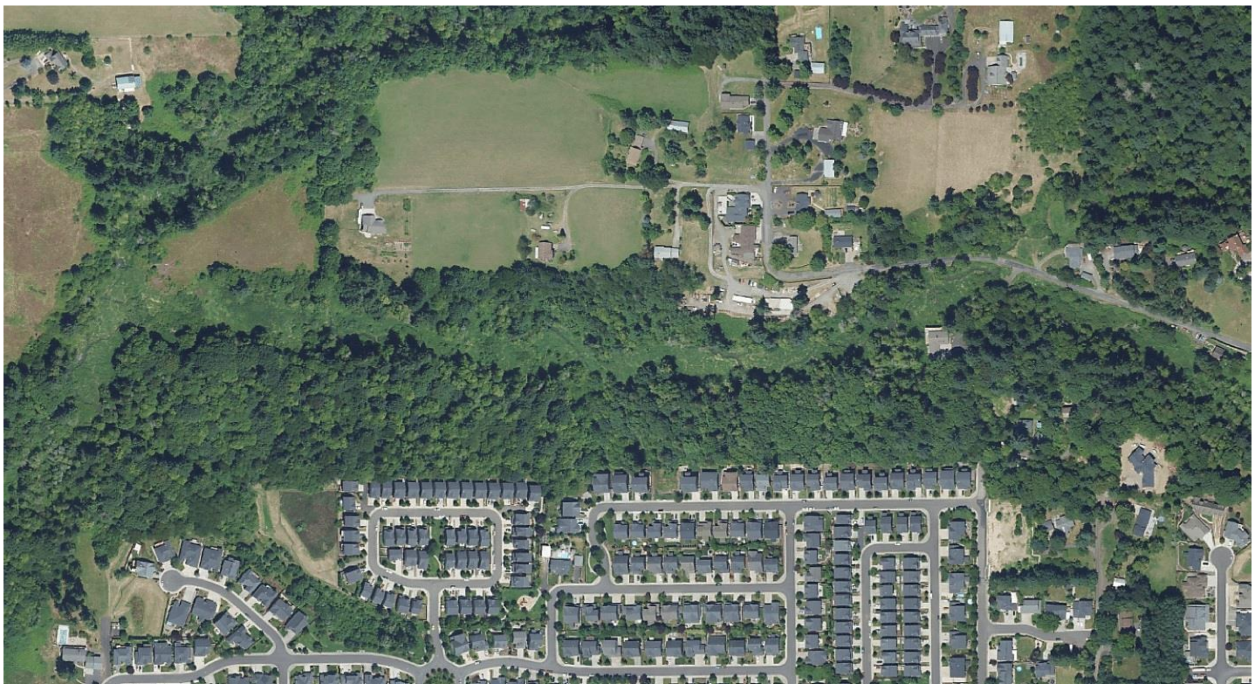
Clark County
Whipple Creek Watershed-Scale Stormwater Plan Report

Submitted in Fulfillment of Municipal Stormwater Permit Condition S5.C.5.c

September 2017



Prepared by Clark County with Otak, Inc. and FSC Group

CLARK COUNTY, WASHINGTON

otak

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Foreword

Report Purpose and Budget Impacts

The actions listed in the Whipple Creek Watershed-Scale Stormwater Plan Report (Report) implementation plan are not part of the Clark County Stormwater Program Plan submitted under Permit condition S5.A., which is supported by the current County budget. The Report is created solely to meet Permit requirement S5.C.5.c.

No new actions in the Report are supported by the current County budget approved by the Clark County Board of County Councilors (BOCC). Implementation of any new action in this plan, not currently supported by the County budget, is subject to future budget approval by the BOCC. The Report may only be used to guide county planning for future actions to improve Whipple Creek stream health.

Submittal of this plan to Washington Department of Ecology has no budget impacts.

Submittal for S5.C.5.c: Whipple Creek Watershed-Scale Stormwater Plan Report

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Introduction

A. Summary

The Whipple Creek Watershed-Scale Stormwater Plan Report (Report) is presented to fulfill condition S5.C.5.c of Clark County's National Pollutant Discharge Elimination System (NPDES) Phase I Municipal Stormwater Permit (Permit), issued by the Washington Department of Ecology (Ecology).

The Report documents the results of a high-level conceptual exercise to estimate the magnitude of effort needed to meet state-established water quality standards and in-stream flow conditions for the Whipple Creek watershed. The watershed spans about 12 square miles in southwest Clark County, Washington. It is situated north of Salmon Creek and south of Gee and Flume Creeks. Nearly five square miles of the upper watershed is inside the Vancouver urban growth area (UGA).

The analyses in this Report relied on water quality and hydrology data in the watershed collected by Clark County over the past ten or more years. Observed conditions in the streams were used to calibrate computer models of the watershed, which allowed the County to estimate the effects of future planned land uses on Whipple Creek's water quality and in-stream conditions. Results generated by simulated future land use conditions did not meet some state water quality standards and did not result in in-stream flow conditions that would allow salmon and other aquatic life to thrive.

Numerous watershed-scale management strategies directly supportive of aquatic life were considered and some were simulated in the models. With full implementation throughout the watershed of strategies described in this plan, Whipple Creek would be predicted to meet state water quality standards for dissolved metals and temperature and to have improved (reduced) levels of fecal coliform bacteria. Modeled strategies did not appear capable of providing stream flow similar to a forested watershed that would fully support salmon and other aquatic life; although some improvements compared to current degraded conditions would be expected.

Full implementation could incur capital expenditures of $346 million and ongoing operational costs of $4 million annually.

B. Purpose and Background

Knowledge about the adverse impacts of stormwater runoff on water bodies is changing rapidly. Most stormwater mitigation is applied site-by-site as land is converted from forest or fields to roads, parking lots, buildings, and lawns.

To analyze approaches to protecting streams and lakes, King County studied the predicted effects of alternative strategies in a single watershed. Juanita Creek is an urbanized 6.8 square mile watershed in King County and the City of Kirkland which was developed before current water quality treatment and flow control standards were required in western Washington.

In 2012, King County and partners published the *Stormwater Retrofit Analysis and Recommendations for Juanita Creek Basin in the Lake Washington Watershed* under a grant from Ecology. The retrofit analysis studied numerous stormwater management scenarios in an attempt to find a strategy or combination of strategies that would improve flow and water quality conditions to support fish use and other aquatic life in the watershed's streams (King County, 2012).

The Juanita Creek study found that if small distributed on-site stormwater management facilities (called low impact development (LID)) were applied to nearly all impervious surfaces and if larger traditional end-of-pipe treatment and detention facilities were constructed to retrofit most impervious surfaces up to contemporary treatment and flow control standards, Juanita Creek's streams would achieve the goals at an estimated cost of $1.4 billion (King County, 2012).

On the heels of the Juanita Creek plan, Ecology began requiring each of the four Phase I western Washington counties – King, Snohomish, Pierce, and Clark – to conduct a similar study on an urban or urbanizing watershed. In its 2013-2018 Permit, Ecology required Clark County to select a watershed and perform watershed-scale stormwater planning as outlined in Permit section S5.C.5.c. The Permit-stated objective was to "identify a stormwater management strategy or strategies that would result in hydrologic and water quality conditions that fully support 'existing uses' and 'designated uses,' as those terms are defined in WAC 173-201A-020, throughout the stream system.[1]"

In June 2014, Clark County submitted a scope of work and schedule outlining its plan to complete the watershed-scale stormwater planning requirement in the Whipple Creek watershed. Ecology approved the County's scope in September 2014 and set a deadline of September 6, 2017 for submittal of a final report. Appendix R includes the approved scope of work.

Clark County's scope of work identified tasks necessary to meet specific sub-requirements of the watershed-scale stormwater planning requirement and to gather sufficient data to simulate Whipple Creek's hydrology and water quality in a computer model. The model, calibrated to Whipple Creek's observed current conditions, would then be used to simulate future development and stormwater management strategies in an attempt to find strategies that would attain designated uses.

Clark County, together with Otak, Inc., implemented the scope of work from 2014 to 2017.

The result is a conceptual watershed-scale stormwater plan report for Whipple Creek presented here to satisfy Permit requirement S5.C.5.c.

C. Regulation

The Clean Water Act (CWA) of 1972 is the principal federal law regulating discharge of pollutants into streams, rivers, and lakes. It controls discharges of pollutants by regulating both industries and government entities, such as cities and counties, which operate storm sewer systems that collect and discharge polluted stormwater runoff from urban and suburban areas. The National Pollutant Discharge Elimination System (NPDES) is the CWA's permitting program.

The CWA relies on the concept of designated uses to set goals for water quality. At a minimum, any existing use that the water body supported in 1974, such as fishing, swimming, or providing drinking water, must be maintained.

[1] WAC means Washington Administrative Code.

The Washington State Water Pollution Control Act (RCW 90.48) similarly protects surface waters of Washington State and ground water from discharge of contaminants, and it tasks Ecology with setting water quality standards.

In Washington, the CWA's NPDES permitting program is delegated by EPA and administered by Ecology. Ecology establishes designated uses, which may equal or exceed the CWA's existing uses, for Washington's surface waters. Ecology sets water quality standards that, if met, would theoretically sustain the designated uses. Ecology issues municipal stormwater permits and state waste discharge permits pursuant to the CWA and RCW 90.48. Clark County's Permit is issued under this program. The Clark County Permit authorizes the discharge of stormwater from the county storm drainage system to waters of the state.

D. Water Quality Goals

Washington Administrative Code (WAC) Chapter 173-201A establishes water quality standards for Waters of the State. Standards are set for each water body based on its existing uses and designated uses.

Ecology has not established individual designated uses for Whipple Creek, so default uses apply. The highest default uses are primary contact recreation and salmonid spawning, rearing, and migration.

This Report analyzes and models those water quality constituents required by the Permit, and provides a cursory analysis of parameters relating to Whipple Creek's designated uses that are not specifically required to be evaluated in this Report by the Permit. Water quality standards used as the basis for analysis are shown in Table 1.

Table 1: Designated Uses and Water Quality Standards for Whipple Creek Discussed in this Report

Parameter	Applicable Designated Use	State WQ Standard Criteria
Temperature	Aquatic Life: salmonid spawning, rearing, and migration	7-Day Average Daily Maximum (7-DADMax) of 17.5°C
Fecal Coliform	Primary contact recreation	< geometric mean of 100 colonies / 100 mL and <10% of samples: 200 colonies / 100 mL
Dissolved Copper	Aquatic Life – most sensitive biota: Toxic substances	Acute and chronic criteria math formulas incorporating water hardness
Dissolved Zinc	Aquatic Life – most sensitive biota: Toxic substances	Acute and chronic criteria math formulas incorporating water hardness

E. In-Stream Hydrology Goals

The ultimate goal of the state is to restore designated uses, chiefly to provide adequate habitat and in-stream flow conditions to ensure the survival and recovery of native salmon.

Hydrology and water quality models, however, do not directly estimate the ability of a stream to support fish populations. To account for this, the Permit requires in-stream flow conditions (hydrology) to be used as a surrogate for stream biologic integrity - a stream's ability to support aquatic life from the bottom of the food chain to the top.

Introduction

This Report uses four different methods to correlate modeled hydrology to stream biologic integrity, as described below.

i. Relationship of Flow Metrics to B-IBI Score

The Benthic Index of Biological Integrity (B-IBI) is a widely used indicator of stream biologic health in the Pacific Northwest. The index uses a multi-metric analysis of macroinvertebrate taxa (bugs) that are present in gravel riffles of wadeable streams.

The Permit requires the County to use a statistically valid relationship between one or more stream flow metrics reported by the hydrology model and B-IBI score.

The applicability to Whipple Creek of several hydrologic metrics that are commonly used in the Pacific Northwest were evaluated, emphasizing those from research done on Puget Sound lowland streams (DeGasperi *et al*. 2009). Metrics are calculated using daily average flows.

Using Clark County's long-term local monitoring data and statistical regression, three hydrologic metrics were evaluated for use in a correlation to B-IBI score: 1) T_{Qmean}; 2) High Pulse Count (HPC); and 3) High Pulse Range (HPR). Table 2 provides a definition for each metric and for high flow pulse, which is the base observation for two of the calculated metrics.

Table 2: Hydrologic Metric Definitions and Selection Status

Hydrologic Metric	Definition	Selection Status
TQmean *	Fraction of a year that the daily mean discharge rate exceeds the annual mean discharge rate	Selected for use in Report
High Flow Pulse ~	Occurrence of daily average flows that are equal to or greater than a threshold set at twice (two times) the long-term daily average flow rate	N/A – this is a base metric used to calculate HPC and HPR
High Pulse Count (HPC) ~	The number of days each water year that discrete high flow pulses occur	Selected for use in this Report
High Pulse Range (HPR) ~	The 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	Not selected for use in this Report

Sources: Booth *et al.* (2001, pp. 19-20) * and DeGasperi *et al.* (2009, pp. 512 and 518) ~

Six Clark County watersheds were eligible for inclusion in the evaluation of a statistically valid relationship between flow metrics and B-IBI. The three criteria for inclusion in the study were similarity to Whipple Creek and presence of sufficient B-IBI and continuous flow monitoring data. Two metrics were selected for use in this Report – T_{Qmean} and HPC, described below. A detailed discussion of the analysis can be found in Appendix H.

T_{Qmean}

The T_{Qmean} metric has previously been used by Clark County and in the Puget Sound area (Booth *et al.*, 2001). All three metrics were used in a more recent Puget Sound lowland study (DeGasperi, *et al.*, 2009).

Linear regression showed that only T_{Qmean} using the equation below had a significant relationship to B-IBI based on local data:

$$\text{Avg B-IBI} = -16.7 + 154 \text{ Avg } T_{Qmean}$$

Further analysis during the effort to calibrate a hydrology model to observed conditions in Whipple Creek (see Chapter II) resulted in adjustments to the equation's coefficients. This Report uses a linear relationship between T_{Qmean} and B-IBI that best fits observed conditions to estimate future B-IBI scores under future planning scenarios in Whipple Creek.

The equation used in this Report for calculating B-IBI from T_{Qmean} is:

$$\text{Avg B-IBI} = -24.1 + 154 \text{ Avg } T_{Qmean}$$

High Pulse Count (HPC)

Although it was not found to have a statistically significant relationship to B-IBI score in Whipple Creek based on local data, this Report also uses the relationship between HPC and B-IBI published by King County in its Juanita Creek basin plan.

The equation used for calculating B-IBI from HPC is:

$$\text{Avg B-IBI} = 53.05 + -30.106 \log_{10} \text{ Avg HPC (King County, 2012)}$$

ii. Using Flow Metrics to Estimate Salmonid Use Attainment

As required by the Permit, B-IBI scores are used to estimate future aquatic biologic integrity as described above. This Report also uses two other indicators of whether a stream can support salmonid uses (salmonid use attainment): direct correlations between HPC and salmonid use attainment and between T_{Qmean} and salmonid use attainment.

Context

In 2014, Ecology used B-IBI scores to list streams that did not meet narrative standards for salmonid uses. The criteria ranges Ecology used were: greater than 37 for fully supporting beneficial uses, less than 28 for non-supporting , and 28 through 37 for waters of concern (Ecology, 2014).The B-IBI metric has a top score of 50. Non-supporting streams were listed on the State 303(d) List, which officially records impaired waters under the CWA.

Table 3: Correlation of B-IBI to Salmonid Use Attainment for Ecology's 303(d) Listing

		Salmonid Uses	
	Non-supporting	Partially Supporting	Fully Supporting
B-IBI	<28	28-37	>37

Because sub-watershed-scale pool-riffle sites having both flow data and B-IBI scores are extremely rare in western Washington, statistical conclusions about relationships between flow and B-IBI as described above, are weak. There is scant data and a great deal of scatter in correlating flow metric to B-IBI scores.

Introduction

B-IBI itself is an indirect indicator of a stream's ability to support salmonid uses. B-IBI is a measure of the health of aquatic macroinvertebrates, not fish. Many stream and watershed conditions other than hydrologic regime influence B-IBI scores. These include channel substrate quality, temperature, and the presence of pollutants from urban runoff and other sources.

High Pulse Count (HPC) and T_{Qmean}

To account for the difficulties with B-IBI, this Report also uses HPC and T_{Qmean} to evaluate whether Whipple Creek will meet standards for salmonid uses under future scenarios.

A review of King County's analysis of flow and water quality targets for a Water Resource Inventory Area 9 planning project (Horner, 2013) reveals that flow metrics can be directly correlated to salmonid use attainment. A discussion of this analysis can be found in Appendix I.

King County recognized HPC as one of the more useful metrics for calculating the B-IBI score. Horner found that sites having HPCs between 3 and 7 generally supported salmon use (using B-IBI score range greater than 35). The report also found that very low B-IBI scores (< 16) were associated with HPCs above 15. B-IBI scores above 25 were associated with HPCs less than 11.

King County published a regression equation for HPC and B-IBI (King County, 2012). Clark County data also showed increasing B-IBI with lower HPC, making it a viable indicator based on local data and the Puget Sound results.

Table 4: Correlation of HPC to Salmonid Use Attainment

	Salmonid Uses		
	Non-supporting	Partially Supporting	Fully Supporting
HPC Range	>11	7-11	<7

The King County analysis also identified T_{Qmean} as a useful metric for calculating the B-IBI score. Evaluation of Clark County data for basins similar to Whipple Creek found a strong correlation. King County published a regression equation for T_{Qmean} and B-IBI (King County, 2012).

Clark County data suggest that a T_{Qmean} of about 25% to 27% is equivalent to the threshold for streams that do not support salmonid uses (non-supporting) and that about 37% is the lower threshold for streams that fully support salmonid uses (fully supporting).

Table 5: Correlation of TQmean to Salmonid Use Attainment

	Salmonid Uses		
	Non-supporting	Partially supporting	Fully Supporting
TQmean	10-27 %	28-37 %	>37 %

High Pulse Range was not used because it was not appropriate for the short time period modeled in Whipple Creek. It would be more appropriate to model results for decades.

Introduction

This Report describes the results of modeled future scenarios in terms of all three indicator metrics: B-IBI, HPC, and T_{Qmean} and correlates each metric to salmonid use attainment as described above.

I. Existing Conditions

A. Watershed Setting

The Whipple Creek Watershed spans about 12 square miles in southwest Clark County, Washington. It is situated north of Salmon Creek and south of Gee and Flume Creeks. Nearly five square miles of the upper watershed is inside the Vancouver urban growth area (UGA).

Whipple Creek flows generally west from headwaters east of Interstate-5 (I-5) between Vancouver and Ridgefield to Lake River. The confluence with Lake River is just six miles upstream of the Columbia River. The watershed includes an area draining directly to Green Lake on the Columbia River floodplain.

Currently, the watershed is moderately developed with rural and agricultural areas in the western portion. The Vancouver UGA in the east is rapidly urbanizing. Suburban and large-lot rural residences are common in the lower watershed outside of the UGA. I-5, a major interstate transportation corridor, traverses nearly two miles of the upper watershed.

