WHITE PAPER

Recent Analytical Approaches for Evaluation of Stormwater Quality Impacts

Prepared for

Washington State Department of Transportation

December 2007

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Recent Analytical Approaches for Evaluation of Stormwater Quality Impacts

Prepared for

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Introduction

This white paper identifies, compares, and evaluates various approaches that have recently been used in Washington State for Endangered Species Act (ESA) Section (7) consultations to evaluate impacts of highway runoff on listed aquatic species. The evaluation describes the strengths and weaknesses of these approaches and also examines how effective and technically sound these various approaches have been. As a measure of the level of effort required by each approach, the evaluation also identifies the duration of the ESA consultation process.

The evaluation is based primarily on three separate transportation improvement projects in Washington State. The white paper focuses on the different analytical approaches used by the various agencies involved in assessing stormwater quality impacts for those projects. To provide adequate context for the white paper evaluation, the following section summarizes each of these three transportation projects. Following the project summaries, a detailed evaluation of the various methodologies is presented.

Documents Evaluated for this White Paper

Based on input from the Policy Management Team members (the Washington State Department of Transportation [WSDOT], Federal Highway Administration [FHWA], U.S. Fish and Wildlife Service [USFWS], and National Marine Fisheries Service [NMFS]), Herrera Environmental Consultants compiled a sample of methodologies and ESA consultation documents (biological assessments and biological opinions) used for determining the effect of stormwater from highway projects on listed fish species in western Washington. The documents obtained and evaluated in this white paper analysis include the following:

- State Route (SR) 524 FHWA-WSDOT Biological Assessment (WSDOT 2004a)
- SR 524 USFWS Biological Opinion (USFWS 2005)
- SR 524 NMFS Biological Opinion (NMFS 2005)
- I-405 Bellevue Nickel Improvement Project FHWA–WSDOT Biological Assessment (WSDOT 2005a)
    - Supplemental stormwater methodology and related analysis (December 6 and 28, 2005, respectively) (WSDOT 2005b and c)
    - Addendum to I-405 Bellevue Nickel Improvement Project Biological Assessment; Request to Conference on Puget Sound Steelhead (July 10, 2006) (WSDOT 2006a)
- I-405 Bellevue Nickel Improvement Project USFWS Concurrence Letter (USFWS 2006)
- I-405 Bellevue Nickel Improvement Project NMFS Concurrence Letter (NMFS 2006)
- SR 167 Extension FHWA–WSDOT stormwater analysis information including preliminary studies, biological assessment data, letters, and e-mail correspondence (WSDOT 2007) and the WSDOT Biological Assessment (BA) Writers Guidance for Preparing the Stormwater Section of Biological Assessments (November 13, 2006) (WSDOT 2006b)
- SR 167 Extension USFWS Biological Opinion (USFWS 2007)

On September 17, 2007, NMFS issued its biological opinion for the SR 167 project. This analysis was not included in the evaluation presented in this white paper.

Each of the documents listed above is summarized briefly below.

SR 524 FHWA–WSDOT Biological Assessment

The proposed project is to widen 3.7 miles of SR 524 between 24th Avenue West and SR 527 (milepost 5.87 to 9.57) in Snohomish County, Washington. The purpose of the project is to improve safety while reducing traffic congestion. Construction will occur in three phases, and funding has been secured for construction of Phase IA of the project. Phases I and II will be constructed as funding becomes available.

In Phase IA, the roadway will be widened from two to five lanes with a two-way center turn-lane, bicycle lanes, and sidewalks. The road will consist of two 12-foot wide through-lanes in both directions; 5-foot wide bike lanes and 6-foot wide sidewalks on both sides of the roadway; and a 13-foot wide, two-way center turn lane.

To reduce impacts on wetlands and stream buffers along Swamp Creek and to create a straighter alignment, Phases I and II will create a new route through the King's Court Mobile home park in the westernmost portion of the corridor. In addition, a six-lane bridge will be built at the Swamp Creek crossing, and a five-lane bridge will be built at the North Creek crossing. In addition, existing culverts at Martha Creek, Upper Filbert Creek, and Lover Filbert Creek will be replaced with fish-passable culverts per Washington Department of Fish and Wildlife (WDFW) guidelines.

