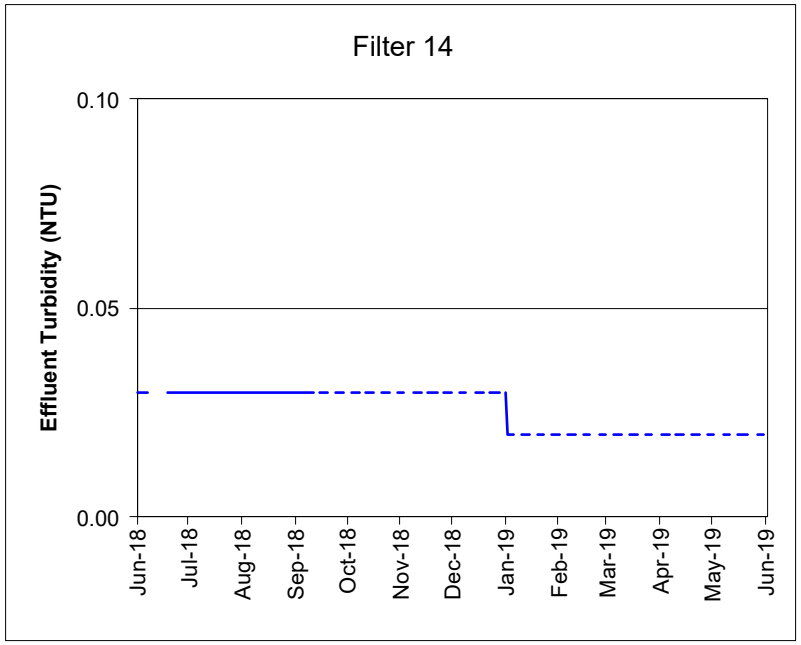


Plant 2 Max Daily Individual Filter Turbidity Trend



Plant 2 Max Daily Individual Filter Turbidity Trend continued





Plant 2 Max Daily Individual Filter Turbidity Trend continued

Surface Water Treatment Optimization Training
West Fargo, North Dakota
April 22, 2025

AWOP Workshop:
Performance Data Interpretation and Assessment

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AWOP Workshop:
Performance Data Interpretation and Assessment

Instructions:

Collecting and assessing plant performance data is an important step to establish the status of a plant relative to achieving optimized performance goals. The purpose of this workshop is for the participants to explore methods for summarizing and evaluating a plant's historical performance data and to develop interpretation skills.

Below are the optimization performance goals for the sedimentation barrier and the filtration barrier.

Barrier	Performance Goals
Sedimentation	• Max Daily Turbidity: o 2 NTU 95% time when source turbidity >10 NTU • Max Daily Turbidity: o 1 NTU 95% time when source turbidity ≤ 10 NTU • Frequency of sampling: o Grab – every 4 hours o Continuous – capture highest value per day from SCADA

Filtration	• Max Daily Turbidity: ≤ 0.10 NTU 95% time • Maximum turbidity:≤ 0.30 NTU • Continuous monitoring for IFE and CFE (capture highest value per day from SCADA)

Attached are plant summary reports from Optimization Assessment for a surface water treatment plant. Within your small group, review and evaluate the performance data. Be prepared to discuss your answers to the questions.

Plant 3:

1) What are the turbidity goals for this plant? How is it performing relative to each specific goal?

The average of the maximum daily raw water turbidities over the year was 10.4 NTU, which is above 10 NTU so the goal would be 2.0 NTU for maximum daily settled water turbidity.

The plant never met the 2.0 settled water turbidity goal and the 95th percentile of the maximum daily settled water turbidity was 15.2 NTU, well above the goal. Settled water performance could definitely be improved.

The plant met the individual filter turbidity goal only on 6% of the days and the 95th percentile of the individual filter maximum daily turbidity was 2.00 NTU, indicating poor performance from the filtration barrier.

The plant met the combined filtered water turbidity goal 37% of the days and the 95th percentile of the combined filtered maximum daily turbidity was 0.32 NTU, well above the combined filtered water goal of 0.10 NTU.