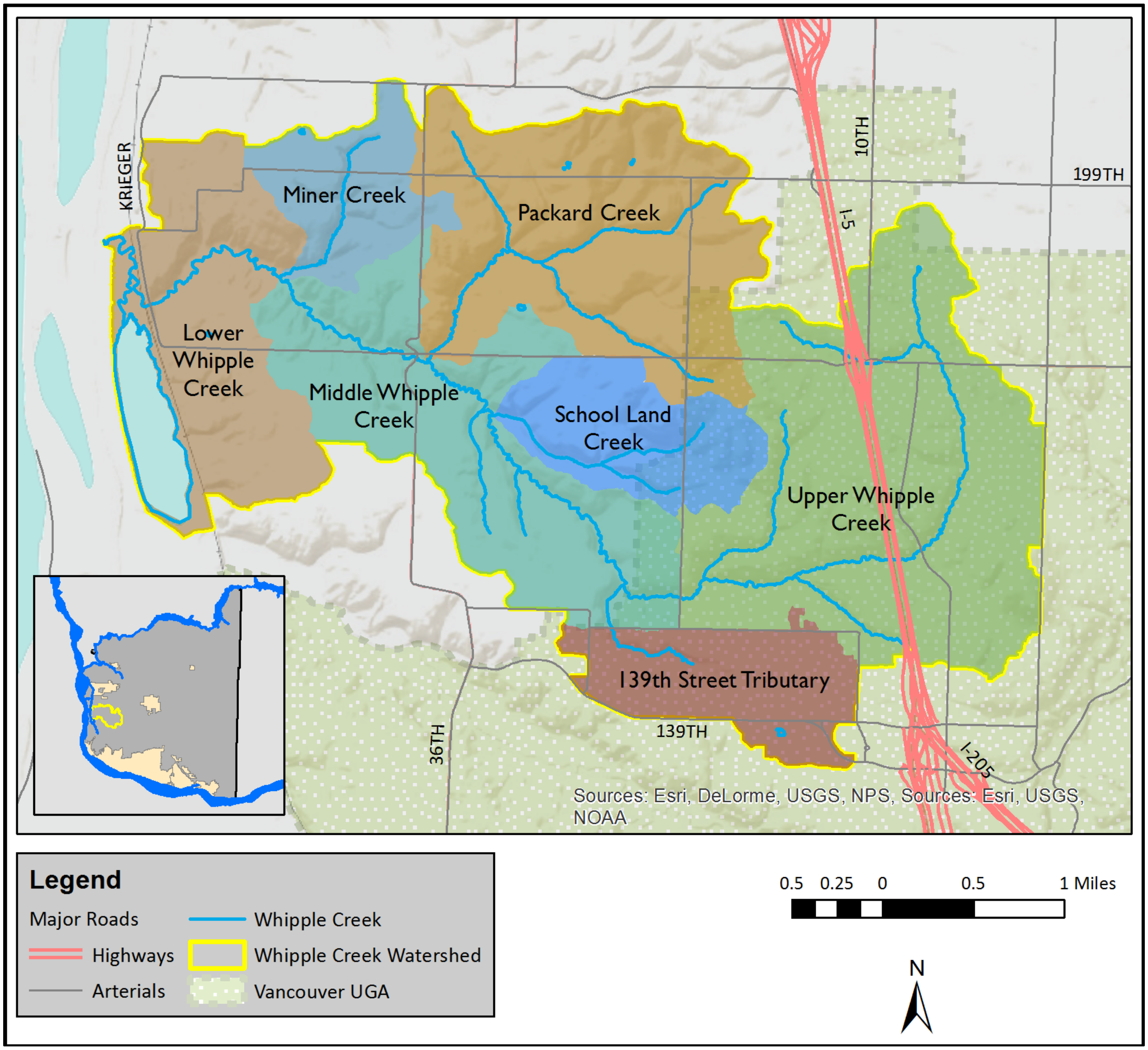
The creek is thought to be degraded in terms of hydrology, water quality, and salmon habitat compared to its historic condition.

Data about existing conditions in the watershed were collected and described following Tasks 1 and 2 of The Whipple Creek Watershed-Scale Stormwater Planning Scope of Work and Schedule, June 2014.

i. Basins

Whipple Creek has several important tributaries and about nine miles of main stem, divided into upper, middle, and lower. See Figure 1.

Figure 1: Whipple Creek Study Area



Lower Whipple Creek

Lower Whipple Creek begins where the creek meets Lake River a few miles upstream of the Columbia River. It includes Green Lake. The lowermost portion of this basin has a broad floodplain and is tidally influenced by the Columbia River. It also includes an area where small streams drain directly to Green Lake on the Columbia River Flood Plain. Further upstream, the creek also flows through a broad floodplain and contains potential salmon spawning habitat. Just below Packard Creek, large trees and good riparian corridors remain. The creek is nearly flat here. The area is characterized by agricultural uses.

Middle Whipple Creek

Middle Whipple Creek has some potential salmon habitat and pool-riffle sequences that have potential for salmon habitat restoration in its lower reaches. An important long-term water quality and stream flow monitoring site is located on the main stem downstream of the confluence with Packard Creek. Near the School Land Creek tributary, beaver ponds are numerous. The creek is nearly flat here. The area is characterized by rural and agricultural uses.

Upper Whipple Creek

The lower reaches of Upper Whipple Creek also have some low gradients and beaver ponds. Most headwater streams in Upper Whipple Creek have high gradients and flow through narrow canyons. All of Upper Whipple Creek is in the Vancouver Urban Growth Area (UGA). The I-5 corridor and the southeast portion of this basin are urbanized already while other areas of future growth are still characterized by open agricultural tracts. There is a full fish passage barrier at I-5.

Miner Creek Tributary

Miner Creek has salmon spawning gravel and the best water quality conditions in the watershed. The stream has good riparian corridors. The area is characterized by agricultural uses.

Packard Creek Tributary

Packard Creek is the largest tributary to Whipple Creek. The creek has gravel channel substrate providing salmon habitat. Stream conditions and water quality are degraded as a result of rural land uses and urbanization in headwaters along I-5. The stream has good riparian corridors. Packard Creek provides an opportunity for salmon habitat restoration. The area is characterized by agricultural uses.

School Land Creek Tributary

The School Land Creek tributary is an area where Clark County has significant land holdings. It has potential salmon habitat that is likely blocked by a culvert. The tributary has good riparian corridors, particularly within Whipple Creek Park.

139 St Tributary

The tributary to Whipple Creek at NW 139th Street drains an urbanized area in the UGA. Stream hydrology is greatly altered due to urban runoff. The area developed over the last 30 years.

ii. Topography

Whipple Creek is a part of the Columbia Slope watershed, which generally falls to the west toward the Columbia River. Upper reaches of the main stem and tributaries originate in rolling hills with a maximum elevation of about 350 feet. The creek ends in a broad wetland floodplain where it meets Lake River at 10 feet above sea level.

Headwater streams tend to flow through deep valleys with little or no room for a floodplain. The lower main stem flows through a broad floodplain as wide at 800 feet in the lowest reaches. Packard Creek also has a wide floodplain in its lower reaches. Floodplains tend to be bounded by deep, steep valleys (Inter-Fluve, 2006).

iii. Geology and Soils

The basin is covered mostly with deposits of sands and silts from the Late Ice Age Missoula Floods or Cataclysmic Floods. These deposits are moderately to poorly drained and have moderate to high erodibility. In some areas of the basin, weathered deposits of the Troutdale Formation gravels are at or near the surface. The weathered Troutdale Formation deposits are rich in clay and have very slow infiltration rates.

Most stream channels are characterized by highly erodible fine sediments, with only a few reaches characterized by coarse sediments (Inter-Fluve, 2006), such as the cobbles and gravels favored for spawning by many species of native fish.

iv. Wildlife

Beaver are known to live and to build dams in the main stem and some tributaries. Extensive sediment deposits can accumulate behind beaver dams and may contribute to filling incised stream channels. Ponds behind beaver dams may suffer from high nutrients, sediment, and high temperatures (Clark County, 2006).

The watershed is also home to deer, raccoon, song-birds, waterfowl, amphibians, and mussels (Clark County, 2006). Invertebrates found in streams form the base of the food chain for native fish.

Clark County staff found no anadromous fish (fish that migrate from freshwater to the ocean and back to spawn, including salmon and steelhead), no crayfish, and few resident fish while conducting fieldwork for the 2006 assessment of Whipple Creek (Clark County, 2006).

v. Vegetation

The Whipple Creek watershed, like most of western Washington, was once mostly forested.

Today, few large tracts of forest remain, and half of the land cover in the watershed is field, meadow, and pasture (Inter-Fluve, 2006). Invasive Himalayan blackberry are common, occurring on stream banks, in floodplains, and at times spanning the channel itself. In its assessment, Clark County staff noted that blackberries encroach to varying degrees from nearly every road crossing and stormwater outfall (2006).

Where riparian coniferous forest cover has been removed along the streams in many locations, fast-growing alders, succeeded by invasive species, now dominate (Inter-Fluve, 2006).

vi. County Storm Sewer Drainage

Clark County operates a municipal separate storm sewer system (MS4) throughout unincorporated Clark County and in the Whipple Creek watershed. The MS4 is a network of pipes and ditches along with water quality treatment and detention facilities.

The MS4 discharges to Whipple Creek and its tributaries through numerous outfalls. In its 2006 assessment, Clark County identified maintenance needs and significant impacts downstream of many of the county's outfalls. Common impacts described include erosion, invasive plant colonization, and trash accumulation (Clark County, 2006).

Many large agricultural lots drain directly to Whipple Creek or a tributary without first passing through the county's storm sewer.

vii. Land Use, Land Cover, and History

The watershed is a moderately developed rural and agricultural area, which is rapidly urbanizing in the UGA. Large-lot rural residences are interspersed with agriculture in the lower watershed outside of the UGA.

Historic dense coniferous forests were cleared by the early 1900s for building materials and agriculture, and the watershed has been home to a saw mill and shingle mill.

In 1978, *The Columbian* characterized Whipple Creek near the intersection of NW 179th Street and NW 41st Avenue as a "lazy, quiet stream" flowing through a traditional farming area (Sara) that was transitioning to rural large-lot development of 5-acre tracts (Columbian Archives, 2006).

Clark County's 2006 assessment records anecdotal accounts of the creek from longtime streamside landowners, which suggest the creek has changed over the past 50 years:

> Several landowners reminisced about the historical presence of steelhead and sea-run cutthroat trout on their properties. Others noted the disappearance of once-abundant crayfish populations…A number of residents commented they had not been near the creek on their property for years, citing impenetrable blackberry thickets as the reason (Clark County, 2006).

Changes in land use are continuing to impact Whipple Creek. In portions of the watershed that have been urbanizing since the 1980s, County staff observed several cases of downstream impacts such as incision and headcuts that appear to have occurred as a result of recent development projects (Clark County, 2006).

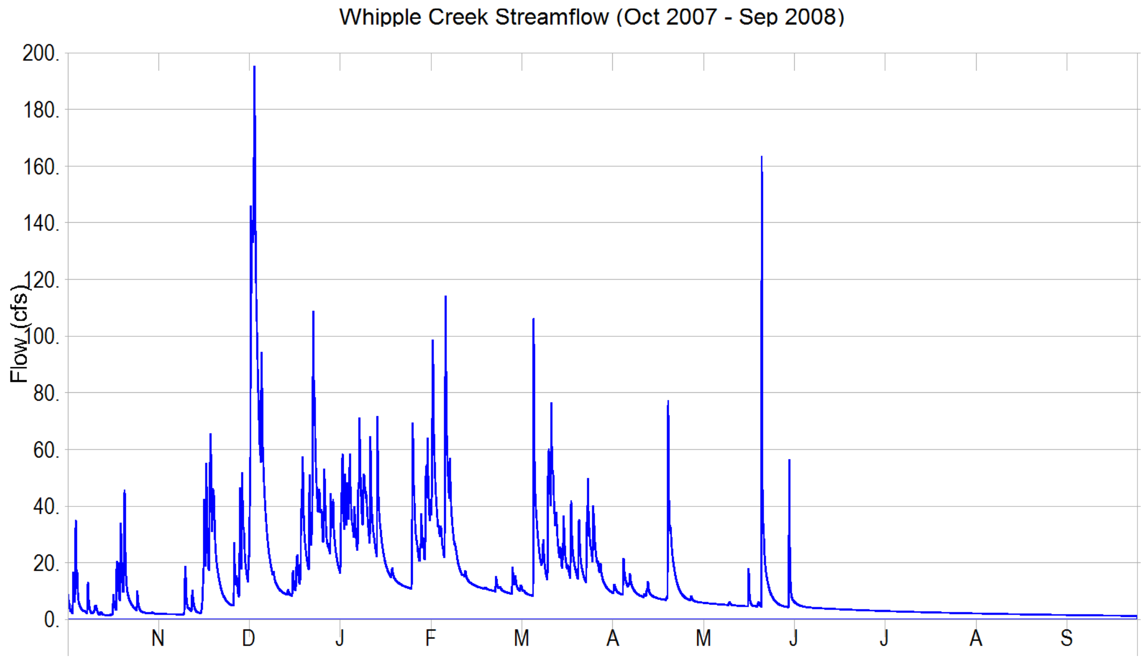
The percentages of land covers include 34% forested, 12% impervious, 51% non-canopy (fields/meadows), and 2% water (Inter-Fluve, 2006). Loss of historic forests has implications for channel stability, stream temperature, and stream habitat complexity. The county's 2006 assessment concluded that Whipple Creek has been heavily impacted by human activity in both rural and urban portions, and degraded areas far outnumber intact areas.

B. Hydrology

Whipple Creek can be described as a flashy stream, which means that the amount of flow in the creek changes quickly in response to rainfall from major storm events. Peak flows rise quickly in the stream channel during storm events and then once the rain stops the flows return to normal or low flow conditions. A graph of stream flow (hydrograph) illustrates these sharp peaks at a stream gage in the lower middle watershed in Figure 2, below.

Existing Conditions

Figure 2: Whipple Creek Observed Stream Flow at WPL050 Gage (in cubic feet per second (cfs))



This quick response to rainfall is the result of a number of factors.

Many of the soils in the watershed have low infiltration rates. Heavy rainfall does not soak into the ground but instead quickly runs off into the nearest stream. This surface runoff produces high peak flows, and the lack of infiltration produces low base flows. The replacement of forest with impervious surfaces intensifies this pattern.

Another major factor is that the upper portions of the main stem of Whipple Creek and headwater tributaries are relatively steep, as shown in Table 6.

Table 6: Whipple Creek Main Stem Channel Slopes

Channel	Reach	Length (mi)	Elev Change (ft)	Slope (%)
Upper	195	0.283	17.03	1.1%
Upper	190	0.832	20.77	0.5%
Upper	180	1.167	60.58	1.0%
Upper	175	0.194	12.86	1.3%
Upper	170	0.578	19.60	0.6%
Upper	160	0.733	18.40	0.5%
Middle	150	0.608	13.53	0.4%
Middle	140	1.080	14.72	0.3%
Middle	130	1.045	17.43	0.3%
Middle	120	1.095	35.12	0.6%
Lower	110	1.264	10.47	0.2%
Lower	100	0.773	4.08	0.1%
Total/Average		**9.652**	**244.59**	**0.5%**

Existing Conditions

These steep stream channel slopes produce high stream channel velocities and high peak flows. This, in turn, results in channel erosion through downcutting (also known as incision). Downcutting deepens the channel and prevents flood flows from overtopping the channel banks and spreading out onto the adjacent floodplain.

The stream channel slopes decrease in the middle portion of the main stem of Whipple Creek. This is a section of the stream channel where sediment deposition can occur and where beaver dams further encourage sediment deposition. Erosion that does occur in this section is mainly from the stream channel banks rather than the channel bottom.

The lower portion of Whipple Creek is in the Columbia River floodplain and the stream's bottom slopes are very low (0.1 to 0.2%). In this portion of the channel the stream velocities are lower than in the upper sections and the potential for sediment deposition is greater.

The total distance from the headwaters of Whipple Creek to its downstream confluence with Lake River is approximately 9.6 miles. During major storms the travel time for flood flows to reach the mouth of the creek is less than 24 hours.

Packard Creek, the main tributary to Whipple Creek, presents many of the same hydrologic characteristics. The upper section of Packard Creek's stream channel is steep and the slope flattens out near the confluence with Whipple Creek, as shown in Table 7.

Table 7: Packard Creek Main Stem Channel Bottom Slopes

Channel	Reach	Length (mi)	Elev Change (ft)	Slope (%)
Upper	225	1.266	171.66	2.6%
Middle	219	0.206	13.41	1.2%
Lower	210	1.030	43.66	0.8%
Total/Average		**2.502**	**228.73**	**1.7%**

Overall Packard Creek's stream channel is significantly steeper than Whipple Creek's channel.

In 2006, Clark County's 2006 assessment confirmed the presence of erosion in the watershed, noting that stream scour, incision, and channel instability were common. The county found that deliberate modifications to the channel (e.g. channel straightening, in-line ponds) were relatively infrequent. However, channel crossings from past agricultural activities and driveways are fairly common in tributaries.

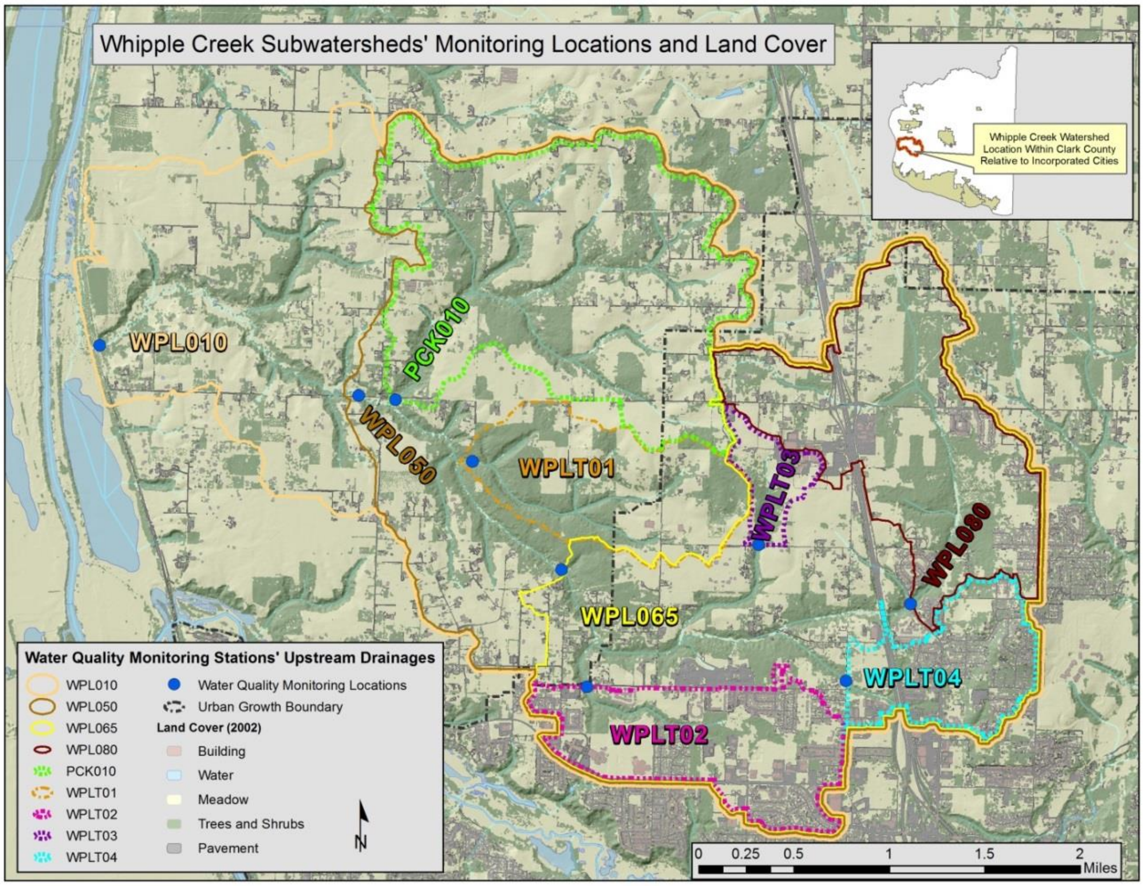
Stream hydrology has been altered as a result of development that occurred over many decades without stormwater detention. In addition, Inter-Fluve noted in its technical memo (2006) that because most development is occurring in the upper watershed, peak flows in the lower main stem could continue to increase significantly.

C. Water Quality

Information about water quality was gathered from several assessments and studies conducted between 2001 and 2015. Figure 3 shows nine stations where water quality data were collected at various times.

Appendix B contains a detailed assessment of Whipple Creek's water quality.

Figure 3: Monitoring Stations and Contributing Basins to Each Station



Water quality in the Whipple Creek watershed is often poor and is impacted by urban and rural development, which channels polluted runoff to the creeks. Ecology includes the lower main stem of Whipple Creek on its 303(d) Category 5 List of polluted waters for fecal coliform bacteria and temperature (Ecology, 2016).

High fecal coliform levels are a watershed-wide issue. The creek frequently exceeds the state's standards for primary contact recreation. Monitoring results suggest there are multiple sources of bacteria in the watershed. Typical sources are urban runoff carrying pet waste; rural non-point pollution from livestock; failing septic systems; and natural contributions from beaver, waterfowl, and other wildlife. Non-stormwater sources of bacteria such as these do not enter streams through the county's storm sewer system.

Existing Conditions

Long-term monitoring results show that Whipple Creek rarely exceeds state standards for either dissolved copper or dissolved zinc, suggesting that these urban pollutants are not limiting water quality in the watershed.

Table 8 summarizes the water quality parameters considered in the assessment of existing conditions and describes whether Whipple Creek meets state standards based on data collected in 2014 and 2015.

