APPENDIX E

Supplemental Documentation
in support of the City of Philadelphia's Combined Sewer Overflow Long Term Control Plan Update

April 2011

The City of Philadelphia (City) submitted its Long Term Control Plan Update to the Department of Environmental Protection (DEP) on September, 1, 2009. Since that date the City and DEP have engaged in a series of discussions regarding the Update.

As a result of these discussions, the City hereby submits the attached Supplemental Documentation to the LTCP Update. This Supplemental Documentation hereby amends, and becomes fully incorporated into, the City's LTCP Update.

The Supplemental Documentation consists of six (6) separate documents as described below:

Document #1 - PWD System-wide Combined Sewer Overflow Volume Summary

Document #2 - Mass Loading Presumptive Approach

Document #3 - Background and purpose of the conversion of the combined sewer system hydrologic and hydraulic models from USEPA SWMM4 to SWMM5

Document #4 - Description of interceptor lining program (TTF and Cobbs), history and context

Document #5 - Rationale for Equal Distribution of Green Stormwater Infrastructure Implementation in all Neighborhoods

Document #6 - Application of Sensitive Area Criteria to City of Philadelphia CSO Receiving Waters

Document #1
Technical Memorandum
Office of Watersheds - PWD
March, 2011

Subject: **PWD System-wide Combined Sewer Overflow Volume Summary**

SUMMARY

This technical memorandum describes the methodology and results of the Philadelphia Water Department's estimation of the system-wide combined sewer overflow volume. At present, the system-wide overflow volume calculation is based on USEPA SWMM Version 4 modeling results from the individual sewershed regulators that then are aggregated based on interceptor and drainage district configuration and accumulated to a PWD system-wide result. The methodology and results described in this technical memorandum are those developed using the 2009 SWMM4 versions of PWD's combined sewer system hydrologic and hydraulic models.

Further detail regarding the hydrologic and hydraulic models used as basis for the combined sewer overflow and capture volume calculation can be found in *LTCPU Supplemental Document 4: Hydrologic and Hydraulic Modeling.*

PWD System-wide Overflow Volume

System-wide overflow volume is the aggregation of each interceptor and Water Pollution Control Plant (WPCP) district combined sewer overflow volume. Aggregation to the interceptor level begins with individual sewershed regulators and the respective capture and overflow volumes. WPCP district level aggregation is from the interceptors draining to that district's WPCP. The PWD system-wide aggregation calculation is from either interceptor or WPCP district level, summing each system or district's overflow volume to total system-wide overflow volume.

Capture Methodology

Capture of combined sanitary and stormwater flows requires first that wet weather events are defined. In the Long Term Control Plan Update (LTCPU), baseline wet weather is defined as when the flow in the dry weather pipe, connecting the regulator to the interceptor, increases by more than 5 percent of the dry weather baseflow. Capture calculations are performed in two steps. In the baseline condition, captured volume is the volume of combined sewer flow that is sent to the WPCPs during wet weather. In alternatives with CSO controls in place, captured volume includes volume sent to the WPCPs and the volume prevented from reaching the Combined Sewer System (CSS) by source controls (infiltrated, evaporated, and/or transpired runoff volume). Percent capture is calculated as the ratio of the captured volume to the sum of captured volume and volume overflowed to receiving waters.

The capture calculations are performed at each regulator. Each of the regulators is assigned to an interceptor system and the capture results from each regulator can be aggregated for that interceptor system. These results from the interceptors are further aggregated by WPCP drainage district and by watershed.

Baseline Capture Calculations and Overflow Estimation

Baseline capture calculations use the following approach.

1. The capture formula is "Percentage Capture at a given regulator = 100 * [Total Volume through the dry weather pipe at the regulator / (Total Volume through the dry weather pipe at the regulator + Total volume that overflows to receiving water from the regulator)]".
2. For each regulator in the CSS, the dry weather flow pipe (DWO) and wet weather overflow pipe (SWO) is identified.
3. Flow for all the pipes identified in the last step is generated from the SWMM models. Another set of flows for the same pipes as above are generated for the same period as the wet weather simulation except using 0 (zero) precipitation. The zero precipitation simulation is performed to obtain the dry weather flows for the period of interest.
4. For each of the regulators, DWO and SWO pipe flow calculations are performed as follows.
    a. A tolerance is set for the baseflow for all the regulators which when exceeded indicates the regulator is in wet weather conditions (This tolerance is set at 5% for the LTCPU, when flow in the DWO pipe is above 5% of baseflow, the regulator is assumed to be in wet weather). Based on the baseflow tolerance, the wet weather events are identified for the regulator. Capture calculations are performed for the wet weather events (using the formula in step 1).
    b. If overflows from one regulator (Regulator "A") are re-regulated at another regulator (Regulator "B"), the overflow from A will be ignored when the capture result is aggregated to interceptor system. Overflow in A is considered "negative flow" in the calculations.
    c. If a regulator (Regulator "C") re-regulates flow from upstream regulator's DWO (Regulator "D", Regulator "E"), all the DWO flows from D and E (negative flows) are ignored and only DWO flow from C is used when capture result is aggregated to the interceptor system.
    d. Negative flow through DWO (flow being relieved) pipes is subtracted when the capture calculation is performed. This accounts for regulators relieving other regulators.
    e. The result from the CAPTURE program is summarized for annual totals and aggregated by interceptor, WPCP and watershed systems.

The volume of combined sewer overflow is estimated directly as the sewage volume not captured within the combined sewer system. The current estimate of the average annual City-wide overflow volumes is between 10,307 million gallons to 15,952 million gallons, with an inferred average overflow volume of 13,100 million gallons. This estimate range was developed using the hydrologic and hydraulic model, and the uncertainty estimation methodology, as described in the *LTCPU Supplemental Document 4: Hydrologic and Hydraulic Mode*ling. These estimates will be refined, and the uncertainty reduced, as the City GIS and flow monitoring information base is refined and expanded, and as the hydrologic and hydraulic model code, structures and validations evolve in response to those improvements and technology innovations.

Green Stormwater Infrastructure, Traditional Infrastructure and Large Scale Centralized Storage Capture Calculation Methodology

Capture calculations for the alternatives that have been analyzed in the LTCPU – Green Stormwater Infrastructure, Traditional Infrastructure (Transmission to the WPCP) and Large Scale Centralized Storage (Tunnel) – are performed using the baseline model capture values as the foundation. The approach described below assumes that the overflow volume reduction, as compared to the baseline values, is due to implementation of the alternatives.

Steps included in alternative capture calculation

1. The overflow volume (SWO_0) to the receiving waters and treated volume (DWO_0) from the baseline models are obtained. This may be aggregated to the interceptor level or further aggregated to the WPCP drainage district level or the watershed level depending on the alternative for which effective capture calculations need to be performed.
2. The alternative scenario's overflow volume (SWO_1) is aggregated to the interceptor level or further aggregated to the WPCP drainage district level or the watershed level, depending on the alternative (representing Green Stormwater Infrastructure, Traditional Infrastructure or Large Scale Centralized Storage).
3. The treated flow that accounts for the reduction in volume that overflows to the receiving water due to implementation of the alternatives when compared to the baseline is inferred by the water balance: $[(SWO_0 + DWO_0) - (SWO_1)]$
4. The alternative capture formula is: $100*[(SWO_0 + DWO_0) - (SWO_1)] / (SWO_0 + DWO_0)$

Document #2
Technical Memorandum
Office of Watersheds - PWD
March, 2011

Subject: **Mass Loading Presumptive Approach**

SUMMARY

As suggested by NRDC, Clean Water Action, and Penn Future, PWD has completed a preliminary analysis of the elimination or removal of no less than the mass of the pollutants that would be eliminated or captured for treatment under an 85% capture by volume scenario, as discussed in Section II.C.4.a of the National CSO Policy. The results suggest that a presumption approach based on equivalent mass removal is viable as an alternative to the demonstration approach.

