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# Stormwater Retrofit Implementation Strategies for Water Resources Inventory Area (WRIA) 9

**A Project Funded in Part by the Puget Sound Watershed Management Assistance Program FY 2009**

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King County

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# Stormwater Retrofit Implementation Strategies for Water Resources Inventory Area (WRIA) 9

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**Funded by the** United States Environmental Protection Agency, King County, University of Washington, and the Cities of Auburn, Covington, and SeaTac

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# EXECUTIVE SUMMARY

Stormwater from developed landscapes is one of the biggest threats to water quality and ecological health of the waters of Puget Sound, both fresh and marine. The goal of this project is to estimate the numbers of different types of stormwater treatment facilities, and their costs, necessary to rehabilitate stream flows and water quality to near-pre-development conditions within the Water Resource Inventory Area (WRIA) 9. This report summarizes the tasks undertaken and the results of this effort, and also presents a discussion of strategic options for implementing improved stormwater management.

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. Within this area, stream flow and water quality were measured, and watershed hydrology and water quality models were developed. Using this information, stormwater facilities required to restore stream flow and water quality were modeled using 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). Additional analyses were made on the impacts of population growth and economic activity on stormwater facility construction, the uncertainty associated with climate change impacts on stormwater facility sizing, and the presence of existing facilities.

This study found that to improve stream flow and water quality to near-pre-development conditions in the study area, stormwater treatment facilities equivalent to over two million rain garden units, 190,000 roadside bioretention units, 75,000 detention pond units, and 34,000 cisterns are needed.[1] As required by existing stormwater regulations, most of the facilities need to treat stormwater runoff from nearly one-half of the landscape are projected to be constructed as part of new and redevelopment over the next 30 years, although some detention ponds would be unlikely to be constructed as part of single family residential redevelopment.

A public program to construct the rest of the facilities necessary to improve stream flow and water quality could be developed. A stormwater retrofit program focusing on roads and highways would require building about 6,000 roadside bioswale units and over 160 detention units per year for 30 years. A stormwater program intended to build stormwater facilities to provide treatment for all other developed land, meaning developed private and public parcels that are not roads or highways and are not newly developed or redeveloped in the next 30 years, would require building about 31,000 rain garden units, about 800 detention units, and about 450 cisterns per year for 30 years. Uncertainty associated with climate change impacts on rainfall amounts and patterns are likely to increase facility

[1] The study used unit BMPs designed to treat runoff from a designated unit area. BMP design details are available in the SUSTAIN modeling report (King County 2014). Each rain garden and roadside bioretention unit was 100 ft2 in area. Three different detention pond units were designed to treat low, medium and high intensity development runoff. The average size of a detention pond unit was 2,500 ft2 and 5 ft deep. Each cistern unit had a storage capacity of 3,000 gallons.

needs by about 10 percent, although this is large uncertainty with this estimate and it is possible that needs may actually decrease by up to about 10 percent.

Construction of these facilities would require a substantial expansion of public stormwater programs in every jurisdiction. Expansion would include construction of facilities not built as part of new or redevelopment, operation and maintenance of publically-owned facilities, and inspection and enforcement of privately-owned facilities. Public expenditures on operation and maintenance and inspection and enforcement would increase annually as more facilities are built. Based on a 30 year period of construction for all facilities, the first year of public capital cost would be about $165M for the project area. Operation and maintenance of public facilities would increase annually for 30 years before leveling off. If all facilities were actually being operated and maintained in 2013, the annual public cost would be about $130M. If all private facilities built as part of new and redevelopment were actually being inspected, and any necessary enforcement actions taken, in 2013, the annual public cost would be about an additional $370M per year. Actual future costs depend on assumptions regarding inflation and discount rates

Key findings from this study include:

1. Stormwater mitigation requirements for new and redevelopment are likely to result in substantial improvements in stormwater treatment over time since future growth is focused on redevelopment of already urbanized areas. This leads to the counterintuitive conclusion that future population growth will largely result in improved stormwater treatment, as rural sprawl is limited and urban areas are upgraded with modern stormwater facilities.
2. A very substantial public investment will be required for routine inspection and enforcement activities on all of the private facilities projected to be constructed due to new and redevelopment stormwater mitigation requirements. It is unclear whether local surface water management fees could be increased sufficiently to cover this cost. Whether inspections could occur less frequently while maintaining facility performance is likely worth future investigation.
3. The percentage of the landscape that is projected to receive stormwater treatment as a result of new and redevelopment increases with longer planning horizons. By 2040, nearly ½ of the landscape is projected receive at least some stormwater treatment due to new or redevelopment. At this rate, nearly the entire landscape, except roads and highways, would receive treatment before the end of the century.
4. If quicker restoration is desired, a public stormwater retrofit program could be implemented to construct facilities where redevelopment is not occurring. Such a program could focus on roads and highways, or could also include constructing facilities to treat runoff from parcels in high priority areas that are unlikely to be redeveloped in the near future. It is likely that federal, state, or regional funds would be needed to fund construction of these facilities. It is unknown whether local surface water management fees could be increased sufficiently to fund the operation and maintenance of these facilities.

# 1.0. INTRODUCTION

Rain is a part of life in the Pacific Northwest. Stormwater runoff is rain (or snowmelt) that flows off developed land—such as roads, parking areas, rooftops and lawns—into nearby streams, rivers and Puget Sound. Runoff enters these waterbodies either directly or through drainage systems.