Table 8: Summary Comparison of Whipple Creek Water Quality to State Standards

Water Quality Parameter	State Designated Use Protection: Water Quality Standard Criteria & As Applicable Exceedance Frequency Limit	Met Water Quality Standard	Comments on 2014-2015 Watershed-wide Monitoring Results Exceedance of State Water Quality Standards Criteria
Temperature	Aquatic Life Use: 7-Day Average Daily Maximum (7-DADMax) of 17.5°C (63.5°F) once every 10 years on average	No	Most lower main stem and some tributary sub-watersheds commonly exceeded criteria especially during July & August, up to 87 and 77 times / year, respectively
Fecal Coliform	Primary Contact Recreation Use: < geom. mean of 100 cols./100 mL & < 10% of samples: 200 cols./100 mL Preferable to average by season of < 12 months	No	Except for WPL065 and WPL080 wet season, all of the other sub-watersheds exceeded the state's geometric mean criterion during both seasons. All the stations also exceeded the 10% criterion during both the wet and dry seasons.
Dissolved Copper	Aquatic Life Use: Criteria formula using water hardness Acute: 1 hr. avg. < once every 3 yrs. Chronic: 4 day avg.<once every 3 yrs. Apply both acute & chronic on average over 3 years	Mostly Yes	Only WPLT03 & WPLT04 exceed chronic and acute criteria and for both stations' criteria in only 6% of their respective samples. PCK010 exceeds chronic in 11% and acute in 6% of samples
Dissolved Zinc	Aquatic Life Use: Criteria formula using water hardness Acute: 1 hr. avg. < once every 3 yrs. Chronic: 4 day avg.<once every 3 yrs. Apply both acute & chronic on average over 3 years	Mostly Yes	Only WPLT03 exceeded either criterion but did so for both in only 6% of its samples

Three additional water quality parameters are of concern to Clark County. Dissolved oxygen, turbidity, and pH have standards established in state law to support the designated use of salmonid spawning, rearing, and migration. Whipple Creek is listed as a Category 2 water of concern for dissolved oxygen on the state's 303(d) List.

The Permit does not require consideration of these parameters. They are discussed in Appendix B but are not otherwise discussed in this Report.

D. Temperature

Information on existing conditions for temperature was gathered from the County's long-term temperature monitoring station at WPL050 and from watershed-wide temperature monitoring during the summers of 2014 and 2015.

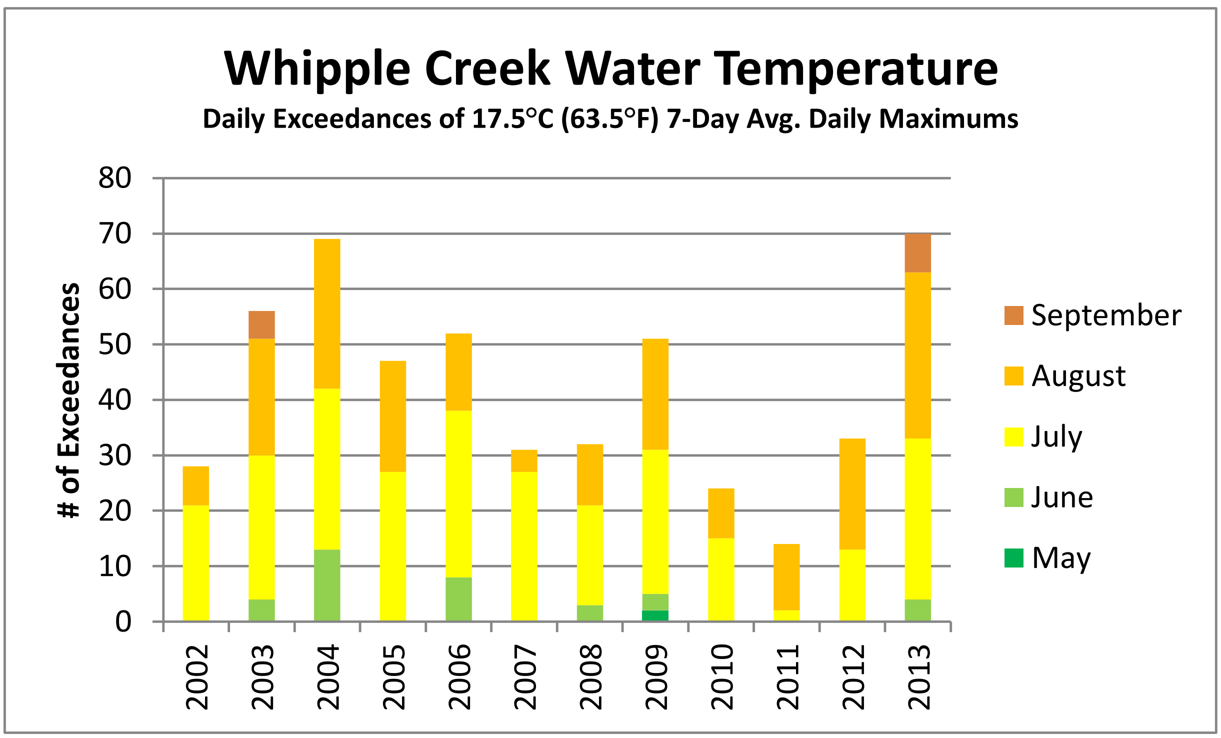
A detailed discussion of Whipple Creek's temperature is in Appendix B.

Whipple Creek is known to be warm and often exceeds temperatures known to kill or stress salmon and steelhead. High summer stream temperatures are frequent, peaking in July and August. Whipple Creek is on the state's 303(d) Category 5 List of polluted waters for temperature.

Long-term monitoring shows that the lower main stem has exceeded the 7-Day Average Daily Maximum temperature of 63.5°F established by the state between 13 and 70 times a year since 2002.

See Figure 4 for long-term exceedances at the WPL050 monitoring station in Middle Whipple Creek.

Figure 4: Lower Whipple Creek WPL050 Main Stem Exceedances of Temperature Criterion



E. Benthic Macroinvertebrates - Biologic Health

Information about existing conditions for biologic integrity was gathered from Clark County's long-term sampling site in the mid-watershed main stem as well as from sampling at four locations during 2014 and 2015.

A more detailed discussion of the macroinvertebrate sampling is in Appendix C.

Existing Conditions

In the summers of 2014 and 2015, the County sampled four locations to assess stream health based on the B-IBI score.

Whipple Creek appears to have poor biologic health. Low B-IBI scores consistent with streams not supporting salmonid uses were found in the rural Middle Whipple Creek, near the mouth of the rural Packard Creek tributary, and in the urbanized Upper Whipple Creek east of I-5. Miner Creek had B-IBI scores consistent with streams that partially support salmonid uses. Lower Whipple Creek is on the 303(d) Category 5 List of polluted waters for bioassessment.

Table 9: 2014 and 2015 Salmonid Use Attainment Based on B-IBI (Based on Observed Conditions)

Location	2014	2015	Key
Lower Main Stem (WPL050)	Non-Supporting	Non-Supporting	Fully Supporting
Upper Main Stem (WPL080)	Non-Supporting	Non-Supporting	Partially Supporting
Miner Creek (MCT010)	Partially Supporting	Partially Supporting	Non-Supporting
Packard Creek (PCK010)	Non-Supporting	Non-Supporting	

F. Fish Distribution and Habitat

Data on fish distribution were gathered from the Statewide Washington Integrated Fish Distribution geodatabase (Washington State Department of Fish and Wildlife [WDFW], 2014) and the SalmonScape web page (WDFW, 2014).

A detailed discussion of fish presence and distribution is in Appendix D.

Figure 5 (next page) shows WDFW fish distribution maps for coho salmon, fall chinook salmon, and winter steelhead.

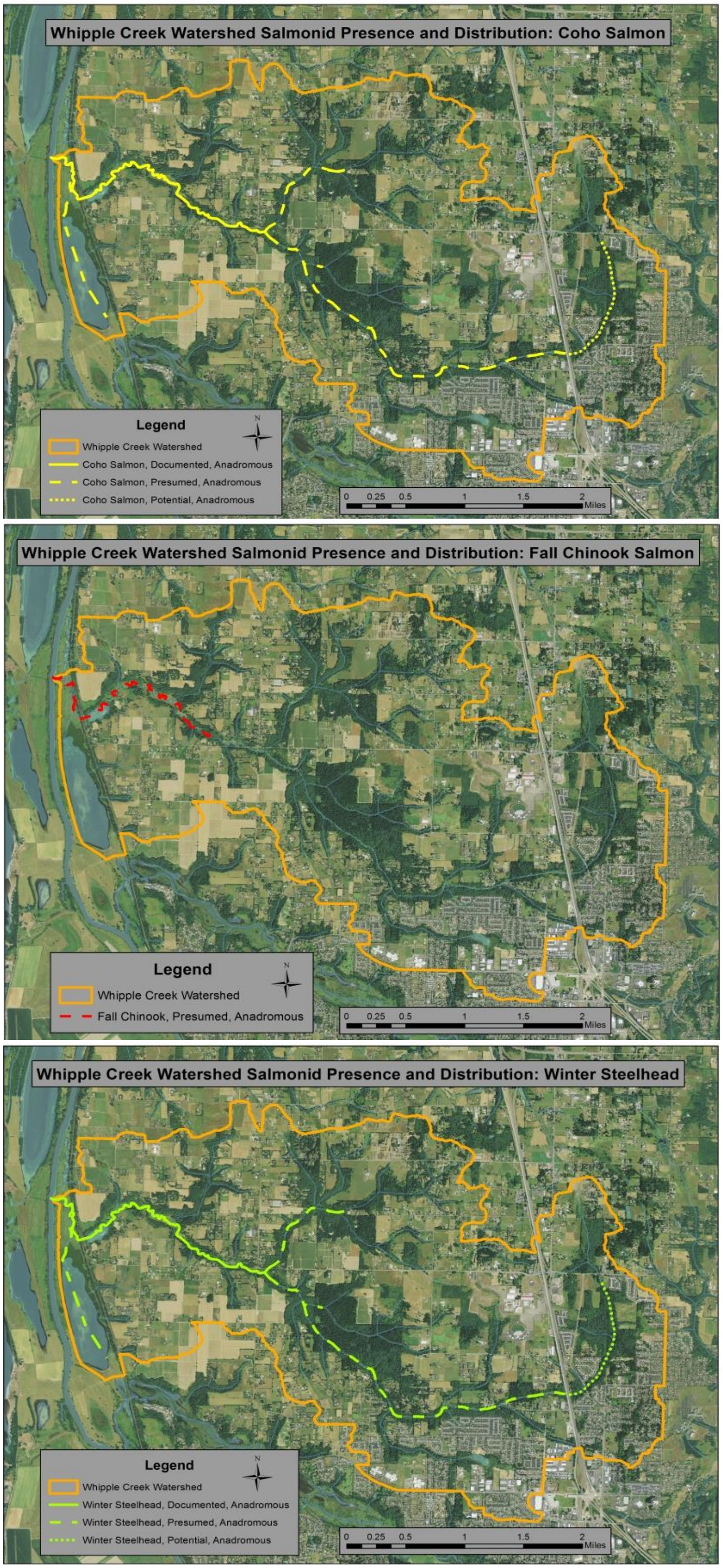
Field observations suggest a lack of spawning habitat for salmonids in the watershed. Low gradient channels are mostly bedded with sand and silt that is unsuitable for spawning, and fish passage barriers limit access to potentially good quality habitat (Inter-Fluve, 2006). The most suitable habitat has been identified in the lower watershed (Inter-Fluve, 2006).

Several partial fish passage barriers exist in the main stem, and there is a complete barrier at I-5. The barrier at I-5 would prevent anadromous fish from using any portion of Whipple Creek upstream of there. There are also barriers in lower Miner Creek and School Land Creek.

Overall, the status of the Whipple Creek watershed's fish community appears degraded. Good quality salmonid habitat is very limited due to small stream sizes, substrate conditions, and passage barriers. Whipple Creek's anadromous fish are listed as Threatened under the Endangered Species Act, including fall Chinook, coho salmon, and winter steelhead.

Existing Conditions

Figure 5: WDFW Fish Distribution Maps



G. Areas of Special Attention

Information about areas of special attention in Whipple Creek was gather from historic field observations, existing reports, and geographic information system (GIS) data analyses. Such areas include riparian buffers, wetlands, hydric soils, floodplains, steep slopes, forests, valuable habitat zones, and other sensitive resource areas.

A detailed discussion of areas of special attention is in Appendix E.

II. Creating Models of Whipple Creek

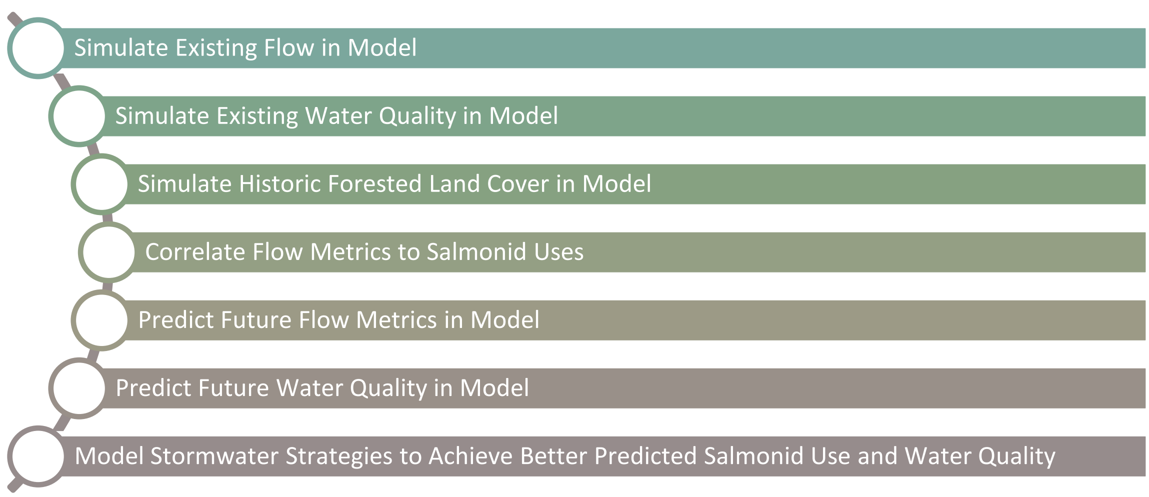
Models were calibrated following Task 3 of The Whipple Creek Watershed-Scale Stormwater Planning Scope of Work and Schedule, June 2014.

A. Purpose of Models

Stream hydrology and water quality change when land cover changes. Modification from forest to agriculture or to urban areas increases runoff and pollutants directed to creeks. As the Whipple Creek watershed develops over time, stream flow, the shape of the stream channel and banks, water quality, and temperature all change as a result of the impacts of stormwater runoff.

Using predictions of future land uses and land covers, this Report estimates future water quality and hydrologic conditions of Whipple Creek and its tributaries. Once the magnitude of potential impact is understood, the models can be used to test the effectiveness of stormwater management strategies and other strategies the County might use to mitigate the impacts of future development.

Figure 6: Purpose of Computer Models of Whipple Creek's Hydrology and Water Quality



Detailed discussions of hydrology model calibration and water quality model calibration are found in Appendices F and G.

B. Calibration Period and Data

Model calibration uses available data about precipitation, land cover, stream flow, pollutant concentrations, and air and stream temperatures in Whipple Creek from the recent past to match observed conditions as much as possible. Once calibrated, the models can be used to estimate hydrology, pollutant concentrations, and stream temperature under different future scenarios of land cover and stormwater management strategies.

Creating Models of Whipple Creek

The calibration period for both the hydrology and the water quality models was selected based on availability of the best quality stream flow data. The calibration period was for a five-year span beginning October 2003 and continuing through September 2008 (water years 2004 through 2008).

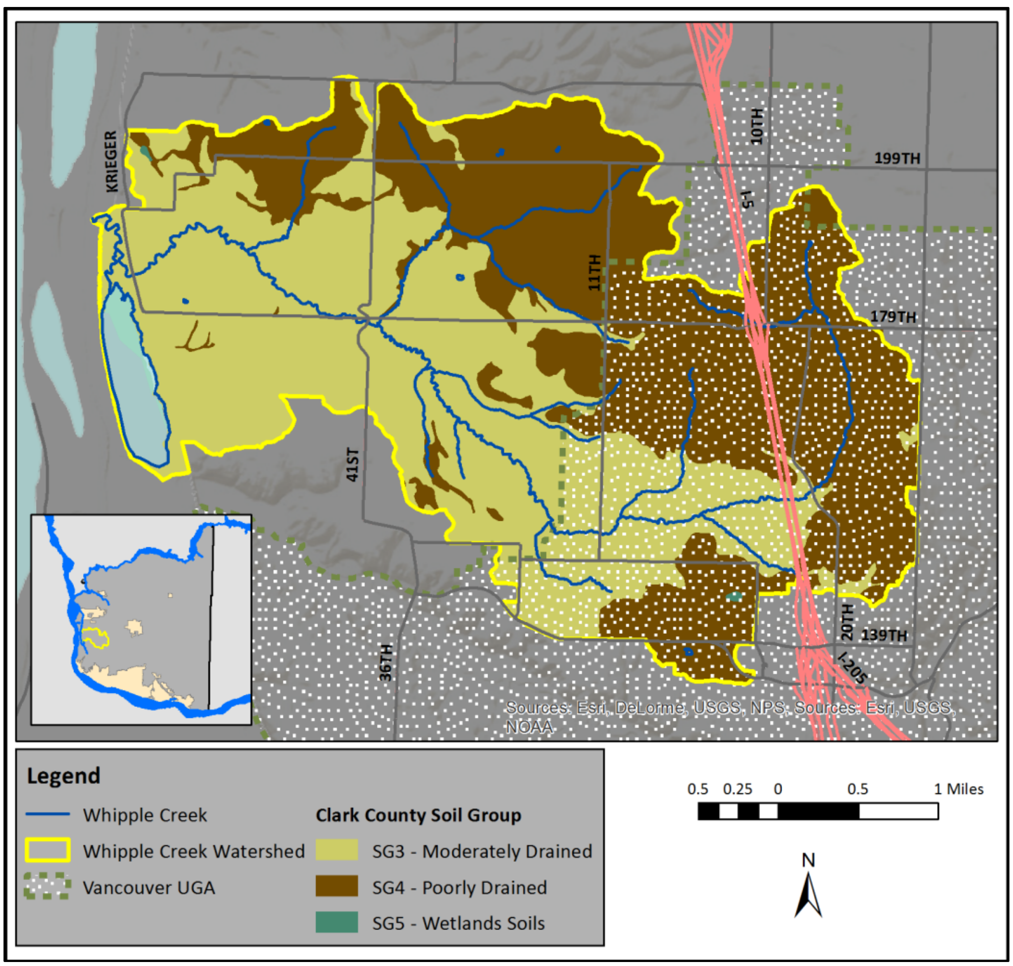
Data included continuous flow monitoring from Clark County's monitoring stations, stream temperature data, pollutant concentrations, and B-IBI collected and calculated as described in the assessment of Whipple Creek's existing conditions in Appendices B and C. The calibration for flow and water quality was at the WPL050 site.

Meteorological data (rainfall, evaporation, air temperature, cloud cover, dew point, temperature, wind speed, and solar radiation) were assembled from local sources for the calibration period.

