Development of a Stormwater Retrofit Plan for Water Resources Inventory Area 9: SUSTAIN Modeling Report

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King County

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Development of a Stormwater Retrofit Plan for Water Resources Inventory Area 9:

SUSTAIN Modeling Report

DRAFT

Prepared for:

U.S. Environmental Protection Agency Region 10

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EXECUTIVE SUMMARY

Stormwater from a disturbed landscape is one of the biggest threats to water quality and ecological health of the waters of Puget Sound, both fresh and marine. The overall goal of this planning study is to develop a cost estimate for implementing stormwater Best Management Practices (BMPs) and Low Impact Development (LID) techniques in existing and future developed areas within the Water Resource Inventory Area (WRIA) 9.

This report documents the methodology and results from coupling a watershed hydrology model (a long-standing centerpiece of stormwater planning in the Puget Sound region) with a relatively new stormwater BMP modeling and planning tool developed by the U.S. EPA - the SUSTAIN model (**S**ystem for **U**rban **S**tormwater **T**reatment and **A**nalysis **IN**tegration) - to assess BMP strategies for the WRIA 9 project area. The stormwater treatment strategies for this study target deleterious stream flows and water quality pollutants from a disturbed landscape. Input from Stakeholders and Project Management Team members developed stormwater treatment trains (i.e., a sequence of various stormwater treatment facilities) using a 30 year time horizon to quantify life-cycle costs and effectiveness. Cost-effectiveness BMP solutions were modeled using the SUSTAIN optimization to reduce the flow exceedance frequency above a threshold.

The study area covers 278 square miles of the Green-Duwamish watershed and portions of the Central Puget Sound watershed that comprise WRIA 9, excluding the areas upstream of the Howard Hanson Dam and the city of Seattle. 100-acre hypothetical catchments representing the land use land cover (LULC) of the study area were modeled with SUSTAIN to optimize the best BMP solutions to meet flow targets. The effectiveness of the SUSTAIN results were measured as the relative ability of a selected solution to reduce stream flashiness from existing developed conditions.

BMP units, effectiveness and cost results from SUSTAIN's optimization where scaled to projected future (2040) land use based on the unique combination of the hypothetical catchments that make up the study area. Present value (PV) life-cycle costs assume construction of the modeled BMP units occur over the 30 year period, with annual operation and maintenance (O&M) and inspection and enforcement (I&E) costs increasing with installation of additional BMPs. PV costs for the stormwater management scenarios are presented in 2013 dollars assuming a 5% real discount rate. Scaling the units to the study area resulted in approximately 34,000 cisterns, 2,700,000 rain gardens, 190,000 roadside bioretention, and 76,000 detention ponds.

Another goal of the planning study is to explore the effectiveness and associated costs of implementing stormwater management scenarios as part of a public program for future development. Considering a portion of the study area is projected to require stormwater control with new and redevelopment between now and the year 2040, three scenarios were evaluated:

1. Required stormwater treatment with new and redevelopment
2. Required stormwater treatment plus control of stormwater from roads and highways

3. Required stormwater treatment plus control of stormwater from unchanged development (i.e. full stormwater treatment of the study area)

In this report, treatment refers to flow quantity and water quality control. The effectiveness of the scenarios was measured by the reduction, or improvement, of hydrologic and water quality indicators. The scenarios were compared to modeled fully-forested conditions, 2007 existing LULC and 2040 LULC with no stormwater treatment.

Projected 2040 future land use for the study area catchments had approximately 9 to 41 percent higher hydrologic indicator values than 2007 existing conditions, reflecting further degradation of stream health with future development. Required stormwater treatment with new and redevelopment alone decreased the indicator values by as much as 50 percent for many of the catchments. Roads and highways make up approximately 4 percent of the study area and provided an additional small improvement. Full stormwater treatment improved the hydrologic indicator values similar to those of fully-forested conditions.

Statistical models were used to extrapolate improvements in hydrologic indicators to improvements in benthic index of biotic integrity (B-IBI) scores for the stormwater treatment scenarios. Based on the calculated B-IBI scores, the modeled fully-forested conditions had a biological health of “Fair” for all study area catchments. 2007 existing condition B-IBI scores were generally categorized as “Very Poor” in the western portion of the study area to “Fair” in the eastern portion, with many central catchments categorized as “Poor”. The biological health of 2040 LULC was worse than 2007 existing LULC, with more of the central and eastern portion of the study area classified as “Very Poor”. Required stormwater treatment with new and redevelopment improved the majority of the “Very Poor” catchments to “Poor” as well as improving many of the “Poor” catchments to “Fair” conditions. As with the hydrologic indicators, there is some additional improvement in biological health with the treatment of roads and highways. Full stormwater treatment of 2040 LULC improved the majority of study area’s biological health to “Fair”, the same as fully-forested conditions.

Statistical extrapolations of total suspended solids (TSS) to turbidity, total copper (TCu) and zinc (TZn), and dissolved copper and zinc also suggested improvements in water quality. Required stormwater treatment with new and redevelopment significantly reduced TSS loads with an additional small reduction with the treatment of roads and highways. Full stormwater treatment reduced TSS loads similar to values of forested conditions. Stormwater treatment was less effective at reducing TCu and TZn loads. Required treatment reduced 2040 LULC loads to values similar to 2007 existing conditions. Full stormwater treatment provided a small amount of additional improvement but was not 100 percent effective at reducing TCu or TZn loads to forested conditions.

Dissolved copper and dissolved zinc concentrations were not predicted to exceed acute or chronic water quality standards as defined by Washington State Department of Ecology. Turbidity concentrations for 2007 existing and 2040 LULC exceeded water quality standards 1.3 and 1.6 percent of the time, respectively. Required stormwater treatment reduced the exceedances to 0.6 percent of the time, while full treatment reduced exceedances to less than 0.1 percent of the time.

Total public stormwater program PV costs for the management scenarios were $3.9 billion for required stormwater treatment only, $4.6 billion for required treatment plus additional treatment of roads and highways, and $8.4 billion for full treatment of the study area. These costs are equivalent to $14 million, $17 million, and $30 million per square mile, respectively. Full treatment costs include $3.9 billion in capital, $0.8 billion in O&M, and $3.7 billion in I&E. I&E accounts for a large portion of the BMP life cycle costs and was approximately 44 percent of the total public program costs.

The next steps of the WRIA 9 retrofit project include adjusting public stormwater program costs to account for existing detention facilities as well as evaluating potential cost implications of climate change within the same future time horizon (2040).

1.0. INTRODUCTION

King County was awarded a Puget Sound Watershed Management Assistance Program Fiscal Year 2009 grant by Region 10 of the U.S. Environmental Protection Agency (U.S. EPA) to develop a stormwater retrofit plan for Water Resources Inventory Area (WRIA) 9 (King County 2010).[1] The goal of this grant-funded study was to develop a plan and associated costs to implement stormwater Best Management Practices (BMPs) in developed areas of WRIA 9 built primarily without stormwater controls. This report documents the methods, results, conclusions and recommendations of the modeling effort to develop public stormwater program cost estimates for WRIA 9. In this report, stormwater treatment refers to flow quantity and water quality control.

1.1 Background

Stormwater is one of the biggest threats to the water quality and ecological health of the waters of Puget Sound, both fresh and marine. [2] The overall goal of this planning study is to develop a cost estimate for implementing stormwater BMPs and low impact development (LID) techniques in previously developed areas of WRIA 9. The focus of this study is to estimate the stormwater mitigation needs and cost by coupling the watershed hydrology model Hydrologic Simulation Program-FORTRAN (HSPF) with a relatively new stormwater BMP modeling and planning tool developed by the U.S. EPA - the SUSTAIN model (**S**ystem for **U**rban **S**tormwater **T**reatment and **A**nalysis **IN**tegration). [3]

A pilot study was completed that developed a method to couple SUSTAIN and HSPF to estimate stormwater mitigation needs and costs for existing conditions in a small urban catchment within the Newaukum Creek Basin (King County 2013a). The pilot study documented the use of a hydrologic target for SUSTAIN cost-effectiveness optimization and the method to extrapolate results to biological and water quality improvements. Stakeholders and Project Management Team members developed BMP cost and design assumptions as well as in-stream flow and water quality goals that allow the coupled models to be used to optimize the numbers and types of BMPs needed to best meet specific targets at the lowest cost.

The goal of this study is to expand upon the methods used for the pilot study to scale stormwater management costs to future (2040) development of the full study area. Another goal of the planning study is to evaluate the costs associated with a potential public stormwater program to implement stormwater facilities for future (2040)

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[1] http://your.kingcounty.gov/dnrp/library/water-and-land/watersheds/green-duwamish/stormwater-retrofit-project/stormwater-retrofit-workplan.pdf

[2] Ecology – Threats to Puget Sound (http://www.ecy.wa.gov/puget_sound/threats.html)

[3] U.S. EPA's SUSTAIN website: http://www.epa.gov/nrmrl/wswrd/wq/models/sustain/

development as well as the potential cost implications of climate change within the same future time horizon.

1.2 Study Area

The study area consists of the Green-Duwamish watershed and portions of the Central Puget Sound watershed that comprise WRIA 9, excluding the areas upstream of Howard Hanson Dam and the city of Seattle (Figure 1). Vashon-Maury Island, which is technically in WRIA 15, but is included in WRIA 9 for planning purposes is also excluded from the study area. Lands within Seattle are not included in the study area because a vast majority of Seattle's lands within WRIA 9 are served by a combined sewer and stormwater system and a combined sewer overflow (CSO) control program is already underway in this area. The area of WRIA 9 upstream of Howard Hanson Dam is not included in the study area because it is primarily forested and maintained to protect Tacoma Public Utilities' water supply.

The total area being evaluated is approximately 278 mi^2 and includes 446 catchments delineated based on topographic flow direction and anthropogenic influences (Figure 1). The catchments range in size from 0.21 acres up to 3,567 acres and were further grouped into 28 model domains for HSPF modeling. There are 18 jurisdictions that either partially or fully reside within the study area (Figure 2).

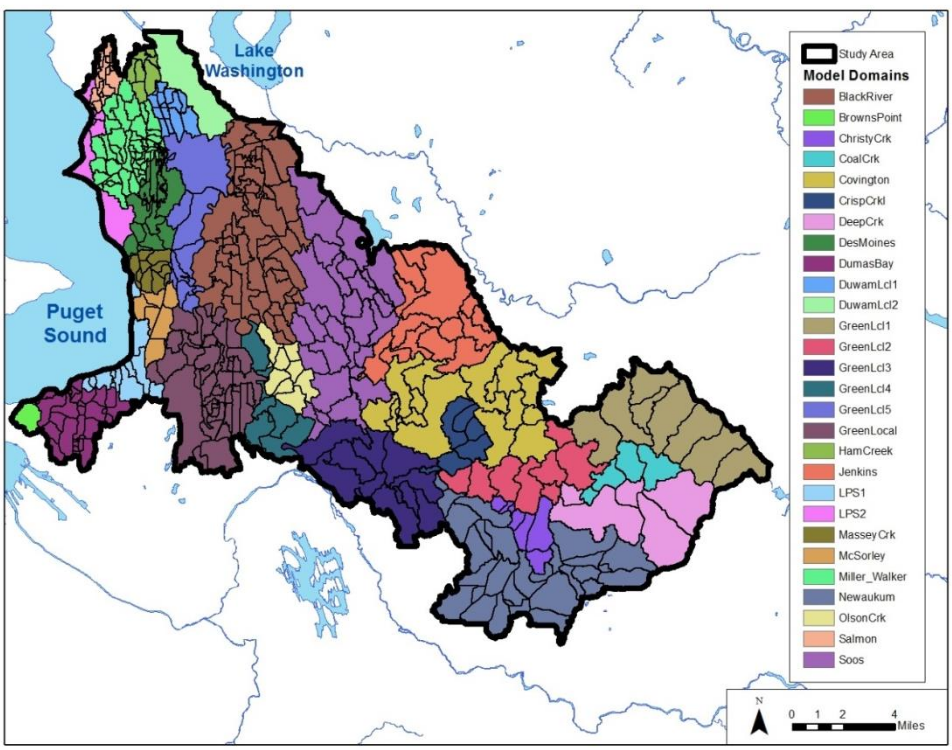

Figure 1. Model Domains and delineated catchments

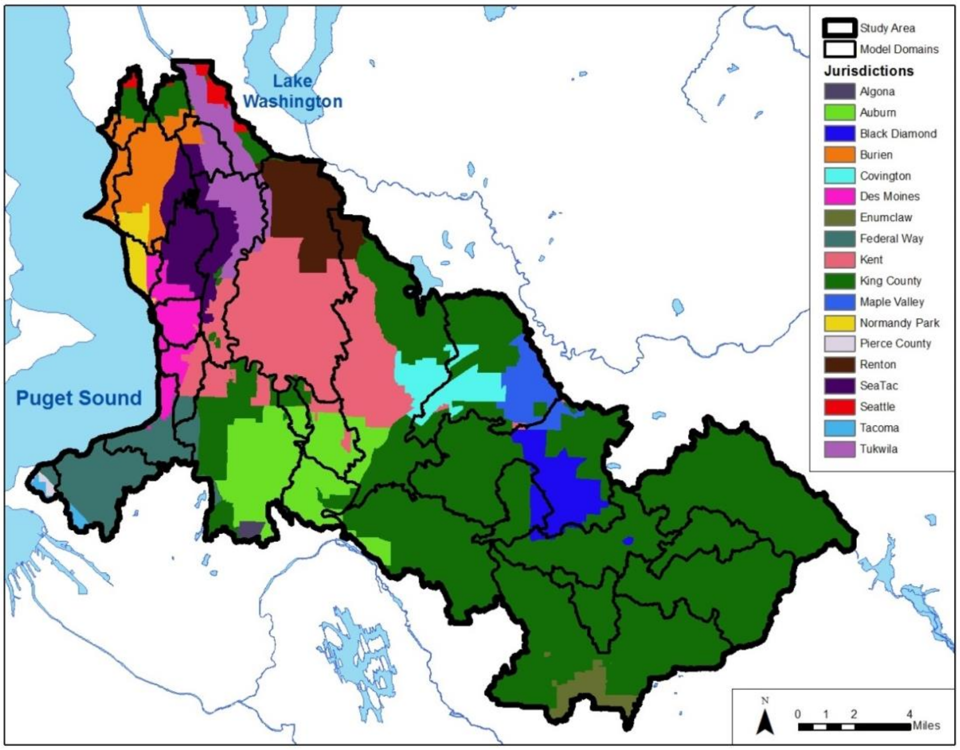

Figure 2. Jurisdiction Boundaries

Land uses range from forested, agricultural, and low density residential uses outside of the designated urban growth area (UGA) to moderate/ high density residential and commercial/industrial lands within the UGA (King County 2010). The existing land use land cover (LULC) conditions were established using derived from 2007 satellite imagery. The study area is approximately 65 percent developed with residential, commercial, industrial, and agricultural land use, as well as the grasslands associated with development (Table 1). Excluding open water, wetlands, and forest, the study area is considered 73-percent disturbed. The distribution of disturbance increases from east to west, progressing towards larger cities and the Puget Sound shorelines (Figure 3). The study area population is projected to grow by about a quarter of a million people between 2000 and 2040. This population increase will result in the conversion of additional land for urban use, and the redevelopment of previously developed land for higher density use.

Table 1. Percent of study area by land use for current (2007) conditions

Land Use Category	Relative Total Area (%)
Heavy Urban	14.2
Medium Urban	22.6
Light Urban	14.7
Cleared for Development	<0.1
Grass, Grasslands	6.7
Deciduous and Mixed Forest	16.3
Coniferous Forest	8.5

Land Use Category	Relative Total Area (%)
Clearcut Forest	0.1
Regenerating Forest	7.9
Agriculture	6.3
Non-forested wetlands	0.4
Open Water	1.9
Snow, Bare rock	<0.1
Shorelines	<0.1

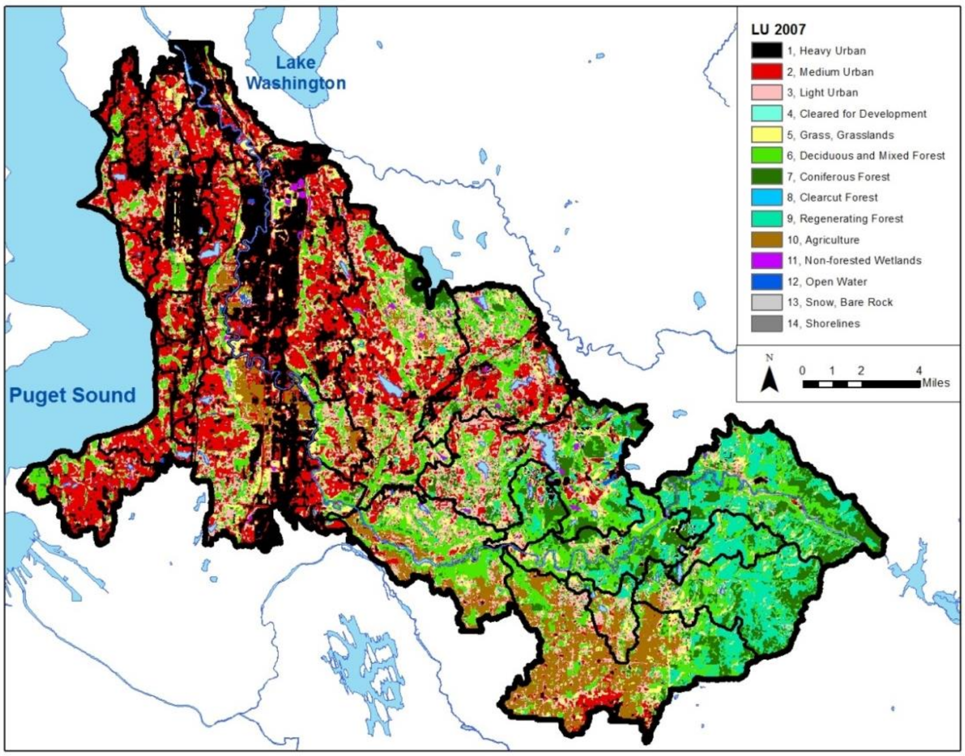

Figure 3. 2007 Satellite-derived Land Use (UW 2007)

Source: Central Puget Sound 2007 Land Cover Classification. Puget Sound Regional Synthesis Model (PRISM). Dr. Marina Alberti, Principal Investigator, Urban Ecology Research Laboratory (UERL), University of Washington, Seattle, WA.

http://urbaneco.washington.edu/wp/

1.3 Future Conditions

Simulated 2040 future conditions (Figure 4) of the study area are based on a modeling framework coupling a land cover change model (LCCM) and an urban socio-economic and transportation model (UrbanSim) (Alberti 2009). The simulation of 2040 land cover is based on a Monte Carlo approach to determine if a land cover transition occurs at each time step. The land cover model predictions were based on changes observed between 1991 and 1995 or 1995 and 1999. Output from the model was available for 2027, 2041 and

2050. Output for 2041 (hereafter referred to as 2040) was chosen as it best represented the study planning time frame. The 2027 and 2050 land cover projections were used to evaluate the impacts of climate and land cover change on Puget Sound basin hydrology (Cuo et al. 2010).

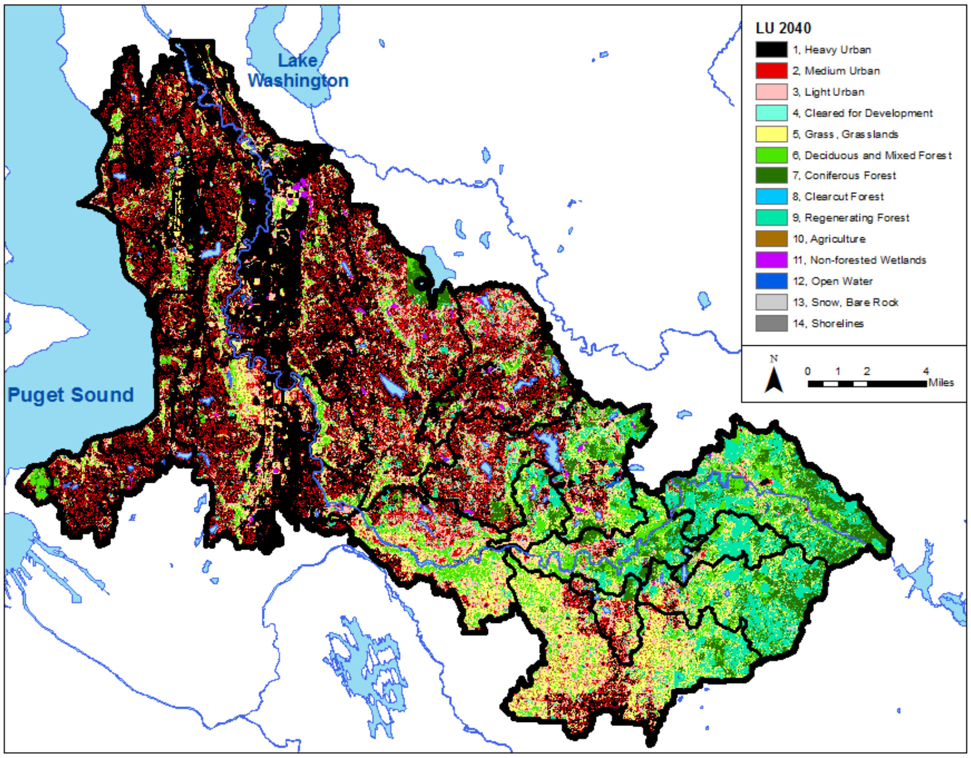

Figure 4. Simulated 2040 Future Land Use (Alberti 2009)

1.4 Project Goals and Objectives

The goal of this study is to document the basic model coupling framework, the selected BMPs and the overall treatment design, BMP design and cost assumptions, and the method of application of the models to the WRIA 9 study area. The specific objectives of this study are identified below:

- Expand on the methods developed in the SUSTAIN model pilot study (King County 2013a) to model the stormwater facility needs and costs for the WRIA 9 study area.
- Document the BMP treatment train modeled in SUSTAIN and the associated design and cost assumptions.
- Use the SUSTAIN model optimization to select the most cost-effective combination of BMPs to reach flow and water quality goals of the study area.
- Scale the cost effective results to future (2040) conditions of the study area.
- Extrapolate the cost-effectiveness results to biological and water quality improvements.
- Calculate public stormwater program costs for future conditions of the study area considering stormwater control requirements with new development and redevelopment.

2.0. MODELING APPROACH

The modeling approach used in this study is based on the capabilities and application guidance for the SUSTAIN model (U.S. EPA et al. 2009, Shoemaker et al. 2011, Lee et al. 2012). The latest release of SUSTAIN (Version 1.2, revised March 2013) was used in this project.

As explored in the pilot study report, this project uses SUSTAIN's external modeling approach with aggregate BMP representation. The external modeling approach was selected to utilize King County's previously developed HSPF models for the study area (King County 2003). The updating, calibration and testing of HSPF models for use in this study are documented in a separate report (King County 2013b). Hourly HSPF model outputs from October 1948 through September 2009 for flow and total suspended solids (TSS) were provided as input to SUSTAIN.

The aggregate BMP modeling approach in SUSTAIN was selected for this study area as recommended for the model application to watersheds greater than 100 square miles. The aggregate approach represents a combination of different types and numbers of BMPs that have no explicit location within the watershed. This approach reduces the effort required for model setup and computation time (U.S. EPA 2009).

2.1 Hypothetical Catchments

Due to the large size of the study area and long model run times, running the SUSTAIN model for all of the catchments within the study area would not be feasible given the schedule and budget limitations of this project. Furthermore, previous studies using SUSTAIN have determined that the aggregate BMP approach planned for this study is most appropriate for watersheds with a low to moderate slope that are on the order of 50 to 150 acres in size (U.S. EPA. 2009). The majority of the catchments in the study area are substantially larger. Therefore, 100-acre hypothetical catchments were developed representing the various hydrologic response units (HRUs) used in HSPF to scale the costs to the study area. The developed land in the study area was categorized into 5 different generic land uses (low density residential, medium/high density residential, commercial/industrial, agricultural, forested), 3 soils (permeable outwash, less permeable till, and poorly draining Type D), and 2 slopes (flat (<5%), moderate (≥5%)) (King County 2013b). The study area was further divided into three different precipitation zones (low, medium, and high) and two land cost regions (low and high), resulting in a total of 135 hypothetical catchments to be modeled using SUSTAIN. A table of the hypothetical catchments can be found in Appendix A, Table 17. SUSTAIN optimization was performed on the developed hypothetical catchments, while the forested hypothetical catchments were modeled to calculate the predevelopment, or fully forested, conditions for the developed catchments.

The distribution of impervious and pervious land cover for each HRU and associated flow and water quality time series for input into the SUSTAIN model were derived from development and calibration of the Des Moines Creek HSPF model. Des Moines Creek HSPF model was selected because it most explicitly models the stormwater infrastructure present in the basin and therefore was calibrated with a more accurate representation of EIA compared with other catchments in the study area. For catchments where the stormwater infrastructure remained unknown, the HSPF models calibrated EIA to account for the existing infrastructure which may be more or less than the actual EIA in the catchment.

2.2 BMP Treatment Train

The pilot study explored 16 different scenarios applying Green or Green+Grey treatment approaches. A modified treatment approach of the Green+Gray Scenario 16 from the pilot study was applied to the hypothetical catchments (King County 2013a). This approach was selected since the Green+Gray treatment trains with 80 percent of the pervious runoff treated were the most effective scenarios in the pilot study. Although scenarios with cisterns and rain barrels produced similar results, cisterns were selected for this study because of their greater storage capacity. Additionally, an aquifer component was used in the treatment train to route the infiltrated water from the BMPs to the outlet.

The modified Natural Drainage and Gray (Green+Gray) Infrastructure Treatment Train using BMP options available in SUSTAIN is presented in Figure 5. The treatment train consisted of detention/storage of residential roof runoff via on-site facilities represented by the SUSTAIN cistern BMP. The overflow from the on-site detention facilities flowed into bioretention facilities (i.e. rain gardens). The bioretention facilities also received runoff from other impervious surfaces on the residential property, primarily driveways and patios. Rooftop runoff from commercial/industrial development was treated using bioretention facilities. Parking areas associated with commercial/industrial development were converted to porous pavement. Untreated surface runoff and underdrain flow from the porous pavement were routed to the bioretention treatment facilities. Impervious surfaces and roads on agriculture lands were treated by bioretention facilities. Road runoff was treated using roadside bioretention facilities. Runoff from 80 percent of the developed pervious areas was also routed to bioretention facilities. Untreated surface runoff and underdrain flow from bioretention facilities were routed to detention facilities routed to the outlet of the catchments.

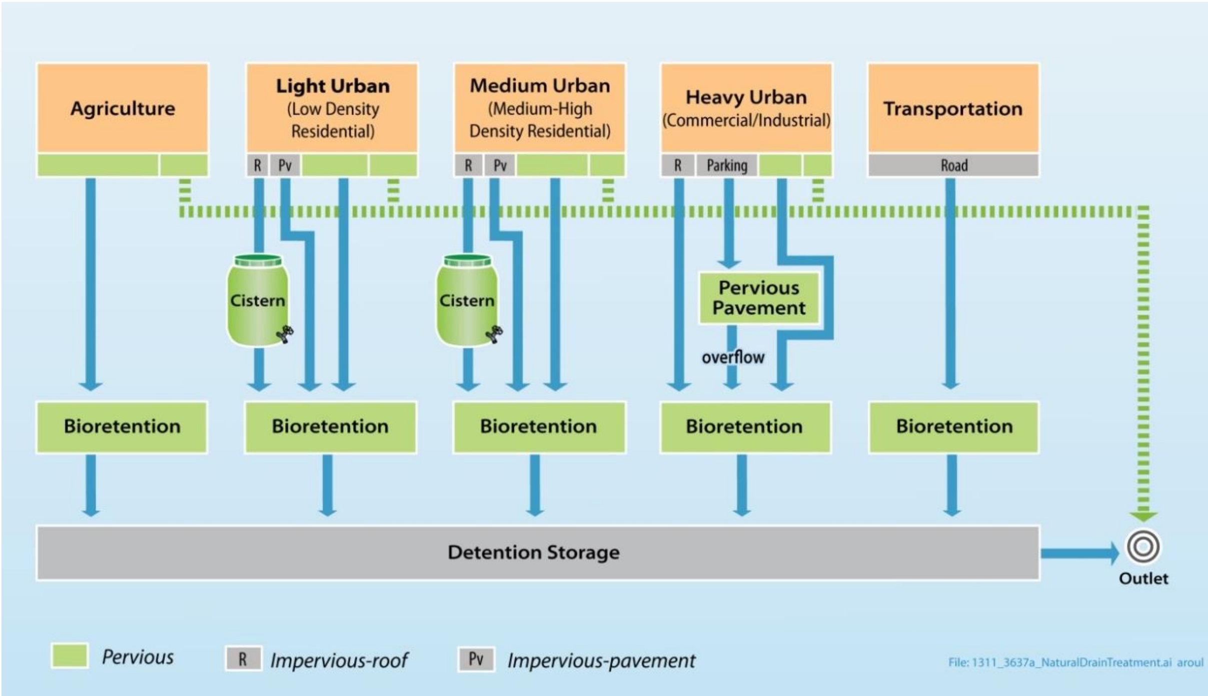

Figure 5. Natural Drainage and Grey Infrastructure Treatment Train

2.3 Application of SUSTAIN Aquifer Component

SUSTAIN version 1.2 provides for the routing of BMP infiltration and pervious subsurface flow (pervious HRU interflow and active groundwater flow from the HSPF model) to aquifer storage reservoirs where it can be treated as infinite storage or released back to the stream network at a rate specified by a recession coefficient. If treatment scenarios focused only on the treatment of runoff from EIA, use of the aquifer component would probably not be necessary. However, in scenarios involving treatment of surface runoff generated from disturbed pervious HRUs associated with development, the use of aquifer storage is necessary. This is because without aquifer storage (and immediate release), the pervious subsurface flow would not be routed to the downstream assessment point. This lack of routing of subsurface flow to the downstream assessment point would be counted as completely treated without passing through any BMP. Immediate routing of pervious subsurface flow to the downstream assessment point is consistent with the routing of this flow at the catchment level in the HSPF model, which already accounts for delayed release from shallow and deep aquifer storage.

A conceptual representation of the SUSTAIN aquifer routing scheme is provided in Figure 6. A second aquifer can be specified to capture the infiltration from bioretention facilities and porous parking areas. The release of this aquifer is determined by assigning a recession coefficient. The recession coefficient used in the SUSTAIN model was calculated using the Des Moines Creek HSPF modeled streamflow time series. The calculation assumes streamflow volume at a given time is the sum of the inflow volume at the same time step and the storage volume of the previous time step, multiplied by the recession coefficient as follows.

$$O(i) = \big(V(i-1) + I(i)\big) * R \quad (1)$$

where V is storage volume, O is outflow volume, I is inflow volume, R is the recession coefficient, and i is the time step. Therefore the recession coefficient R is calculated as:

$$R = \frac{O(i)}{V(i-1)+I(i)} \quad (2)$$

The calculated median recession coefficient of Des Moines Creek is 0.0012. The recession coefficient was used for all hypothetical catchment SUSTAIN model runs.

