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

Comprehensive Needs and Cost Assessment and Extrapolation to Puget Sound

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Development of a Stormwater Retrofit Plan for Water Resources Inventory Area (WRIA) 9: Comprehensive Needs and Cost Assessment and Extrapolation to Puget Sound

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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 strategic framework for developing a stormwater retrofit program for WRIA 9.

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 improve stream flow and water quality were modeled using a relatively new stormwater Best Management Practices (BMPs) 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 providing an average of 2.5 inches of storage for stormwater runoff generated from developed areas are needed in the project area. Relatively more storage would be needed in urban areas, and relatively less storage would be needed in rural areas. The facilities include a combination of rain gardens, roadside bioretention, cisterns and detention ponds. The storage needed reflects the estimated 0.5 inches of storage provided from existing facilities already in the study area as well as additional estimated 10% storage need to accommodate impacts from climate change.

As required by existing stormwater regulations, many of the facilities needed to mitigate 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. However, it is unlikely that many of the larger structures, such as regional detention ponds, would be constructed as part of a single family residential redevelopment due to the size of the thresholds required to be exceeded during redevelopment and due to site feasibility considerations. Another uncertainty to relying on new and redevelopment for stormwater facility construction is associated with potential future changes in stormwater requirements for 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).

Building all stormwater facilities required to improve stream health in WRIA 9 within 30 years would necessitate public programs taking aggressive action to

1. Strengthen stormwater requirements during new and redevelopment to lower thresholds requiring stormwater facilities and to require fee-in-lieu if complete stormwater mitigation is not achieved onsite,
2. Build regional facilities,
3. Retrofit all roads and highways,
4. Retrofit all other non-forested lands not redeveloped within the next 30 years, and
5. Operate and maintain public facilities and inspect private facilities.

Construction of these facilities would cost a public program about $210M per year in capital costs (2013 dollars). Public program operating costs would increase annually as more facilities are built. If all anticipated facilities were built in 2013, the annual operating cost would be up to $650M per year. The annual operating costs are based on the estimated number of units needed; if smaller numbers of larger facilities are constructed than was modeled, then annual operating costs may be lower than estimated. A large fraction of these operating costs would be associated with inspection and enforcement for private facilities. Given these costs, review of the inspection requirements may be justified.

If redevelopment requirements are strengthened and longer time horizons for completion are targeted, a larger percentage of total capital costs would be covered by new and redevelopment, reaching nearly 100 percent of the landscape within about 100 years. The public program could then focus on building 1/100th of the needed regional facilities and road and highway facilities per year. A 100-year approach would cost about $46M per year (2013 dollars) in capital costs. If all anticipated facilities were built in 2013, annual operating costs would be up to $540M per year. The long-term operation and maintenance costs would be lower than the 30 year approach as a lower number of facilities are maintained through a public program. On the other hand, the long-term inspection costs would be similar to the 30 year approach, but take 100 years to increase as facilities get built more slowly.

Constructing stormwater facilities within 30 years throughout the Puget Sound region would require the same four actions, though on a larger scale, as would be required in WRIA 9. Assuming 1/30th of the stormwater facility needs are constructed each year, the annual public capital cost to construct cost-effective stormwater facilities across the Puget Sound basin would cost approximately $4.2 to $4.4 billion. If all facilities were being operated and maintained, and private facilities inspected and appropriate enforcement action taken, in 2013, the annual public cost would range from about $12 to $14 billion per year.

Assuming a 100-year timeframe, public capital costs for constructing stormwater facilities across the Puget Sound basin would be about $650M per year (2013 dollars). Public program operating costs would increase annually as more facilities are built. Use of a 100-year planning horizon would extend completion beyond the 2055 completion date for the Chinook salmon recovery plans, but would be comparable to the length of time over which development occurred and altered the regions hydrology. To align a 100-year stormwater retrofit plan and the Chinook salmon recovery plan, the stormwater retrofit plan could be augmented with stormwater facility construction in sensitive Chinook salmon areas.

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 three 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 one of the key 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 (DeGasperi et al. 2009).