2) Identified areas for performance improvement (i.e., if this were your plant, where would you focus your optimization efforts?)

Both the sedimentation and filtration barriers are in need of improved performance improvement. In reviewing the individual sedimentation data, it appears that two trains are available but only one is used at a time. When operating, Sed 2 seems to perform better than Sed 1. (The 95th percentile of the Sed 2 max daily turbidities is 10.94 for the year vs. 16.87 for Sed 1). Operators should focus on overall improvement to the sedimentation process, which may improve filer performance as well if coagulant feeds can be optimized.

The individual filter data is capped at 2.0 NTU and the 95th percentile is at that limit for 7 of the 14 filters. Filter 10 seems to perform much better than the other filters, even though it's max daily turbidity 95th percentile (0.28 NTU) is still above the optimization goal. Operators should

investigate the large difference between the filtered water turbidity readings at Filter 10 to determine if filter operation or data integrity is causing the difference.

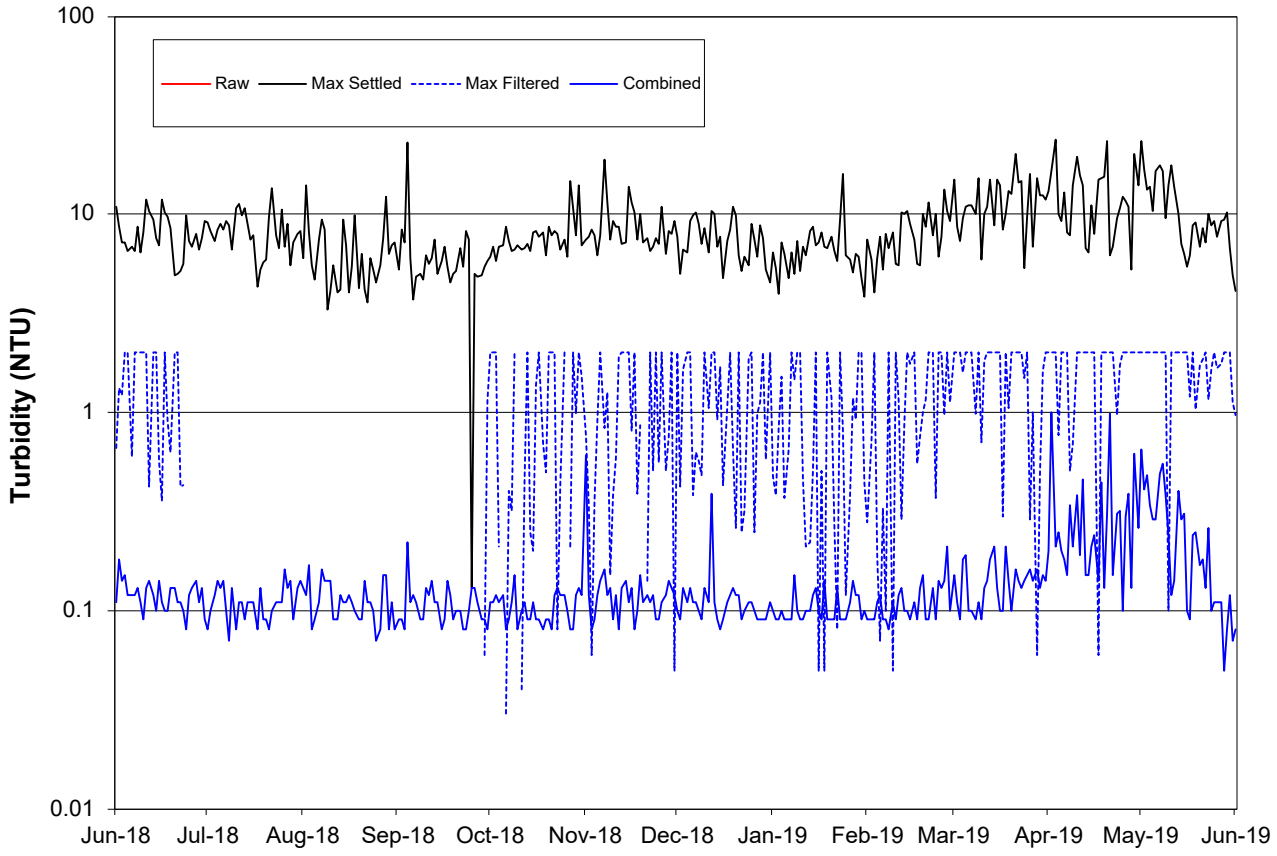
3) Are there any possible data integrity issues that might be evident from the data summaries?