National CSO Policy Language

Section II.C.4.a of the National CSO Policy allows the presumptive approach to be met by a minimum 85% capture of pollutant loads. For reference, here is the language describing the various ways of presuming compliance with the water quality standards:

"A program that meets any of the criteria listed below would be presumed to provide an adequate level of control to meet the water quality-based requirements of the CWA provided the permitting authority determines that such presumption is reasonable in light of the data and analysis conducted in the characterization, monitoring, and modeling of the system ...

i. No more than an average of four overflow events per year, provided that the permitting authority may allow up to two additional overflow events per year. For the purpose of this criterion, an overflow event is one or more overflows from a CSS as the result of a precipitation event that does not receive the minimum treatment specified below; or

ii. The elimination or the capture for treatment of no less than 85% by volume of the combined sewage collected in the CSS during precipitation events on a system-wide annual average basis; or

iii. The elimination or removal of no less than the mass of the pollutants identified as causing water quality impairment through the sewer system characterization, monitoring, and modeling effort for the volumes that would be eliminated or captured for treatment under paragraph ii. above."

It is **paragraph iii** that is the subject of this memorandum.

To establish target pollutant load mass removal rates, 85% of combined sewage must be treated according to the requirements of the Policy, which are primary clarification, solids and floatables disposal, disinfection of effluent, as necessary, and removal of disinfection residuals, where necessary. For reference, text from *Combined Sewer Overflows: Guidance for*

Long Term Control Plan (EPA, 1995) is provided below.

"The definition of "primary clarification" is one of the key implementation issues underlying the presumption approach and has generated considerable debate among regulators, municipalities, consultants, and equipment suppliers. The intent of primary clarification is removal of settleable solids from the waste stream, which will result in the environmental benefits outlined above. The CSO Control Policy does not define specific design criteria or performance criteria for primary clarification, however. This guidance document does not provide a definition either; instead, it discusses general considerations for primary clarification under the presumption approach, recognizing the variable nature of CSOs and general lack of historical data on CSO treatment facility performance. "

The city-wide average primary clarification percent removal numbers used in the subsequent equivalent mass calculations were determined from a sample analysis conducted at each of PWD's Water Pollution Control Plants (WPCP). Samples were taken at influent and effluent points during wet weather conditions for the primary clarification portion of the treatment systems. The sampling period for each WPCP, number of sample events and sample statistics for each district and city-wide are presented in Table 1. The values used in the subsequent calculations are highlighted in blue.

Table 1. Summary of WPCP primary clarification statistics and sampling study data.

		SE	*SW*	*NE*	*City-Wide Numbers*
Sampling Period		6/2008 - 6/2009	8/2008 - 8/2009	11/2008 - 4/2009	Varies between 6/2008 - 8/2009
# of Sample Events		7	16	5	28
TSS - % Removed	*Average*	65	68	69	**67**
	Max	88	80	84	84
	Min	37	44	50	44
BOD_5 - % Removed	*Average*	42	46	29	**39**
	Max	74	57	50	60
	Min	13	40	24	26

*Highlighted Values are the Values Used in this Analysis

Mass Loading Approach

To establish pollutant mass based targets to meet option iii requires a comparison of the pollutant removal by mass of the LTCPU selected alternative with an alternative that achieves 85% capture by volume using a traditional treatment approach. In following Section II.C.4.a of the National CSO Policy, PWD defines the 85% by volume traditional alternative as satellite primary clarification and disinfection (SPC) of the CSOs prior to discharge. To decide on the appropriate pollutant removal efficiencies, the results of sampling of the primary settling tanks from the PWD wastewater treatment plants were used. These indicated that PWD achieves relatively high removal rates when compared to literature values, and thus sets the 85% mass removal target relatively high. The removal rates for the pollutants of concern are shown in Table 1, as well as the expected concentrations in the untreated stormwater and sanitary sewage, and the expected concentrations of the effluent from green stormwater infrastructure assuming it passes through soil as part of the treatment.

Table 1: Concentrations and Removal Percentages used in the Analysis.

Type	BOD_5 (mg/L)	TSS (mg/L)	Fecal Coliform (per 100 mL)
Untreated Stormwater	8.445[1]	65.679[1]	1.00E+05[2]
Green Infrastructure Treated Stormwater	4.5[3]	8.8[3]	2.00E+02[4]
Sanitary Sewage	134[5]	116[5]	1.45E+06[5]
PCD % Removal	39%[6]	67%[6]	99.99%[7]

PCD = Primary Clarification and Disinfection

[1] Analysis of pooled EMC results from the National Urban Runoff Program (NURP), United States Geological Survey, and NPDES Phase I monitoring data.

[2] Study of bacteria concentrations in a combined sewer system in western Pennsylvania. Bacteria concentrations are highly variable, and true event mean concentration (EMC) studies are rare due to sampling difficulties. For reference, fecal coliform concentrations reported in NURP are on the order of 10^4/100 mL, while median concentrations from NPDES Phase I data reported by Robert Pitt are on the order of 10^3/100 mL. However, sensitivity analysis within a range of 10^3-10^5 indicates that changing this value does not change the conclusions of the study.

[3] Event mean concentrations in effluent from green stormwater infrastructure derived from the International Stormwater BMP Database.

[4] Median of grab sample data in effluent from green stormwater infrastructure derived from the International Stormwater BMP Database.