Third, during larger storms, flows can become extremely high and flood, 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 developments, and beyond certain thresholds, all redevelopments, are required to include stormwater facilities that meet stringent requirements. 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) requires development of a watershed plan within one small 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 implementation of these plans could represent a major public expense of unknown magnitude.

There have been two projects to date in the Puget Sound region that have estimated the costs 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. This estimate focused on construction costs to build water quality treatment for solids removal. This estimate did not consider flow control construction costs, operation and maintenance

costs, inspection and enforcement costs, or land purchase costs, and thus is likely an underestimate of the true investment needed to treat stormwater.

In 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 in 2012 dollars 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 building, maintaining and operating 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. The cost estimates are extrapolated to the Puget Sound drainage basin to achieve a truly regional and comprehensive cost estimate.

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 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.

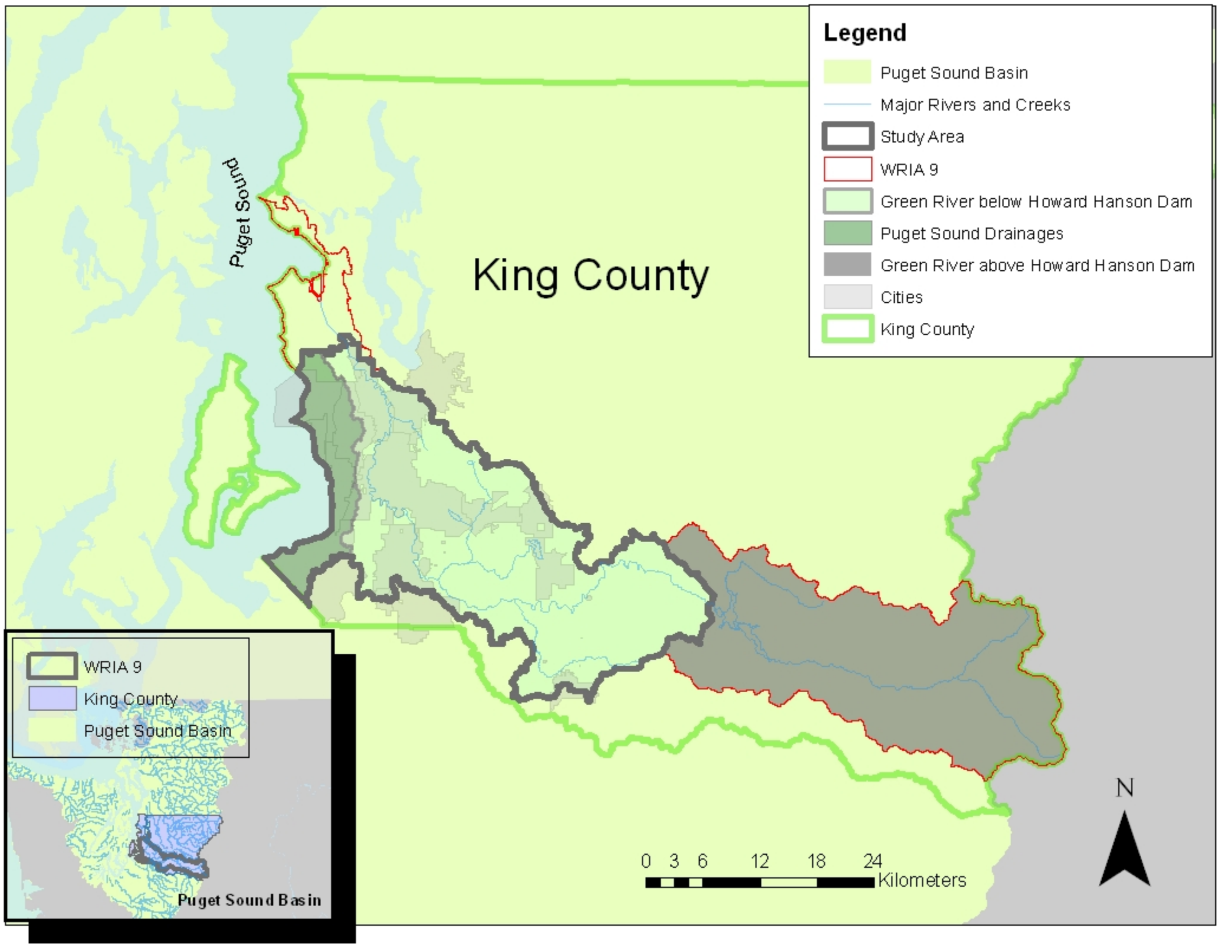

Figure 2. Project Study Area Map

1.3 Project Team, Budget and Schedule

This project was implemented by a project team that included staff from King County, United States Environmental Protection Agency (USEPA), Washington State Department of Ecology (Ecology), University of Washington, 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 USEPA 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.

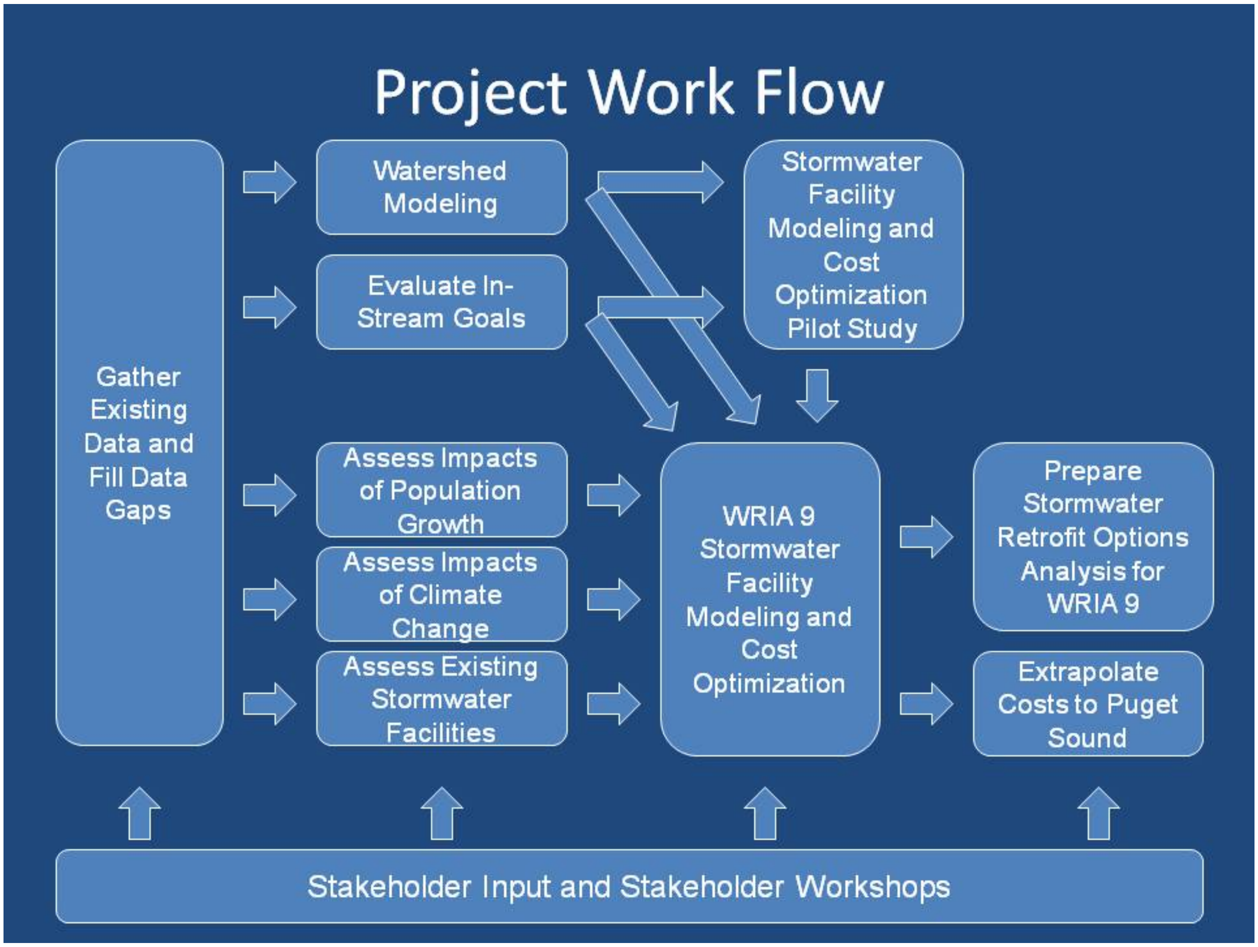

Figure 3. Project Work Flow

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, along with total suspended solids and turbidity data. 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 stresses the importance of also 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), turbidity, and metals (Table 1).