There are signal span/data capping issues. The individual filter turbidity data seems to be capped at 2.0 NTU and the combined filtered turbidity data seems to be capped at 1.0 NTU.

There is a large discrepancy between the filter performance at filter 10 compared to the other filters, which could be due to a data integrity issue.

There is much variation in the maximum daily individual filter turbidity trend line, possibly caused by some sort of data integrity issue.

Although the summary table shows ave., max., and min values for the daily raw water turbidity, there is insufficient data to graph on the plant profile and likely insufficient data to confidently set the settled water goal and to read trends that the profile graph might display. Operators should collect at least daily raw water turbidity samples and run analyses.



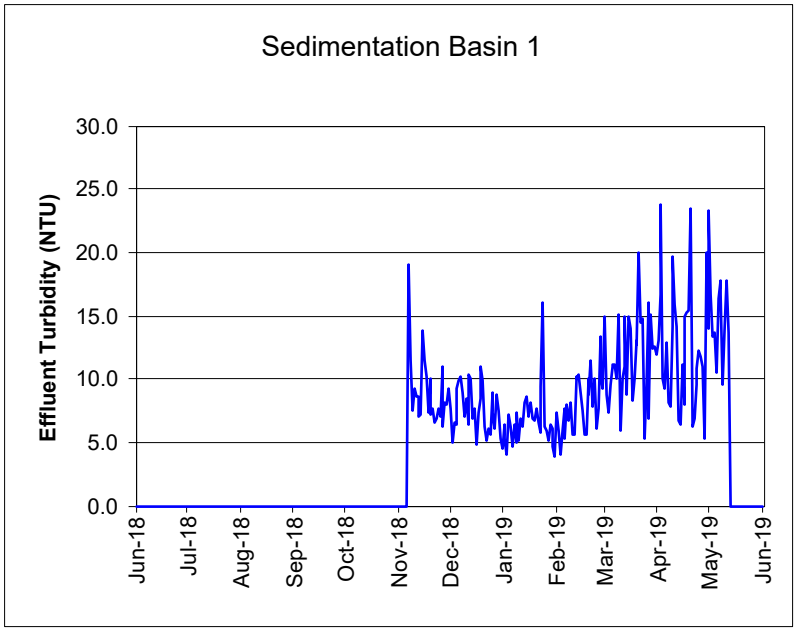
Plant 3 Turbidity Profile Trend

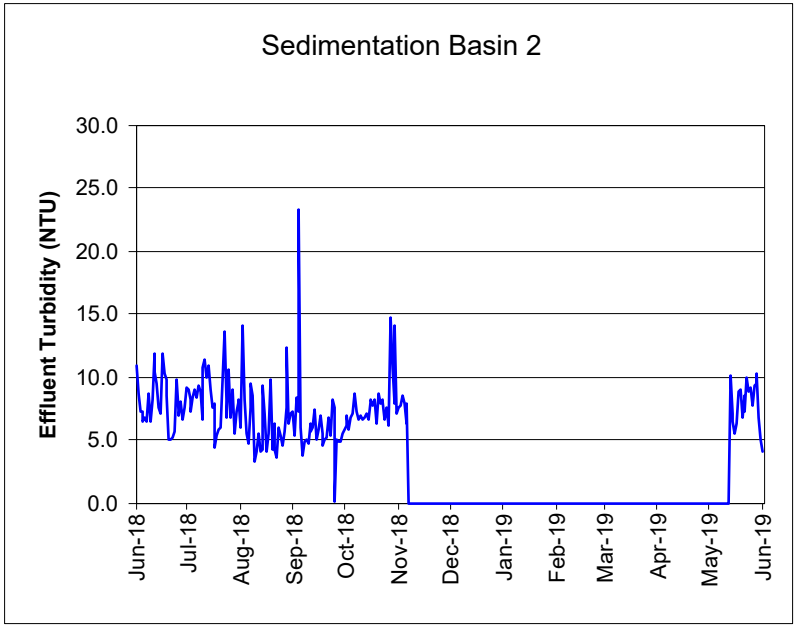
ANNUAL DATA	Avg	Min	Max	95%	Opt. Goal
	NTU	NTU	NTU	NTU	% Values
Raw Turbidity	10.4	8.6	12.2	12.0	n/a
Max. Settled Turbidity	8.5	0.1	23.8	15.2	0
Max. Filtered Turbidity	1.33	0.03	2.00	2.00	6
Combined Filtered Turbidity	0.14	0.05	1.00	0.32	37

