At the Intersection of Process & Design: The Road from Demonstration Testing to Design Reality for High Rate Wet Weather Treatment

by
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Background

The Northeast Ohio Regional Sewer District (District) operates three wastewater treatment plants (WWTP; Easterly, Southerly, and Westerly) and associated interceptor sewers, which service the city of Cleveland and adjoining communities. As a result of a negotiated Consent Decree (CD) the District is responsible for the construction and upgrade of wet weather treatment facilities at all three District plants. The District was required to conduct pilot / full-scale demonstration testing of chemically enhanced primary treatment (CEPT) and high rate disinfection (HRD) technologies (termed CEPT-HRD for the purposes of this abstract) to reliably meet effluent performance criteria of less than 40 mg/L total suspended solids (TSS) and *E. coli* concentrations equivalent to recreational water quality criteria (126 CFU/100 mL). Based on the success of the testing, the District is proceeding with the design and construction of a standalone 400 mgd CEPT-HRD facility at their Easterly WWTP to meet the CD control measure requirements. Implementation of the full-scale facilities is to be achieved through design and construction schedule duration milestones.

Objective

Demonstrate performance data from the CEPT-HRD testing program were used in combination with specialty bench testing to evaluate performance limits and refine design criteria for the coagulation, flocculation, settling, and disinfection processes in the full-scale implementation. Lessons learned from operating and maintaining full-scale demonstrations for optimized solids removal and bacteria kill performance, and how these are translated into process design criteria and operating philosophy for full-scale implementation to achieve CD performance criteria will be presented.

CEPT-HRD Demonstration

CEPT-HRD was proven in achieving the performance criteria at all three District facilities, in facilities ranging from a 180 gpm pilot to a 70 mgd full-scale primary clarifier. Prior papers were published with details of the facilities and test program results (Bucurel, et al, 2015). This paper will focus on the features from the pilot and demonstration facilities that were incorporated into the full-scale Easterly CEPT-HRD facility. Full-scale testing demonstrated the performance criteria (< 40 mg/L TSS) could be reliably met at surface overflow rates (SOR) as high as 10,600 gpd/ft^2.

Full-Scale Implementation at Easterly WWTP

In order to comply with CD requirements, a standalone 400 mgd CEPT-HRD facility will be constructed adjacent to and connected to the existing wet weather bypass at the Easterly WWTP.

The CEPT-HRD facility will divert wet weather flow in excess of the Easterly WWTP capacity and treat through settling in CEPT clarifiers and an HRD contact tank, which provides disinfection and dechlorination. An Operations Building is provided for chemical feed and storage. Figure 1 illustrates the elements and the layout of the facility. The paper will discuss how aggressive process design parameters stemming from the testing results allowed the facility footprint to be minimized and yielded cost savings as exemplified below.

Chemical application, mixing, and contact time are critical elements to the successful application of CEPT and HRD. The CEPT process starts in the influent channel with coagulant addition, mixing, and reaction time. As such, the channel length and velocity are critical process design parameters, and impact the footprint of the facility. Previous implementations of CEPT have identified coagulation reaction time as high as five minutes. Jar testing to evaluate performance at a range of lower coagulation reaction times indicated that the coagulation reaction time could be reduced to one minute with no anticipated loss in performance (Figure 2). This dramatically minimized channel length requirements.

Reductions in coagulation reaction time are only possible when sufficient mixing is applied at the point of coagulation. Chemical mixing in high rate applications have typically relied upon mechanical induction mixers to provide the required mix energy. During CEPT-HRD testing, induction mixers were regularly bound with rags and debris common in CSO influent. An innovative method for chemical mixing through atomization and injection through diffusers with compressed air was tested in the pilot scale at Easterly and full-scale at Westerly. Use of this approach proved to effectively disperse the coagulant and eliminated maintenance downtime associated with mixer ragging and damage. Figure 3 shows the diffuser system installed at the Westerly demonstration, and illustrates how this novel approach was scaled up and applied to treat up to 400 mgd in the full-scale design.

