Startup and Commissioning Enhanced High-Rate Treatment in Cincinnati

27 June 2019

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Principal Process Engineer

OWEA 2019

METROPOLITAN SEWER DISTRICT of greater CINCINNATI

BLACK & VEATCH

Agenda

- Background
- Process Overview
- Operational Modes
- Commissioning Update
- Q&A

PROJECT GROUNDWORK
your pipeline to clean water

Background

Combined Sewer Overflow 522

- Headwaters for Schaible Creek
- Highly active CSO
  - 66 discharge events in typical year
  - ~600 MGY overflow
  - Wide range of flows up to 1,400-mgd
- Site for EHRT demonstration facility

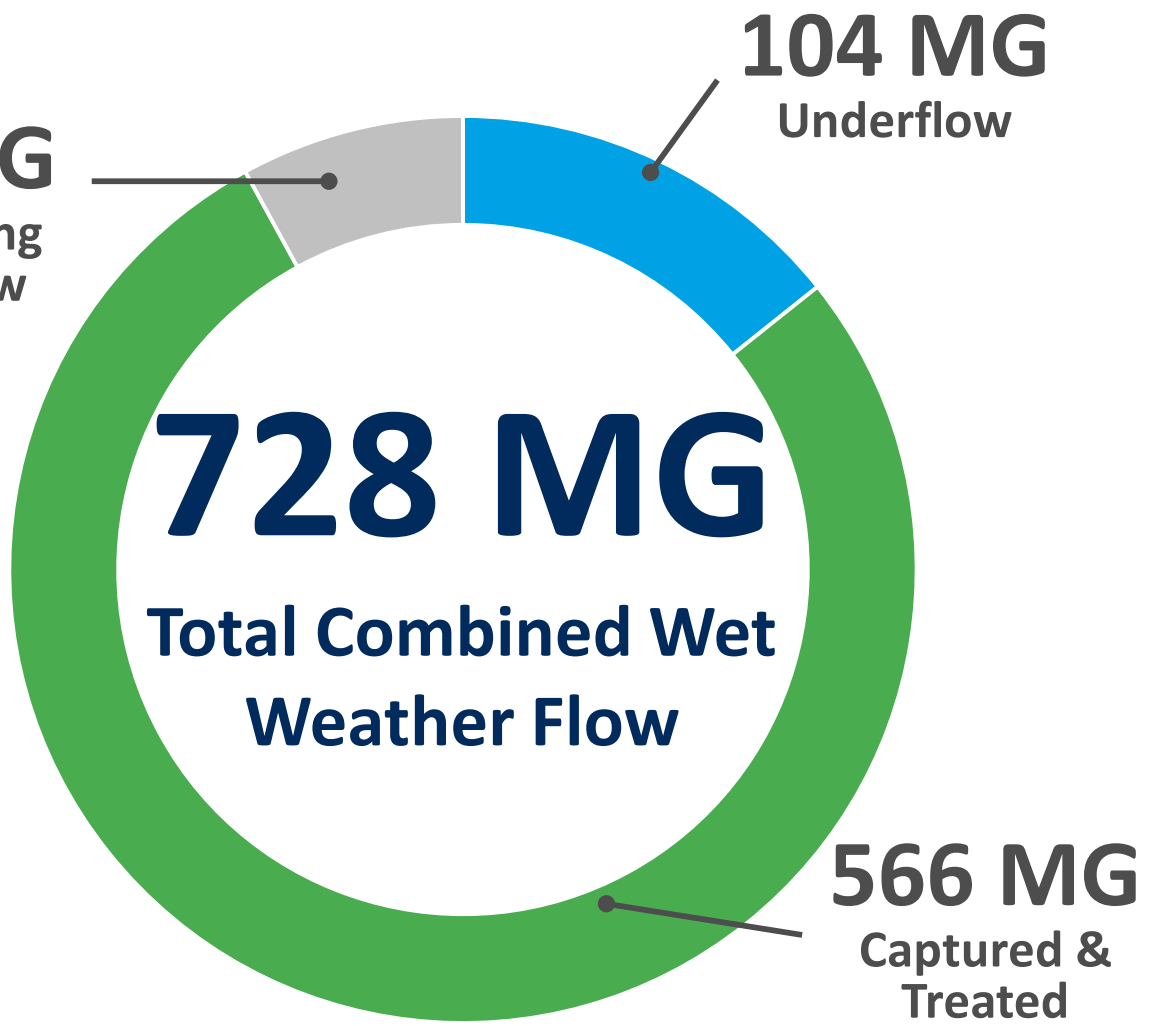
Community Priority to minimize public health risk, sewer debris, and odors

Consent Decree Requirements for EHRT

Effluent Quality Goals (May 1 – October 30 Recreation Season)	
TSS (average)	TSS_{INF} > 150 mg/L → 70% removal, **OR** TSS_{INF} ≤ 150 mg/L → ≤ 45 mg/L
E. coli (mean)	≥3 to 4 log reduction • Estimated to provide ≤ 1,030 cfu/mL in effluent
Processes and Design Criteria	
Fine Screens	-
Chemically Enhanced Sedimentation	SOR ≤ 7,000 gpd/ft^2
Hypochlorite Disinfection	Contact time ≥ 10 minutes
Dechlorination	

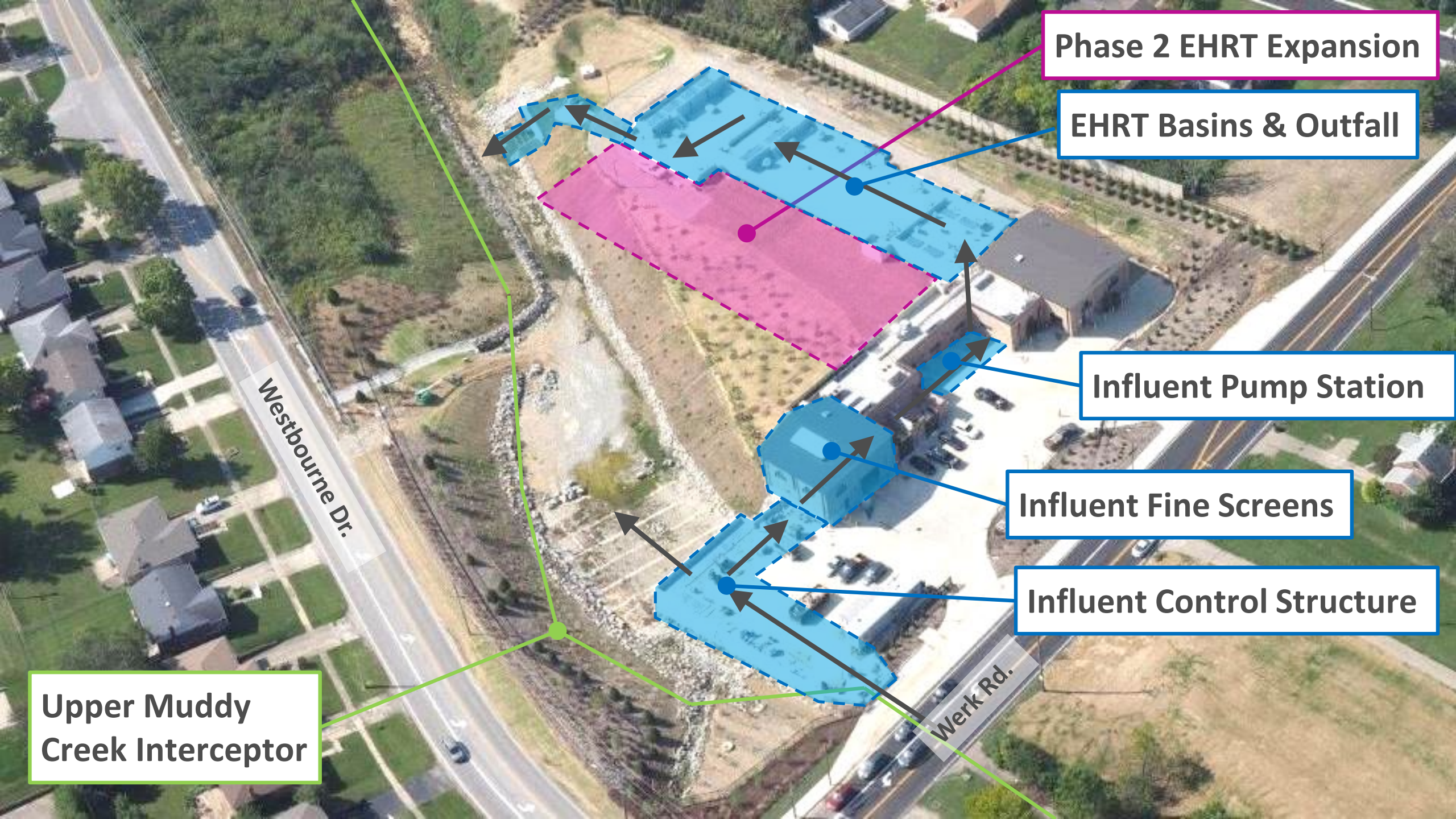
WWEHRTF Volumetric Control

- Typical Year
- Phase 1 EHRT - Pilot
- Phase 2 EHRT for ≤ 64.7 MG



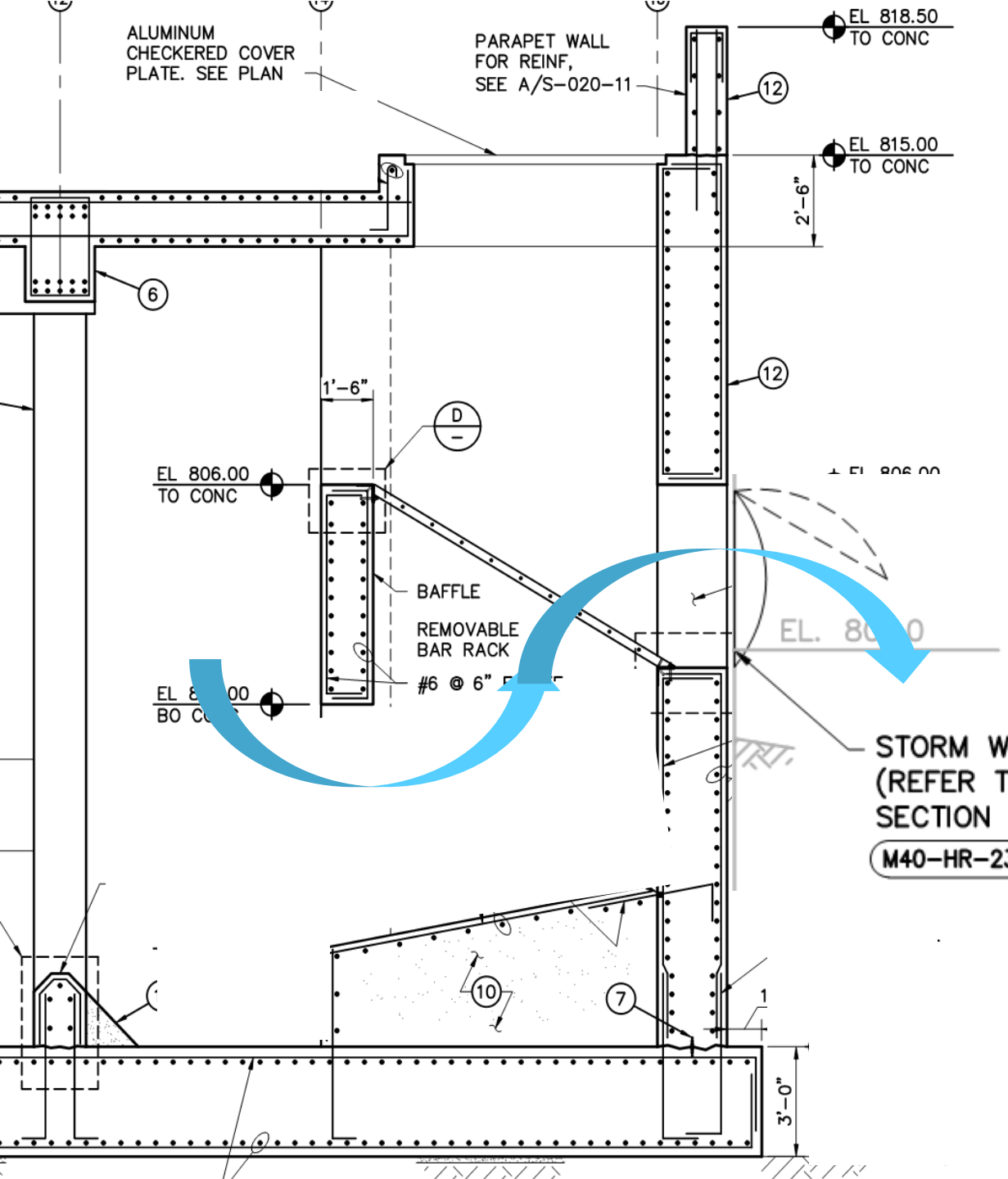
100 Percent of Flows Receive Coarse Screenings and Floatables Control at Minimum Under Phases 1 & 2

Process Overview


Phase 2 EHRT Expansion
EHRT Basins & Outfall
Influent Pump Station
Influent Fine Screens
Influent Control Structure
Upper Muddy Creek Interceptor
Westbourne Dr.
Werk Rd.