[5] Derived from PWD dry weather CSS monitoring data

[6] Derived from PWD wet weather primary clarifier data

[7] 4-log reduction derived from study of chlorination units

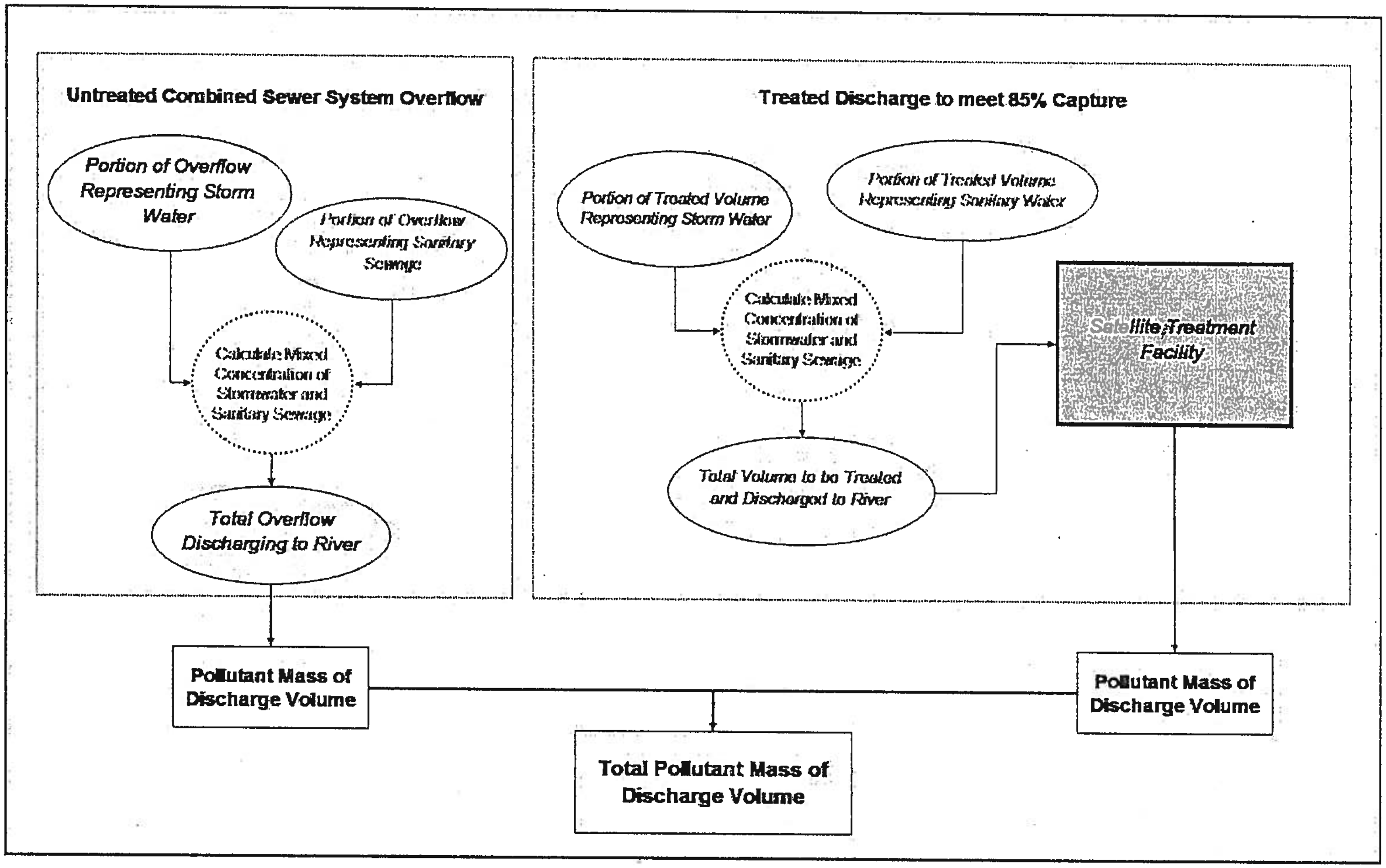


Figure 1. Traditional Alternative: Primary clarification, solids and floatables disposal, disinfection of effluent, as necessary, and removal of disinfection residuals, where necessary.

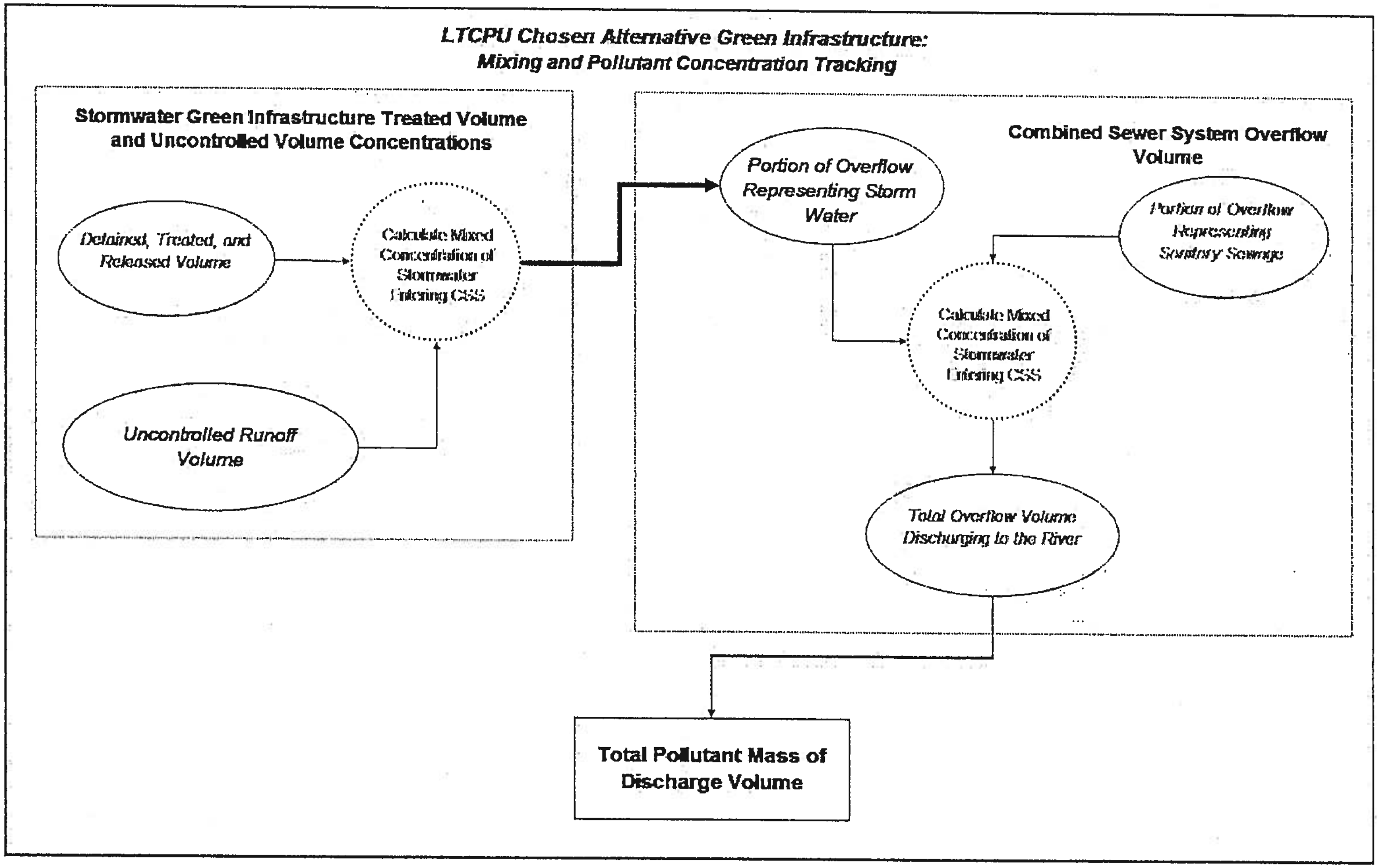


Figure 2. Green Stormwater Infrastructure Alternative

Figures 1 and 2 show a comparison of the flow paths for the traditional alternative and the LTCPU selected alternative.

For the traditional alternative, the combined sewage follows three paths to the receiving water, either as CSO, as treated effluent of the satellite primary clarifiers (SPCs), or as treated effluent from the wastewater plant (not shown). The discharge to the wastewater treatment plant is similar for both the traditional and selected options, and is not part of the comparison.

For the selected alternative, the flow path is more complex, as the green stormwater infrastructure intercepts some of the stormwater flow, eliminating some as infiltration or evapotranspiration. The remaining flow follows only two paths to the river. Part of the flow of stormwater routed to green stormwater infrastructure will bypass the structure and enter the CSS to mix with sanitary sewage, a portion of which ultimately discharges untreated to the receiving water as CSO. Some will be filtered through soil, eventually to be released slowly to flow to the treatment plants for treatment and release to the receiving water, or to remix with combined sewage and discharge to the receiving water as CSO.

An estimate of mass removal for the traditional alternative is needed to establish the equivalent mass removal target. This was done as follows.

- **85% Volume**: the volume of CSO that is represented by 85% capture was calculated. The SWMM model provides estimates of the volume of CSO plus the volume being captured at the treatment plants in wet weather under current conditions. 85% of this number represents the target volume to be captured and treated.

- **85% Pollutant Mass Removal Targets:** To establish if the selected alternative can achieve the presumptive target for mass removal at less than 85% capture by volume, the equivalent mass removal must be estimated for the 85% by volume traditional alternative. It makes sense to assume what goes to the treatment plants now would be part of the assumed treatment of the traditional alternative. This handles approximately 60% of the total volume. The remaining 25% must be treated elsewhere by satellite primary clarification and disinfection to achieve 85% capture by volume. The SPCs provide 39% removal of BOD_5, 67% removal of TSS, and 99.99% removal (4 log) of bacteria, thus establishing the target pollutant load reductions.

This establishes the pollutant mass removal targets for 85% of the volume that are equivalent to a reasonable treatment process for Philadelphia utilizing the treatment plants as they are today, and adds satellite primary clarifiers with disinfection to treat the remaining volume.