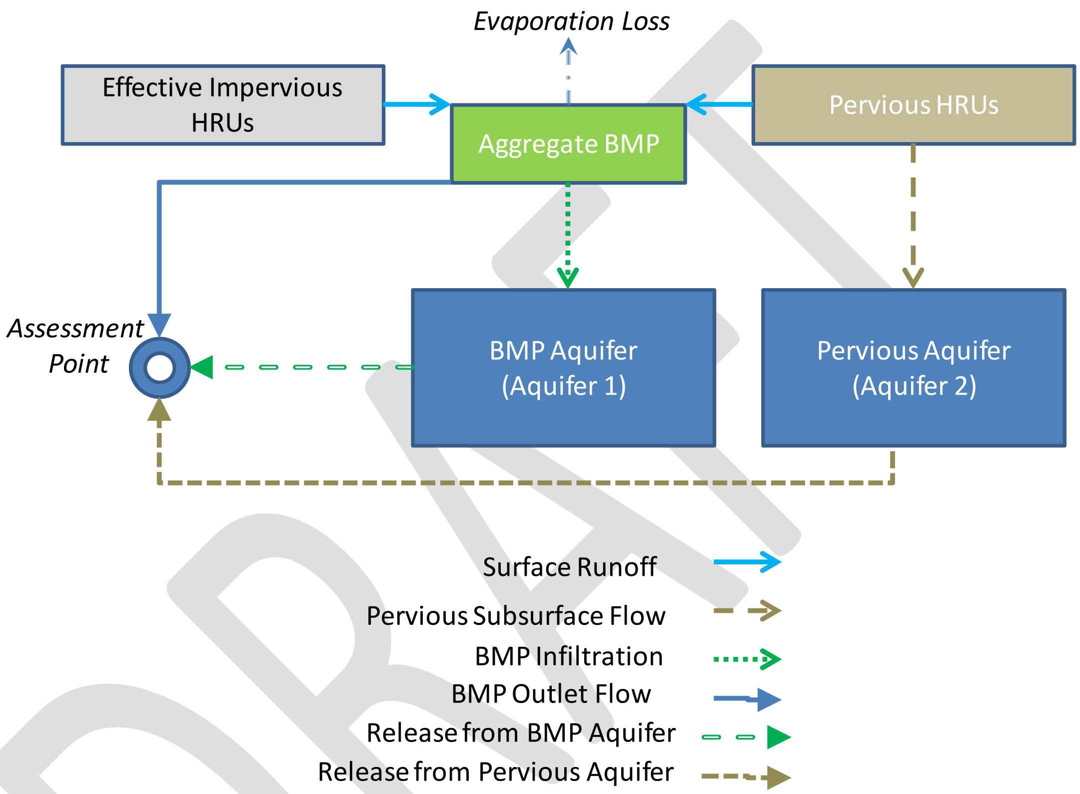

Figure 6. Schematic illustrating the aquifer routing scheme used in the SUSTAIN models for this study

2.4 BMP Design Assumptions

Stormwater BMP designs and associated unit costs for use in SUSTAIN were developed by a technical workgroup during the pilot study (King County 2013a).[4] The designs were tailored to provide inputs to the SUSTAIN model and required simplification of as-built designs to match the complexity allowed within the model. The design goals and general concepts are described for each BMP type below. The detailed SUTAIN model inputs required to implement these designs are provided in Appendix A, Table 18. Most of the

[4] The technical workgroup consisted of King County staff (Jeff Burkey, Curtis DeGasperi, Mark Wilgus, Olivia Wright), Dr. Rich Horner (University of Washington) and Ben Parrish (City of Covington) and the workgroup was facilitated by Tamie Kellog (Kellog Consulting).

design details are the same as those used in the pilot study with the exception of the design of the detention ponds.

2.4.1 Residential On-site Detention Facilities

The residential on-site detention facilities considered in this study conceptually detain residential rooftop runoff, but provide no water quality benefit. The facilities used in SUSTAIN were cisterns, or custom on-site detention BMPs. The cistern is 10 ft in diameter and 5 ft in height ($(10/2)^2 \times \pi \times 5 = 392.7\ ft^3$; $392.7 \times 7.48052 = 2{,}937.6$ gal). The facilities are designed with a rectangular weir that has a weir crest width of 5 ft so overflow from the facility is not limited by the weir. The orifice is at the bottom of the cistern and has a diameter of 5/8" (0.625 in), the size of a typical garden hose. The number of dry days required before water is released through the orifice is 1 day. The first-order pollutant decay rate was set to zero so no TSS removal occurs. The cistern design is reflective of typical cisterns available on the market.

2.4.2 Bioretention Facilities

Two types of bioretention facilities were considered in this study. One type represents a residential BMP characterized as a rain garden. The second type of facility represents a bioretention BMP that treats runoff from public roads. Depending on the dominant underlying soil type in a particular model catchment, either facility may or may not have an underdrain. In catchments underlain predominantly by very poorly drained soils (Type D soils), the facility includes an underdrain that will capture all of the infiltrated water. In all other areas, no underdrain is included in the design.

A unit of bioretention was represented by a 100-ft^2 area with a 1.5-ft layer of bioretention soil with a porosity of 0.4 (40%) and a 1-ft ponding depth.[5] Infiltration rates to native till and outwash soils (no underdrain) were set to 0.3 and 2.0 in/hr, respectively, to represent long-term percolation rates in these soils. In areas with very poorly drained Type D soils, bioretention facilities will include an underdrain (i.e., no infiltration to native soils) that releases water to the detention pond. Overflow from the ponding layer is directly routed to the detention pond.

First-order TSS decay rates to simulate TSS removal in BMPs were selected based on analyses conducted by Herrera in their development of SUSTAIN models to evaluate cost-effective pollutant treatment approaches in an urbanized basin in Federal Way, WA (Herrera 2013). A 1st order TSS decay rate of 0.02/hr was chosen to simulate TSS removal in the bioretention cell. When an underdrain was incorporated, a removal fraction of 0.08 was used to represent TSS removal in the underdrain. Note that water infiltrating into native soil (i.e., does not overflow or exit through the underdrain when present) results in complete removal of associated TSS.

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[5] The maximum ponding depth of 1 foot is based on expected revisions to the King County Surface Water Drainage Manual, which will require a Vb/Vr ratio of 3 (The ratio of the facility storage volume Vb to the volume of runoff from the mean annual storm Vr, where Vr = mean annual storm depth x runoff coefficient).

Evapotranspiration loss from these facilities is included in the SUSTAIN model as an annually repeating monthly average potential evapotranspiration rate derived from the long-term (Oct 1948-Sep 2009) daily rates used in the HSPF model. The monthly rates specified in the model are shown in Figure 7.

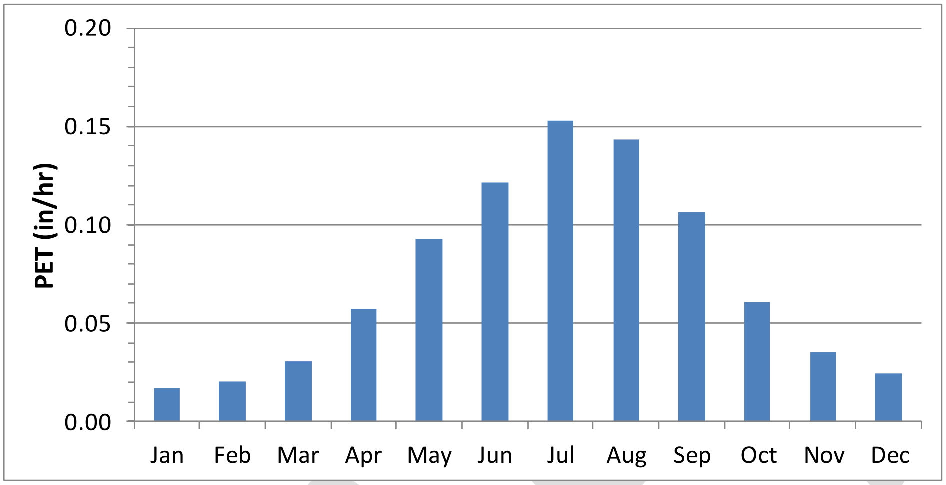

Figure 7. Bar chart showing monthly varying potential evapotranspiration (PET) specified for bioretention facilities.

Note: Monthly average PET derived from the long-term (1949-2009) input to the Newaukum HSPF model.

2.4.3 Porous Commercial Parking Areas

Porous pavement (consisting of concrete or asphalt) was considered in this study and represents replacement of impervious parking areas on commercial developments with porous pavement. Depending on the underlying soil type, the porous pavement may or may not have an underdrain. In areas underlain by very poorly drained soils (Type D soils), the porous pavement will include an underdrain that will capture all of the infiltrated water. In all other areas, no underdrain will be included in the design. In either case, surface overflow under saturated pavement conditions is directed to a rain garden (see above) and when an underdrain is present, flow from the underdrain is also routed to the rain garden.

A unit of porous pavement was represented by a 100-ft^2 area with a 1.6-ft layer of porous surfacing material and engineered subsurface aggregate layers with an average porosity of 0.3 (30%) and a 0.01-in depression storage depth. Infiltration rates to native till and outwash soils (no underdrain) were set to 0.3 and 2.0 in/hr, respectively, to represent long-term percolation rates in these soils.

2.4.4 Detention Ponds

Detention ponds were designed using version 3.0 of the Western Washington Hydrology Model (WWHM3). 60 separate detention pond designs were developed to treat 1-acre of runoff generated from the different hypothetical catchments, with variations due to LULC, soil type, slope, and precipitation zone. SUSTAIN provides an F-table feature that allows the user to input the stage-surface area-storage-discharge relationships of the detention pond. A summary of the area, volume and weir height for each of the detention ponds associated with each HRU is presented in Appendix A, Table 19.

Detention ponds placed on till and D soils are stacked dry/wet ponds. The wet ponds are lined to allow no infiltration and receive water quality benefit from vegetation. Detention ponds placed in outwash soils are dry ponds with a maximum infiltration rate of 2 in/hr. The outwash ponds are designed to remain dry with no liner.

A 1st order TSS decay rate of 0.02/hr was chosen to simulate TSS removal. The monthly PET values described for the bioretention facilities above are also applied to the detention pond BMP.

2.5 BMP Cost Assumptions

Unit BMP costs for use in SUSTAIN were estimated using costs summarized from the Puget Sound Stormwater BMP Cost Database (Herrera 2011), and the expertise of a technical workgroup formed for the purpose of BMP designs and design unit costs.[6] Unit cost estimates were developed based on available information on the costs of 1) design and permitting, 2) construction (including materials), 3) annual O&M costs and 4) I&E costs when applicable. The unit cost estimate for storm water ponds also included an estimate of land cost per unit pond assuming that retrofit construction of storm water ponds will require the public acquisition of private property. Refer to the pilot study report for additional details regarding the development and selection of BMP costs (King County 2013a).

The costs per unit were converted to life cycle costs for input into SUSTAIN. King County's Life Cycle Cost Analysis (LCCA) Guide recommends a discount rate of 7-10% for private projects and a 2 to 6 percent for public projects (King County 2006). This project calculates the Present Value (PV) unit cost of a particular BMP using a real discount rate of 5% and a 30-year O&M/I&E period following the approach described by Pomeroy and Houdeshel (2009). A 5% real discount rate is equivalent to a nominal discount rate of 8.15% assuming a 3% inflation rate. No replacement costs were assumed during the life of the 30 year planning period. All costs presented in this report are in 2013 dollars.

A sensitivity analysis was performed to explore the impact of the discount rate selected on SUSTAIN optimization. A real discount rate of 2.18% was selected, equivalent to a nominal discount rate of 5.25% assuming a 3% inflation, as used by King County Wastewater Treatment Division (WTD) (King County 2008). Four additional SUSTAIN models were run representing different hypothetical catchment with cost input reflecting a lower discount rate to compare to the 5% discount rate SUSTAIN cost results. Results are presented below in Section 3.3.

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[6] The technical workgroup consisted of King County staff (Jeff Burkey, Curtis DeGasperi, Mark Wilgus, Olivia Wright), Dr. Rich Horner (University of Washington) and Ben Parrish (City of Covington) and the workgroup was facilitated by Tamie Kellog (Kellog Consulting).

Private costs were assumed to be equal to the cost of all BMPs developed on private property, which includes on-site detention facilities (i.e., cisterns), bioretention (i.e., rain gardens) and conversion of commercial parking lots to porous pavement. Public costs are associated with bioretention facilities that treat road runoff, detention ponds, I&E costs of private and public facilities, and computed weighted area land value costs as a unit area cost. The land costs of the study area were grouped into low costs and high costs; high costs being those West/North of State Route 18 (SR-18), and low costs lands are East/South of SR-18.

2.5.1 Residential On-site Detention Facilities

Construction costs selected for use in SUSTAIN were $1,600 unit cost for a custom residential on-site detention facility. These costs conceptually represent round figures for cost of materials and construction, including the cost of labor to construct or install the systems. O&M costs are considered to be negligible. However, it is presumed that these facilities would require inspection every five years by a public inspector and a 15% frequency of enforcement actions for private facilities resulting in an annual per unit I&E cost of $85.40. The total PV cost then becomes $2,913 for a custom cistern. Construction costs are private and I&E costs are public. Conceptually, these facilities will be constructed on available private land and will not require the purchase of additional land. Proposed total PV unit cost of the residential on-site detention BMP and associated cost details are presented in Table 2.

2.5.2 Bioretention Facilities

Construction costs selected for rain gardens was $20 per ft^2, which implies that a 100 ft^2 (10x10 ft) rain garden unit (or 100 ft^2 unit of road runoff bioretention BMP) used in SUSTAIN costs $2,000 to build and $1,691 (O&M = $1.10 ft^{-2} yr^{-1}) to maintain over a 30-year period assuming a discount rate of 5%. Adding in the cost of I&E for private rain garden facilities and inspection only for public roadside bioretention resulted in total PV costs of $69.73 and $63.04 per ft^2 for rain gardens and roadside bioretention facilities, respectively. These PV costs are used in the SUSTAIN model assuming that private land is available at no additional cost for rain gardens and that public right of way is available at no additional cost for road bioretention facilities. Total PV unit cost of the bioretention BMPs and associated cost details are presented in Table 2.

2.5.3 Porous Commercial Parking Areas

This study used a $20 per ft^2 construction and $0.02 per ft^2 O&M cost to develop the SUSTAIN porous pavement total cost input. It was assumed that the design cost is included in the estimated construction cost. An I&E cost per 100 ft^2 unit of porous pavement was developed, which resulted in an estimated annual I&E cost of $427.00. These costs result in a total PV cost of $85.95 per ft^2 of porous pavement over a 30-year period assuming a discount rate of 5%. Proposed total PV unit cost of the porous pavement BMP and associated cost details are presented in Table 2.

2.5.4 Detention Ponds

Including the O&M cost and a 30-year planning period with a 5% discount rate results in a total cost estimate for detention pond design, construction and O&M of \$4.78 per ft^3, which is equivalent to \$25.81 per ft^2 (Table 2). Land costs will be input separately into SUSTAIN as the present value cost per ft^2 of land depending on the cost of land associated with each model run, i.e. low or high cost (Table 3). Although the land costs in SUSTAIN only account for the surface area of the pond, no consideration has been made to adjust the land costs to account for necessary buffer areas around the ponds. In general, unit ponds as modeled in SUSTAIN using the aggregate BMP approach are conceptual and in reality several unit ponds might be aggregated and placed at a single site, which would affect assumptions made about necessary buffer areas and associated scaling factors.

Table 2. Cost Assumptions for BMPs (30-yr planning horizon with 5% discount rate)

	Residential On-site Detention Facility	Bioretention		Porous Pavement	Detention Pond
		Rain Garden	Roadside [a]		
Design Unit Size	393 ft^3 (2,938 gal)	100 ft^2	100 ft^2	100 ft^2	d
Total Present Value	\$ 2,913 /unit	\$ 69.73 /ft^2	\$ 63.04 /ft^2	\$85.95 / ft^2	d
Inspections/Enforcement [a]	\$ 85.40 /yr	\$ 213.50 /yr	\$ 170.00 /yr	\$ 427.00 /yr	\$25.81 /ft^2 \$4.78 /ft^3)
Design and Permitting Cost	~\$0 [b]	c	c	c	\$1.20 /ft^2
Construction Cost	\$ 1,600 /unit	\$ 20 /ft^2	\$ 20 /ft^2	\$20 /ft^2	\$3.43 /ft^2
Annual Operation and Maintenance Cost	NA	\$ 1.10 /ft^2	\$ 1.10 /ft^2	\$0.02 /ft^2	\$0.01 /ft^2
Land Cost	NA	NA	NA	NA	e

Costs presented in 2013 dollars

NA = Not applicable.

[a] I&E is a public cost and construction and O&M costs for roadside bioretention are public costs.

[b] Assumed to be negligible.

c Conceptually included in construction cost

d Varies with hypothetical catchment; see Appendix A, Table 19 e Cost of land for detention pond varies with type of development and location; see Table 3

Table 3. Detention Pond Land Costs

Land Use	Low Land Cost (East/South SR-18)	High Land Cost (West/North SR-18)
	Unit Value ($\$/ft^2$)	Unit Value ($\$/ft^2$)
Commercial/Industrial	25.63	26.03
High Density Residential	11.24	19.75
Low Density Residential	3.68	8.72
Agriculture	1.06	3.38

2.6 Estimation of Rooftop, Commercial Parking, and Road Surface Areas

The HSPF models developed for this project explicitly model the runoff from roads, but do not separately model the runoff from effective impervious area (EIA) associated with rooftops and paved areas within residential and commercial land uses. The road EIA from the HSPF model (and the associated HRU time series file) was used as the area to be treated via roadside bioretention in the pilot study SUSTAIN model. The fraction of EIA associated with rooftop and paved areas is necessary to route the fraction of runoff to be treated by cisterns and rain gardens, respectively, for residential development, or rain gardens and porous pavement, respectively, for commercial development.

Because the HSPF model does not explicitly model runoff from residential roofs or commercial parking areas, a method was developed to estimate the contributing area of these particular surfaces within the study catchment. The selected method relies on readily available county-wide GIS data and was based on an initial effort conducted by Gardner et al. (2012).

The method uses a county-wide 6-ft resolution grid of lidar-derived heights of man-made features (i.e., impervious cover) [7]. Grid cells classified as impervious based on a 2009 multi-source interpretation of impervious/impacted surfaces[8] were assigned a height above ground based on the difference between the digital surface and ground models derived from county-wide lidar data referenced above. The man-made feature height grid was

[7] King County. 2010. Man Made Features Area and Height. (http://www5.kingcounty.gov/sdc/raster/landcover/ManmadeFeatureElevationMetadata.html)

[8] King County. 2011. 2009 Impervious and Impacted Surface of King County, Washington. (http://www5.kingcounty.gov/sdc/raster/landcover/Landcover2009ImperviousMetadata.html)

intersected with the grid used to develop the HSPF HRUs.[9] The area of man-made features above and below a 6-ft height threshold was used to quantify the rooftop area and remaining impervious area for each type of HRU in the catchment. A 6-ft threshold was chosen based on previous experience with height models derived from the county-wide lidar data, which tend to be less accurate for the ground surface due to the confounding influence of vegetation.[10]

The fraction of the total impervious area above 6 ft within residential HRUs was considered roof area. The impervious surfaces calculated using this method are considered total impervious area (TIA), therefore, requiring the adjustment of EIA fractions extracted from HSPF. The EIA fractions of the HRUs calibrated in HSPF were converted to TIA fractions for each hypothetical catchment using the regression equation from Elmer (2001) below.

$$EIA_{total} = 1.0428 * TIA_{total} - 0.1128$$

$$EIA_{total} = EIA_{road} + EIA_{nonroad}$$

$$TIA_{total} = \frac{(EIA_{nonroad} + EIA_{road} + 0.1128)}{1.0428} \quad (3)$$

where $EIA_{nonroad}$ is the fraction of non-road EIA from HSPF and EIA_{road} is the road EIA from HSPF. The road EIA as modeled in HSPF was assumed to be equivalent to road TIA and stayed the same.

$$EIA^*_{road} = EIA_{road} \quad (4)$$

where EIA^*_{road} is the adjusted EIA road fractions. In order to adjust the non-road EIA, the roof fraction was subtracted from the TIA fraction and multiplied by the ratio of HSPF nonroad EIA:TIA. The derivation of this equation is shown below.

$$EIA^*{}_{nonroad} = \left(TIA_{total} - TIA_{roof}\right) * \frac{EIA_{nonroad}}{TIA_{total}} \quad (9)$$

$$Pervious = 1.0 - EIA^*_{nonroad} - EIA^*_{road} - TIA_{roof} \quad (10)$$

The resulting roof and non-road fractions were used to calculate the portion of a hypothetical catchment routed to the on-site detention system or that could be converted to porous pavement, respectively, in SUSTAIN.

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[9] This grid precedes the last step in the creation of the "lumped" HRU types/areas that become inputs to the HSPF model. The last step uses estimates of EIA associated with each gridded HRU type to estimate the area within the catchment represented by EIA (road, two residential density levels, and commercial EIA) and pervious HRUs, which is the remainder of the area of the gridded HRU types.

[10] The county lidar flights were flown during seasonal leaf-off periods, but twiggy ground vegetation confounded ground elevation estimates in some areas.

2.7 Optimization Target

As described in the pilot study (King County 2013a), the NSGA-II optimization option was selected for use in this study to allow for the exploration of costs to meet a wide range of flow management (and by extension biological) goals from the cost-effectiveness curve. The NSGA-II optimization option in SUSTAIN is used to develop a set of optimal solutions over a range of levels of effectiveness (i.e., cost-effectiveness curves).

This study uses SUSTAIN's cost-effectiveness analysis option of minimizing the cost of reducing the frequency flow exceeds a specified flow threshold. This option is consistent with one of the three hydrologic metrics chosen for use in this study, High Pulse Count (HPC) (Horner 2013). HPC is the number of times in a water year the daily mean flow discretely exceeds a high pulse flow threshold set as twice the long-term mean annual flow. The objective in the optimization is to reduce the number of HPCs observed under current conditions to numbers more typical of the pre-development forested condition.

The objective in the optimization is to reduce the number of HPCs observed under current conditions to numbers that are more typical of the pre-development forested conditions. HPC (and a number of other hydrologic metrics commonly called "flashiness" metrics) has shown a correlation with the benthic index of biotic integrity (B-IBI) in King County streams (DeGasperi et al. 2009, Horner 2013), so it is hypothesized that reductions in flow flashiness will result in improvement in the biological integrity of local streams as represented by B-IBI scores.

In addition to the selection of an optimization target, a range from zero to an upper limit of the possible number of units of each BMP treatment type and the step increment from zero to the maximum possible number of BMPs of each type must be specified. The number of BMP types to optimize and the number of steps selected for an optimization run affect the number of possible BMP type and number of permutations and hence the number of scenario iterations needed to generate a relatively smooth cost-effectiveness curve. The number of possible BMP types was determined based on the design treatment drainage area for each BMP (see Appendix A, Table 18) with 20 equal steps from zero to the maximum number of BMPs. Table 4 shows the range and step size of the number of units of each BMP considered in the cost-effectiveness optimization runs.

A maximum number of model scenarios must also be specified. The SUSTAIN optimization model runs conducted for this study were based on 1,000 individual scenario model runs, as done in the pilot study (King County 2013a).

Table 4. Summary of the range and steps of the number of BMP units specified in the SUSTAIN cost-effectiveness model runs.

BMP Type	Number of Units		
	From	To	Step
Cistern	0	600	30
Rain Garden	0	4,100	205

BMP Type	Number of Units		
	From	To	Step
Porous Parking	0	18,200	910
Roadside Bioretention	0	300	15
Detention Pond	0	100	10

2.8 Post Processing SUSTAIN Results

The output from a SUSTAIN cost-effectiveness model run consists of hourly time series files for the pre-developed forested catchment condition and existing development conditions with no BMP treatment. In addition, the SUSTAIN output includes the effectiveness, total cost and cost breakdown by BMP type for the BMP scenarios for all model iterations and a subset of optimal (Best) solutions over the range of most cost-effective solutions. The effectiveness is quantified as the percent reduction of the flow exceedance frequency from existing conditions. An Excel-based post-processor is provided with the SUSTAIN distribution that allows for the analysis of the model output and selection of any particular "Best" solution so the scenario can be run again to obtain an output time series file for further analysis of that particular BMP scenario (U.S. EPA 2009).

Ideally, the "Best" solution could easily be identified as the most cost-effective solution, but due to the differences in the shape of SUSTAIN's cost-effectiveness curve output for the various hypothetical catchments, a set of rules were established as a guide for selecting the solutions. The "Best" solution for each model run was selected based on the following set of rules: 1) select the solution at the "knee" of the curve if it is within 5 percent of maximum effectiveness, 2) if the "knee" of the curve is more than 5 percent less than the maximum effectiveness, select the solution that is 5 percent less than maximum, 3) if there is no obvious "knee" in the curve, select the most effective solution within 5 percent of maximum.

A sensitivity analysis was performed to evaluate the impact of the best solution selected on the final cost when scaled up to a full catchment of the study area. This analysis compared the total costs when selecting the "Best" solution 5 percent less than the maximum, as stated in the rules above, with the total costs when selecting solutions 10 percent less than the maximum, and when selecting the maximum effective solution at the lowest cost. These results are presented below in section 3.2.

SUSTAIN only outputs the average number of annual HPCs over the simulation period and does not provide a time series output of the annual HPCs over the simulation period. Post-processing tools were developed to provide further analysis of the SUSTAIN output, including time series comparisons of HPCs among pre-development, existing conditions and selected optimum solutions. The post-processing tools also provide the ability to calculate the other two hydrologic metrics selected for evaluation in this study, high pulse range (HPR) and 2-year frequency peak flow:mean winter base flow ratio(PEAK:BASE), and the ability to extrapolate to potential improvements in B-IBI scores (Horner 2013). HPR is the number of days in a water year between the first and last exceedance of the high pulse flow threshold set as twice the long-term mean annual flow.

Analysis of potential water quality benefits (turbidity, copper and zinc) were also extrapolated from modeled TSS concentrations using the regression equations developed by Horner (2013) for this project. These extrapolations generally assume that TSS will continue to be a reasonable surrogate for turbidity, copper and zinc concentrations through the treatment system. The extrapolation to water quality benefits is meant to provide a first-order estimate of the potential reductions in loads and concentrations of sediment and trace metals, with uncertainty in these predictions increasing from TSS and turbidity to trace metals.

2.9 Scaling BMP Solutions and Cost-Effectiveness to Study Area

The study area is made up of catchments that have a unique combination of LULC and HSPF HRUs represented by the hypothetical catchments. The hydrologic and water quality indicators of the hypothetical catchment solutions were scaled to the study area by calculating the area weighted average of the indicator values associated with the actual distribution of future LULC from the simulated 2040 GIS land cover data (Alberti, M., University of Washington Urban Ecology Research Laboratory). Potential improvements in B-IBI score were extrapolated from the scaled hydrologic indicators to provide an estimate of the potential improvement in biological health after all modeled BMP facilities are constructed by year 2040.

Based on the numbers and combination of BMP units selected during SUSTAIN optimization, costs were calculated based on an alternative cost model approach where construction of the BMP units is evenly distributed throughout the 30-year period. Therefore each year, construction costs ensue for 1/30th of the BMP units selected as well as the O&M and I&E costs of any BMPs constructed in years prior. This approach reduces the O&M and I&E costs by distributing the construction of the BMP units over the 30-year period instead of requiring O&M and I&E for all of the units at once. The hypothetical catchment "Best" solution units and costs were scaled to projected 2040 future conditions of the study area.

2.10 Future New and Redevelopment

The population increase projected by 2040 will result in the conversion of additional land for urban use, and the redevelopment of previously developed land for higher density use. Current stormwater guidelines (King County 2009 Stormwater Design Manual) allow limited amounts of disturbance without requiring stormwater mitigation. Therefore, a portion of the study area will require stormwater control between now and the year 2040. King County (2013c) developed and documented a method to estimate how much of the study area is projected to be modified as a result of new and re-development based on simulated 2040 projections for planning level purposes. Future projected development is categorized as disturbed or minimally disturbed. If the disturbed areas transition from a lesser level of development in existing conditions (2007) to a higher level in future projections (2040) in the same geographic location, it was assumed to categorized as new or redevelopment. Development unchanged in the future is assumed to not require additional stormwater controls.

2.11 Stormwater Management Scenarios

The facility needs and their effectiveness were evaluated by modeling various levels of stormwater management of the future (2040) LULC of the study area. In this report, stormwater treatment refers to flow quantity and water quality control. Three management scenarios were explored for a public stormwater program:

1. Required stormwater treatment occurring with new and redevelopment (i.e. 2040 required stormwater treatment)
2. Required stormwater treatment with new and redevelopment plus control of stormwater from roads and highways (i.e. 2040 required stormwater treatment plus roads and highways)
3. Required stormwater treatment plus control of stormwater from unchanged development (i.e. 2040 full stormwater treatment)

The required stormwater treatment scenario assumes BMP facilities are installed with new development and redevelopment as outlined in current stormwater guidelines. The construction and O&M of facilities are assumed to be private or public costs based on what type of facility built. Private facilities are constructed independent of a stormwater program while costs associated with public facilities are part of a public stormwater program. Additionally, ongoing I&E private stormwater facility costs are considered to be part of a public stormwater program.

The required stormwater treatment plus stormwater control of roads and highways scenario assumes BMP facilities are installed as required with new and redevelopment as well as additional treatment facilities for local roads and highways. Our approach assumes all developed road area remains unmodified in 2040 future land use and therefore is treated in this scenario. The roadside stormwater treatment facilities are public facilities consisting of roadside bioretention as well as the detention ponds the bioretention facilities are routed too. Considering roadside bioretention and rain gardens have the same design and performance, the ratio of roadside bioretention to detention ponds and rain gardens to detention ponds are consistent.

Required stormwater treatment plus control of stormwater from unchanged development is considered full treatment of the study area. This scenario assumes that treatment facilities are installed with new and redevelopment, facilities are installed to treat stormwater runoff from local roads and highways, and additional treatment facilities are installed for the remaining developed area through a public stormwater program.

3.0. HYPOTHETICAL CATCHMENT RESULTS AND DISCUSSION

Stormwater BMP techniques were optimized using the SUSTAIN cost-effectiveness model for 100-acre hypothetical catchments representing the various LULC of the study area. The SUSTAIN BMP solutions and cost-effectiveness results are presented in the sections that follow.

3.1 Hypothetical Catchment Cost-Effectiveness Results

SUSTAIN's optimization selected best solutions that included a combination of cisterns, rain gardens, roadside bioretention and detention ponds. The optimization did not choose any porous pavement for commercial land use model runs. The percent effectiveness, or the relative ability of a selected hypothetical catchment solution to reduce HPC from existing conditions, ranged from 21 to 92 percent. The modeled costs for the hypothetical catchments in SUSTAIN assume the initial construction of all BMP units followed by 30 years of O&M and I&E costs. The total 30 year life-cycle costs for the 100-acre hypothetical catchments ranged from $0.86 to $33.26 million (Table 5). The variation of costs within each land use group reflects the different slopes, soils, precipitation zones, and costs.

The "Best" solutions of the hypothetical catchments with greater intensity development had higher percent effectiveness than those with less intense development. The maximum effectiveness of agricultural best solutions is 46 percent, approximately half of the effectiveness of higher intensity development, but with still a considerably high cost. Figures 8 through 11 display the range and variability of indicator results for the hypothetical catchments grouped by land use. The indicator values are presented for predevelopment (predev), i.e. fully forested conditions, post development (postdev), i.e. existing developed conditions with no stormwater treatment, and the SUSTAIN model's "Best" solution (Best Sol), i.e. existing development with the most cost-effective stormwater treatment. The "Best" solutions of the hypothetical catchments reduced the indicator values from post development for all land uses. Although all hypothetical catchments "Best" solutions did not quite meet fully forested predevelopment conditions, all solutions reduced the indicator values from post development conditions and the medians were reduced to similar values of the fully forested medians.

As the intensity of development decreases, the post development conditions with no BMP treatment indicator values were also lower. Agricultural indicators for existing development were significantly lower than the other land use, but only had a slightly lower maximum cost for BMP treatment. The variability of the "Best" solution indicator results are greatest in commercial and high residential compared to low residential and agricultural. Table 20 in Appendix B provides the total costs, percent reduction, and the BMP units and cost details for the hypothetical catchment's "Best" solutions as well as the average HPC, HPR, PEAK:BASE, and TSS load forested, existing and "Best" solution values.

Table 5. Range of hypothetical catchment total cost and effectiveness grouped by land use.