Using infiltration capacity, soils in Clark County were grouped into five generalized categories. Underlying soils in the Whipple Creek watershed are a mix of moderately drained soils, poorly drained soils, and wetland soils. The following three soil groups were used in the model calibration:

1. SG3: Moderately Drained soils (hydrologic soil groups B & C)
2. SG4: Poorly Drained soils (slowly infiltrating C soils, as well as D soils)
3. SG5: Wetlands soils (mucks)

Figure 7: Whipple Creek Soil Groups

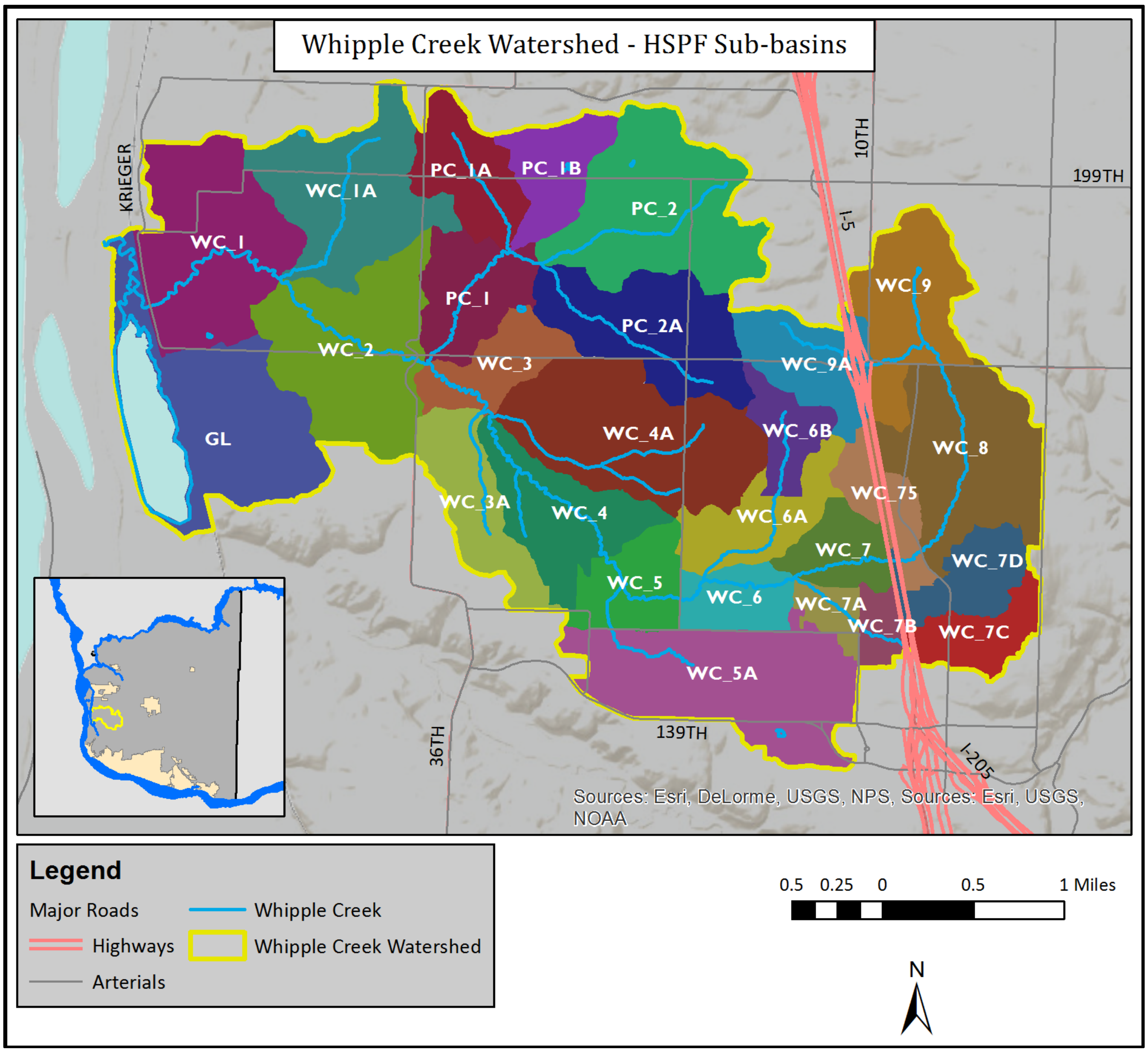


C. Hydrology Model Creation and Calibration

The Whipple Creek watershed hydrology model calibration produced a computer model of the contributing land area rainfall-runoff processes and stream flow routing from the upper end of Whipple Creek and its tributaries.

The hydrology model calibration required first dividing the Whipple Creek watershed into 27 sub-basins. The land area for each sub-basin was divided into bare soil, forest, grass, paved urban, and water land covers. The stream reach boundaries were selected based on topography, confluence with other major reaches, and flow travel time in the stream channel.

Figure 8: Modeled Sub-basin Boundaries



The calibration process is iterative and requires the input and adjustment of hydrologic parameter values and the comparison of simulated and recorded streamflow. Different hydrologic parameters and their values impact or change the timing and distribution of runoff. Some parameters represent different soil and vegetation characteristics while other parameters represent different runoff processes.

Based on experience in calibrating other hydrology models in western Washington, appropriate hydrologic parameter values were selected for the calibration. The hydrology model computed the simulated stream flow using these values. The results were compared with the recorded (observed) stream flow at the WPL050 gage located on the main stem in Middle Whipple Creek below Packard Creek. The results were compared in terms of hydrograph shape and size for multiple major flood events, annual total runoff volume, and flow duration. Flow duration is the percent of time different size flows occur at the gage site.

After each comparison, the hydrologic parameter values were adjusted with the goal of producing a better fit or comparison with the recorded stream flow data. The calibration process ended when it was decided that the hydrologic parameter values produced the best results and no further adjustment of these parameters would improve the calibration.

Table 10 shows the model performance for each of four comparative measures.

Table 10: Hydrology Model Performance

Calibration Period (WY 2004-2008)	Whipple Creek	Overall Model Performance
Annual Volume Error	Very Good	Very Good
Daily Flow R Squared	Very Good	Very Good
Flow Duration Curves	Excellent	Very Good
Hydrographs	Good to Very Good	Very Good

The calibration provided a sound hydrologic model of Whipple Creek. The resulting model parameters were appropriate for evaluating the impact of hydromodification management strategies and calibrating a water quality model. The calibration results demonstrate a good representation of the observed data.

The specifics of the hydrology calibration, the final selection of hydrologic parameter values, and the comparison of the simulated and recorded streamflow data are described in detail in the hydrology model calibration report in Appendix F.

D. Water Quality Model Creation and Calibration

The Whipple Creek watershed water quality model calibration produced a computer model of the contributing land area pollutant-producing processes and transport of these pollutants from the upper end of Whipple Creek and its tributaries. This water quality model was used to model water quality for both existing land use and future development conditions.

The water quality model calibration followed the completion of the hydrology model calibration. After the hydrology model calibration was finished, then water quality inputs were added for the simulation of copper, zinc, fecal coliform, and water temperature.

Creating Models of Whipple Creek

The same sub-basins and stream reaches used in the hydrology model calibration were used to calibrate the water quality model. Pollutant loading rates were based on sub-basin impervious area, soil group, and vegetation category. Soil temperature was correlated to air temperature. The movement of the pollutants (copper, zinc, and fecal coliform) and the calculation of water temperature were based on the stream channel characteristics.

The calibration process was iterative and required the input and adjustment of water quality model parameter values and the comparison of simulated and recorded water quality constituents (copper, zinc, fecal coliform, and water temperature). Different water quality parameters and their values impact or change the timing and distribution of each individual constituent. Some parameters represent different soil and vegetation-related pollutant loading rates while other parameters represent different interactions with the meteorological input.

Based on experience in calibrating other water quality models in western Washington, appropriate model parameter values were selected for the calibration of copper, zinc, fecal coliform, and water temperature. The water quality model computed the simulated water quality results in Whipple Creek using these parameter values. The results were compared with the recorded (observed) copper, zinc, and fecal coliform concentrations and water temperature at the WPL050 gage. The results were compared in terms of seasonal and annual values.

After each comparison, the model calibration parameter values were adjusted with the goal of producing a better fit or comparison with the recorded data. The calibration process ended when it was decided that the final selection of model calibration parameter values produced the best results and no further adjustments would improve the calibration.

Table 11 shows the model performance for each constituent.

Table 11: Water Quality Model Performance

Parameter	Model Performance
Temperature	Very Good to Excellent
Dissolved Metals	Appears Good
Fecal Coliform	Good
Overall Performance	**Good to Very Good**

Overall, the water quality calibration is considered good to very good. The water quality calibration model can be used to model water quality for both existing land use and future development conditions and scenarios.

The specifics of the water quality calibration are described in detail in Appendix G.

E. Reporting Model Results

The calibrated models produce simulated conditions for stream reaches in 27 sub-basins. To simplify presentation of model results, flow metrics and B-IBI scores are reported for a set of eight stream reaches.

Reaches were selected to represent the full range of conditions in the watershed and to demonstrate whether strategies will meet the Permit goal of restoring designated uses. Criteria for selection included:

- Presence of actual or potential salmon habitat
- Contribution of a significant part of the watershed
- Importance for modeling future conditions
- Represent areas to preserve/restore or retrofit
- Not subject to Columbia River backwater conditions

Reporting reaches are described below and are represented as sub-basins in Figure 9.

WC-2 – Lowermost Whipple Creek

This reach has a broad floodplain and potential for salmon spawning habitat restoration. It is the lowest Whipple Creek reach not subject to backwater conditions from the Columbia River floodplain. Temperature is a concern here. See Map A in Figure 9.

WC-3 – Whipple Creek at Sara

This reach includes significant potential salmon habitat and pool-riffle channel sequences that have potential for salmon habitat restoration. The lower end of the reach includes the mouth of Packard Creek, and it is the closest point to the county's long-term monitoring site at the Sara gage (WPL050). Temperature is a concern here. See Map B in Figure 9.

WC-5 – Whipple Creek above Whipple Creek Park

This point represents the main stem between I-5 and Whipple Creek Park. This reach has a fairly low gradient and extensive beaver ponds. Temperature is a concern here. See Map C in Figure 9.

WC-7.5 – Whipple Creek above I-5

There is a full fish passage barrier at I-5 making the area above I-5 a single area of interest for delivering flow and pollutants to downstream salmon habitat. See Map D in Figure 9.

WC-1A – Miner Creek Tributary

Miner Creek has spawning gravel and the best water quality conditions in the watershed. It is of interest for preservation and restoration. See Map D in Figure 9.

PC-1 – Packard Creek Tributary

Packard Creek is the largest tributary to Whipple Creek. The creek has gravel channel substrate providing salmon habitat. While it is significantly degraded due to hydrologic modification and rural land uses, Packard Creek provides an opportunity for salmon habitat restoration. See Map D in Figure 9.

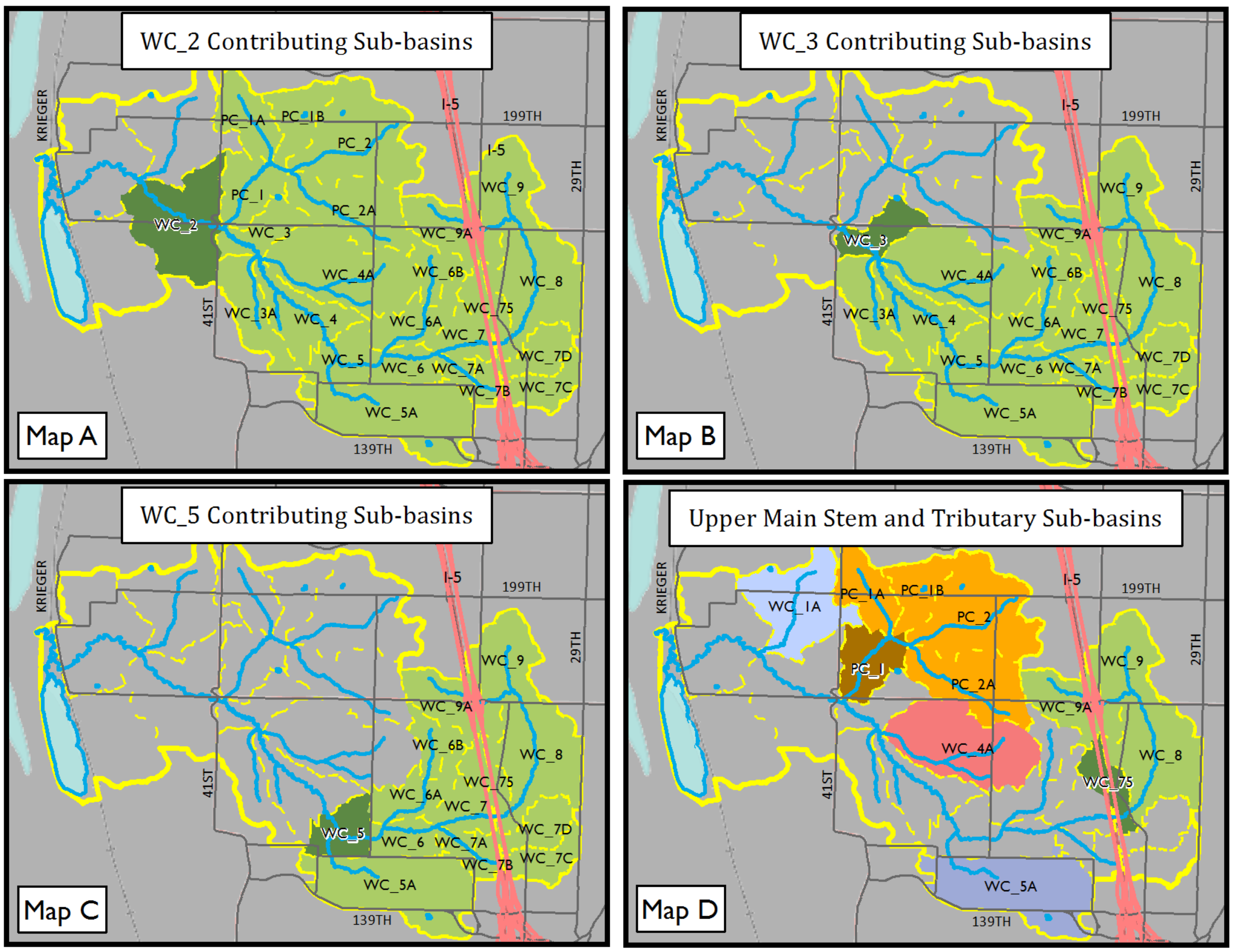
WC-4A – School Land Creek Tributary

School Land Creek drains an area that has potential as salmon habitat and is a sub-basin where Clark County has extensive land holdings as parks and open space. See Map D in Figure 9.

WC-5A – 139 St Tributary

WC-5A is a completely developed urban area built out over the last 30 years. Stream hydrology is greatly altered due to urban runoff and will require extensive retrofitting to restore the tributary's lower reach as salmon habitat. See Map D in Figure 9.

Figure 9: Model Results Reporting Reaches (Shown as Sub-basins) and Contributing Sub-basins



Darker sub-basins = Reporting sub-basins
Lighter sub-basins = Contributing flow to reporting sub-basin

III. Predicting the Future in Whipple Creek

A. Future Development in Whipple Creek

In 2016, Clark County adopted a *Comprehensive Growth Management Plan 2015-2035* (Comp Plan) to guide growth and development for the next 20 years. The Comp Plan's Community Framework Plan describes a vision in which land outside of urban growth areas is predominantly rural with farms, forests, open space, and large lot residences while urban growth areas are targeted for higher densities and a mix of more urban land uses (Clark County, 2016).

i. Land Use

The Whipple Creek watershed contains both the unincorporated Vancouver UGA (nearly 5 sq. mi. in the upper and middle watershed) and rural land throughout the watershed (approximately 7 sq. mi.).

Broadly, the Comp Plan describes a Whipple Creek watershed in which the I-5 corridor will become even more densely developed with industrial and commercial uses, as well as single-family and multi-family homes. The remainder of the UGA will be filled in with lower and medium density residential uses and mixed use. Open spaces will also be present in the UGA outside of the I-5 corridor.

Outside of the UGA, the Comp Plan describes a Whipple Creek watershed that will remain predominantly rural in character, with designations for rural, agriculture, parks/open space, and a small rural commercial area in the traditional unincorporated center of Sara.

Assumptions about future land uses based on Comp Plan designations were used to calculate future land covers. Future land covers form the basis for models that predict water quality and hydrologic conditions in Whipple Creek and its tributaries as the area develops. If all lands in the Whipple Creek watershed were developed to the full densities allowed under the Comp Plan and zoning designations, the watershed would contain the quantities of land covers shown in Table 12.

Table 12: Future Land Cover in Whipple Creek

Land Cover	Residential Impervious	Non-residential Impervious	Forest	Pasture	Lawn	Water
Acres	695	603	1,824	2,284	2,132	185

Land cover from allowed future build-out of the watershed was used to model future development scenarios to predict the effects on water quality and hydrology.

A full discussion of land use assumptions is given in Appendix J.

ii. Development and Engineering Standards

Modeled future scenarios assume that development in Whipple Creek will meet a number of County code chapters and standards that are pertinent to modeling hydrology and water quality. Assumptions are described below. For a chronology of past stormwater-related engineering standards enforced by Clark County, see Appendix N.

Stormwater Code and Manual

Future scenarios assume development will manage stormwater in accordance with Clark County's current Clark County Code Chapter 40.386, Stormwater and Erosion Control, which adopts the *2015 Clark County Stormwater Manual* (CCSM). This code is intended to protect water quality of surface and ground waters for drinking water supply, recreation, fishing, and other beneficial uses. The county manual is equivalent to the Ecology Stormwater Management Manual for Western Washington.

The adopted code and manual meet the requirement to use "all known, available, and reasonable methods of prevention, control, and treatment (AKART)" under the Washington Water Pollution Control Act (RCW 90.48) and reduces discharges to the "maximum extent practicable (MEP)" as required under the Clean Water Act (USC, Title 13, Section 1251 *et seq.*).

LID and County Code

In 2012 and 2015, Clark County revised road standards and development standards in Title 40 to remove barriers to Low Impact Development (LID).

LID is required in the CCSM, and modeled future scenarios assume that the bioretention LID best management practice will be used in development whenever feasible.

Use of other LID techniques such as lot clustering to reduce impervious surfaces could impact future development. County Code allows new subdivisions to cluster lots to preserve open space such as pasture and forest in rural zoned areas. Use of optional lot clustering provisions is difficult to predict and to model at the watershed scale. Considering this, future scenarios assume forested critical areas including both habitat and geologic hazard areas will remain forested.

Areas of Special Concern and County Code

Areas of Special Concern include critical areas where development is regulated under Title 40 to protect the environment, public safety, and public health. These are:

- Critical aquifer recharge areas
- Flood hazard areas
- Geologic hazard areas
- Habitat conservation areas
- Wetland protection areas
- Shorelines of the state

Several critical areas are assumed to remain forested in modeled future scenarios, including:

- Geologic hazards, which are mapped primarily as steep slopes and potential landslide areas;
- Habitat conservation areas; and
- Wetlands that are forested in the existing condition.

Modeled future scenarios do not consider critical aquifer recharge areas (CARAs) or flood hazard areas because they do not influence stream conditions. The entire watershed is a CARA to protect the regional gravel aquifer.

Predicting the Future in Whipple Creek

Whipple Creek is a shoreline water body, having regulated shoreline and floodplain from the Columbia River floodplain upstream to near the confluence with Packard Creek. Shorelines are often redundant with wetlands and riparian buffers, which were assumed to remain forested in the future scenarios.

B. Baseline Scenarios

Two baseline scenarios were modeled following Task 4 of The Whipple Creek Watershed-Scale Stormwater Planning Scope of Work and Schedule, June 2014.

i. Forested Land Cover Baseline Scenario

To form a baseline of hydrology for comparing future scenarios, the calibrated hydrology model was used to predict the hydrology of Whipple Creek with simulated historic forest land cover (Baseline Forested Scenario).

Using the modeled flow metrics with the established correlation of flow to B-IBI scores and salmonid uses, the model predicted the ability of the watershed to support salmon and steelhead under forested conditions.

Model Description

The Baseline Forested Scenario assumes a fully forested land cover in each of the modeled sub-basins. A limitation of the model is the inability to recreate pre-disturbance stream structure and drainage patterns, so the Baseline Forested Scenario assumes the forested land cover is applied to the watershed’s current stream morphology.

Model Results

The Baseline Forested Scenario simulated stream flow for five water years (2004-2008). Flow metrics including T_{Qmean} and HPC were estimated using reported meteorological data from those years.

Predicted B-IBI scores were calculated from simulated flow metrics as the average annual scores for five years, estimated using the relationships established each for T_{Qmean} and HPC, as described in the Introduction.

Table 13: Predicted B-IBI Under Simulated Forested Land Cover

Sub-basin	Average B-IBI	Standard Salmonid Use Range (B-IBI)
WC-1A	34	Partially Supporting
WC-2	34	Partially Supporting
WC-3	34	Partially Supporting
WC-4A	33	Partially Supporting
WC-5	34	Partially Supporting
WC-5A	35	Partially Supporting
WC-7.5	34	Partially Supporting
PC-1	33	Partially Supporting

Under simulated forested conditions with the watershed's current stream morphology, a B-IBI score of 39 was the highest single score achieved in any reporting sub-basin. This score was calculated from T_{Qmean} and was achieved at WC-2 and at WC-4A in 2007.