Plant 3 Summary

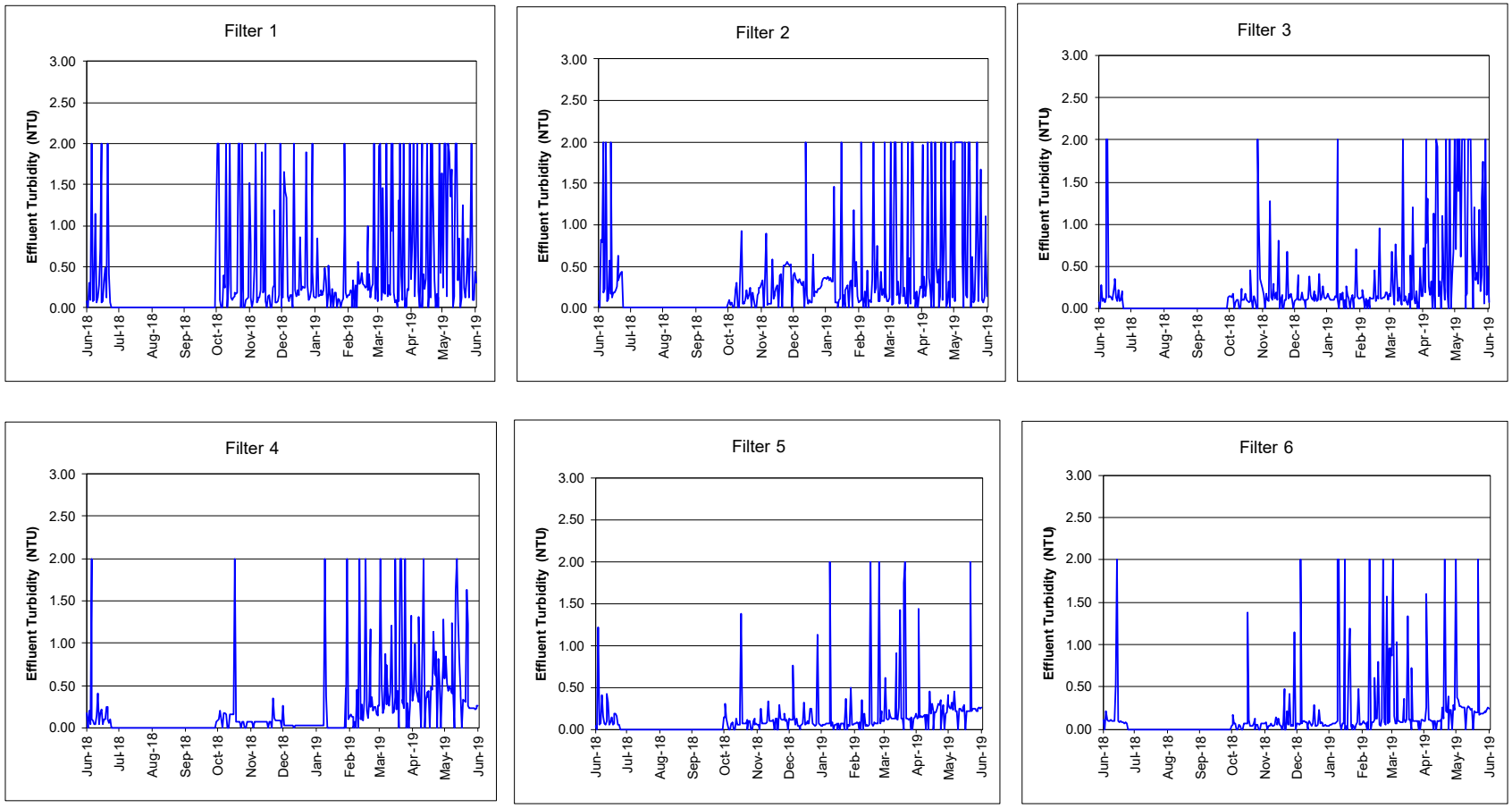
	Settled Water Turbidity					Filtered Water Turbidity												
	95th Percentile Values (NTU)			Percent Meeting Goal		95th Percentile Values (NTU)												
	Sed 1	Sed 2	All Sed	2 NTU	1 NTU	Filter 1	Filter 2	Filter 3	Filter 4	Filter 5	Filter 6	Filter 7	Filter 8	Filter 9	Filter 10	Filter 11	Filter 12	Combined
Jun-18		11.40	11.40			2.00	2.00	1.84	0.39	0.42	0.50	0.36	1.94	0.54	0.08	2.00	1.24	0.15
Jul-18		11.05	11.05															0.14
Aug-18		11.06	11.06															0.16
Sep-18		8.30	8.30	3.33	3.3	1.09	0.05	0.13	0.08	0.13	0.04	0.05	0.31	0.10	0.03	0.08	0.33	0.14
Oct-18		12.40	12.40			2.00	0.38	0.72	0.19	0.25	0.15	2.00	0.22	0.37	0.11	0.60	0.27	0.13