In total, 25.91 acres of new impervious surface (of which 4.39 acres will consist of stormwater detention ponds) will be added to the existing 12.47 acres. Current stormwater drainage consists of roadside ditches with no treatment or detention. The project will include installation of a drainage system, six stormwater ponds, and four enclosed vaults for detention per the 2001 Department of Ecology (Ecology) Stormwater Management Manual (Ecology 2001), the 2001 WSDOT Hydraulics Manual, the current WSDOT Highway Runoff Manual (WSDOT 2004d), and the WSDOT instructional letter IL4020.02 (WSDOT 2002a).

Summary of Stormwater Quality Analysis

In the SR 524 FHWA–WSDOT Biological Assessment, no quantitative analysis is provided for changes in impervious surface area and stormwater quality. The project description outlines the anticipated best management practice (BMP types), associated outfalls, and where they will be located. A qualitative discussion of new impervious area and treatment of this area and existing impervious surface area by BMP is provided per the Ecology Stormwater Management Manual (Ecology 2001), the WSDOT Hydraulics Manual (WSDOT 1997b), the current WSDOT Highway Runoff Manual (WSDOT 2004d), and the WSDOT instructional letter IL4020.02 (WSDOT 2002a). Because no stormwater treatment facilities currently exist, it is assumed that the proposed facilities will improve water quality.

All the information incorporated into the biological assessment pertaining to stormwater would be available from the project description and ESA Stormwater Design Checklist (Appendix 2b of the Highway Runoff Manual, included as Appendix A in this white paper) provided to the

project biologist from project engineers. Information on environmental baseline conditions is based on numerous commonly referenced resources including but not limited to Ecology 303(d) listings (Ecology 2004, 2007), limiting factors reports, and county research reports.

The stormwater quality analysis provided in the biological assessment does not address specific stormwater constituents, nor does it examine effectiveness of proposed BMPs and the resultant concentrations or pollutant loading associated with treatment facilities or the effects on hydrology that could result from the project. In addition, the analysis does not evaluate how listed fish species would be affected by project-related runoff.

No specific analytical method for analyzing stormwater quality impacts is used in the biological assessment; as a result, this document is not discussed further in this white paper. Appendix B of this white paper contains a more detailed summary of stormwater-related information contained in the biological assessment.

Subsequently, USFWS and NMFS (i.e., the Services) requested additional stormwater information for the project from WSDOT. The initial stormwater quality analysis that was provided on February 11, 2004 by Snohomish County (Appendix F from the SR 524 Environmental Impact Statement [EIS] [Snohomish County 2004]) was based on the FHWA method (described in the *Summary and Evaluation of Methodologies* section below). Inputs to the model included data collected by FHWA from 1975 to 1985 on the level of pollutants in highway runoff. The concentrations of pollutants were then converted to the annual amount in kilograms per year that would run off of the pavement based on the mean (average) storm event from storm data generated for the Seattle area, the area with the most complete precipitation dataset with conditions similar to those in the project area. This analysis was conducted for each of the proposed stormwater treatment facilities and was used to estimate annual pollutant loading based on annual rainfall. WSDOT dismissed this initial assessment because it did not generate data that provided the Services with the information they requested (i.e., concentrations of pollutants for a range of storms throughout a particular month for both the current and proposed site conditions). In addition, these initial results did not include anticipated removal efficiencies for tested BMPs.

A second analysis was prepared by WSDOT in May 2005. This analysis used Method 1: WSDOT Data–FHWA method (described in the *Summary and Evaluation of Methodologies* section below) from WSDOT's 2005 Environmental Procedures Manual (WSDOT 2005d) to develop a projection of the percentage change of pollutants discharged to receiving water bodies. The projections were based on pre- vs. postdevelopment pollution-generating surface area and the efficiency of the pre- vs. postdevelopment stormwater treatment BMPs utilized. Projections were developed for each of the project subbasins.

Consultation History

The detailed consultation histories with both USFWS and NMFS are provided in the SR 524 USFWS Biological Opinion and SR 524 NMFS Biological Opinion sections below. In general,

the consultation with USFWS extended 15 months, from December 2003 to February 2005. Consultation with NMFS extended 20 months, from December 2003 to July 2005.

SR 524 USFWS Biological Opinion

A project description for the SR 524 project is provided above in the SR 524 FHWA-WSDOT Biological Assessment discussion.

Summary of Stormwater Quality Analysis

No single protocol was used for the USFWS stormwater quality analysis. For the most part, the analysis consists of qualitative discussions about the range of impacts that would result from permanent alteration of upland habitat (i.e., base flow reduction, increased peak flows, and degradation of water quality). In addition, the analysis relied upon toxicity analysis completed in a prior consultation.

