Green City, Clean Waters

Wet Weather Facility Plan

Consent Order & Agreement

Regulatory Deliverable

City of Philadelphia Combined Sewer Overflow Long Term Control Plan Update

Submitted to

The Commonwealth of Pennsylvania

Department of Environmental Protection

By Philadelphia Water

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1.0 Introduction

On September 1, 2009, a Long Term Control Plan Update was submitted to the Pennsylvania Department of Environmental Protection (PADEP) and on June 1, 2011, Philadelphia Water entered into a Consent Order and Agreement (COA) with the PADEP which enforces the implementation of the Long Term Control Plan Update and its supplements (LTCPU). Pursuant to Paragraph 3.a.iv of that COA, a Facility Concept Plan for each of the three Water Pollution Control Plants (WPCPs) must be submitted within 24 months of the agreement date (by June 2013). Appendix G of the COA requires the Facility Concept Plans to describe the specific engineering and construction activities proposed to increase the maximum wet weather flow through each WPCP and thereby increase the capture rate of combined sewage. The Facility Concept Plans were submitted on June 1, 2013. After receiving comments, a revised Northeast WPCP Facility Concept Plan was submitted on December 31, 2013 and approved on January 28, 2015.

In each of the three Facility Concept Plans, Philadelphia Water committed to delivering a Wet Weather Facility Plan report by June 2016. Within this Wet Weather Facility Plan, details on scheduling, cost, and anticipated construction completion for each project listed in the Facility Concept Plans are provided. Philadelphia Water also committed to providing an update on ongoing studies and new concepts being developed by the Department to increase wet weather flow capacity in both the Collection System and the WPCPs.

Philadelphia Water's implementation approach to the approved LTCPU has been developed to integrate the management of Philadelphia's watersheds into a larger context. The program was designed to provide multiple benefits beyond the reduction of combined sewer overflows (CSOs) so that every dollar spent provides a maximum return in benefits to the public and the environment. In a similar approach, the Wet Weather Facility Plan looks beyond infrastructure improvements and studies which modifications to facility operations as well as collection system optimization can be implemented to address wet weather flow delivery to the WPCPs.

2.0 Goals of Wet Weather Facility Plans

The Wet Weather Facility Plans provide a description of the City's strategy to achieve increased flows to the WPCPs through:

- WPCP capacity increases,
- Collection System modifications to increase the capture and transmission of wet weather flows,
- Potential operational changes of the existing WPCPs to ensure sustained wet weather treatment capacity, and
- Continued study and investigation of strategies and technologies for implementation at the WPCPs to achieve CSO reductions.

All modifications to the three WPCPs and the Collection System will be completed within regulatory timeframe as stated in the LTCPU. Additionally, Philadelphia Water is committed to continuing to conduct research and study new technologies for improvements within the Collection System and WPCPs to decrease combined sewer overflows and increase wet weather treatment through the LTCPU implementation.

The goals of this Wet Weather Facility Plan are to provide details including schedule, cost and anticipated performance for each project presented in the Facility Concept Plans as well as updates on any studies and new concepts being developed by Philadelphia Water to increase flow to the WPCPs. This Wet Weather Facility Plan supersedes the 2013 Facility Concept Plans. The status of the projects presented in the Wet Weather Facility Plan will be provided within Philadelphia Water's annual report to PADEP.

3.0 WPCP Permit Modifications

As per Appendix G of the COA (2011), the peak flow requirements for each treatment facility will become permit requirements through incorporations into future versions of the NPDES permit for each WPCP. Within the LTCPU, Philadelphia Water committed to expanding the wet weather treatment capacities for the three WPCPs (LTCPU, p. 10-52).

The wet weather treatment capacity at the Northeast WPCP will be increased by 215 million gallons per day (MGD) through the construction and use of a secondary treatment bypass conduit and an additional preliminary treatment facility. A gravity sludge thickening facility will be constructed to allow for the operation of the primary sedimentation tanks without a sludge blanket. The secondary treatment bypass conduit will allow for the primary treatment and disinfection of additional wet weather flow, which will be reflected in future modifications to the NPDES permit as presented in Table 1:

Table 1: Current and Future Northeast WPCP Permitted Capacity

	2007-2012 NPDES Permit	Future (2031)
Facility Design Flow Rate	210 MGD	210 MGD
NPDES Maximum Daily Flow	315 MGD	315 MGD
NPDES Peak Instantaneous Flow	435 MGD	650 MGD

The wet weather treatment capacity at the Southeast WPCP will be increased by 50 MGD through process and hydraulic improvements. The replacement of the influent bar rack system will allow for the treatment of additional wet weather flow, which will be reflected in future modifications to the NPDES permit as presented in Table 2:

Table 2: Current and Future Southeast WPCP Permitted Capacity

	2007-2012 NPDES Permit	Future (2031)
Facility Design Flow Rate	112 MGD	112 MGD
NPDES Maximum Daily Flow	168 MGD	168 MGD
NPDES Peak Instantaneous Flow	224 MGD	274 MGD

The wet weather treatment capacity at the Southwest WPCP will be increased by 60 MGD through a redundant effluent pump. The increased capacity will allow for the treatment of additional wet weather flow, which will be reflected in future modifications to the NPDES permit as presented in Table 3:

Table 3: Current and Future Southwest WPCP Permitted Capacity

	2007-2012 NPDES Permit	Future (2031)
Facility Design Flow Rate	200 MGD	200 MGD
NPDES Maximum Daily Flow	300 MGD	300 MGD
NPDES Peak Instantaneous Flow	400 MGD	460 MGD

4.0 Implementation Approach for the Water Pollution Control Plants

Philadelphia Water is taking a comprehensive approach to achieving increased wet weather treatment capacity and reduced CSO volume. The implementation approach includes construction projects within the WPCPs, but also looks outside the boundaries of the WPCPs to the Collection System to achieve desired flow delivery. Additionally, operational strategies at the WPCPs may be implemented if it is determined that they assist in increasing wet weather flows through the WPCPs.

The Northeast WPCP is receiving the largest increase in wet weather treatment capacity. Philadelphia Water has prioritized analysis and planning activities for the Northeast WPCP. Some of the identified projects have been completed at the Northeast WPCP and others are either in progress or scheduled for implementation.

As part of the LTCPU, 24 improvements for modifications were considered at the WPCPs for increasing the plants' wet weather treatment capacities. The 2013 Facility Concept Plan identified 12 projects to achieve the goals of the approved LTCPU. Design and construction updates on the projects are described in subsequent sections.

4.1 Northeast Water Pollution Control Plant

As part of the LTCPU, eleven improvements for plant modifications were considered for the Northeast WPCP to increase wet weather treatment capacity at the facility. Philadelphia Water has selected seven of the LTCPU improvements and introduced one operational strategy to achieve wet weather treatment capacity increases at the Northeast WPCP. Additionally, one study was also identified for further analysis to evaluate ways to optimize the wet weather capture and treatment of flows in the WPCP. Within Table 4, the selected projects and studies related to the Northeast WPCP are presented. The projects and studies for Philadelphia Water's Collection System are discussed in Section 5.0.

Table 4: Status of Projects and Studies for the Northeast WPCP

Description		Status
Projects	New Bypass Conduit from Primary Sedimentation Tanks (PST) Set 1 to Chlorine Contact Tanks with Disinfection Upstream of Chlorine Contact Tanks	**Under Construction** at 75% complete
	Preliminary Treatment Building (PTB) #2	**Design Started**
	New Influent Baffles in PST Set 2	**Design Started**
	Remove Double Deck Effluent Channel in Final Sedimentation Tanks (FST) Set 2	**Complete**
	New (4 x 48") conduits from PTB to PST Set 1	**Complete**
Operational Improvements	Operate with minimal sludge blanket when Gravity Sludge Thickeners in service	**Gravity Sludge Thickeners are Under Construction** at 20% complete
Studies	Potential Modification to the Secondary Clarifiers for Increased Wet Weather Treatment Capacity	**Complete**

4.1.1 Completed Northeast WPCP Facility Improvements

Remove Double Deck Effluent Channel in FST Set 2

In December 2011, Philadelphia Water removed the hydraulic restriction in the double deck effluent channel of FST Set 2. Under high flow conditions, excessive energy losses caused weir flooding and a hydraulic imbalance between the two sets of FSTs. The energy loss that occurred in the channels was alleviated by connecting the upper effluent channel directly to the effluent conduit. Removal of this hydraulic restriction required the relocation of the return activated sludge line and the removal of an FST tank wall.

The removal of the Double Deck Effluent Channel in FST Set 2 was completed in 2011 and is in operation.

New (4 x 48") Conduits from the PTB to PST Set 2

In August 2012, four new conduits were constructed to connect the existing PTB with the PST Set 1, which improved hydraulic capacity in the grit tanks during high flow conditions. This project involved the construction of four 48"diameter conduits between the PTB and PST Set 1.

As of 2012, the new conduits from PTB to PST Set 1 are in operation.

4.1.2 Current and Future Northeast WPCP Facility Improvements

Two new planned facilities will add to the wet weather treatment capacity of the Northeast WPCP. A new Secondary Treatment Bypass Conduit will allow for up to 215 MGD of additional wet weather flow to receive primary treatment and disinfection during wet weather events. An additional PTB will increase the amount of flow that can be delivered to the plant from the Frankford High Level (FHL) Sewer.