Influent Control Structure

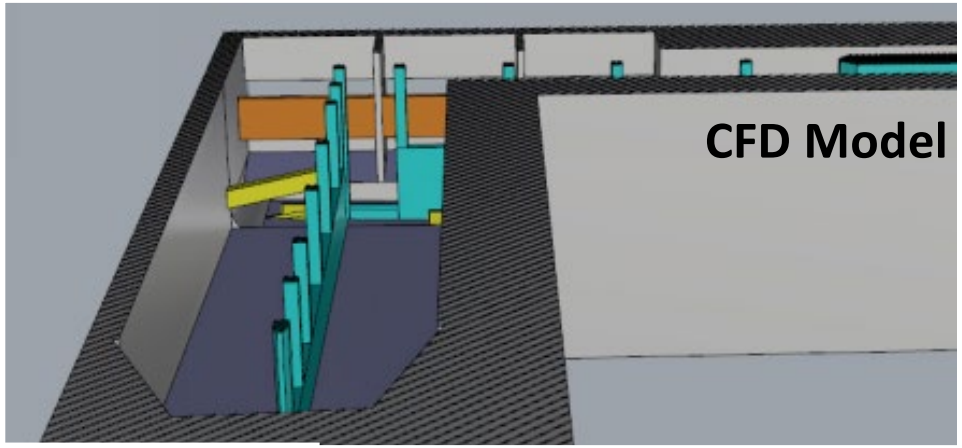
- Dissipate energy
- Control flows into facility up to peak capacity and release excess flows to creek
- Promote solids capture and clean-up post event for odor control
- No dry weather flow
- Coarse screening and floatables control

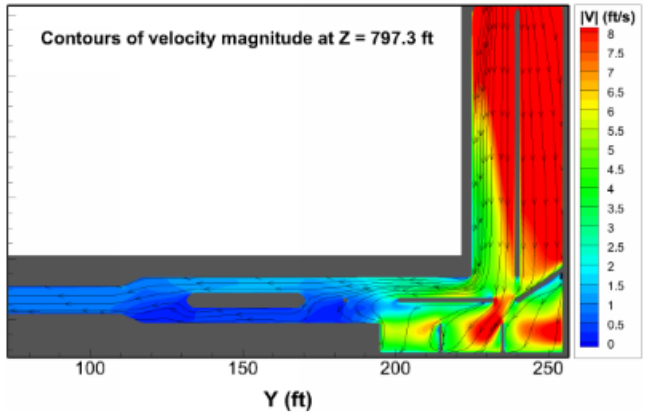


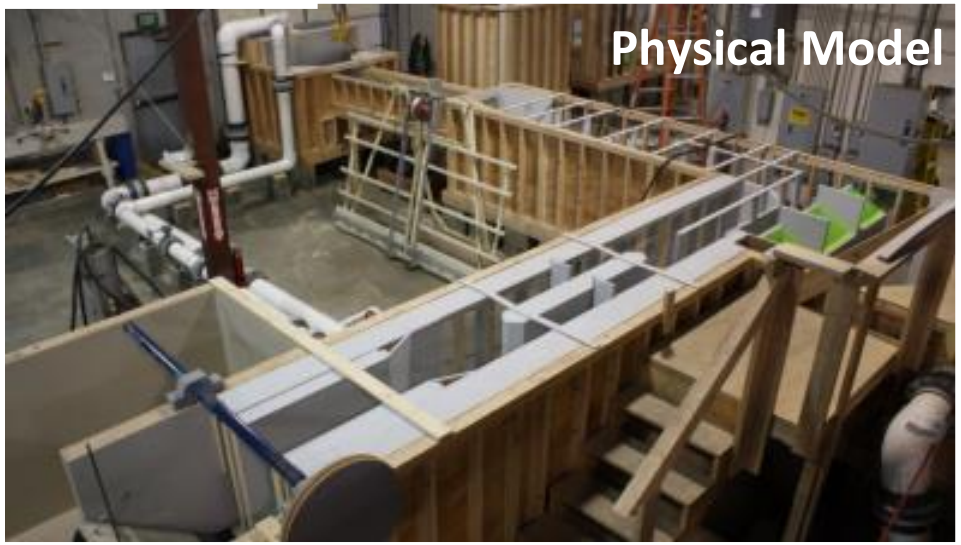
ICS Screens and Floatables Control

- Flows over EHRT capacity
- 3 Bar Racks w/ 2” Openings
- 3 Flap Gates
- Overflows to Schaible Creek

Creek bed armored with ArmorFlex and aggregate infill



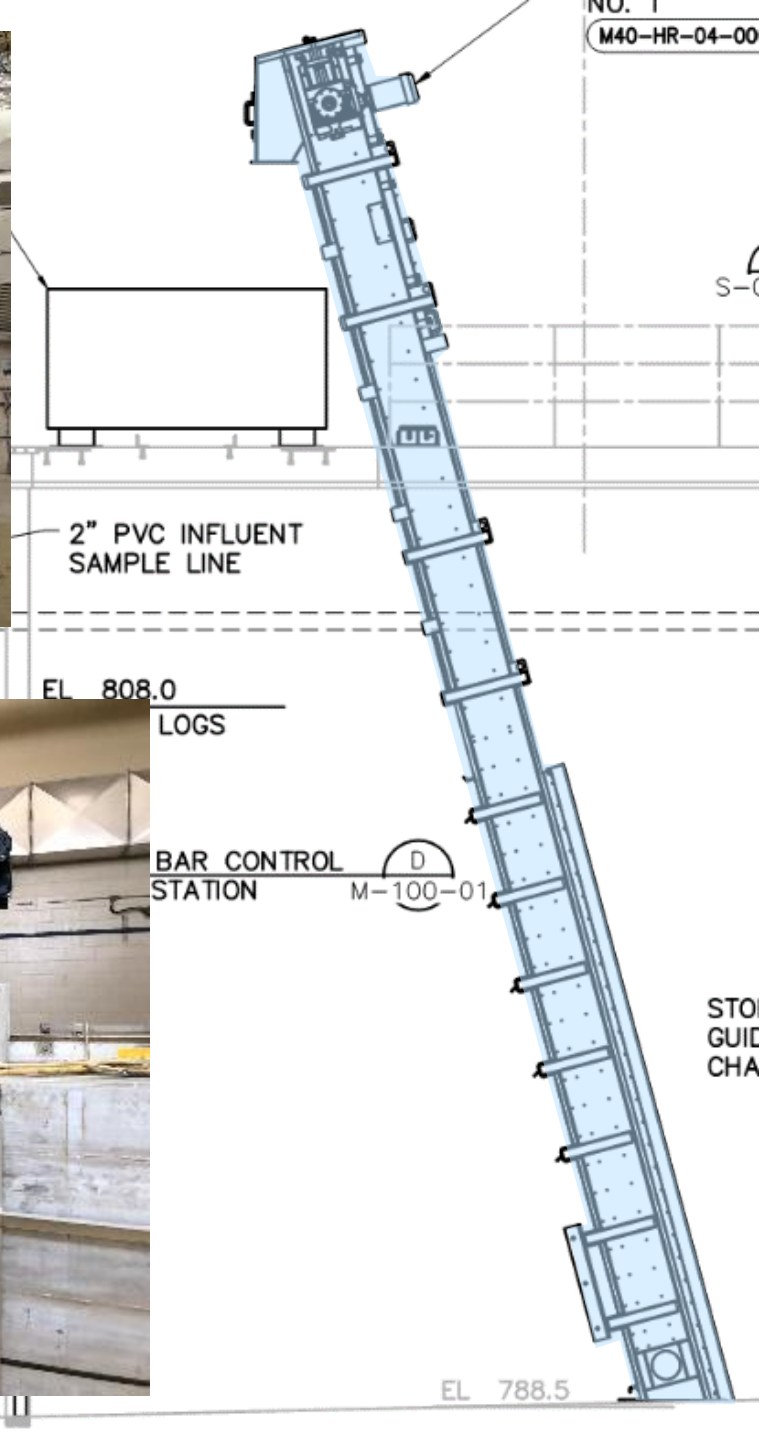




Combined CFD and Physical Scale Modeling

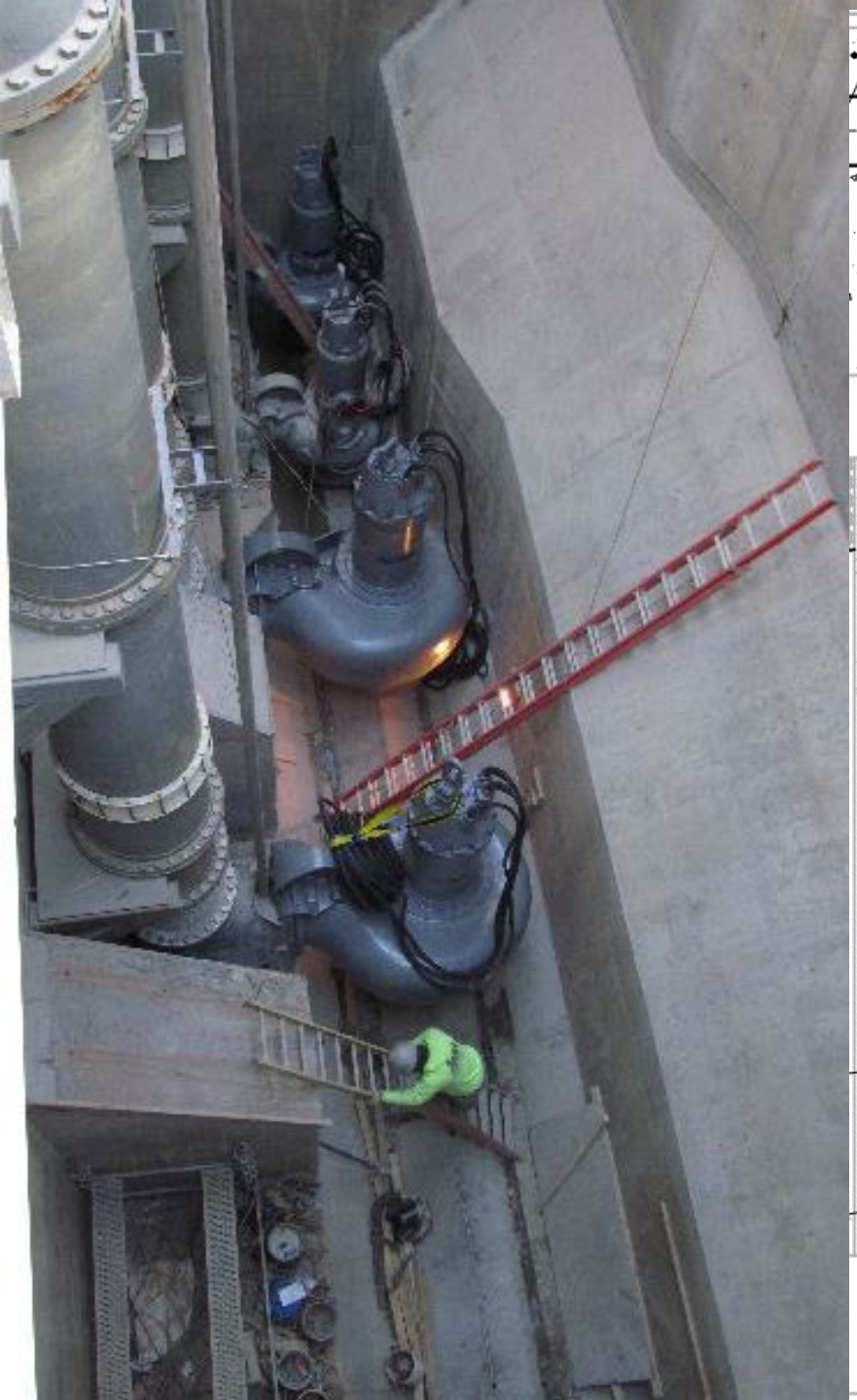
- Optimize design of Influent Control Structure
  - Flow distribution
  - Velocity control
  - Solids deposition (grit)
  - Screen loading
- Interior baffle and wall details

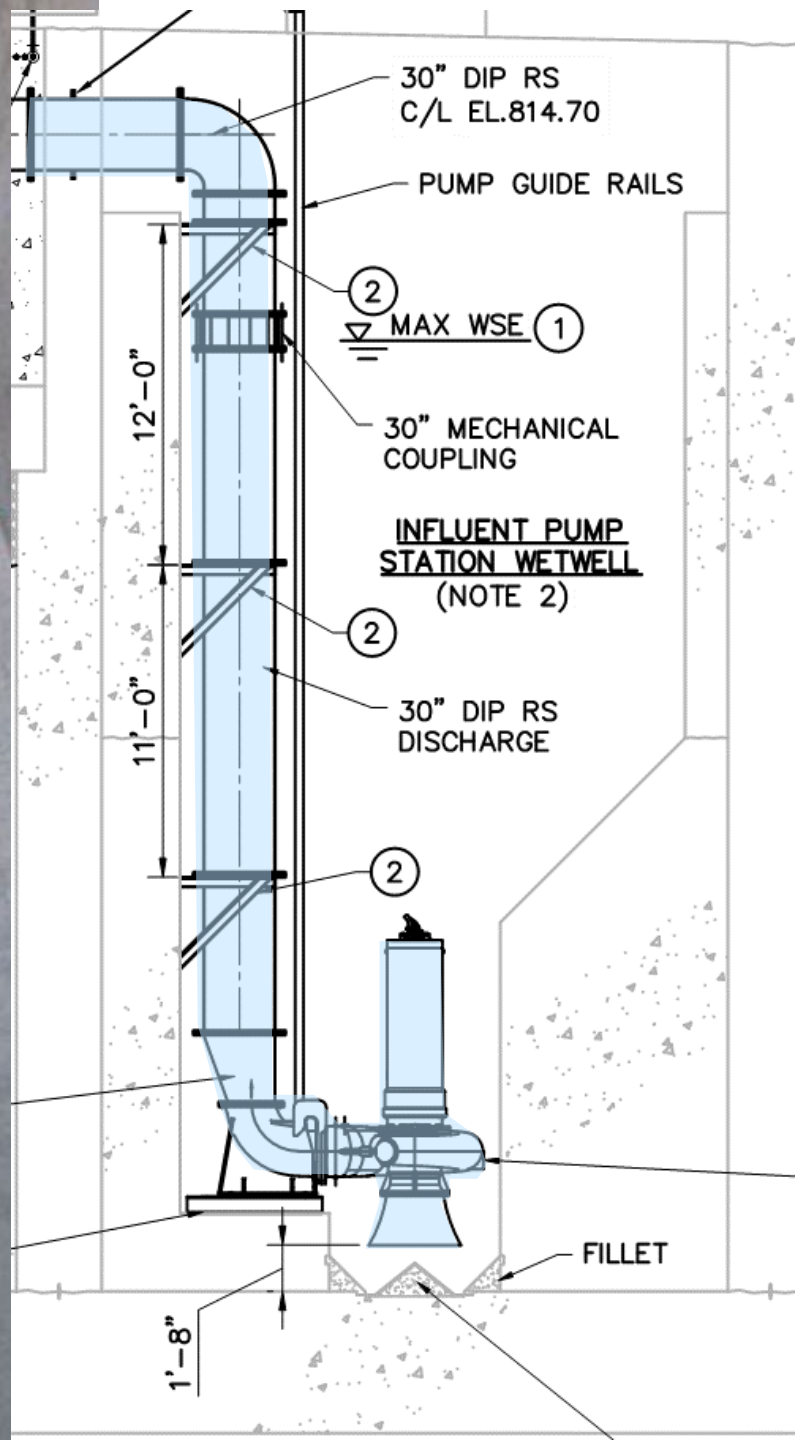
Key to good design for heavy solids and post-event self-cleaning