For the stormwater quality analysis, USFWS assumed the following:

- The drainage system and ponds would be designed per the Ecology Stormwater Management Manual (2001), WSDOT Hydraulics Manual (2001), the current WSDOT Highway Runoff Manual (WSDOT 2004d), and WSDOT instructional letter IL4020.02 (WSDOT 2002a).

- Stormwater discharge would meet the Washington State water quality standards at the point of discharge.

The biological opinion generally addresses variability in the treatment effectiveness of various BMPs (ponds and wet vaults in Comings et al. 2000, WSDOT 2002b, and Ecology 2001), but this information is not fully integrated into the analysis. Where project-related stormwater is discharged to wetlands prior to Swamp and North creeks, it is assumed that pollutant levels would not be measurable by the time it reaches these water bodies. Where stormwater discharges directly to tributaries of Swamp and North creeks, it is assumed that contamination concentrations will be measurable and have effects on bull trout (*Salvelinus confluentus*). Discharges anticipated for specific project-related BMPs are not addressed.

The pollutant loading information developed by WSDOT (in May 2005) was not used in the USFWS analysis. Instead, USFWS assumed that the project would adhere to state and federal regulations (e.g., the Clean Water Act) and that stormwater discharged from the proposed road widening and associated future development would meet Washington State water quality standards. For the stormwater toxicity analysis that was completed, USFWS compared Washington State water quality standards with the minimum toxicity levels described in a previous biological opinion written for the Brightwater Treatment Systems project (USFWS

2004a). The constituents evaluated included those considered to be most toxic to fish (namely cadmium, chromium, copper, lead, and zinc).

Although the analysis mentions how toxicity levels might be affected by different water quality conditions (pH, temperature, hardness, etc.), the baseline conditions in the action area pertaining to these specific parameters during times of probable discharge are not fully explored. The analysis also mentions the aquatic species life-history stages that are potentially present but that specific duration of exposure is unknown.

Based on the number of variables affecting toxicity levels and uncertainties of potential exposure and duration times, USFWS was not able to determine the significance of stormwater effects on individual fish, so a general discussion is presented that describes potential effects associated with long-term water quality degradation.

Appendix B of this white paper contains a more detailed summary of stormwater-related information contained in the document.

Consultation History

Consultation on this project extended 15 months, from December 2003 to February 2005. The following timeline summarizes significant issues and actions related to the history of this consultation.

December 18, 2003	A biological assessment (BA) dated November 2003 was submitted by WSDOT for informal consultation, with an effect determination of "may affect, not likely to adversely affect" bull trout and bald eagle (*Haliaeetus leucocephalus*).
March 3, 2004:	WSDOT retracted the BA.
April 7, 2004:	A new BA (dated March 2004) for this project was submitted by the FHWA with a request for formal consultation with an effect determination of "may affect, not likely to adversely effect" for bull trout and bald eagle.
May 18, 2004:	USFWS met with NMFS and WSDOT representatives and identified a number of issues for which additional information and analysis was needed.
June 14, 2004:	FHWA submitted some of the additional information needs.
June 23, 2004:	FHWA contacted USFWS regarding the effect determination for this project. Via e-mail, USFWS responded that they did not concur with the effect determination of "may affect, not likely to adversely affect" for bull trout. By e-mail, FHWA retracted the BA. USFWS withdrew the project BA from the consultation process.

July 23, 2004:	At a meeting on this date, FHWA presented USFWS with a "no effect letter" for bull trout and bald eagle.
November 12, 2004:	The FHWA submitted a request for informal consultation.
November 29, 2004:	By e-mail, USFWS responded that the project, as proposed, was expected to adversely affect bull trout, and thus USFWS could not conclude informal consultation.
December 15, 2004:	FHWA submitted a request for formal consultation. USFWS initiated formal consultation.
February 15, 2005:	Biological opinion is completed.

SR 524 NMFS Biological Opinion

A project description for the SR 524 project is provided above in the SR 524 FHWA–WSDOT Biological Assessment discussion.