Table 1. Flow and water quality metrics evaluated

Metric	Definition
High Pulse Count	Number of times 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, slope, precipitation, soil, geology, 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 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.

2.5 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).

Projected 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).

2.6 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 estimated 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 and costs of stormwater facilities needed to cost-effectively improve stream flow and water quality was allocated between private and public costs 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 and construction cost, operation and maintenance, inspection, and enforcement.

The study used unit BMPs designed to treat runoff from a designated unit area (King County 2014b). Each rain garden and roadside bioretention unit was 100 ft^2 in area. Sixty separate detention pond designs were developed to treat 1-acre of runoff generated from the different hypothetical catchments, with variations due to level of development, precipitation zone, soil, and slope. The average size of a detention pond unit was 2,500 ft^2 and 5 feet deep. Each cistern unit had a storage capacity of 3,000 gallons. The designs were standardized and simplified to reduce complexity and facilitate the input into the SUSTAIN model. Actual facility size and shape, along with the corresponding number of units, will vary.

2.7 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 (Horner2014). The results of the inventory estimated approximately 0.5 watershed-inches of storage is provided by existing facilities in the study area.

2.8 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 projected 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 2014c). Given this uncertainty, the different models and scenarios show climate change impacts on runoff amounts and patterns are estimated to increase stormwater facility needs by about 10 percent.

2.9 Extrapolating to Puget Sound

The cost-effective stormwater facility needs and costs for the WRIA 9 project study area were extrapolated to the Puget Sound drainage basin based on the cost of developed land within the Urban Growth Area (UGA) boundary and rural area outside the UGA. About 10 percent of the Puget Sound basin is inside the UGA boundary, while the remaining area is 24 percent rural and 67 percent forested or timberland (Appendix A, Figure 6). To capture the variability of land costs in urban areas, urban costs associated with low and high land costs were used to calculate a cost range for stormwater management in the basin.

2.10 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
- A project website with all meeting minutes and project deliverables

3.0. RESULTS

3.1 Facilities

Because the SUSTAIN modeling was conducted based on BMP units that are likely to be smaller than actual built facilities, the amount of watershed-inches of stormwater storage was estimated. Storage in watershed-inches is defined as the inches of runoff generated from developed areas that is needed to be captured by stormwater facilities. Storage is calculated as the volume of facilities divided by the developed area in the project area. The equivalent storage in watershed-inches needed to be provided by the facilities is shown for the project area and for each model catchment in Table 2 and Figure 4, respectively.

Table 2. Estimated watershed-inches of storage provided by the different types of stormwater facilities needed to be built to improve project area streams.

Type of Facility	Total Storage Need (inches)	Storage needed as Part of New and Redevelopment (inches)	Storage needed for Roads and Highways (inches)	Storage needed for Potential Public Retrofit Program for Developed Land (inches)
Rain gardens	0.79	0.51	0	0.28
Roadside bioretention	0.06	0	0.06	0
Detention ponds	1.60	0.99	0.11	0.50
Cistern	0.02	0.01	0	0.01