Influent Fine Screens

- Multi-rake bar screens
- Two @ 53-mgd each
- 5-ft wide channels
- ½" openings
- 75° inclination
- Direct discharge to 20 CY roll-off container





Influent Pump Station

- Submersible, non-clog
- Two large (35-mgd), two small (18-mgd), spare slot
- Firm capacity: 71-mgd (Phase 1), 106-mgd (Phase 2)
- Level-controlled, adjustable speed
- Self-cleaning, trench wetwell

Chemically Enhanced Sedimentation and Disinfection

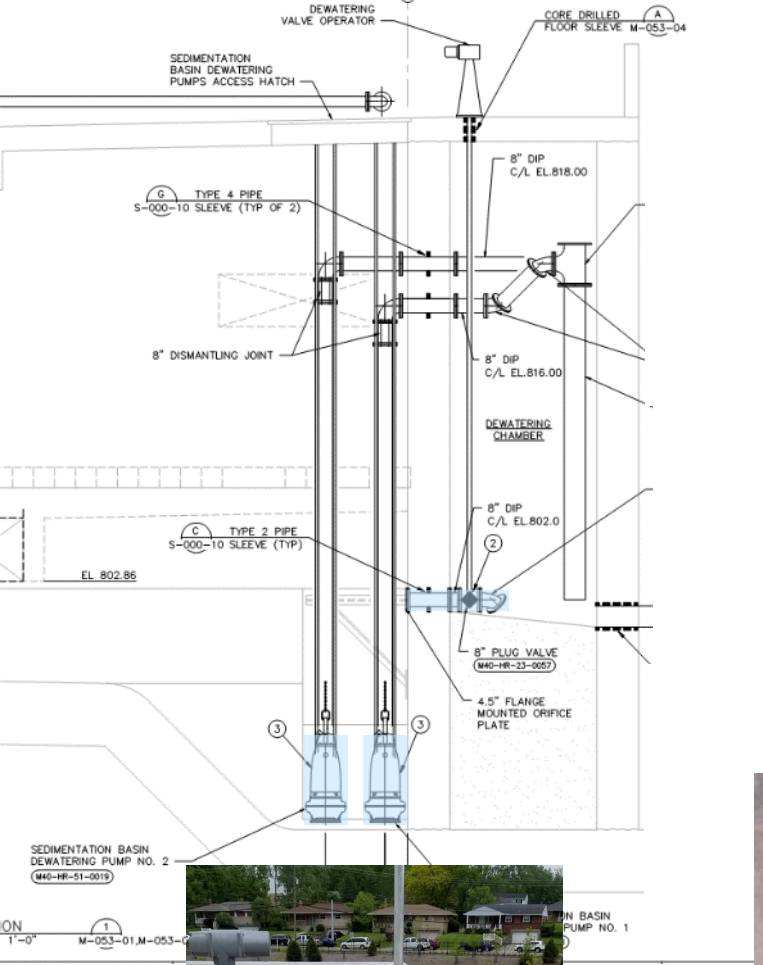
- Coagulant rapid mix, polymer rapid mix and flocculation chambers
- Sedimentation: SOR 7,000 gpd/sf @ 35-mgd, 3:1 length to width
- Disinfection: 15-min contact time @ 35 mgd, 10-min @ 53-mgd
- Mixed-mode channel for disinfection of fine screened effluent (optional)

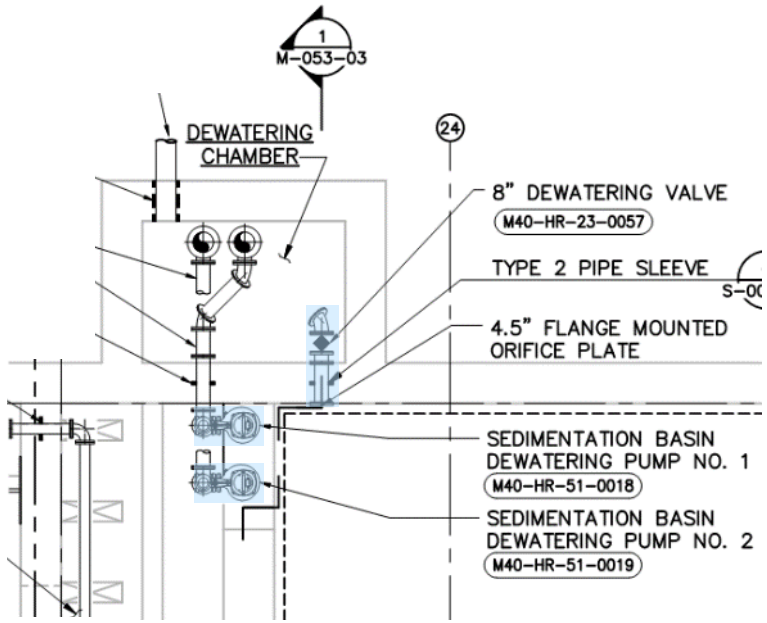
Chemical Systems

- Coagulant (ferric chloride)
  - 6000-gal tank
  - Two peristaltic feed pumps
- Polymer (anionic polyacrylamide)
  - Two 400-gal yotes
  - Two feeder/blenders (progressive cavity pumps)
- Sodium Hypochlorite
  - 6000-gal tank
  - Three peristaltic hose pumps
  - Two centrifugal recirculation pumps
- Sodium Bisulfite
  - Two 400-gal totes
  - Two peristaltic feed pumps

Sample System

- Three submersible sample pumps
  - Screened influent
  - CES effluent
  - Final effluent
- Pump to sample sink and refrigerated samplers





Dewatering System

- Gravity-flow headbox
- ~50% by gravity then pumped
- Two 1.5-mgd pumps, 20 hp, submersible, non-clog
- Level-controlled, adjustable speed

CNPW and Flushing Systems

- Break tank, 3 pumps, hydropneumatic tank
- Automated flushing sequence
  - 13 tipping buckets
  - 11 spray bars

Operational Modes

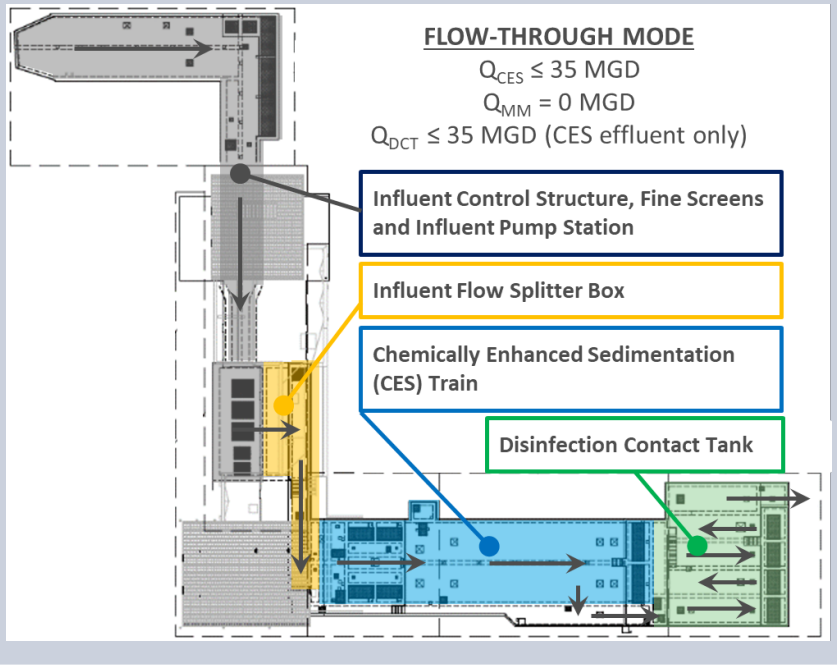
Pre-Event Activities

- ✓Weather forecast
- ✓Chemical inventories
- ✓Weather forecast
- ✓Exercise equipment
- ✓Weather forecast
- ✓Preventative maintenance
- ✓Weather forecast
- ✓Inspection and troubleshooting
- ✓Weather forecast
- ✓Training
- ✓Weather forecast
- ✓Public education and facility tours

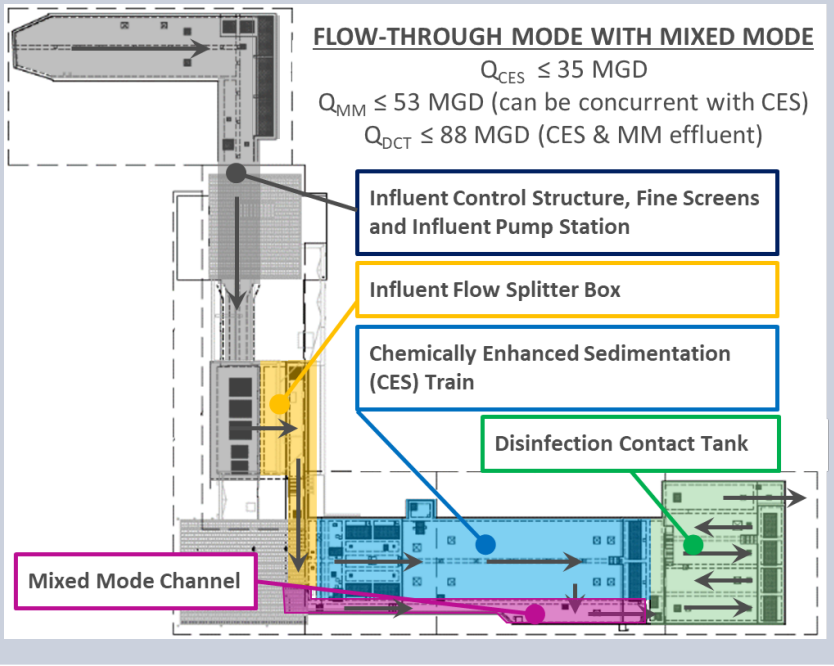
Did you check the weather forecast?