Salmonid use attainment ranges were also estimated based on the correlations described in the Introduction for T_{Qmean} and HPC. The metrics and associated ranges are shown in Table 14.

Table 14: Simulated Flow Metrics and Salmonid Use Attainment Under Simulated Forest Land Cover

Sub-basin	Average T_{Qmean}	T_{Qmean} Salmonid Use Range	Average HPC	HPC Salmonid Use Range
WC-1A	34%	Partially Supporting	3	Fully Supporting
WC-2	35%	Partially Supporting	4	Fully Supporting
WC-3	35%	Partially Supporting	3	Fully Supporting
WC-4A	35%	Partially Supporting	4	Fully Supporting
WC-5	35%	Partially Supporting	4	Fully Supporting
WC-5A	36%	Partially Supporting	3	Fully Supporting
WC-7.5	34%	Partially Supporting	3	Fully Supporting
PC-1	34%	Partially Supporting	3	Fully Supporting

Average B-IBI scores and T_{Qmean} calculations suggest that all reporting sub-basins would partially support salmonid uses under forested land cover, while the average of the HPC metric suggests that all reporting sub-basins would fully support salmonid uses under forested land cover.

Adjusting the Fully Supporting B-IBI Score

Ecology's written guidance on watershed planning recommends using the lower of either a B-IBI score of 38 or 90% of the B-IBI score modeled for forested land cover as the threshold for fully supporting salmonid uses in future scenarios (Ecology, March 29, 2016). Following this guidance, the range of B-IBI scores for fully supporting salmonid uses in future scenarios was adjusted as shown in Table 15.

Table 15: Adjusted Salmonid Fully Supporting Use Range (B-IBI) by Reporting Sub-basin

Sub-basin	Average Forested Baseline B-IBI	Adjusted Fully Supporting Range (B-IBI)
WC-1A	34	>31
WC-2	34	>30
WC-3	34	>31
WC-4A	33	>30
WC-5	34	>30
WC-5A	35	>32
WC-7.5	34	>31
PC-1	33	>30

Conclusions

The simulated Forested Baseline Scenario does not unambiguously show that Whipple Creek would fully support salmonid uses even under forested land cover.

Clark County's investigations of the watershed suggest that some of the reasons for these limitations are inherent in the watershed's stream sizes, topography, and natural substrate (see Chapter I, Section F).

For determining fish use attainment predicted for modeled future scenarios, the lower threshold for attaining fully supporting salmonid uses based on B-IBI is adjusted to 90% of the B-IBI attained in the Forested Baseline Scenario.

ii. Full Build-out Baseline Scenario (Future Scenario 1)

Future Scenario 1 (FS1) is the future full build-out of the urban portion of the watershed. FS1 forms the baseline for decision-making in this Report. If the results of FS1 show that the Whipple Creek watershed will not meet water quality standards or attain designated salmonid uses, then the Permit requires Clark County to analyze management strategies it could implement to meet those requirements.

Description of Full Build-out Baseline Scenario

FS1 assumes that the UGA in the watershed will develop under existing land use designations to full densities allowed under the current Comprehensive Plan, which plans for county growth through 2035.

Using the build-out assumptions stated above, FS1 models the impact of land cover changes and the required stormwater controls under the 2015 Title 40 and the CCSM.

Stormwater facilities for full build-out were modeled as a single bioretention facility and a single stormwater detention pond for each sub-basin within the UGA. The bioretention facility included infiltration for Soil Group 3 (SG3), but no infiltration for Soil Group 4 (SG4).

The modeled stormwater facilities were sized using the Western Washington Hydrology Model version 2012 (WWHM2012). The bioretention facilities were sized to meet the water quality treatment standard (Minimum Requirement #6 of the CCSM). Bioretention facilities in sub-basins with SG3 soils were also sized to meet the LID Performance Standard (Minimum Requirement #5 of the CCSM). Stormwater detention ponds were sized to meet the western Washington Flow Control Standard (Minimum Requirement #7 of the CCSM).

Appendix K describes modeling stormwater facilities in FS1 using WWHM2012.

Bioretention facilities and stormwater detention ponds were modeled to reduce copper, zinc, and fecal coliform concentrations in stormwater runoff based on Ecology's watershed planning assumptions guidance (March 29, 2016).

Ecology's recommended pollutant removal rates are shown in Table 16.

Table 16: Pollutant Removal Rates

Runoff Flow Route	Copper	Zinc	Fecal Coliform
Bioretention flow through riser	0%	0%	0%
Bioretention flow through media to underdrain	0%	60%	50%
Bioretention flow to groundwater	100%	100%	100%
Stormwater Detention Pond discharge to stream	0%	0%	50%

These pollutant removal rates were incorporated into all subsequent future scenario water quality models.

Model Results

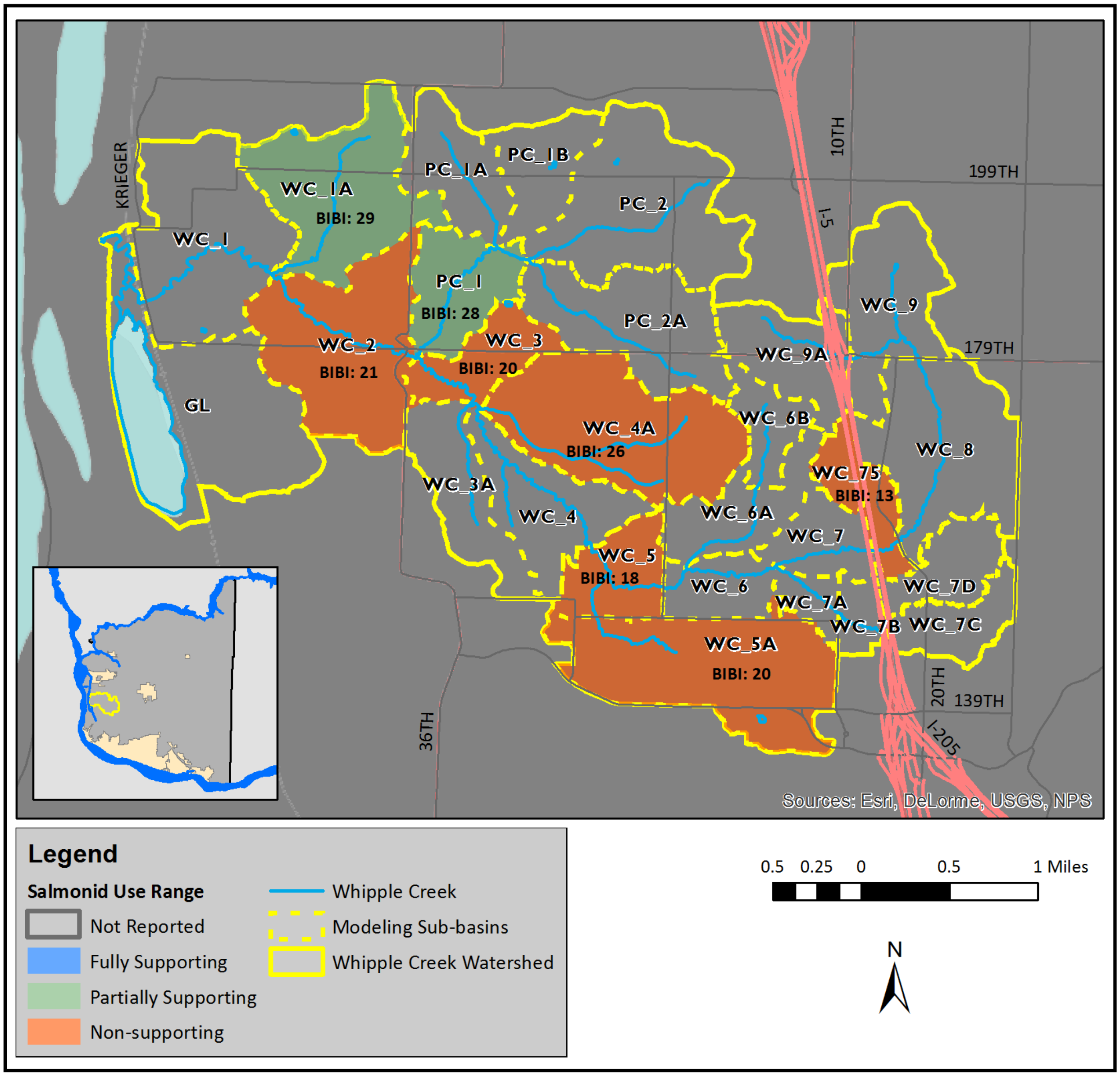
FS1 model results simulated stream flow and water quality parameters for five water years (2004-2008).

Predicted B-IBI scores were calculated from simulated flow metrics as the average annual score for five years, estimated using the relationships established each for T_{Qmean} and HPC. Predicted flow metrics were also directly reported. The B-IBI scores, flow metrics, and related salmonid use ranges are shown in Table 17. Figure 10 is a map of B-IBI scores.

Table 17: Predicted B-IBI, Flow Metrics, and Salmonid Use Ranges for Full Build-out Baseline (FS1)

	B-IBI			T_{Qmean}		HPC	
Sub-basin	Average B-IBI	Adjusted Salmonid Use Range	Adjusted Fully Supporting B-IBI	Average T_{Qmean}	Salmonid Use Range	Average HPC	Salmonid Use Range
WC-1A	29	Partially Supporting	>31	34%	Partially Supporting	6	Fully Supporting
WC-2	21	Non-supporting	>30	32%	Partially Supporting	14	Non-supporting
WC-3	20	Non-supporting	>31	30%	Partially Supporting	15	Non-supporting
WC-4A	26	Non-supporting	>30	33%	Partially Supporting	9	Partially Supporting
WC-5	18	Non-supporting	>30	29%	Partially Supporting	18	Non-supporting
WC-5A	20	Non-supporting	>32	31%	Partially Supporting	17	Non-supporting
WC-7.5	13	Non-supporting	>31	26%	Non-supporting	29	Non-supporting
PC-1	29	Partially Supporting	>30	33%	Partially Supporting	6	Fully Supporting

Figure 10: Map of Predicted B-IBI Scores and Adjusted Salmonid Uses - Full Build-out (FS1)



Based on B-IBI scores, the main stem of Whipple Creek (sub-basins WC-2, WC-3, WC-5, and WC-7.5) likely would not support salmonid use at full build-out. However, based on T_{Qmean}, most main stem and tributaries may partially support salmonid uses. HPC is less optimistic than T_{Qmean} and more optimistic than B-IBI; HPC shows a majority of reaches not supporting salmonid uses under full build-out and two that may fully support.

The water quality results are presented in terms of violations of the state water quality standards for copper, zinc, fecal coliform, and water temperature. The number of violations that occurred in reporting sub-basins during the five-year simulation period are shown below.

Table 18: Predicted Water Quality Violations, Full Build-out Baseline (FS1)

Sub-basin	Copper - Acute	Copper - Chronic	Zinc - Acute	Zinc - Chronic	Fecal Coliform	Water Temperature
WC-1A	0	0	0	0	1263	9
WC-2	0	0	0	0	1352	494
WC-3	0	0	0	0	1365	407
WC-4A	0	0	0	0	1266	2
WC-5	0	0	0	0	1384	413
WC-5A	0	0	0	0	1358	20
WC-75	0	0	0	0	1440	295
PC-1	0	0	0	0	1268	6

Copper and zinc concentrations in Whipple Creek are not predicted to exceed state water quality standards under full build-out. Predicted number of fecal coliform and water temperature violations are quite high in this scenario in all reporting sub-basins.

Estimated Costs

Full build-out is implemented primarily by private developers and has no estimated capital costs for the county.

Conclusions

The full build-out of the Whipple Creek watershed under current land use assumptions and stormwater control standards mitigates some of the stormwater runoff impacts from expected future development in the UGA, but still results in high fecal coliform and high water temperatures due in large part to the adverse impacts of stormwater runoff from existing development.

Predictions of fish use appear to lean to non-supporting based on B-IBI and HPC, with perhaps some basins partially supporting salmonid uses.

Modeled results of FS1 show that Whipple Creek will achieve neither state water quality standards nor salmonid beneficial uses as the watershed develops under the County’s current zoning, development regulations, and stormwater regulations.

Recognizing this, Clark County considered numerous strategies, as described in Section C, that might allow Whipple Creek to achieve the required water quality standards and support salmonid uses as it develops.

C. Strategies to Meet Water Quality Goals

The Permit requires the county to consider several types of strategies to restore or protect designated uses if the full build-out scenario predicts that water quality standards will not be met or salmonid uses will not be attained. The Permit also allows other types of management actions to be considered. This Report contemplates a number of these.

i. Modeled Strategies Required by the Permit

The Permit requires Clark County to model the following stormwater management strategies:

- Future structural stormwater control projects; and
- Changes to development-related codes, rules, standards and plans.

Structural Stormwater Retrofits

The Permit requires Clark County to evaluate the potential effect of a structural retrofit program to add detention and water quality treatment to areas of existing development that do not currently have these controls.

Accordingly, structural stormwater retrofits were modeled for urbanized sub-basins in Future Scenario 2. Additional structural retrofits were modeled for the watershed's rural area in Future Scenario 4. See Section D for a discussion of modeled future scenarios.

Changes to Development-related Codes, Rules, Standards, and Plans

The Permit requires the county to evaluate the potential effect of changes to development-related codes, rules, standards, and plans. Because the county's current development and stormwater codes were updated in recent years to remove barriers to LID and to adopt an equivalent version of Ecology's stormwater manual that is considered AKART, this Report does not suggest any additional development-related code changes.

A brief discussion of each item category and its relevance to Clark County is below.

County Stormwater Code

Clark County development code meets the standards of the current Permit and is unlikely to be changed to the point where potential model scenarios could be created. The Clark County Stormwater Manual (CCSM) is considered to be AKART, and it is the standard for the full build-out scenario.

Rules

Clark County does not use administrative rules; all "rules" are adopted as County Code through legislative process.

Standards

Clark County does not use standards separate from County Code; all standards such as those of the CCSM are adopted as County Code through legislative process.

Comprehensive Growth Management Plan

The Clark County Comp Plan is adopted by the Clark County Board of County Councilors pursuant to state law. This Report does not consider updates to the Comp Plan. Future Comp Plan updates may consider actions for managing stormwater impacts related to growth.

ii. Optional Strategies

In addition to the two required strategies, the Permit allows other stormwater management strategies to be modeled, such as:

- Basin-specific stormwater control requirements for new development and redevelopment (per a basin plan); or
- Strategies to encourage redevelopment and infill.

The Permit also allows evaluating other strategies that influence maintenance of existing and designated uses of the stream, including, but not limited to:

- Channel restoration
- In-stream culvert replacement
- Quality of the riparian zone
- Gravel disturbance regime
- Presence and distribution of large woody debris

Consideration of Optional Strategies

During the planning process, optional strategies were evaluated and selected for inclusion in this Report. Selection criteria included benefits to flow, water quality, or other environmental benefits; whether the strategy applied in developed or undeveloped areas; and whether the benefit could be modeled or estimated. Some selected strategies were modeled in future scenarios and some were included as management options although their benefits were not modeled.

Table 19: Optional Management Strategies Considered

Management Strategy	Water Quality	Flow	Other Env Benefits	Notes	Selection Status
Floodplain reconnection to improve hydrology		X	X	Benefit cannot be modeled. Included in Channel Restoration strategy.	Selected
Stream channel and floodplain repair	X		X	Benefit cannot be modeled. Included in Channel Restoration strategy.	Selected
Stream channel restoration to improve hydrology		X	X	Could be a practical and cost effective alternative to improve hydrology, in the absence of space outside stream corridors to build flow control facilities. Benefit cannot be modeled. Included in Channel Restoration strategy.	Selected
Culvert/barrier removal to improve fish habitat access			X	Benefit cannot be modeled. Included in Channel Restoration strategy.	Selected

Management Strategy	Water Quality	Flow	Other Env Benefits	Notes	Selection Status
Reforestation and forest management	X		X	May be a cost effective alternative. Included in Full Shade strategy.	Selected
Riparian vegetation restoration for shade and large woody debris	X			Included in Full Shade strategy.	Selected
Stormwater control requirements under an Approved Basin Plan		X		Currently there is no basin plan for Whipple Creek.	Not Selected
Redevelopment and infill policies (incentives for infill)	X	X		Future Scenario 2 assumes the entire urban area is retrofitted to manual standards.	Not Selected
Regional stormwater facilities for infill and redevelopment	X	X	X	This action is inherent in the Structural Retrofits strategy, but it was not discretely modeled.	Not Selected
Natural resources conservation (critical/sensitive areas protection)	X	X		Critical areas are currently protected under Title 40, and future scenario models recognize some protected areas as undevelopable.	Ongoing
Stream corridor protection (critical/sensitive areas protection, Shoreline Management Areas protection)			X	Shoreline Management Areas are currently protected under Title 40.	Ongoing
General county-wide stormwater program outreach, education, and technical assistance	X		X	Benefit cannot be modeled. Any effects of the ongoing program are inherent in the calibrated models of exiting conditions.	Ongoing
Wetland protection strategies	X	X	X	Wetlands are currently protected under Title 40, and future scenarios models recognize some wetlands as undevelopable.	Ongoing
Roof downspout disconnects (that are not flow control facilities)				Uncertain benefit	Not Selected
Enhanced street sweeping	X			Benefit cannot be modeled.	Not Selected
Enhanced catch basin cleaning	X			Benefit cannot be modeled.	Not Selected
Targeted outreach	X			Benefit cannot be modeled.	Not Selected
Enhanced source control inspections	X			Benefit cannot be modeled.	Not Selected
Enhanced conveyance system cleaning	X			Benefit cannot be modeled.	Not Selected

Optional Strategies Modeled

Two optional strategies were combined into a single strategy for adding shade to reduce stream temperatures, which can be modeled. These are:

- Reforestation and forest management
- Riparian vegetation restoration for shade and large woody debris

See Future Scenario 3 in Section D for more on the Full Shade strategy.

Optional Strategies Not Modeled

Several other optional strategies were selected as management options, although their benefits cannot be modeled in future scenarios.

Four optional strategies were combined into a single strategy of Channel Restoration. These are:

- Floodplain reconnection to improve hydrology
- Stream channel and floodplain repair
- Stream channel restoration to improve hydrology
- Culvert/barrier removal to improve fish habitat access

D. Future Scenario Models

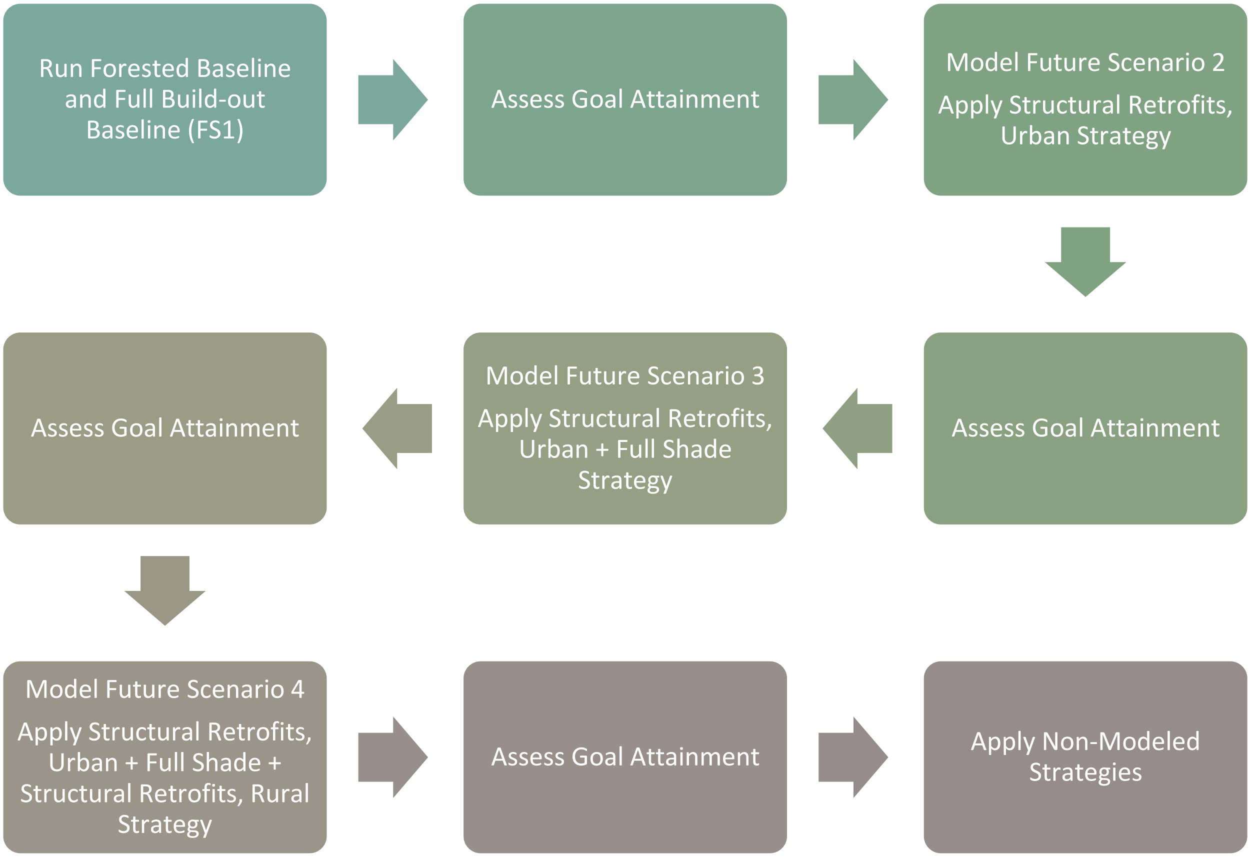
Future scenarios were modeled following Task 5 of The Whipple Creek Watershed-Scale Stormwater Planning Scope of Work and Schedule, June 2014.