Nov-18	13.46	8.29	12.77			2.00	0.58	0.75	0.11	0.27	0.45	1.43	1.30	0.51	0.08	0.88	1.44	0.16
Dec-18	10.25		10.25			1.95	0.54	0.39	0.03	0.54	0.26	0.25	2.00	0.90	0.14	1.49	0.97	0.13
Jan-19	8.97		8.97			0.88	1.32	0.48	1.24	0.43	2.00	0.49	2.00	2.00	0.27	0.76	0.76	0.14
Feb-19	11.12		11.12			0.85	2.00	0.38	1.71	1.42	1.85	0.80	1.71	0.81	0.29	0.92	1.27	0.15
Mar-19	15.55		15.55			2.00	2.00	0.98	2.00	1.58	1.18	2.00	2.00	2.00	0.28	1.91	2.00	0.20
Apr-19	21.93		21.93			2.00	2.00	2.00	1.30	0.43	1.82	0.56	1.04	1.72	0.26	2.00	2.00	0.82
May-19	20.28	10.05	17.80			2.00	2.00	2.00	1.63	0.38	1.19	0.22	1.08	2.00	1.80	2.00	2.00	0.52
Yr. 95%	16.67	10.94				2.00	2.00	2.00	1.63	0.57	1.48	1.11	2.00	2.00	0.28	2.00	2.00	0.32
Yr. Goal		0.6%				24.2%	32.0%	29.7%	49.4%	51.3%	63.2%	50.2%	56.5%	31.6%	79.2%	30.9%	47.0%	37.4%