Land Use	Total Cost ($M)			Effectiveness (% Reduction)		
	Min	Max	Median	Min	Max	Median
Commercial	$7.49	$33.19	$28.10	44%	92%	87%
High Residential	$2.17	$31.46	$26.21	35%	90%	74%
Low Residential	$0.86	$33.26	$26.71	41%	82%	58%
Agricultural	$3.20	$26.49	$15.62	21%	46%	26%

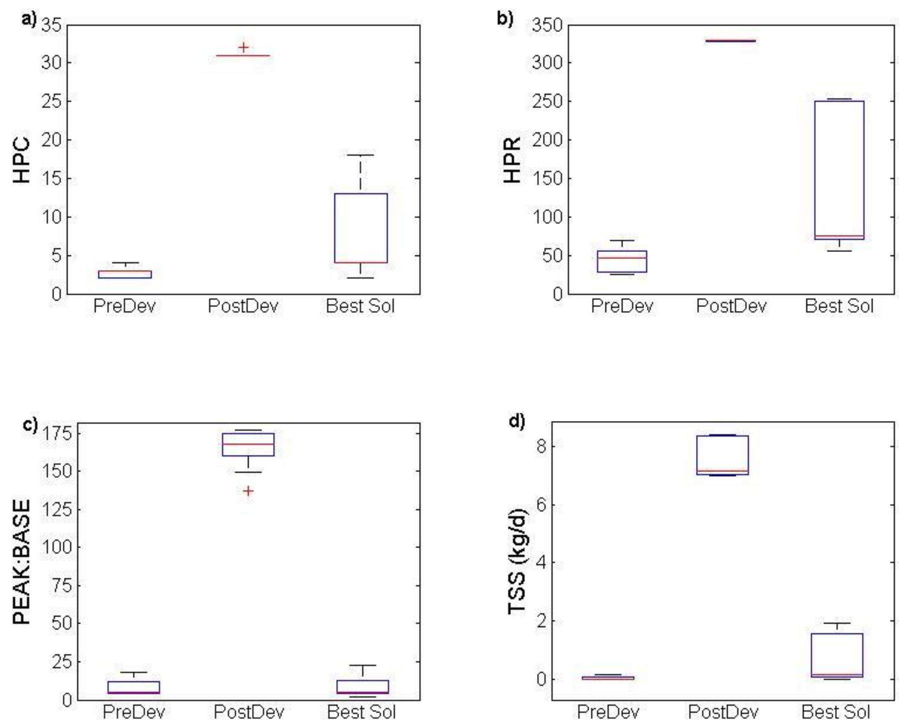

Figure 8. Commercial Indicator Results a) HPC, b) HPR, c) PEAKBASE, d) TSS

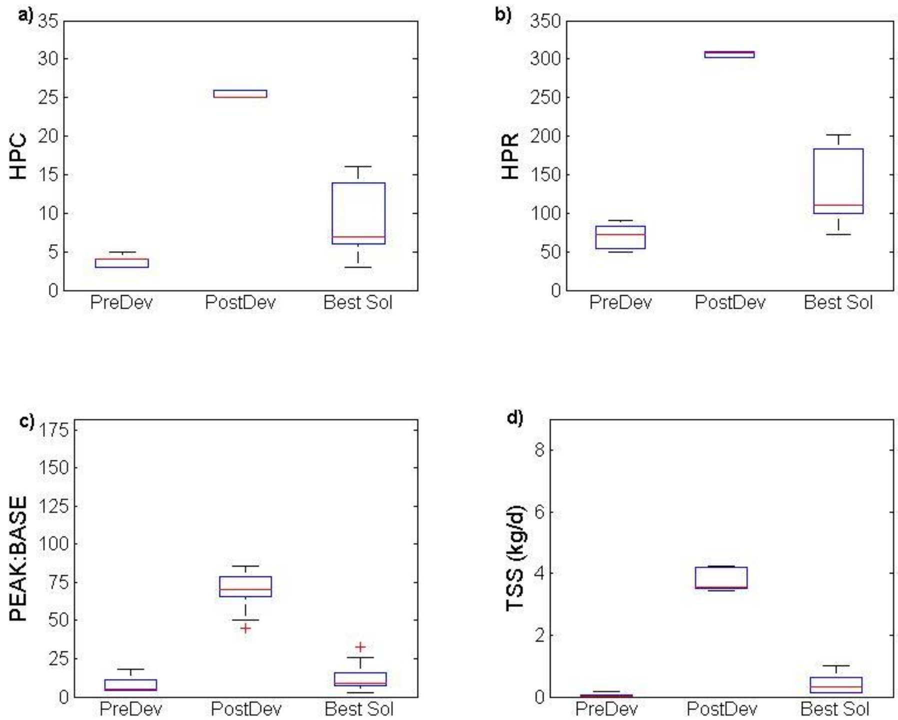

Figure 9. **High Residential Development Indicator Results a) HPC, b) HPR, c) PEAKBASE, d) TSS**

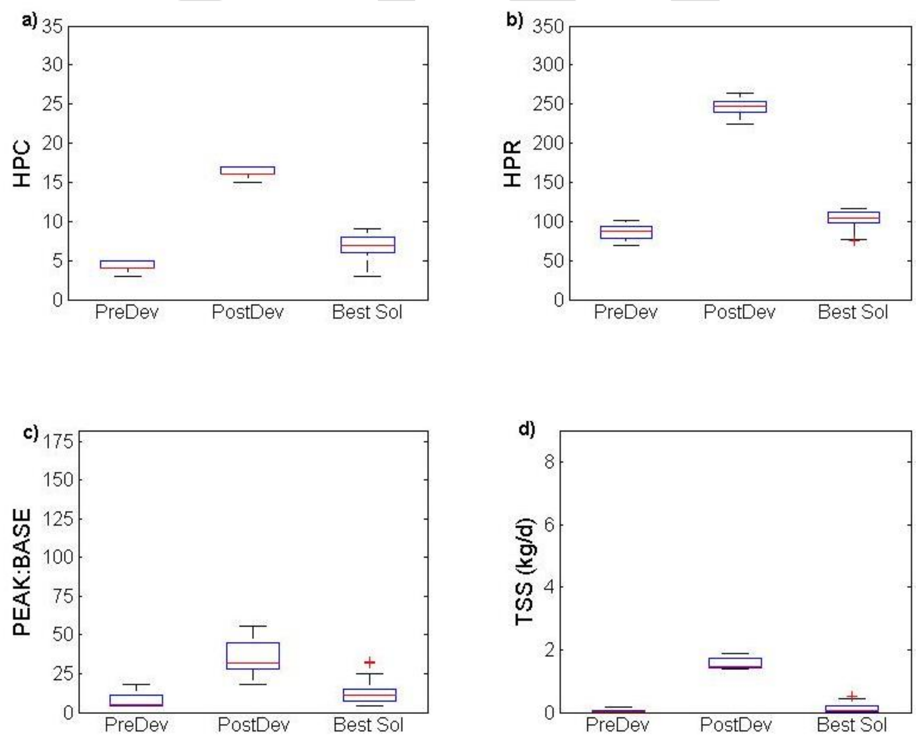

Figure 10. **Low Residential Development Indicator Results a) HPC, b) HPR, c) PEAKBASE, d) TSS**

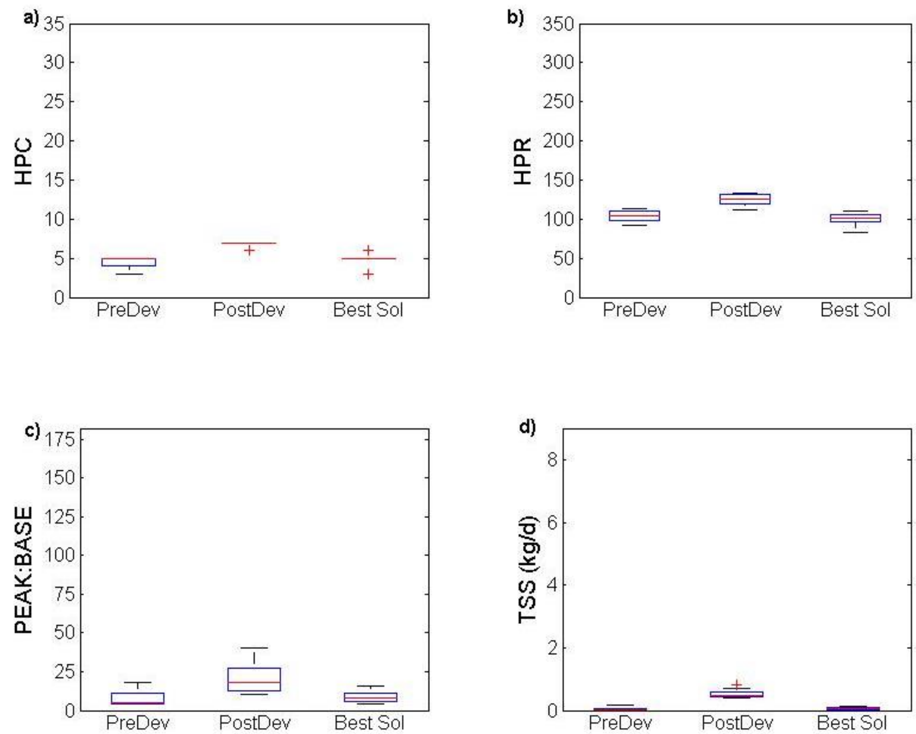

Figure 11. Agriculture Indicator Results a) HPC, b) HPR, c) PEAKBASE, d) TSS

3.2 SUSTAIN Best Solution Sensitivity Analysis

The sensitivity of total stormwater treatment costs to the method of selecting a hypothetical catchment's "Best" Solution was explored by scaling costs to the pilot study catchment, the Newaukum Creek sub-basin (NEW151). Three methods of selecting the "Best" solution were compared: if there is no obvious knee in the curve, select the solution 5% less than the maximum, 10% less than the maximum, or the maximum effective solution at the lowest cost.

As described in the pilot study report (King County 2013a), the majority of the Newaukum Creek sub-basin land cover is disturbed area associated with High/Medium Density Residential land use with some low density residential and commercial area. The surficial geology consists of till and type D soils. The catchment has high land cost and is located in the high precipitation zone of the study area.

The sub-basin's land use is covered by 12 different hypothetical catchments. Of these 12 model runs, 5 of the models runs produced cost-effectiveness curves with the best solution falling on the "knee" of the curve with no need for adjustment (they fell within 5% and 10% of the maximum effectiveness). Table 6 compares Newaukum sub-basin's stormwater treatment cost differences as a result of changing the "Best" solution selected in the 7 remaining hypothetical catchment models.

Using the 5% selection rules described in section 2.8, total cost for public and private stormwater infrastructure is $ 63.5 million. When no significant knee in the curve is present, selecting the maximum effective solution resulted in a cost of $76.2 million. When selecting the solution 10 percent less than the maximum, stormwater infrastructure costs are $52.6 million. There is approximately 18 percent cost difference between the three "Best" solution options. Of the three solutions, selecting 5 percent less than maximum solution is the most cost-effective since there is a slightly smaller percent difference between the 5 percent less than maximum solution and maximum solution than between the 10 percent less than maximum and 5 percent less than maximum solutions.

Table 6. Newaukum Sub-basin "Best" Solution sensitivity analysis

Best Solution	Total PV Cost ($M)	HPC
10% less than max	$52.6	10.5
5% less than max	$63.5	9.8
max	$76.2	9.4

3.3 Discount Rate Sensitivity Analysis

The 30 year life-cycle costs input into SUSTAIN for optimization were converted to 2013 dollars with a real discount rate of 5 percent. The sensitivity of SUSTAIN's optimization to the discount rate was explored by comparing model results with cost inputs reflecting a 5% real discount rate with cost inputs reflecting King County's Wastewater Treatment Division (WTD) real discount rate of 2.18 percent. SUSTAIN was rerun for commercial and high density residential development hypothetical catchments with low/high precipitation and low/high costs (Table 7).

The 2.18 percent discount rate best solution costs approximately 21 to 31 percent more with similar percent reduction. The selection of number and type of BMP units were similar although a lower discount rate seemed to choose slightly more detention ponds and less roadside bioretention in 3 out of 4 scenarios. Overall, SUSTAIN's optimization was not significantly impacted by the selected discount rate in choosing the most effective combination of BMP facilities. Therefore, the BMP units and effectiveness will be similar when scaling to the study area and the PV costs can be recalculated using a different discount rate as needed.

Table 7. Discount Rate Comparison

Hypothetical Catchment	Discount rate	Total Cost ($M)	Eff./ % Red	Cisterns	Rain gardens	Roadside Bio	Porous Pavement	Detention Ponds
				#units	#units	#units	#units	#units
P1C1TC1	5%	$30.39	88%	0	4,100	285	0	0
	2.18%	$44.16	87%	0	4,100	165	0	30
P3C2TC1	5%	$33.02	87%	0	4,100	270	0	5
	2.18%	$41.88	87%	0	4,100	240	0	10
P1C1THR1	5%	$27.70	78%	60	3,690	285	0	0
	2.18%	$37.41	78%	0	3,690	285	0	20
P3C2THR1	5%	$27.62	73%	0	3,690	300	0	0

Hypothetical Catchment	Discount rate	Total Cost ($M)	Eff./ % Red	Cisterns	Rain gardens	Roadside Bio	Porous Pavement	Detention Ponds
				#units	#units	#units	#units	#units
	2.18%	$35.97	72%	90	3,690	270	0	0

3.4 Distributed Construction Life-Cycle Cost Approach

The hypothetical catchment stormwater facility costs presented thus far in reflect the 30 year life-cycle costs input into SUSTAIN that assumes all BMP units are constructed initially, followed by 30 years of O&M and I&E. The public and private cost details for the hypothetical catchment "Best" solutions can be found in Table 21 of Appendix B. Public costs ranged from $0.81 to $27.46 million, and private costs ranged from $0 to $15.13 million.

The stormwater facility costs were scaled to the study area assuming the alternative life-cycle cost approach. This approach distributes the construction of BMP units evenly throughout 30 years, reducing the total annual O&M and I&E costs occurring over the 30 years. This method results in hypothetical catchment total PV costs ranging from $0.45 to $15.57 million. Public costs ranged from $0.42 M to $14.13 M, and private costs ranged from $0 to $7.18 million. The public and private cost details for the hypothetical catchments using the distributed construction approach can be found in Table 22 of Appendix B. The distributed construction approach costs were scaled to the study area.

4.0. STUDY AREA EFFECTIVENESS RESULTS AND DISCUSSION

The SUSTAIN model "best" solution results for the hypothetical catchments were scaled to the study area based on the weighted average of the unique distribution of the future (2040) LULC in the study area catchments. The sections that follow present the effectiveness and cost results of scaling the optimized solutions to the study area considering the following stormwater management scenarios (discussed in section 2.11):

1. Required stormwater treatment occurring with new and redevelopment (i.e. 2040 required stormwater treatment)
2. Required stormwater treatment with new and redevelopment plus control of stormwater from roads and highways (i.e. 2040 required stormwater treatment plus roads and highways)
3. Required stormwater treatment plus control of stormwater from unchanged development (i.e. 2040 full stormwater treatment)

4.1 New and Redevelopment of Study Area

A portion of the future developed LULC of the study area is projected to require stormwater control with new development and redevelopment. The remainder of the developed area is forecasted to remain unmodified. Table 8 summarized the fraction of developed LULC in the study area that is categorized as new and redevelopment in 2040 and the fraction that remains developed with no change by 2040. The fractions were used to calculate the number of facilities that will be implemented with new and redevelopment from those that will require a public stormwater program.

77 percent of the study area, or approximately 215 square miles, is forecasted to be developed in 2040. Of the developed area, 61 percent is projected to be to have undergone new and redevelopment, while the remaining 39 percent is unmodified.

Table 8. Summary of new and redevelopment fraction and unmodified fraction of future (2040) developed land by Jurisdiction

Jurisdiction	Total Development	
	2040 New and Redevelopment Fraction	Unmodified Fraction
Algona	59%	41%
Auburn	58%	42%
Black Diamond	72%	28%
Burien	59%	41%
Covington	62%	38%
Des Moines	57%	43%
Enumclaw	72%	28%
Kent	57%	43%
Maple Valley	59%	41%

Jurisdiction	Total Development	
	2040 New and Redevelopment Fraction	Unmodified Fraction
Normandy Park	67%	33%
Pierce County	64%	36%
Renton	65%	35%
SeaTac	44%	56%
Seattle	38%	62%
Tukwila	58%	42%
Federal Way	59%	41%
Tacoma	38%	62%
King County	64%	36%
Study Area	61%	39%

4.2 Number of Facilities in Study Area

The numbers of facilities were scaled to study area based on the unique combination of hypothetical catchments that make up the future (2040) simulated LULC of each jurisdiction. Assuming the units are evenly distributed throughout each jurisdiction, the number of units required with new and redevelopment are calculated by multiplying the associated fraction to the scaled units of each jurisdiction. The remaining numbers of BMP units have the potential to be implemented with a public stormwater program. The number of BMP facilities scaled to jurisdictions and model domains are presented in Table 9 and 10, respectively. The tables break up the BMP units for full stormwater treatment of the study area into incremental amounts associated with each increase in stormwater control for the management scenarios. The numbers of BMP units are presented as those that will be required with new and redevelopment, units for stormwater treatment of roads and highways only, and additional units for stormwater treatment of the remaining non-road development.

The facilities required with new and redevelopment by the year 2040 are approximately 21,000 cisterns, 1,700,000 rain gardens, and 46,000 detention ponds. A stormwater program that installs stormwater facilities for local roads and highways will result in an addition of about 190,000 roadside bioretention and 5,000 detention ponds. A stormwater program that installs stormwater facilities for the unchanged remainder of developed area will results in an additional 13,000 cisterns, 950,000 rain gardens, and 25,000 detention ponds. Therefore, full stormwater treatment of the study area will result in a total of 34,000 cisterns, 2,700,000 rain gardens, 190,000 roadside bioretention, and 76,000 detention ponds. The number of facilities were modeled conceptually as small units distributed throughout the study area and may not be representative of the actual number of units to be installed but instead provide an estimate of the volume of storage needed. The units can be lumped into larger units as project specific needs are identified.

Table 9. Estimated number of BMP units required with 2040 new and redevelopment, units for roads and highways, and additional units for unmitigated lands for consideration in a public stormwater program by Jurisdiction

Jurisdiction	Cisterns			Rain Gardens			Roadside Bioretention			Detention Ponds		
	2040 New and Redevelop-ment	Roads and Highways	Additional Units for Stormwater Program	2040 New and Redevelop-ment	Roads and Highways	Additional Units for Stormwater Program	2040 New and Redevelop-ment	Roads and Highways	Additional Units for Stormwater Program	2040 New and Redevelop-ment	Roads and Highways	Additional Units for Stormwater Program
Algona	58	-	41	2,100	-	1,300	-	180	-	170	15	110
Auburn	1,200	-	860	120,000	-	75,000	-	14,000	-	4,500	490	2,700
Black Diamond	860	-	340	38,000	-	12,000	-	3,100	-	1,000	83	320
Burien	1,100	-	790	83,000	-	47,000	-	10,000	-	1,700	210	980
Covington	270	-	160	28,000	-	14,000	-	3,000	-	1,500	170	750
Des Moines	550	-	420	70,000	-	45,000	-	8,200	-	700	83	460
Enumclaw	250	-	99	34,000	-	10,000	-	3,100	-	730	67	220
Kent	2,500	-	1,800	280,000	-	180,000	-	32,000	-	5,800	660	3,600
Maple Valley	860	-	610	23,000	-	13,000	-	2,600	-	960	110	570
Normandy Park	350	-	170	17,000	-	6,500	-	2,000	-	620	71	240
Pierce County	16	-	9	660	-	290	-	90	-	24	3	10
Renton	690	-	380	100,000	-	44,000	-	10,000	-	1,600	160	690
SeaTac	490	-	630	70,000	-	80,000	-	11,000	-	1,100	170	1,200
Seattle	47	-	79	6,900	-	10,000	-	1,300	-	240	46	360
Tukwila	240	-	170	44,000	-	26,000	-	5,600	-	2,300	290	1,300
Federal Way	1,300	-	890	100,000	-	61,000	-	13,000	-	2,100	250	1,200
Tacoma	36	-	59	3,500	-	5,000	-	690	-	120	23	170
King County	10,000	-	5,800	710,000	-	320,000	-	72,000	-	21,000	2,100	9,600
Study Area	21,000	-	13,000	1,700,000	-	950,000	-	190,000	-	46,000	5,000	25,000

Table 10. Estimated number of BMP units required with 2040 new and redevelopment, units for roads and highways, and additional units for unmitigated lands for consideration in a public stormwater program by Model Domain

Model Domain	Cisterns			Rain Gardens			Roadside Bioretention			Detention Ponds		
	2040 New and Redevelop-ment	Roads and Highways	Additional Units for Stormwater Program	2040 New and Redevelop-ment	Roads and Highways	Additional Units for Stormwater Program	2040 New and Redevelop-ment	Roads and Highways	Additional Units for Stormwater Program	2040 New and Redevelop-ment	Roads and Highways	Additional Units for Stormwater Program
BlackRiver	1,500	-	1,100	200,000	-	120,000	-	22,000	-	5,200	600	3,200
BrownsPoint	40	-	53	2,000	-	2,200	-	380	-	96	18	110
ChristyCrk	740	-	270	28,000	-	9,100	-	2,400	-	720	61	220
CoalCrk	110	-	150	9,200	-	5,000	-	830	-	290	28	190
Covington	1,800	-	960	93,000	-	40,000	-	9,100	-	4,100	380	1,500

Model Domain	Cisterns			Rain Gardens			Roadside Bioretention			Detention Ponds		
	2040 New and Redevelop-ment	Roads and Highways	Additional Units for Stormwater Program	2040 New and Redevelop-ment	Roads and Highways	Additional Units for Stormwater Program	2040 New and Redevelop-ment	Roads and Highways	Additional Units for Stormwater Program	2040 New and Redevelop-ment	Roads and Highways	Additional Units for Stormwater Program
CrispCrkl	450	-	360	17,000	-	6,500	-	1,500	-	540	53	280
DeepCrk	600	-	420	36,000	-	18,000	-	2,800	-	1,100	86	560
DesMoines	290	-	210	34,000	-	48,000	-	6,000	-	830	100	590
DumasBay	850	-	580	56,000	-	33,000	-	7,000	-	1,400	180	820
DuwamLcl1	220	-	160	29,000	-	19,000	-	3,500	-	350	41	230
DuwamLcl2	130	-	160	23,000	-	25,000	-	3,800	-	910	150	980
GreenLcl1	570	-	720	24,000	-	24,000	-	2,700	-	750	85	770
GreenLcl2	740	-	520	29,000	-	16,000	-	2,800	-	900	89	530
GreenLcl3	830	-	410	91,000	-	38,000	-	9,700	-	3,100	330	1,400
GreenLcl4	230	-	200	19,000	-	13,000	-	2,300	-	1,500	180	1,100
GreenLcl5	490	-	330	66,000	-	37,000	-	7,800	-	2,000	230	990
GreenLocal	1,300	-	970	140,000	-	89,000	-	16,000	-	3,700	440	2,700
HamCreek	200	-	140	12,000	-	7,000	-	1,600	-	470	65	320
Jenkins	2,100	-	980	100,000	-	28,000	-	9,700	-	4,000	400	1,500
LPS1	400	-	300	44,000	-	28,000	-	5,200	-	640	75	390
LPS2	510	-	440	24,000	-	15,000	-	3,300	-	740	110	500
MasseyCrk	170	-	130	29,000	-	18,000	-	3,300	-	210	25	140
McSorley	240	-	190	37,000	-	23,000	-	4,200	-	310	35	190
Miller_Walker	850	-	630	64,000	-	45,000	-	8,500	-	1,600	200	990
Newaukum	2,100	-	1,100	190,000	-	79,000	-	19,000	-	5,400	530	2,300
OlsonCrk	430	-	210	43,000	-	19,000	-	4,500	-	610	69	340
Salmon	180	-	180	18,000	-	18,000	-	2,700	-	220	32	200
Soos	3,100	-	1,500	280,000	-	110,000	-	29,000	-	4,300	430	1,700
Study Area	21,000	-	13,000	1,800,000	-	930,000	-	190,000	-	46,000	5,000	25,000

4.3 Study Area Effectiveness

The improvement, or reduction, in hydrologic and water quality indicator values of the study area from developed conditions with no stormwater controls to the different stormwater management scenarios reflect the effectiveness of the BMP facilities. The hypothetical catchment hydrologic and water quality indicators were scaled considering the management scenarios and compared to existing (2007) and future (2040) LULC indicators of the study area.

Figure 12 presents the range and variability of hydrologic indicator results for six different modeled conditions of the study area catchments: fully-forested, 2007 existing development, 2040 development with no stormwater treatment, 2040 development with required stormwater treatment only, 2040 development with required stormwater treatment plus additional treatment of roads and highways, and 2040 development with full stormwater treatment.

2040 development with no stormwater treatment had a similar range of hydrologic indicator values as 2007 existing development for the study area catchments, but had a higher interquartile range and approximately 16 percent higher median. The 2040 no stormwater treatment interquartile range of HPC values fell between 19 and 28, with a median of 24. Required stormwater treatment with new and redevelopment reduced the interquartile range from 8 to15 and reduced the median by 50 percent with a value of 12. There is a slight improvement of HPC with the additional treatment of roads and highways, reducing the median to 11. Full mitigation of the study area decreases the HPC interquartile range from 4 to 5 and reduces the median again by more than half with a value of 4, similar to forested conditions.

The HPR of the study area catchments had a 9 percent higher median for 2040 LULC than 2007 existing LULC. PEAK:BASE showed the largest difference in 2007 and 2040 LULC of the hydrologic indicators with approximately 41 percent higher median for 2040 LULC. The effectiveness of stormwater treatment revealed a similar behavior in HPR and PEAK:BASE values as seen with HPC. Increasing the level of stormwater treatment reduces, or improves, the indicator results of the study area catchments. Treatment of roads and highways provided some additional reduction of indicator values. Full stormwater treatment of development in the study area reduced the HPR and PEAK:BASE indicator values and medians close to forested conditions.

TSS concentrations for the stormwater management scenarios were extrapolated to turbidity, total copper (TCu) and zinc (TZn), and dissolved copper and zinc based on relationships developed by Horner (2013). Figure 13 presents the range and variability of TSS , TCu, and TZn load (in kg per day) results for the six conditions of the study area catchments. Required stormwater treatment with new and redevelopment significantly reduced TSS loads with an additional small reduction with the treatment of roads and highways. . Full stormwater treatment reduced the range and variability of TSS loads with a median very similar to forested conditions. Stormwater treatment was less effective at reducing TCu and TZn loads. Required treatment reduced 2040 LULC loads to values similar to 2007 existing conditions. Full stormwater treatment provided a small amount of additional improvement but was not 100 percent effective at reducing TCu or TZn loads to forested conditions.

Dissolved copper, dissolved zinc, and turbidity concentrations were compared to Washington Department of Ecology water quality standards. Acute and chronic dissolved copper and zinc standard exceedances were calculated based on equations provided in 173-201A WAC Table 204(s), assuming a hardness of 25 mg/L for the acute standard and 50 mg/L for the chronic standard. Turbidity standard exceedances were based on core summer salmonid habitat (Table 200 (1)(e)), which specifies that turbidity shall not exceed 5 NTU over background when background is 50 NTU or less and not to exceed a 10 percent increase when background is above 50 NTU. The calculated turbidity concentrations of the modeled fully-forested conditions were used as the background concentration.

Dissolved copper and dissolved zinc of the study area catchments did not exceed water quality standards. On the other hand, turbidity concentrations exceeded water quality standards a small portion of the time (<2 percent). Figure 14 presents the range and variability of the percent of time turbidity exceeded water quality standards for the six study area conditions. The 2007 existing study area catchment conditions had a turbidity median that exceeded standards approximately 1.3 percent of the time. The future 2040 no stormwater treatment increased the median to exceed standards 1.6 percent of the time. Required stormwater treatment reduced the exceedance median by more than half with a median of 0.6 percent and had slightly more reduction with the additional treatment of roads and highways. Full stormwater treatment reduced the exceedance median to less than 0.1 percent of the time.

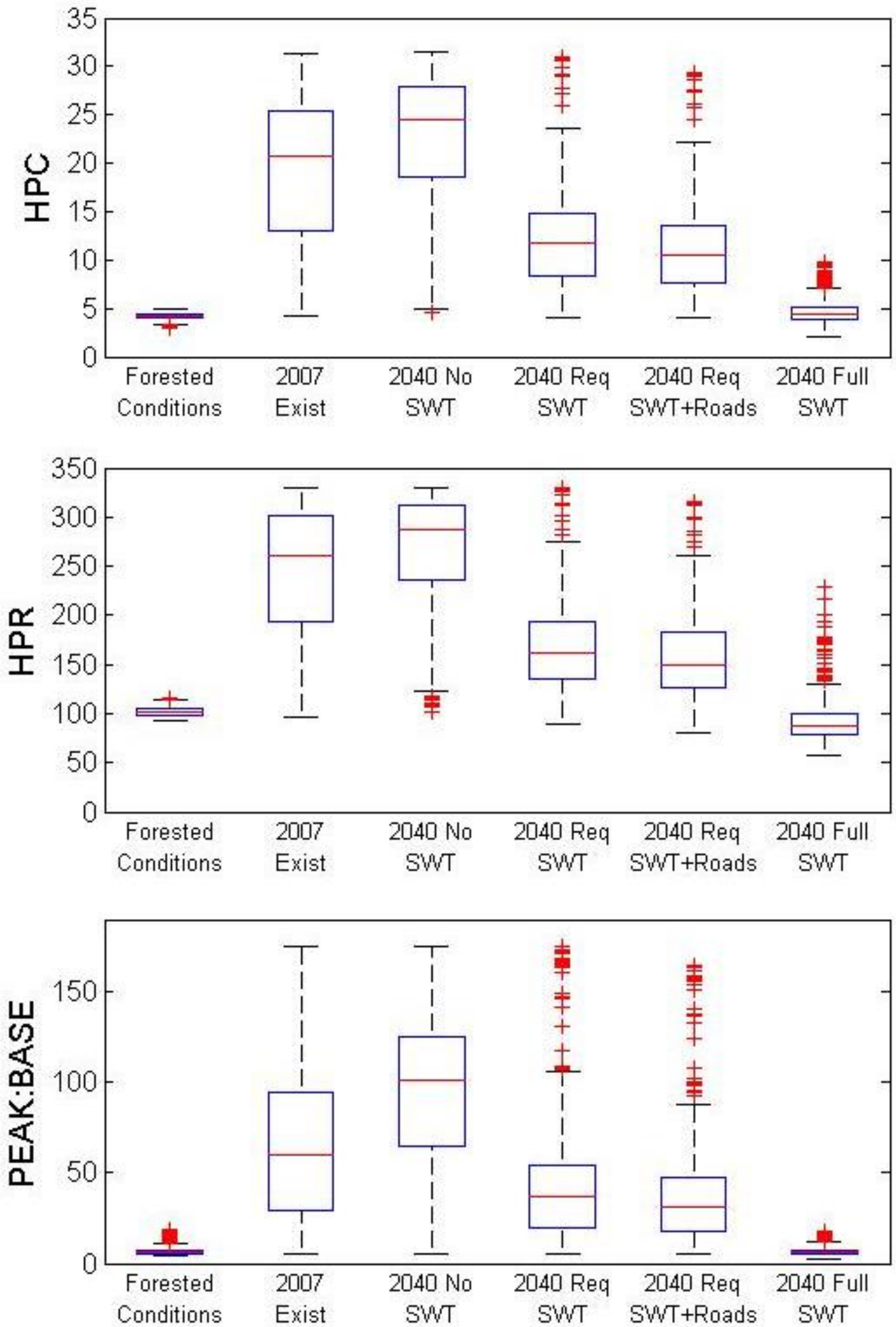

Figure 12. Study Area Catchment HPC, HPR and PEAK:BASE results for various mitigation options

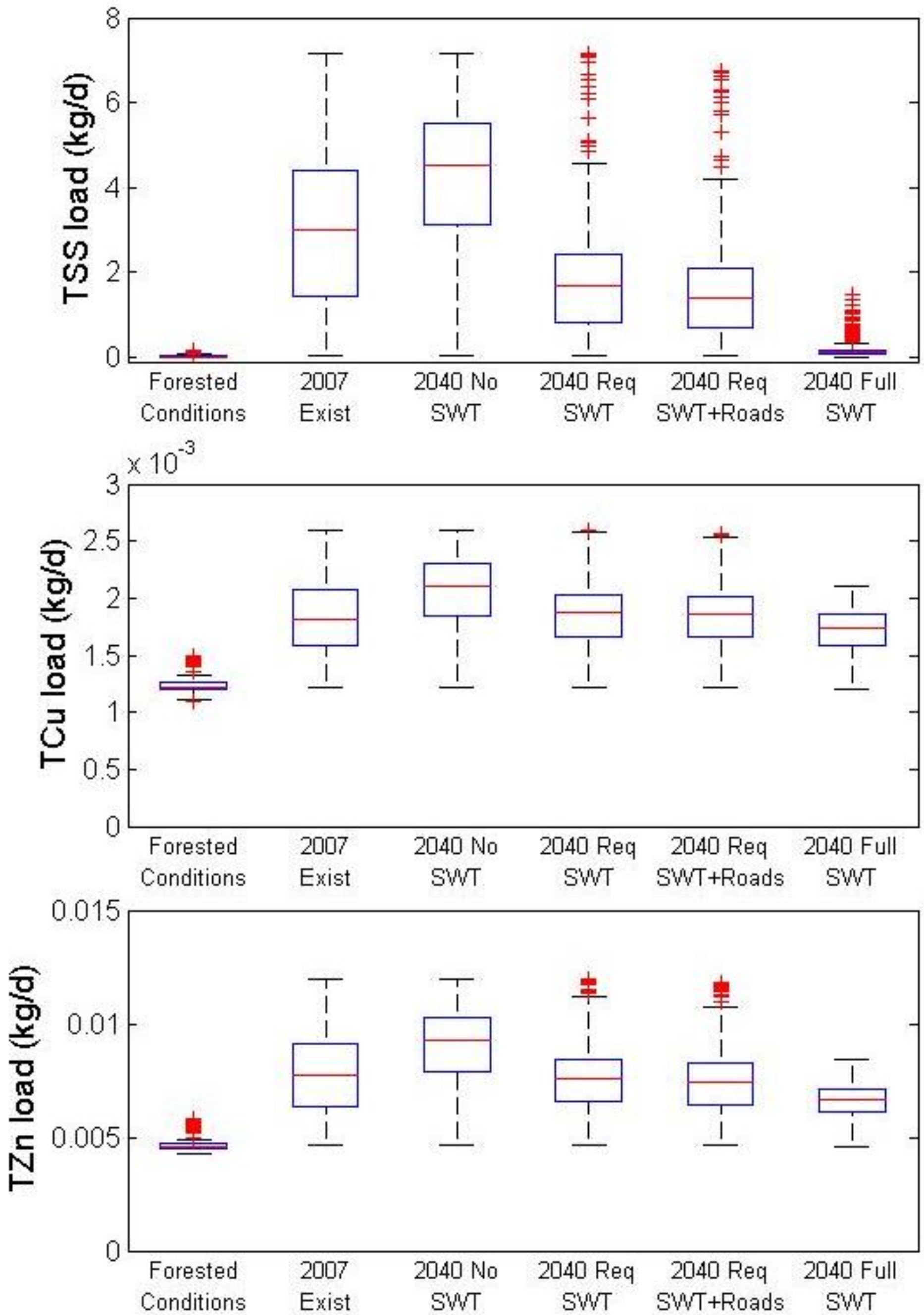

Figure 13. Study Area Catchment TSS load, TCu load and TZn load results for various mitigation options

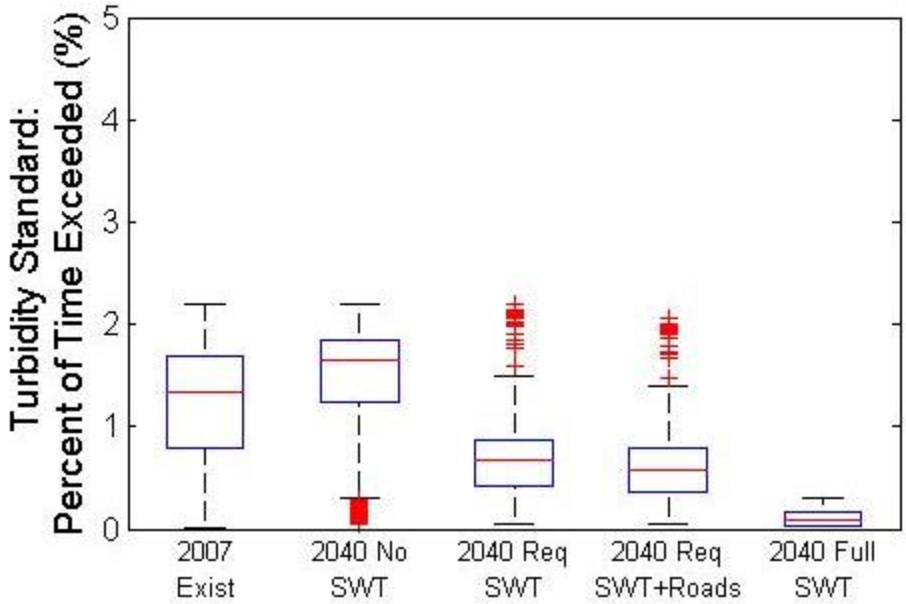

Figure 14. Study Area Catchment Percent of Time exceeding Washington Department of Ecology turbidity standards

4.4 Potential Improvement in B-IBI Scores

Horner (2013) developed logistic regressions for HPC and HPR that could be employed to provide probabilistic estimates of improvement in B-IBI scores. These predictions are qualified as being based on providing hydrologic conditions that are necessary, but not necessarily sufficient, for improvements in B-IBI scores (Horner 2013). There are other limiting factors in any particular catchment that might prevent substantial improvements in B-IBI scores, such as degraded riparian areas, poor water quality or altered stream channel geomorphology. Regardless, the underlying premise is that hydrologic restoration to conditions closer to that which occurred prior to significant human disturbance and development is required before any substantial biological improvement can be achieved.