For the selected alternative, the pollutant mass removal rate must be estimated for comparison with the target mass removal established by the traditional alternative. Results of computer modeling indicate that the LTCPU selected alternative removes less than 85% of the volume of wet weather combined sewage. If the selected alternative removes at least as much pollutant mass as the traditional alternative removes, then according to Section II.C.4.a of the National CSO Policy, it meets the requirements for a presumptive approach. The pollutant mass removal by the selected alternative occurs primarily because:

- the CSO volume is reduced
- mass is removed as stormwater filters through the green stormwater infrastructure, and
- more mass is sent to treatment plants as stored volume is slowly released

Selected Alternative Compared to Target Mass Removal (Traditional or "Gray")

Table 2: Pollutant mass removal comparison of selected alternative with target mass removal of 85% by volume traditional alternative

		City-Wide		Mid-Point of Range	
Range	**Constituent**	**Green**	**Gray**	**Green**	**Gray**
HIGH	BOD_5 (lbs)	1,931,162	801,453	1,579,428	620,880
LOW	BOD_5 (lbs)	1,227,695	440,308		
HIGH	TSS (lbs)	5,802,360	4,056,809	4,771,307	3,194,241
LOW	TSS (lbs)	3,740,254	2,331,672		
HIGH	# of Bacteria (10^16)	9.88	10.38	8.08	8.05
LOW	# of Bacteria (10^16)	6.28	5.71		

*Highlighted values have a greater mass removed.

Table 2 provides the results of this analysis. The pollutant loads removed for the selected alternative are compared to the target pollutant removal loads represented by the traditional alternative using SPCs. The estimates are provided for a range representing flows from the SWMM models indicative of the model's accuracy. Table 2 also presents the mid-point of this range. The blue shading indicates which alternative is more successful at removing pollutants for each comparison (upper limit, lower limit, and mid-point for each pollutant).

Does the Selected Alternative Meet the Equivalent Pollutant Mass Removal Targets?

A comparison of the selected alternative with the traditional alternative can have three possible outcomes:

- the selected alternative has a higher pollutant mass removal rate than the target represented by SPCs at 85% capture by volume

- the selected alternative has the same pollutant mass removal rate than the target represented by SPCs at 85% capture by volume (the results are not significantly different)

- the selected alternative has a lower pollutant mass removal rate than the target represented by SPCs at 85% capture by volume

The results provided in Table 2 suggest that under all scenarios (upper limit, lower limit, and mid-point), the selected alternative provides at least as much mass removal as the traditional alternative at 85% capture by volume for TSS, BOD_5 and fecal coliform.

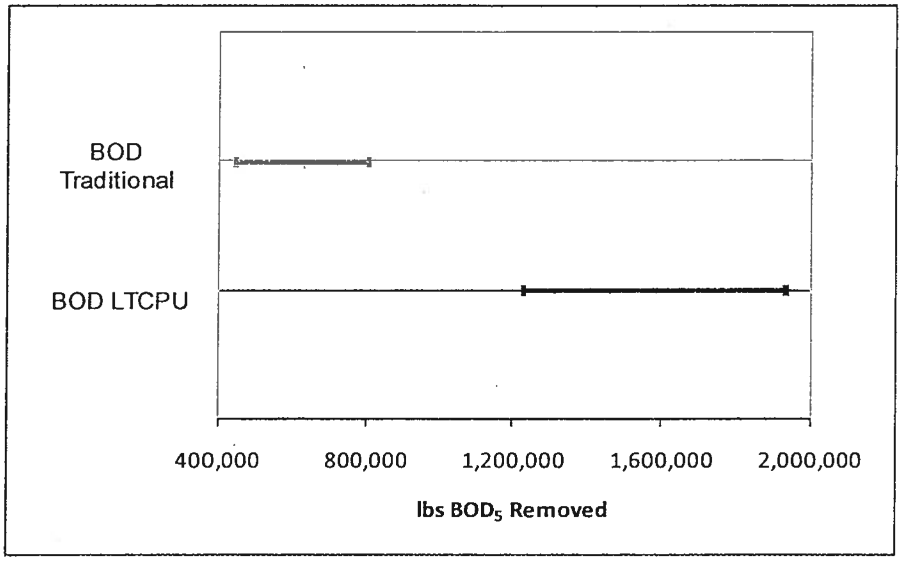


Figure 2: Annual removal of BOD5 for Selected and Traditional alternatives

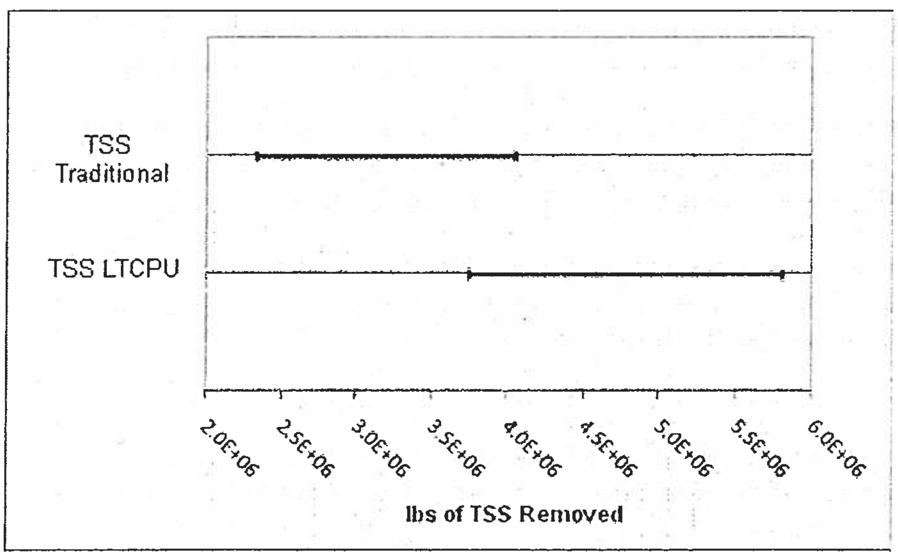


Figure 3: Annual removal of Total Suspended Solids for Selected and Traditional alternatives

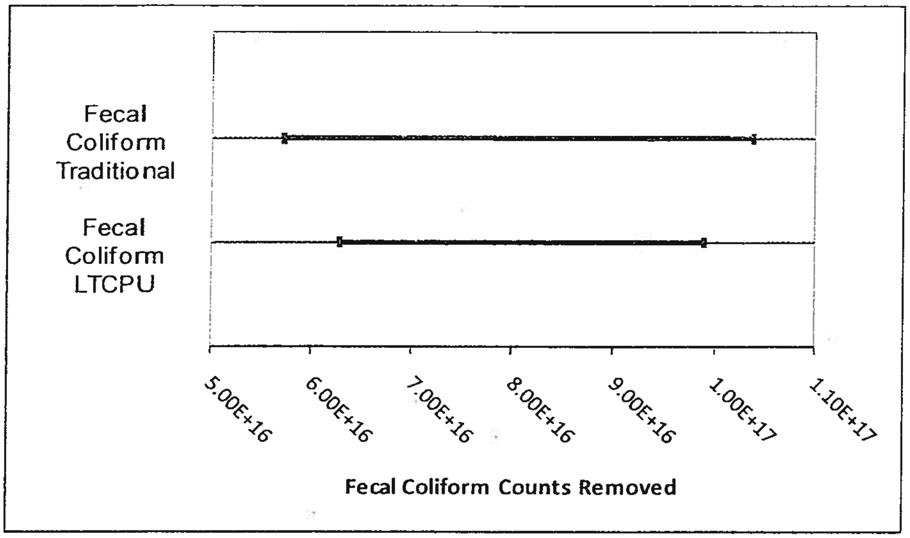


Figure 4: Annual removal of Fecal Coliform for Selected and Traditional alternatives

Figures 2 through 4 show the results for BOD_5, TSS, and fecal coliform graphically as a range of estimated mass removal of pollutant loads. The range is a result of the estimated accuracy of the SWMM model output and includes estimates for a confidence interval based on uncertainty in flow monitoring data. Based on Table 2 and Figures 2 through 4, the following conclusions are drawn.

- **5-day biochemical oxygen demand (BOD_5):** The selected green alternative removes more than the traditional gray alternative (the entire range of selected alternative removal estimates is higher than the upper end of the traditional alternative range).
- **Total suspended solids (TSS):** The selected alternative removes slightly more than the equivalent traditional alternative, but the difference is not large and the range of removal rates for the selected alternative and the traditional alternative overlap.
- **Fecal coliform:** The selected alternative removes slightly more than the equivalent traditional alternative, but the difference is not large and the range of removal rates for the selected alternative and the traditional alternative overlap.