Treatment Modes

Flow-Through

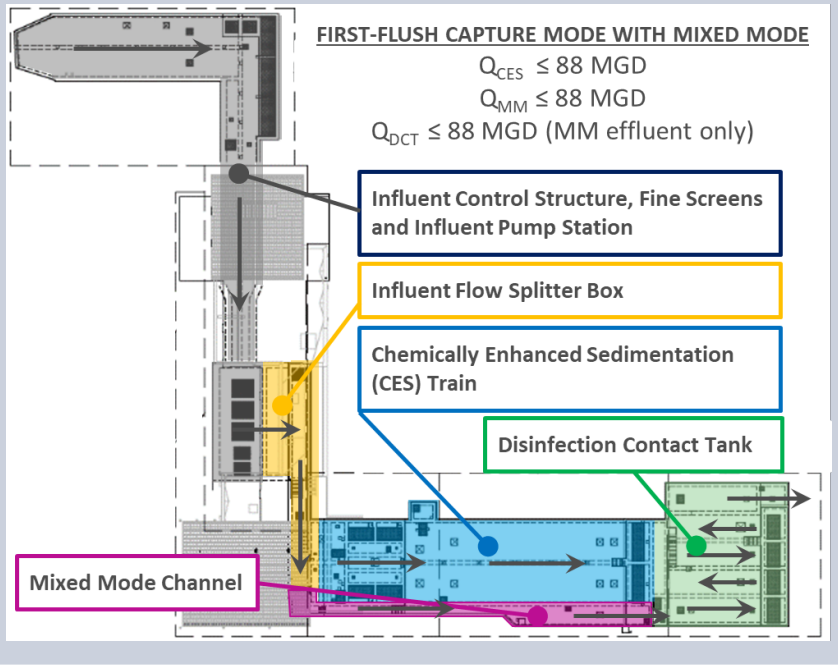


Baseline



Aspirational

First-Flush Capture

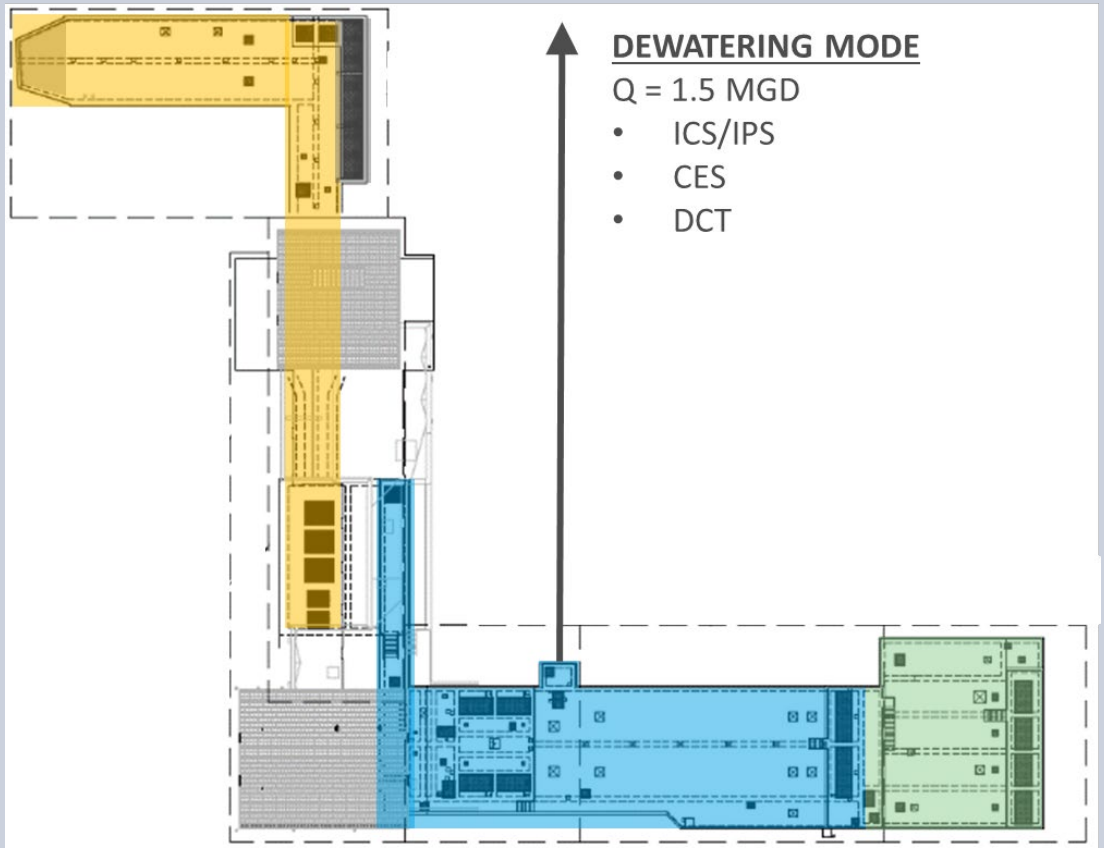


Aspirational

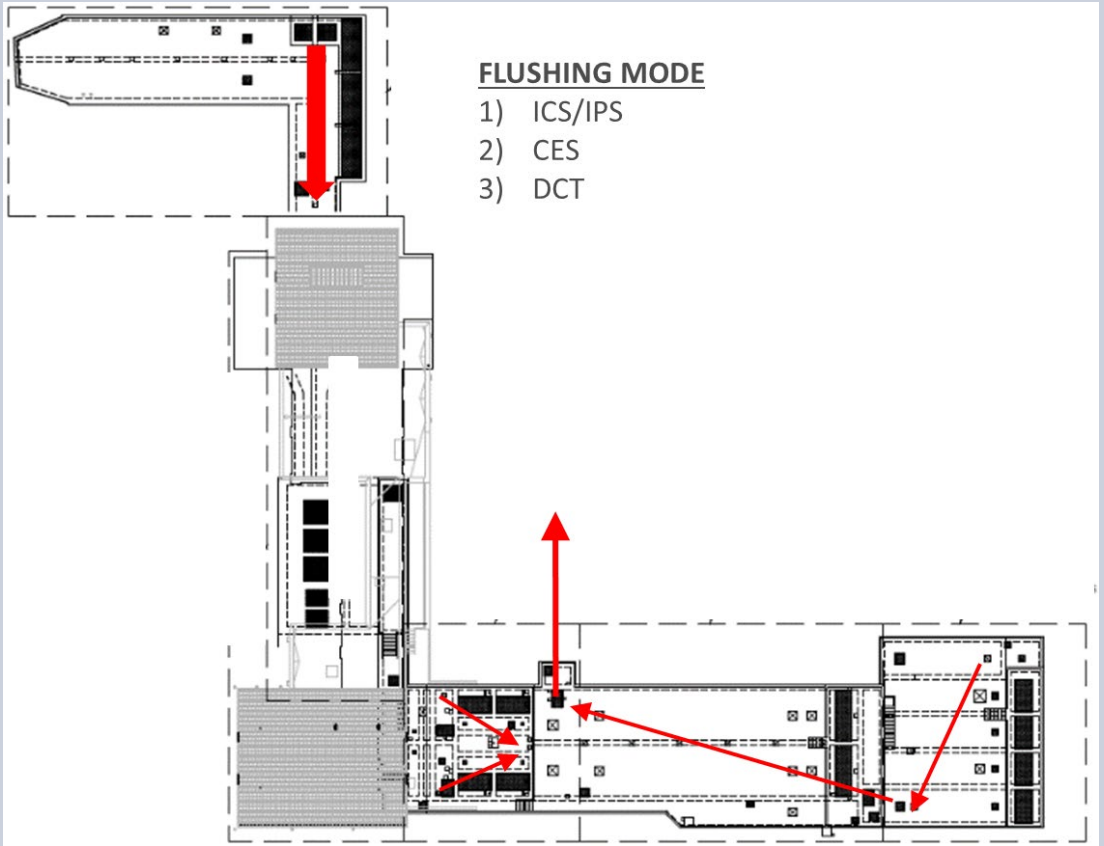
Demonstration testing to compare treatment modes

Post-Event Activities

Dewatering



Flushing



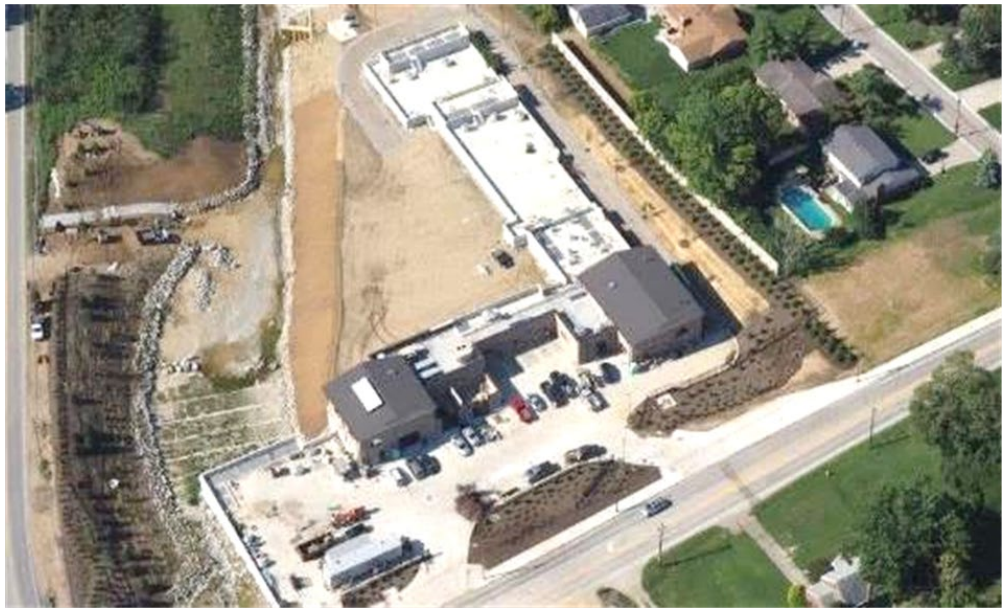
Coordinate with interceptor capacity and Muddy & Westbourne HRT Facility

Commissioning Update

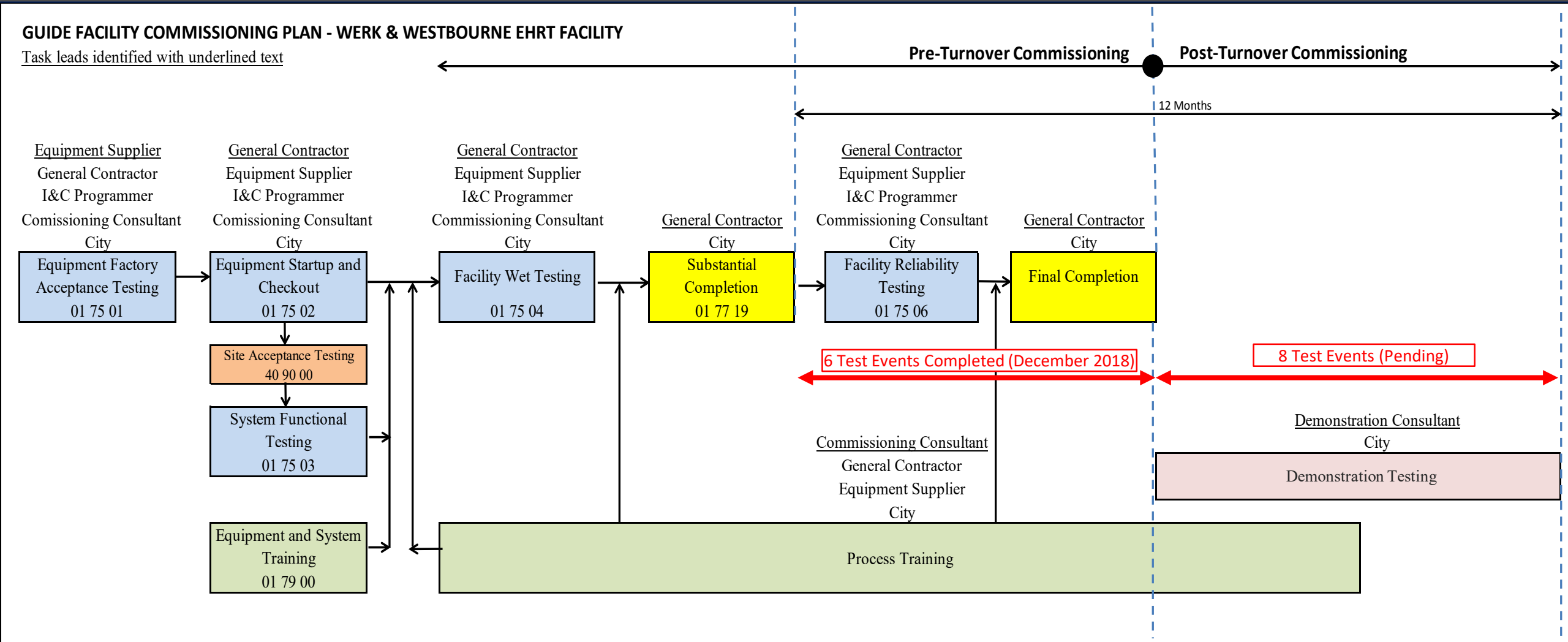
Construction Progress

Planned

Actual



Startup and Commissioning Plan



Event Definition

Qualifying Treatment Event	
Cause	Wet weather causes influent flow to WWEHRTF
Magnitude	Influent up to at least 35 mgd
Duration	Release of disinfected effluent for at least 4 hours with data capture
Frequency	12 hours since last influent flow

~3-MG required to yield treated effluent

Event Response Planning

Weekly Testing Call

- Review weather forecast for predicted volume, intensity, and duration
- Prepare response teams
  - MSDGC (Operations)
  - Demonstration Consultant (Sampling and Testing)
  - Contractor (Construction Activities)
- Follow-up call closer to predicted event(s)

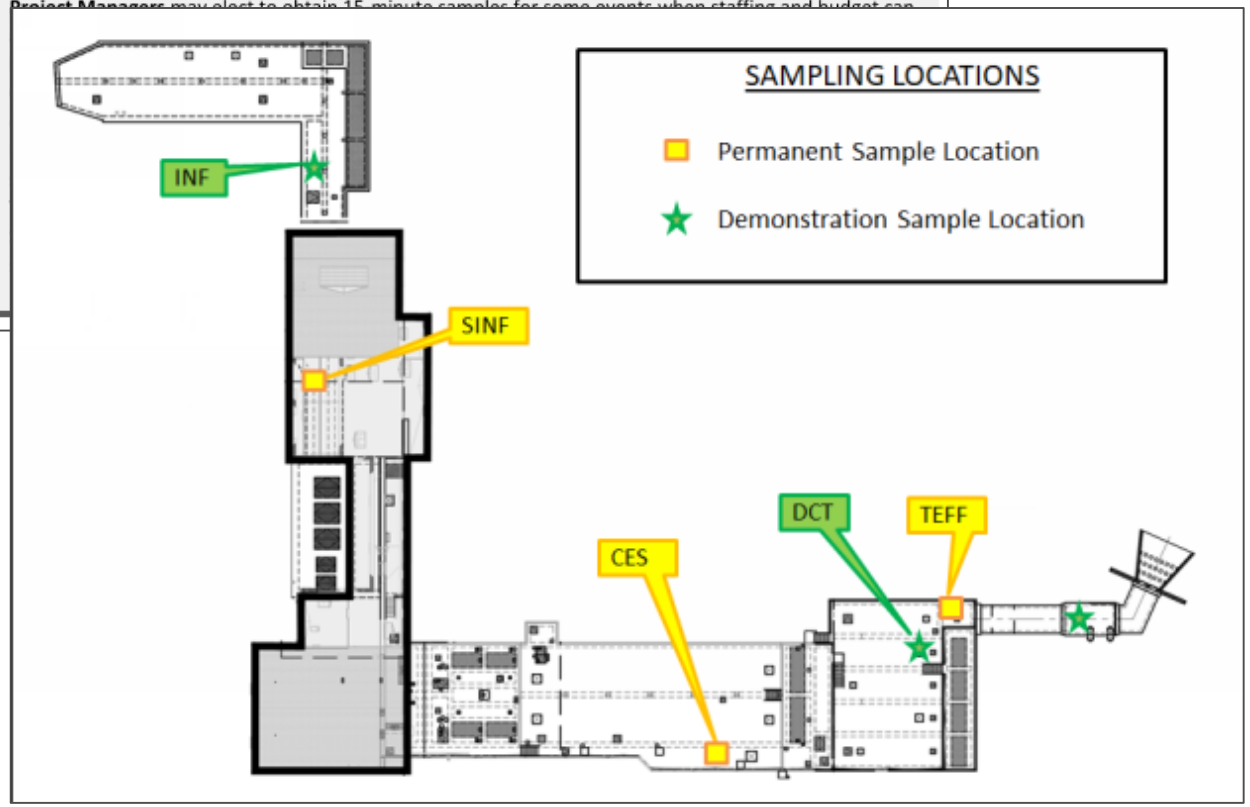
Reliability Testing Events 1 - 6

- Over 65 hours of operation
- Hourly grab samples representing
  - 46 hours of treatment
  - 57 MG of flow
- Quantity of samples analyzed
  - 133 TSS
  - 82 *E. coli*
  - 74 residual chlorine

PARAMETER	ANALYSIS LOCATION	TYPE	FREQUENCY	INF	SINF	CES	DCT AND/OR TEFF	OUT
TSS	Laboratory	Grab	Hourly[1]	X	X	X[2]		
E. coli	Laboratory	Grab	Hourly[1]		X		X[3]	
Total Residual Chlorine	Field	Grab and Field Meter or Probe with Reagent	Hourly[1]				X[4]	X[4]
Temperature	Field	Grab (or sink) and Portable Field Meter or Probe[5]	Hourly[1]		X		X[3]	
pH	Field	Grab (or sink) and Portable Field Meter or Probe[5]	Hourly[1]		X		X[3]	
Turbidity	Field	Grab (or sink) and Portable Field Meter or Probe[5]	Hourly[1]			X[2]		

Notes:

1. **Project Managers** may elect to obtain 15-minute samples for some events when staffing and budget can
2.
3.
4.
5.