Plant 3 Monthly Performance by Basin and Filter

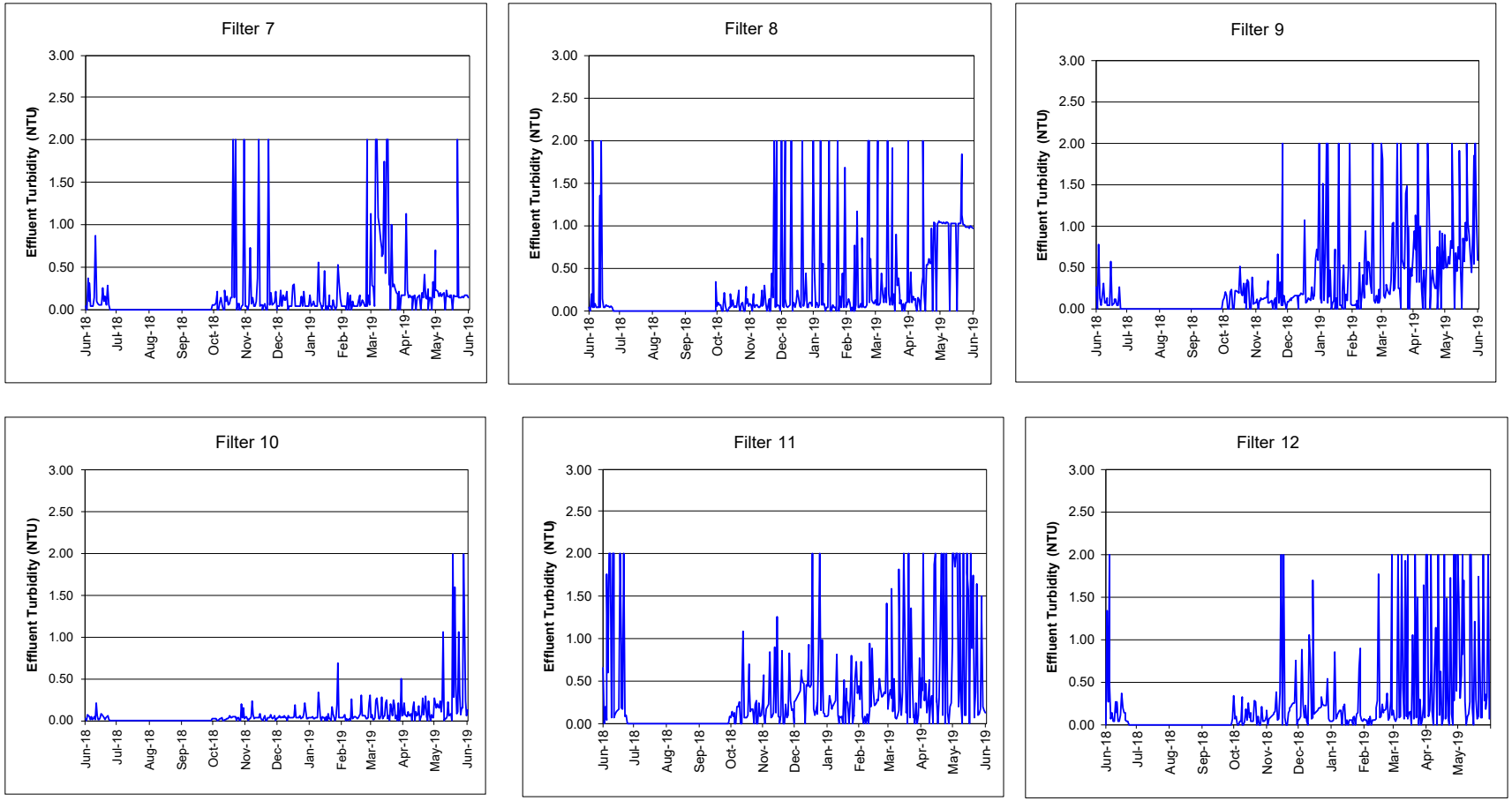




Plant 3 Max Daily Individual Sedimentation Basin Settled Water Turbidity Trend



Plant 3 Max Daily Individual Filter Turbidity Trend



Plant 2 Max Daily Individual Filter Turbidity Trend continued