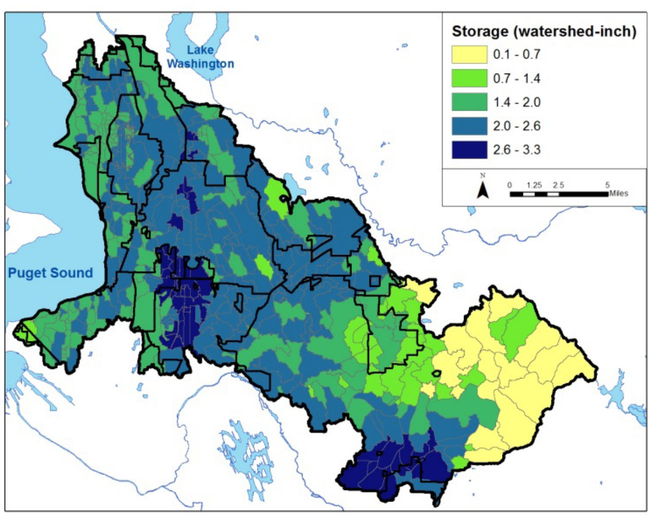

Figure 4. Watershed-inches of stormwater storage needed by 2040 to improve stream health.

3.2 Projected Effectiveness

The SUSTAIN modeling output shows substantial improvement in stream flows, water quality, and in potential benthic invertebrate community health associated with the modeled stormwater facilities. 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 of indicator values across the 28 stream basins for future scenarios with and without stormwater management is shown in Figure 5. Full stormwater management includes construction of stormwater facilities with new and redevelopment, for roads and highways, as well as for the remaining developed area.

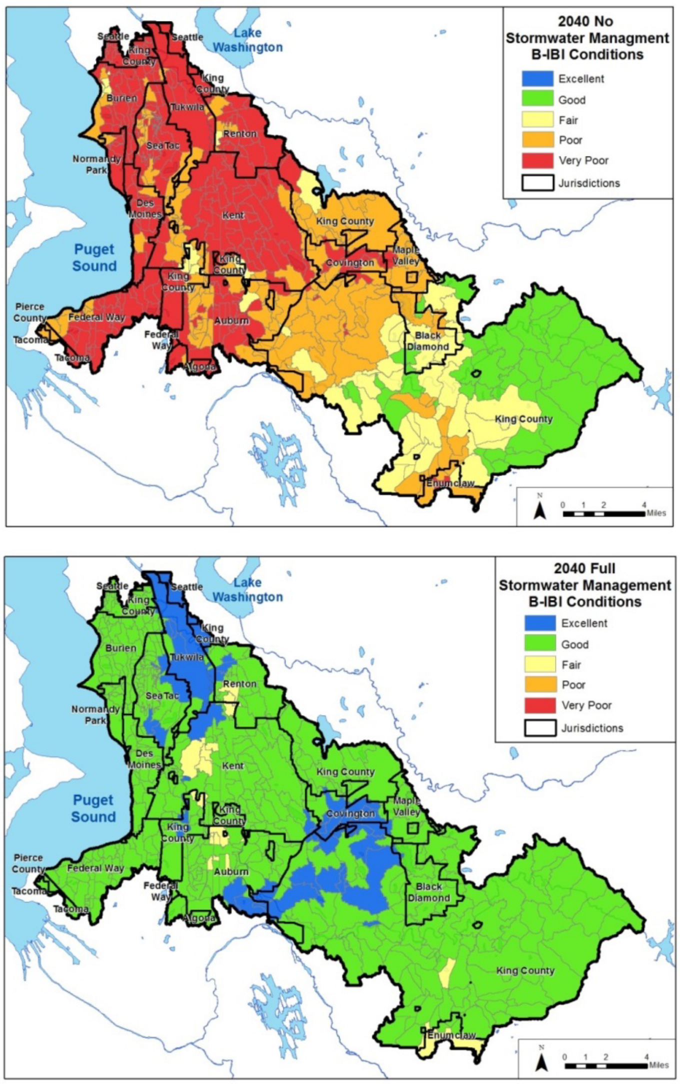

Figure 5. Potential year 2040 B-IBI scores in study area catchments with no stormwater management (top) and full stormwater management (bottom) based on relationship with high pulse count and a 90% upper confidence limit of B-IBI.

4.0. COST ESTIMATES

4.1 Benefits and Costs of New and Redevelopment

Substantial new and redevelopment is projected in WRIA 9 by 2040, with additional redevelopment likely beyond 2040. Current regulations and requirements call for stormwater facilities to be constructed when certain development or redevelopment thresholds are exceeded and when site feasibility allows for their construction. Analyses of projected 2040 land use shows that nearly 50 percent of the project study area is anticipated to be newly developed or redeveloped. 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, in less than 100 years.