Stormwater runoff poses a high risk to the health of Puget Sound by causing two major problems.

First, stormwater transports a mixture of pollutants such as petroleum products, heavy metals, animal waste and sediments from construction sites, roads, highways, parking lots, lawns and other developed lands, with the following results documented for Puget Sound:

- Stormwater pollution has harmed virtually all urban creeks, streams and rivers in Puget Sound (Booth et al. 2004).
- Stormwater is the leading contributor to water quality pollution of urban waterways (Ecology 2011).
- Two species of salmon and bull trout are threatened with extinction under the federal Endangered Species Act. Loss of habitat due to stormwater and development is one of the causes (Moscrip and Montgomery, 1997).
- Shellfish harvest at many beaches is restricted or prohibited due to pollution. Stormwater runoff is often one of the causes (WDOH 2012).
- Stormwater likely contributes to the killing of high percentages of healthy coho salmon in Seattle creeks within hours of the fish entering the creeks, before the fish are able to spawn (Scholz et al. 2011).
- English sole in urban estuaries are more likely to develop cancerous lesions on their livers. Stormwater likely plays a role (Johnson et al. 2008).

Second, during rain events, impervious area such as pavements and roof cause rain to run off quickly into receiving waters as opposed to soaking into the ground and flowing slowly to streams. This results in “flashy” stream flows that quickly increase then quickly decrease with the start and stop of each storm. Excessive stream flashiness is correlated with poor biological communities.

Third, during larger storms, flows can become extremely high and cause flooding, damage property, and harm and render unusable fish and wildlife habitat by eroding stream banks, widening stream channels, depositing excessive sediment and altering natural streams and wetlands.

## 1.1 Stormwater Retrofit Needs

Until about the late 1980s or early 1990s, development in the Puget Sound region typically did not include any stormwater treatment. Development through that time included conveyance, which largely consisted of pipes and ditches designed to move stormwater downhill as quickly as possible to the nearest surface water body. Only in the last two decades have development regulations changed to require stormwater treatment. While these regulations have substantially reduced stormwater impacts of new development, they do not fully mitigate impacts, and they do not require stormwater treatment to be constructed where none was constructed as part of existing development, except when certain thresholds are exceeded as part of redevelopment projects.

Modern stormwater management principles call for treating stormwater flows and quality as close to the point of generation as possible to avoid surface water impacts. This shift in stormwater management approach is shown in Figure 1. All new development, and beyond certain thresholds, all redevelopment, are required to implement stringent stormwater management techniques. Construction of stormwater facilities as part of redevelopment will, over time, reduce stormwater impacts as stormwater is treated over larger percentages of the landscape.

| Time Period | Paradigm | Description |
|---|---|---|
| Prior to 1992 | Drainage Efficiency | Convey water downhill as efficiently as possible |
| 1992 – 2013 | Reduce New Impacts | Reduce harm from new construction with flow control and treatment |
| Future | Minimize New Impacts and Reduce Existing Impacts | Capture, infiltrate, detain, and treat stormwater everywhere to protect and rehabilitate receiving waters |

**Figure 1. Evolution of Stormwater Management Approaches in Washington State**

The current municipal National Pollutant Discharge Elimination System (NPDES) permit for stormwater discharges for Phase I counties (King, Pierce, Snohomish, and Clark) also requires development of a watershed plan within one watershed in each county. These plans are intended to define approaches to prevent stormwater impacts from new development and reduce stormwater impacts from existing development via a variety of approaches, including the construction of stormwater facilities where none exist. The retrofitting of already developed areas with new stormwater facilities could represent a major public expense.

There have been two projects to date in the Puget Sound region that have estimated amount of stormwater facility needs. In the first project, Bissonnette and Parametrix (2010) estimated that an investment between $3B and $15B is needed to construct stormwater water quality treatment facilities to treat all stormwater in the Puget Sound region. Unfortunately, this estimate focused on solids removal and did not consider flow control. Nor did this estimate include operation and maintenance costs or land purchase costs, and thus is likely an underestimate of the true investment needed to treat stormwater.

The second project, King County (2012a) modeled the stormwater facilities needed to improve stream flow and water quality in Juanita Creek to meet water quality standards and to meet flow requirements for salmonids. This project estimated that $1.4B of investment in stormwater infrastructure is needed in the about 7-square mile basin. These costs include land acquisition, construction, and operation and maintenance. However, no distinction was made between what part of the cost might be borne by a public program versus private development, and how population growth and redevelopment might influence a public retrofit program.

The purpose of this project is to expand and improve on the available information, and estimate as rigorously as possible the potential public cost of implementing stormwater Best Management Practices (BMPs) and Low Impact Development (LID) techniques in existing and future (2040) developed areas of WRIA 9 to improve stream flow and water quality to near-pre-development conditions.

## 1.2 Project Area

The study area consists of the streams and creeks in 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 2). 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 square miles and includes a diversity of land cover and land use types. 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 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.