Potential improvement in B-IBI scores are based on the scaled average HPC, HPR and PEAK:BASE to the study area. Results for predictions based on HPC and HPR are presented as upper and lower confidence predictions (as percent of maximum possible B-IBI score) that reflect the uncertainty inherent in the scatter of the underlying data used to develop the regression relationships between HPC (and HPR) and B-IBI scores. Predictions were calculated as percent of maximum B-IBI score because of the difference in the underlying B-IBI data available for developing relationships with HPC, HPR and PEAK:BASE. The PEAK:BASE relationship was developed earlier when the B-IBI score ranged from 5 to 45 rather than 10 to 50 as is the case for HPC and HPR (Horner 2013). The predictions for B-IBI score improvement using PEAK:BASE are based on a logistic regression equation that predicts the probability (in percent) of improving B-IBI scores to greater than or equal to 40 percent of the maximum possible score (Horner 2013). The percent of the maximum B-IBI scores calculated from the statistical models are converted to the associated B-IBI scores to better summarize the results for a large audience.

Figure 15 and 16 provides a summary of the range and variability of potential improvement in B-IBI scores based on the relationship with HPC and HPR (Horner 2013), respectively, for six different modeled conditions of the study area catchments: fully-forested, 2007 existing development, 2040 development with no stormwater treatment, 2040 development with required stormwater treatment only, 2040 development with required stormwater treatment plus treatment of roads and highways, and 2040 development with full stormwater treatment. The results are presented for B-IBI best estimate regression equations as well as the 90 percent upper confidence limit (UCL) and lower confidence limit (LCL) (Horner 2013).

Based on the relationship with HPC, the B-IBI scores for the study area catchments had 13 percent lower values for future 2040 development with no stormwater treatment than 2007 existing developed conditions. The median B-IBI scores for the 2040 no stormwater treatment conditions ranged from the most optimistic prediction (90% UCL) of 17 to the most pessimistic prediction (90% LCL) of 10, with a best estimate B-IBI value of 10. 2040 required stormwater treatment was predicted to improve the median value range from 32 (90% UCL) to 14 (90% LCL), with the best estimate of 21. The additional treatment of roads and highways slightly improves the median values to a range from 33 (90% UCL) to 15 (90% LCL), with a best estimate of 22. Full stormwater treatment of the study area improved the B-IBI scores similar to forested conditions with median values ranging from 45 (90% UCL) to 25 (90% LCL) and a B-IBI best estimate of 34.

Based on the relationship with HPR, the predicted improvement in median B-IBI scores for the various levels of stormwater treatment behaved similarly to the relationship with HPC. The B-IBI scores for the study area catchments had 19 percent lower values for future 2040 development with no stormwater treatment than 2007 existing developed conditions. The study area catchments with 2040 development and no stormwater treatment medians ranged from 22 (90% UCL) to 10 (90% LCL), with a best estimate of 13. Required stormwater treatment improved the median values to range from 37 (90% UCL) to 14 (90% LCL), with a best estimate of 24. Additional treatment of roads and highways slightly improved the median values to range from 39 (90% UCL) to 15 (90% LCL), with a best estimate of 26. Full stormwater treatment of the study area improved the B-IBI scores similar to forested conditions with median values ranging from 50 (90% UCL) to 23 (90% LCL) and a best estimate of 35.

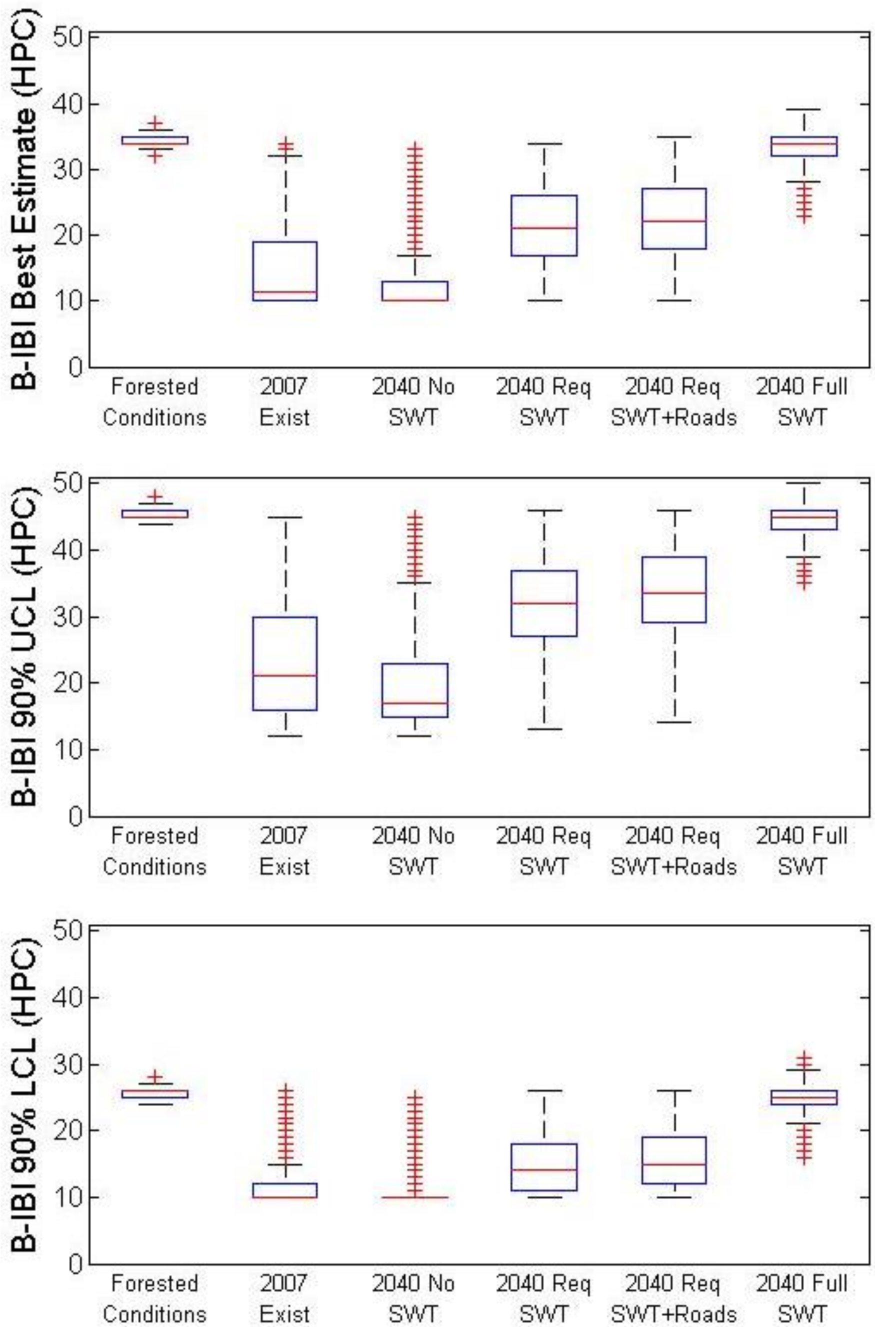

Figure 15. Potential improvement in B-IBI scores of study area catchments based on relationship with HPC developed by Horner (2013).

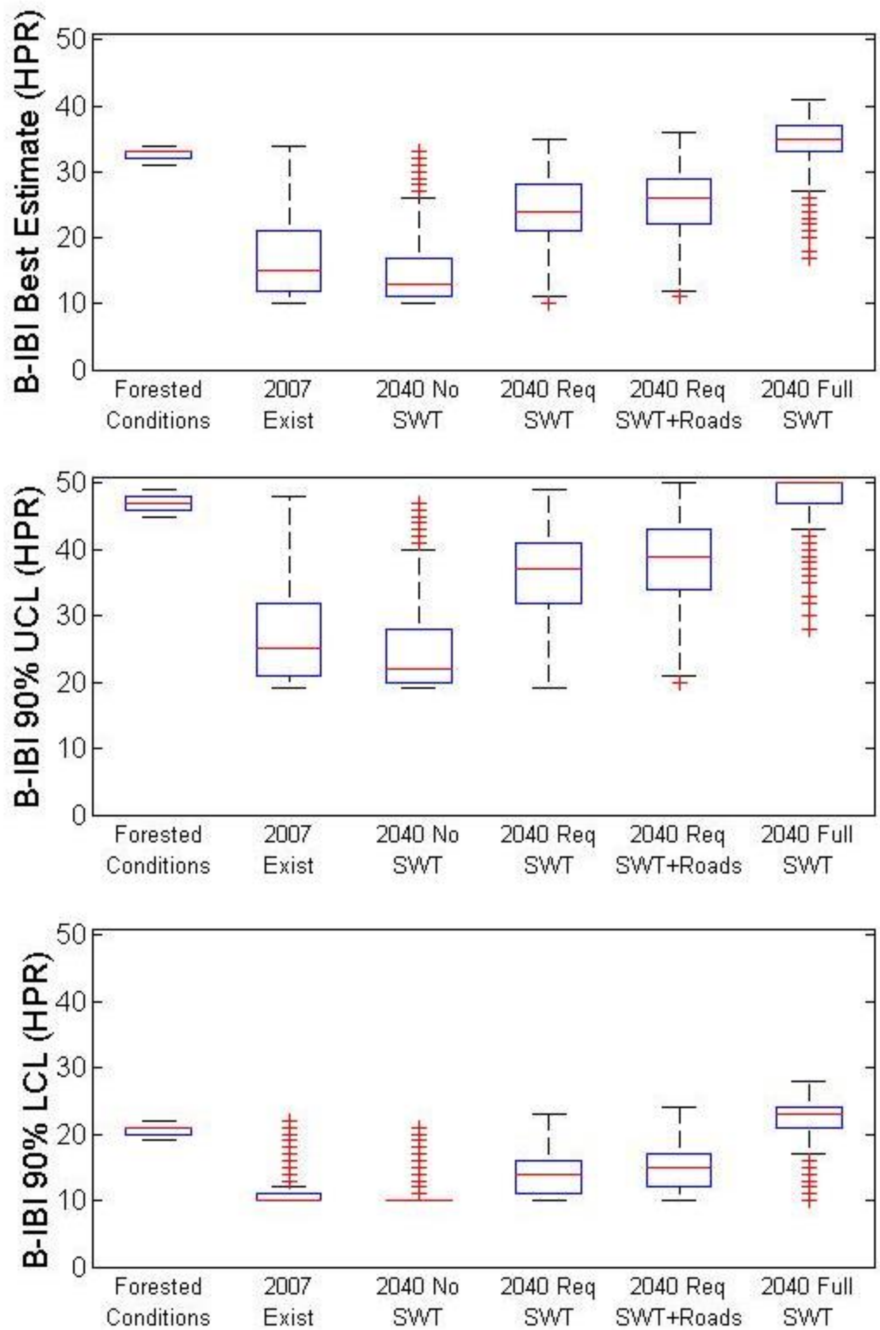

Figure 16. Potential improvement in B-IBI scores of study area catchments based on relationship with HPR developed by Horner (2013).

Horner (2013) developed logistic regression equations to predict the likelihood of B-IBI falling in a certain numerical group using the PEAK:BASE indicator. Figure 17 presents the probability of improving B-IBI scores above 40 percent of the maximum based on the relationship with PEAK:BASE for the stormwater treatment scenarios.

The predicted probability of B-IBI scores above 40 percent of the maximum possible score for forested conditions of the study area catchments have a median value of 99 percent. The median value for 2007 existing development was 17 percent. 2040 development with no stormwater treatment reduced the probability to 5 percent. Required stormwater treatment increased the median probability to 44 percent, and the additional treatment of roads and highways improved the median probability to 54 percent. Full stormwater treatment of the study area catchments increased the median probability to 99 percent, the same as forested conditions.

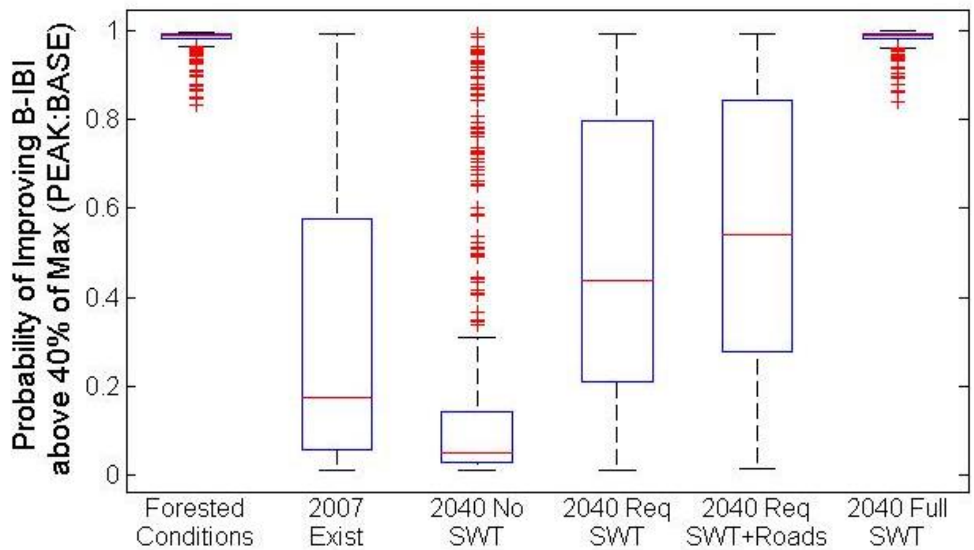

Figure 17. Probability of improving B-IBI scores above 40% of the maximum for the study area catchments based on relationship with PEAK:BASE developed by Horner (2013).

Specific B-IBI scores are associated with biological condition categories that describe stream health. Table 11 presented the B-IBI Biological Condition Categories as used in the Puget Sound. The categories were developed by Karr et al. (1986) and modified by Morley (2000).

Table 11. B-IBI Biological Condition Categories

Biological Condition	B-IBI Range
Excellent	46 - 50
Good	38 - 44
Fair	28 - 36
Poor	18 - 26
Very Poor	10 - 16

Figure 18 through 20 present the spatial distribution of B-IBI biological condition categories of the study area catchments for three study area conditions with no stormwater treatment: forested, 2007 existing LULC, and 2040 projected LULC. The selected categories of the study area catchments were based on B-IBI scores estimated from HPC using the best estimate regression equations developed by Horner (2013). The figures do not include upper and lower confidence limits B-IBI scores. The modeled fully-forested condition B-IBI scores fell in the "Fair" category for all study area catchments. 2007 existing condition B-IBI scores were generally categorized as "Very Poor" in the western portion of the study area to "Fair" in the eastern portion, with many central catchments categorized as "Poor". The biological health of 2040 LULC was worse than 2007 existing LULC, with more of the central and eastern portion of the study area categorized as "Very Poor".

Figures 21 through 23 present the spatial distribution of B-IBI biological condition categories of the study area catchments for the stormwater treatment scenarios: 2040 required treatment with new and redevelopment, 2040 required treatment plus treatment of roads and highways, and 2040 full stormwater treatment. Required stormwater treatment with new and redevelopment improved the majority of the "Very Poor" subcatchments to "Poor" as well as improving many of the "Poor" catchments to "Fair" conditions. There is some additional improvement in categories with the treatment of roads and highways. Full stormwater treatment of 2040 LULC improves the majority of study area catchments to the biological conditions of fully-forested catchments of "Fair". There are a few catchments that do not reach fully-forested conditions but improve to "Poor" as well as a few catchments that have slightly better biological health than forested and are categorized as "Good".

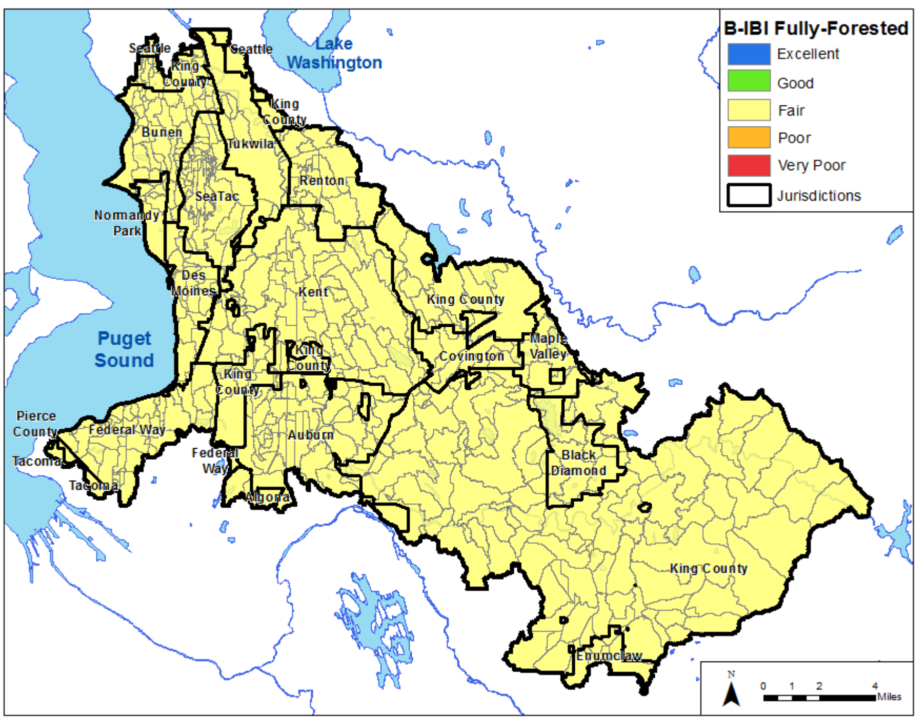

Figure 18. **B-IBI conditions for <u>fully-forested LULC</u> based on B-IBI estimated calculated from best estimate regression equations for HPC developed by Horner (2013).**

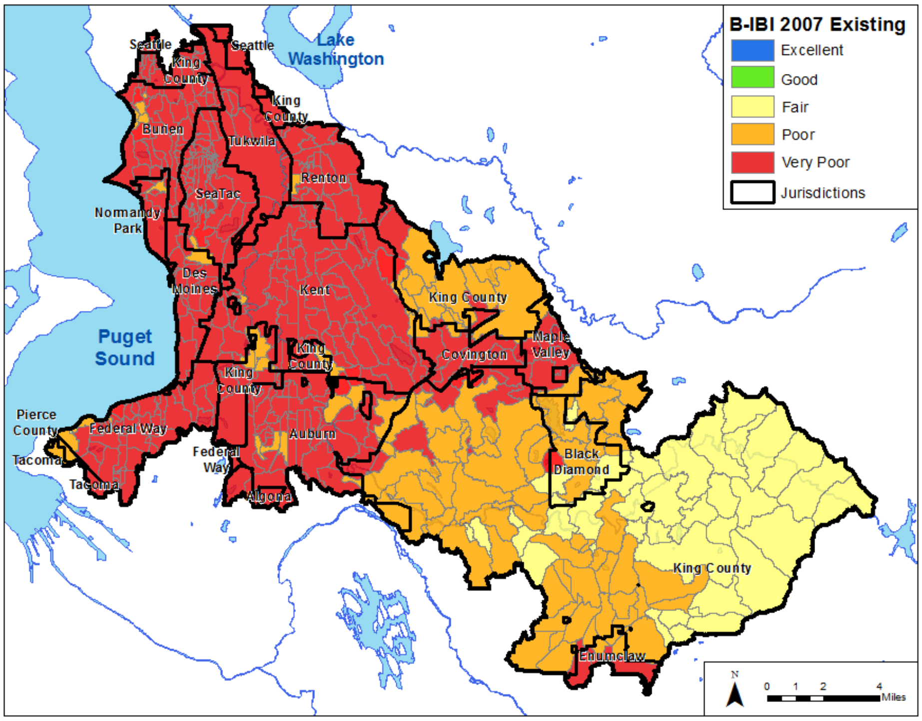

Figure 19. **B-IBI conditions for <u>2007 existing LULC</u> based on B-IBI estimates calculated from regression equations for HPC developed by Horner (2013).**

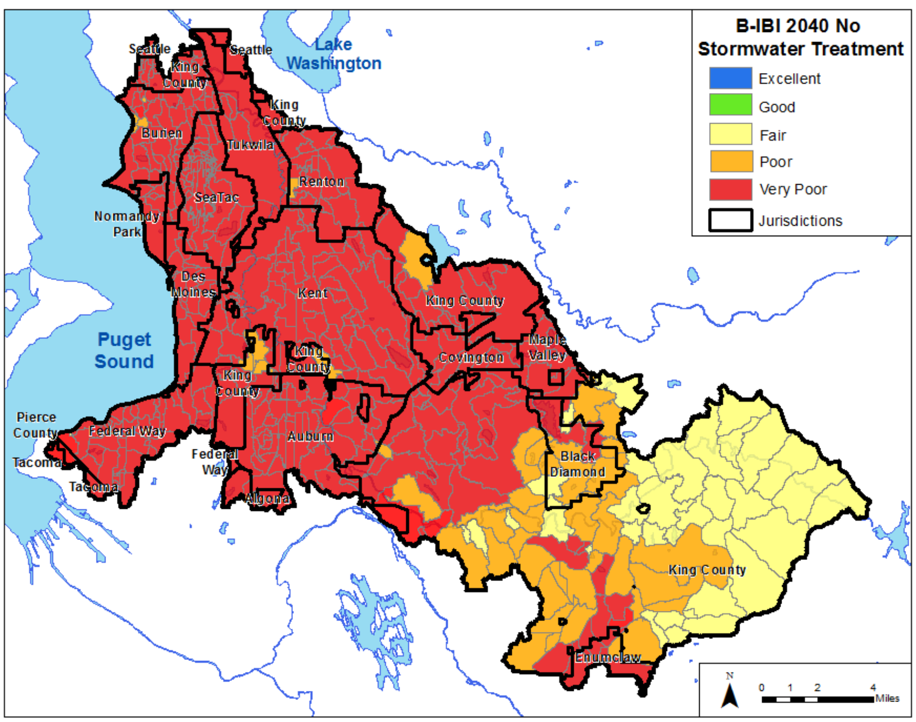

Figure 20. **B-IBI conditions for <u>2040 LULC with no stormwater treatment</u> based on B-IBI estimates calculated from regression equations for HPC developed by Horner (2013).**

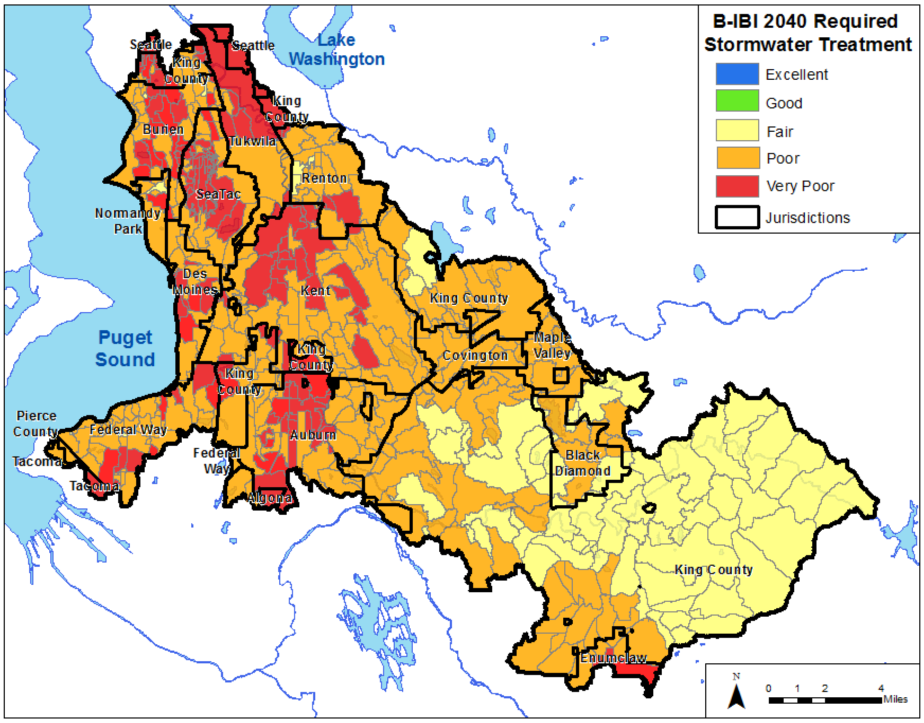

Figure 21. B-IBI conditions for <u>2040 LULC with required stormwater treatment</u> only based on B-IBI estimates calculated from regression equations for HPC developed by Horner (2013).

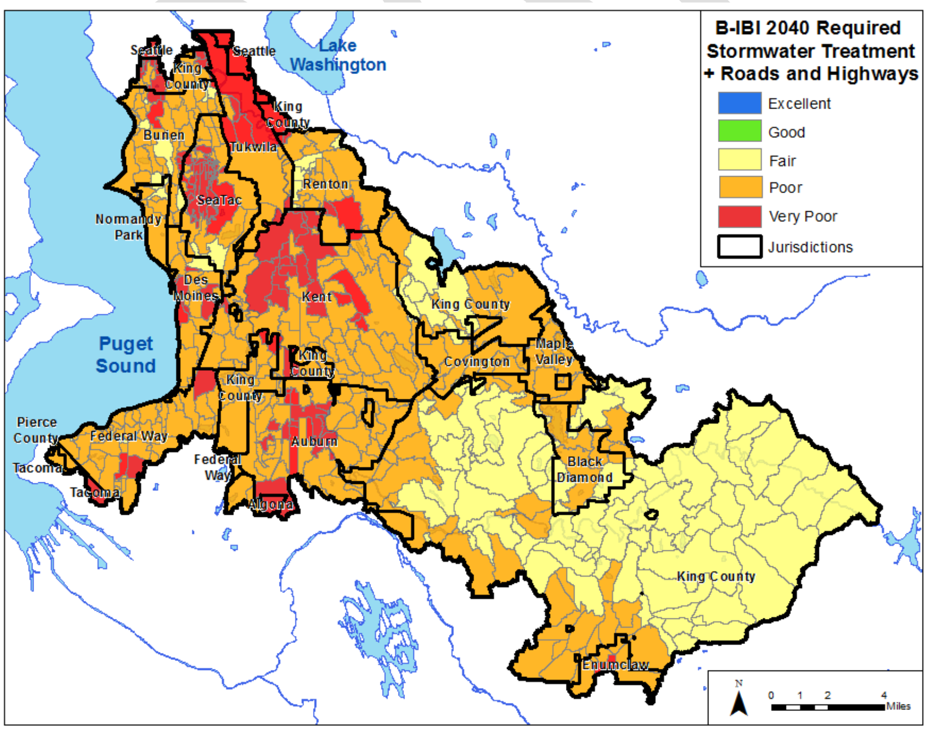

Figure 22. B-IBI conditions for <u>2040 LULC with required stormwater treatment plus roads and highways</u> based on B-IBI estimates calculated from regression equations for HPC developed by Horner (2013).

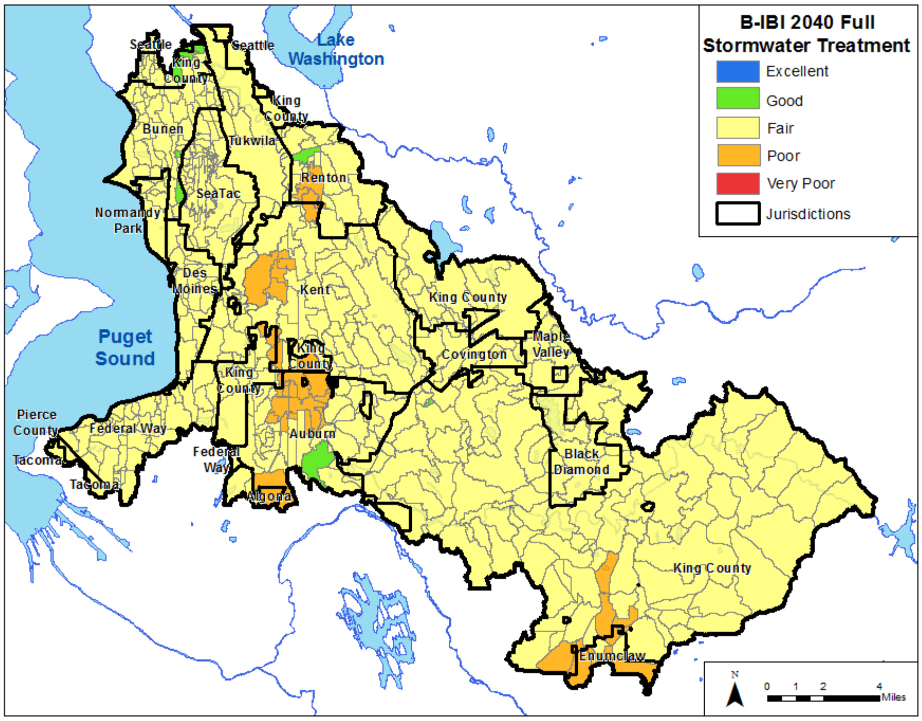

Figure 23. **B-IBI conditions for <u>2040 LULC with full stormwater treatment</u> based on B-IBI estimates calculated from regression equations for HPC developed by Horner (2013).**

4.5 Observed Big Soos Creek B-IBI Scores

King County Water and Land Resources Division's Ambient Monitoring Project collects annual benthic macroinvertebrate samples from approximately 150 stream location in the Greater Lake Washington and Green-Duwamish River watersheds. [11] The stream benthos data collected, as well as other benthos data for the region, can be found in the Puget Sound Stream Benthos data management system (King County 2009). One such location is located on Big Soos Creek near the outlet of the watershed (Figure 24). At this location, B-IBI samples were collected in 2002, 2003, and from 2005 to 2012. The average overall B-IBI score is 29.8, categorizing Big Soos Creek's biological condition as "Fair" (See Table 11). Observed B-IBI scores for Big Soos Creek were compared to B-IBI scores estimated with HSPF modeled flow and the scaling model approach used in this study.