To model strategies required or allowed by the Permit, this Report combines strategies into future scenarios.

Future scenarios were modeled sequentially. The results of each future scenario were evaluated to determine if water quality standards were met and if salmonid use goals were attained. If not, additional strategies were contemplated in the subsequent future scenario.

Figure 11 illustrates the sequential modeling of scenarios.

Figure 11: Sequential Scenario Modeling and Strategy Application Concept



i. Future Scenario 2 – Urban Structural Retrofits

Description of Future Scenario 2

Future Scenario 2 (FS2) simulates the effects of providing new water quality treatment and detention facilities for the currently urbanized areas of the Whipple Creek watershed.

FS2 builds on FS1 and includes all of the water quality and detention facilities described for future build-out, as well new structural stormwater retrofits for areas of existing development within the UGA sub-basins.

Structural retrofits were assumed to apply to the land area that is currently designated urban impervious and lawn land cover.

As with FS1, urban structural retrofits were modeled as a single bioretention facility and a single stormwater detention pond for each sub-basin. The bioretention facility included infiltration for Soil Group 3 (SG3), but no infiltration for Soil Group 4 (SG4).

Like facilities modeled in FS1, the retrofit facilities for existing development were sized using the WWHM2012 to the design standards for water quality treatment, LID performance, and flow control described in the CCSM. Pollutant removal rates for facilities were also the same as those used in FS1.

Model Results

FS2 model results simulated stream flow and water quality parameters for five water years (2004-2008).

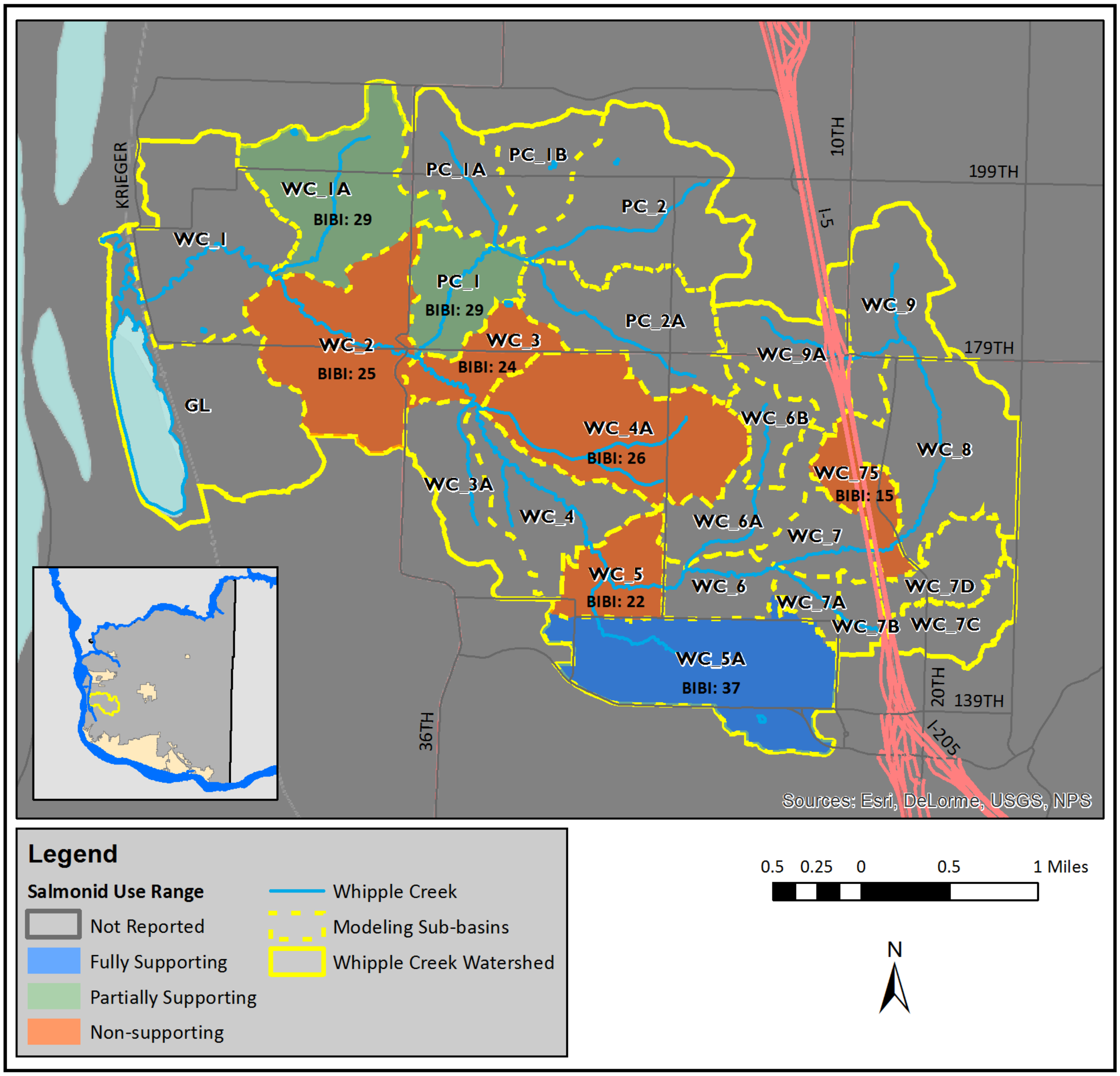
For reporting sub-basins, predicted B-IBI scores were calculated from simulated flow metrics as the average annual scores for five years, estimated using the relationships established each for T_{Qmean} and HPC. Predicted flow metrics were also directly reported.

The B-IBI scores, flow metrics, and related salmonid use ranges are shown in Table 20. Figure 12 is a map of B-IBI scores.

Table 20: Predicted B-IBI, Flow Metrics, and Salmonid Use Ranges - Urban Structural Retrofits (FS2)

	B-IBI			T_{Qmean}		HPC	
Sub-basin	Average B-IBI	Adjusted Salmonid Use Range	Adjusted Fully Supporting B-IBI	Average T_{Qmean}	Salmonid Use Range	Average HPC	Salmonid Use Range
WC-1A	29	Partially Supporting	>31	34%	Partially Supporting	6	Fully Supporting
WC-2	25	Non-supporting	>30	34%	Partially Supporting	10	Partially Supporting
WC-3	24	Non-supporting	>31	33%	Partially Supporting	11	Partially Supporting
WC-4A	26	Non-supporting	>30	33%	Partially Supporting	9	Partially Supporting
WC-5	22	Non-supporting	>30	33%	Partially Supporting	15	Non-supporting
WC-5A	37	Fully Supporting	>32	37%	Partially Supporting	3	Fully Supporting
WC-7.5	15	Non-supporting	>31	26%	Partially Supporting	20	Non-supporting
PC-1	29	Partially Supporting	>30	33%	Partially Supporting	7	Partially Supporting

Figure 12: Map of Predicted B-IBI Scores and Adjusted Salmonid Uses - Urban Structural Retrofits (FS2)



With urban structural retrofits, B-IBI scores in the lower main stem improve compared to FS1 but remain low and in the non-supporting range of salmonid use attainment. Tributary WC-5A improves to from a non-supporting score in FS1 to a score fully supporting salmonid uses in FS2. Other tributaries in the rural area are not impacted by structural retrofits in existing urbanized areas.

Under FS2, T_{Qmean} improves slightly in three main stem sub-basins – WC-2, WC-3, and WC-5 – but not enough to move from partially supporting to fully supporting salmonid uses. HPC improves in five sub-basins. WC-2 improves from non-supporting to partially supporting salmonid uses, and WC-5A improves significantly from non-supporting to fully supporting based on HPC.

The water quality results are presented in terms of violations of the state water quality standards for copper, zinc, fecal coliform, and water temperature. The number of violations occurring during the five-year simulation period are shown in Table 21.

Table 21: Water Quality Violations, Urban Structural Retrofits (FS2)

Sub-basin	Copper – Acute Violations	Copper – Chronic Violations	Zinc – Acute Violations	Zinc – Chronic Violations	Fecal Coliform Violations	Water Temperature Violations
WC-1A	0	0	0	0	1263	9
WC- 2	0	0	0	0	1190	468
WC-3	0	0	0	0	1087	371
WC-4A	0	0	0	0	1266	2
WC-5	0	0	0	0	587	287
WC-5A	0	0	0	0	19	0
WC-75	0	0	0	0	938	112
PC-1	0	0	0	0	1268	6

As with FS1, copper and zinc concentrations in Whipple Creek are not predicted to exceed state water quality standards.

Fecal coliform and water temperatures remain high in most reporting sub-basins. Sub-basin WC-5A shows the greatest improvement in reduction of fecal coliform and water temperature violations because 400 acres of existing development, which is more than 80% of the sub-basin total drainage area, is directed into a stormwater control or retrofit facility for water quality treatment.

The best management practice for urban areas that can eliminate fecal coliform in stormwater runoff is infiltration, including infiltration in bioretention facilities. Unfortunately, soil conditions prevent use of infiltration through much of the watershed, so eliminating fecal coliform violations from Whipple Creek's urban sub-basins may not be feasible.

Comparative Benefits

Compared to FS1, FS2 maintains attainment of water quality standards for dissolved metals. FS2 reduces exceedances of standards for temperatures and for concentrations of fecal coliform, but does not meet standards in the reporting sub-basins.

FS2 improves B-IBI scores and flow metrics, and improves one reporting sub-basin from non-supporting to fully supporting salmonid uses.

For these gains, the Urban Structural Retrofits components of FS2 could cost $263 million for capital improvements.

Table 22: Comparative Benefits of FS2

Constituent or Metric	Forested Baseline	FS1	FS2
Dissolved Copper	✓ *	✓	✓
Dissolved Zinc	✓ *	✓	✓
Temperature	✓ *	✗	✗
Fecal Coliform	✗ *	✗	✗
Salmon Use (B-IBI)†	Partially Supporting	Non-supporting	Non-supporting

* These parameters were not modeled, and assessments of goal attainment under the forested baseline scenario were determined using professional judgement.
† Reported as the majority of use ranges associated with average B-IBI within the set of reporting sub-basins

Conclusions

Overall FS2 results in low to moderate B-IBI scores, high fecal coliform, and high water temperatures.

ii. Future Scenario 3 – Adding Riparian Restoration for Full Shade

Description of Future Scenario 3

Future Scenario 3 (FS3) includes all of the stormwater control and retrofit facilities contemplated in FS1 and FS2. In addition, FS3 simulates the effects of increased stream channel shading in stream reaches that are not currently fully shaded.

Shading of the stream channel reduces direct solar radiation on the water surface area and that, in turn, reduces water temperatures. Shading has no impact on B-IBI scores or on copper, zinc, and fecal coliform. In the model, shading is expressed as a percentage of water surface that is fully shaded. All of the tributaries except Packard Creek are assumed to be fully shaded in the base model.

Existing and proposed percentages of stream channel shading for sub-basins that are not fully shaded are shown in Table 23.

Table 23: Existing and Future Shade (in % of Stream Reach Where Base Model was not Fully Shaded)

Sub-basin	Existing % of Reach Surface Area Shaded	FS3 % Shaded
WC-1	50.0%	99.9%
WC-2	50.0%	99.9%
WC-3	50.0%	99.9%
WC-4	50.0%	99.9%
WC-5	50.0%	99.9%
WC-6	50.0%	99.9%
WC-7	50.0%	99.9%
WC-8	50.0%	99.9%
PC-2	90.0%	99.9%
PC-2A	90.0%	99.9%

Model Results

FS3 model results simulated stream temperature for five water years (2004-2008).

The strategy to increase stream shading impacts temperature only. Neither water quality nor flow metrics are impacted by FS3, so they are not reported. Table 24 compares the number of water temperatures violations from FS1 to FS3.

Table 24: Comparison of Water Temperature Violations, FS1 and FS3

Sub-basin	FS1		FS3	
	Water Temperature Violations	Meet State Water Quality Standard?	Water Temperature Violations	Meet State Water Quality Standard?
WC-1A*	9	✗ †	9	✗ †
WC-2	494	✗	4	✗ †
WC-3	407	✗	0	✓
WC-4A*	2	✗ †	2	✗ †
WC-5	413	✗	0	✓
WC-5A	20	✗	0	✓
WC-7.5	295	✗	0	✓
PC-1	6	✗ †	4	✗ †

*Note: WC-1A and WC-4A are fully shaded in the base model.
† These very nearly met the standards.

Water temperature violations improve significantly with simulated full shading. Under FS3, violations of the state temperature standard for salmonid uses are reduced by more than 1,000 violations over five years. Four sub-basins meet the standard, and four other sub-basins nearly meet the standard.

Comparative Benefits

Compared to FS2, FS3 nearly eliminates exceedances of standards for temperatures in the reporting sub-basins. FS3 is not intended to have any impact on fecal coliform, B-IBI, or flow metrics.

For these gains, the Full Shade components of FS3 could cost $2.7 million in one-time expenditures.

Table 25: Comparative Benefits of FS3

Constituent or Metric	Forested Baseline	FS1	FS2	FS3
Dissolved Copper	✓ *	✓	✓	✓
Dissolved Zinc	✓ *	✓	✓	✓
Temperature	✓ *	✗	✗	✓
Fecal Coliform	✗ *	✗	✗	✗
Salmon Use (B-IBI)†	Partially Supporting	Non-supporting	Non-supporting	Not reported

* These parameters were not modeled, and assessments of goal attainment under the forested baseline scenario were determined using professional judgement.
† Reported as the majority of use ranges associated with average B-IBI within the set of reporting sub-basins

Conclusions

Increasing the shading to the maximum amount possible eliminates high water temperatures violations in a majority of the sub-basins. Although not all sub-basins reach zero violations, this Report assumes that full shading is effective in supporting salmonid beneficial uses through control of temperature as the watershed recovers from existing impacts and develops to full build-out.

iii. Future Scenario 4 – Adding Rural Area Structural Retrofits

Description of Future Scenario 4

Future Scenario 4 (FS4) includes all of the stormwater control and retrofit facilities of FS1 and FS2 plus the increased shading of the stream channel of FS3. In addition, FS4 simulates the effects of stormwater retrofit facilities to treat runoff from existing impervious surfaces and lawn/landscaping in the rural watershed outside the UGA.

Rural structural retrofits were modeled as a single bioretention facility and a single stormwater detention pond for each sub-basin outside of the UGA. The bioretention facility included infiltration for Soil Group 3 (SG3), but no infiltration for Soil Group 4 (SG4).

As in FS1 and FS2, the retrofit facilities were sized using the WWHM2012 to meet applicable standards under the CCSM and were modeled to remove pollutants at the same rates as facilities modeled in prior future scenarios.

Model Results

FS4 model results simulated stream flow and water quality parameters for five water years (2004-2008).

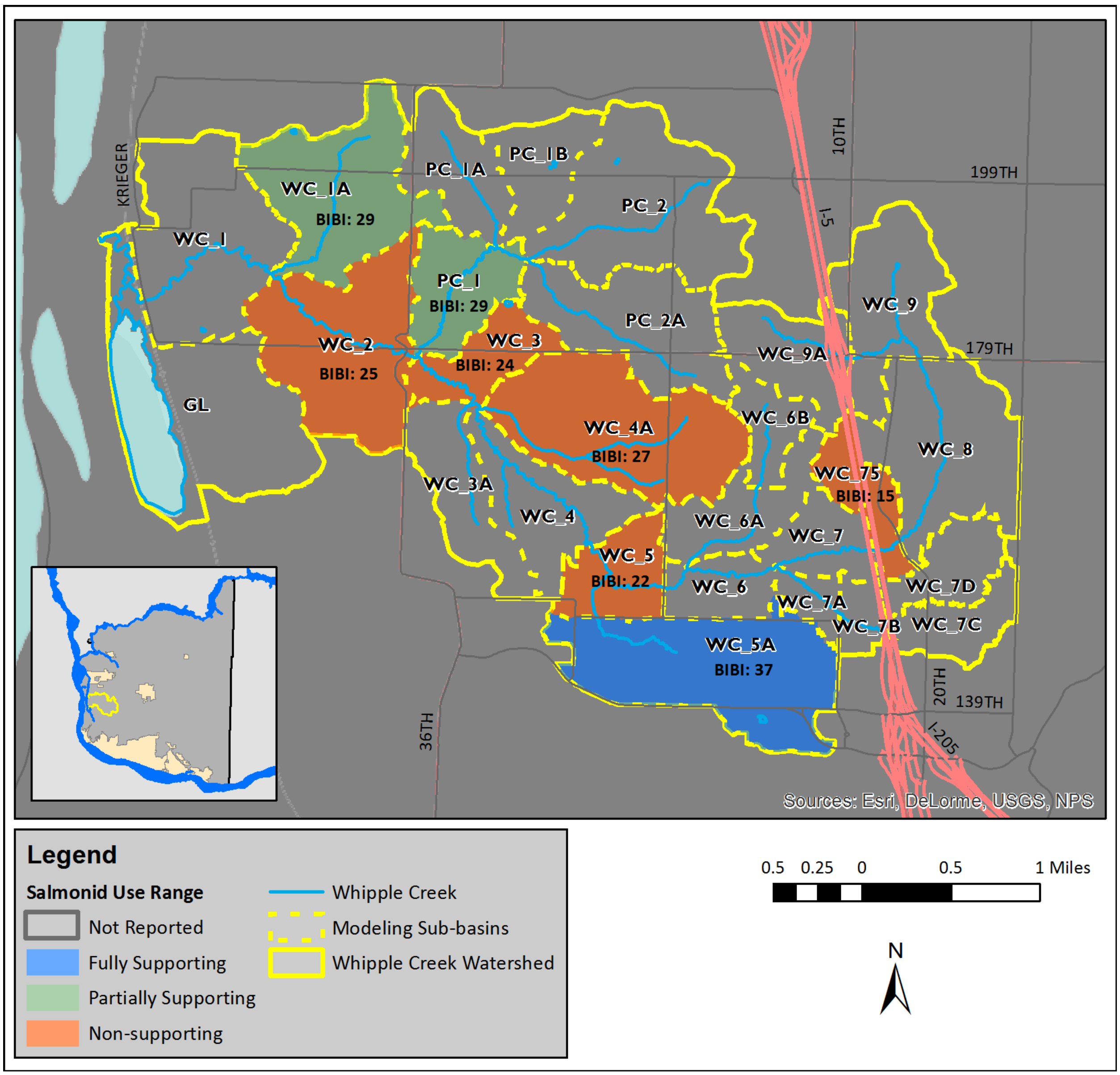
Predicted B-IBI scores were calculated from simulated flow metrics as the average annual scores for five years estimated using the relationships established each for T_{Qmean} and HPC. Predicted flow metrics were also directly reported. The B-IBI scores, flow metrics, and related salmonid use ranges are shown in Table 26. Figure 13 is a map of B-IBI scores.