Conclusion

It appears that the selected alternative removes an equivalent mass of pollutants to an alternative consisting of satellite primary clarifiers with disinfection that controls 85% of the wet weather flow by volume. To paraphrase the language of the CSO guidance document:

Based on the analysis of pollutant loading removal for the selected LTCPU alternative, it can be considered to provide for the elimination or removal of no less than the mass of the pollutants identified as causing water quality impairment that would be eliminated or captured for treatment by an alternative treatment train that captures and treats 85% by volume of the combined sewage collected in the CSS during precipitation events on a system-wide annual average basis.

This implies that a presumption approach would be viable for PWD's selected alternative.

It is important to note that the greatest benefit from green stormwater infrastructure stems from its ability to manage stormwater by cleaning and allowing the stormwater to infiltrate. The infiltrated volume is prevented from entering the CSS entirely and subsequently reduces the total volume discharging to the waterways. This reduction in volume discharging to the rivers and streams due to green stormwater infrastructure allows for high efficiency of pollutant mass removal. Interestingly, even though the traditional infrastructure treats a large portion of the discharge, the green stormwater infrastructure reduces pollutant loads even further by significantly reducing discharge volume through infiltration, by increasing flow delivered to WPCPs, and by reducing pollutant loads in the stormwater that does eventually discharge as a component of CSO.

Document #3
Technical Memorandum
Office of Watersheds - PWD
March, 2011

Subject: Background and purpose of the conversion of the combined sewer system hydrologic and hydraulic models from USEPA SWMM4 to SWMM5

Between 1994 and 1997, Tier I hydrologic and hydraulic (H&H) models of PWD's combined sewer system (CSS) were developed to support permit requirements for development of the System Inventory and Characterization, the System Hydraulic Characterization, the Documentation of the Implementation of the Nine Minimum Controls, and the Long Term Control Plan (LTCP). The Tier I modeling efforts included applications of a combination of the USEPA Stormwater Management Model's (SWMM 3.x) Extended Transport (EXTRAN) module for hydraulic models of the combined sewer interceptors and critical hydraulic control points, and the US Army Corps of Engineer's Storage Treatment Overflow Runoff model (STORM) for sewershed hydrology.

Between1997 and 2000, Tier II (SWMM4.x) Continuous Simulations models were developed to simulate the hydrologic and hydraulic (H&H) response of PWD's collection system to wet weather events. These models were utilized to estimate Combined Sewer Overflow (CSO) frequencies, volumes and percent capture by interceptor sub-system for an eight year period of record (1990-1997) corresponding to the period of record with the best data available for PWD rain gages. The Tier II models are based on calibrated Tier I EXTRAN models developed for the CSO compliance program, and included the development of SWMM RUNOFF module representations of sewershed hydrology, eliminating reliance on STORM and unifying the modeling system in SWMM4.

The Tier II models were modified further between 2001 and 2005 to support design-level considerations of the combined sewer system, expanding the system to about 10,000 nodes and pipes. These larger refined and complex models required longer simulation periods, as longs as 14-16 hours for each drainage district for a one-year continuous simulation.

For the development of the Long Term Control Plan Update, a planning version of the H&H models were produced to support CSO control alternatives analyses. This streamlining of the models was based on a network of about 4,000 nodes and pipes and resulted in a reduction of simulation times to a level suitable to support planning needs, allowing for the many (typical or average) year-long continuous simulations required for the evaluation of the numerous CSO control alternatives required. The streamlining process was performed with strict adherence to hydraulic principles that were designed to ensure that the hydraulic characteristics of the system were properly represented. These streamlined models were used to generate the planning level estimates for the H&H portion of PWD's Long Term Control Plan Update (LTCPU) submitted in September 2009.

The current H&H models were developed to quantify the volume and frequencies of CSOs for both existing conditions and for numerous possible CSO control alternatives. The models also currently provide an indispensable tool for the capital projects design support, stream restoration support, flood relief project evaluations, watershed planning support, operations support, green stormwater infrastructure evaluation and support, PA Act 157 support, and outlying community contract evaluation and support.

All of the SWMM models discussed above were developed using initially 3.x and later 4.x versions of the SWMM engine code. Due to the size of the Philadelphia's H&H models and the associated requirements for specialized modeling, in the recent past, a modified version of the SWMM4.4 engine was used. This version included enhancements to the array sizes of input and output elements to accommodate more model elements than initially allowable. In addition, there were also some modifications made to the solution techniques based on recommendations from modeling groups in Philadelphia and elsewhere.

The USEPA started working on a new version of SWMM in 2002. This new version, SWMM5, is written in the *C* language, unlike earlier versions that were written in *FORTRAN*. The development and modifications for all earlier SWMM4 versions has been discontinued by EPA and the SWMM community affiliates. Support from the SWMM users community has all but ended for the versions prior to SWMM5. The official releases of SWMM by the USEPA now are limited to version 5.

SWMM5 has some advantages over its predecessors:

1. Due to dynamic memory allocation there are no limits on number of elements that can be simulated.
2. The new engine has better solution techniques like the one used to solve the dynamic wave equation for flow (Saint Venant equations are solved by a successive approximation technique that helps the solutions converge faster). There have been improvements in the way the orifices and weirs are simulated (SWMM5 now uses the classical orifice and weir equations instead of using equivalent pipe approximation).
3. The ability to use variable time steps for simulations.
4. The ability to lengthen pipes based on user inputs if shorter pipes have convergence issues.
5. Better simulation of force mains.
6. Like its predecessors, it is well supported by the online SWMM user community.

However, SWMM5 has some disadvantages:

1. The engine has bugs that are still being addressed and worked on.
2. The output format makes post-processing a little more cumbersome.
3. If users are not careful, the continuous simulation result files can be extremely large and difficult to post-process.

The PWD decided several years ago that future versions of the City's H&H models would be maintained in SWMM5. The principal reason for the decision to convert the models was because the USEPA no longer was supporting the SWMM4 versions of the models, because the new version is much more compatible with evolving changes in personal computer operating systems, and because of the improvements to the solution techniques and the hydraulics. However, the schedule for the development of the Long Term Control Plan Update required that the conversion not take place until the Update was completed.

The aim of this conversion process is to convert the existing simplified H&H models from SWMM4 to SWMM5 with minimal changes to the model structure and results. Structural changes to the model (*e.g.*, converting all the equivalent pipes to their original lengths or converting all the orifices and weirs represented by equivalent pipes back to actual orifices and weirs) will not be included in the initial stages of this conversion. Structural changes to the model will be performed gradually as the model is further expanded and refined. Initial test results indicate that the new models are fully compatible with previous versions, and simulations produce only modest differences in CSO characteristics, due in part to how the SWMM5 engine is setup, and in part to the hydraulic enhancements over the SWMM4 engine that have been implemented.

Proposed future development activities for the models include:

- refinements of the sewershed delineations and rainfall-runoff characteristics (i.e., area, slope, impervious cover, etc.) in response to improvements in the quality of the remotely sensed data sources used in the City geographic information system
- improved model performance, through further refinements of directly connected impervious cover and rainfall-dependant infiltration and inflow model validation parameters, as the City increases the areal and temporal coverage of the sewer flow monitoring network
- model technology improvements to better-represent evapo-transpiration and application of snow melt-runoff capabilities
- changing over to the new SWMM5 hydrodynamic representations of hydraulic structures such as weirs and orifices
- employing the new low impact development features of the most recent model code releases.

As these refinements and improvements are implemented, the model-based estimates of overflow frequency, volume and duration, and the associated estimation uncertainty, will be refined and redefined.

Document #4
Technical Memorandum
Office of Watersheds - PWD
March, 2011

Subject: **Description of interceptor lining program (TTF and Cobbs), history and context**

SUMMARY

As a part of PWD's commitment to achievement of Target A (Improvement of water quality and aesthetics in dry weather) in both the Cobbs and Tacony-Frankford watersheds, the integrated watershed management plans (IWMPs) include commitments to lining the interceptors that run along the mainstems of each. This commitment has been formalized in the City's Consent Order & Agreement and will be tracked by the WQBEL.