Results of the CEPT testing demonstrated the dramatic changes in the settleability of particles in the wastewater, resulting in discrete particles which were proven to settle in accordance with the principal of Stokes' Law as illustrated in Figure 4. The settling velocity for discrete particles were measured in settling columns at Easterly and Westerly during test events, and average velocities for particles ranging from < 1 mm to > 4 mm were identified, as presented in Table 1. These settling velocities, in combination with the horizontal fluid velocity, provided information to determine the necessary clarifier size and was validated during full-scale testing at Westerly. The full-scale design of the CEPT clarifiers turned away from traditional sizing based on SOR and simplified the approach based on horizontal velocity in concert with clarifier design guidelines. The resulting CEPT clarifier design is illustrated in Figure 5, and correlates to an SOR of 8,500 gpd/ft^2 – the highest known CEPT design SOR in the country.

One of the greatest challenges during design was the schedule constraints imposed by the CD, which required design to be completed in 18 months and allowed only 30 months for construction. Proactive collaboration with the District was key to managing risks of making design decisions early in the project that lead to additional cost and schedule savings to meet the CD, including:

- Early constructability evaluations to identify design features to minimize construction duration and risk

- Evaluation of early action construction projects to complete high risk excavation and foundation construction prior to completion of larger design
- Workshop based approach early in, and throughout the design process to gain buy-in for design decisions from all stakeholders

Significance

Only two other facilities in the U.S. currently utilize CEPT as a wet weather treatment process. By demonstrating performance criteria could be reliably met, the District was provided the flexibility to apply innovative approaches in design of the largest standalone CEPT-HRD facility in the country. Further capital cost savings will be realized by maximizing the hydraulic loading and minimizing chemical contact times to reduce the facility footprint. For context of scale, the layout of the facility is shown in Figure 6 in relation to the 400 mgd Easterly WWTP.

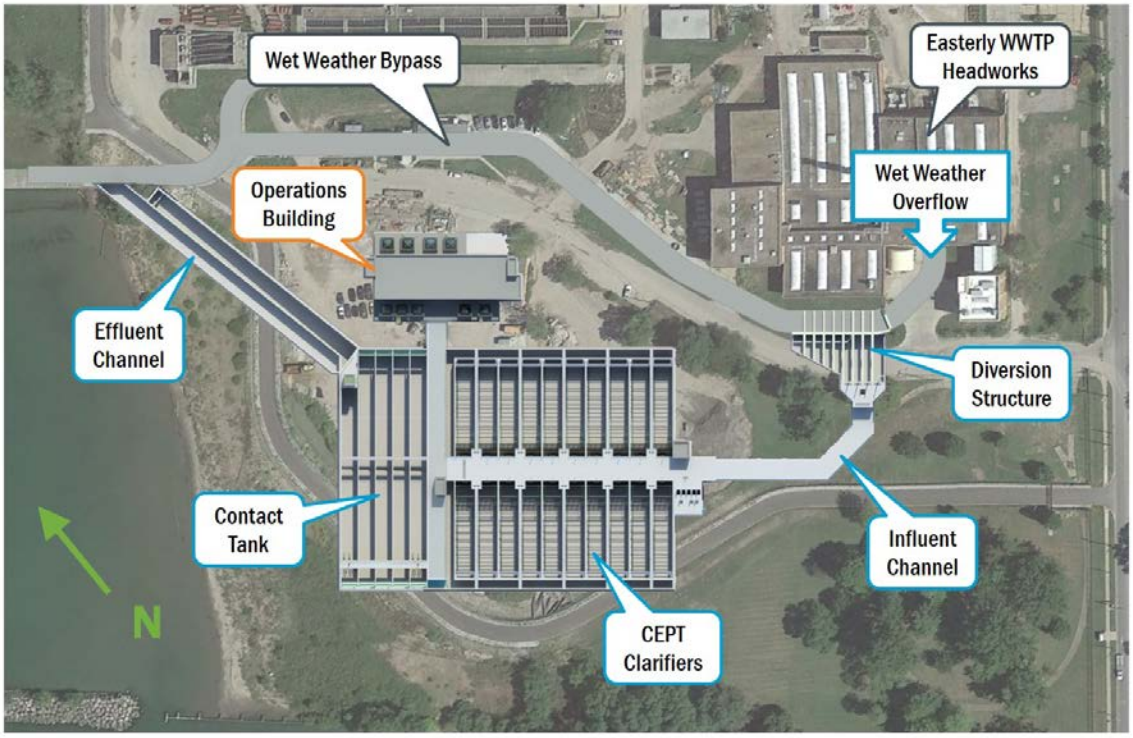

Figure 1. Layout and features of the 400 mgd standalone CEPT-HRD facility at the Easterly WWTP