Currently, redevelopment in single family residential areas typically does not meet thresholds triggering stormwater facility construction, and full stormwater mitigation may not be required due to costs or site feasibility constraints. However, if this issue were addressed such that on-site cisterns and rain gardens were constructed by developers and a “fee-in-lieu” payment was made to fund public construction of regional detention ponds, then the full benefits of new and redevelopment on improved stormwater management could be obtained. If the first year of construction for $1/30^{th}$ of the regional facilities sufficient for all redevelopment were to occur in 2013, the annual public program cost would be about $90M in 2013 dollars.

Increasing numbers of private cisterns and rain gardens as a result of new and redevelopment would result in increasing public expenditure associated with inspections and enforcements (I&E) of these facilities. The public cost for this I&E program would be anticipated to increase annually as these facilities are constructed. In addition, regional detention ponds constructed with “fee-in-lieu” payments would need to be operated and maintained. The total cost of this program depends on several assumptions, including discount rates, new and redevelopment rates, and enforcement levels. 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 facilities providing this amount of storage would be about $330M in 2013 dollars.

4.2 Retrofit of Roads and Highways

Except in unique and unusual situations, retrofitting public roads and highways in WRIA 9 with stormwater facilities would be conducted as part of a public program. For complete stormwater treatment, this program would need to build facilities for 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. Roads and highways account for about four percent of the project area. 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 a combination of roadside bioretention and detention pond facilities that would provide 0.17 inches of storage distributed over 30 years. If the first

year of construction for 1/30th of the facilities were to occur in 2013, the 2013 annual capital cost would have been estimated to be about $20M.

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 expenditure. If all of these facilities required O&M in 2013, the 2013 annual cost would be about $19M. Additionally, if all of these facilities required inspection 2013, the 2013 annual cost would be an additional $30M.

4.3 Full Stormwater Treatment within 30 Years

The most comprehensive and effective approach for treating stormwater would include:

- Maintaining or expanding treatment requirements for new and redevelopment, including implementing a public program for building regional facilities necessary for full stormwater mitigation.
- 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 management in the project area. To build stormwater facilities for developed lands that are not projected to be redeveloped in the next 30 years or treat runoff generated from roads and highways would require constructing over the next 30 years of a combination of cisterns, rain gardens, and detention pond facilities providing storage equivalent to 0.78 inches of storage for runoff generated from developed area. If the first year of construction for 1/30th of the facilities were to occur in 2013, the 2013 capital cost would be about $100M. This cost would be in addition to the cost to build regional facilities for redeveloped properties ($90M), and to build facilities for roads and highways ($20M).

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 $96M. If all of these facilities required inspection in 2013, the additional annual cost would be approximately $170.

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

4.4 Extrapolated Puget Sound Costs

Extrapolating the WRIA 9 project area results to the Puget Sound basin provides an estimate of capital, O&M and I&E costs necessary to cost-effectively mitigate stormwater impacts in the basin. Assuming 1/30th of the stormwater facility needs are constructed

each year, the annual public capital cost to implement cost-effective stormwater facilities across the Puget Sound basin would be about $4.2 to $4.4 billion in 2013 dollars. If all facilities were being operated and maintained in 2013, the annual public cost would range from about $2.1 to $2.5 billion. If all stormwater facilities for new and redevelopment as well as the additional facilities from a public stormwater program were being inspected in 2013, the annual public cost would range from $10.5 to $11.7 billion. The details of the annual capital costs for 1/30th of the stormwater facilities and the annual O&M and I&E costs after construction of all stormwater facilities can be found in Appendix A.

5.0. DISCUSSION AND FINDINGS

This project provides an estimate of the amount of stormwater facilities needed to improve stream flow and water quality in WRIA 9 to near-pre-development conditions, along with public-sector capital and operating cost estimates to put these in place within a 30-year period. This study found that stormwater treatment facilities providing an average of about 2.5 inches of storage for stormwater runoff generated from developed areas are needed throughout the project area to improve stream flow and water quality to near-pre-development conditions in the study area, with more storage needed in urban areas and less storage needed in rural areas. The facilities include a combination of rain gardens, roadside bioretention, cisterns and detention ponds. The storage needed reflects the estimated 0.5 inches of storage provided from existing facilities already in the study area as well as additional estimated 10% storage need to accommodate impacts from climate change.