Benefits:

- Decrease pollutant loads to surface waters by decreasing exfiltration
- Decrease amount of flow in sewer system by decreasing Inflow/Infiltration (I/I)
- Rehabilitation of sewers will increase the efficiency of the sewer system

Planning and Design is underway for the lining of the entire length of interceptor within Philadelphia in the Cobbs and Tacony-Frankford Watersheds. For planning purposes, the interceptors within both watersheds were split into sections of approximately 1.5 miles in length, with goals for lining one section per year. In the Cobbs Watershed, two of these segments have already been relined, one in 1999 and the other in 2004 at a cost of $3,500,000. The 4 remaining sections in the Cobbs Watershed will take place starting in 2011. The total estimated cost of this project is $12,500,000. The Tacony Frankford Watershed interceptor was split into 5 sections and will take place starting in 2011. The total estimated cost of this project is $20,600,000. The following tables and maps illustrate the interceptor relining projects within each watershed.

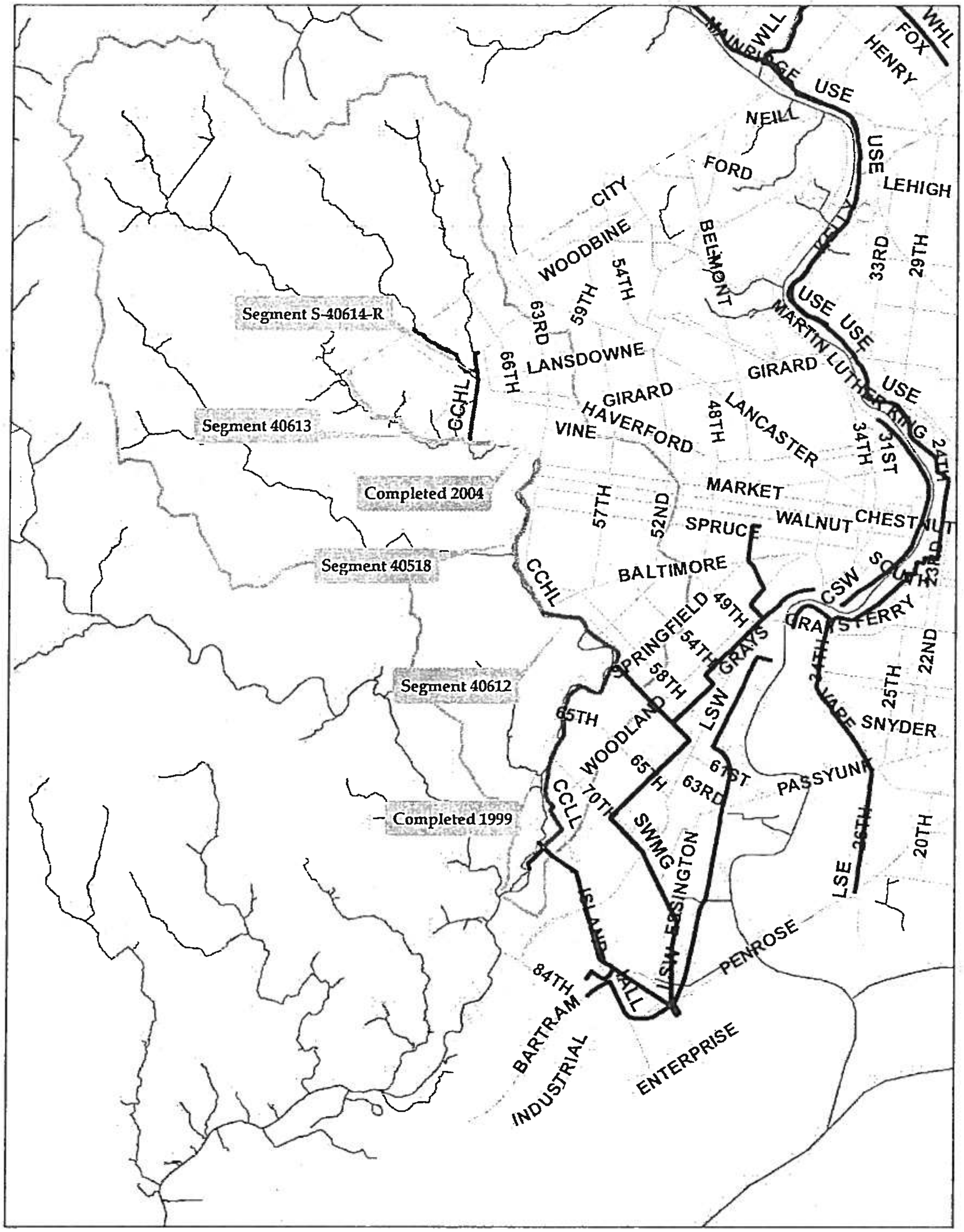
Cobbs Watershed Project Data

Project Title	Extents:
40518 - Cobbs Creek Interceptor Phase 1 CIPP Lining Contract	63rd and Market to 62nd and Baltimore
40612 - Cobbs Creek Intercepting Sewer Lining Phase 2	61st and Baltimore to 60th and Warrington
40613 - Cobbs Creek Interceptor Lining Phase 3	City Avenue to D R/W in former 67th Street
40614 - Cobbs Creek Intercepting Sewer Lining Phase 4 (Indian Creek Branch)	City Avenue to D R/W in former 67th Street

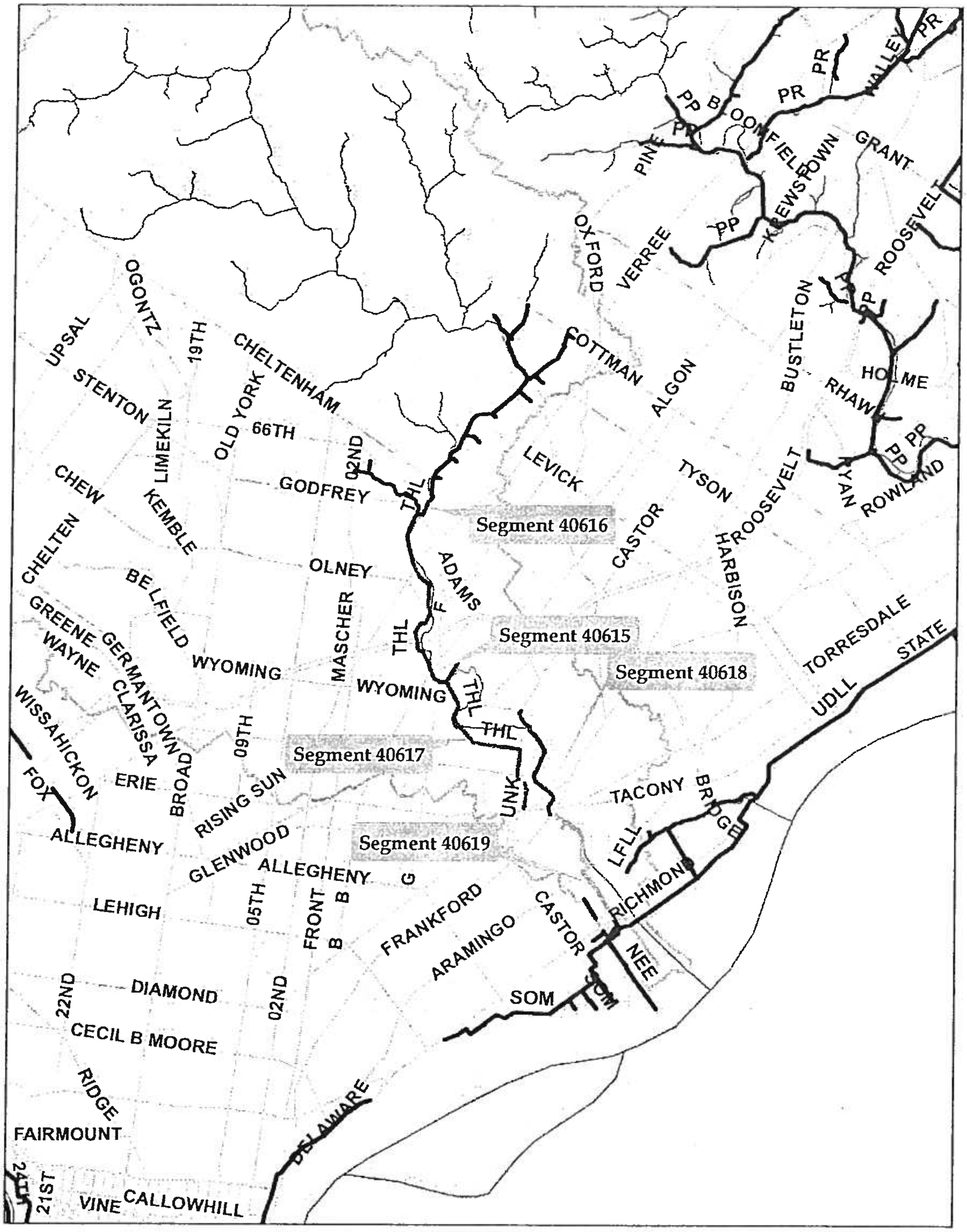
Tacony – Frankford Watershed Project Data