	Jar 2	Jar 3	Jar 4	Jar 5	Jar 6
Coagulant, mg/L $FeCl_3$	30	30	30	30	30
Flocculant	---	---	---	---	---
Coagulation Time, sec	15	30	60	90	120

Figure 2. Visual observation of the effect of coagulation reaction time, indicating 60 seconds of coagulation reaction time as a minimum requirement

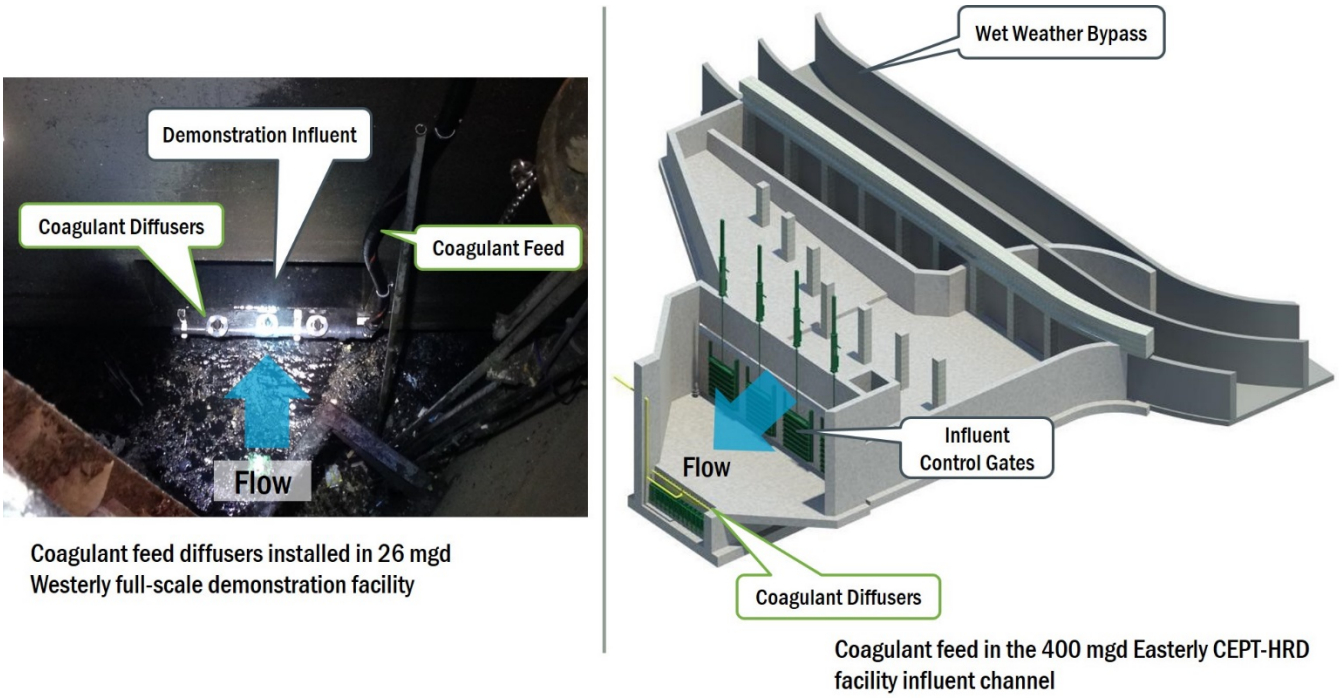

Figure 3. Installation of coagulant feed diffusers as tested in the Westerly full-scale CEPT demonstration served as the basis for upscaling the design at the Easterly CEPT-HRD facility