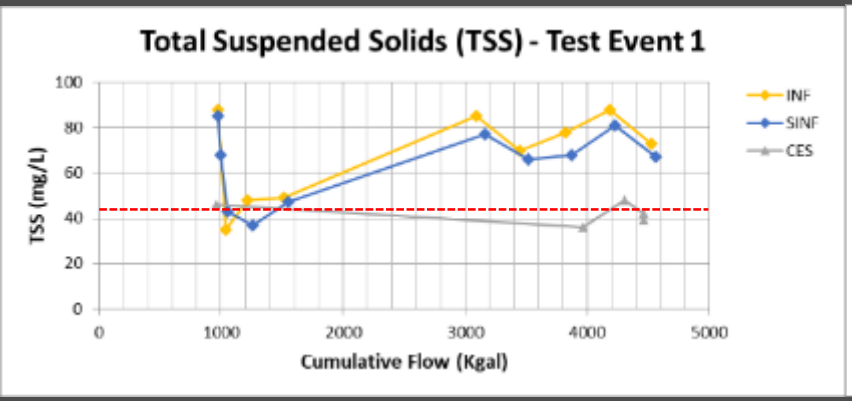
Testing Protocol

- Supplement Commissioning Plan
- Testing Team

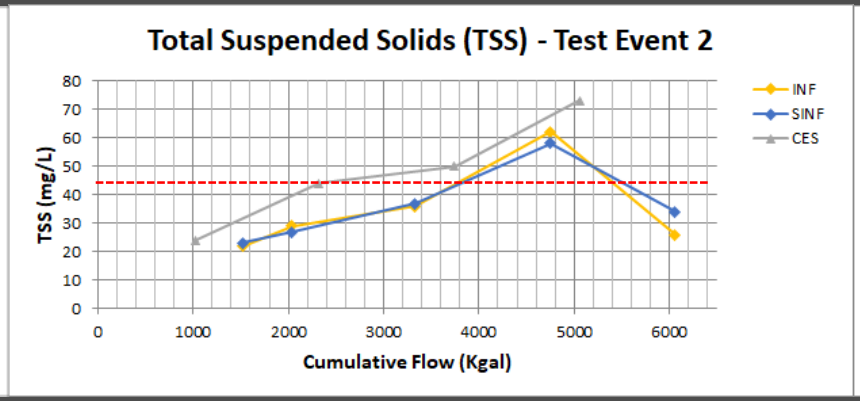
Operation	Sampling and Evaluation
MSDGC	Black & Veatch
	RA Consultants
	Brown and Caldwell

- Sample up to 12 hours per event

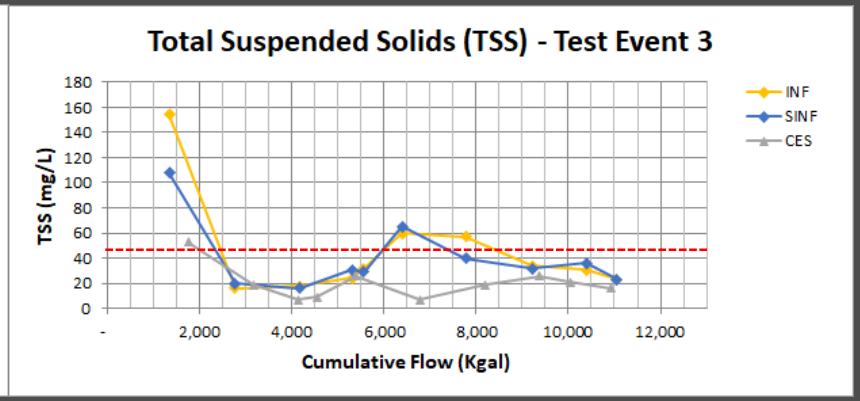
TSS Results



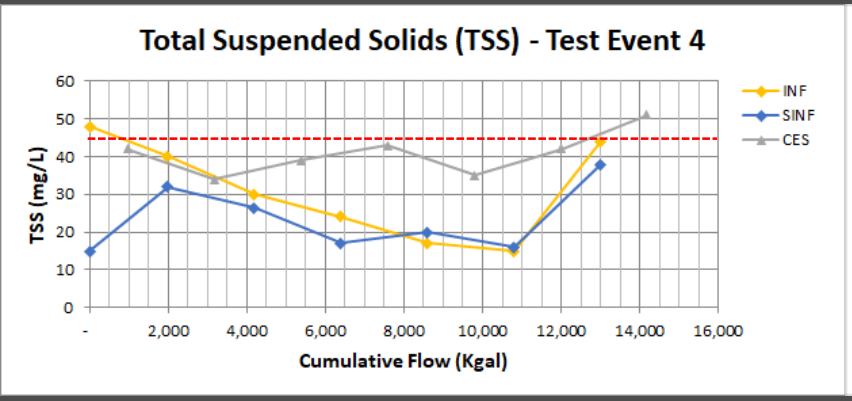
Initial ferric malfunction, ferric 56 mg/L & poly 0.33 mg/L



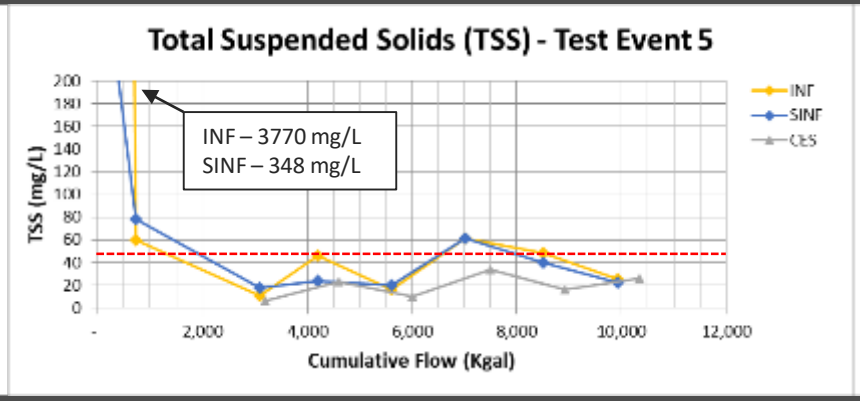
Initial ferric and polymer malfunction, ferric and poly overdose (pH, visual)



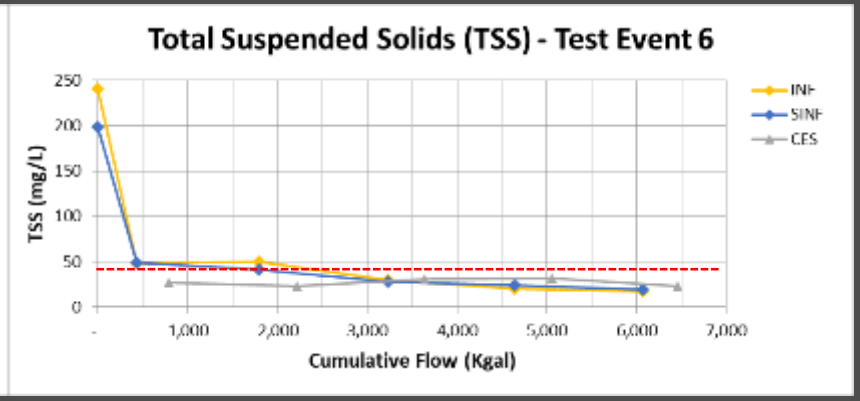
Facility full at startup, underfed ferric (22 mg/L vs. 28 mg/L)



Facility full at startup, high SOR 53 mgd = 10,500 gpd/sf



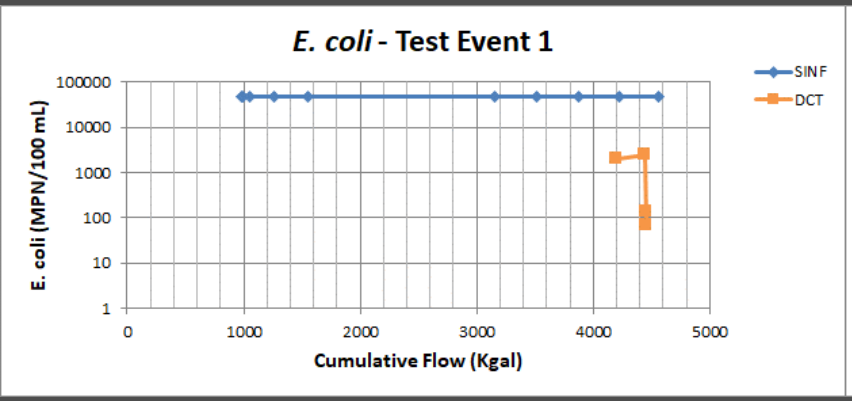
90% TSS removal rate



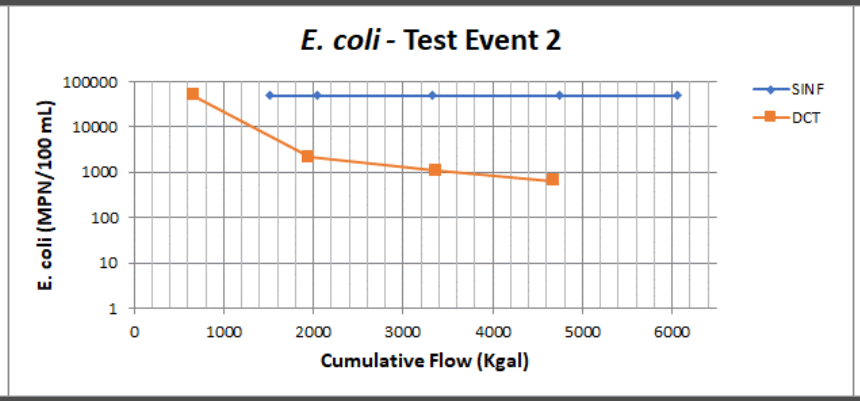
CES Effluent TSS 27 mg/L

Effluent flow-weighted TSS average ≤ 45 mg/L in all events

E. coli Results



SINF lab dilution inadequate, hypo feed malfunction



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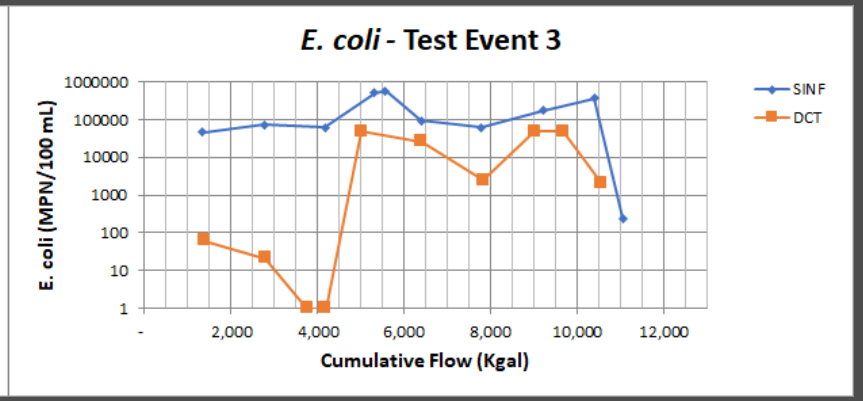
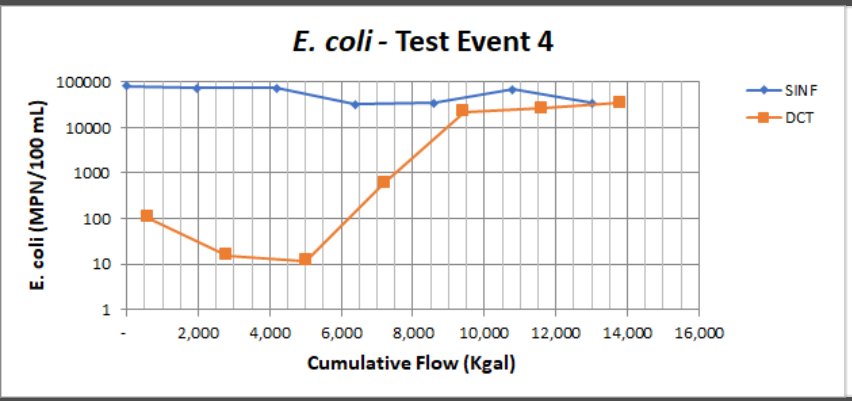


Hypo feed malfunction during later portion of event



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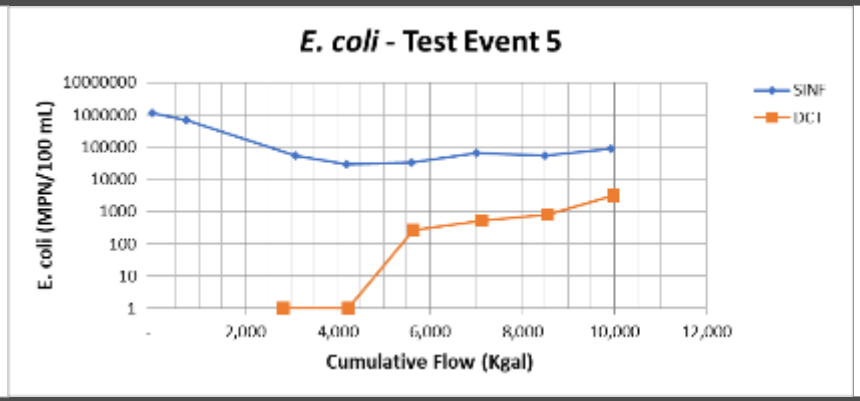
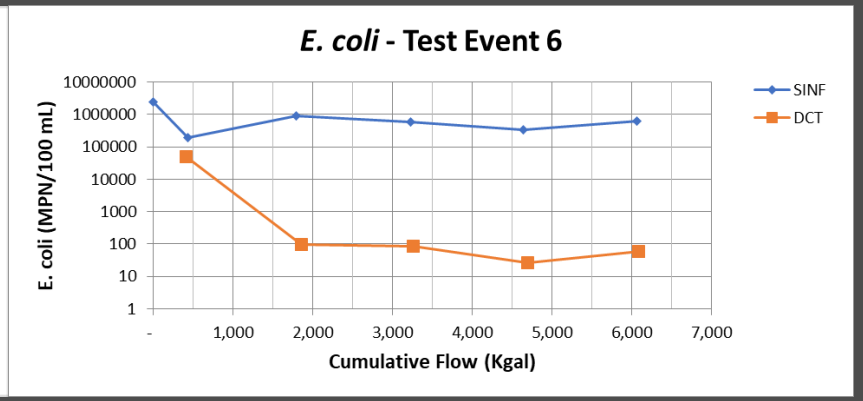