Project Title	Extents:
40615 - Tacony Creek intercepting Sewer Lining Phase 1	Chew & Rising Sun to I & Ramona
40616 - Tacony Creek intercepting Sewer Lining Phase 2	2nd St & 64th Ave to Chew & Rising Sun; DRW Mascher to Tacony Interceptor; Cheltenham Ave to Crescentville & Godfrey
40617 - Tacony Creek intercepting Sewer Lining Phase 3	I & Ramona to O & Erie
40618 - Upper Frankford LL Collector/Tacony Intercepting Sewer Lining Phase 4	Castor & Wyoming to Frankford/Hunting Park
46019 - Upper Frankford Creek LL Collector/Tacony Intercepting Sewer Lining Phase 5	Frankford/Hunting Park to Luzerne & Richmond

Segment Locations for Lining in the Cobbs Creek



Segment Locations for Lining in the Tacony – Frankford Creek



Document #5
Technical Memorandum
Office of Watersheds - PWD
March, 2011

Subject: **Rationale for Equal Distribution of Green Stormwater Infrastructure Implementation in all Neighborhoods**

SUMMARY

The public in Philadelphia will invest $2B in the *Green City, Clean Waters* program over the next 25 years. The proposed system-wide distribution of green stormwater infrastructure will yield water quality benefits and improvements uniformly to the aquatic habitat and living resources of the City's waterways, restoring resources long forsaken as assets by most residents. The uniform investment of green stormwater infrastructure will ensure equal access for all to the expected environmental, social and economic benefits derived from green infrastructure. The program is designed to maximize return on investment to benefit the residents, distributed as equally as possible across all neighborhoods to achieve a fair and equitable distribution of those benefits, and to garner maximum popular support. This keystone aspect of the *Green City, Clean Waters* plan lays the groundwork for the revitalization of our City in areas of public health, recreation, housing and neighborhood values.

Philadelphia is the first city to propose adoption of a green stormwater approach as the foundation for compliance with the national CSO Control Policy. The program will require coordinated support from the Mayor's Office and City Council as well as numerous City agencies, making an equal-distribution approach critical to widespread acceptance of the plan. It is for this reason that the *Greenworks Philadelphia* plan, the overall sustainability plan for the City that was developed independently from the CSO control plan, made *Green City, Clean Waters* the centerpiece of its "Equity Goals" strategy. *Greenworks Philadelphia's* Equity Goal is that "… Philadelphia delivers more equitable access to healthy neighborhoods through the distribution of green infrastructure."

Program Components lend themselves to system-wide application:
The 2006 revision of the City's stormwater regulations requires that development and redevelopment projects manage the first inch of runoff from the project sites. This same measure is utilized for PWD's Greened Acres concept, and is applied in both separate and combined sewered areas. Thus the application of the Greened Acres concept is intended to be equally distributed throughout the combined sewered area of the City, taking advantage of market-driven development and redevelopment. The stormwater regulations were envisioned, devised and implemented around this fundamental concept, and therefore the equal-areal application concept is a critically important success factor for the *Green City, Clean Waters* program.

Similarly, it is important for PWD's greening strategy to take advantage of opportunities that exist for implementation on publicly-owned lands, such as PWD and other City-owned properties, streets and rights-of-way, which constitute roughly 45% of the impervious land area of the City. PWD's plan for implementation of the *Green City, Clean Waters* program is to target these publicly owned sites – which are by their nature distributed throughout the neighborhoods of the CSS.

Environmental Justice:
The USEPA defines environmental justice as

> *...the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. EPA has this goal for all communities and persons across this Nation. It will be achieved when everyone enjoys the same degree of protection from environmental and health hazards and equal access to the decision-making process to have a healthy environment in which to live, learn, and work.*

From the developmental stages of the program, the preservation of a fair and just basis for the implementation of the *Green City, Clean Waters* program was based on an equal investment of greening efforts throughout the combined sewered areas such that there is an equitable spatial distribution of burdens and benefits.

The figure included here describes the anticipated results of the equitable distribution of green stormwater infrastructure investment among economic levels, as envisioned in the *Green City, Clean Waters* program. The figure shows how investment will be equal in all combined sewer areas of the city, regardless of household income. It is clear that deviations from this distribution of investment likely would result in unfair, and environmentally and socially unjust, accumulations of investment and benefits in some areas of the City over others. Additionally, disproportionate investment of green stormwater infrastructure would reduce the expected environmental, social and economic benefits derived from the spatially equitable implementation. These so-called triple bottom line benefits are dependent upon widespread uniform applications of green infrastructure

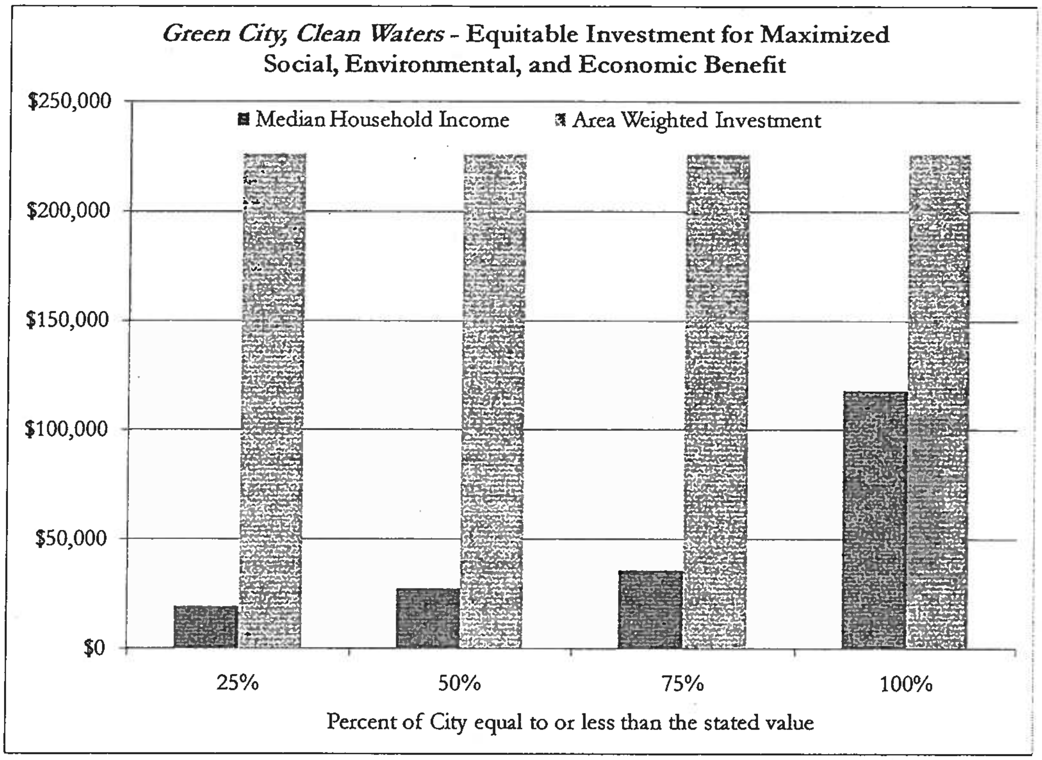


Figure 1: Distribution of Census Block Group Median Household Incomes and Green City, Clean Waters Area Weighted Investment in green stormwater infrastructure.