Table 26: Predicted B-IBI, Flow Metrics, and Salmonid Use Ranges - Adding Rural Structural Retrofits (FS4)

	B-IBI			T_{Qmean}		HPC	
Sub-basin	Average B-IBI	Adjusted Salmonid Use Range	Adjusted Fully Supporting B-IBI	Average T_{Qmean}	Salmonid Use Range	Average HPC	Salmonid Use Range
WC-1A	29	Partially Supporting	>31	34%	Partially Supporting	6	Fully Supporting
WC-2	25	Non-supporting	>30	34%	Partially Supporting	10	Partially Supporting
WC-3	24	Non-supporting	>31	34%	Partially Supporting	12	Partially Supporting
WC-4A	27	Non-supporting	>30	34%	Partially Supporting	9	Partially Supporting
WC-5	22	Non-supporting	>30	33%	Partially Supporting	15	Non-supporting

	B-IBI			T_{Qmean}		HPC	
Sub-basin	Average B-IBI	Adjusted Salmonid Use Range	Adjusted Fully Supporting B-IBI	Average T_{Qmean}	Salmonid Use Range	Average HPC	Salmonid Use Range
WC-5A	37	Fully Supporting	>32	37%	Partially Supporting	3	Fully Supporting
WC-7.5	15	Non-supporting	>31	26%	Non-supporting	20	Non-supporting
PC-1	29	Partially Supporting	>30	33%	Partially Supporting	6	Fully Supporting

Figure 13: Map of Predicted B-IBI Scores and Adjusted Salmonid Uses - Rural Retrofits (FS4)



Based on predicted metrics there is no real improvement in B-IBI scores or salmonid use attainment in comparison to FS2. This is probably because the rural sub-basins do not produce as much stormwater runoff as the urban sub-basins mitigated in FS2 and, thus, the rural structural retrofit facilities do not significantly change the stream flow values in the main stem of Whipple Creek. Another factor is that bioretention is infeasible in large parts of the rural headwaters of Packard Creek and Whipple Creek.

Water quality results are presented in terms of violations of the state water quality standards for fecal coliform and water temperature. Because FS2 eliminated water quality violations for copper and zinc, those results are not shown for FS4. Table 27 compares the number of fecal coliform and temperature violations during the five-year simulation period for FS2, FS3, and FS4.

Table 27: Comparison of Water Quality Violations in Different Scenarios

	Fecal Coliform				Water Temperature	
Sub-basin	Violations (FS1)	Violations (FS2)	Violations (FS4)	% Reduction in Violations from FS1 to FS4	Violations (FS3)	Violations (FS4)
WC-1A	1263	1263	933	26%	9	0
WC-2	1352	1190	993	27%	4	5
WC-3	1365	1087	743	46%	0	0
WC-4A	1266	1266	1034	18%	2	0
WC-5	1384	587	587	58%	0	0
WC-5A	1358	19	19	99%	0	0
WC-75	1440	938	938	35%	0	0
PC-1	1268	1268	945	25%	4	0

Under FS4, fecal coliform remains high in most sub-basins. WC-3 sub-basin fecal coliform violations are reduced by 32%, but they remain high with 743 violations over a five year period. With an 18% reduction in violations, WC-4A still has more than 1,000 violations under FS4. Fecal coliform contributions from forest and pasture provide a significant source of this pollutant in the watershed. These sources generally cannot be controlled with public structural retrofits of the MS4.

Minor improvements in the number of water quality violations shows that all sub-basins except WC 2 would meet water quality standards for temperature under FS4. However, the improvements are extremely small because the violations were nearly eliminated under FS3.

Comparative Benefits

Compared to FS2 and FS3, FS4 has very little benefit.

For these questionable gains, the Rural Structural Retrofits component of FS4 could cost $56 million for capital improvements.

Table 28: Comparative Benefits of FS4

Constituent or Metric	Forested Baseline	FS1	FS2	FS3	FS4
Dissolved Copper	✔ *	✔	✔	✔	✔
Dissolved Zinc	✔ *	✔	✔	✔	✔
Temperature	✔ *	✖	✖	✔	✔
Fecal Coliform	✖ *	✖	✖	N/A	✖
Salmon Use (B-IBI)†	Partially Supporting	Non-supporting	Non-supporting	N/A	Non-supporting

* These parameters were not modeled, and assessments of goal attainment under the forested baseline scenario were determined using professional judgement.
† Reported as the majority of use ranges associated with average B-IBI within the set of reporting sub-basins

Conclusions

Overall, FS4 does little to reduce the impacts of stormwater runoff from existing and expected future new development in the watershed.

E. Future Scenario Supplemental Strategies (Not Modeled)

i. Channel Restoration

Channel restoration is a strategy that can improve habitat conditions for fish by reducing turbidity, preserving or restoring gravel stream beds used for spawning, restoring access to functioning habitat, and providing refuge for fish and macroinvertebrates from high flows, high temperatures, and predators.

Clark County has experience restoring approximately 1,000 feet of the Whipple Creek main stem just upstream of I-5 using grade controls and channel spanning log jams to create floodplain detention and improve channel hydraulics. See Appendix L for an initial analysis of floodplain detention opportunities.

Description of Channel Restoration Techniques

Channel restoration was selected for consideration in this Report. A discussion of techniques and benefits is below.

Grade Control

Grade control uses obstructions in the stream to slow the flow of water and sometimes to create step-pools. Slowing the flow helps prevent or slow channel lowering. Channel lowering can result from headcuts or incision. Channel lowering can drain wetlands, disconnect a stream from its floodplain, and increase flow rates during storms.

Structural grade controls use large rocks, large logs, or engineered obstructions. These are appropriate for streams subject to high flows. Low-tech grade controls use fascines or wooden posts to span the channel of smaller streams that are not subject to high flows.

Grade controls tend to mimic the natural functions of beaver dams and log jams in a functioning forested stream system.

Stream Bank Stabilization
Stream bank stabilization includes numerous techniques both natural, engineered, or some combination thereof, to protect stream banks from erosion, landslide, and slumping. A few examples are bioengineered slope, brush matting, tree revetments, rock buttressing, and retaining walls.

Protecting stream banks, in turn, helps aquatic habitat by reducing turbidity and protecting gravel spawning beds from being buried by silt or landslide.

Stream Bed Fill and Gravel Enhancement
A stream channel that has already been damaged by erosion, resulting in incision, headcuts, or an undermined toe of a bank can benefit from fill. Rocks, gravel or other materials are placed in the stream channel and the banks. Fill may restore an incised channel, prevent further erosion, protect banks, or restore spawning beds. This technique may improve habitat for aquatic species in an already degraded stream.

Stream Culvert Fish Barrier Removal
In some stream systems, good fish habitat is left unused because culverts or other obstructions block access. Culverts built before modern regulations often did not consider fish passage or did not properly accommodate it. Replacing culverts with new designs or bridges can restore access to good fish habitat.

Comparative Benefits
Degree of improvement in B-IBI score resulting from Channel Restoration cannot be modeled using the tools employed in this Report. Channel Restoration is assumed to have a positive effect on fish habitat in targeted locations, but it is not expected to have a watershed-wide impact on fish use attainment.

Channel Restoration could result in improvements to B-IBI scores, but would in most cases have no effect on dissolved metals, fecal coliform, or flow metrics, and little effect on temperature.

Nonetheless, because of its ability to target improvements in fish habitat, Clark County considers Channel Restoration to be among the most effective strategies for improving fish use attainment in targeted locations and preventing further channel degradation such as bank erosion, even if those gains cannot be estimated through correlation with B-IBI scores or flow metrics.

For these gains, the Channel Restoration strategy could cost $23.7 million for capital improvements.

F. Goal Attainment
The success of strategies contemplated in this Report for reducing copper, zinc, and temperatures in the Whipple Creek watershed is clear. These parameters may be managed using LID and traditional stormwater management techniques appropriate for a large MS4. Modeled scenarios predict the watershed can meet state standards for copper, zinc, and temperature through stormwater management, urban structural retrofits, and riparian restoration techniques.

The success of strategies analyzed for meeting state standards for fecal coliform and salmonid beneficial uses is less clear. Investigations into the existing conditions of the Whipple Creek watershed suggest that watershed conditions may never have reached these standards.

It is possible that background levels of fecal coliform from natural sources and other non-stormwater sources (e.g. beaver, water fowl, livestock, and possibly septic systems) exceed state standards even without discharges of urban runoff from the county's MS4. DNA studies of fecal coliform could reveal the background levels of fecal coliform that cannot be managed using stormwater strategies.

Likewise, information on fish presence in the watershed suggest that some of the reasons for limited salmonid use are inherent in the watershed's stream sizes, topography, and natural substrate (see Chapter I, Section F).

Table 29: Summary of Goal Attainment Under All Strategies

Constituent or Metric	Forested Baseline	FS1	FS2	FS3	FS4	Channel Restoration
Dissolved Copper	✔ *	✔	✔	✔	✔	N/A
Dissolved Zinc	✔ *	✔	✔	✔	✔	N/A
Temperature	✔ *	✘	✘	✔	✔	N/A
Fecal Coliform	✘ *	✘	✘	N/A	✘	N/A
Salmon Use (B-IBI)†	Partially Supporting	Non-supporting	Non-supporting	N/A	Non-supporting	Non-supporting*

* These parameters were not modeled, and assessments of goal attainment under the forested baseline scenario and channel restoration strategy were determined using professional judgement.
† Reported as the majority of use ranges associated with average B-IBI within the set of reporting sub-basins

The Implementation Plan (Chapter IV) discusses potential future actions to implement strategies modeled in future scenarios.

i. Stream Temperature

Implementing the riparian Full Shade strategy modeled in FS3 would essentially eliminate violations of state stream temperature standards.

ii. Dissolved Metals

Whipple Creek would not exceed state water quality standards for dissolved metals under the baseline full build-out scenario. This suggests that continuing to implement the current stormwater management program plan would maintain compliance with state water quality standards for dissolved metals.

iii. Fecal Coliform

No modeled strategy evaluated in this Report would completely eliminate fecal coliform violations. This result suggests stormwater management alone would not be effective in attaining compliance with standards. Activities outside the scope of the Permit would be needed.

Investigations into existing patterns of fecal coliform counts indicate that wildlife, livestock, or failing septic systems may contribute to baseline conditions in several tributaries. In addition, soils with low permeability throughout the watershed inhibit the use of LID or other infiltration techniques to manage contributions of fecal coliform from urban runoff.

iv. Aquatic Life as Defined by B-IBI

No modeled strategy evaluated in this Report makes an unambiguous improvement to stream flow conditions to the point where resulting B-IBI scores suggest the stream would fully support aquatic life. Of the eight reporting sub-basins, only the WC-5A sub-basin may achieve a B-IBI score indicating full support of salmonid uses using the Urban Retrofit strategy modeled in FS2.

Table 30: Best B-IBI-Correlated Salmonid Use Ranges Achieved Under Modeled Scenarios

Sub-basin	Adjusted Salmonid Use Range (B-IBI)
WC-1A	Partially Supporting
WC-2	Non-supporting
WC-3	Non-supporting
WC-4A	Non-supporting
WC-5	Non-supporting
WC-5A	Fully Supporting
WC-7.5	Non-supporting
PC-1	Partially Supporting

IV. Implementation Plan

An Implementation Plan is a Permit-required component of the Whipple Creek Watershed-Scale Stormwater Plan Report. The Permit requires an implementation plan and schedule to include:

- Potential future actions to implement the identified stormwater management strategies;
- Responsible parties;
- Estimated costs; and
- Potential funding mechanisms.

Potential actions are based on the results of the modeling exercise and the recognition that existing budgets are insufficient to begin implementation of the strategies evaluated in this Report.

A. Scope and Limitations

This Report's strategies to improve water quality and in-stream conditions in Whipple Creek are conceptual-level considerations based on broad evaluations of existing conditions and future land uses. The described undertakings are massive in scope and, by necessity, imprecise at a sub-basin-scale.

Structural facilities modeled in the Report provide one illustration.

Modeled structural facilities are purely hypothetical. Models simulate the facility size needed to achieve desired results using only one water quality facility and one detention facility per sub-basin. Facilities may not be realistically designed or constructed as modeled.

Further development of a capital program to support the state's goals would include intensive capital planning to identify feasible locations, developing individual planning-level project designs, and prioritizing projects. Capital project development furthermore would be subject to the availability of capital funding and the acquisition of land and rights-of-way (including likely actions to condemn private property under the county's eminent domain authorities in both urban and rural areas), engineering design, and construction.

In aggregate, land area required for conceptual structural facilities and riparian restoration in this Report is nearly 0.5 square miles and exceeds 4% of the watershed's land area. Total one-time capital costs of nearly $346 million exceed the county's Stormwater Capital Program's six-year budget by more than $330 million dollars.

This Implementation Plan is intended as long-term guidance that may assist in meeting Permit objectives. It is not intended to recommend or prioritize particular capital projects, strategies, or management actions.

B. Responsible Parties

Clark County is responsible for enforcing its development and stormwater codes, operating and maintaining its MS4, and for meeting Permit requirements.

This Report assumes certain actions by private land owners and land developers that are part of the current program, such as maintaining private stormwater facilities and developing land under the standards of the CCSM.

FS1 describes the full build-out of the Vancouver UGA in Whipple Creek. These activities are carried out principally by private developers who convert forest or pasture to developed residential or commercial properties and redevelop urban areas. Landowners and developers acting to build in Whipple Creek, as everywhere in the county, are required to comply with the Title 40 and zoning, including assumptions for densities, critical areas protection, and stormwater and erosion control requirements.

This Report assumes other public entities and quasi-governmental organizations operating in the Whipple Creek watershed continue their actions to benefit water quality and in-stream conditions in the watershed.

For example, Washington Department of Transportation (WSDOT) is also subject to a NPDES municipal stormwater permit, and it expands and replaces roads and operates transportation facilities and associated stormwater facilities in the watershed.

As another example, the Clark County Conservation District has programs that help the watershed by preserving the productivity of agricultural lands through reducing soil erosion, helping with manure management plans, and restoring riparian buffers. These activities also reduce transport of eroded soils to Whipple Creek and its tributaries and benefit water quality and fish habitat in the stream.

C. Estimated Costs

Conceptual-level cost estimates were prepared for each modeled strategy and the Channel Restoration strategy based on model outputs of hypothetical facilities to estimate the relative magnitude of costs for each strategy. Capital cost estimates rely on the county's recent historical costs for land, engineering design, construction, and operation & maintenance.

Costs are estimated independently for each strategy. Costs for each future scenario would include the costs of the component strategies. The sum of one-time capital costs for all modeled strategies and the Channel Restoration strategy is nearly $347 million. Operation and maintenance of structural facilities is estimated at $4 million annually once fully built.

All costs are in 2017 dollars.

Detailed cost estimates are given in Appendix O.

i. Costs of FS1, Full Build-out Baseline

FS1, the full build-out baseline, is implemented by private developers and has no new costs for the county.

ii. Costs of Urban Structural Retrofits Strategy

The Urban Structural Retrofits strategy is modeled as a component of FS2, FS3, and FS4. It results in 29 acres of bioretention (at pond surface) and 38 acres of detention pond (at pond surface). Additional land would be needed.

A conceptual-level cost estimate, below, does not include capital planning to identify and study feasibility of individual projects, nor does it attempt to anticipate a realistic number of facilities that would provide the modeled treatment and hydrology performance.

Table 31: Conceptual Cost Estimate of Urban Structural Retrofits

Modeled Facility Size		Capital Costs ($Millions)				O&M Costs ($Millions)
Bioretention Surface Area (ac)	Detention Pond Surface Area (ac)	Bioretention	Detention	Land Acquisition	Total One-Time Capital Costs	Annual
29	38	$62.23	$11.54	$189.69	$263.46	$2.70

iii. Costs of Full Shade Strategy

The Full Shade strategy is modeled as a component of FS3 and FS4. It assumes riparian restoration spans 75 feet on each side of an unshaded stream channel. 3.79 miles of channel are assumed to be eligible for riparian restoration.

A conceptual-level cost estimate of the Full Shade strategy, below, includes capital planning to identify and study feasibility of individual projects, easement costs, and three years of anticipated maintenance for plant establishment as a one-time capital cost.

Table 32: Conceptual Cost Estimate for Full Shade Strategy

Stream Length with Shade BMP Applied (mi)	Total Cost ($ Millions)
3.79	$2.65

iv. Costs of Adding Rural Structural Retrofits

The Rural Structural Retrofits strategy is modeled as a component of FS4. It results in 14 acres of bioretention (at pond surface) and 21 acres of detention pond (at pond surface). Additional land would be required.

A conceptual-level cost estimate, below, does not include capital planning to identify and study feasibility of individual projects, nor does it attempt to anticipate a realistic number of facilities that would provide the modeled treatment and hydrology performance.

Table 33: Conceptual Cost Estimate for Adding Rural Structural Retrofits Strategy

Modeled Facility Size		Capital Costs ($Millions)				O&M Costs ($Millions)
Bioretention Surface Area (ac)	Detention Pond Surface Area (ac)	Bio-retention	Detention	Land Acquisition	Total One-Time Capital Costs	Annual
14	21	$30.41	$6.21	$19.36	$55.98	$1.34

v. Costs of Channel Restoration Strategy

The Channel Restoration strategy could consider channel restoration on approximately 7 miles of main stem Whipple Creek. A conceptual-level cost estimate, below, does not include capital planning to identify and study benefits and feasibility of individual projects. Only stream miles on the main stem are included.

Table 34: Conceptual Cost Estimate for the Channel Restoration Strategy

Channel Restoration Stream Length (mi)	Capital Costs ($ Millions)
7.18	$23.68

vi. Other Costs

The cost estimate does not include ongoing Stormwater Management Program actions, even when program elements are anticipated to benefit Whipple Creek.

Initial costs of implementing strategies discussed in this Report are not itemized. Initial costs would be anticipated to include recommended studies such as a Use Attainability Study, a detailed revenue requirements and financial study, and initiation of a capital planning protocol for Whipple Creek.

vii. Total Costs by Sub-basin

Capital and annual operation & maintenance costs are summarized by sub-basin in Table 35 and Table 36.

By a factor of three, WC-5A is the costliest sub-basin for capital projects, at $85 million. On the other hand, WC-5A is also the only reporting sub-basin that appears to improve sufficiently to fully support salmonid uses.

Three sub-basins in the Packard Creek tributary are estimated to cost less than $2 million each for capital projects, solely for rural structural retrofits. Reporting sub-basin PC-1 remains in the partially supporting salmonid use range under all modeled future scenarios and shows a 25% decrease in violations of fecal coliform standards. For PC-1, violations of temperature standards drop from six to zero.