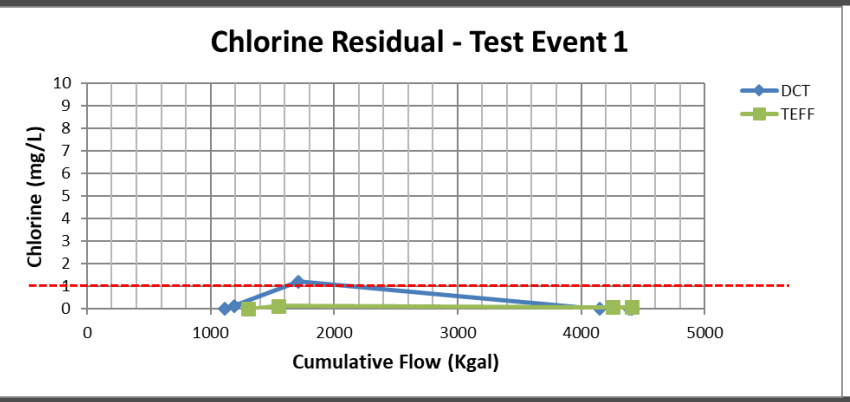
3.1 log reduction; hypo feed adjusted down during later portion of event



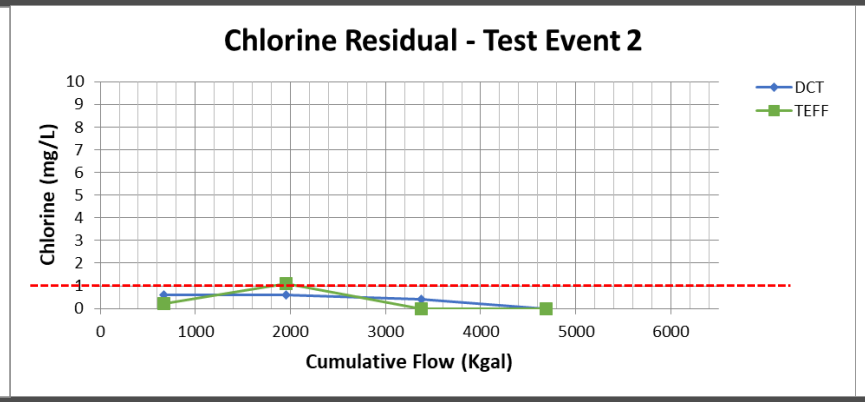
3.3 log reduction; hypo feed malfunction at start

E. Coli reduction goal met when hypo equipment functional

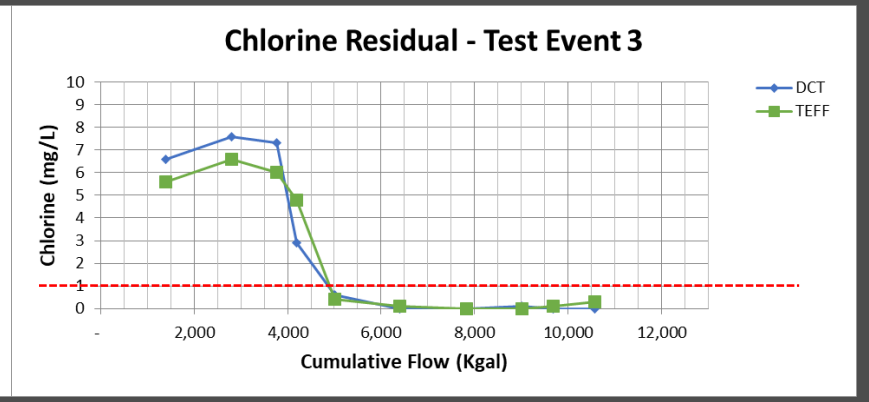
Residual Chlorine Results



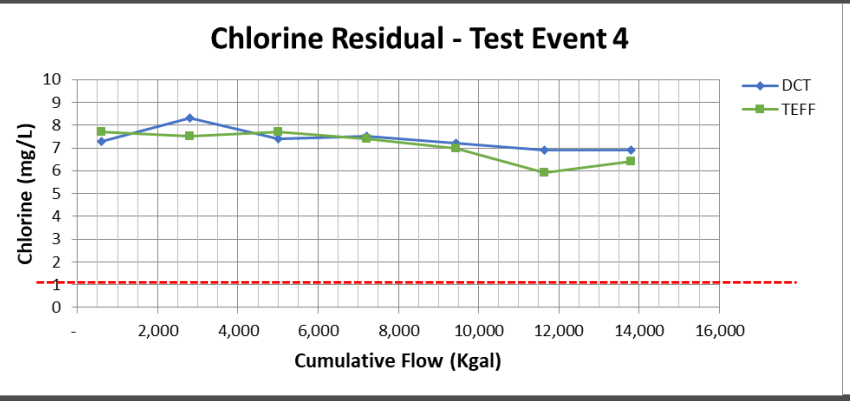
Bisulfite feed malfunction



Bisulfite feed malfunction



No bisulfite feed



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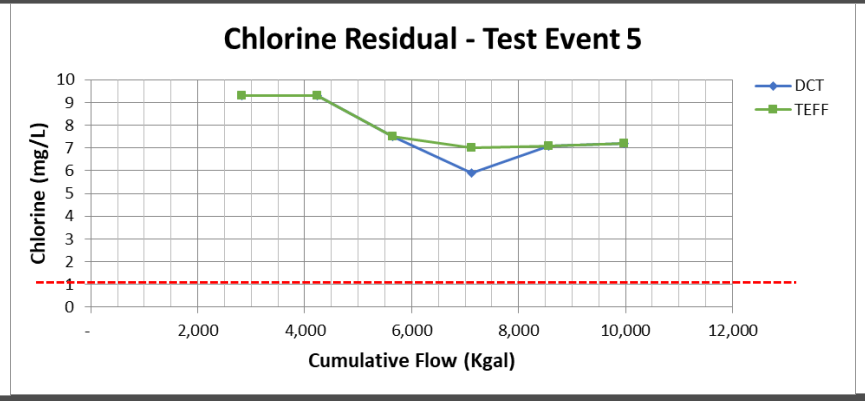
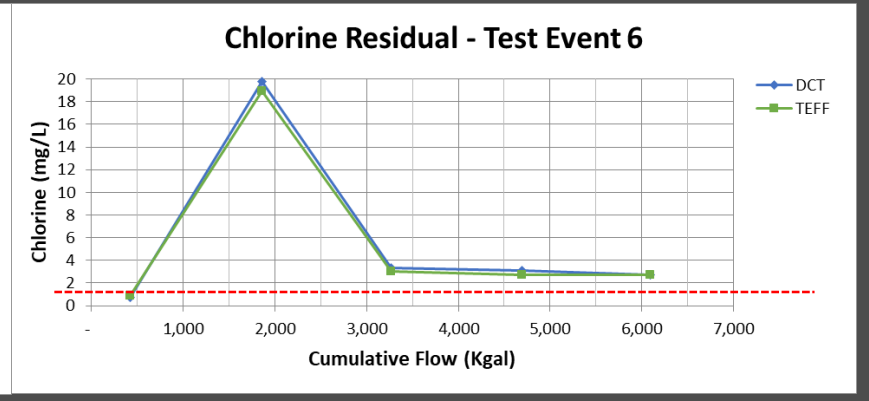


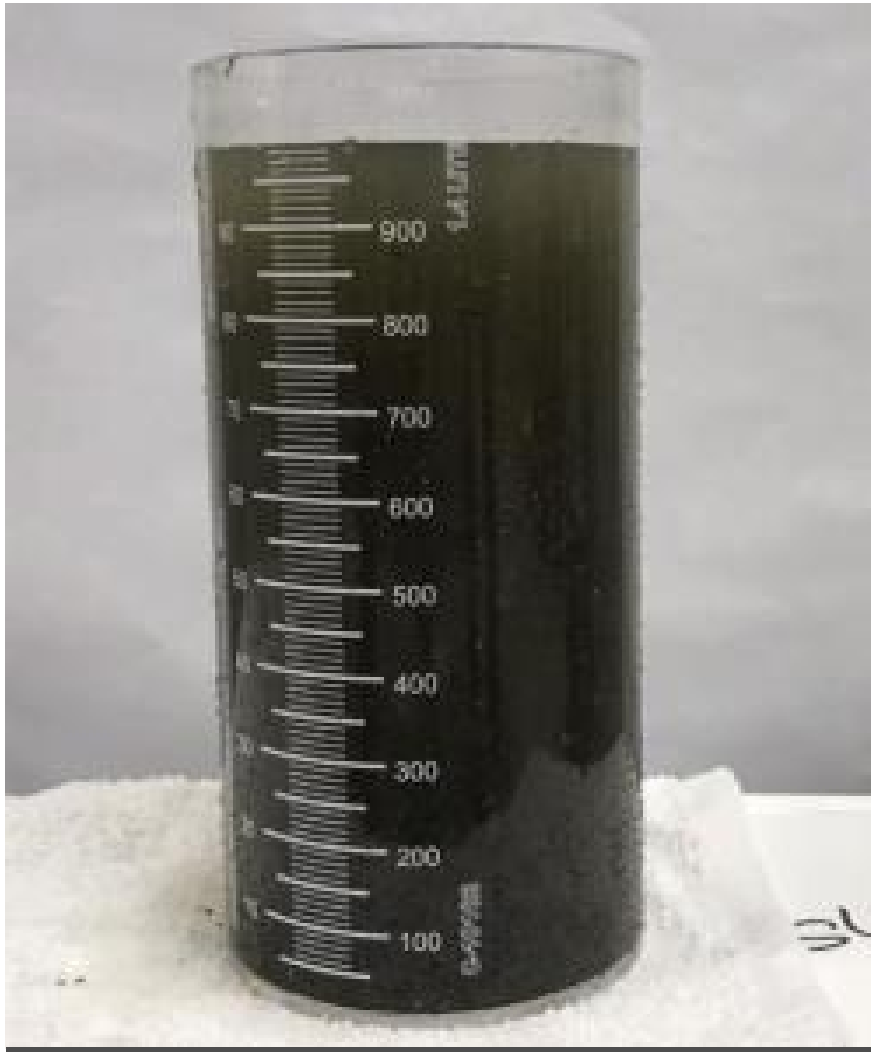
Bisulfite feed malfunction



Bisulfite feed malfunction

Inconclusive. Recommend moving sample point to outfall.

Sample Comparison (Event 5)



Influent

After CES

Effluent

Lessons Learned from WWEHRTF

- Very “flashy”. Influent within ~30 minutes after ¼” rain.
- Pre- and post-event VERY important. Field adjust spray nozzles. Operator adjustable flushing program. Visual/CCTV inspection.
- Solids impact to dewatering pumps and gates
- High-rate CES and chlor/dechlor need reliable and quick-starting chemical feed
- Avoid overdosing ferric and polymer
- Is CES really needed after initial first-flush?

SCADA invaluable for remote monitoring and readiness (chemical inventory, equipment status, etc.)

Acknowledgements

Definitely a team effort. Too many to list everybody here.

THANK YOU!!

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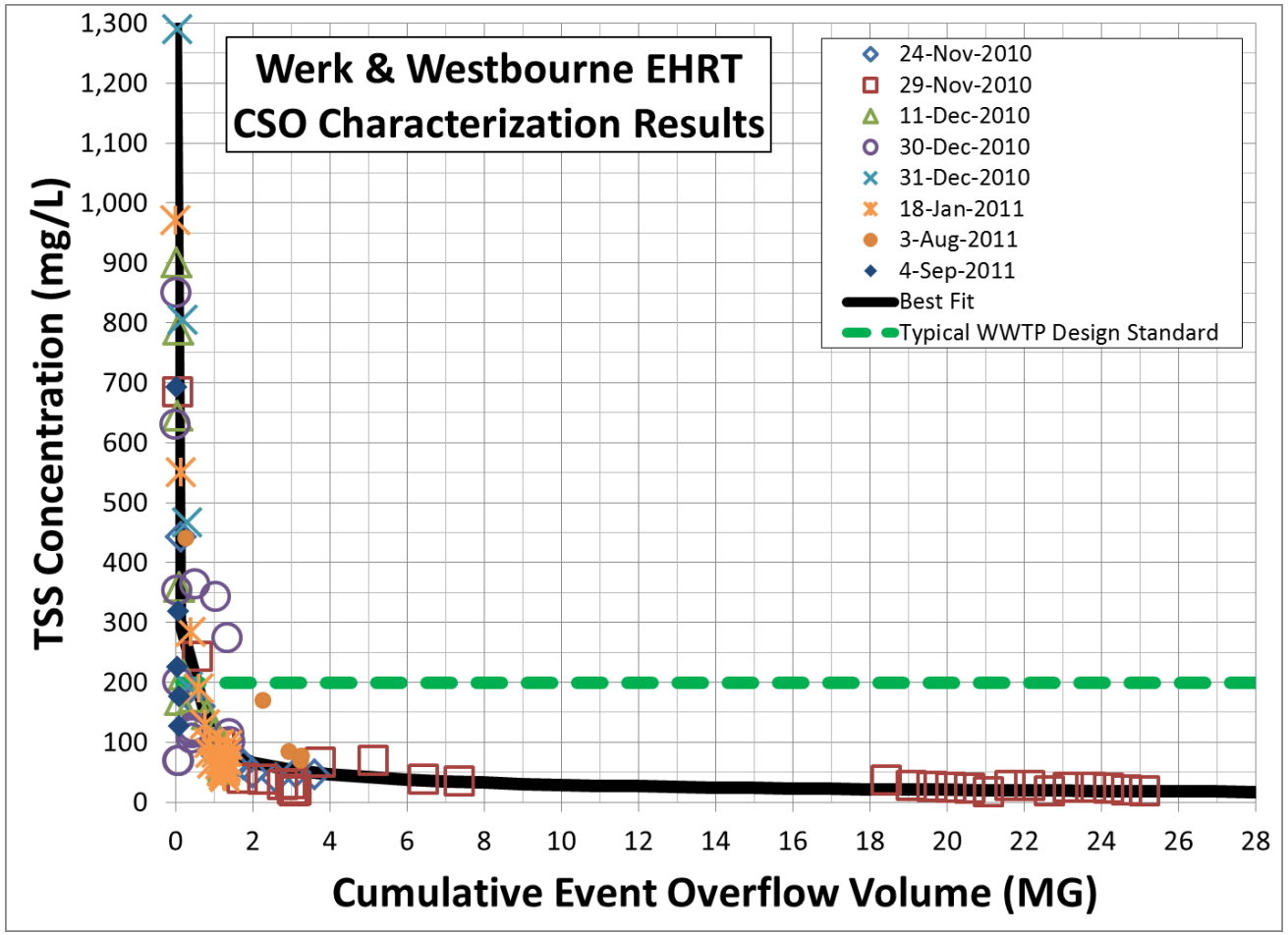
Bullpen