New Bypass Conduit from PST Set 1 to the Chlorine Contact Tanks with Disinfection Upstream of Chlorine Contact Tanks

Philadelphia Water has begun construction of a Secondary Treatment Bypass Conduit from the PST Set 1 to the upstream area of the Chlorine Contact Tanks, thereby bypassing aeration and secondary clarification. The Secondary Treatment Bypass Conduit will include chlorine addition at the conduit influent. Pursuant to the existing NPDES permit (2007), Philadelphia Water received approval for a 100 MGD bypass on April 1, 2009. Subsequently, upon further engineering analysis and review, it was determined that the Northeast WPCP Secondary Treatment Bypass Conduit could accommodate wet weather flows of 215 MGD. The 215 MGD was incorporated and approved within the LTCPU. Up to 215 MGD of primary-treated flow will be blended with 435 MGD of secondary-treated flow prior to disinfection and discharge.

Philadelphia Water performed sodium hypochlorite disinfection studies to design a chemical feed system at the head of the Secondary Treatment Bypass Conduit. Disinfection will be provided as the flow enters the bypass channel, so chlorine contact time is provided within the bypass, as well as at the Chlorine Contact Tanks. Chlorination of the bypassed water will precondition this stream resulting in blended water with similar chlorine consumption requirements to minimize potential disinfection performance changes in the Chlorine Contact Tank.

Construction of the Secondary Treatment Bypass Conduit has begun and is more than 50 percent complete. The contractor bid construction cost is $15 M.

Additional Preliminary Treatment Building (PTB #2)

To achieve a peak maximum influent wet weather flow of 650 MGD, an additional preliminary treatment building is required. The additional PTB will accept and treat the increased flow from the FHL sewer and reduce hydraulic energy losses in the plant.

The additional PTB is designed to provide treatment for 250 MGD of flow from the FHL sewer. The project is currently in the design phase with an engineer's estimated construction cost of $63 M.

New Influent Baffles in PST Set 2

Philadelphia Water will construct influent baffles to ensure that increased flow into the PST Set 2 will not re-suspend any settled solids. Additionally, the construction of Gravity Sludge Thickeners (GST) will allow the Northeast WPCP to operate the PSTs with a minimal sludge blanket, further reducing the likelihood of re-suspending settled solids in the PSTs with wet weather flows. A computational fluid dynamics analysis of the baffle plates has been completed;

a design was created to minimize scouring velocities at the tank influent and the sludge collection channel.

The construction of the New Influent Baffles will be included with the construction of the additional PTB; the cost of the baffles is included in the additional PTB's construction cost.

4.1.3 Operational Improvements at the Northeast WPCP

Changes to a plant's operations may result in flow capacity increases, thus the plant may process more flow. Philadelphia Water will continue to look at ways to improve the operation and treatment capacity of the Northeast WPCP. One operational change that is planned for the Northeast WPCP to process additional flow is the operation of the PSTs with a minimal sludge blanket when the GSTs are in operation. This operational strategy is described below.

Operate with Minimal Sludge Blanket when the Gravity Sludge Thickeners are in Service.

Philadelphia Water has committed to constructing GSTs to increase primary treatment capacity by allowing future operation of the PSTs with a minimal sludge blanket. A secondary benefit of this operational change is minimizing odors generated inside the plant. Implementation of the GSTs will allow continuous removal of primary solids, thereby increasing primary treatment capacity, particularly under wet weather solids loading conditions. Within the LTCPU, a PST capacity of 650 MGD, which was based on a surface overflow rate of 3,200 gpd/ft^2, was discussed to maintain NPDES-permitted total suspended solids effluent limits. In addition, the GSTs will reduce wet weather solids loading on the FSTs without overloading the anaerobic digesters.

The construction of the GSTs is 25 percent complete. The contractor bid construction cost, including demolition of existing structures on the site, is $40M.

4.1.4 Facility Improvement Studies for the Northeast WPCP

Potential Modification to the FSTs for Increased Wet Weather Treatment Capacity

Philadelphia Water has installed a chemical feed system at the Northeast WPCP for optional coagulant application in the mixed liquor channels to improve wet weather treatment in the FSTs when needed.

4.2 Southeast Water Pollution Control Plant

As part of the LTCPU, seven plant improvements were considered to increase wet weather treatment capacity at the Southeast WPCP; two of the seven LTCPU improvements were selected for the Southeast WPCP. Additionally, one study was identified for further analysis to evaluate the optimization of wet weather flow treatment in the WPCP. The selected projects and studies specific to the Southeast WPCP are presented in Table 5.