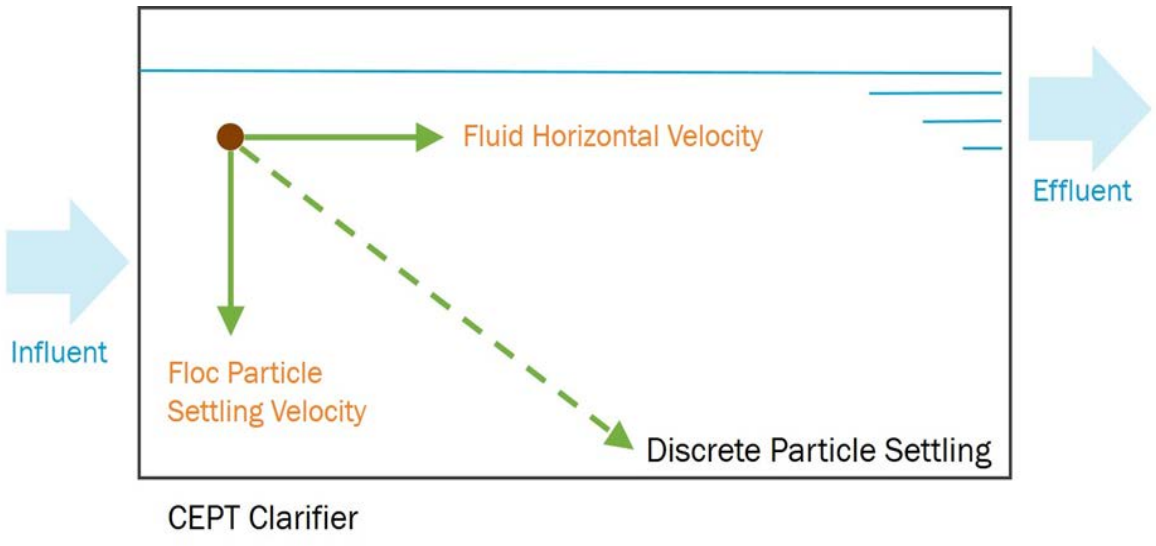

Figure 4. Discrete particle settling simplifies CEPT clarifiers – clarifier length is determined by the distance the particle travels in the fluid before it settles at its settling velocity

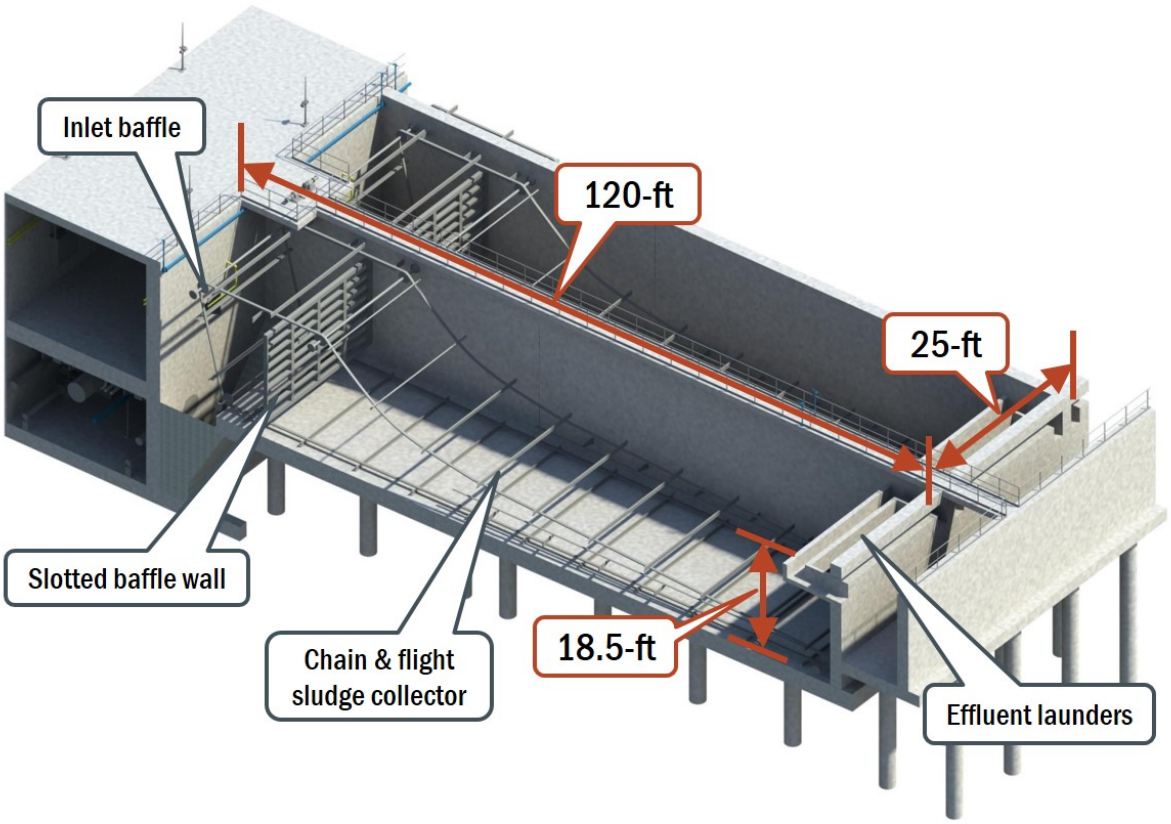

Figure 5. Section cut through the Easterly CEPT clarifiers, indicating dimensions based on design approach using horizontal velocity and features from the full-scale testing success