As required by existing stormwater regulations, many of the facilities needed to mitigate 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. However, it is unlikely that many of the larger structures, such as regional detention ponds, would be constructed as part of a single family residential redevelopment due to the size of the thresholds required to be exceeded during redevelopment and due to site feasibility considerations. Another uncertainty to relying on new and redevelopment for stormwater facility construction is associated with potential future changes in stormwater requirements for 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).

Building all stormwater facilities required to improve stream health in WRIA 9 within 30 years would necessitate public programs taking aggressive action to

1. Strengthen stormwater requirements during new and redevelopment to lower thresholds requiring stormwater facilities and to require fee-in-lieu if complete stormwater mitigation is not achieved onsite,
2. Build regional facilities,
3. Retrofit all roads and highways,
4. Retrofit all other non-forested lands not redeveloped within the next 30 years, and
5. Operate and maintain public facilities and inspect private facilities.

Construction of these facilities would cost a public program about $210M per year in capital costs (2013 dollars). Public program operating costs would increase annually as more facilities are built. If all anticipated facilities were built in 2013, the annual operating cost would be up to $650M per year. The annual operating costs are based on the estimated number of units needed; if smaller numbers of larger facilities are constructed than was modeled, then annual operating costs may be lower than estimated. A large fraction of

these operating costs would be associated with inspection and enforcement for private facilities. Given these costs, review of the inspection requirements may be justified.

If redevelopment requirements are strengthened and longer time horizons for completion are targeted, a larger percentage of total capital costs would be covered by new and redevelopment, reaching nearly 100 percent of the landscape within about 100 years. The public program could then focus on building 1/100th of the needed regional facilities and road and highway facilities per year. A 100-year approach would cost about $46M per year (2013 dollars) in capital costs. If all anticipated facilities were built in 2013, annual operating costs would be up to $540M per year. The long-term operation and maintenance costs would be lower than the 30 year approach as a smaller number of facilities are maintained through a public program. On the other hand, the long-term inspection costs would be similar to the 30 year approach, but take 100 years to increase as facilities get built more slowly.

Constructing stormwater facilities within 30 years throughout the Puget Sound region would require the same four actions, though on a larger scale, as would be required in WRIA 9. Assuming 1/30th of the stormwater facility needs are constructed each year, the annual public capital cost to implement cost-effective stormwater facilities across the Puget Sound basin would cost approximately $4.2 to $4.4 billion. If all facilities were being operated and maintained, and private facilities inspected and appropriate enforcement action taken, in 2013, the annual public cost would range from about $12 to $14 billion per year.

Assuming a 100-year timeframe, public capital costs for constructing stormwater facilities across the Puget Sound basin would be about $650M per year (2013 dollars). Public program operating costs would increase annually as more facilities are built. Use of a 100-year planning horizon would extend completion beyond the 2055 completion date for the Chinook salmon recovery plans, but would be comparable to the length of time over which development occurred and altered the regions hydrology. To align a 100-year stormwater retrofit plan and the Chinook salmon recovery plan, the stormwater retrofit plan could be augmented with stormwater facility construction in sensitive Chinook salmon areas.

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Appendix A

Extrapolate to Puget Sound Basin:

Figures and Tables

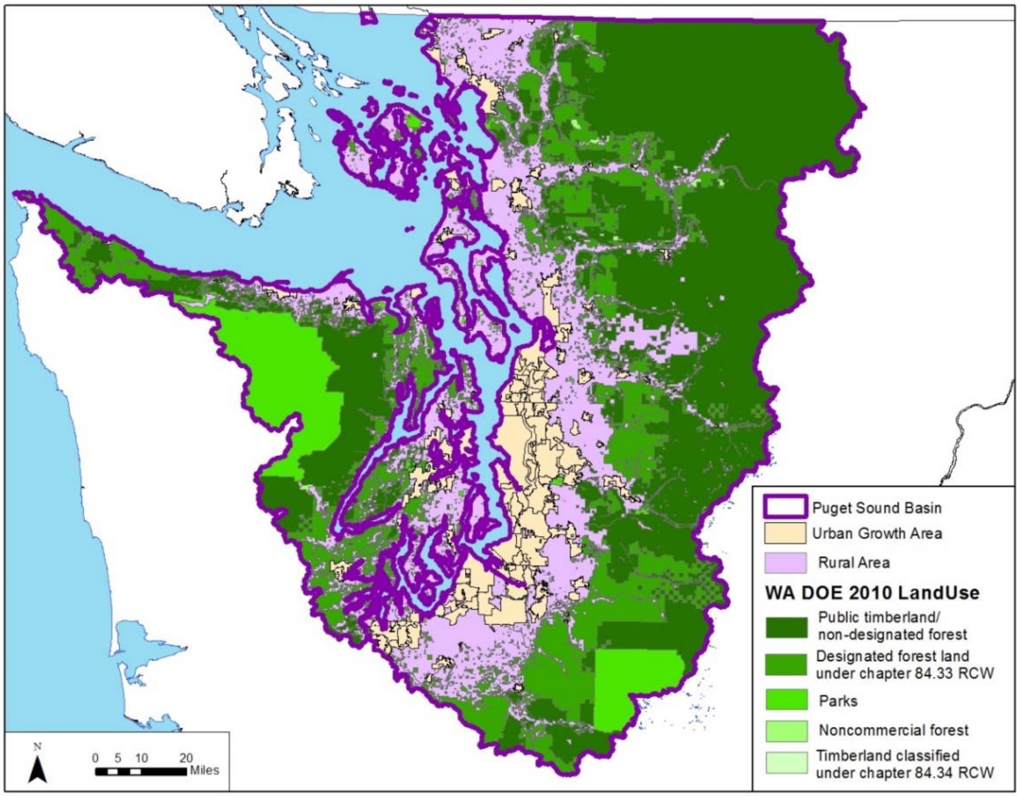

Figure 6. Urban growth Area (UGA), rural area and forested areas of the Puget Sound drainage basin.

Table 3. WRIA 9 public stormwater program annual capital costs for 1/30th of BMP units in 2013 dollars.

Land Category	Annual Capital costs for 1/30th of all BMP units	
	Low ($B)	High ($B)
UGA (low land costs)	$1.7	--
UGA (high land costs)	--	$1.5
Rural (all land costs)	$2.7	$2.7
Total	$4.4	$4.2

**All costs are presented in 2013 dollars.*

Table 4. Public stormwater program annual O&M and I&E costs once all BMP units are constructed. All costs are in 2013 dollars.

Land Category	Annual O&M costs assuming all BMP units constructed		Annual I&E costs assuming all BMP units constructed	
	Low ($B)	High ($B)	Low ($B)	High ($B)
UGA (low land costs)	$0.5	--	$2.6	--
UGA (high land costs)	--	$0.9	--	$3.8
Rural (all land costs)	$1.6	$1.6	$7.9	$7.9
Total	$2.1	$2.5	$10.5	$11.7

**All costs are presented in 2013 dollars.*

Table 5. Total present value 30-year life cycle costs for the Puget Sound Basin in 2013 dollars.

Land Category	Capital Costs		O&M Costs		I&E Costs		Total Public Stormwater Program Costs	
	Low ($B)	High ($B)	Low ($B)	High ($B)	Low ($B)	High ($B)	Low ($B)	High ($B)
UGA (low land costs)	$28.0	--	$2.9	--	$16.0	--	$47.0	--
UGA (high land costs)	--	$24.0	--	$5.2	--	$23.0	--	$52.0
Rural (all land costs)	$42.0	$42.0	$9.4	$9.4	$49.0	$49.0	$100.0	$100.0
Total	$70.0	$66.0	$12.3	$14.6	$65.0	$72.0	$147.0	$152.0

**Total present value costs assume a 30 year lifecycle with a real discount rate of 5%. All costs are presented in 2013 dollars.*