Table 5: Status of Facility Concept Plan Projects and Studies for the Southeast WPCP

Project/Study		Status
Facility Improvements	Provide facilities for phosphorus addition to wastewater	**Completed**
	Resolve capacity limitation associated with having one coarse bar rack out of service and hydraulic bottleneck at existing influent pump station	**Completed**
Studies	Resolve hydraulic limitation between primary clarifiers and the aeration basin	**Study Completed, Modifications not required** to achieve 274 MGD capacity

4.2.1 Completed Southeast WPCP Improvements

To ensure unit operation redundancy to consistently meet the increased wet weather treatment capacity, the following projects were identified and completed:

Provide facilities with phosphorus for addition to wastewater.

Philadelphia Water has installed and currently operates a phosphoric acid feed system.

Replace Influent Pump Station Coarse Bar Rack System

The influent pumping station coarse bar racks were identified as a limitation to increased flow capacity. In 2016, the construction of a new Influent Pump Station Coarse Bar Rack system rated above 274 MGD was completed and is in operation.

4.2.2 Current and Future Southeast WPCP Improvements

At this time, no facility improvements at the Southeast WPCP are planned.

4.2.3 Operational Improvements at the Southeast WPCP

At this time, no operational improvements at the Southeast WPCP are planned.

4.2.4 Facility Improvement Studies for the Southeast WPCP

In an effort to address potential operational limitations of increasing Southeast WPCP's wet weather treatment capacity by 50 MGD, Philadelphia Water initiated additional hydraulic investigations. The following facility improvement study was identified and completed:

Aeration Basin Hydraulic Limitation Study

As identified in the LTCPU, a study was initiated to investigate a hydraulic limitation between the PSTs and the Aeration Tanks. Historical operations at the Southeast WPCP indicated that the Aeration Tanks' influent weirs may not distribute flow evenly to the Aeration Tanks at or near peak wet weather flow.

To complete this study, Philadelphia Water created and calibrated a Computational Fluid Dynamic model. The geometry of the model included the Primary Effluent Channel to the Aeration Influent Structure and the Aeration Distribution Conduits into the Aeration Tanks through to the Aeration Effluent Channel. The model identified that during high flows, a restriction exists in the influent openings into the Aeration Tanks. However, the results of the study indicated that while the Aeration Influent Structure Weirs may become submerged at high flows, the flow distribution into the Aeration Tanks remained evenly distributed. Therefore, no capital projects or operational changes are required to treat a peak instantaneous flow of 274 MGD at the Southeast WPCP.

4.3 Southwest Water Pollution Control Plant

As part of the LTCPU, six improvements for plant modifications were considered for the Southwest WPCP to increase the plant's wet weather treatment capacity. Philadelphia Water selected two of the six projects from the LTCPU improvements to achieve increased wet weather treatment capacity at the Southwest WPCP. Additionally, two studies were also identified for further analysis to evaluate ways to optimize the wet weather flow capture and treatment. The selected projects and studies related to the Southwest WPCP are presented in Table 6. The projects and studies for Philadelphia Water's Collection System are discussed in Section 5.0.

Table 6: Status of Facility Concept Plan Projects and Studies for the Southwest WPCP

Projects/Studies		Status
Facility Improvements	Replace caulking on secondary clarifier launders to improve flow distribution.	**Completed 2002**
	Provide an additional effluent pump at the effluent pump station.	**Design complete,** anticipated bid in 2017

Within the LTCPU, Philadelphia Water committed to the expansion of the Southwest WPCP's secondary treatment capacity by 60 MGD. Accordingly, Philadelphia Water has committed to a future NPDES-permitted peak instantaneous wet weather treatment capacity of 460 MGD.

4.3.1 Completed Southwest WPCP Improvements

To maintain operational reliability and consistently meet the required peak wet weather treatment capacity, the following capital project was completed:

Caulking on Final Sedimentation Tank Launders

All effluent weirs in the FSTs were replaced and sealed to prevent short circuiting and improve flow distribution. Philadelphia Water has observed improved performance of the FSTs as a result of this capital investment.

Caulking of the FST Launders is completed and in service.

4.3.2 Current and Future Southwest WPCP Facility Improvements

To ensure unit operation redundancy in the future, the following capital project has been identified:

Effluent Pumping Redundancy

As the result of the investigations conducted to date, as well as observations made by Southwest WPCP Operations Staff during wet weather events in August and September of 2011, Philadelphia Water has determined that an additional effluent pump is required. Currently, the Southwest WPCP has five effluent pumps, each rated at 115 MGD, which provide redundancy at 460 MGD. The addition of a sixth pump will allow the plant to have one pump out of service and still meet peak instantaneous flows of over 460MGD. Philadelphia Water has completed the design for installation of an additional pump, to be located within available space inside the existing effluent pump station.

The design of the additional effluent pump has been completed with an estimated cost of $2M. The project will move to construction as funding allows and will be completed within the regulatory timeframe (i.e., by June 2026).