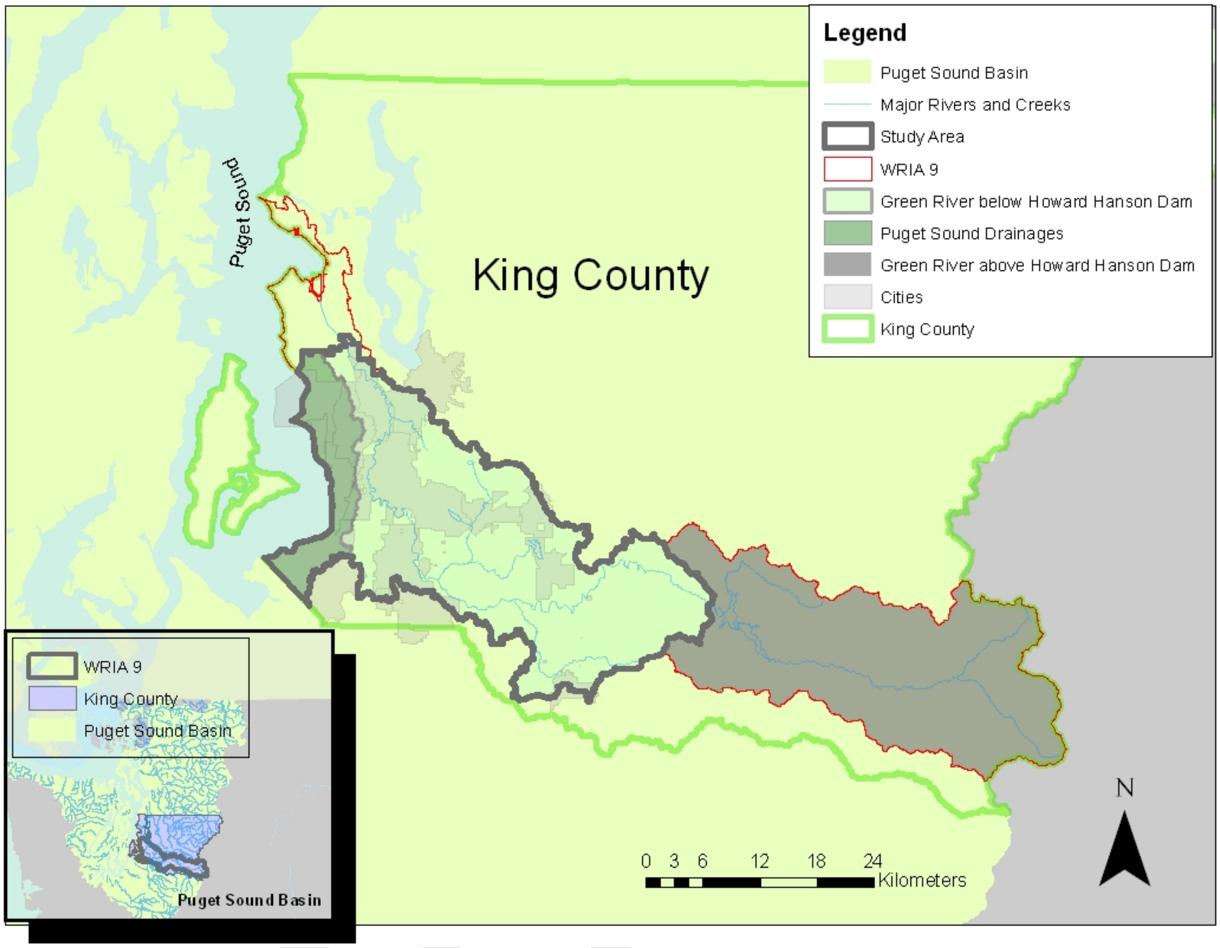


**Figure 2. Project Study Area Map**

## 1.3 Project Team, Budget and Schedule

This project was implemented by a project team that included staff from King County, USEPA, Ecology, University of Washington, and the cities of Auburn, Covington, and SeaTac, and Kellogg Consulting. King County was awarded a Puget Sound Watershed Management Assistance Program FY 2009 grant of $999,981 by Region 10 of the U.S. Environmental Protection Agency (EPA) to conduct the project. Matching funds were provided by King County ($300,000), University of Washington ($20,000), and the cities of Auburn, Covington, and SeaTac ($5,000 each). The project began in 2010 and ends in mid-2014.

# 2.0. METHODS

This project included many components and tasks that work together that support the estimate of stormwater facility needs to improve stream flow and water quality. An overview of these tasks is shown in Figure 3. Each task is summarized below.