Summary of Stormwater Quality Analysis

The NMFS stormwater quality analysis, like the USFWS analysis, did not rely upon the supplemental stormwater analyses generated by WSDOT. The NMFS analysis provides a substantially more detailed environmental baseline discussion, pertaining specifically to water quality parameters, than is provided in the USFWS biological opinion. The NMFS document also provides a rigorous discussion of the potential timing of pollutant exposure relative to listed Chinook salmon (*Oncorhynchus tshawytscha*), explicit assumptions regarding the effectiveness of specific BMPs proposed as part of the project, and a detailed discussion of baseline metals concentrations based on 14 years of site-specific data. Based on multiple linear regression models derived from Kayhanian et al. (2003), NMFS projected metals concentrations and compared this information to baseline conditions and ultimately to toxicity threshold information for Chinook salmon. Annual pollutant loadings were also modeled using procedures described in FHWA (1990) as the FHWA methods and in Schueler (1987) as the Simple method. Both the FHWA and Simple methods generate loading information by pollutant and BMP type. NMFS then provided a discussion of general effects on fish from exposure to metals, followed by a general discussion of effects on Chinook salmon. The metals analysis specifically addresses copper, cadmium, chromium, lead, zinc, and polycyclic aromatic hydrocarbons (PAHs). The NMFS analysis and modeling results indicate significant impacts associated with the project. Despite these results, the conclusions in the NMFS biological opinion and analysis rely on a performance commitment of no net increase of total suspended solids (TSS), total and dissolved copper, lead, and zinc discharge to North and Swamp creeks.

Appendix B of this white paper contains a more detailed summary of stormwater-related information contained in the document.

Consultation History

Consultation on this project extended 20 months, from December 2003 to July 2005. The following timeline summarizes significant issues and actions related to the history of this consultation.

December 18, 2003: NMFS received a BA and Essential Fish Habitat (EFH) assessment, dated November 2003, and request for ESA Section 7 informal consultation and Magnuson-Stevens Fishery Conservation and Management Act (MSA) consultation from WSDOT. The BA concluded that the project is "not likely to adversely affect" Puget Sound Evolutionarily Significant Unit (ESU) Chinook salmon (PS Chinook salmon) and will have "no adverse impact" on EFH for coho salmon (*Oncorhynchus kisutch)*.

January 22, 2004: NMFS sent a letter to WSDOT indicating that the effects of the project are not expected to be discountable and insignificant and that it could not concur with the WSDOT effect determination. NMFS requested that formal consultation be initiated and that additional information be provided. NMFS requested the following information pertaining to stormwater quality: (1) estimates of the changes in concentrations of copper, zinc, lead, and PAHs due to the proposed action (the letter referenced serious toxicity issues in both Swamp and North creeks); (2) a description of the location of outfalls of wet vaults and wet ponds; (3) a description of if/how the proposed action would result in altered drainage area, flow duration, or peak and base flows for any streams and wetlands; and (4) the amount of impervious area and how it was calculated.

March 22, 2004: WSDOT and NMFS met to discuss information needs identified in the January 22 letter.

April 7, 2004: FHWA submitted a new BA with a request for formal ESA Section 7 consultation and MSA consultation. FHWA concluded that the project is "not likely to adversely affect" PS Chinook salmon and would have "no adverse impact" on EFH for coho salmon, but requested formal consultation to engage the default timelines inherent in formal consultation.

May 18, 2004: Staff from the WSDOT, NMFS, and USFWS met to discuss the new BA, including: (1) information needs identified in the January 22 letter not addressed in the new BA, (2) removal of Snohomish County's heavy metals data from the environmental baseline in the new BA, and

	(3) Chinook salmon presence in the project area. The parties also discussed interdependent and interrelated actions, indirect effects, and cumulative effects. NMFS agreed to initiate formal consultation immediately if the information discussed was provided by June 1.
June 8, 2004:	WSDOT notified NMFS via e-mail that the information agreed to at the May 18 meeting would not be forthcoming.
June 14, 2004:	FHWA e-mailed NMFS, responding to the May 18 meeting notes. The response did not answer many of the questions raised at the May 18 meeting and in the January 22 letter.
July 26, 2004:	FHWA and NMFS met to discuss continuing information needs.
July 28, 2004:	FHWA retracted its April 7, 2004 BA.
July 29, 2004:	FHWA informed NMFS via e-mail that it had determined that the proposed action will have "no effect" on PS Chinook. The FHWA and NMFS discussed the rationale for the effect determination via teleconference. NMFS encouraged continued consultation.
August 4, 2004:	NMFS received a letter from FHWA concluding that the proposed action will have "no effect" on PS Chinook salmon.
December 1, 2004:	NMFS, WSDOT, and USFWS met (via telephone) and discussed remaining information needs requiring resolution before consultation could proceed.
December 7, 2004:	NMFS e-mailed WSDOT its informal comments on the WSDOT's pollutant loading analysis from the replacement of the SR 520 floating bridge, suggesting that an analysis similar to the SR 520 analysis could be provided for the SR 524 project.
December 12, 2004:	WSDOT, NMFS, and USFWS attended a site visit to assess the impacts of the proposed action on off-channel habitat for salmonids.
December 15, 2004:	FHWA submitted a request for formal consultation (although the BA effect call was "not likely to adversely affect"), and NMFS initiated formal consultation.
April 7, 2005:	NMFS sent a draft biological opinion to WSDOT for review.
April 25, 2005:	NMFS received a letter from FHWA with comments regarding the Incidental Take Statement of the draft biological opinion.