4.3.3 Operational Improvements at the Southwest WPCP

At this time, no operational improvements are planned for the Southwest WPCP.

4.3.4 Facility Improvement Studies for the Southwest WPCP

At this time, no facility improvement studies relating to increases in wet weather treatment capacity are planned for the Southwest WPCP.

5.0 Implementation Approach for the Philadelphia Collection System

Philadelphia Water continues to evaluate and implement projects to maximize delivery of wet weather flow to the WPCPs during implementation of the *Green City, Clean Waters* program. Hydraulic studies focus on identifying and resolving any capacity limitations and identifying modifications to influent pumping that may increase flow delivery. Hydraulic and hydrologic modeling also seeks to increase duration of wet weather flows in support of green infrastructure which manages stormwater through slow-release into combined sewers.

Philadelphia Water's three WPCP's are hydraulically interconnected at a number of crucial large diversion structures and large hydraulic control points. The drainage areas contributing to those WPCPs are not easily defined by natural surface drainage divides. The interconnecting hydraulic structures are significant capital assets that continuously distribute contributing flows among the sewers leading to the three WPCPs during normal operating conditions in both dry and wet weather. These structures were developed and implemented over many years of operational experience to provide efficient operating conditions in both dry and wet weather and, most importantly, to provide relief from flooding conditions for large areas of the city.

The Collection System is deliberately interconnected to maximize treatment flexibility and efficiency as well as to help mitigate flooding impacts. Hydraulic studies and modeling provides insight into understanding how the combined systems work together to convey and distribute flow through the city. The existing hydraulic interconnectivity, as well as any changes made to the system in the future, provides Philadelphia Water with opportunities to address its targets for capture and treatment of CSOs.

Table 7: Status of Collection System Projects and Studies Identified in *Facility Concept Plans* (2013 Consent Order & Agreement Deliverables V, VI, and VII)

	Description	Status
Projects	FHL Sewer Second Barrel Rehabilitation	**Complete**
	Secondary 66" Frankford Grit Chamber Bypass	**Complete**
Studies	Potential Modification to the Upper Delaware Low Level Sewer	**Ongoing**
	Potential Modifications to the Frankford High Level Sewer	**Ongoing**
	Balancing of CSO Regulator Wet Weather Capacities*	**Ongoing**

*Projects may result from the recommendations of this study.

5.1 Completed Collection System Studies

5.1.1 Potential Modification to the Upper Delaware Low Level Sewer

Philadelphia Water completed a study to identify locations of potential limitations within the Upper Delaware Low Level Sewer by considering: Northeast WPCP influent pumping capacity, hydraulic and hydrologic modeling of the Upper Delaware Low Level Sewer capacity, and

observed operations data. Potential projects to remove the bottlenecks within the Upper Delaware Low Level sewer were evaluated in combination with the balancing of CSO Regulator wet weather capacities.

5.1.2 Potential Modifications to the Frankford High Level Sewer

Expansion of the FHL Sewer

In 2012, Philadelphia Water completed a conceptual design study to evaluate the potential expansion of the FHL sewer capacity through the construction of an additional intercepting sewer. Expansions options included either enlarging the FHL sewer by constructing an additional 90" sewer barrel or replacing the out-of-service 78" barrel with a new, larger capacity sewer. The Collection System model included replacing the Frankford Grit Chamber Bypass, modifying the R-18 weir, and balancing CSO Regulator wet weather capacities.

Increase Capacity of the FHL Sewer by Rehabilitation of the Out-of-Service 78" Barrel and Out-of-Service 66" Frankford Grit Chamber Bypass Conduit

In 2013, Philadelphia Water completed hydraulic modeling of the FHL sewer to evaluate the effect of rehabilitating an out-of service 78" conduit. Preliminary hydraulic modeling estimated that returning the 78" barrel to service could provide approximately 40-50 MGD of additional flow to the FHL sewer capacity without any modifications to the existing PTB at the Northeast WPCP. Upon the completion of the additional PTB at the Northeast WPCP, planned for 2031, the FHL sewer capacity with the 66" and 78" barrels in-service has an estimated conveyance capacity of 200 MGD.

The hydraulic modeling of the FHL sewer also considered returning an out-of-service 66" Frankford Grit Chamber Bypass Conduit into operation, in conjunction with the 78" FHL Barrel. Returning the bypass to service is in lieu of constructing a new Frankford Grit Chamber Bypass, as identified in the LTCPU. The sewer modeling confirmed that putting the Grit Chamber Bypass in-service reduces a constriction necessary to provide approximately 205 MGD of conveyance capacity associated with returning the FHL sewer's 78" conduit into service.