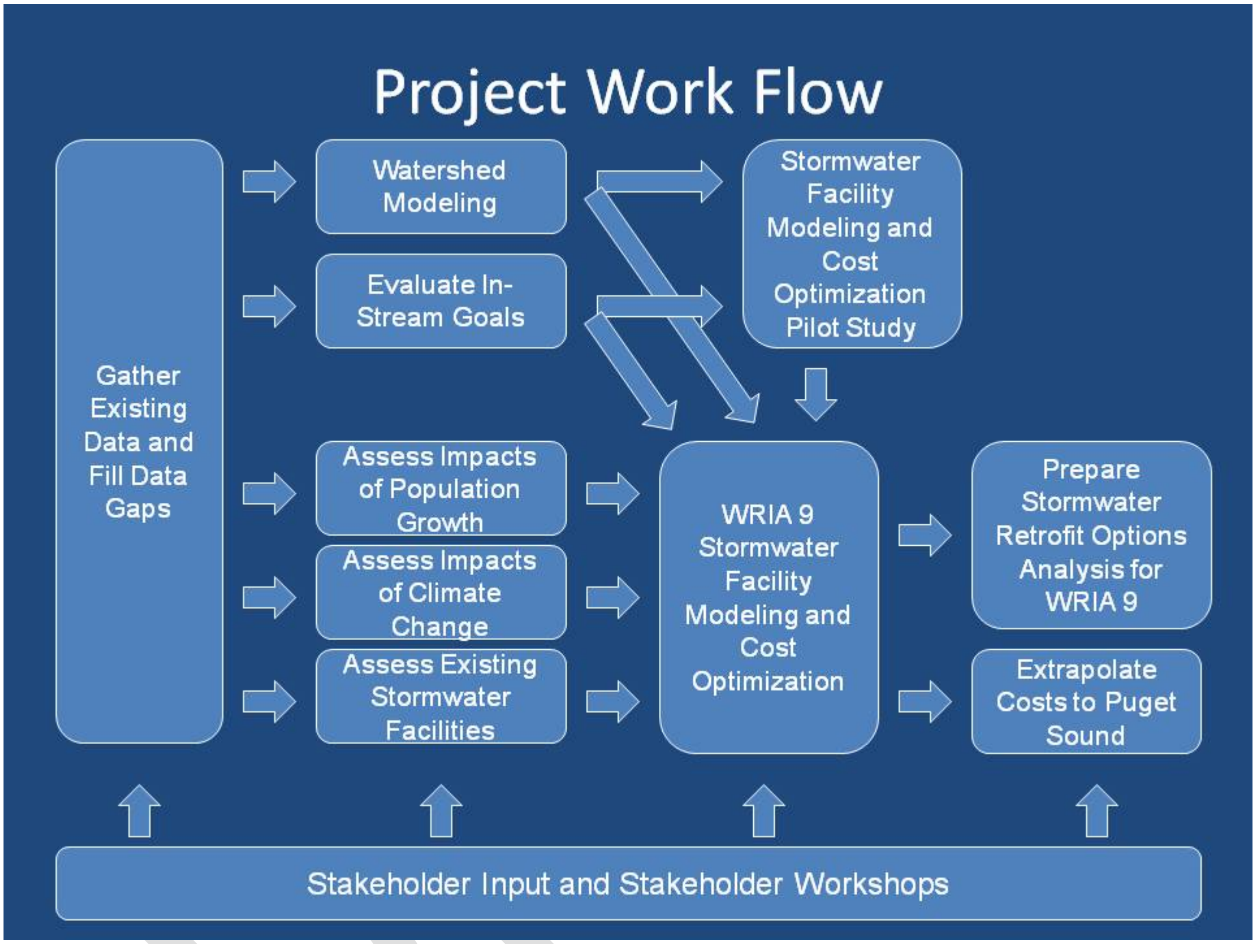


**Figure 3. Project Work Flow**

## 2.1 Gather Existing Data and Fill Data Gaps

King County and the United States Geological Survey (USGS) collectively maintain over 30 flow measuring stations (known as flow gages) on rivers and streams in the project area. Data from these flow gages were assembled and used to assess current flow conditions, and to assist in the development of watershed models in the project area. Total suspended solids and turbidity data were also gathered for this effort. These data are presented by King County (2011).

Even with this extensive data set, several substantial data gaps were identified. No flow or turbidity data were available for several smaller streams, thus limiting the project team's ability to develop accurate watershed models. A field data collection effort was implemented from October 2010 through September 2011 to gather one water year's worth of continuous flow data at 10 locations, and several months of continuous turbidity data at 20 sites (King County 2012b).

## 2.2 Evaluate In-Stream Goals

For the most part, stormwater management has historically focused on limiting peak flows and/or removing suspended solids. While peak flows are related to streambed erosion and flooding concerns, recent literature supports evaluating other metrics that are correlated with the health of the biological community. In this project (Horner 2013), we focused on assessing three flow metrics, total suspended solids (TSS), and metals (Table 1).

**Table 1. Flow and water quality metrics evaluated**

| Metric | Definition |
|---|---|
| High Pulse Count | Number of days in each water year that discrete high flow pulses occur, with twice the mean flow rate taken as the threshold to identify a high pulse |
| High Pulse Range | Range in days between the start of the first high-flow pulse and the end of the last high flow pulse during a water year |
| Ratio of the 2-Year Peak Flow to the Winter Base Flow | Ratio of peak flow rate with a 2-year return frequency to the mean base flow rate during October 1-April 30 |
| Turbidity | Comparison of in-stream turbidity (calculated from total suspended solids concentrations) to Washington State water quality standard |
| Dissolved Copper and Zinc | Comparison of in-stream dissolved copper and zinc concentrations (calculated from total suspended solids concentrations) to Washington State water quality standards |

## 2.3 Watershed Modeling

Watershed hydrology models were developed for the entire project area to calculate hourly stream flow and total suspended solids concentrations (King County 2013a). The models incorporate site-specific land use data, slope data, precipitation data, soil and geology data, and stream channel data. The project area was divided into 28 distinct modeling basins for this purpose, with the modeling basins further divided into 446 distinct catchments. Modeling was completed using software called Hydrologic Simulation Program – Fortran (HSPF), which is a standard approach for estimating streamflows and water quality in King County. HSPF also provides output suitable for use as input to the model used to estimate stormwater facility needs and costs.