Influent Characteristics

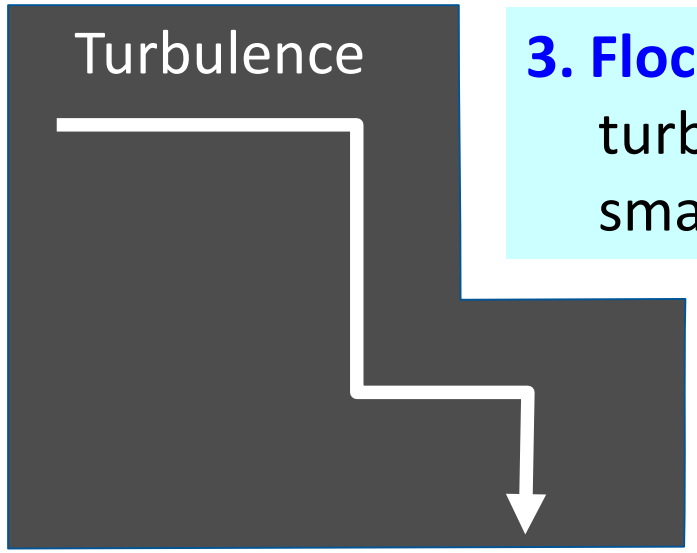


Mostly stormwater after first 2 MG

4 Steps to Chemically Enhanced Sedimentation (CES)

1. Coagulant Addition. Rapid mix. Add trivalent metal salt (Fe^{3+} or Al^{3+})

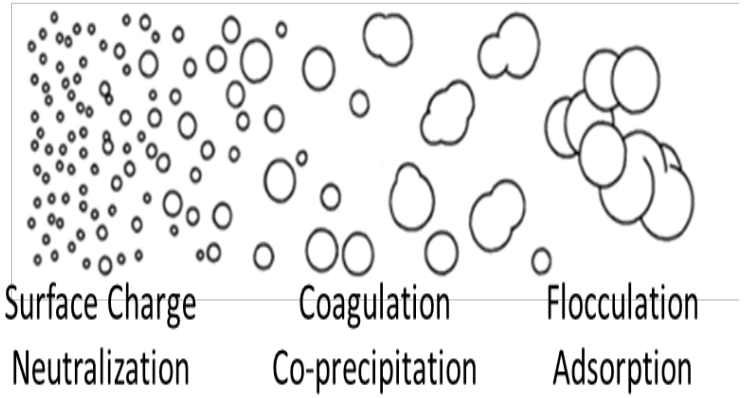
2. Flocculant Addition. Rapid mix. Add anionic polymer. If Step 1 & 3 are ideal (rarely in wet weather), then optional.



3. Flocculation. Medium to low turbulence. Build floc and "sweep" small particles. Enhance floc settling.

4. Settling. Non-turbulent quiescent zone. Separate solids from liquids.

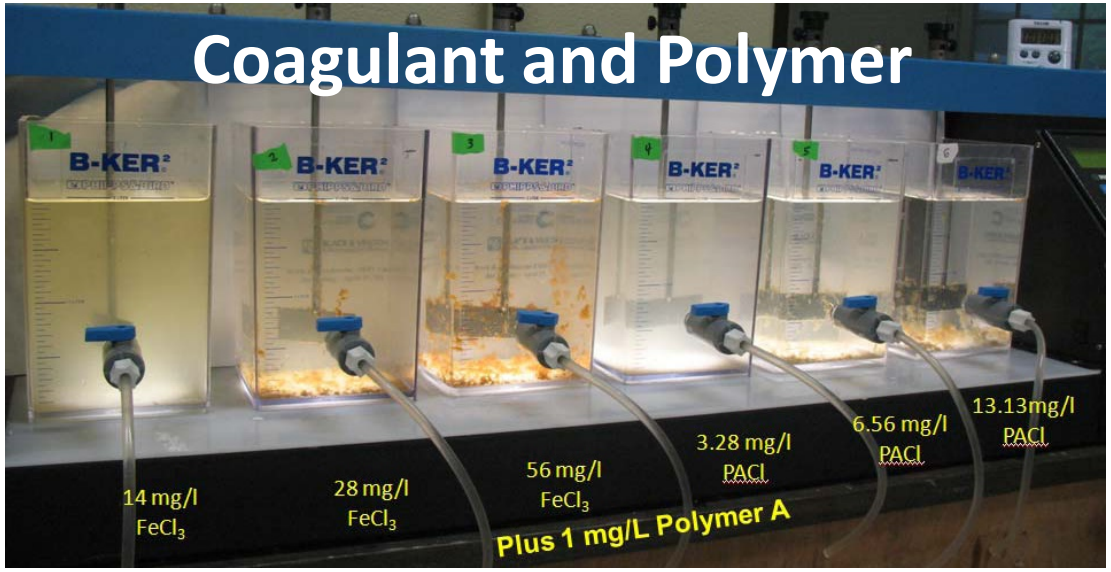
Particle Conditioning

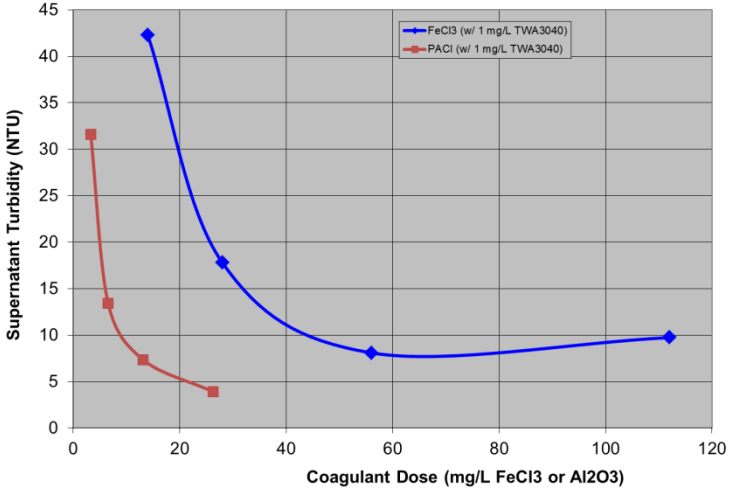


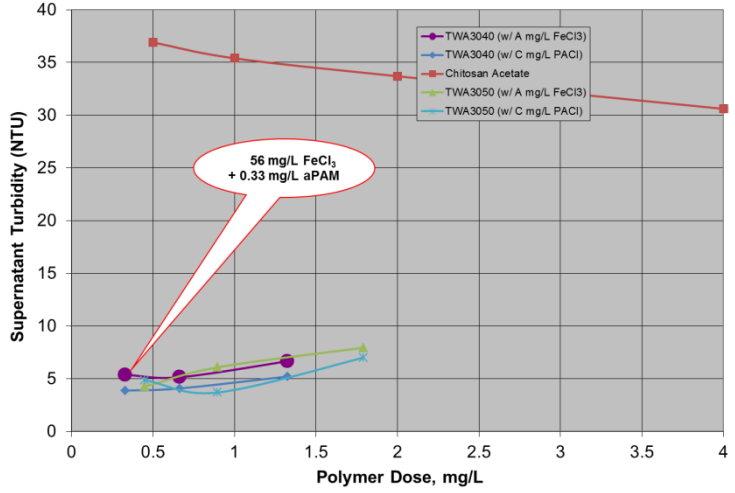
Jar test to optimize design of Steps 1, 2 and 3

Steps 1, 2 and 3 are key to how fast Step 4 will work

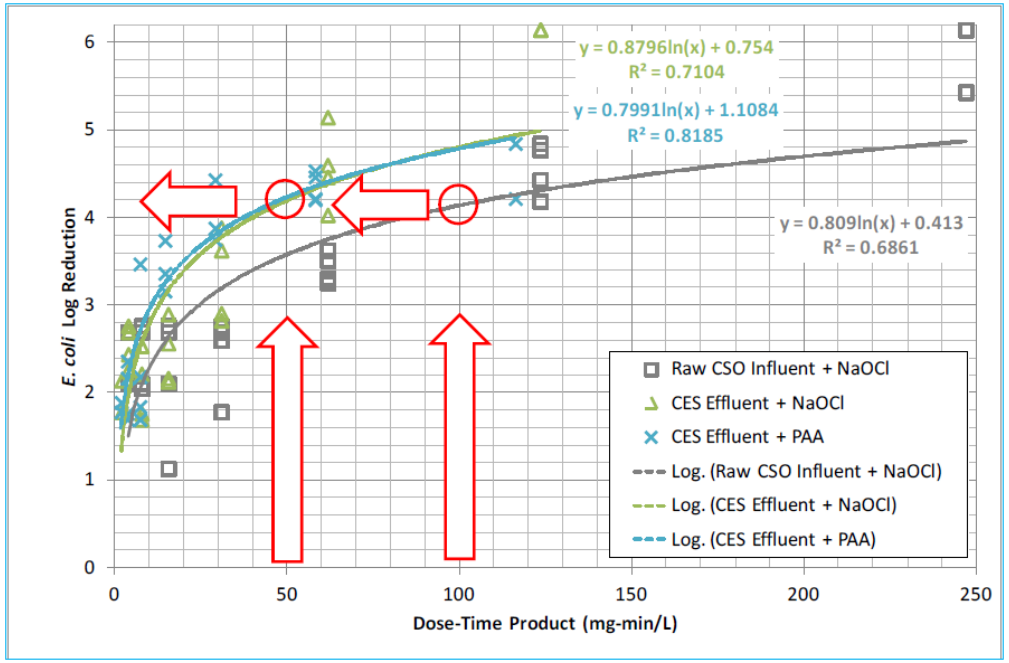
Chemical Doses from CSO 522 Jar Tests (April-May 2011)