5.1.3 Conclusion of Studies

The results of the studies described in Sections 5.1.1 and 5.1.2 indicated that the rehabilitation and returning to service of the 78" FHL sewer barrel and the 66" Frankford Grit Chamber Bypass Conduit, the balancing of CSO Regulator wet weather capacities in conjunction with regulator modifications in the low level sewer, and modification of the R-18 weir can most cost-effectively achieve the peak instantaneous flow requirement of 650 MGD for the Northeast WPCP for year 2031. Furthermore, some preliminary analysis indicates that expanding the FHL sewer with a new barrel and constructing a new Grit Chamber Bypass may not be required to meet the 650 MGD conveyance commitments for the Northeast WPCP. Likewise, preliminary modeling analysis indicated that removing constrictions in the Upper Delaware Low Level Sewer (independent of regulator balancing) were not required for adequate flow conveyance from the low level system to the Northeast WPCP. Philadelphia Water will periodically re-evaluate the

Collection System modeling and analysis as part of the approved LTCPU (2009) adaptive management plan.

5.2 Completed Philadelphia Collection System Projects

Based on the Collection System studies cited in Section 5.1, Philadelphia Water initiated capital projects to increase conveyance to the Northeast WPCP, which will allow Philadelphia Water to achieve the flows committed to for future NPDES permits. The following capital projects have been completed:

FHL Sewer Second Barrel Rehabilitation

Rehabilitation of the barrel included rebuilding twelve sewer manholes with pressure seals, sealing the openings at Diversion Chamber B, and resealing 200 reinforced concrete pipe joints from Almond Street to the plant entrance east of Richmond Street. As of April 2016, the rehabilitation of the FHL Second Barrel is complete and in service.

Secondary 66" Frankford Grit Chamber Bypass In Service

In August 2012, the secondary 66" Frankford Grit Chamber Bypass Conduit was returned to service.

5.3 Ongoing Collection System Studies and Projects

5.3.1 Balancing CSO Regulator Wet Weather Capacities

Background

The approved LTCPU relies, in part, upon land-based stormwater management practices. Those practices are intended to control stormwater runoff at the source through infiltration, evapotranspiration, decentralized storage, and slow release to the combined sewer system for conveyance to the WPCPs. For the slow release of stormwater detained in green stormwater infrastructure to be most effective in reducing overflow volume and duration, there must be sufficient treatment capacity at the regulator to admit the cumulative stormwater flows that have been achieved by all management practices in the entire sewershed. This requires sufficiently balancing wet weather regulator capacities, on a unit drainage area basis, among the regulators located within the entire city drainage area, to allow for the balanced treatment of slow releases from management practices in all combined sewer areas.

In the course of developing the green stormwater infrastructure approach to control sewer overflows, hydrologic and hydraulic modeling-based analyses revealed that the WPCPs provide a unit area treatment rate for combined sewage flows in wet weather equal to approximately 0.05 cubic feet per second per acre of impervious cover. Further, the approved LTCPU firmly established the seminal concept that the efficient implementation of green stormwater infrastructure as an overflow control does not lend itself to special targeting of different levels of implementation in different sewersheds. The only realistic and practical approach to implementing green stormwater infrastructure within the City's combined sewer areas is to treat

all areas equally in seeking opportunities for that implementation.[1] As a result, Philadelphia Water's combined system-wide design standard for all green stormwater management facilities that incorporate storage and slow-release is set at 0.05 cubic feet per second (or less) per acre of tributary impervious area draining directly to the control facility. Therefore, the balancing of the wet weather treatment rates provided by the WPCPs equally across the Collection System for all regulating chambers, to the extent technically and economically feasible, is a fundamental design assumption underlying the successful implementation of the City's approved LTCPU.

Therefore, Philadelphia Water's plan to improve the Collection System capacity focuses on studies and subsequent capital projects to modify the Collection System hydraulic controls, increasing the average annual duration of peak wet weather flows and balancing regulator capacities, on a unit drainage area basis.

Regulator Modification Options Considered for Capacity Improvements

In 2014, Philadelphia Water completed hydrologic and hydraulic modeling on the Collection System to develop planning-level analyses for a broad range of interceptor and trunk sewer improvement alternatives designed to increase wet weather flow delivery to the WPCPs in a balanced manner and to maximize performance of planned green stormwater infrastructure. Regulator modifications considered include:

- Modification to regulator dry-weather orifice control settings
- Regulator orifice enlargement
- Regulator connector pipe enlargement / replacement
- Raising existing regulator overflow weir elevations without regulating chamber reconstruction
- Regulator overflow weir elevations increased through chamber reconstruction and/or adding moveable weirs with local-reactive controls

These regulator modifications fall into two primary categories: increasing regulator orifice and/or connector pipe capacities and increasing overflow weir elevations.