## 2.4 Impacts of Population Growth

The number of people living within the project area is expected to increase from about 511,000 in 2010 to about 639,000 in 2035, an increase of about 128,000 people, or 28 percent. Analyses of the changes in land use by 2040 associated with this population growth were previously done by the University of Washington (Alberti 2009).

Project land use changes were used to estimate the percent of area (by catchment and by jurisdiction) that would have substantial new development or substantial redevelopment by 2040 and thus have stormwater facilities constructed as part of the project (King County 2014a).

## 2.5 Impacts of Climate Change

Output from global climate models has been used by researchers at the University of Washington to project future climate conditions at the regional and local scale. These studies show that while there is a high degree of confidence on the project future temperature change, there is a large degree of uncertainty regarding changes in precipitation patterns in the Puget Sound region. Review of available literature and statistical analysis of downscaled climate change data confirms that climate change may result in changes to regional precipitation patterns that may either increase or decrease stormwater retrofit needs (King County 2014b). The different models and scenarios show a likely increase of about 10 percent in facility needs, with uncertainty ranges from a decrease in facility needs of about 10 percent to an increase in facility needs of about 50 percent.

## 2.6 Stormwater Facility Modeling Pilot Study

A relatively new model developed by the USEPA was used to estimate stormwater facility needs in a small urban catchment in the Newaukum Creek basin (King County 2013b). The model, **S**ystem for **U**rban **S**tormwater **T**reatment and **A**nalysis **IN**tegration (SUSTAIN), was applied to a 230-acre catchment in the city of Enumclaw. This pilot study demonstrated the functionality of the SUSTAIN model, and allowed for testing of design and cost assumptions, and presentation approaches for the results.

## 2.7 Stormwater Facility Modeling

The SUSTAIN model was used to estimate stormwater facility needs in the entire project area (King County 2014b). Stormwater facility needs and costs was first conducted for 135 different generic 100-acre catchments representing different combinations of five land uses (forested, agricultural, low density residential, medium/high density residential, commercial/industrial), three precipitation zones, two slopes, three soil types, and two land costs. The number of different types of stormwater facilities per catchment was then calculated based on the area-weighted average of the amount of each combination of land use, precipitation, slope, soil type, and land cost within each catchment. The number of each type of stormwater facility needed to maximize the cost-effectiveness of stream flow and water quality rehabilitation was adjusted down to account for new and redevelopment associated with population growth and economic activity. Costs associated with the adjusted number of facilities were assessed over a 30-year construction window, and include land cost and construction cost, operation and maintenance, inspection, and enforcement.

The study used unit BMPs designed to treat runoff from a designated unit area. BMP design details are available in the SUSTAIN modeling report (King County 2014). Each rain garden and roadside bioretention unit was 100 $ft^2$ in area. Three different detention pond units were designed to treat low, medium and high intensity development runoff. The average size of a detention pond unit was 2,500 $ft^2$ and 5 ft deep. Each cistern unit had a storage capacity of 3,000 gallons. During implementation, actual facility size and shape, along with the corresponding number of units, will vary.

## 2.8 Existing Stormwater Facilities

The SUSTAIN modeling conducted to estimate stormwater facilities needed to improve stream flow and water quality to near-pre-development conditions does not account for existing large facilities. To address treatment provided by existing large facilities, the project team surveyed staff from the Port of Seattle, King County, and the cities of Covington, Burien, Des Moines, and Normandy Park to develop an inventory of large facilities in Miller/Walker Creek basin, Des Moines Creek basin, and the city of Covington (Horner and King County, in prep). In addition, HSPF model output was analyzed to estimate the amount of stormwater facilities implicitly included in the model calibration (Horner and King County, in prep).

## 2.9 Stakeholder Engagement

The project used an extensive stakeholder engagement process to ensure that the highest priority questions were addressed. The process included:

- Four stakeholder workshops
- Project update emails delivered approximately quarterly
- One-on-one briefings with key stakeholders
- Stakeholder comment periods on draft reports
- Outreach to the WRIA 9 Ecosystem and Watershed Forum
- An project website with all meeting minutes and project deliverables

# 3.0. RESULTS

## 3.1 Numbers of Facilities

The estimated numbers of units of different types of facilities that would be needed to be built as part of a public stormwater retrofit program to rehabilitate project area streams are shown in Table 2. The numbers of facilities by jurisdiction are shown in Tables 3.

**Table 2. Estimated number of different types of stormwater facilities needed to be built to restore project area streams**

| Type of Facility | Total Need | Built by 2040 as Part of New and Redevelopment | Built for Roads and Highways | Potential Public Retrofit Program for Developed Land |
|---|---|---|---|---|
| Rain gardens | 2,685,717 | 1,736,050 | 0 | 949,664 |
| Roadside bioretention | 191,493 | 0 | 191,492 | 0 |
| Detention ponds | 75,610 | 46,054 | 5,032 | 24,525 |
| Cistern | 34,440 | 21,132 | 0 | 13,307 |