Comparison of Average Floc Settling Velocity by Size at Easterly and Westerly		
Floc Particle Size	Easterly WWTP	Westerly WWTC
Small (< 1 mm)	1.26 ft/min	1.16 ft/min
Medium (2 - 4 mm)	1.9 ft/min	1.6 ft/min
Large (> 4mm)	2.6 ft/min	2.2 ft/min

Table 1. Comparison of floc particle settling velocity measured during CEPT-HRD test events and used in the CEPT clarifier sizing

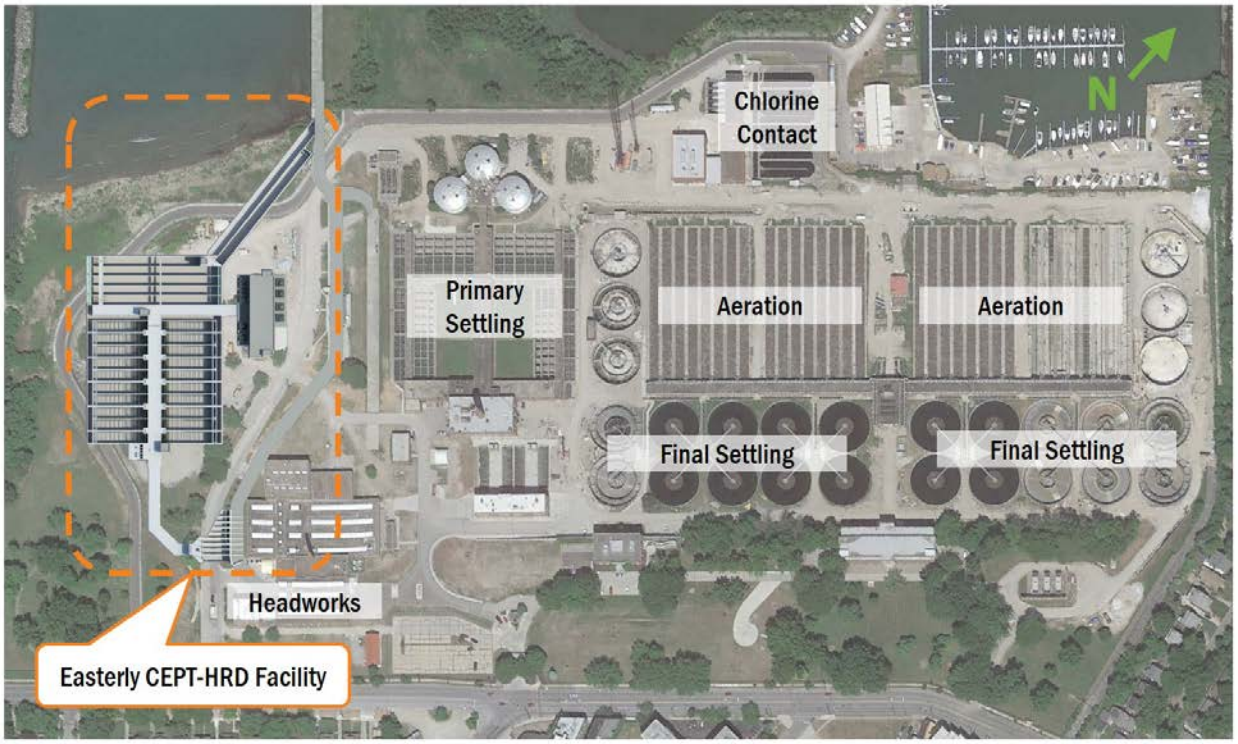

Figure 6. Layout of the 400 mgd CEPT-HRD facility in comparison to size of the 400 mgd Easterly WWTP