[11] Puget Sound Stream Benthos data management system: http://pugetsoundstreambenthos.org/default.aspx

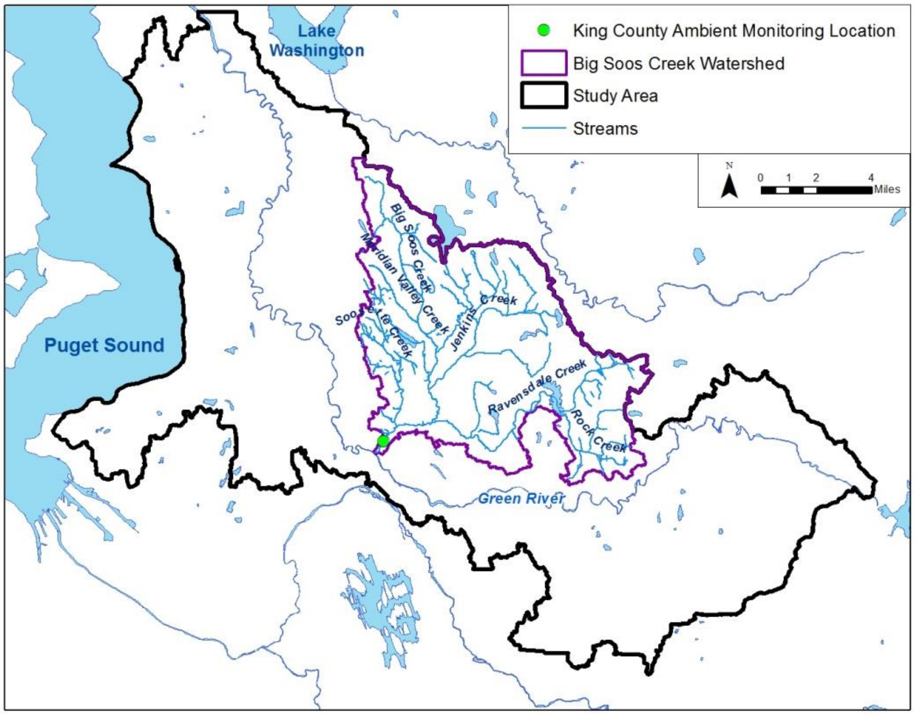

Figure 24. King County DNRP Ambient Monitoring Location at the outlet of Big Soos Creek Watershed.

The B-IBI score was calculated for the HSPF modeled existing (2007) streamflow at the outlet of Big Soos Creek Basin using the regression equations for HPC developed by Horner (2013) for this project. The modeled existing streamflow at the outlet of Big Soos Creek had an average HPC of 5.8. This resulted in a B-IBI best estimate of 30.8 which also falls in the "Fair" category of biological conditions. The 90 percent confidence interval ranged from a score of 42.1 (UCL) to 22.5 (LCL). There is a 3 percent difference in observed and HSPF modeled B-IBI scores at the outlet of Big Soos Creek.

In this report, B-IBI scores were estimated using HPC values calculated by taking the area weighted average of the hypothetical catchment results that make up the study area catchments. The catchment that contains the Big Soos Creek Ambient Monitoring location (Soos 602) has a best estimate B-IBI score of 16 which falls into the "Very Poor" biological conditions category. The 90 percent confidence interval ranges from a score of 26 (UCL) to 10 (LCL). There is a 60 percent difference in observed and HPC scaled B-IBI scores for the outlet of Big Soos Creek. The large difference may reflect the lack of existing stormwater infrastructure and flow attenuation modeled in the basin when scaling the hypothetical catchment results to the study area. The modeling approach does not consider existing stormwater facilities present or any additional routing in the study area catchments.

5.0. STUDY AREA COST RESULTS AND DISCUSSION

5.1 Potential Public Stormwater Costs

The PV life-cycle costs of the hypothetical catchment's "best" solutions were scaled to the study area assuming BMP unit construction is distributed over the 30 year period. The capital, O&M and I&E costs for the BMP facilities were calculated for the stormwater management scenarios and the costs associated with a public stormwater program were identified. Life-cycle costs are presented in 2013 dollars assuming a 5% real discount rate. Table 12-14 summarized the PV life-cycle costs and public stormwater program costs associated with each incremental step of stormwater treatment.

The total PV public stormwater program cost for required treatment with new and redevelopment in the study area is approximately $3.9 billion (Table 12). The costs associated with a stormwater program are the I&E of private cisterns and rain gardens as well as the capital and O&M of public detention ponds. The total PV stormwater program cost for treatment of roads and highways only is approximately $0.7 billion (Table 13). This cost consists of the capital, O&M, and inspection of roadside bioretention facilities as well as capital and O&M of the detention ponds. The total PV stormwater program cost for treatment of non-road development only is approximately $3.8 billion (Table 14). This cost includes the capital and I&E of cisterns, the capital, O&M, and I&E of rain gardens, and the capital and O&M of detention ponds.

Table 15 provides a summary of the total PV public stormwater program costs associated with each complete level of mitigation. Total public PV costs for the stormwater management scenarios were $3.9 billion for required stormwater treatment only, $4.6 billion for required treatment plus roads and highways, and $8.4 billion for full treatment of the study area. These costs are equivalent to $14 million, $17 million, and $30 million per square mile, respectively. The treatment of roads and highways alone make up $0.7 billion, or $4,000 per acre, of the full stormwater treatment cost. The study area full treatment costs include $3.9 billion in capital, $0.8 billion in O&M, and $3.7 billion in I&E (Table 16). I&E accounts for approximately 44 percent of the total public program costs.

Table 12. PV costs of stormwater facilities required with new and redevelopment and associated public stormwater program costs for future (2040) conditions of the study area and jurisdictions.

Jurisdiction	Cisterns			Rain Gardens			Detention Ponds			Total Public Stormwater Program Costs ($M)
	Capital ($M)	O&M ($M)	I&E ($M)	Capital ($M)	O&M ($M)	I&E ($M)	Capital ($M)	O&M ($M)	I&E ($M)	
Algona	$0.05	-	$0.03	$2.30	$1.40	$2.70	$13.00	$0.15	-	$15.00
Auburn	$1.00	-	$0.63	$130.00	$83.00	$160.00	$220.00	$2.70	-	$380.00
Black Diamond	$0.74	-	$0.45	$41.00	$25.00	$49.00	$37.00	$0.47	-	$86.00
Burien	$0.97	-	$0.59	$89.00	$56.00	$110.00	$67.00	$0.76	-	$170.00
Covington	$0.23	-	$0.14	$30.00	$19.00	$36.00	$45.00	$0.54	-	$82.00
Des Moines	$0.47	-	$0.29	$75.00	$47.00	$90.00	$30.00	$0.38	-	$120.00
Enumclaw	$0.22	-	$0.13	$36.00	$23.00	$43.00	$64.00	$0.79	-	$110.00
Kent	$2.10	-	$1.30	$300.00	$190.00	$360.00	$280.00	$3.40	-	$640.00
Maple Valley	$0.74	-	$0.45	$24.00	$15.00	$29.00	$48.00	$0.53	-	$78.00
Normandy Park	$0.30	-	$0.18	$18.00	$11.00	$22.00	$21.00	$0.25	-	$44.00
Pierce County	$0.01	-	$0.01	$0.71	$0.45	$0.85	$0.52	$0.01	-	$1.40
Renton	$0.60	-	$0.36	$110.00	$67.00	$130.00	$70.00	$0.88	-	$200.00
SeaTac	$0.42	-	$0.26	$76.00	$47.00	$91.00	$36.00	$0.43	-	$130.00
Seattle	$0.04	-	$0.03	$7.40	$4.70	$8.90	$8.60	$0.10	-	$18.00
Tukwila	$0.21	-	$0.13	$48.00	$30.00	$57.00	$80.00	$0.88	-	$140.00
Federal Way	$1.10	-	$0.66	$110.00	$70.00	$130.00	$80.00	$0.93	-	$220.00
Tacoma	$0.03	-	$0.02	$3.80	$2.40	$4.50	$5.10	$0.06	-	$9.70
King County	$8.90	-	$5.40	$770.00	$480.00	$920.00	$500.00	$7.50	-	$1,400.00
Study Area	$18.00	-	$11.00	$1,900.00	$1,200.00	$2,200.00	$1,600.00	$21.00	-	$3,900.00

Note: Costs are presenting in 2013 dollars over a 30 year life-cycle with a real discount rate of 5%.

Table 13. PV costs of stormwater facilities for treatment of roads and highways and associated public stormwater program costs for the future (2040) conditions of the study area and jurisdictions.

Jurisdiction	Roadside Bioretention			Detention Pond			Total Public Stormwater Program Costs ($M)
	Capital ($M)	O&M ($M)	I&E ($M)	Capital ($M)	O&M ($M)	I&E ($M)	
Algona	$0.20	$0.12	$0.19	$1.10	$0.01	-	$1.60
Auburn	$15.00	$9.20	$14.00	$24.00	$0.30	-	$62.00
Black Diamond	$3.30	$2.10	$3.20	$3.00	$0.04	-	$12.00
Burien	$11.00	$6.80	$11.00	$8.20	$0.09	-	$37.00
Covington	$3.30	$2.00	$3.20	$5.00	$0.06	-	$14.00
Des Moines	$8.80	$5.50	$8.50	$3.60	$0.05	-	$26.00
Enumclaw	$3.30	$2.10	$3.20	$5.80	$0.07	-	$14.00
Kent	$34.00	$22.00	$33.00	$32.00	$0.38	-	$120.00
Maple Valley	$2.80	$1.70	$2.70	$5.40	$0.06	-	$13.00
Normandy Park	$2.10	$1.30	$2.00	$2.40	$0.03	-	$7.90

Jurisdiction	Roadside Bioretention			Detention Pond			Total Public Stormwater Program Costs ($M)
	Capital ($M)	O&M ($M)	I&E ($M)	Capital ($M)	O&M ($M)	I&E ($M)	
Pierce County	$0.10	$0.06	$0.09	$0.07	$0.00	-	$0.32
Renton	$11.00	$6.90	$11.00	$7.20	$0.09	-	$36.00
SeaTac	$12.00	$7.50	$12.00	$5.70	$0.07	-	$37.00
Seattle	$1.40	$0.89	$1.40	$1.60	$0.02	-	$5.30
Tukwila	$6.10	$3.80	$5.90	$10.00	$0.11	-	$26.00
Federal Way	$14.00	$8.50	$13.00	$9.60	$0.11	-	$45.00
Tacoma	$0.74	$0.47	$0.72	$1.00	$0.01	-	$3.00
King County	$78.00	$49.00	$75.00	$50.00	$0.76	-	$250.00
Study Area	$210.00	$130.00	$200.00	$180.00	$2.30	-	$710.00

Note: Costs are presenting in 2013 dollars over a 30 year life-cycle with a real discount rate of 5%.

Table 14. PV costs of stormwater facilities for treatment of non-road unchanged developed area and associated public stormwater program costs for the future (2040) conditions of the study area and jurisdictions.

Jurisdiction	Cistern			Rain Gardens			Detention Pond			Total Public Stormwater Program Costs ($M)
	Capital ($M)	O&M ($M)	I&E ($M)	Capital ($M)	O&M ($M)	I&E ($M)	Capital ($M)	O&M ($M)	I&E ($M)	
Algona	$0.04	-	$0.02	$1.40	$0.89	$1.70	$7.80	$0.10	-	$12.00
Auburn	$0.74	-	$0.45	$80.00	$50.00	$100.00	$130.00	$1.60	-	$360.00
Black Diamond	$0.29	-	$0.18	$13.00	$8.00	$16.00	$12.00	$0.15	-	$49.00
Burien	$0.68	-	$0.41	$51.00	$32.00	$64.00	$38.00	$0.43	-	$190.00
Covington	$0.14	-	$0.09	$15.00	$9.10	$18.00	$22.00	$0.27	-	$65.00
Des Moines	$0.36	-	$0.22	$49.00	$30.00	$60.00	$20.00	$0.25	-	$160.00
Enumclaw	$0.09	-	$0.05	$11.00	$6.90	$14.00	$19.00	$0.24	-	$52.00
Kent	$1.60	-	$0.97	$190.00	$120.00	$240.00	$170.00	$2.10	-	$720.00
Maple Valley	$0.52	-	$0.32	$14.00	$9.10	$18.00	$28.00	$0.32	-	$71.00
Normandy Park	$0.15	-	$0.09	$7.00	$4.40	$8.90	$8.10	$0.09	-	$29.00
Pierce County	$0.01	-	$0.00	$0.31	$0.19	$0.39	$0.23	$0.00	-	$1.10
Renton	$0.32	-	$0.20	$47.00	$30.00	$59.00	$31.00	$0.39	-	$170.00
SeaTac	$0.54	-	$0.33	$86.00	$54.00	$110.00	$41.00	$0.48	-	$290.00
Seattle	$0.07	-	$0.04	$11.00	$6.90	$13.00	$13.00	$0.14	-	$44.00
Tukwila	$0.15	-	$0.09	$28.00	$18.00	$35.00	$47.00	$0.52	-	$130.00
Federal Way	$0.77	-	$0.47	$66.00	$41.00	$82.00	$47.00	$0.55	-	$240.00
Tacoma	$0.05	-	$0.03	$5.40	$3.40	$6.60	$7.30	$0.08	-	$23.00
King County	$5.00	-	$3.00	$350.00	$220.00	$440.00	$230.00	$3.40	-	$1,200.00
Study Area	$11.00	-	$7.00	$1,000.00	$640.00	$1,300.00	$870.00	$11.00	-	$3,800.00

Note: Costs are presenting in 2013 dollars over a 30 year life-cycle with a real discount rate of 5%.

Table 15. Total public stormwater program PV costs for three stormwater management scenarios of the future (2040) conditions of the study area: required stormwater treatment, required stormwater treatment plus treatment of roads and highways, and full stormwater treatment.

Jurisdiction	Required Stormwater Treatment ($M)		Required Stormwater Treatment + Roads and Highways ($M)		Full Stormwater Treatment ($M)	
	$M	$M/mi2	$M	$M/mi2	$M	$M/mi2
Algona	$15.00	$26.00	$17.00	$30.00	$29.00	$51.00
Auburn	$380.00	$19.00	$440.00	$22.00	$800.00	$41.00
Black Diamond	$86.00	$12.00	$98.00	$14.00	$150.00	$21.00
Burien	$170.00	$17.00	$210.00	$21.00	$400.00	$41.00
Covington	$82.00	$14.00	$95.00	$16.00	$160.00	$27.00
Des Moines	$120.00	$19.00	$150.00	$24.00	$310.00	$49.00
Enumclaw	$110.00	$36.00	$120.00	$39.00	$170.00	$55.00
Kent	$640.00	$19.00	$760.00	$22.00	$1,500.00	$44.00
Maple Valley	$78.00	$16.00	$91.00	$18.00	$160.00	$32.00
Normandy Park	$44.00	$18.00	$51.00	$20.00	$80.00	$32.00
Pierce County	$1.40	$4.10	$1.70	$4.90	$2.80	$8.10
Renton	$200.00	$21.00	$240.00	$25.00	$400.00	$42.00
SeaTac	$130.00	$13.00	$160.00	$16.00	$450.00	$44.00
Seattle	$18.00	$11.00	$23.00	$14.00	$67.00	$40.00
Tukwila	$140.00	$15.00	$160.00	$17.00	$290.00	$30.00
Federal Way	$220.00	$18.00	$260.00	$21.00	$500.00	$40.00
Tacoma	$9.70	$12.00	$13.00	$15.00	$35.00	$42.00
King County	$1,400.00	$10.00	$1,700.00	$12.00	$2,900.00	$21.00
Study Area	$3,900.00	$14.00	$4,600.00	$17.00	$8,400.00	$30.00

Note: Costs are presenting in 2013 dollars over a 30 year life-cycle with a real discount rate of 5%.

Table 16. Public stormwater program PV capital, O&M, I&E, and total costs for full stormwater treatment of the future (2040) conditions of the study area.

Jurisdiction	Capital ($M)	O&M ($M)	I&E ($M)	Total Costs ($M)
Algona	$23.00	$1.30	$4.70	$29.00
Auburn	$460.00	$64.00	$270.00	$800.00
Black Diamond	$68.00	$11.00	$69.00	$150.00
Burien	$180.00	$40.00	$180.00	$400.00
Covington	$91.00	$12.00	$57.00	$160.00
Des Moines	$110.00	$37.00	$160.00	$310.00
Enumclaw	$100.00	$10.00	$61.00	$170.00
Kent	$710.00	$150.00	$630.00	$1,500.00

Jurisdiction	Capital ($M)	O&M ($M)	I&E ($M)	Total Costs ($M)
Maple Valley	$99.00	$12.00	$51.00	$160.00
Normandy Park	$41.00	$6.10	$33.00	$80.00
Pierce County	$1.20	$0.27	$1.30	$2.80
Renton	$170.00	$38.00	$200.00	$400.00
SeaTac	$180.00	$62.00	$210.00	$450.00
Seattle	$35.00	$8.00	$24.00	$67.00
Tukwila	$170.00	$23.00	$98.00	$290.00
Federal Way	$220.00	$51.00	$230.00	$500.00
Tacoma	$20.00	$4.00	$12.00	$35.00
King County	$1,200.00	$280.00	$1,400.00	$2,900.00
Study Area	$3,900.00	$800.00	$3,700.00	$8,400.00

Note: Costs are presenting in 2013 dollars over a 30 year life-cycle with a real discount rate of 5%.

6.0. MODEL LIMITATIONS AND UNCERTAINTY

There is a fair amount of uncertainty inherent in the assumptions of the modeling approach. Simplifying the HSPF HRUs into 135 hypothetical catchments may not capture the full variability of soil characteristics, geological conditions, precipitation intensity, or relative amount of EIA to TIA over the study area. Furthermore, the aggregate BMP approach and design templates in SUSTAIN require simplification of BMP designs and types for optimization. Site specific analysis is needed to determine the most appropriate BMP design to meet project needs.

Unit BMP costs for use in SUSTAIN were estimated using costs summarized from the Puget Sound Stormwater BMP Cost Database (Herrera 2011), additional sources of information and the expertise of a technical workgroup formed for the purpose of developing BMP designs. These cost assumptions are best estimates for the average costs of the region and may vary across the project area. Estimating life-cycle costs required the selection of a real discount rate to convert future dollars into present value dollars. The range of possible discount rates varies widely in the literature and the selected rate should be project specific, reflecting the opportunity cost of a project. For planning level purposes, a 5% real discount rate was selected based on a range of values suggested by King County's LCCA (King County 2006).

The model approach assumes development will follow the assumptions made in the future land use forecasting model reflecting existing regulations and land use planning. Given the considerable amount of uncertainty in projecting future land use, the results of this report provide the best planning estimate based on the available forecast information. The model does not account for the influence of policy changes that may influence future land use patterns.

Scaling the model results to the study area does not composite the flow and pollutant time series from the hypothetical catchments or account for routing issues to calculate the indicator values for the study area catchments. There may be attenuation of flow or pollutants not recognized in the scaling process. The scaled hydrologic and water quality indicators give an estimate of the overall effectiveness of stormwater facilities at the catchment scale.

Statistical extrapolations of modeled TSS concentrations to TCu and TZn concentrations incorporate uncertainly based on the data they were developed from, but may not be as effective as our modeling suggests. The expected positive effect of these treatment scenarios is predicated on the design and construction of BMPs that do not themselves generate contamination, but rather effectively treat them through filtration, settling and dispersion through subsurface flow pathways that result in low (and generally non-hazardous) levels reaching groundwater systems and/or streams and rivers.

There is also a fair amount of uncertainty in the predicted increases in B-IBI scores in response to implementation of the scaled "best" solutions; uncertainty not only in the assumption that there is a direct causal relationship between HPC (and HPR/PEAK:BASE) and B-IBI scores, but also in the predictive uncertainty in the log-linear regression equations that attempt to quantify the expected relationship between HPC (or HPR) and B-IBI scores. Even if there is a direct causal relationship between HPC and HPR and declines in B-IBI scores with increased development and associated flashy hydrologic response, there is uncertainty regarding the potential to restore biological integrity to these streams as there are no well documented cases where stormwater BMPs such as those proposed here have resulted in improvements in B-IBI scores. Ultimately, hydrologic restoration to conditions that more closely resemble those of pre-disturbance/development are considered necessary, but not necessarily sufficient for the restoration of stream biological integrity (Horner 2013).

7.0. CONCLUSIONS AND RECOMMENDATIONS

This planning study provides cost estimates for implementing stormwater BMPs and LID techniques in existing and future developed areas of WRIA 9. SUSTAIN's optimization selected different combinations of cisterns, rain gardens, roadside bioretention and detention ponds for the modeled hypothetical catchments. The SUSTAIN model did not select porous pavement during optimization. This should not be interpreted to mean that porous pavement is not a cost effective option for stormwater management. At the project-specific scale, it is recommended to identify if porous pavement or other BMP alternatives will be the most effective tool to meet stormwater management goals. Furthermore, the numbers of facilities were modeled conceptually as small units distributed throughout the study area and may not be representative of the actual number of units but instead provide an estimate of the volume of storage needed. The units may be lumped into larger units as project site allows.

Additional analysis of the relationship between percent effectiveness and reduction is recommended to evaluate if less effective solutions at a lower cost would achieve a similar or acceptable reduction in indicator values. This may be more likely in lower intensity development land use. For example, agricultural land use existing conditions had much lower indicator values than higher intensity developed land uses. The “Best” solutions had especially low percent reduction compared with higher intensity development, but with similar costs.

Model results predict biological health will decline with future development as reflected in the predicted decrease in B-IBI scores based on hydrologic indicators from 2007 existing LULC to 2040 LULC. Stormwater treatment required with new and redevelopment significantly improved hydrologic and water quality indicators, reducing some study area catchment values by more than half. Additional treatment of roads provided some improvement in indicators while full treatment of the study area improved values close to forested conditions. Potential public stormwater program PV costs for the stormwater management scenarios were $3.9 billion for required stormwater treatment only, $4.6 billion for required treatment plus roads and highways, and $8.4 billion for full treatment of the study area. These costs are equivalent to $14 million, $17 million, and $30 million per square mile, respectively. I&E accounts for a large portion of the BMP life cycle costs and was approximately 44 percent of the total public program costs.

Site specific analysis is recommended to select the most appropriate BMPs, costs and discount rate that meet project specific goals. The next steps of the WRIA 9 retrofit project include adjusting stormwater facility units and costs to account for existing stormwater detention facilities and evaluating potential cost implications of climate change within the same future time horizon (2040).

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Appendix A

Model Approach Details

Table 17. Hypothetical Catchments representing HRU's in study area

Hypothetical Catchment Number	Hypothetical Catchment ID	Precip Zone	Land Cost	Land Cover	Soils	Slope
1	P1C1TC1	Low	Low Cost	Commercial	Till	Flat
2	P1C1TC3					Moderate
3	P1C1THR1			High Density Residential		Flat
4	P1C1THR3					Moderate
5	P1C1TLR1			Low Density Residential		Flat
6	P1C1TLR3					Moderate
7	P1C1TAG1			Agricultural		Flat
8	P1C1TAG3					Moderate
9	P1C1OC			Commercial	Outwash	NA
10	P1C1OHD			High Density Residential		NA
11	P1C1OLD			Low Density Residential		NA
12	P1C1OAG			Agricultural		NA
13	P1C1DC1			Commercial	D Soils	Flat
14	P1C1DC3					Moderate
15	P1C1DHR1			High Density Residential		Flat
16	P1C1DHR3					Moderate
17	P1C1DLR1			Low Density Residential		Flat
18	P1C1DLR3					Moderate
19	P1C1DAG1			Agricultural		Flat
20	P1C1DAG3					Moderate
21	P1C2TC1		High Cost	Commercial	Till	Flat
22	P1C2TC3					Moderate
23	P1C2THR1			High Density Residential		Flat
24	P1C2THR3					Moderate
25	P1C2TLR1			Low Density Residential		Flat
26	P1C2TLR3					Moderate
27	P1C2TAG1			Agricultural		Flat
28	P1C2TAG3					Moderate
29	P1C2OC			Commercial	Outwash	NA
30	P1C2OHD			High Density Residential		NA
31	P1C2OLD			Low Density Residential		NA
32	P1C2OAG			Agricultural		NA

Hypothetical Catchment Number	Hypothetical Catchment ID	Precip Zone	Land Cost	Land Cover	Soils	Slope
33	P1C2DC1			Commercial	D Soils	Flat
34	P1C2DC3					Moderate
35	P1C2DHR1			High Density Residential		Flat
36	P1C2DHR3					Moderate
37	P1C2DLR1			Low Density Residential		Flat
38	P1C2DLR3					Moderate
39	P1C2DAG1			Agricultural		Flat
40	P1C2DAG3					Moderate
41	P1TF1		NA	Forested	Till	Flat
42	P1TF3					Moderate
43	P1OF				Outwash	NA
44	P1DF1				D soils	Flat
45	P1DF3					Moderate
46	P2C1TC1	Moderate	Low Cost	Commercial	Till	Flat
47	P2C1TC3					Moderate
48	P2C1THR1			High Density Residential		Flat
49	P2C1THR3					Moderate
50	P2C1TLR1			Low Density Residential		Flat
51	P2C1TLR3					Moderate
52	P2C1TAG1			Agricultural		Flat
53	P2C1TAG3					Moderate
54	P2C1OC			Commercial	Outwash	NA
55	P2C1OHD			High Density Residential		NA
56	P2C1OLD			Low Density Residential		NA
57	P2C1OAG			Agricultural		NA
58	P2C1DC1			Commercial	D Soils	Flat
59	P2C1DC3					Moderate
60	P2C1DHR1			High Density Residential		Flat
61	P2C1DHR3					Moderate
62	P2C1DLR1			Low Density Residential		Flat
63	P2C1DLR3					Moderate
64	P2C1DAG1			Agricultural		Flat
65	P2C1DAG3					Moderate
66	P2C2TC1		High Cost	Commercial	Till	Flat
67	P2C2TC3					Moderate

Hypothetical Catchment Number	Hypothetical Catchment ID	Precip Zone	Land Cost	Land Cover	Soils	Slope
68	P2C2THR1			High Density Residential		Flat
69	P2C2THR3					Moderate
70	P2C2TLR1			Low Density Residential		Flat
71	P2C2TLR3					Moderate
72	P2C2TAG1			Agricultural		Flat
73	P2C2TAG3					Moderate
74	P2C2OC			Commercial	Outwash	NA
75	P2C2OHD			High Density Residential		NA
76	P2C2OLD			Low Density Residential		NA
77	P2C2OAG			Agricultural		NA
78	P2C2DC1			Commercial	D Soils	Flat
79	P2C2DC3					Moderate
80	P2C2DHR1			High Density Residential		Flat
81	P2C2DHR3					Moderate
82	P2C2DLR1			Low Density Residential		Flat
83	P2C2DLR3					Moderate
84	P2C2DAG1			Agricultural		Flat
85	P2C2DAG3					Moderate
86	P2TF1		NA	Forested	Till	Flat
87	P2TF3					Moderate
88	P2OF				Outwash	NA
89	P2DF1				D soils	Flat
90	P2DF3					Moderate
91	P3C1TC1	High	Low Cost	Commercial	Till	Flat
92	P3C1TC3					Moderate
93	P3C1THR1			High Density Residential		Flat
94	P3C1THR3					Moderate
95	P3C1TLR1			Low Density Residential		Flat
96	P3C1TLR3					Moderate
97	P3C1TAG1			Agricultural		Flat
98	P3C1TAG3					Moderate
99	P3C1OC			Commercial	Outwash	NA
100	P3C1OHD			High Density Residential		NA
101	P3C1OLD			Low Density		NA

Hypothetical Catchment Number	Hypothetical Catchment ID	Precip Zone	Land Cost	Land Cover	Soils	Slope
				Residential		
102	P3C1OAG			Agricultural		NA
103	P3C1DC1			Commercial		Flat
104	P3C1DC3					Moderate
105	P3C1DHR1			High Density Residential		Flat
106	P3C1DHR3				D Soils	Moderate
107	P3C1DLR1			Low Density Residential		Flat
108	P3C1DLR3					Moderate
109	P3C1DAG1			Agricultural		Flat
110	P3C1DAG3					Moderate
111	P3C2TC1			Commercial		Flat
112	P3C2TC3					Moderate
113	P3C2THR1			High Density Residential		Flat
114	P3C2THR3				Till	Moderate
115	P3C2TLR1			Low Density Residential		Flat
116	P3C2TLR3					Moderate
117	P3C2TAG1			Agricultural		Flat
118	P3C2TAG3					Moderate
119	P3C2OC			Commercial		NA
120	P3C2OHD			High Density Residential		NA
121	P3C2OLD		High Cost	Low Density Residential	Outwash	NA
122	P3C2OAG			Agricultural		NA
123	P3C2DC1			Commercial		Flat
124	P3C2DC3					Moderate
125	P3C2DHR1			High Density Residential		Flat
126	P3C2DHR3					Moderate
127	P3C2DLR1			Low Density Residential	D Soils	Flat
128	P3C2DLR3					Moderate
129	P3C2DAG1			Agricultural		Flat
130	P3C2DAG3					Moderate
131	P3TF1				Till	Flat
132	P3TF3					Moderate
133	P3OF		NA	Forested	Outwash	NA
134	P3DF1				D soils	Flat
135	P3DF3					Moderate

Table 18. SUSTAIN BMP Design Details.