**Table 3. Estimated number of different types of stormwater facilities needed to be built to restore project area streams by jurisdiction.**

| Jurisdiction | Cisterns | Rain Gardens | Roadside Bioretention | Detention Ponds |
|---|---|---|---|---|
| Algona | 99 | 3,419 | 182 | 291 |
| Auburn | 2,055 | 197,736 | 13,596 | 7,631 |
| Black Diamond | 1,203 | 49,470 | 3,063 | 1,426 |
| Burien | 1,918 | 130,038 | 10,151 | 2,914 |
| Covington | 436 | 41,117 | 3,029 | 2,457 |
| Des Moines | 965 | 114,701 | 8,175 | 1,242 |
| Enumclaw | 350 | 43,757 | 3,065 | 1,018 |
| Kent | 4,331 | 455,187 | 32,000 | 10,038 |
| Maple Valley | 1,465 | 36,075 | 2,560 | 1,644 |
| Normandy Park | 523 | 23,537 | 1,955 | 927 |
| Pierce County | 25 | 949 | 90 | 37 |
| Renton | 1,070 | 143,683 | 10,282 | 2,409 |
| SeaTac | 1,119 | 150,227 | 11,083 | 2,490 |

| | | | | |
|---|---|---|---|---|
| Seattle | 126 | 17,101 | 1,320 | 642 |
| Tukwila | 416 | 70,421 | 5,626 | 3,881 |
| Federal Way | 2,144 | 164,962 | 12,552 | 3,509 |
| Tacoma | 95 | 8,487 | 691 | 305 |
| King County | 16,100 | 1,034,850 | 72,073 | 32,749 |
| TOTAL | 34,440 | 2,685,717 | 191,493 | 75,610 |

## 3.2 Projected Effectiveness

The output from the SUSTAIN modeling output shows substantial improvement in stream flows, water quality, and in potential benthic invertebrate community health. This modeling output shows that comprehensive stormwater treatment over larger portions of the landscape reduces stream flashiness and improves stream water quality to near-pre-development (e.g., fully-forested) conditions. The distribution across the 26 stream basins of each of the project indicators for future scenarios with and without stormwater management is shown in figures 4 and 5, respectively.

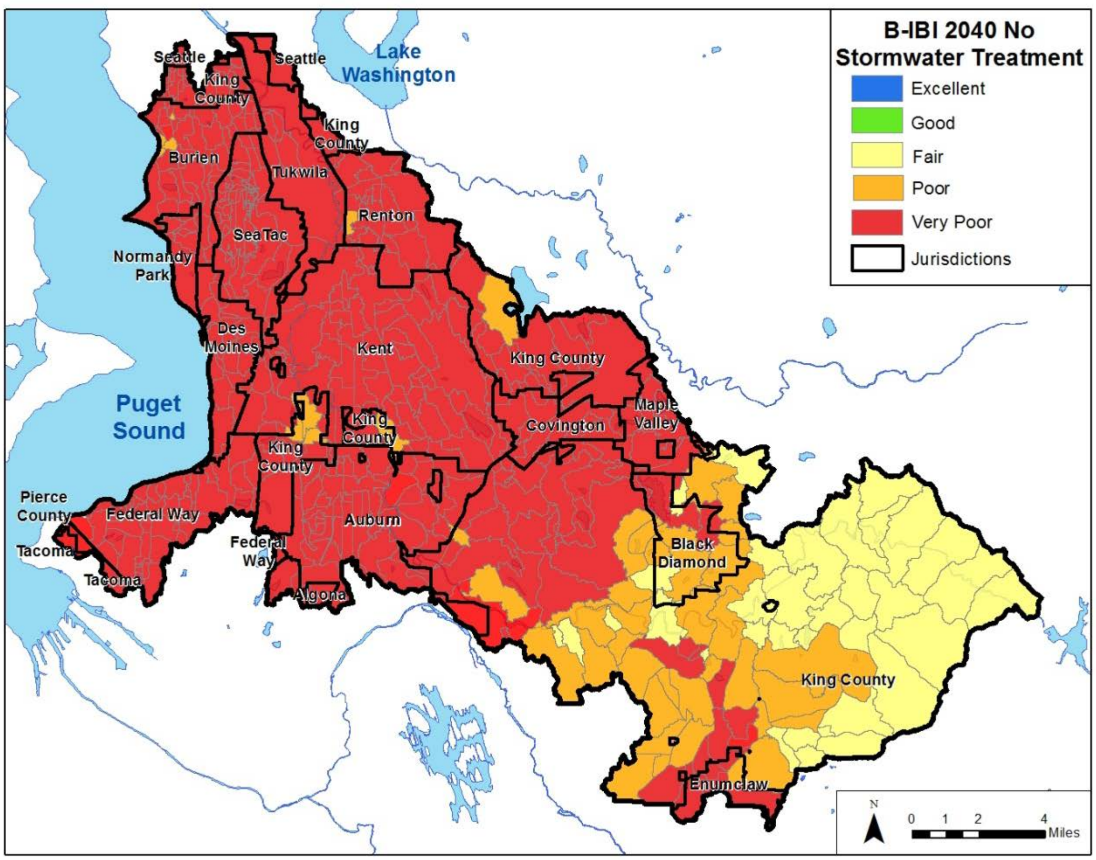


**Figure 4. Potential best-estimate year 2040 B-IBI scores in study area catchments based on relationship with high pulse count and high pulse range and no stormwater mitigation**