Improvements to regulator orifice sizes can range from simple modification of existing structures to complete reconstruction of regulating chambers. Enlargement of dry weather outlet pipes (*i.e.*, pipes connecting the combined sewer regulating structure to the interceptor sewers) generally requires replacing existing conduits with pipes of increased diameter, but in some cases require construction of an additional parallel pipe from the regulating chamber to the interceptor.

Improvements to increase regulator overflow weir elevations range from the simple addition of stop logs to larger capital projects to raise the dams. These modifications improve treatment rate through increasing the hydraulic gradient between the regulating chamber and the

[1] Consent Order and Agreement, Appendix E, Document #5

interceptor, as well as increasing in-system storage volumes below the overflow elevation. Modeling must consider that increasing overflow weir elevation increases the hydraulic grade line in trunk sewers during storm events, which increases the risk of basement and structural flooding in the upstream collection system. Some degree of reconstruction of the regulating chambers may be needed to achieve increases in overflow weir elevation while providing necessary flood protection through increasing the length of the weir or adding moveable weirs with local-reactive controls.

Regulator Balancing and Collection System Alternatives Analyses

Planning-level alternatives for regulator and collection system modifications were evaluated in 2014 in support of the LTCPU. The improvement projects considered for the Collection System clearly demonstrated that modifications will support the Northeast, Southeast, and Southwest WPCPs by reliably conveying instantaneous peak wet weather flows of 650 MGD, 274 MGD, and 460 MGD, respectively, by 2031. The modeled Collection System alternatives effectively increased conveyance and fully supported the 0.05 cubic feet per second (or less) per acre of tributary impervious cover treatment by the green stormwater management components of the LTCPU. Estimated construction costs for modifications within the Collection System are presented in Table 11.

In July 2015, Philadelphia Water completed a detailed alternatives analysis for the regulators that convey flow to the Southeast WPCP. As a result of this analysis, Philadelphia Water implemented reversible modifications to specific regulators in 2015. For identified modifications that require capital improvements, such as enlarging orifices and/or lengthening and raising weir dam elevations, Philadelphia Water is currently reviewing the constructability and feasibility prior to entering the detailed design phase. These projects are being evaluated as part of the approved LTCPU's adaptive management approach with implementation of all projects targeted by June 2031. Some regulating chamber modifications are currently under construction.

As of June 2016, Philadelphia Water is in the process of performing a detailed alternatives analysis for the remaining parts of the Collection System.

In the following sections, potential modifications for the Collection System are described in detail.

5.3.2 Implementation of CSO Regulator Balancing Studies

Modifications to Regulator Dry-weather Orifice Control Settings:

The planning-level evaluation completed in 2014 identified locations that have the potential to increase collection system performance through modifications to the regulator dry-weather orifice control settings. Following model evaluations, some modifications have been made to actively-controlled Brown and Brown regulators in a fully reversible manner by chaining the Brown and Brown float-controlled gate in the fully open position. Additional modifications, if any, will be completed in the same manner (*i.e.,* fully reversible.)

The regulators that have been chained open to-date are presented in Table 8.

Table 8: Dry-weather Orifices Modified and Dates of Modifications

Regulator(s)	Date of Modification Completion
D48, D51, D52, S10	8/27/2015
S06, S08, S09	8/28/2015
D53, D54, S15, S17, S18	8/29/2015
S16	8/31/2015
D46, S13, S19	9/1/2015
D37	10/28/2015
D41, D38	11/12/2015
D50, D49, D47	11/13/2015
D67, D59, D61, D64, D65, D66	11/14/2015
D73	11/15/2015
D62, D68, D70, D71, D72	11/16/2015

As discussed in the *Updated Nine Minimum Controls Report (June 2013),* regulator modifications represent changes to previous regulator settings that were designed to prevent flow reversals during major wet-weather events and to prioritize treatment at regulators considered at the time to have a greater potential for contributing higher pollutant loads. These changes, if any, will be made to be fully reversible at this time in order to evaluate the impacts on the Collection System and the three WPCPs that may result from these changes during large wet-weather events.

Regulator Orifice Enlargement:

A planning-level analysis is currently in progress to determine the potential for increasing the capture and treatment of wet weather flows from combined sewers in the Collection System by increasing the dry-weather orifice opening dimensions within the existing regulating chamber structures. Four regulating chambers were selected for this type of modification and three projects are in-service (construction substantially complete as of June 2016). This modification incorporates enlarging the orifice as well as raising and lengthening of regulator weir dams. The modification to the fourth chamber is considered a capital project and is currently in the detailed design phase. Within

Table 9, the four regulating chambers selected for modifications are listed.

Table 9: Regulator Orifice Enlargement and Weir Modifications Identified for Reconstruction.