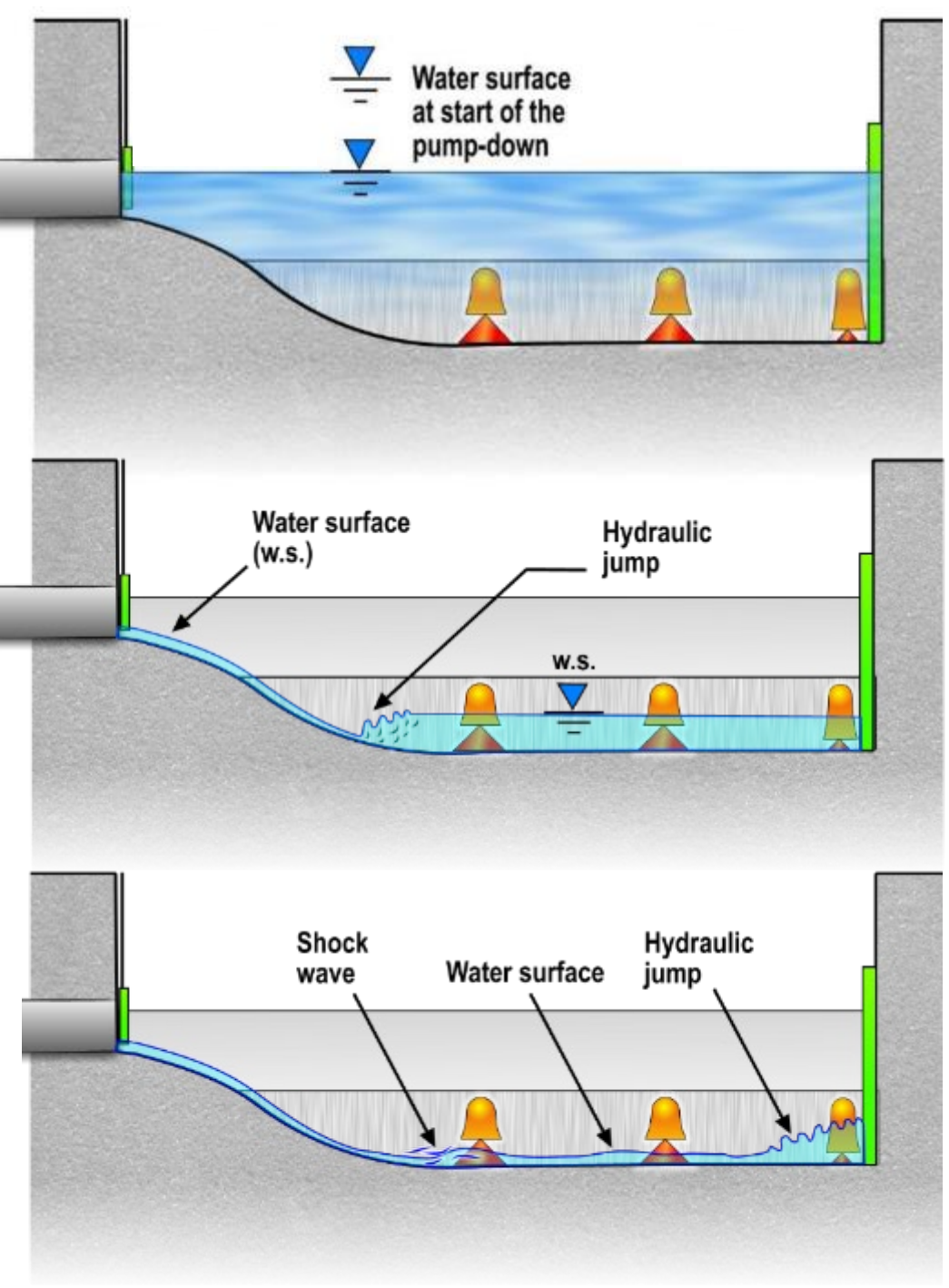


Disinfectant



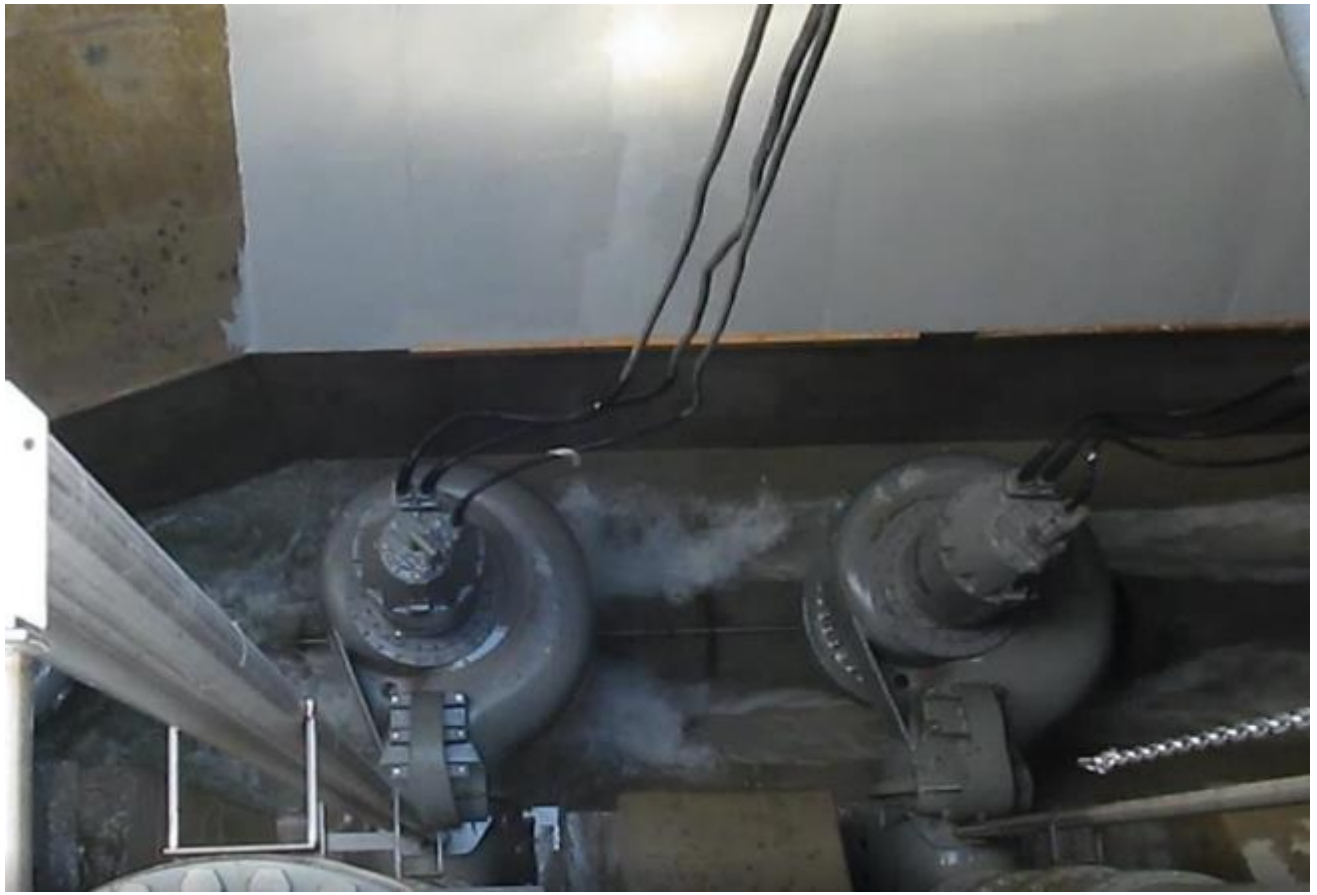
- Similar dose for hypochlorite (NaOCl) or peracetic acid (PAA)
- 4-log reduction required 7 mg/L on CES effluent, 14 mg/L on raw CSO

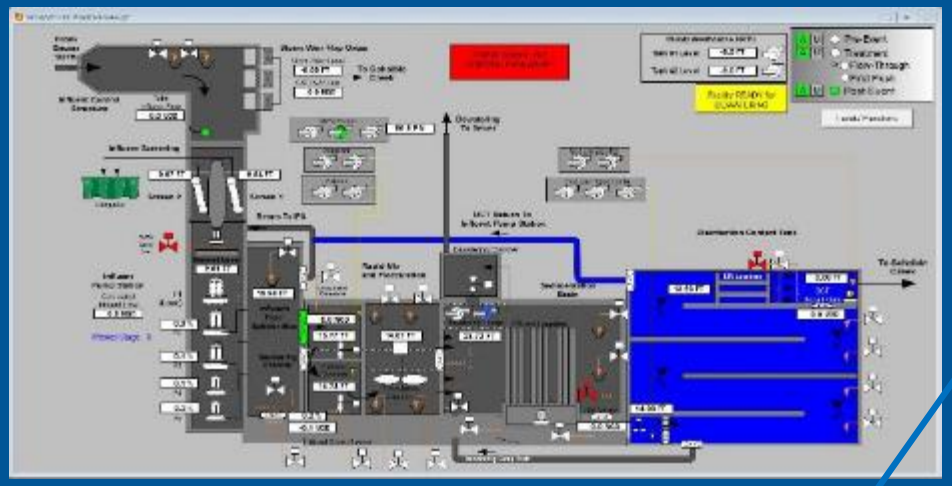
Further optimize during Extended Commissioning

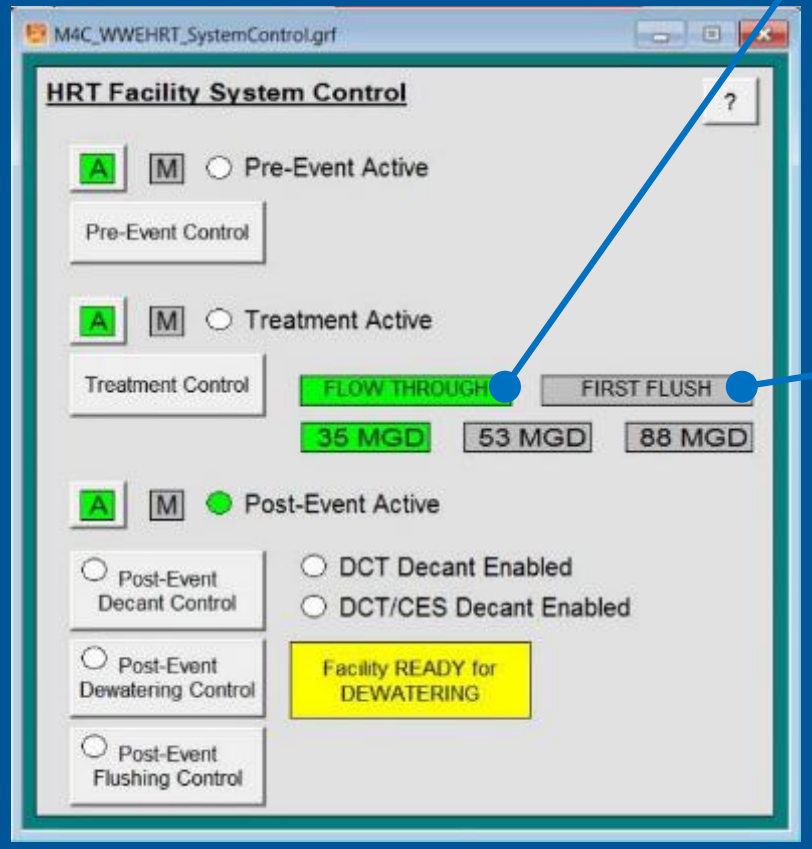


Influent Pump Station

- Self-Cleaning wet well







Operational Modes

- **Flow-Through**
  - Default Operational Mode
  - Flow receives chemically-enhanced sedimentation
  - Flow of 35 MGD is treated by CES. Flow greater than 35 MGD will be routed to Mix Mode Channel and Disinfection Contact Tank.
- **First-Flush Capture**
  - Flow will be sent to CES to store as first flush capture. No chemicals to be added.
  - After CES reaches a certain pre-set First-Flush Capture level, the CES weir gate will close and all remaining flow will go to Mix Mode Channel.

Performance Criteria

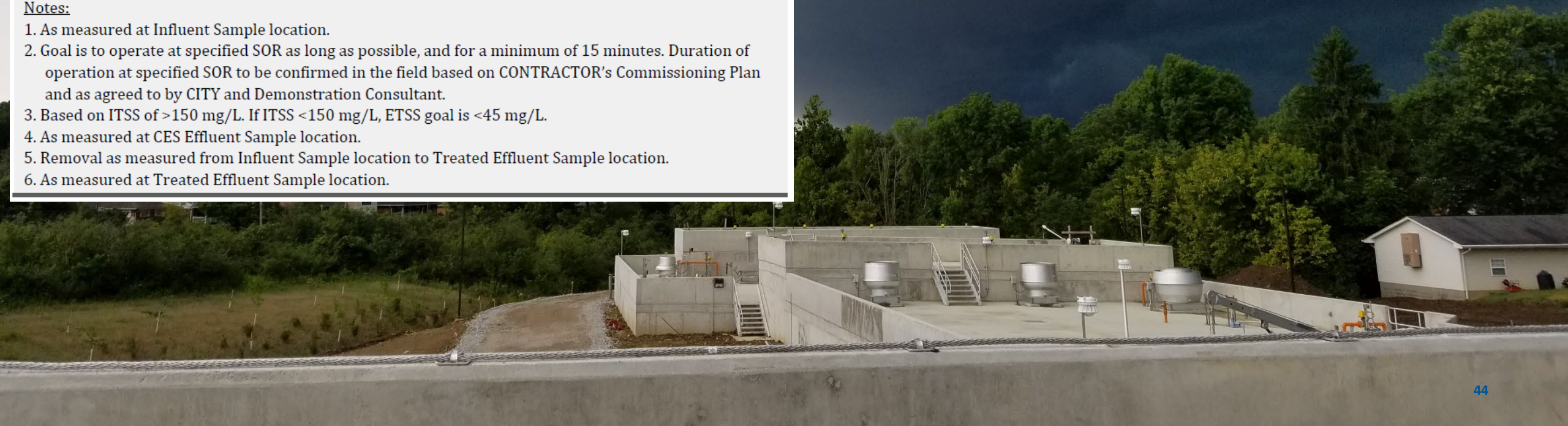
CRITERIA	RT-1	RT-2	RT-3	RT-4
Influent Total Suspended Solids (ITSS)[1]	> 150 mg/L	> 150 mg/L	> 150 mg/L	> 150 mg/L
CES Flow Rate	35 MGD	35 MGD	53 MGD	<88 MGD
Surface Overflow Rate (SOR)[2]	7,000 gpd/sf	7,000 gpd/sf	10,500 gpd/sf	NA
Effluent Total Suspended Solids (ETSS)[3,4]	0.3 x ITSS	0.3 x ITSS	0.3 x ITSS	NA
E. coli[5]	3 to 4 log reduction	3 to 4 log reduction	3 to 4 log reduction	3 to 4 log reduction
Disinfection residuals[6]	< 1 mg/L residual chlorine	< 1 mg/L residual chlorine	< 1 mg/L residual chlorine	< 1 mg/L residual chlorine

Notes:

1. As measured at Influent Sample location.
2. Goal is to operate at specified SOR as long as possible, and for a minimum of 15 minutes. Duration of operation at specified SOR to be confirmed in the field based on CONTRACTOR's Commissioning Plan and as agreed to by CITY and Demonstration Consultant.
3. Based on ITSS of >150 mg/L. If ITSS <150 mg/L, ETSS goal is <45 mg/L.
4. As measured at CES Effluent Sample location.
5. Removal as measured from Influent Sample location to Treated Effluent Sample location.
6. As measured at Treated Effluent Sample location.

Test Conditions

WET WEATHER EVENT	CES FLOW RATE	TREATMENT OPERATIONAL MODE	COMMENTS
RT-1	35 MGD	Flow-Through	7,000 gpd/sf SOR, Chemical Dosage Trial No. 1A;
RT-2	35 MGD	Flow-Through	7,000 gpd/sf SOR, Chemical Dosage Trial No. 1B
RT-3	53 MGD	Flow-Through	10,500 gpd/sf SOR, Chemical Dosage Trial 2A
RT-4	<88 MGD	First Flush Capture	Mixed Mode operation required



Reliability Test Events 1 - 6

RELIABILITY TEST EVENT	RT1	RT2	RT3	RT4	RT5	RT6
Treatment Mode	Flow-Through Mode (FTM) 35 MGD			FTM 53 MGD	FTM 35 MGD	
Volume Treated Plus Stored (MG)	4.8	6.4	12.2	13.8*	11.4	8.7
Average Influent TSS (mg/L)	73	35	53	31	157	35
Average Effluent TSS (mg/L)	42	45	25	41	16	27
Influent E. coli geometric mean (MPN/100 mL)	>48,392	>48,392	74,430	52,800	102,862	612,507
Effluent E. coli geometric mean (MPN/100 mL)	458	NA	NA	819	85	228***
***E. coli* Reduction (Log)**	NA	NA	<2.0	3.0/1.8**	3.1	3.3
Average Effluent Chlorine Residuals (mg/L)	0.07	0.35	2.5	7.1	8.2	5.9

* Flow/level instrument errors noted toward end of event (See Appendix A-4).

** Second value includes data during periods when hypochlorite feed system was malfunctioning.

*** Conservative value; see 4.6.2 for details.