April 27, 2005: NMFS received comments (via e-mail) from WSDOT/FHWA regarding the draft biological opinion.

May 10, 2005: NMFS met with WSDOT and staff from the City of Bothell and Snohomish County to discuss the draft biological opinion and the draft Incidental Take Statement. Most discussion concentrated on the revised draft reasonable and prudent measure number one, which stipulated a "no net increase of annual pollutant loading" as a result of the proposed action. At the meeting, NMFS further clarified the no net increase goal by stating that it should pertain to TSS, lead, copper, and zinc in total and dissolved form for both Swamp and North creeks.

June 6, 2005: NMFS met with WSDOT and requested that WSDOT adopt a "no net increase" performance goal for TSS, lead, copper, and zinc in total and dissolved form as a result of each phase of the proposed action for North Creek and for Swamp Creek. This standard would invalidate NMFS' initial conclusions that the originally proposed action would have appreciably reduced habitat functions and population viability of the Sammamish River Chinook salmon population of PS Chinook. WSDOT agreed to adopt this performance goal as part of its proposed action. WSDOT and NMFS agreed that the biological opinion would be issued without WSDOT demonstrating how it would modify the proposed action to meet this goal, but that WSDOT would send documentation including methods, assumptions, and results of pollutant loading modeling for NMFS' project files after the issuance of the biological opinion.

July 11, 2005: Biological opinion is completed.

I-405 Bellevue Nickel Improvement Project FHWA–WSDOT Biological Assessment

The I-405 – Bellevue Nickel Improvement Project is one of three "Nickel Projects" identified in a multi-year transportation improvement plan for the I-405 corridor. The purpose of the overall plan is to improve personal and freight mobility and reduce foreseeable traffic congestion in the I-405 corridor from Tukwila to Lynnwood.

The Bellevue Nickel Improvement Project will add one new general purpose lane in each direction along a 2-mile section of I-405 between I-90 and SE 8th Street. In addition, upgrades to existing on- and off-ramps and high occupancy vehicle (HOV) lanes will also be constructed. The new lanes will generally be constructed on the median side of the roadway. The project will also build a new tunnel underneath the Burlington Northern Santa Fe Railway to accommodate the relocated and widened roadway. Other improvements include stream and wetland compensatory mitigation.

The project uses a design–build model, in which WSDOT executes a single contract with a contractor for design and construction services to provide a finished product. In this model, WSDOT defines the overall objectives of the project and develop outcome-based requirements to ensure that the project is designed and constructed in accordance with environmental regulations.

The project will increase pollution-generating impervious surface by 10.34 acres, retrofit 1.76 acres of existing impervious surface, and remove 3.63 acres of existing impervious surface. The project will permanently affect three wetlands via partial filling. Functions provided by the wetlands include stormwater retention, improved water quality, and groundwater recharge. None of the wetlands provide rearing habitat or refugia for Chinook salmon or bull trout.

Based on interviews with WSDOT, NMFS, and USFWS, the stormwater quality analysis conducted as part of the consultation process occurred after the biological assessment had been submitted, in response to requests by the Services for additional stormwater information and analysis. The stormwater information in the BA as well as this supplemental information is summarized below.

Summary of Stormwater Quality Analysis

The biological assessment prepared for this project was written in checklist format. This checklist or form template was an attempt by WSDOT and FWHA to provide some standardization to the content and analysis provided in biological assessments. The checklist or form provides detailed information regarding the project description, proposed BMP types (enhanced treatment BMPs) and flow control facilities (or lack thereof for Mercer Slough), net impervious surface changes (new, retrofit, removal), and environmental baseline conditions (contained in the appendix of the biological assessment). However, the effects analysis pertaining to stormwater quality consists of qualitative discussions of water quality and flow impacts.

All the information incorporated into the biological assessment pertaining to stormwater would be available from the project description and ESA Stormwater Design Checklist provided to the project biologist from project engineers. Environmental baseline conditions information is based on numerous commonly referenced resources including but not limited to Ecology 303(d) listings, limiting factors reports, and county research reports.