Document #6
Technical Memorandum
Office of Watersheds - PWD
March, 2011

Subject: **Application of Sensitive Area Criteria to City of Philadelphia CSO Receiving Waters**

SUMMARY

The LTCPU documents that no portions of the City's CSO receiving waters meet the definition of sensitive areas found in the National CSO Control Policy. It is PWD's position that the City's CSO receiving waters should be regarded as a single receiving water body with no single geographic area more sensitive than another. The concept of designating sensitive areas in the National CSO Control Policy clearly never was intended to address the entire domain of the receiving waters for a large city. It is the intent of the PWD program to treat all waterways as equally important, equally sensitive to discharges, and therefore the goal of the CSO control program is to reduce pollutant loading from CSOs to provide equal protection for all the waterways.

Table 1: Application of Sensitive Area Designation Criteria in the City of Philadelphia

Factors indicating Sensitivity	Applicability within City of Philadelphia CSO Receiving Waters
Outstanding National Water Resources	There are no Outstanding National Resource Waters within the CSO receiving waters.
National Marine Sanctuaries	There are no National Marine Sanctuaries within the CSO receiving waters.
Waters with Endangered Species or their Designated Critical Habitat	The literature reviews performed as part of this analysis have yielded no basis to infer that these species or their habitat are directly impacted or excluded by the discharge of stormwater runoff in the Philadelphia area. Absent any such direct evidence specific to Philadelphia's CSO receiving waters, it was not possible to identify any geographic subset of the receiving waters that can be specifically identified as meeting this definition of sensitive areas.
Primary Recreational Waters, such as Bathing Beaches	Though primary contact recreation activities have been observed in waterways throughout the system, these activities are prohibited in many of the CSO receiving water areas. These activities are physically unsafe in addition to exposing recreators to potentially unsafe conditions in wet weather. The City of Philadelphia is addressing these concerns through education, signage, and enforcement.
Public drinking water intakes or their designated protection areas	There are no public drinking water intakes or their designated protection areas within the CSO receiving waters.
Shellfish beds	No shellfish beds have been identified in areas impacted by Philadelphia's CSO outfalls

Waters with Endangered Species or their Designated Critical Habitat:
As described in Section 3.4.3 of the LTCPU, the literature reviews performed as part of this analysis yielded no basis to infer that threatened or endangered species or their habitat are directly impacted by the discharge of stormwater runoff in the Philadelphia area.

There are two endangered species, and two threatened species, listed under the Federal Endangered Species Act, that are known to occur in the Delaware River basin (Pennsylvania or New Jersey).

- *Shortnose Sturgeon, Acipenser brevirostrum (endangered)*
- *Dwarf Wedgemussel, Alasmidonta heterodon (endangered)*
    - Note: Pennsylvania has proposed to change the status of the dwarf wedgemussel to extirpated.
- *Bog Turtle, Clemmys muhlenbergii (threatened)*
    - Note: The bog turtle is listed as extirpated in Philadelphia in the USFWS recovery plan (USFWS, 2001).
- *Bald Eagle, Haliaeetus leucocephalus (threatened)*
    - Note: It was proposed for delisting July 6, 1999 (USFWS 1999). (Source: NatureServe, 2006)
    - Note: This species has been observed in the Philadelphia Naval Yard and in the John Heinz National Wildlife Refuge at Tinicum and their nests have been observed in the Tidal Pennypack Creek, Petty Island in the Delaware River, and the John Heinz National Wildlife Refuge at Tinicum.

Since these species are known to occur within or directly downstream of the waters receiving CSO discharges under existing conditions, it is believed that PWD's proposed plan and reduction in CSO volume will continue to improve their critical habitat.

Recreational Waters
Swimming is prohibited in the City of Philadelphia creeks and streams by the Fairmount Park Commission's "Trail Rules and Regulations", which states that "no person shall bathe or swim except at authorized pools and only when a lifeguard is present". Though this is the established legal guideline for City of Philadelphia residents, PWD is aware that swimming, wading and other forms of primary contact are taking place within the City's waterways despite these legal restrictions. In order to better understand the current baseline recreational usage of the City's waterways, PWD has commissioned Drexel University to assist them with conducting an assessment of current recreational use locations and activity types taking place at each.

A preliminary survey was conducted in the summer of 2008 at six locations distributed throughout the City with locations in the Cobbs, Tacony and Schuylkill waterways. Survey sites were chosen based on discussions with individuals familiar with recreational use patterns on the study waters, results from a pilot survey of sites (conducted in the Spring of 2007) and insights drawn from windshield surveys of sites conducted during the summer and early Fall of 2007. Data including camera-observed recreational use patterns at six water locations were collected during the period of July through September 2008. The following information was collected and documented for all observations: activity location, date, day of the week, activity start time, end time and type (swimming, wading, playing, boating, onshore fishing, fishing, jet skiing, kayaking).

Location	Observed Activity
Schuylkill River	
Fairmount Dam	Boating, jet skiing, kayaking, fishing (on and off shore)
Bartram's Garden	Boating, fishing
Tacony Creek	
Adams Ave	Wading, bathing
T-14	No observed recreational activity
Bingham St	Wading, fishing
Cobbs Creek	
Cobbs Creek Environmental Education Center and Woodland Ave Dam	Wading, fishing, playing with water

PWD's initial recreation observation study did not include survey locations on the Tidal Delaware River; PWD plans to expand upon their survey in the future and will include sites on the Delaware River.

Additional information on recreational usage of the City's waterways that could indicate both primary and secondary contact within CSO receiving waters including the following Philadelphia county-wide information:

- 2009 Boat registrations: 4,531
- 2009 Fishing licenses sold to residents of Philadelphia County: 19,093
- Boating safety education certificates issued to residents of Philadelphia County between the years 2000-2009: 3,873

PWD's Commitment is to Increasing Access and Aesthetics, not Swimming

Assessments of recreational use within the City's waterways indicate that primary contact recreational activities occur in all of our CSO receiving waters, and it appears that the occurrence of those activities is just as probable in the highly urbanized upstream tributary areas as it is in the downstream tidal waters.

PWD has made a commitment to increasing access to currently underutilized and inaccessible waterways as a part of our integrated watershed management approach. This is a commitment to working with the City's Parks and Recreation Department to improve resources within the park system, restore stream banks to allow for passive recreation streamside, and improve the overall look and aesthetic appeal of our waterways. These improvements are not however intended to increase the primary contact usage of the waterways. Swimming is prohibited within the City's creeks and streams for a number of reasons related to safety. The City does not intend to allow or encourage swimming in creeks and streams.

Distribution of Outfalls:

Because of the dense geographic distribution of outfalls within the City's waste water system, it would not make sense to target one geographic area over another for implementation of the green stormwater infrastructure. Targeting one area over another might reduce CSO volume at a particular outfall, but that outfall would still be in close proximity to others. In this context, the City's CSO system waters should be regarded as discharging to a single receiving water body. It essentially is impossible to favor one area over another without requiring widespread reductions, and those are best addressed through the long term planning process across the entire CSS portions of the City.

Table 4: Distribution of CSO Outfalls by watershed

Watershed	**# of CSO Outfalls**	**Avg. Distance Between (ft)**
TTF:	27	965
Cobbs:	33	1678
Schuylkill:	41	918
Delaware:	63	1044