	Residential On-site Detention Facility	Bioretention		Porous Pavement	
		Outwash / Till	D Soils	Outwash / Till	D Soils
Design Unit Size	393 ft^3 (2,938 gal)	100 ft^2	100 ft^2	100 ft^2	100 ft^2
Design Drainage Area	0.04 ac	0.0215 ac	0.0215 ac	100 ft^2	100 ft^2
Infiltration Model (Green-Ampt, Horton, Holtan) [INFILTM]	NA	2 (Holtan)	2 (Holtan)	2 (Holtan)	2 (Holtan)
Pollutant Removal Method (1st Order Decay, K-C' method – Kadlec and Knight Method) [POLREMM]	0 (1st Order Decay)	0 (1st Order Decay)	0 (1st Order Decay)	0 (1st Order Decay)	0 (1st Order Decay)
Pollutant Routing Method (Completely Mixed, CSTRs in series) [POLROTM]	1 (Completely Mixed)	1 (Completely Mixed)	1 (Completely Mixed)	1 (Completely Mixed)	1 (Completely Mixed)
Dimensions Tab					
Number of Units	Optimize	Optimize	Optimize	Optimize	Optimize

	Residential On-site Detention Facility	Bioretention		Porous Pavement	
		Outwash / Till	D Soils	Outwash / Till	D Soils
Design Unit Size	393 ft^3 (2,938 gal)	100 ft^2	100 ft^2	100 ft^2	100 ft^2
Diameter/Length (ft) **[LENGTH]**	10	10	10	10	10
Width (ft) **[WIDTH]**	NA	10	10	10	10
Exit Type **[EXITTYPE]**	1	1	1	NA	NA
Orifice Diameter (in) **[DIAM]**	0.625	0	0	NA	NA
Orifice Height (Ho, ft) **[OHEIGHT]**	0	0	0	NA	NA
Release Type **[RELEASETYPE]**	2	NA	NA	NA	NA
Number of dry days **[DDAYS]**	1	NA	NA	NA	NA
Number of People **[PEOPLE]**	NA	NA	NA	NA	NA
Weir Type **[WEIRTYPE]**	1 (rectangular)	1 (rectangular)	1 (rectangular)	1 (rectangular)	1 (rectangular)
Weir Height (Hw, ft) **[WEIRH]**	5	1.0	1.0	0.01	0.01
Rectangular Weir Crest Width (B, ft) **[WEIRW]**	5	10	10	10	10
Triangular Weir Angle (theta, deg) **[THETA]**	NA	NA	NA	NA	NA

	Residential On-site Detention Facility	Bioretention		Porous Pavement	
		Outwash / Till	D Soils	Outwash / Till	D Soils
Design Unit Size	393 ft^3 (2,938 gal)	100 ft^2	100 ft^2	100 ft^2	100 ft^2
Substrate Properties Tab					
Depth of Soil (Ds, ft) **[SDEPTH]**	NA	1.5	1.5	1.6	1.6
Soil Porosity (0-1) **[POROSITY]**	NA	0.4	0.4	0.3	0.3
Soil Field Capacity **[FCAPACITY]**	NA	0.244	0.244	NA	NA
Soil Wilting Point **[WPOINT]**	NA	0.136	0.136	NA	NA
Initial Surface Water Depth (ft) **[WATDEP_I]**	NA	0	0	0	0
Initial Moisture Content (0-1) **[THETA_I]**	NA	0	0	0	0
Saturated Soil Infiltration (in/hr) **[FINFILT]**	NA	2.0 / 0.3	0	2.0 / 0.3	0
ET Multiplier **[ET_MULT]**	NA	1.0	1.0	0.0	0.0
Route Infiltration to Aquifer	NA	Yes	NA	Yes	NA
Consider Underdrain Structure **[UNDSWITCH]**	NA	0 (No)	1 (Yes)	0 (No)	1 (Yes)
Storage Depth (Du, ft) **[UNDDEPTH]**	NA	NA	0.5	NA	0.25

	Residential On-site Detention Facility	Bioretention		Porous Pavement	
		Outwash / Till	**D Soils**	**Outwash / Till**	**D Soils**
Design Unit Size	393 ft^3 (2,938 gal)	100 ft^2	100 ft^2	100 ft^2	100 ft^2
Media Void Fraction (0-1) **[UNDVOID]**	NA	NA	0.5	NA	0.35
Background Infiltration (in/hr) **[UNDINFILT]**	NA	NA	0	NA	0
Route Underdrain/Outlet to:	Bioretention	NA	Outlet/Pond	NA	Outlet/Pond
Infiltration Parameters Tab					
Green-Amp Infiltration Parameters	NA	NA	NA	NA	NA
Suction Head (in) **[SUCTION]**	NA	NA	NA	NA	NA
Initial Deficit (fraction) **[IMDMAX]**	NA	NA	NA	NA	NA
Horton Infiltration Parameters					
Maximum Infiltration (in/hr) **[MAXINFILT]**	NA	NA	NA	NA	NA
Decay Constant (1/hr) **[DECAYCONS]**	NA	NA	NA	NA	NA
Drying Time (day)	NA	NA	NA	NA	NA

	Residential On-site Detention Facility	Bioretention		Porous Pavement	
		Outwash / Till	D Soils	Outwash / Till	D Soils
Design Unit Size	393 ft^3 (2,938 gal)	100 ft^2	100 ft^2	100 ft^2	100 ft^2
[DRYTIME]					
Maximum Volume (in) **[MAXVOLUME]**	NA	NA	NA	NA	NA
Holtan Infiltration Parameters					
Vegetative Parameter A **[AVEG]**	NA	1	1	1	1
Monthly Growth Index **[GIi]**	NA	1	1	1	1
Water Quality Parameters Tab (for TSS)					
Decay factor (1/hr) **[QUALDECAY1]**	0	0.02	0.02	0.0	0.0
K (ft/yr) **[QUALK1]**	NA	NA	NA	NA	NA
C* (mg/L) **[QUALC*1]**	NA	NA	NA	NA	NA
Underdrain Removal Rate (fraction, 0-1) **[QUALPCTREM1]**	NA	NA	0.08	NA	0.08

NA = Not applicable.

Table 19. SUSTAIN Detention Pond Design Details

Hypothetical Catchment Number	Hypothetical Catchment ID	Weir Height (ft)	Area (ft2)	Volume (ft3)
1	P1C1TC1	4.95	3,785.36	18746.78
2	P1C1TC3	4.91	3,985.74	19548.68
3	P1C1THR1	5.05	2,282.54	11533.55
4	P1C1THR3	4.98	2,456.78	12230.97
5	P1C1TLR1	5.04	1,681.42	8469.53
6	P1C1TLR3	4.98	1,790.32	8907.3
7	P1C1TAG1	5.87	749.23	4393.86
8	P1C1TAG3	5.99	701.32	4203.72
9	P1C1OC	4	1,672.70	6690.93
10	P1C1OHD	4	792.79	3171.26
11	P1C1OLD	4	331.06	1324.58
12	P1C1OAG	4	74.05	295.97
13	P1C1DC1	4.95	3,785.36	18746.78
14	P1C1DC3	4.91	3,985.74	19548.68
15	P1C1DHR1	5.05	2,282.54	11533.55
16	P1C1DHR3	4.98	2,456.78	12230.97
17	P1C1DLR1	5.04	1,681.42	8469.53
18	P1C1DLR3	4.98	1,790.32	8907.3
19	P1C1DAG1	5.87	749.23	4393.86
20	P1C1DAG3	5.99	701.32	4203.72
21	P1C2TC1	4.95	3,785.36	18746.78
22	P1C2TC3	4.91	3,985.74	19548.68
23	P1C2THR1	5.05	2,282.54	11533.55
24	P1C2THR3	4.98	2,456.78	12230.97
25	P1C2TLR1	5.04	1,681.42	8469.53
26	P1C2TLR3	4.98	1,790.32	8907.3
27	P1C2TAG1	5.87	749.23	4393.86
28	P1C2TAG3	5.99	701.32	4203.72
29	P1C2OC	4	1,672.70	6690.93
30	P1C2OHD	4	792.79	3171.26
31	P1C2OLD	4	331.06	1324.58
32	P1C2OAG	4	74.05	295.97
33	P1C2DC1	4.95	3,785.36	18746.78
34	P1C2DC3	4.91	3,985.74	19548.68
35	P1C2DHR1	5.05	2,282.54	11533.55

Hypothetical Catchment Number	Hypothetical Catchment ID	Weir Height (ft)	Area (ft2)	Volume (ft3)
36	P1C2DHR3	4.98	2,456.78	12230.97
37	P1C2DLR1	5.04	1,681.42	8469.53
38	P1C2DLR3	4.98	1,790.32	8907.3
39	P1C2DAG1	5.87	749.23	4393.86
40	P1C2DAG3	5.99	701.32	4203.72
41	P1TF1	NA	NA	NA
42	P1TF3			
43	P1OF			
44	P1DF1			
45	P1DF3			
46	P2C1TC1	4.81	4,447.48	21397.69
47	P2C1TC3	4.81	4,464.90	21468.32
48	P2C1THR1	4.87	2,748.64	13395.55
49	P2C1THR3	4.86	2,796.55	13587.7
50	P2C1TLR1	4.87	2,003.76	9758.78
51	P2C1TLR3	4.87	2,016.83	9813.08
52	P2C1TAG1	5.98	701.32	4194.6
53	P2C1TAG3	5.55	901.69	5004.09
54	P2C1OC	4	2,025.54	8101.37
55	P2C1OHD	4	1,075.93	4303.14
56	P2C1OLD	4	566.28	2265.32
57	P2C1OAG	4	100.19	401.01
58	P2C1DC1	4.81	4,447.48	21397.69
59	P2C1DC3	4.81	4,464.90	21468.32
60	P2C1DHR1	4.87	2,748.64	13395.55
61	P2C1DHR3	4.86	2,796.55	13587.7
62	P2C1DLR1	4.87	2,003.76	9758.78
63	P2C1DLR3	4.87	2,016.83	9813.08
64	P2C1DAG1	5.98	701.32	4194.6
65	P2C1DAG3	5.55	901.69	5004.09
66	P2C2TC1	4.81	4,447.48	21397.69
67	P2C2TC3	4.81	4,464.90	21468.32
68	P2C2THR1	4.87	2,748.64	13395.55
69	P2C2THR3	4.86	2,796.55	13587.7
70	P2C2TLR1	4.87	2,003.76	9758.78

Hypothetical Catchment Number	Hypothetical Catchment ID	Weir Height (ft)	Area (ft2)	Volume (ft3)
71	P2C2TLR3	4.87	2,016.83	9813.08
72	P2C2TAG1	5.98	701.32	4194.6
73	P2C2TAG3	5.55	901.69	5004.09
74	P2C2OC	4	2,025.54	8101.37
75	P2C2OHD	4	1,075.93	4303.14
76	P2C2OLD	4	566.28	2265.32
77	P2C2OAG	4	100.19	401.01
78	P2C2DC1	4.81	4,447.48	21397.69
79	P2C2DC3	4.81	4,464.90	21468.32
80	P2C2DHR1	4.87	2,748.64	13395.55
81	P2C2DHR3	4.86	2,796.55	13587.7
82	P2C2DLR1	4.87	2,003.76	9758.78
83	P2C2DLR3	4.87	2,016.83	9813.08
84	P2C2DAG1	5.98	701.32	4194.6
85	P2C2DAG3	5.55	901.69	5004.09
86	P2TF1			
87	P2TF3			
88	P2OF	NA	NA	NA
89	P2DF1			
90	P2DF3			
91	P3C1TC1	4.83	5,562.61	26858.24
92	P3C1TC3	4.87	5,279.47	25728.51
93	P3C1THR1	4.81	3,811.50	18312.25
94	P3C1THR3	4.84	3,663.40	17721.22
95	P3C1TLR1	4.85	2,626.67	12734.12
96	P3C1TLR3	4.81	2,766.06	13291.55
97	P3C1TAG1	5.74	1,028.02	5895.79
98	P3C1TAG3	5.81	988.81	5741.22
99	P3C1OC	4	2,661.52	10646.32
100	P3C1OHD	4	1,637.86	6551.69
101	P3C1OLD	4	1,176.12	4704.5
102	P3C1OAG	4	169.88	679.7
103	P3C1DC1	4.83	5,562.61	26858.24
104	P3C1DC3	4.87	5,279.47	25728.51
105	P3C1DHR1	4.81	3,811.50	18312.25

Hypothetical Catchment Number	Hypothetical Catchment ID	Weir Height (ft)	Area (ft2)	Volume (ft3)
106	P3C1DHR3	4.84	3,663.40	17721.22
107	P3C1DLR1	4.85	2,626.67	12734.12
108	P3C1DLR3	4.81	2,766.06	13291.55
109	P3C1DAG1	5.74	1,028.02	5895.79
110	P3C1DAG3	5.81	988.81	5741.22
111	P3C2TC1	4.83	5,562.61	26858.24
112	P3C2TC3	4.87	5,279.47	25728.51
113	P3C2THR1	4.81	3,811.50	18312.25
114	P3C2THR3	4.84	3,663.40	17721.22
115	P3C2TLR1	4.85	2,626.67	12734.12
116	P3C2TLR3	4.81	2,766.06	13291.55
117	P3C2TAG1	5.74	1,028.02	5895.79
118	P3C2TAG3	5.81	988.81	5741.22
119	P3C2OC	4	2,661.52	10646.32
120	P3C2OHD	4	1,637.86	6551.69
121	P3C2OLD	4	1,176.12	4704.5
122	P3C2OAG	4	169.88	679.7
123	P3C2DC1	4.83	5,562.61	26858.24
124	P3C2DC3	4.87	5,279.47	25728.51
125	P3C2DHR1	4.81	3,811.50	18312.25
126	P3C2DHR3	4.84	3,663.40	17721.22
127	P3C2DLR1	4.85	2,626.67	12734.12
128	P3C2DLR3	4.81	2,766.06	13291.55
129	P3C2DAG1	5.74	1,028.02	5895.79
130	P3C2DAG3	5.81	988.81	5741.22
131	P3TF1	NA	NA	NA
132	P3TF3	NA	NA	NA
133	P3OF	NA	NA	NA
134	P3DF1	NA	NA	NA
135	P3DF3	NA	NA	NA

Appendix B

Hypothetical Catchment Best Solution Results

Table 20. Hypothetical Catchment Total Costs, BMP Unit Costs, and HPC, HPR, PEAK:BASE and TSS Indicator Results

No.	Hypothetical Catchment	Best Sol. No.	Eff/ % Red	Total Cost ($M)	Number of Units					HPC			HPR			PEAK:BASE			TSS Load (kg/d)		
					Cisterns	Rain Gardens	Porous Pavement	Detention Ponds	Roadside Bio	Fully-Forested	Current Condition	Best Solution	Fully-Forested	Current Condition	Best Solution	Fully-Forested	Current Condition	Best Solution	Forest	Current Condition	Best Solution
1	P1C1TC1	3	88%	$30.39	0	4,100	0	0	285	2	31	4	28	330	73	4	165	4	0	7.15	0.1
2	P1C1TC3	3	88%	$30.39	0	4,100	0	0	285	3	31	4	55	330	71	12	175	5	0.08	7.17	0.11
3	P1C1THR1	17	78%	$27.70	60	3,690	0	0	285	3	25	5	50	308	99	4	67	7	0	3.56	0.19
4	P1C1THR3	9	77%	$27.79	90	3,690	0	0	285	4	25	6	73	309	100	12	79	8	0.08	3.59	0.2
5	P1C1TLR1	5	64%	$20.57	30	2,050	0	100	240	4	17	6	77	253	98	4	28	8	0	1.45	0.02
6	P1C1TLR3	9	60%	$21.53	0	2,870	0	0	240	4	16	6	87	241	105	12	47	15	0.08	1.53	0.19
7	P1C1TAG1	8	27%	$13.67	0	1,435	0	90	270	4	7	5	98	124	102	4	13	6	0	0.43	0.02
8	P1C1TAG3	5	29%	$16.09	0	1,845	0	100	180	5	7	5	104	117	96	12	29	10	0.08	0.51	0.04
9	P1C1OC	14	92%	$7.49	0	0	0	100	0	2	31	2	30	330	61	5	149	2	0	7.12	0
10	P1C1OHD	20	89%	$2.17	0	0	0	90	0	3	25	3	52	308	73	5	50	3	0	3.5	0.01
11	P1C1OLD	17	80%	$0.86	30	0	0	90	15	3	15	3	70	249	80	5	20	4	0	1.41	0
12	P1C1OAG	6	44%	$3.20	0	410	0	100	30	3	6	3	92	112	85	5	10	5	0	0.5	0.09
13	P1C1DC1	6	66%	$16.80	0	0	0	90	0	2	31	10	28	330	232	4	165	11	0	7.15	1.51
14	P1C1DC3	11	71%	$17.61	0	0	0	90	0	3	31	9	55	330	197	12	175	9	0.08	7.17	1.34
15	P1C1DHR1	9	51%	$14.15	120	1,025	0	80	30	3	25	12	50	308	183	4	67	15	0	3.56	0.76
16	P1C1DHR3	10	56%	$9.52	120	0	0	90	225	4	25	11	73	309	183	12	79	13	0.08	3.59	0.55
17	P1C1DLR1	10	52%	$28.53	0	3,690	0	60	0	4	17	8	77	253	107	4	28	13	0	1.45	0.28
18	P1C1DLR3	17	50%	$27.93	30	3,485	0	70	15	4	16	8	87	241	104	12	47	19	0.08	1.53	0.22
19	P1C1DAG1	6	22%	$16.65	0	1,845	0	100	255	4	7	5	98	124	101	4	13	7	0	0.43	0.02
20	P1C1DAG3	13	25%	$20.54	0	2,460	0	90	240	5	7	5	104	117	94	12	29	11	0.08	0.51	0.04
21	P2C1TC1	9	88%	$32.55	0	4,100	0	10	285	2	31	4	26	330	74	4	168	4	0	7.03	0.07
22	P2C1TC3	3	88%	$30.39	0	4,100	0	0	285	3	31	4	52	330	75	11	177	5	0.07	7.04	0.09
23	P2C1THR1	5	78%	$28.66	30	3,690	0	10	300	3	26	6	57	309	103	4	66	7	0	3.49	0.11
24	P2C1THR3	22	78%	$29.92	0	3,895	0	10	285	4	26	6	83	310	100	11	79	8	0.07	3.51	0.15
25	P2C1TLR1	6	66%	$23.44	0	2,460	0	90	225	4	17	6	83	264	104	4	28	7	0	1.42	0.01
26	P2C1TLR3	9	63%	$25.72	0	2,665	0	100	270	5	16	6	94	248	103	11	45	11	0.07	1.48	0.03
27	P2C1TAG1	3	31%	$14.75	0	1,640	0	100	195	4	7	5	104	133	104	4	13	6	0	0.41	0.01
28	P2C1TAG3	10	30%	$16.42	0	2,050	0	70	60	5	7	5	113	127	100	11	27	10	0.07	0.48	0.05
29	P2C1OC	8	92%	$9.07	0	0	0	100	0	2	32	2	25	329	56	5	153	3	0	7	0
30	P2C1OHD	12	90%	$3.65	210	0	0	90	15	3	26	3	54	309	73	5	52	3	0	3.45	0
31	P2C1OLD	20	82%	$1.86	240	0	0	90	0	3	16	3	70	259	77	5	21	4	0	1.38	0
32	P2C1OAG	16	46%	$8.82	0	1,025	0	80	240	4	6	3	94	120	87	5	10	4	0	0.44	0.04
33	P2C1DC1	10	59%	$19.85	0	0	0	90	60	2	31	13	26	330	251	4	168	13	0	7.03	1.57
34	P2C1DC3	24	59%	$19.82	0	0	0	90	45	3	31	13	52	330	252	11	177	14	0.07	7.04	1.6
35	P2C1DHR1	16	45%	$23.70	0	2,255	0	80	60	3	26	14	57	309	193	4	66	16	0	3.49	0.54
36	P2C1DHR3	10	45%	$23.31	90	2,050	0	80	165	4	26	14	83	310	191	11	79	19	0.07	3.51	0.5
37	P2C1DLR1	6	53%	$29.95	30	3,895	0	50	0	4	17	8	83	264	112	4	28	13	0	1.42	0.36

No.	Hypothetical Catchment	Best Sol. No.	Eff/ % Red	Total Cost ($M)	Number of Units					HPC			HPR			PEAK:BASE			TSS Load (kg/d)		
					Cisterns	Rain Gardens	Porous Pavement	Detention Ponds	Roadside Bio	Fully-Forested	Current Condition	Best Solution	Fully-Forested	Current Condition	Best Solution	Fully-Forested	Current Condition	Best Solution	Forest	Current Condition	Best Solution
38	P2C1DLR3	14	48%	$28.72	30	3,690	0	50	30	5	16	9	94	248	113	11	45	25	0.07	1.48	0.35
39	P2C1DAG1	4	26%	$17.98	0	2,050	0	100	255	4	7	5	104	133	103	4	13	7	0	0.41	0.01
40	P2C1DAG3	21	23%	$12.11	0	1,230	0	100	165	5	7	5	113	127	101	11	27	11	0.07	0.48	0.05
41	P3C1TC1	3	87%	$33.19	0	4,100	0	10	300	3	31	4	46	328	76	5	160	5	0.01	8.36	0.14
42	P3C1TC3	3	87%	$30.39	0	4,100	0	0	285	4	31	4	70	328	78	18	171	6	0.17	8.39	0.17
43	P3C1THR1	3	73%	$31.46	60	3,895	0	20	240	4	25	7	73	302	112	5	70	8	0.01	4.2	0.32
44	P3C1THR3	22	73%	$28.50	0	3,690	0	10	240	5	25	7	91	302	114	18	86	10	0.17	4.24	0.39
45	P3C1TLR1	5	58%	$22.86	30	2,050	0	100	225	5	16	7	94	240	109	5	32	9	0.01	1.73	0.04
46	P3C1TLR3	4	56%	$27.15	0	3,690	0	0	225	5	16	7	101	224	113	18	56	13	0.17	1.88	0.08
47	P3C1TAG1	5	23%	$10.35	0	1,025	0	90	90	5	7	6	109	131	109	5	18	8	0.01	0.57	0.06
48	P3C1TAG3	21	21%	$14.95	0	1,845	0	60	60	5	7	6	111	126	110	18	40	16	0.17	0.72	0.14
49	P3C1OC	11	92%	$12.20	0	0	0	100	45	2	32	3	35	328	57	4	137	3	0	8.29	0
50	P3C1OHD	17	89%	$5.32	30	0	0	90	120	3	25	3	59	302	75	4	45	3	0	4.08	0
51	P3C1OLD	11	79%	$2.23	30	0	0	80	0	3	15	3	79	241	83	4	18	4	0	1.64	0.06
52	P3C1OAG	5	46%	$25.77	0	3,485	0	70	195	4	6	3	92	116	83	4	14	5	0	0.83	0.08
53	P3C1DC1	14	48%	$25.81	0	0	0	90	225	3	31	16	46	328	254	5	160	19	0.01	8.36	1.93
54	P3C1DC3	21	44%	$30.48	0	820	0	90	240	4	31	17	70	328	251	18	171	23	0.17	8.39	1.72
55	P3C1DHR1	3	40%	$29.78	90	2,870	0	70	60	4	25	15	73	302	177	5	70	26	0.01	4.2	0.74
56	P3C1DHR3	9	35%	$23.27	90	1,845	0	70	210	5	25	16	91	302	193	18	86	33	0.17	4.24	0.88
57	P3C1DLR1	8	47%	$31.64	0	3,485	0	100	45	5	16	9	94	240	109	5	32	15	0.01	1.73	0.09
58	P3C1DLR3	7	41%	$30.85	0	3,895	0	50	0	5	16	9	101	224	115	18	56	33	0.17	1.88	0.51
59	P3C1DAG1	7	23%	$15.97	0	1,640	0	100	255	5	7	6	109	131	108	5	18	9	0.01	0.57	0.05
60	P3C1DAG3	5	21%	$26.49	0	3,485	0	70	30	5	7	6	111	126	106	18	40	13	0.17	0.72	0.1
61	P1C2TC1	23	88%	$30.29	0	4,100	0	0	270	2	31	4	28	330	73	4	165	5	0	7.15	0.12
62	P1C2TC3	3	88%	$30.39	0	4,100	0	0	285	3	31	4	55	330	71	12	175	5	0.08	7.17	0.11
63	P1C2THR1	26	77%	$29.60	120	3,690	0	20	240	3	25	6	50	308	100	4	67	7	0	3.56	0.27
64	P1C2THR3	19	77%	$28.87	60	3,690	0	10	300	4	26	7	83	310	110	11	79	9	0.07	3.51	0.44
65	P1C2TLR1	9	67%	$25.15	30	2,665	0	90	240	4	17	6	77	253	97	4	28	7	0	1.45	0.01
66	P1C2TLR3	6	61%	$22.92	30	2,460	0	70	255	4	16	6	87	241	100	12	47	12	0.08	1.53	0.07
67	P1C2TAG1	5	26%	$11.31	0	1,230	0	100	60	4	7	5	98	124	102	4	13	6	0	0.43	0.02
68	P1C2TAG3	28	28%	$14.06	0	1,640	0	100	60	5	7	5	104	117	96	12	29	10	0.08	0.51	0.05
69	P1C2OC	12	92%	$7.56	0	0	0	100	0	2	31	2	30	330	61	5	149	2	0	7.12	0
70	P1C2OHD	22	89%	$2.87	0	0	0	90	15	3	25	3	52	308	73	5	50	3	0	3.5	0
71	P1C2OLD	24	80%	$2.15	0	0	0	90	210	3	15	3	70	249	81	5	20	4	0	1.41	0
72	P1C2OAG	3	44%	$3.37	0	410	0	80	60	3	6	3	92	112	85	5	10	5	0	0.5	0.09
73	P1C2DC1	6	66%	$16.94	0	0	0	90	0	2	31	10	28	330	232	4	165	11	0	7.15	1.51
74	P1C2DC3	7	71%	$18.32	0	0	0	90	90	3	31	9	55	330	197	12	175	9	0.08	7.17	1.29
75	P1C2DHR1	9	52%	$18.56	120	1,435	0	80	30	3	25	12	50	308	177	4	67	15	0	3.56	0.69
76	P1C2DHR3	27	57%	$10.64	150	0	0	90	90	4	25	11	73	309	182	12	79	13	0.08	3.59	0.62

No.	Hypothetical Catchment	Best Sol. No.	Eff/ % Red	Total Cost ($M)	Number of Units					HPC			HPR			PEAK:BASE			TSS Load (kg/d)		
					Cisterns	Rain Gardens	Porous Pavement	Detention Ponds	Roadside Bio	Fully-Forested	Current Condition	Best Solution	Fully-Forested	Current Condition	Best Solution	Fully-Forested	Current Condition	Best Solution	Forest	Current Condition	Best Solution
77	P1C2DLR1	11	50%	$26.96	0	3,075	0	100	0	4	17	8	83	264	105	4	28	11	0	1.42	0.07
78	P1C2DLR3	10	52%	$29.32	0	3,690	0	60	15	5	16	8	94	248	104	11	45	17	0.07	1.48	0.07
79	P1C2DAG1	7	27%	$24.26	0	2,870	0	100	300	4	7	5	98	124	98	4	13	6	0	0.43	0.01
80	P1C2DAG3	22	25%	$17.00	0	1,845	0	100	300	5	7	5	113	127	99	11	27	11	0.07	0.48	0.04
81	P2C2TC1	3	88%	$32.66	0	4,100	0	10	300	2	31	4	26	330	74	4	168	4	0	7.03	0.07
82	P2C2TC3	3	88%	$32.67	0	4,100	0	10	300	3	31	4	52	330	75	11	177	4	0.07	7.04	0.08
83	P2C2THR1	12	77%	$28.78	120	3,690	0	10	240	3	26	6	57	309	105	4	66	7	0	3.49	0.3
84	P2C2THR3	3	75%	$28.66	60	3,895	0	0	210	4	26	6	83	310	99	11	79	8	0.07	3.51	0.15
85	P2C2TLR1	16	67%	$27.32	60	3,690	0	0	225	4	17	6	83	264	107	4	28	7	0	1.42	0.02
86	P2C2TLR3	20	63%	$26.45	30	2,665	0	100	210	5	16	6	94	248	103	11	45	11	0.07	1.48	0.03
87	P2C2TAG1	3	31%	$15.00	0	1,640	0	100	210	4	7	5	104	133	104	4	13	6	0	0.41	0.01
88	P2C2TAG3	18	27%	$5.94	0	410	0	100	60	5	7	5	113	127	101	11	27	11	0.07	0.48	0.06
89	P2C2OC	15	92%	$9.34	0	0	0	100	30	2	32	2	25	329	56	5	153	3	0	7	0
90	P2C2OHD	19	90%	$3.95	30	0	0	90	15	3	26	3	54	309	74	5	52	3	0	3.45	0
91	P2C2OLD	3	82%	$2.41	210	0	0	90	60	3	16	3	70	259	76	5	21	4	0	1.38	0
92	P2C2OAG	15	45%	$4.50	0	410	0	100	225	4	6	3	94	120	88	5	10	4	0	0.44	0.05
93	P2C2DC1	15	59%	$19.63	0	0	0	90	0	2	31	13	26	330	251	4	168	13	0	7.03	1.61
94	P2C2DC3	21	59%	$19.99	0	0	0	90	45	3	31	13	52	330	252	11	177	14	0.07	7.04	1.6
95	P2C2DHR1	8	43%	$20.20	90	1,230	0	80	300	3	26	14	57	309	201	4	66	16	0	3.49	0.52
96	P2C2DHR3	23	45%	$25.35	90	2,255	0	70	150	4	26	14	83	310	191	11	79	26	0.07	3.51	0.64
97	P2C2DLR1	11	55%	$30.72	0	3,485	0	100	0	4	17	7	83	264	99	4	28	10	0	1.42	0.02
98	P2C2DLR3	14	51%	$31.42	0	3,485	0	100	105	5	16	8	94	248	102	11	45	17	0.07	1.48	0.05
99	P2C2DAG1	5	27%	$18.24	0	2,050	0	100	270	4	7	5	104	133	103	4	13	7	0	0.41	0.01
100	P2C2DAG3	13	25%	$15.27	0	1,640	0	100	180	5	7	5	113	127	98	11	27	9	0.07	0.48	0.03
101	P3C2TC1	28	87%	$33.02	0	4,100	0	10	270	3	31	4	46	328	76	5	160	5	0.01	8.36	0.16
102	P3C2TC3	3	87%	$30.39	0	4,100	0	0	285	4	31	4	70	328	78	18	171	6	0.17	8.39	0.17
103	P3C2THR1	9	73%	$27.62	0	3,690	0	0	300	4	25	7	73	302	113	5	70	8	0.01	4.2	0.18
104	P3C2THR3	28	74%	$29.23	60	3,895	0	0	300	5	25	6	91	302	110	18	86	9	0.17	4.24	0.17
105	P3C2TLR1	3	59%	$26.46	30	3,485	0	10	195	5	16	7	94	240	116	5	32	9	0.01	1.73	0.15
106	P3C2TLR3	6	56%	$27.15	0	3,690	0	0	225	5	16	7	101	224	113	18	56	13	0.17	1.88	0.08
107	P3C2TAG1	11	26%	$18.29	0	2,255	0	60	105	5	7	5	109	131	109	5	18	8	0.01	0.57	0.06
108	P3C2TAG3	10	24%	$20.81	0	2,665	0	60	60	5	7	6	111	126	108	18	40	14	0.17	0.72	0.1
109	P3C2OC	6	92%	$12.02	0	0	0	100	0	2	32	2	35	328	57	4	137	3	0	8.29	0
110	P3C2OHD	5	89%	$6.26	180	0	0	90	0	3	25	3	59	302	75	4	45	3	0	4.08	0
111	P3C2OLD	10	78%	$3.69	270	0	0	80	45	3	15	3	79	241	81	4	18	4	0	1.64	0.05
112	P3C2OAG	15	44%	$18.82	0	2,460	0	90	210	4	6	3	92	116	84	4	14	5	0	0.83	0.1
113	P3C2DC1	5	48%	$27.64	0	410	0	90	30	3	31	16	46	328	253	5	160	19	0.01	8.36	1.94
114	P3C2DC3	24	44%	$28.10	0	410	0	90	285	4	31	18	70	328	254	18	171	23	0.17	8.39	1.85
115	P3C2DHR1	19	38%	$27.28	90	2,050	0	70	210	4	25	15	73	302	188	5	70	26	0.01	4.2	0.77

No.	Hypothetical Catchment	Best Sol. No.	Eff/ % Red	Total Cost ($M)	Number of Units					HPC			HPR			PEAK:BASE			TSS Load (kg/d)		
					Cisterns	Rain Gardens	Porous Pavement	Detention Ponds	Roadside Bio	Fully-Forested	Current Condition	Best Solution	Fully-Forested	Current Condition	Best Solution	Fully-Forested	Current Condition	Best Solution	Forest	Current Condition	Best Solution
116	P3C2DHR3	11	36%	$27.08	90	2,255	0	70	15	5	25	16	91	302	190	18	86	33	0.17	4.24	1.01
117	P3C2DLR1	3	47%	$32.88	0	4,100	0	50	15	5	16	9	94	240	116	5	32	18	0.01	1.73	0.42
118	P3C2DLR3	25	43%	$33.26	0	4,100	0	50	45	5	16	9	101	224	114	18	56	32	0.17	1.88	0.43
119	P3C2DAG1	4	21%	$14.59	0	1,435	0	100	225	5	7	6	109	131	108	5	18	9	0.01	0.57	0.05
120	P3C2DAG3	26	21%	$24.68	0	2,870	0	90	300	5	7	6	111	126	106	18	40	13	0.17	0.72	0.09

Table 21. Detailed cost breakdown for "Best" cost-effectiveness optimization scenarios for hypothetical catchments assuming all units are constructed initially followed by 30 years of O&M and I&E. All costs in 2013 dollars.