Table 35: Total Conceptual Capital Costs by Sub-basin

Total Capital Costs ($ Millions)					
Sub-basin	Urban Retrofits (FS2)	Full Shade (FS3)	Rural Retrofits (FS4)	Channel Restoration	Total
WC-5	$19.53	$0.21		$2.01	$21.75
WC-5A	$85.01	$0.00		$0.00	$85.01
WC-6	$24.68	$0.26		$2.42	$27.35
WC-6A	$22.28	$0.00		$0.00	$22.28
WC-6B	$10.54	$0.00		$0.00	$10.54
WC-7	$9.38	$0.20		$1.91	$11.49
WC-7A	$6.96	$0.00		$0.00	$6.96
WC-7B	$10.96	$0.00		$0.00	$10.96
WC-7C	$9.72	$0.00		$0.00	$9.72
WC-7D	$11.75	$0.00		$0.00	$11.75
WC-75	$9.39	$0.00		$0.00	$9.39
WC-8	$18.41	$0.41		$0.00	$18.82
WC-9	$11.10	$0.00		$0.00	$11.10
WC-9A	$13.76	$0.00		$0.00	$13.76
GL		$0.00	$6.33	$2.55	$8.88
WC-1		$0.44	$10.01	$4.17	$14.62
WC-1A		$0.00	$3.96	$0.00	$3.96
WC-2		$0.38	$7.72	$3.61	$11.72
WC-3		$0.37	$1.91	$3.45	$5.73
WC-3A		$0.00	$3.64	$0.00	$3.64
WC-4		$0.38	$3.11	$3.56	$7.05
WC-4A		$0.00	$3.87	$0.00	$3.87
PC-1		$0.00	$1.22	$0.00	$1.22
PC-1A		$0.00	$1.88	$0.00	$1.88
PC-1B		$0.00	$1.24	$0.00	$1.24
PC-2		$0.00	$4.75	$0.00	$4.75
PC-2A		$0.00	$6.34	$0.00	$6.34
Total	**$263.46**	**$2.65**	**$55.98**	**$23.68**	**$345.77**

Table 36: Total Conceptual Annual O&M by Sub-basin at Full Implementation

Total Annual O&M Costs ($Millions)					
Sub-basin	**Urban Retrofits (FS2)**	**Full Shade (FS3)**	**Rural Retrofits (FS4)**	**Channel Restoration**	**Total**
WC-5	$0.15	N/A		N/A	$0.15
WC-5A	$0.91	N/A		N/A	$0.91
WC-6	$0.21	N/A		N/A	$0.21
WC-6A	$0.20	N/A		N/A	$0.20
WC-6B	$0.11	N/A		N/A	$0.11
WC-7	$0.07	N/A		N/A	$0.07
WC-7A	$0.05	N/A		N/A	$0.05
WC-7B	$0.11	N/A		N/A	$0.11
WC-7C	$0.13	N/A		N/A	$0.13
WC-7D	$0.14	N/A		N/A	$0.14
WC-75	$0.11	N/A		N/A	$0.11
WC-8	$0.25	N/A		N/A	$0.25
WC-9	$0.12	N/A		N/A	$0.12
WC-9A	$0.14	N/A		N/A	$0.14
GL		N/A	$0.14	N/A	$0.14
WC-1		N/A	$0.21	N/A	$0.21
WC-1A		N/A	$0.10	N/A	$0.10
WC-2		N/A	$0.19	N/A	$0.19
WC-3		N/A	$0.04	N/A	$0.04
WC-3A		N/A	$0.08	N/A	$0.08
WC-4		N/A	$0.07	N/A	$0.07
WC-4A		N/A	$0.11	N/A	$0.11
PC-1		N/A	$0.03	N/A	$0.03
PC-1A		N/A	$0.05	N/A	$0.05
PC-1B		N/A	$0.04	N/A	$0.04
PC-2		N/A	$0.13	N/A	$0.13
PC-2A		N/A	$0.16	N/A	$0.16
Total	**$2.70**	**$ -**	**$1.34**	**$ -**	**$4.04**

D. Financial Analysis

A high-level financial study was completed to determine capital and operational costs of strategies over 30 years.

See Appendix P for a summary of the financial analysis.

i. Cost Summary

The cost summary reflects the assumption that Future Scenarios 2, 3, and 4, as well as the Channel Restoration strategy projects, would be implemented over a 30-year span.

Capital implementation is assumed to occur on a straight-line basis, with 1/30th of capital costs, plus construction cost inflation, anticipated for each year. Operational costs are assumed to occur over a 25-year period beginning in Year 6 of implementation. In each subsequent year, operational costs are assumed to increase by 1/25th of the estimated annual operating costs, plus general cost inflation. Industry-standard cost inflation factors were used to project cost increases over time.

Table 37 summarizes projected costs over 30 years.

Table 37: Cost Summary

Year from Start	1	2	3	4	5	10	20	30
	2018	2019	2020	2021	2022	2027	2037	2047
Base Revenue	$534,844	$543,035	$551,352	$559,797	$568,370		$613,249	$713,916
Additional O&M Cost	0	0	0	0	0	962,962	3,442,929	6,838,717
Additional Capital Cost	11,862,591	12,209,400	12,566,348	12,933,731	13,311,856	15,374,903	20,509,732	27,359,464
Adjusted Revenue	12,397,435	12,752,435	13,117,700	13,493,528	13,880,226	16,951,114	24,666,578	35,029,289
Percentage Increase	2218%	2248%	2279%	2310%	2342%	2664%	3355%	4115%

ii. Stormwater Fee Revenue

The revenue summary assumes that all revenues for actions considered in this Report would be generated from stormwater fees within the Whipple Creek watershed itself.

Equivalent residential units (ERUs) are the basis for calculating stormwater fees. One ERU is 3,500 square feet of hard surface (roof, driveway, roadway, etc.).

In 2017, the Whipple Creek watershed has 10,626 ERUs generating approximately $525,000 annually. If the watershed were fully built-out to maximum densities allowed under the Comp Plan, then the number of ERUs was estimated to be 16,765.

The financial analysis estimates the impact to stormwater fee rates in the watershed over time.

Table 38 shows potential increases in annual stormwater fees over 30 years.

Table 38: Annual Stormwater Fee Increase per ERU

Year from Start	1	2	3	4	5	10	20	30
	2018	2019	2020	2021	2022	2027	2037	2047
Base ERU Rate	$49.83	$50.08	$50.34	$50.59	$50.84	$52.08	$54.39	$56.56
Additional O&M Cost	$0.00	$0.00	$0.00	$0.00	$0.00	$81.77	$262.31	$465.40
Additional Capital Cost	$1,105	$1,126	$1,147	$1,168	$1,190	$1,305	$1,562	$1,861
Adjusted ERU Rate	$1,155	$1,176	$1,197	$1,219	$1,241	$1,439	$1,879	$2,383
Percentage Increase	2218%	2248%	2279%	2310%	2342%	2664%	3355%	4115%

iii. Other Potential Revenue

Beyond stormwater fee revenue from developed properties within the Whipple Creek watershed, other potential funding mechanisms could include stormwater fees generated county-wide (Clean Water Fund), the county's Legacy Lands Fund, the County Road Fund, state grants, and partnerships with quasi-governmental organization such as the Clark Conservation District or non-profit organizations such as Fish First.

E. Adaptive Management

As long-term guidance that may assist in meeting Permit objectives, this Report is not readily implementable. Yet, there are actions that can be taken to set foundations for actions in the Whipple Creek watershed.

Adaptive management would allow goals and methods to change in response to new information, feedback on progress, changing technologies, and new or updated regulatory and community goals. Key elements of the adaptive management program would include a Use Attainability Analysis and future data gathering.

i. Assess Where Designated Uses are Attainable

The objective of the CWA is to restore and maintain the integrity of the nation's waters in terms of chemical composition, physical form, and aquatic life. Unless other uses are designated, water quality must support fishing and swimming (Copeland, 2016). The law allows a designated use that has been assigned to a water body to be removed if evidence shows that attaining the use is not feasible. Six conditions must be met and demonstrated through a Use Attainability Analysis to remove a use (Ecology, 2005).

This Report recommends studying attainability of salmonid uses for Whipple Creek. Historic accounts indicate that anadromous fish once used Whipple Creek in greater numbers than they do today, but the magnitude of historic fish use is unclear given what is known about the geology of the watershed.

Current fish use is clearly limited, although due to Whipple Creek's low priority for salmon recovery, almost no field data exist. To illustrate this point, Whipple Creek is such a low priority for salmon recovery that is it not evaluated in the Lower Columbia Fish Recovery Plan (LCFRB, 2010).

Also recommended is a study of attainability of the primary contact recreation designated use. A large portion of the Whipple Creek watershed is rural in nature and, as is common for streams in rural and forested areas, hosts wildlife populations that contribute fecal coliform directly and indirectly to streams. Whipple Creek's urbanized and urbanizing areas largely have soil conditions that are incompatible with the use of infiltration to remove bacteria from runoff. Given these limitations, it may be infeasible for some reaches in the watershed to attain the primary contact recreation designated use.

This Report considers a Use Attainability Analysis as precursor to any other strategy or action contemplated for the Whipple Creek watershed, but not as an effort to update state standards under WAC 173-201A.

See Appendix M for an initial discussion of use attainability in Whipple Creek.

ii. Modify the Stormwater Capital Program

The county has been formally planning stormwater capital improvements since 2007. Current planning allocates approximately $9.8 million for the 2013-2018 Stormwater Capital Program, which covers the entire Permit area.

A 2019-2024 plan is currently under development. At the time of writing, 17 structural projects are under consideration in the Whipple Creek watershed, comprised of nine channel restoration projects, one facility repair, two retrofits where treatment and detention are currently lacking, and five retrofits of existing facilities to increase treatment and/or detention capabilities.

This Report suggests considering that capital projects prioritized for Whipple Creek be incorporated into the county's Stormwater Capital Program for planning and construction as funding allows.

iii. Prioritization Categories

An adaptive management approach could consider a number of prioritization strategies in contemplating management actions in the Whipple Creek watershed.

Implementation Plan

Table 39 (next page) lists potential prioritization categories in a Whipple Creek adaptive management approach.

Table 39: Prioritization Categories

Category	Description	Prioritization
Goal Attainment by Sub-basin	Some sub-basins come much closer to meeting water quality standards and attaining beneficial fish uses than others. Other sub-basins remain degraded under all future scenarios. Sub-basins with best overall goal attainment for all variables should be prioritized if further study of the sub-basin indicates that strategies are feasible in the area. Factors such as land availability, availability of capital funding, and availability of operational funding help determine feasibility. A capital planning process should take predictions of sub-basin goal attainment into account both when prioritizing investigations to identify potential projects (locations and designs) and when prioritizing projects.	Consider prioritizing sub-basins with the best potential for goal attainment, as determined through further study. Consider incorporating analysis of predicted goal attainment into capital planning procedures for Whipple Creek.
Channel Restoration	Channel restoration, such as grade controls, stream bank stabilization, floodplain detention, and stream bed fill, could help preserve or restore pockets of viable salmon habitat in the Whipple Creek main stem. Fish passage barrier removal can restores access to currently inaccessible stream channels that may have good salmon habitat.	Consider prioritizing channel restoration.
Areas of Special Attention	Areas include regulated critical areas such as wetlands and habitat conservation areas and areas characterized by stream channel erosion, floodplain disconnection, suitable salmon spawning habitat, low temperatures suitable for thermal refugia for salmon, complete lack of stormwater detention, complete lack of stormwater treatment, and degraded riparian conditions on public land. (See Appendix E for a discussion of these areas.) A capital planning process could take areas of special attention into account both when prioritizing investigations to identify potential projects (locations and designs) and when prioritizing projects..	Consider incorporating areas of special attention into capital planning procedures for Whipple Creek.
Planned Projects	The county's Stormwater Capital Program may include projects in Whipple Creek watershed.	Take advantage of existing planned capital investments in the watershed.
Land Availability	Project feasibility due to access to land is likely a concern for most capital projects that would be proposed in the Whipple Creek watershed.	Incorporate land availability into capital planning procedures for Whipple Creek.
MS4 Nexus	Numerous factors outside of discharges from the MS4 impact water quality and in-stream conditions. Some strategies discussed in this Report, such as the riparian Full Shade strategy (see FS3) and the Channel Restoration strategy, operate outside the boundaries of Clark County's MS4. These strategies may be the most cost-effective strategies for progressing toward achieving beneficial uses. On the other hand, riparian and channel restoration projects do not assist Clark County in meeting the regulatory requirements of its Permit.	Prioritize the most cost-effective projects for protecting or restoring beneficial uses, regardless of relationship to MS4.

iv. Whipple Creek Monitoring

In following its scope of work for writing this Report, Clark County expanded elements of its ongoing county-wide monitoring program to focus on Whipple Creek.

An adaptive management approach could continue the targeted data collection effort in Whipple Creek to include continuous flow monitoring, temperature monitoring, water quality sampling, and macroinvertebrate sampling. Special projects could look for problem areas such as bacteria sources. Data and analyses could contribute to the Use Attainability Study, capital planning, modeling, and prioritization of management options.

v. Continue Model Development

The hydrology model is well-calibrated at the watershed scale, but additional work could improve the accuracy at the sub-basin scale based on data collected in Packard Creek and upper Whipple Creek. Continued model development could lead to detailed modeling of UGA sub-basins as part of an effort to plan effective restoration or protection plans.

vi. Other Prioritization Tools

Recently, the Washington Department of Commerce released a guidance document titled *Building Cities in the Rain – Watershed Prioritization for Stormwater Retrofits.* The aim is to most effectively deploy scarce resources to protect and restore receiving waters for stormwater runoff by prioritizing areas for stormwater retrofitting. The guidance relies heavily on companion guidance by Ecology for elaborate GIS-based watershed characterization and the newer proposed stormwater control transfer program that would promote placing restorative stormwater controls where there is the greatest benefit.

An adaptive management approach could classify subareas for protection, restoration or development based on hydrologic modeling, water quality modeling, and areas of special interest such as salmon bearing stream reaches.

An assessment of the *Building Cities in the Rain* methodology is included in Appendix Q.

F. Schedule

This Report uses a 30-year planning horizon.

By 2040, the median prediction for population of Clark County nears 600,000, up from 425,000 in 2010 (State of Washington Office of Financial Management, 2012). Population in the entire Vancouver UGA (not limited to Whipple Creek) is predicted to rise from 315,000 to 372,000 by 2035 (Clark County, 2016). It seems likely that the Vancouver UGA could continue to expand west into the Whipple Creek watershed as decades pass.

Land use assumptions are based on the 20-year Comp Plan through 2035. No land cover conversions beyond full build-out at 20 years are anticipated in this Report.

A start date has not been established. Actions are conceptually scheduled from Year 1.

Implementation Plan

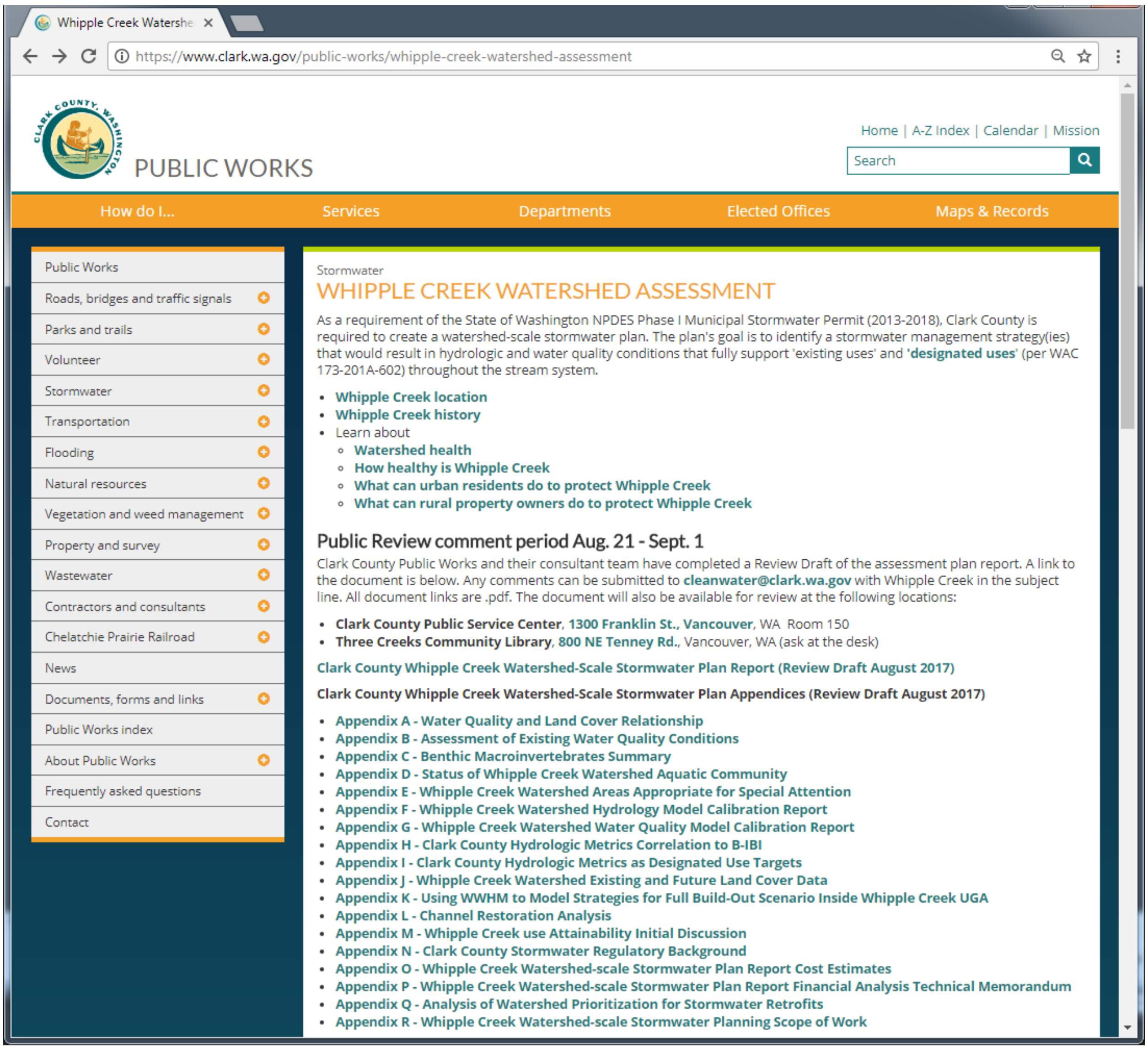
Table 40: Conceptual Schedule

Years 1 - 5	• Implement the contemporaneous Clark County Stormwater Management Program and Stormwater Capital Program • Continue Whipple Creek targeted monitoring studies • Initiate a Use Attainability Analysis
Years 6 - 15	• Implement the contemporaneous Clark County Stormwater Management Program • Adaptive Management • High Priority Capital Projects as Funding Allows
Years 16 - 30	• Implement the contemporaneous Clark County Stormwater Management Program • Adaptive Management • Medium Priority Capital Projects as Funding Allows

V. Public Review Process

Clark County published a web page about the watershed planning process in 2015 at https://www.clark.wa.gov/public-works/whipple-creek-watershed-plan. The draft report was available online and in public libraries for public comment for a two week period from August 21 to September 1, 2017.

Figure 14: Screenshot of Whipple Creek Watershed Assessment Web Page


Whipple Creek Watershe

https://www.clark.wa.gov/public-works/whipple-creek-watershed-assessment

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Stormwater

WHIPPLE CREEK WATERSHED ASSESSMENT

As a requirement of the State of Washington NPDES Phase I Municipal Stormwater Permit (2013-2018), Clark County is required to create a watershed-scale stormwater plan. The plan's goal is to identify a stormwater management strategy(ies) that would result in hydrologic and water quality conditions that fully support 'existing uses' and 'designated uses' (per WAC 173-201A-602) throughout the stream system.

- Whipple Creek location
- Whipple Creek history
- Learn about
  - Watershed health
  - How healthy is Whipple Creek
  - What can urban residents do to protect Whipple Creek
  - What can rural property owners do to protect Whipple Creek

Public Review comment period Aug. 21 - Sept. 1

Clark County Public Works and their consultant team have completed a Review Draft of the assessment plan report. A link to the document is below. Any comments can be submitted to cleanwater@clark.wa.gov with Whipple Creek in the subject line. All document links are .pdf. The document will also be available for review at the following locations:

- Clark County Public Service Center, 1300 Franklin St., Vancouver, WA Room 150
- Three Creeks Community Library, 800 NE Tenney Rd., Vancouver, WA (ask at the desk)

Clark County Whipple Creek Watershed-Scale Stormwater Plan Report (Review Draft August 2017)

Clark County Whipple Creek Watershed-Scale Stormwater Plan Appendices (Review Draft August 2017)

- Appendix A - Water Quality and Land Cover Relationship
- Appendix B - Assessment of Existing Water Quality Conditions
- Appendix C - Benthic Macroinvertebrates Summary
- Appendix D - Status of Whipple Creek Watershed Aquatic Community
- Appendix E - Whipple Creek Watershed Areas Appropriate for Special Attention
- Appendix F - Whipple Creek Watershed Hydrology Model Calibration Report
- Appendix G - Whipple Creek Watershed Water Quality Model Calibration Report
- Appendix H - Clark County Hydrologic Metrics Correlation to B-IBI
- Appendix I - Clark County Hydrologic Metrics as Designated Use Targets
- Appendix J - Whipple Creek Watershed Existing and Future Land Cover Data
- Appendix K - Using WWHM to Model Strategies for Full Build-Out Scenario Inside Whipple Creek UGA
- Appendix L - Channel Restoration Analysis
- Appendix M - Whipple Creek use Attainability Initial Discussion
- Appendix N - Clark County Stormwater Regulatory Background
- Appendix O - Whipple Creek Watershed-scale Stormwater Plan Report Cost Estimates
- Appendix P - Whipple Creek Watershed-scale Stormwater Plan Report Financial Analysis Technical Memorandum
- Appendix Q - Analysis of Watershed Prioritization for Stormwater Retrofits
- Appendix R - Whipple Creek Watershed-scale Stormwater Planning Scope of Work

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