Regulator	Modification	Current Status
D25	Raise and widen overflow weir, enlarge orifice	In-service 2015
D44	Raise and widen overflow weir, enlarge orifice	In-service 2015
D45	Raise and widen overflow weir, enlarge orifice	In-service 2016
D67	Raise and widen overflow weir, enlarge orifice	In Design

Another eight locations were identified for regulator orifice enlargement; the constructability and cost of these potential projects are currently being evaluated. Projects, if any, will be selected for implementation based on comprehensive alternatives analyses performed as part of the approved LTCPU's adaptive management approach with a targeted completion date of June 2031.

Regulator Connector Pipe Enlargement / Replacement:

The potential for increasing capture and treatment of wet weather flows from combined sewers in the Collection System in support of the LTCPU through increasing the regulator connector pipe capacity is being evaluated. A planning-level evaluation has been completed for some connector pipe capacities; the results did not identify projects to increase connector pipe capacity to achieve cost-effective improvements in system performance for any of the areas analyzed. Upon further evaluation, projects, if any, will be selected for implementation based on comprehensive alternatives analyses performed as part of the approved LTCPU's adaptive management approach with a targeted completion date of June 2031.

Raising Existing Regulator Overflow Weir Elevations without Regulating Chamber Reconstruction

Raising overflow weir elevations without measures to maintain flood protection has *not* been considered in the Collection System. All combined sewer regulators that convey flow to the Southeast WPCP are tidally impacted. Therefore, these specific regulators can be considered to be susceptible to upstream flooding and basement back-ups during extreme hydrologic conditions.

Raising Regulator Overflow Weir Elevations through Chamber Reconstruction and/or Adding Moveable Weirs with Local-Reactive Controls

A planning-level analysis was completed in 2014, in support of the LTCPU, to analyze the potential for increasing capture and treatment of wet weather flows from combined sewers by increasing regulator overflow weir elevations, increasing weir lengths, and providing current levels of flood protection through chamber reconstruction. Further evaluations are required to identify the potential for increasing capture and treatment of wet weather flows at new or existing regulating structures to be achieved by raising overflow weir elevations using moveable weirs with local-reactive controls.

An alternatives analysis for the Collection System, completed in 2015, identified six locations with the potential to increase flow conveyance through the construction of new regulating structures with increases in overflow weir elevations and weir lengths. An evaluation is

currently in progress to determine the constructability, feasibility, and cost of these projects; the implementation of moveable weirs with local-reactive controls at all of these locations is also being evaluated. Projects will be selected for implementation based on comprehensive alternatives analyses performed as part of the approved LTCPU's adaptive management approach, with a targeted completion date of June 2031.

Within Table 10, three recently-completed projects for the Collection System are listed, which employ movable weirs and local-reactive controls.

Table 10: Local-Reactive Control Modifications to Regulating Chambers

Regulator	Modification	Current Status
T14	Movable crest weir with reactive control	In Service
R15	Storm Flood Relief Structure	In Service
H35	Inflatable dam	In Service

6.0 Design and Implementation Schedule

Specific project details, such as anticipated construction completion and costs, for each of the planned capital projects for the Northeast, Southeast, and Southwest WPCPs and the city-wide Collection System are included in Table 11.

Table 11: Anticipated Design and Implementation Schedule for Identified Projects

WPCP and Collection System Improvements	Anticipated Construction Completion	Actual / Estimated Cost
Northeast WPCP		
Facility Improvements		
Remove Double Deck Effluent Channel in FST Set-2	Operational 2012	$ 1.0 M[1]
New (4 x 48") conduits from PTB to PST Set-1	Operational 2012	$ 3.9 M[1]
Secondary Treatment Bypass	June 2021	$ 15.1 M[1]
Gravity Sludge Thickeners	December 2018	$ 41.8 M[1]
Preliminary Treatment Building #2	June 2031	$ 63.0 M[2]
New Influent Baffles in PST Set-2	June 2031	Included in PTB #2
Operational Improvements		
Operate with minimal sludge blanket when GSTs in service	December 2018	--
Southeast WPCP		
Facility Improvements		
Replacement Influent Pump Station Coarse Bar Rack	Operational 2016	$ 2.0 M[1]
Operational Improvements		
None Identified to Date	--	--
Southwest WPCP		
Facility Improvements		
Add Redundant Effluent Pump	June 2026	$ 2.0 M[2]
Operational Improvements		
None Identified to Date	--	--
Collection System		
Facility Improvements		
Second 66" Frankford Grit Chamber Bypass In Service	Operational 2014	$ 0
FHL Second Barrel Rehabilitation	Operational 2016	$ 0.9 M[1]
Balancing CSO Regulator Wet Weather Capacity	June 2031[3]	$ 71.0 M[4]

[1]Contract cost
[2]Engineer's Estimate
[3]All Improvements outlined in the LTCPU (2009) will be completed at this time.
[4]Planning-level cost estimate