Number	Hypothetical Catchment	Best Sol. No.	Eff/ % Red	TPV Cost ($M)	Onsite Detention		Rain Garden		Porous Pavement		Roadside Bio		Detention Pond		Total						
															Private			Public			
					Private ($M)	Public ($M)	Private ($M)	Public ($M)	Private ($M)	Public ($M)	Private ($M)	Public ($M)	Public ($M)	Land ($M)	Capital ($M)	O&M ($M)	Total ($M)	Capital ($M)	O&M ($M)	I&E ($M)	Total ($M)
1	P1C1TC1	3	88%	$ 30.39	$ -	$ -	$ 15.13	$ 13.46	$ -	$ -	$ -	$ 1.80	$ -	$ -	$ 8.20	$ 6.93	$ 15.13	$ 0.57	$ 0.48	$ 14.20	$ 15.25
2	P1C1TC3	3	88%	$ 30.39	$ -	$ -	$ 15.13	$ 13.46	$ -	$ -	$ -	$ 1.80	$ -	$ -	$ 8.20	$ 6.93	$ 15.13	$ 0.57	$ 0.48	$ 14.20	$ 15.25
3	P1C1THR1	17	78%	$ 27.70	$ 0.10	$ 0.08	$ 13.62	$ 12.11	$ -	$ -	$ -	$ 1.80	$ -	$ -	$ 7.48	$ 6.24	$ 13.72	$ 0.57	$ 0.48	$ 12.93	$ 13.99
4	P1C1THR3	9	77%	$ 27.79	$ 0.14	$ 0.12	$ 13.62	$ 12.11	$ -	$ -	$ -	$ 1.80	$ -	$ -	$ 7.52	$ 6.24	$ 13.76	$ 0.57	$ 0.48	$ 12.97	$ 14.03
5	P1C1TLR1	5	64%	$ 20.57	$ 0.05	$ 0.04	$ 7.57	$ 6.73	$ -	$ -	$ -	$ 1.51	$ 4.05	$ 0.62	$ 4.15	$ 3.47	$ 7.61	$ 5.02	$ 0.54	$ 7.39	$ 12.95
6	P1C1TLR3	9	60%	$ 21.53	$ -	$ -	$ 10.59	$ 9.42	$ -	$ -	$ -	$ 1.51	$ -	$ -	$ 5.74	$ 4.85	$ 10.59	$ 0.48	$ 0.41	$ 10.05	$ 10.93
7	P1C1TAG1	8	27%	$ 13.67	$ -	$ -	$ 5.30	$ 4.71	$ -	$ -	$ -	$ 1.70	$ 1.89	$ 0.07	$ 2.87	$ 2.43	$ 5.30	$ 2.44	$ 0.52	$ 5.42	$ 8.38
8	P1C1TAG3	5	29%	$ 16.09	$ -	$ -	$ 6.81	$ 6.06	$ -	$ -	$ -	$ 1.13	$ 2.01	$ 0.07	$ 3.69	$ 3.12	$ 6.81	$ 2.38	$ 0.37	$ 6.53	$ 9.28
9	P1C1OC	14	92%	$ 7.49	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 3.20	$ 4.29	$ -	$ -	$ -	$ 7.38	$ 0.10	$ -	$ 7.49
10	P1C1OHD	20	89%	$ 2.17	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1.37	$ 0.80	$ -	$ -	$ -	$ 2.12	$ 0.04	$ -	$ 2.17
11	P1C1OLD	17	80%	$ 0.86	$ 0.05	$ 0.04	$ -	$ -	$ -	$ -	$ -	$ 0.09	$ 0.57	$ 0.11	$ 0.05	$ -	$ 0.05	$ 0.69	$ 0.04	$ 0.08	$ 0.81
12	P1C1OAG	6	44%	$ 3.20	$ -	$ -	$ 1.51	$ 1.35	$ -	$ -	$ -	$ 0.19	$ 0.14	$ 0.01	$ 0.82	$ 0.69	$ 1.51	$ 0.20	$ 0.06	$ 1.42	$ 1.68
13	P1C1DC1	6	66%	$ 16.80	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 8.07	$ 8.73	$ -	$ -	$ -	$ 16.54	$ 0.26	$ -	$ 16.80
14	P1C1DC3	11	71%	$ 17.61	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 8.42	$ 9.19	$ -	$ -	$ -	$ 17.34	$ 0.27	$ -	$ 17.61
15	P1C1DHR1	9	51%	$ 14.15	$ 0.19	$ 0.16	$ 3.78	$ 3.36	$ -	$ -	$ -	$ 0.19	$ 4.41	$ 2.05	$ 2.24	$ 1.73	$ 3.98	$ 6.38	$ 0.19	$ 3.60	$ 10.18
16	P1C1DHR3	10	56%	$ 9.52	$ 0.19	$ 0.16	$ -	$ -	$ -	$ -	$ -	$ 1.42	$ 5.27	$ 2.49	$ 0.19	$ -	$ 0.19	$ 8.03	$ 0.55	$ 0.75	$ 9.33
17	P1C1DLR1	10	52%	$ 28.53	$ -	$ -	$ 13.62	$ 12.11	$ -	$ -	$ -	$ -	$ 2.43	$ 0.37	$ 7.38	$ 6.24	$ 13.62	$ 2.72	$ 0.08	$ 12.11	$ 14.91
18	P1C1DLR3	17	50%	$ 27.93	$ 0.05	$ 0.04	$ 12.86	$ 11.44	$ -	$ -	$ -	$ 0.09	$ 2.98	$ 0.46	$ 7.02	$ 5.89	$ 12.91	$ 3.38	$ 0.12	$ 11.52	$ 15.02
19	P1C1DAG1	6	22%	$ 16.65	$ -	$ -	$ 6.81	$ 6.06	$ -	$ -	$ -	$ 1.61	$ 2.10	$ 0.08	$ 3.69	$ 3.12	$ 6.81	$ 2.62	$ 0.50	$ 6.72	$ 9.84
20	P1C1DAG3	13	25%	$ 20.54	$ -	$ -	$ 9.08	$ 8.07	$ -	$ -	$ -	$ 1.51	$ 1.81	$ 0.07	$ 4.92	$ 4.16	$ 9.08	$ 2.30	$ 0.46	$ 8.70	$ 11.46
21	P2C1TC1	9	88%	$ 32.55	$ -	$ -	$ 15.13	$ 13.46	$ -	$ -	$ -	$ 1.80	$ 1.02	$ 1.14	$ 8.20	$ 6.93	$ 15.13	$ 2.70	$ 0.51	$ 14.20	$ 17.42
22	P2C1TC3	3	88%	$ 30.39	$ -	$ -	$ 15.13	$ 13.46	$ -	$ -	$ -	$ 1.80	$ -	$ -	$ 8.20	$ 6.93	$ 15.13	$ 0.57	$ 0.48	$ 14.20	$ 15.25
23	P2C1THR1	5	78%	$ 28.66	$ 0.05	$ 0.04	$ 13.62	$ 12.11	$ -	$ -	$ -	$ 1.89	$ 0.64	$ 0.31	$ 7.43	$ 6.24	$ 13.67	$ 1.53	$ 0.53	$ 12.93	$ 14.99
24	P2C1THR3	22	78%	$ 29.92	$ -	$ -	$ 14.38	$ 12.78	$ -	$ -	$ -	$ 1.80	$ 0.65	$ 0.31	$ 7.79	$ 6.59	$ 14.38	$ 1.51	$ 0.50	$ 13.53	$ 15.54

Number	Hypothetical Catchment	Best Sol. No.	Eff/ % Red	TPV Cost ($M)	Onsite Detention Private ($M)	Onsite Detention Public ($M)	Rain Garden Private ($M)	Rain Garden Public ($M)	Porous Pavement Private ($M)	Porous Pavement Public ($M)	Roadside Bio Private ($M)	Roadside Bio Public ($M)	Detention Pond Public ($M)	Detention Pond Land ($M)	Total Private Capital ($M)	Total Private O&M ($M)	Total Private Total ($M)	Total Public Capital ($M)	Total Public O&M ($M)	Total Public I&E ($M)	Total Public Total ($M)
25	P2C1TLR1	6	66%	$ 23.44	$ -	$ -	$ 9.08	$ 8.07	$ -	$ -	$ -	$ 1.42	$ 4.20	$ 0.66	$ 4.92	$ 4.16	$ 9.08	$ 5.18	$ 0.52	$ 8.66	$ 14.36
26	P2C1TLR3	9	63%	$ 25.72	$ -	$ -	$ 9.84	$ 8.75	$ -	$ -	$ -	$ 1.70	$ 4.69	$ 0.74	$ 5.33	$ 4.51	$ 9.84	$ 5.83	$ 0.61	$ 9.45	$ 15.88
27	P2C1TAG1	3	31%	$ 14.75	$ -	$ -	$ 6.05	$ 5.38	$ -	$ -	$ -	$ 1.23	$ 2.01	$ 0.07	$ 3.28	$ 2.77	$ 6.05	$ 2.41	$ 0.39	$ 5.89	$ 8.69
28	P2C1TAG3	10	30%	$ 16.42	$ -	$ -	$ 7.57	$ 6.73	$ -	$ -	$ -	$ 0.38	$ 1.68	$ 0.07	$ 4.10	$ 3.47	$ 7.57	$ 1.81	$ 0.16	$ 6.88	$ 8.85
29	P2C1OC	8	92%	$ 9.07	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 3.88	$ 5.19	$ -	$ -	$ -	$ 8.94	$ 0.12	$ -	$ 9.07
30	P2C1OHD	12	90%	$ 3.65	$ 0.34	$ 0.28	$ -	$ -	$ -	$ -	$ -	$ 0.09	$ 1.85	$ 1.09	$ 0.34	$ -	$ 0.34	$ 2.91	$ 0.08	$ 0.31	$ 3.31
31	P2C1OLD	20	82%	$ 1.86	$ 0.38	$ 0.32	$ -	$ -	$ -	$ -	$ -	$ -	$ 0.98	$ 0.19	$ 0.38	$ -	$ 0.38	$ 1.13	$ 0.03	$ 0.32	$ 1.48
32	P2C1OAG	16	46%	$ 8.82	$ -	$ -	$ 3.78	$ 3.36	$ -	$ -	$ -	$ 1.51	$ 0.15	$ 0.01	$ 2.05	$ 1.73	$ 3.78	$ 0.64	$ 0.41	$ 3.99	$ 5.04
33	P2C1DC1	10	59%	$ 19.85	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 0.38	$ 9.21	$ 10.26	$ -	$ -	$ -	$ 19.29	$ 0.40	$ 0.16	$ 19.85
34	P2C1DC3	24	59%	$ 19.82	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 0.28	$ 9.24	$ 10.30	$ -	$ -	$ -	$ 19.33	$ 0.37	$ 0.12	$ 19.82
35	P2C1DHR1	16	45%	$ 23.70	$ -	$ -	$ 8.32	$ 7.40	$ -	$ -	$ -	$ 0.38	$ 5.13	$ 2.47	$ 4.51	$ 3.81	$ 8.32	$ 7.55	$ 0.27	$ 7.56	$ 15.38
36	P2C1DHR3	10	45%	$ 23.31	$ 0.14	$ 0.12	$ 7.57	$ 6.73	$ -	$ -	$ -	$ 1.04	$ 5.20	$ 2.52	$ 4.24	$ 3.47	$ 7.71	$ 7.88	$ 0.45	$ 7.28	$ 15.60
37	P2C1DLR1	6	53%	$ 29.95	$ 0.05	$ 0.04	$ 14.38	$ 12.78	$ -	$ -	$ -	$ -	$ 2.33	$ 0.37	$ 7.84	$ 6.59	$ 14.42	$ 2.63	$ 0.08	$ 12.82	$ 15.53
38	P2C1DLR3	14	48%	$ 28.72	$ 0.05	$ 0.04	$ 13.62	$ 12.11	$ -	$ -	$ -	$ 0.19	$ 2.35	$ 0.37	$ 7.43	$ 6.24	$ 13.67	$ 2.70	$ 0.13	$ 12.23	$ 15.06
39	P2C1DAG1	4	26%	$ 17.98	$ -	$ -	$ 7.57	$ 6.73	$ -	$ -	$ -	$ 1.61	$ 2.01	$ 0.07	$ 4.10	$ 3.47	$ 7.57	$ 2.53	$ 0.50	$ 7.39	$ 10.42
40	P2C1DAG3	21	23%	$ 12.11	$ -	$ -	$ 4.54	$ 4.04	$ -	$ -	$ -	$ 1.04	$ 2.39	$ 0.10	$ 2.46	$ 2.08	$ 4.54	$ 2.74	$ 0.36	$ 4.47	$ 7.57
41	P3C1TC1	3	87%	$ 33.19	$ -	$ -	$ 15.13	$ 13.46	$ -	$ -	$ -	$ 1.89	$ 1.28	$ 1.43	$ 8.20	$ 6.93	$ 15.13	$ 3.27	$ 0.55	$ 14.24	$ 18.06
42	P3C1TC3	3	87%	$ 30.39	$ -	$ -	$ 15.13	$ 13.46	$ -	$ -	$ -	$ 1.80	$ -	$ -	$ 8.20	$ 6.93	$ 15.13	$ 0.57	$ 0.48	$ 14.20	$ 15.25
43	P3C1THR1	3	73%	$ 31.46	$ 0.10	$ 0.08	$ 14.38	$ 12.78	$ -	$ -	$ -	$ 1.51	$ 1.75	$ 0.86	$ 7.89	$ 6.59	$ 14.47	$ 3.03	$ 0.46	$ 13.49	$ 16.98
44	P3C1THR3	22	73%	$ 28.50	$ -	$ -	$ 13.62	$ 12.11	$ -	$ -	$ -	$ 1.51	$ 0.85	$ 0.41	$ 7.38	$ 6.24	$ 13.62	$ 1.71	$ 0.43	$ 12.74	$ 14.88
45	P3C1TLR1	5	58%	$ 22.86	$ 0.05	$ 0.04	$ 7.57	$ 6.73	$ -	$ -	$ -	$ 1.42	$ 6.09	$ 0.97	$ 4.15	$ 3.47	$ 7.61	$ 7.31	$ 0.58	$ 7.36	$ 15.24
46	P3C1TLR3	4	56%	$ 27.15	$ -	$ -	$ 13.62	$ 12.11	$ -	$ -	$ -	$ 1.42	$ -	$ -	$ 7.38	$ 6.24	$ 13.62	$ 0.45	$ 0.38	$ 12.70	$ 13.53
47	P3C1TAG1	5	23%	$ 10.35	$ -	$ -	$ 3.78	$ 3.36	$ -	$ -	$ -	$ 0.57	$ 2.54	$ 0.10	$ 2.05	$ 1.73	$ 3.78	$ 2.73	$ 0.23	$ 3.60	$ 6.57
48	P3C1TAG3	21	21%	$ 14.95	$ -	$ -	$ 6.81	$ 6.06	$ -	$ -	$ -	$ 0.38	$ 1.65	$ 0.06	$ 3.69	$ 3.12	$ 6.81	$ 1.78	$ 0.15	$ 6.21	$ 8.14
49	P3C1OC	11	92%	$ 12.20	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 0.28	$ 5.09	$ 6.82	$ -	$ -	$ -	$ 11.84	$ 0.24	$ 0.12	$ 12.20
50	P3C1OHD	17	89%	$ 5.32	$ 0.05	$ 0.04	$ -	$ -	$ -	$ -	$ -	$ 0.76	$ 2.82	$ 1.66	$ 0.05	$ -	$ 0.05	$ 4.63	$ 0.29	$ 0.35	$ 5.27
51	P3C1OLD	11	79%	$ 2.23	$ 0.05	$ 0.04	$ -	$ -	$ -	$ -	$ -	$ -	$ 1.80	$ 0.35	$ 0.05	$ -	$ 0.05	$ 2.09	$ 0.06	$ 0.04	$ 2.19
52	P3C1OAG	5	46%	$ 25.77	$ -	$ -	$ 12.86	$ 11.44	$ -	$ -	$ -	$ 1.23	$ 0.23	$ 0.01	$ 6.97	$ 5.89	$ 12.86	$ 0.62	$ 0.34	$ 11.95	$ 12.91
53	P3C1DC1	14	48%	$ 25.81	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1.42	$ 11.56	$ 12.83	$ -	$ -	$ -	$ 24.47	$ 0.75	$ 0.59	$ 25.81
54	P3C1DC3	21	44%	$ 30.48	$ -	$ -	$ 3.03	$ 2.69	$ -	$ -	$ -	$ 1.51	$ 11.08	$ 12.18	$ 1.64	$ 1.39	$ 3.03	$ 23.38	$ 0.76	$ 3.32	$ 27.46
55	P3C1DHR1	3	40%	$ 29.78	$ 0.14	$ 0.12	$ 10.59	$ 9.42	$ -	$ -	$ -	$ 0.38	$ 6.13	$ 3.00	$ 5.88	$ 4.85	$ 10.74	$ 9.05	$ 0.30	$ 9.69	$ 19.05
56	P3C1DHR3	9	35%	$ 23.27	$ 0.14	$ 0.12	$ 6.81	$ 6.06	$ -	$ -	$ -	$ 1.32	$ 5.93	$ 2.88	$ 3.83	$ 3.12	$ 6.95	$ 9.05	$ 0.55	$ 6.72	$ 16.31
57	P3C1DLR1	8	47%	$ 31.64	$ -	$ -	$ 12.86	$ 11.44	$ -	$ -	$ -	$ 0.28	$ 6.09	$ 0.97	$ 6.97	$ 5.89	$ 12.86	$ 6.95	$ 0.27	$ 11.56	$ 18.78
58	P3C1DLR3	7	41%	$ 30.85	$ -	$ -	$ 14.38	$ 12.78	$ -	$ -	$ -	$ -	$ 3.18	$ 0.51	$ 7.79	$ 6.59	$ 14.38	$ 3.59	$ 0.10	$ 12.78	$ 16.47

Number	Hypothetical Catchment	Best Sol. No.	Eff/ % Red	TPV Cost ($M)	Onsite Detention Private ($M)	Onsite Detention Public ($M)	Rain Garden Private ($M)	Rain Garden Public ($M)	Porous Pavement Private ($M)	Porous Pavement Public ($M)	Roadside Bio Private ($M)	Roadside Bio Public ($M)	Detention Pond Public ($M)	Detention Pond Land ($M)	Total Private Capital ($M)	Total Private O&M ($M)	Total Private Total ($M)	Total Public Capital ($M)	Total Public O&M ($M)	Total Public I&E ($M)	Total Public Total ($M)
59	P3C1DAG1	7	23%	$ 15.97	$ -	$ -	$ 6.05	$ 5.38	$ -	$ -	$ -	$ 1.61	$ 2.82	$ 0.11	$ 3.28	$ 2.77	$ 6.05	$ 3.35	$ 0.52	$ 6.05	$ 9.92
60	P3C1DAG3	5	21%	$ 26.49	$ -	$ -	$ 12.86	$ 11.44	$ -	$ -	$ -	$ 0.19	$ 1.92	$ 0.07	$ 6.97	$ 5.89	$ 12.86	$ 1.99	$ 0.11	$ 11.52	$ 13.62
61	P1C2TC1	23	88%	$ 30.29	$ -	$ -	$ 15.13	$ 13.46	$ -	$ -	$ -	$ 1.70	$ -	$ -	$ 8.20	$ 6.93	$ 15.13	$ 0.54	$ 0.46	$ 14.16	$ 15.16
62	P1C2TC3	3	88%	$ 30.39	$ -	$ -	$ 15.13	$ 13.46	$ -	$ -	$ -	$ 1.80	$ -	$ -	$ 8.20	$ 6.93	$ 15.13	$ 0.57	$ 0.48	$ 14.20	$ 15.25
63	P1C2THR1	26	77%	$ 29.60	$ 0.19	$ 0.16	$ 13.62	$ 12.11	$ -	$ -	$ -	$ 1.51	$ 1.10	$ 0.90	$ 7.57	$ 6.24	$ 13.81	$ 2.45	$ 0.44	$ 12.90	$ 15.79
64	P1C2THR3	19	77%	$ 28.87	$ 0.10	$ 0.08	$ 13.62	$ 12.11	$ -	$ -	$ -	$ 1.89	$ 0.59	$ 0.49	$ 7.48	$ 6.24	$ 13.72	$ 1.65	$ 0.53	$ 12.97	$ 15.15
65	P1C2TLR1	9	67%	$ 25.15	$ 0.05	$ 0.04	$ 9.84	$ 8.75	$ -	$ -	$ -	$ 1.51	$ 3.65	$ 1.32	$ 5.38	$ 4.51	$ 9.88	$ 5.33	$ 0.52	$ 9.41	$ 15.27
66	P1C2TLR3	6	61%	$ 22.92	$ 0.05	$ 0.04	$ 9.08	$ 8.07	$ -	$ -	$ -	$ 1.61	$ 2.98	$ 1.09	$ 4.97	$ 4.16	$ 9.13	$ 4.49	$ 0.53	$ 8.78	$ 13.80
67	P1C2TAG1	5	26%	$ 11.31	$ -	$ -	$ 4.54	$ 4.04	$ -	$ -	$ -	$ 0.38	$ 2.10	$ 0.25	$ 2.46	$ 2.08	$ 4.54	$ 2.41	$ 0.17	$ 4.19	$ 6.77
68	P1C2TAG3	28	28%	$ 14.06	$ -	$ -	$ 6.05	$ 5.38	$ -	$ -	$ -	$ 0.38	$ 2.01	$ 0.24	$ 3.28	$ 2.77	$ 6.05	$ 2.30	$ 0.17	$ 5.54	$ 8.01
69	P1C2OC	12	92%	$ 7.56	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 3.20	$ 4.35	$ -	$ -	$ -	$ 7.45	$ 0.10	$ -	$ 7.56
70	P1C2OHD	22	89%	$ 2.87	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 0.09	$ 1.37	$ 1.41	$ -	$ -	$ -	$ 2.76	$ 0.07	$ 0.04	$ 2.87
71	P1C2OLD	24	80%	$ 2.15	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1.32	$ 0.57	$ 0.26	$ -	$ -	$ -	$ 1.23	$ 0.37	$ 0.55	$ 2.15
72	P1C2OAG	3	44%	$ 3.37	$ -	$ -	$ 1.51	$ 1.35	$ -	$ -	$ -	$ 0.38	$ 0.11	$ 0.02	$ 0.82	$ 0.69	$ 1.51	$ 0.25	$ 0.11	$ 1.50	$ 1.86
73	P1C2DC1	6	66%	$ 16.94	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 8.07	$ 8.87	$ -	$ -	$ -	$ 16.68	$ 0.26	$ -	$ 16.94
74	P1C2DC3	7	71%	$ 18.32	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 0.57	$ 8.42	$ 9.34	$ -	$ -	$ -	$ 17.66	$ 0.42	$ 0.24	$ 18.32
75	P1C2DHR1	9	52%	$ 18.56	$ 0.19	$ 0.16	$ 5.30	$ 4.71	$ -	$ -	$ -	$ 0.19	$ 4.41	$ 3.61	$ 3.06	$ 2.43	$ 5.49	$ 7.94	$ 0.19	$ 4.95	$ 13.08
76	P1C2DHR3	27	57%	$ 10.64	$ 0.24	$ 0.20	$ -	$ -	$ -	$ -	$ -	$ 0.57	$ 5.27	$ 4.37	$ 0.24	$ -	$ 0.24	$ 9.64	$ 0.32	$ 0.43	$ 10.40
77	P1C2DLR1	11	50%	$ 26.96	$ -	$ -	$ 11.35	$ 10.09	$ -	$ -	$ -	$ -	$ 4.05	$ 1.47	$ 6.15	$ 5.20	$ 11.35	$ 5.39	$ 0.13	$ 10.09	$ 15.61
78	P1C2DLR3	10	52%	$ 29.32	$ -	$ -	$ 13.62	$ 12.11	$ -	$ -	$ -	$ 0.09	$ 2.56	$ 0.94	$ 7.38	$ 6.24	$ 13.62	$ 3.44	$ 0.11	$ 12.15	$ 15.70
79	P1C2DAG1	7	27%	$ 24.26	$ -	$ -	$ 10.59	$ 9.42	$ -	$ -	$ -	$ 1.89	$ 2.10	$ 0.25	$ 5.74	$ 4.85	$ 10.59	$ 2.89	$ 0.57	$ 10.20	$ 13.67
80	P1C2DAG3	22	25%	$ 17.00	$ -	$ -	$ 6.81	$ 6.06	$ -	$ -	$ -	$ 1.89	$ 2.01	$ 0.24	$ 3.69	$ 3.12	$ 6.81	$ 2.78	$ 0.57	$ 6.84	$ 10.19
81	P2C2TC1	3	88%	$ 32.66	$ -	$ -	$ 15.13	$ 13.46	$ -	$ -	$ -	$ 1.89	$ 1.02	$ 1.16	$ 8.20	$ 6.93	$ 15.13	$ 2.75	$ 0.54	$ 14.24	$ 17.53
82	P2C2TC3	3	88%	$ 32.67	$ -	$ -	$ 15.13	$ 13.46	$ -	$ -	$ -	$ 1.89	$ 1.03	$ 1.16	$ 8.20	$ 6.93	$ 15.13	$ 2.76	$ 0.54	$ 14.24	$ 17.54
83	P2C2THR1	12	77%	$ 28.78	$ 0.19	$ 0.16	$ 13.62	$ 12.11	$ -	$ -	$ -	$ 1.51	$ 0.64	$ 0.54	$ 7.57	$ 6.24	$ 13.81	$ 1.64	$ 0.43	$ 12.90	$ 14.96
84	P2C2THR3	3	75%	$ 28.66	$ 0.10	$ 0.08	$ 14.38	$ 12.78	$ -	$ -	$ -	$ 1.32	$ -	$ -	$ 7.89	$ 6.59	$ 14.47	$ 0.42	$ 0.36	$ 13.41	$ 14.19
85	P2C2TLR1	16	67%	$ 27.32	$ 0.10	$ 0.08	$ 13.62	$ 12.11	$ -	$ -	$ -	$ 1.42	$ -	$ -	$ 7.48	$ 6.24	$ 13.72	$ 0.45	$ 0.38	$ 12.78	$ 13.61
86	P2C2TLR3	20	63%	$ 26.45	$ 0.05	$ 0.04	$ 9.84	$ 8.75	$ -	$ -	$ -	$ 1.32	$ 4.69	$ 1.76	$ 5.38	$ 4.51	$ 9.88	$ 6.72	$ 0.51	$ 9.33	$ 16.56
87	P2C2TAG1	3	31%	$ 15.00	$ -	$ -	$ 6.05	$ 5.38	$ -	$ -	$ -	$ 1.32	$ 2.01	$ 0.24	$ 3.28	$ 2.77	$ 6.05	$ 2.60	$ 0.42	$ 5.93	$ 8.95
88	P2C2TAG3	18	27%	$ 5.94	$ -	$ -	$ 1.51	$ 1.35	$ -	$ -	$ -	$ 0.38	$ 2.39	$ 0.30	$ 0.82	$ 0.69	$ 1.51	$ 2.74	$ 0.18	$ 1.50	$ 4.42
89	P2C2OC	15	92%	$ 9.34	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 0.19	$ 3.88	$ 5.27	$ -	$ -	$ -	$ 9.08	$ 0.18	$ 0.08	$ 9.34
90	P2C2OHD	19	90%	$ 3.95	$ 0.05	$ 0.04	$ -	$ -	$ -	$ -	$ -	$ 0.09	$ 1.85	$ 1.91	$ 0.05	$ -	$ 0.05	$ 3.74	$ 0.08	$ 0.08	$ 3.90
91	P2C2OLD	3	82%	$ 2.41	$ 0.34	$ 0.28	$ -	$ -	$ -	$ -	$ -	$ 0.38	$ 0.98	$ 0.44	$ 0.34	$ -	$ 0.34	$ 1.51	$ 0.13	$ 0.43	$ 2.07
92	P2C2OAG	15	45%	$ 4.50	$ -	$ -	$ 1.51	$ 1.35	$ -	$ -	$ -	$ 1.42	$ 0.19	$ 0.03	$ 0.82	$ 0.69	$ 1.51	$ 0.67	$ 0.39	$ 1.93	$ 2.99

Number	Hypothetical Catchment	Best Sol. No.	Eff/ % Red	TPV Cost ($M)	Onsite Detention		Rain Garden		Porous Pavement		Roadside Bio		Detention Pond		Total						
															Private			Public			
					Private ($M)	Public ($M)	Private ($M)	Public ($M)	Private ($M)	Public ($M)	Private ($M)	Public ($M)	Public ($M)	Land ($M)	Capital ($M)	O&M ($M)	Total ($M)	Capital ($M)	O&M ($M)	I&E ($M)	Total ($M)
93	P2C2DC1	15	59%	$ 19.63	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 9.21	$ 10.42	$ -	$ -	$ -	$ 19.34	$ 0.30	$ -	$ 19.63
94	P2C2DC3	21	59%	$ 19.99	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 0.28	$ 9.24	$ 10.46	$ -	$ -	$ -	$ 19.50	$ 0.37	$ 0.12	$ 19.99
95	P2C2DHR1	8	43%	$ 20.20	$ 0.14	$ 0.12	$ 4.54	$ 4.04	$ -	$ -	$ -	$ 1.89	$ 5.13	$ 4.34	$ 2.60	$ 2.08	$ 4.68	$ 9.90	$ 0.67	$ 4.94	$ 15.52
96	P2C2DHR3	23	45%	$ 25.35	$ 0.14	$ 0.12	$ 8.32	$ 7.40	$ -	$ -	$ -	$ 0.95	$ 4.55	$ 3.87	$ 4.65	$ 3.81	$ 8.47	$ 8.57	$ 0.40	$ 7.91	$ 16.88
97	P2C2DLR1	11	55%	$ 30.72	$ -	$ -	$ 12.86	$ 11.44	$ -	$ -	$ -	$ -	$ 4.67	$ 1.75	$ 6.97	$ 5.89	$ 12.86	$ 6.27	$ 0.15	$ 11.44	$ 17.85
98	P2C2DLR3	14	51%	$ 31.42	$ -	$ -	$ 12.86	$ 11.44	$ -	$ -	$ -	$ 0.66	$ 4.69	$ 1.76	$ 6.97	$ 5.89	$ 12.86	$ 6.51	$ 0.33	$ 11.71	$ 18.55
99	P2C2DAG1	5	27%	$ 18.24	$ -	$ -	$ 7.57	$ 6.73	$ -	$ -	$ -	$ 1.70	$ 2.01	$ 0.24	$ 4.10	$ 3.47	$ 7.57	$ 2.72	$ 0.52	$ 7.43	$ 10.67
100	P2C2DAG3	13	25%	$ 15.27	$ -	$ -	$ 6.05	$ 5.38	$ -	$ -	$ -	$ 1.13	$ 2.39	$ 0.30	$ 3.28	$ 2.77	$ 6.05	$ 2.98	$ 0.38	$ 5.85	$ 9.22
101	P3C2TC1	28	87%	$ 33.02	$ -	$ -	$ 15.13	$ 13.46	$ -	$ -	$ -	$ 1.70	$ 1.28	$ 1.45	$ 8.20	$ 6.93	$ 15.13	$ 3.23	$ 0.50	$ 14.16	$ 17.89
102	P3C2TC3	3	87%	$ 30.39	$ -	$ -	$ 15.13	$ 13.46	$ -	$ -	$ -	$ 1.80	$ -	$ -	$ 8.20	$ 6.93	$ 15.13	$ 0.57	$ 0.48	$ 14.20	$ 15.25
103	P3C2THR1	9	73%	$ 27.62	$ -	$ -	$ 13.62	$ 12.11	$ -	$ -	$ -	$ 1.89	$ -	$ -	$ 7.38	$ 6.24	$ 13.62	$ 0.60	$ 0.51	$ 12.89	$ 14.00
104	P3C2THR3	28	74%	$ 29.23	$ 0.10	$ 0.08	$ 14.38	$ 12.78	$ -	$ -	$ -	$ 1.89	$ -	$ -	$ 7.89	$ 6.59	$ 14.47	$ 0.60	$ 0.51	$ 13.65	$ 14.75
105	P3C2TLR1	3	59%	$ 26.46	$ 0.05	$ 0.04	$ 12.86	$ 11.44	$ -	$ -	$ -	$ 1.23	$ 0.61	$ 0.23	$ 7.02	$ 5.89	$ 12.91	$ 1.21	$ 0.35	$ 11.99	$ 13.54
106	P3C2TLR3	6	56%	$ 27.15	$ -	$ -	$ 13.62	$ 12.11	$ -	$ -	$ -	$ 1.42	$ -	$ -	$ 7.38	$ 6.24	$ 13.62	$ 0.45	$ 0.38	$ 12.70	$ 13.53
107	P3C2TAG1	11	26%	$ 18.29	$ -	$ -	$ 8.32	$ 7.40	$ -	$ -	$ -	$ 0.66	$ 1.69	$ 0.21	$ 4.51	$ 3.81	$ 8.32	$ 2.06	$ 0.23	$ 7.68	$ 9.96
108	P3C2TAG3	10	24%	$ 20.81	$ -	$ -	$ 9.84	$ 8.75	$ -	$ -	$ -	$ 0.38	$ 1.65	$ 0.20	$ 5.33	$ 4.51	$ 9.84	$ 1.92	$ 0.15	$ 8.90	$ 10.97
109	P3C2OC	6	92%	$ 12.02	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 5.09	$ 6.93	$ -	$ -	$ -	$ 11.86	$ 0.16	$ -	$ 12.02
110	P3C2OHD	5	89%	$ 6.26	$ 0.29	$ 0.24	$ -	$ -	$ -	$ -	$ -	$ -	$ 2.82	$ 2.91	$ 0.29	$ -	$ 0.29	$ 5.64	$ 0.09	$ 0.24	$ 5.97
111	P3C2OLD	10	78%	$ 3.69	$ 0.43	$ 0.35	$ -	$ -	$ -	$ -	$ -	$ 0.28	$ 1.80	$ 0.82	$ 0.43	$ -	$ 0.43	$ 2.65	$ 0.13	$ 0.47	$ 3.26
112	P3C2OAG	15	44%	$ 18.82	$ -	$ -	$ 9.08	$ 8.07	$ -	$ -	$ -	$ 1.32	$ 0.29	$ 0.05	$ 4.92	$ 4.16	$ 9.08	$ 0.75	$ 0.36	$ 8.62	$ 9.74
113	P3C2DC1	5	48%	$ 27.64	$ -	$ -	$ 1.51	$ 1.35	$ -	$ -	$ -	$ 0.19	$ 11.56	$ 13.03	$ 0.82	$ 0.69	$ 1.51	$ 24.28	$ 0.42	$ 1.42	$ 26.13
114	P3C2DC3	24	44%	$ 28.10	$ -	$ -	$ 1.51	$ 1.35	$ -	$ -	$ -	$ 1.80	$ 11.08	$ 12.37	$ 0.82	$ 0.69	$ 1.51	$ 23.66	$ 0.84	$ 2.09	$ 26.59
115	P3C2DHR1	19	38%	$ 27.28	$ 0.14	$ 0.12	$ 7.57	$ 6.73	$ -	$ -	$ -	$ 1.32	$ 6.13	$ 5.27	$ 4.24	$ 3.47	$ 7.71	$ 11.62	$ 0.55	$ 7.40	$ 19.57
116	P3C2DHR3	11	36%	$ 27.08	$ 0.14	$ 0.12	$ 8.32	$ 7.40	$ -	$ -	$ -	$ 0.09	$ 5.93	$ 5.06	$ 4.65	$ 3.81	$ 8.47	$ 10.84	$ 0.22	$ 7.56	$ 18.61
117	P3C2DLR1	3	47%	$ 32.88	$ -	$ -	$ 15.13	$ 13.46	$ -	$ -	$ -	$ 0.09	$ 3.05	$ 1.15	$ 8.20	$ 6.93	$ 15.13	$ 4.12	$ 0.12	$ 13.50	$ 17.74
118	P3C2DLR3	25	43%	$ 33.26	$ -	$ -	$ 15.13	$ 13.46	$ -	$ -	$ -	$ 0.28	$ 3.18	$ 1.21	$ 8.20	$ 6.93	$ 15.13	$ 4.37	$ 0.18	$ 13.57	$ 18.13
119	P3C2DAG1	4	21%	$ 14.59	$ -	$ -	$ 5.30	$ 4.71	$ -	$ -	$ -	$ 1.42	$ 2.82	$ 0.35	$ 2.87	$ 2.43	$ 5.30	$ 3.53	$ 0.47	$ 5.30	$ 9.30
120	P3C2DAG3	26	21%	$ 24.68	$ -	$ -	$ 10.59	$ 9.42	$ -	$ -	$ -	$ 1.89	$ 2.47	$ 0.30	$ 5.74	$ 4.85	$ 10.59	$ 3.29	$ 0.59	$ 10.20	$ 14.08

Table 22. Detailed cost breakdown for "Best" cost-effectiveness optimization scenarios for hypothetical catchments assuming construction of BMP units are distributed over 30 years. All costs in 2013 dollars.