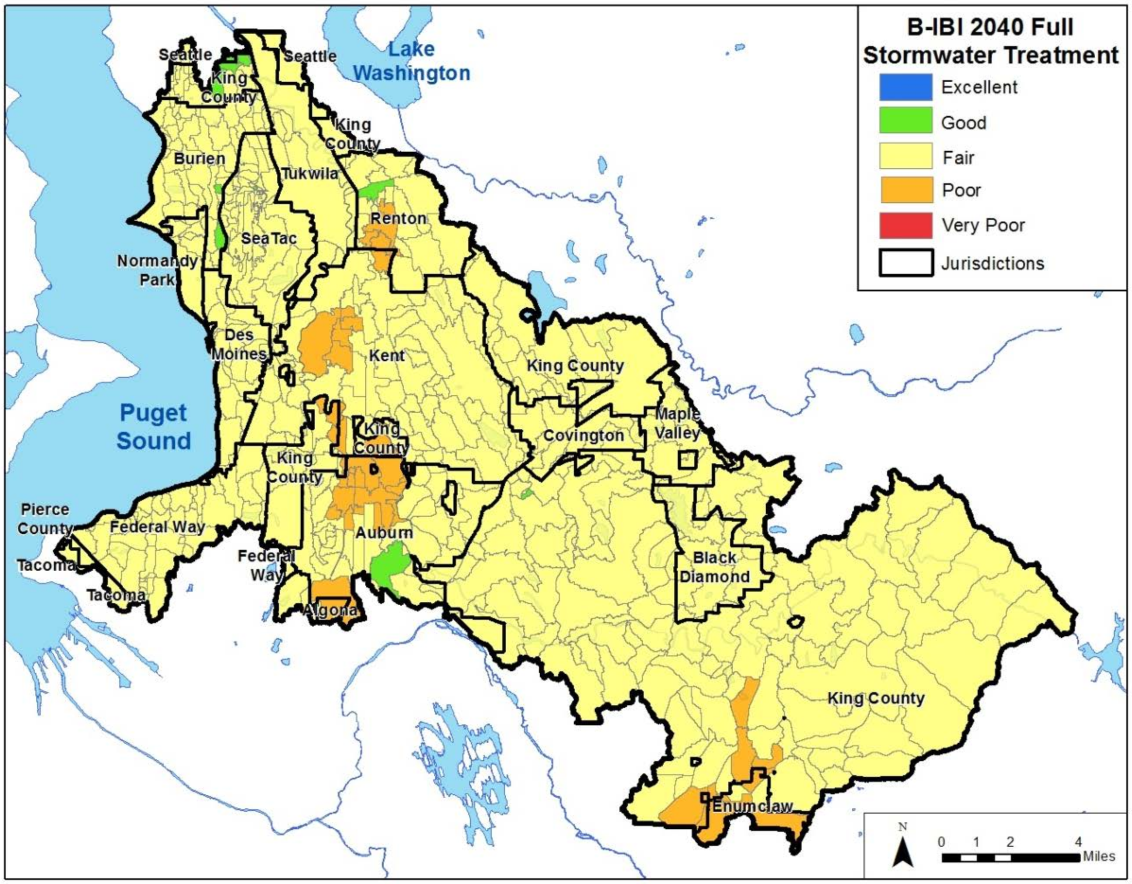


**Figure 5. Potential best-estimate improvement in year 2040 B-IBI scores of study area catchments based on relationship with high pulse count and high pulse range and full stormwater mitigation**

# 4.0. IMPLEMENTATION COSTS AND OPTIONS

## 4.1 Status Quo – No Retrofits and Maintain New and Redevelopment Requirements

One option for reducing stream flashiness and improving stream water quality is to rely on new and redevelopment for future construction of stormwater facilities, as required by current regulations. Existing stormwater requirements call for stormwater facilities to be constructed when certain development or redevelopment thresholds are exceeded. The project's analysis of future land use change shows that by 2040, nearly 50 percent of the project study area will likely have new stormwater facilities built as part of new or redevelopment. Based on an estimated new and redevelopment rate of about 1.6%, facilities would be built over nearly the entire project area, except road and highways, within about 60 to 80 years. Roads and highways account for about four percent of the project area.

One uncertainty to adopting this approach is associated with potential future changes in stormwater requirements for redevelopment in urban centers (Gates 2013). Multiple comments have been submitted to the Washington State Department of Ecology over the years to reduce and/or eliminate the requirement to build stormwater facilities during redevelopment in urban centers. To address concerns raised about the costs of stormwater requirements relative to the environmental benefits in the context of overall urban planning goals for the Puget Sound region, the Washington State Department of Commerce has assembled a committee to identify approaches to managing stormwater in infill areas (Gates 2013).

The reliance on new development and redevelopment would result in an increasing public expenditure associated with inspections and enforcements (I&E) of these facilities. By 2040, a public I&E program would need to check about 1,736,050 unit rain gardens, 46,054 unit detention ponds, and 21,132 cisterns on a routine basis. The public cost for this I&E program would be anticipated to increase annually as these facilities are constructed. The total cost of this program depends on assumptions about interest rates, discount rates, and new and redevelopment rates. To put potential future costs in perspective, if all of these facilities were already constructed and needed to be inspected, the annual public I&E program for this many facilities would be about $372M in 2013.