Number	Hypothetical Catchment	Best Sol. No.	Eff/ % Red	Total Cost ($M)	Onsite Detention		Rain Garden		Porous Pavement		Roadside Bio		Detention Pond		Total						
															Private			Public			
					Private ($M)	Public ($M)	Private ($M)	Public ($M)	Private ($M)	Public ($M)	Private ($M)	Public ($M)	Public ($M)	Land ($M)	Capital ($M)	O&M ($M)	Total ($M)	Capital ($M)	O&M ($M)	I&E ($M)	Total ($M)

Number	Hypothetical Catchment	Best Sol. No.	Eff/ % Red	Total Cost ($M)	Onsite Detention		Rain Garden		Porous Pavement		Roadside Bio		Detention Pond		Total						
															Private			Public			
					Private ($M)	Public ($M)	Private ($M)	Public ($M)	Private ($M)	Public ($M)	Private ($M)	Public ($M)	Public ($M)	Land ($M)	Capital ($M)	O&M ($M)	Total ($M)	Capital ($M)	O&M ($M)	I&E ($M)	Total ($M)
1	P1C1TC1	3	88%	$13.34	$ -	0	$7.18	$5.37	$ -	$ -	$ -	$0.80	$ -	$ -	$4.41	$2.77	$7.18	$0.31	$0.19	$5.67	$6.16
2	P1C1TC3	3	88%	$13.34	0	0	$7.18	$5.37	$ -	$ -	$ -	$0.80	$ -	$ -	$4.41	$2.77	$7.18	$0.31	$0.19	$5.67	$6.16
3	P1C1THR1	17	78%	$12.17	$0.05	$0.03	$6.46	$4.83	$ -	$ -	$ -	$0.80	$ -	$ -	$4.02	$2.49	$6.51	$0.31	$0.19	$5.16	$5.66
4	P1C1THR3	9	77%	$12.21	$0.08	$0.05	$6.46	$4.83	$ -	$ -	$ -	$0.80	$ -	$ -	$4.05	$2.49	$6.54	$0.31	$0.19	$5.18	$5.68
5	P1C1TLR1	5	64%	$9.77	$0.03	$0.02	$3.59	$2.68	$ -	$ -	$ -	$0.67	$2.16	$0.33	$2.23	$1.38	$3.61	$2.70	$0.21	$2.95	$5.86
6	P1C1TLR3	9	60%	$9.45	$ -	$ -	$5.02	$3.76	$ -	$ -	$ -	$0.67	$ -	$ -	$3.09	$1.94	$5.02	$0.26	$0.16	$4.01	$4.43
7	P1C1TAG1	8	27%	$6.23	$ -	$ -	$2.51	$1.88	$ -	$ -	$ -	$0.75	$1.01	$0.04	$1.54	$0.97	$2.51	$1.31	$0.21	$2.16	$3.68
8	P1C1TAG3	5	29%	$7.30	$ -	$ -	$3.23	$2.42	$ -	$ -	$ -	$0.50	$1.07	$0.04	$1.99	$1.24	$3.23	$1.28	$0.15	$2.60	$4.03
9	P1C1OC	14	92%	$5.99	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$1.71	$2.28	$ -	$ -	$ -	$3.95	$0.04	$ -	$3.99
10	P1C1OHD	20	89%	$1.53	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$0.73	$0.43	$ -	$ -	$ -	$1.14	$0.02	$ -	$1.16
11	P1C1OLD	17	80%	$0.50	$0.03	$0.02	$ -	$ -	$ -	$ -	$ -	$0.04	$0.30	$0.06	$0.03	$ -	$0.03	$0.37	$0.02	$0.03	$0.42
12	P1C1OAG	6	44%	$1.42	$ -	$ -	$0.72	$0.54	$ -	$ -	$ -	$0.08	$0.08	$0.00	$0.44	$0.28	$0.72	$0.11	$0.02	$0.57	$0.70
13	P1C1DC1	6	66%	$13.04	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$4.31	$4.64	$ -	$ -	$ -	$8.85	$0.10	$ -	$8.95
14	P1C1DC3	11	71%	$13.68	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$4.49	$4.89	$ -	$ -	$ -	$9.27	$0.11	$ -	$9.38
15	P1C1DHR1	9	51%	$7.79	$0.10	$0.06	$1.79	$1.34	$ -	$ -	$ -	$0.08	$2.36	$1.09	$1.21	$0.69	$1.90	$3.42	$0.08	$1.44	$4.94
16	P1C1DHR3	10	56%	$6.09	$0.10	$0.06	$ -	$ -	$ -	$ -	$ -	$0.63	$2.81	$1.32	$0.10	$ -	$0.10	$4.31	$0.22	$0.30	$4.82
17	P1C1DLR1	10	52%	$12.96	$ -	$ -	$6.46	$4.83	$ -	$ -	$ -	$ -	$1.30	$0.20	$3.97	$2.49	$6.46	$1.46	$0.03	$4.83	$6.33
18	P1C1DLR3	17	50%	$12.80	$0.03	$0.02	$6.10	$4.56	$ -	$ -	$ -	$0.04	$1.59	$0.25	$3.78	$2.35	$6.13	$1.81	$0.05	$4.59	$6.46
19	P1C1DAG1	6	22%	$7.56	$ -	$ -	$3.23	$2.42	$ -	$ -	$ -	$0.71	$1.12	$0.04	$1.99	$1.24	$3.23	$1.41	$0.20	$2.68	$4.29
20	P1C1DAG3	13	25%	$9.23	$ -	$ -	$4.31	$3.22	$ -	$ -	$ -	$0.67	$0.97	$0.04	$2.65	$1.66	$4.31	$1.24	$0.19	$3.47	$4.89
21	P2C1TC1	9	88%	$15.03	$ -	$ -	$7.18	$5.37	$ -	$ -	$ -	$0.80	$0.55	$0.61	$4.41	$2.77	$7.18	$1.45	$0.21	$5.67	$7.32
22	P2C1TC3	3	88%	$13.34	$ -	$ -	$7.18	$5.37	$ -	$ -	$ -	$0.80	$ -	$ -	$4.41	$2.77	$7.18	$0.31	$0.19	$5.67	$6.16
23	P2C1THR1	5	78%	$12.82	$0.03	$0.02	$6.46	$4.83	$ -	$ -	$ -	$0.84	$0.34	$0.16	$4.00	$2.49	$6.49	$0.82	$0.21	$5.16	$6.19
24	P2C1THR3	22	78%	$13.38	$ -	$ -	$6.82	$5.10	$ -	$ -	$ -	$0.80	$0.35	$0.17	$4.19	$2.63	$6.82	$0.81	$0.20	$5.40	$6.41
25	P2C1TLR1	6	66%	$11.06	$ -	$ -	$4.31	$3.22	$ -	$ -	$ -	$0.63	$2.24	$0.35	$2.65	$1.66	$4.31	$2.78	$0.21	$3.46	$6.44
26	P2C1TLR3	9	63%	$12.16	$ -	$ -	$4.67	$3.49	$ -	$ -	$ -	$0.75	$2.50	$0.39	$2.87	$1.80	$4.67	$3.13	$0.24	$3.77	$7.14
27	P2C1TAG1	3	31%	$6.71	$ -	$ -	$2.87	$2.15	$ -	$ -	$ -	$0.54	$1.07	$0.04	$1.76	$1.11	$2.87	$1.29	$0.16	$2.35	$3.80
28	P2C1TAG3	10	30%	$7.40	$ -	$ -	$3.59	$2.68	$ -	$ -	$ -	$0.17	$0.89	$0.04	$2.21	$1.38	$3.59	$0.97	$0.06	$2.75	$3.78
29	P2C1OC	8	92%	$7.26	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$2.07	$2.76	$ -	$ -	$ -	$4.78	$0.05	$ -	$4.83
30	P2C1OHD	12	90%	$2.41	$0.18	$0.11	$ -	$ -	$ -	$ -	$ -	$0.04	$0.99	$0.58	$0.18	$ -	$0.18	$1.56	$0.03	$0.13	$1.72
31	P2C1OLD	20	82%	$1.04	$0.21	$0.13	$ -	$ -	$ -	$ -	$ -	$ -	$0.52	$0.10	$0.21	$ -	$0.21	$0.61	$0.01	$0.13	$0.75
32	P2C1OAG	16	46%	$3.90	$ -	$ -	$1.79	$1.34	$ -	$ -	$ -	$0.67	$0.08	$0.00	$1.10	$0.69	$1.79	$0.34	$0.16	$1.59	$2.10
33	P2C1DC1	10	59%	$15.34	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$0.17	$4.92	$5.46	$ -	$ -	$ -	$10.32	$0.16	$0.06	$10.54
34	P2C1DC3	24	59%	$15.36	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$0.13	$4.93	$5.48	$ -	$ -	$ -	$10.34	$0.15	$0.05	$10.53
35	P2C1DHR1	16	45%	$12.28	$ -	$ -	$3.95	$2.95	$ -	$ -	$ -	$0.17	$2.74	$1.31	$2.43	$1.52	$3.95	$4.05	$0.11	$3.02	$7.17
36	P2C1DHR3	10	45%	$12.15	$0.08	$0.05	$3.59	$2.68	$ -	$ -	$ -	$0.46	$2.77	$1.34	$2.28	$1.38	$3.67	$4.22	$0.18	$2.90	$7.30
37	P2C1DLR1	6	53%	$13.57	$0.03	$0.02	$6.82	$5.10	$ -	$ -	$ -	$ -	$1.25	$0.20	$4.22	$2.63	$6.84	$1.41	$0.03	$5.12	$6.56

Number	Hypothetical Catchment	Best Sol. No.	Eff/ % Red	Total Cost ($M)	Onsite Detention		Rain Garden		Porous Pavement		Roadside Bio		Detention Pond		Total						
															Private			Public			
					Private ($M)	Public ($M)	Private ($M)	Public ($M)	Private ($M)	Public ($M)	Private ($M)	Public ($M)	Public ($M)	Land ($M)	Capital ($M)	O&M ($M)	Total ($M)	Capital ($M)	O&M ($M)	I&E ($M)	Total ($M)
38	P2C1DLR3	14	48%	$13.04	$0.03	$0.02	$6.46	$4.83	$ -	$ -	$ -	$0.08	$1.25	$0.20	$4.00	$2.49	$6.49	$1.45	$0.05	$4.88	$6.38
39	P2C1DAG1	4	26%	$8.13	$ -	$ -	$3.59	$2.68	$ -	$ -	$ -	$0.71	$1.07	$0.04	$2.21	$1.38	$3.59	$1.36	$0.20	$2.95	$4.51
40	P2C1DAG3	21	23%	$5.60	$ -	$ -	$2.15	$1.61	$ -	$ -	$ -	$0.46	$1.28	$0.05	$1.32	$0.83	$2.15	$1.47	$0.14	$1.78	$3.40
41	P3C1TC1	3	87%	$15.50	$ -	$ -	$7.18	$5.37	$ -	$ -	$ -	$0.84	$0.69	$0.76	$4.41	$2.77	$7.18	$1.75	$0.22	$5.68	$7.65
42	P3C1TC3	3	87%	$13.34	$ -	$ -	$7.18	$5.37	$ -	$ -	$ -	$0.80	$ -	$ -	$4.41	$2.77	$7.18	$0.31	$0.19	$5.67	$6.16
43	P3C1THR1	3	73%	$14.46	$0.05	$0.03	$6.82	$5.10	$ -	$ -	$ -	$0.67	$0.93	$0.46	$4.24	$2.63	$6.87	$1.63	$0.18	$5.38	$7.19
44	P3C1THR3	22	73%	$12.83	$ -	$ -	$6.46	$4.83	$ -	$ -	$ -	$0.67	$0.45	$0.22	$3.97	$2.49	$6.46	$0.92	$0.17	$5.08	$6.17
45	P3C1TLR1	5	58%	$11.16	$0.03	$0.02	$3.59	$2.68	$ -	$ -	$ -	$0.63	$3.25	$0.51	$2.23	$1.38	$3.61	$3.93	$0.23	$2.93	$7.09
46	P3C1TLR3	4	56%	$11.92	$ -	$ -	$6.46	$4.83	$ -	$ -	$ -	$0.63	$ -	$ -	$3.97	$2.49	$6.46	$0.24	$0.15	$5.07	$5.46
47	P3C1TAG1	5	23%	$4.84	$ -	$ -	$1.79	$1.34	$ -	$ -	$ -	$0.25	$1.35	$0.05	$1.10	$0.69	$1.79	$1.47	$0.09	$1.44	$3.00
48	P3C1TAG3	21	21%	$6.76	$ -	$ -	$3.23	$2.42	$ -	$ -	$ -	$0.17	$0.88	$0.03	$1.99	$1.24	$3.23	$0.96	$0.06	$2.48	$3.50
49	P3C1OC	11	92%	$9.66	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$0.13	$2.72	$3.63	$ -	$ -	$ -	$6.33	$0.10	$0.05	$6.47
50	P3C1OHD	17	89%	$3.54	$0.03	$0.02	$ -	$ -	$ -	$ -	$ -	$0.34	$1.51	$0.88	$0.03	$ -	$0.03	$2.48	$0.12	$0.14	$2.74
51	P3C1OLD	11	79%	$1.35	$0.03	$0.02	$ -	$ -	$ -	$ -	$ -	$ -	$0.96	$0.18	$0.03	$ -	$0.03	$1.12	$0.02	$0.02	$1.16
52	P3C1OAG	5	46%	$11.34	$ -	$ -	$6.10	$4.56	$ -	$ -	$ -	$0.54	$0.12	$0.01	$3.75	$2.35	$6.10	$0.34	$0.13	$4.77	$5.24
53	P3C1DC1	14	48%	$19.63	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$0.63	$6.17	$6.82	$ -	$ -	$ -	$13.09	$0.30	$0.23	$13.62
54	P3C1DC3	21	44%	$21.27	$ -	$ -	$1.44	$1.07	$ -	$ -	$ -	$0.67	$5.91	$6.48	$0.88	$0.55	$1.44	$12.50	$0.30	$1.32	$14.13
55	P3C1DHR1	3	40%	$15.35	$0.08	$0.05	$5.02	$3.76	$ -	$ -	$ -	$0.17	$3.27	$1.60	$3.17	$1.94	$5.10	$4.85	$0.12	$3.87	$8.84
56	P3C1DHR3	9	35%	$12.41	$0.08	$0.05	$3.23	$2.42	$ -	$ -	$ -	$0.59	$3.17	$1.53	$2.06	$1.24	$3.31	$4.85	$0.22	$2.68	$7.75
57	P3C1DLR1	8	47%	$15.01	$ -	$ -	$6.10	$4.56	$ -	$ -	$ -	$0.13	$3.25	$0.51	$3.75	$2.35	$6.10	$3.73	$0.11	$4.61	$8.45
58	P3C1DLR3	7	41%	$14.12	$ -	$ -	$6.82	$5.10	$ -	$ -	$ -	$ -	$1.70	$0.27	$4.19	$2.63	$6.82	$1.93	$0.04	$5.10	$7.07
59	P3C1DAG1	7	23%	$7.34	$ -	$ -	$2.87	$2.15	$ -	$ -	$ -	$0.71	$1.50	$0.06	$1.76	$1.11	$2.87	$1.80	$0.21	$2.41	$4.42
60	P3C1DAG3	5	21%	$11.85	$ -	$ -	$6.10	$4.56	$ -	$ -	$ -	$0.08	$1.03	$0.04	$3.75	$2.35	$6.10	$1.07	$0.04	$4.59	$5.71
61	P1C2TC1	23	88%	$13.30	$ -	$ -	$7.18	$5.37	$ -	$ -	$ -	$0.75	$ -	$ -	$4.41	$2.77	$7.18	$0.29	$0.18	$5.65	$6.12
62	P1C2TC3	3	88%	$13.34	$ -	$ -	$7.18	$5.37	$ -	$ -	$ -	$0.80	$ -	$ -	$4.41	$2.77	$7.18	$0.31	$0.19	$5.67	$6.16
63	P1C2THR1	26	77%	$13.62	$0.10	$0.06	$6.46	$4.83	$ -	$ -	$ -	$0.67	$0.59	$0.48	$4.07	$2.49	$6.56	$1.31	$0.18	$5.14	$6.63
64	P1C2THR3	19	77%	$13.01	$0.05	$0.03	$6.46	$4.83	$ -	$ -	$ -	$0.84	$0.31	$0.26	$4.02	$2.49	$6.51	$0.89	$0.21	$5.18	$6.27
65	P1C2TLR1	9	67%	$12.13	$0.03	$0.02	$4.67	$3.49	$ -	$ -	$ -	$0.67	$1.95	$0.70	$2.89	$1.80	$4.69	$2.86	$0.21	$3.76	$6.82
66	P1C2TLR3	6	61%	$10.97	$0.03	$0.02	$4.31	$3.22	$ -	$ -	$ -	$0.71	$1.59	$0.58	$2.67	$1.66	$4.33	$2.41	$0.21	$3.50	$6.12
67	P1C2TAG1	5	26%	$5.31	$ -	$ -	$2.15	$1.61	$ -	$ -	$ -	$0.17	$1.12	$0.13	$1.32	$0.83	$2.15	$1.29	$0.07	$1.67	$3.03
68	P1C2TAG3	28	28%	$6.50	$ -	$ -	$2.87	$2.15	$ -	$ -	$ -	$0.17	$1.07	$0.13	$1.76	$1.11	$2.87	$1.24	$0.07	$2.21	$3.51
69	P1C2OC	12	92%	$6.06	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$1.71	$2.32	$ -	$ -	$ -	$3.98	$0.04	$ -	$4.02
70	P1C2OHD	22	89%	$2.18	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$0.04	$0.73	$0.75	$ -	$ -	$ -	$1.48	$0.03	$0.02	$1.52
71	P1C2OLD	24	80%	$1.15	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$0.59	$0.30	$0.14	$ -	$ -	$ -	$0.66	$0.15	$0.22	$1.03
72	P1C2OAG	3	44%	$1.50	$ -	$ -	$0.72	$0.54	$ -	$ -	$ -	$0.17	$0.06	$0.01	$0.44	$0.28	$0.72	$0.13	$0.04	$0.60	$0.78
73	P1C2DC1	6	66%	$13.18	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$4.31	$4.72	$ -	$ -	$ -	$8.92	$0.10	$ -	$9.02
74	P1C2DC3	7	71%	$14.08	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$0.25	$4.49	$4.97	$ -	$ -	$ -	$9.45	$0.17	$0.09	$9.71
75	P1C2DHR1	9	52%	$10.60	$0.10	$0.06	$2.51	$1.88	$ -	$ -	$ -	$0.08	$2.36	$1.92	$1.65	$0.97	$2.62	$4.25	$0.08	$1.97	$6.30

Number	Hypothetical Catchment	Best Sol. No.	Eff/ % Red	Total Cost ($M)	Onsite Detention		Rain Garden		Porous Pavement		Roadside Bio		Detention Pond		Total						
															Private			Public			
					Private ($M)	Public ($M)	Private ($M)	Public ($M)	Private ($M)	Public ($M)	Private ($M)	Public ($M)	Public ($M)	Land ($M)	Capital ($M)	O&M ($M)	Total ($M)	Capital ($M)	O&M ($M)	I&E ($M)	Total ($M)
76	P1C2DHR3	27	57%	$7.64	$0.13	$0.08	$ -	$ -	$ -	$ -	$ -	$0.25	$2.81	$2.32	$0.13	$ -	$0.13	$5.16	$0.13	$0.17	$5.46
77	P1C2DLR1	11	50%	$13.04	$ -	$ -	$5.38	$4.03	$ -	$ -	$ -	$ -	$2.16	$0.78	$3.31	$2.07	$5.38	$2.89	$0.05	$4.03	$6.97
78	P1C2DLR3	10	52%	$13.64	$ -	$ -	$6.46	$4.83	$ -	$ -	$ -	$0.04	$1.36	$0.50	$3.97	$2.49	$6.46	$1.85	$0.04	$4.85	$6.74
79	P1C2DAG1	7	27%	$11.00	$ -	$ -	$5.02	$3.76	$ -	$ -	$ -	$0.84	$1.12	$0.13	$3.09	$1.94	$5.02	$1.55	$0.23	$4.07	$5.85
80	P1C2DAG3	22	25%	$7.79	$ -	$ -	$3.23	$2.42	$ -	$ -	$ -	$0.84	$1.07	$0.13	$1.99	$1.24	$3.23	$1.50	$0.23	$2.73	$4.45
81	P2C2TC1	3	88%	$15.09	$ -	$ -	$7.18	$5.37	$ -	$ -	$ -	$0.84	$0.55	$0.62	$4.41	$2.77	$7.18	$1.47	$0.22	$5.68	$7.37
82	P2C2TC3	3	88%	$15.09	$ -	$ -	$7.18	$5.37	$ -	$ -	$ -	$0.84	$0.55	$0.62	$4.41	$2.77	$7.18	$1.48	$0.22	$5.68	$7.37
83	P2C2THR1	12	77%	$13.01	$0.10	$0.06	$6.46	$4.83	$ -	$ -	$ -	$0.67	$0.34	$0.29	$4.07	$2.49	$6.56	$0.88	$0.17	$5.14	$6.20
84	P2C2THR3	3	75%	$12.59	$0.05	$0.03	$6.82	$5.10	$ -	$ -	$ -	$0.59	$ -	$ -	$4.24	$2.63	$6.87	$0.23	$0.14	$5.35	$5.72
85	P2C2TLR1	16	67%	$12.00	$0.05	$0.03	$6.46	$4.83	$ -	$ -	$ -	$0.63	$ -	$ -	$4.02	$2.49	$6.51	$0.24	$0.15	$5.10	$5.49
86	P2C2TLR3	20	63%	$13.05	$0.03	$0.02	$4.67	$3.49	$ -	$ -	$ -	$0.59	$2.50	$0.94	$2.89	$1.80	$4.69	$3.61	$0.20	$3.72	$7.53
87	P2C2TAG1	3	31%	$6.91	$ -	$ -	$2.87	$2.15	$ -	$ -	$ -	$0.59	$1.07	$0.13	$1.76	$1.11	$2.87	$1.40	$0.17	$2.37	$3.93
88	P2C2TAG3	18	27%	$3.00	$ -	$ -	$0.72	$0.54	$ -	$ -	$ -	$0.17	$1.28	$0.16	$0.44	$0.28	$0.72	$1.47	$0.07	$0.60	$2.14
89	P2C2OC	15	92%	$7.42	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$0.08	$2.07	$2.80	$ -	$ -	$ -	$4.85	$0.07	$0.03	$4.96
90	P2C2OHD	19	90%	$2.98	$0.03	$0.02	$ -	$ -	$ -	$ -	$ -	$0.04	$0.99	$1.02	$0.03	$ -	$0.03	$2.00	$0.03	$0.03	$2.06
91	P2C2OLD	3	82%	$1.42	$0.18	$0.11	$ -	$ -	$ -	$ -	$ -	$0.17	$0.52	$0.24	$0.18	$ -	$0.18	$0.81	$0.05	$0.17	$1.03
92	P2C2OAG	15	45%	$2.02	$ -	$ -	$0.72	$0.54	$ -	$ -	$ -	$0.63	$0.10	$0.02	$0.44	$0.28	$0.72	$0.36	$0.15	$0.77	$1.29
93	P2C2DC1	15	59%	$15.34	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$4.92	$5.54	$ -	$ -	$ -	$10.34	$0.12	$ -	$10.46
94	P2C2DC3	21	59%	$15.52	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$0.13	$4.93	$5.56	$ -	$ -	$ -	$10.42	$0.15	$0.05	$10.62
95	P2C2DHR1	8	43%	$11.80	$0.08	$0.05	$2.15	$1.61	$ -	$ -	$ -	$0.84	$2.74	$2.31	$1.40	$0.83	$2.23	$5.30	$0.27	$1.97	$7.54
96	P2C2DHR3	23	45%	$13.74	$0.08	$0.05	$3.95	$2.95	$ -	$ -	$ -	$0.42	$2.43	$2.06	$2.50	$1.52	$4.03	$4.59	$0.16	$3.16	$7.90
97	P2C2DLR1	11	55%	$14.90	$ -	$ -	$6.10	$4.56	$ -	$ -	$ -	$ -	$2.49	$0.93	$3.75	$2.35	$6.10	$3.36	$0.06	$4.56	$7.98
98	P2C2DLR3	14	51%	$15.22	$ -	$ -	$6.10	$4.56	$ -	$ -	$ -	$0.29	$2.50	$0.94	$3.75	$2.35	$6.10	$3.49	$0.13	$4.67	$8.30
99	P2C2DAG1	5	27%	$8.34	$ -	$ -	$3.59	$2.68	$ -	$ -	$ -	$0.75	$1.07	$0.13	$2.21	$1.38	$3.59	$1.46	$0.21	$2.97	$4.64
100	P2C2DAG3	13	25%	$7.10	$ -	$ -	$2.87	$2.15	$ -	$ -	$ -	$0.50	$1.28	$0.16	$1.76	$1.11	$2.87	$1.60	$0.15	$2.34	$4.09
101	P3C2TC1	28	87%	$15.43	$ -	$ -	$7.18	$5.37	$ -	$ -	$ -	$0.75	$0.69	$0.77	$4.41	$2.77	$7.18	$1.73	$0.20	$5.65	$7.58
102	P3C2TC3	3	87%	$13.34	$ -	$ -	$7.18	$5.37	$ -	$ -	$ -	$0.80	$ -	$ -	$4.41	$2.77	$7.18	$0.31	$0.19	$5.67	$6.16
103	P3C2THR1	9	73%	$12.13	$ -	$ -	$6.46	$4.83	$ -	$ -	$ -	$0.84	$ -	$ -	$3.97	$2.49	$6.46	$0.32	$0.20	$5.14	$5.67
104	P3C2THR3	28	74%	$12.84	$0.05	$0.03	$6.82	$5.10	$ -	$ -	$ -	$0.84	$ -	$ -	$4.24	$2.63	$6.87	$0.32	$0.20	$5.44	$5.97
105	P3C2TLR1	3	59%	$11.81	$0.03	$0.02	$6.10	$4.56	$ -	$ -	$ -	$0.54	$0.33	$0.12	$3.78	$2.35	$6.13	$0.65	$0.14	$4.78	$5.57
106	P3C2TLR3	6	56%	$11.92	$ -	$ -	$6.46	$4.83	$ -	$ -	$ -	$0.63	$ -	$ -	$3.97	$2.49	$6.46	$0.24	$0.15	$5.07	$5.46
107	P3C2TAG1	11	26%	$8.31	$ -	$ -	$3.95	$2.95	$ -	$ -	$ -	$0.29	$0.90	$0.11	$2.43	$1.52	$3.95	$1.11	$0.09	$3.06	$4.26
108	P3C2TAG3	10	24%	$9.40	$ -	$ -	$4.67	$3.49	$ -	$ -	$ -	$0.17	$0.88	$0.11	$2.87	$1.80	$4.67	$1.03	$0.06	$3.55	$4.64
109	P3C2OC	6	92%	$9.65	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$2.72	$3.68	$ -	$ -	$ -	$6.34	$0.07	$ -	$6.40
110	P3C2OHD	5	89%	$4.67	$0.15	$0.09	$ -	$ -	$ -	$ -	$ -	$ -	$1.51	$1.55	$0.15	$ -	$0.15	$3.02	$0.04	$0.09	$3.15
111	P3C2OLD	10	78%	$2.28	$0.23	$0.14	$ -	$ -	$ -	$ -	$ -	$0.13	$0.96	$0.44	$0.23	$ -	$0.23	$1.42	$0.05	$0.19	$1.66
112	P3C2OAG	15	44%	$8.32	$ -	$ -	$4.31	$3.22	$ -	$ -	$ -	$0.59	$0.16	$0.03	$2.65	$1.66	$4.31	$0.41	$0.15	$3.44	$3.99
113	P3C2DC1	5	48%	$20.54	$ -	$ -	$0.72	$0.54	$ -	$ -	$ -	$0.08	$6.17	$6.93	$0.44	$0.28	$0.72	$12.99	$0.17	$0.57	$13.72

Number	Hypothetical Catchment	Best Sol. No.	Eff/ % Red	Total Cost ($M)	Onsite Detention		Rain Garden		Porous Pavement		Roadside Bio		Detention Pond		Total						
															Private			Public			
					Private ($M)	Public ($M)	Private ($M)	Public ($M)	Private ($M)	Public ($M)	Private ($M)	Public ($M)	Public ($M)	Land ($M)	Capital ($M)	O&M ($M)	Total ($M)	Capital ($M)	O&M ($M)	I&E ($M)	Total ($M)
114	P3C2DC3	24	44%	$20.33	$ -	$ -	$0.72	$0.54	$ -	$ -	$ -	$0.80	$5.91	$6.58	$0.44	$0.28	$0.72	$12.65	$0.33	$0.83	$13.82
115	P3C2DHR1	19	38%	$15.53	$0.08	$0.05	$3.59	$2.68	$ -	$ -	$ -	$0.59	$3.27	$2.80	$2.28	$1.38	$3.67	$6.22	$0.22	$2.95	$9.39
116	P3C2DHR3	11	36%	$15.30	$0.08	$0.05	$3.95	$2.95	$ -	$ -	$ -	$0.04	$3.17	$2.69	$2.50	$1.52	$4.03	$5.80	$0.09	$3.02	$8.90
117	P3C2DLR1	3	47%	$15.36	$ -	$ -	$7.18	$5.37	$ -	$ -	$ -	$0.04	$1.63	$0.61	$4.41	$2.77	$7.18	$2.21	$0.05	$5.38	$7.65
118	P3C2DLR3	25	43%	$15.58	$ -	$ -	$7.18	$5.37	$ -	$ -	$ -	$0.13	$1.70	$0.64	$4.41	$2.77	$7.18	$2.35	$0.07	$5.42	$7.83
119	P3C2DAG1	4	21%	$6.87	$ -	$ -	$2.51	$1.88	$ -	$ -	$ -	$0.63	$1.50	$0.18	$1.54	$0.97	$2.51	$1.90	$0.19	$2.11	$4.20
120	P3C2DAG3	26	21%	$11.24	$ -	$ -	$5.02	$3.76	$ -	$ -	$ -	$0.84	$1.32	$0.16	$3.09	$1.94	$5.02	$1.77	$0.23	$4.07	$6.07