## 4.2 Implement Public Program to Retrofit Roads and Highways

A public stormwater retrofit program that focuses on treating stormwater runoff from roads and highways is one option for moving forward. This program would need to treat about 174 linear miles (over 3 square miles) of state and federal highways, and over 2,100 linear miles (over 8 square miles) of local roads. To be completed in 30 years, this program would need to build stormwater treatment of over 70 linear miles of roads and highways per year. This program would include construction of over 6,000 unit roadside bioretention units and over 160 detention pond units per year. If the first year of construction were to occur in 2013, the 2013 capital cost would have been estimated to be about $23M. Future capital costs would vary based on the assumed inflation rate and discount rate.

Operation and maintenance of these roadside facilities would increase annually as more facilities are constructed. Upon completion, operation and maintenance (O&M) of these facilities would represent a substantial ongoing expense. If all of these facilities required O&M in 2013, the 2013 annual cost would be about $22M.

## 4.3 Full Stormwater Treatment within 30 Years

The most comprehensive approach for treating stormwater would include:

- Maintaining or expanding treatment requirements for new and redevelopment
- Implementing a public stormwater retrofit program to build facilities to treat runoff from all roads and highways
- Implementing a public stormwater retrofit program to build facilities to treat runoff from all other developed lands currently lacking adequate facilities that will not be redeveloped within 30 years.

This approach would minimize the length of time necessary to implement comprehensive stormwater treatment in the project area. To build stormwater facilities for developed lands that are not projected to be redeveloped in the next 30 years would require constructing about 31,000 rain garden units, about 800 detention pond units, and about 450 cisterns per year for 30 years. If the first year of construction were to occur in 2013, the 2013 capital cost would be about $140M. Future capital costs would vary based on the assumed inflation rate and discount rate.

Operation and maintenance of these stormwater facilities would increase annually as more facilities are constructed. Upon completion, operation and maintenance (O&M) of these facilities would represent a substantial ongoing expense. If all of these facilities required O&M in 2013, the 2013 annual cost would be about $130M.

It may be possible to prioritize basins for earlier implementation of this type of program. Such a prioritization could depend on fish use, relative current condition of the basin, or citizen/jurisdiction interest in early restoration.

# 5.0. DISCUSSION AND FINDINGS

This project provides the most rigorous estimate possible of the number of different types of stormwater facilities needed to rehabilitate stream flow and water quality in WRIA 9 to near-pre-development conditions, along with capital and operating cost estimates.

This study found that to improve stream flow and water quality to near-pre-development conditions in the study area, stormwater treatment facilities equivalent to over two million rain garden units, 190,000 roadside bioretention units, 75,000 detention pond units, and 34,000 cisterns are needed. As required by existing stormwater regulations, most of the facilities need to treat stormwater runoff from nearly one-half of the landscape are projected to be constructed as part of new and redevelopment over the next 30 years, although some detention ponds would be unlikely to be constructed as part of single family residential redevelopment.

A public program to construct the rest of the facilities could be developed. A stormwater retrofit program focusing on roads and highways would require building about 6,000 roadside biotreatment units and over 160 detention pond units per year. A stormwater program intended to build stormwater facilities to provide treatment for all other developed land, meaning developed private and public parcels that are not roads or highways and are not redeveloped in the next 30 years, would require building about 31,000 rain garden units, about 800 detention pond units, and about 450 cisterns per year for 30 years. Uncertainty associated with climate change impacts on rainfall amounts and patterns are likely to increase facility needs, although the uncertainty with this estimate is large.

Construction of these facilities would require a substantial expansion of public stormwater programs in every jurisdiction. Expansion would include construction of facilities not built as part of new or redevelopment, O&M of publically-owned facilities, and I&E of privately-owned facilities. Public costs would increase annually to account for increased O&M and I&E as more facilities are built. Based on a 30 year period of construction for all facilities, the first year of public capital cost would be about $165M for the project area. O&M of public facilities would increase annually for 30 years before leveling off. If all facilities were actually operated and maintained in 2013, the annual public cost would be about $130M. If all private facilities were actually inspected, and any necessary enforcement actions taken, in 2013, the annual public cost would be about $370M. Actual future costs depend on assumptions regarding inflation and discount rates

Key findings from this study include:

1. Stormwater mitigation requirements for new and redevelopment are likely to result in substantial improvements in stormwater treatment over time since future growth is focused on redevelopment of already urbanized areas. This leads to the counterintuitive conclusion that future population growth will largely result in improved stormwater treatment, as rural sprawl is limited and urban areas are upgraded with modern stormwater facilities.
2. A very substantial public investment will be required for routine inspection and enforcement activities on all of the private facilities projected to be constructed due

to new and redevelopment stormwater mitigation requirements. It is unclear whether local surface water management fees could be increased sufficiently to cover this cost. Whether inspections could occur less frequently while maintaining facility performance is likely worth future investigation.

3. The percentage of the landscape that is projected to receive stormwater treatment as a result of new and redevelopment increases with longer planning horizons. By 2040, nearly ½ of the landscape is projected receive at least some stormwater treatment due to new or redevelopment. At this rate, nearly the entire landscape, except roads and highways, would receive treatment before the end of the century.
4. If quicker restoration is desired, a public stormwater retrofit program could be implemented to construct facilities where redevelopment is not occurring. Such a program could focus on roads and highways, or could also include constructing facilities to treat runoff from parcels in high priority areas that are unlikely to be redeveloped in the near future. It is likely that federal, state, or regional funds would be needed to fund construction of these facilities. It is unknown whether local surface water management fees could be increased sufficiently to fund the operation and maintenance of these facilities.

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