The stormwater quality analysis provided in the biological assessment does not address specific stormwater constituents in any detail, nor does it examine the effectiveness of proposed project BMPs and the resultant concentrations or pollutant loading associated with treatment facilities or the effects to hydrology that could result from the project. Finally, the analysis does not evaluate how listed fish species would be affected specifically by project-related runoff.

No specific analytical method for analyzing stormwater quality impacts is used in the biological assessment; as a result, this document is not discussed further in this white paper. Appendix B of this white paper contains a more detailed summary of stormwater-related information contained in the document.

The stormwater quality analysis completed as part of the consultation process was a comparison of pre- and postproject pollutant loads. The WSDOT Data–FHWA method (described in the *Summary and Evaluation of Methodologies* section below) was used to estimate annual pollutant loads based on highway runoff characterization and BMP effectiveness data collected in western Washington since 2002. The December 2005 analysis addressed changes associated with the I-405 Bellevue Nickel Project from I-90 to SE 8th Street in Bellevue. The analysis focused on TSS, total copper, and total zinc, and provided the following rationale for doing so, "Using total metals in the analysis provides a worst-case estimate in the unlikely event that all of the metals later become dissolved."

At the completion of the I-405 Bellevue Nickel Project, the December 2005 analysis projected that 14.04 acres of new pavement would be added to the existing 38.15 acres. Enhanced stormwater quality treatment BMPs would treat an additional 30.79 acres or 81 percent of the existing placement within the five affected drainage basins. In addition, the project proposed to retrofit 100 percent of the existing pavement within the basins between I-90 and SE 8th Street.

Subsequently, an addendum to the BA was provided to NMFS (July 10, 2006) describing a change in roadway alignment and requesting a conference for Puget Sound steelhead (*Oncorhynchus mykiss)*. The change in alignment, stemming from Burlington Northern Santa Fe Railway's abandonment of the Wilburton Tunnel, included construction of one additional southbound land along the existing I-405 alignment instead of creating an all-new alignment of southbound lanes into the median of I-405. This change in alignment resulted in a reduction of stream and wetland impacts, minimized widening and excavation into the median, and allowed for water quality treatment to a greater percentage of the existing pavement. In summary, the project would add 6.6 acres of new impervious area to 37.67 acres of existing impervious area and would treat 18.89 acres of impervious surface. Using WSDOT Data–FHWA method methodology, the project was projected to reduce total suspended solids by 25 percent, total copper by 15 percent, and total zinc by 16 percent.

Consultation History

Consultation with USFWS extended 3 months, from November 2005 to January 2006. Consultation with NMFS extended 9 months, from November 2005 to July 2006.

I-405 Bellevue Nickel Improvement Project USFWS Concurrence Letter

The consultation for the I-405 Bellevue Nickel Improvement project was ultimately an informal consultation for USFWS. As a result, no biological opinion was issued for this project, and the concurrence letter does not include a detailed stormwater analysis. USFWS based the conclusions in its concurrence letter (January 19, 2006), in part, on the December 2005 stormwater information generated by WSDOT. It is important to note that the USFWS

concurrence on this project addressed the projects as described, prior to the design modifications described in the addendum provided to NMFS.

I-405 Bellevue Nickel Improvement Project NMFS Concurrence Letter

The consultation for the I-405 Bellevue Nickel Improvement project was an informal consultation for NMFS. The NMFS concurrence letter does not include a detailed stormwater analysis and addresses the modified project as described in the addendum. Although NMFS used the new impervious surface calculations provided in the BA addendum in its concurrence letter (July 20, 2006), it did not reference the stormwater quality analysis provided in this document. Instead, NMFS' conclusions pertaining to stormwater quality-related impacts rely on a performance standard of "no net increase of TSS, total and dissolved copper, zinc, and hydrocarbons for any stormwater that discharges to Mercer Slough and Lake Washington and any associated tributaries to those water bodies."

SR 167 Extension FHWA–WSDOT Stormwater Quality Analysis and USFWS Biological Opinion

The proposed SR 167 project will extend the existing SR 167 by constructing a new highway from SR 161 in north Puyallup to SR 509 in Tacoma, within Pierce County. The project is intended to relieve congestion and will consist of two lanes in each direction, plus HOV lanes to be constructed in the future. The project includes freeway-to-freeway connections with SR 509 and I-5; new local access interchanges at 54th Avenue East and Valley Avenue; completion of the SR 161 interchange; multiple crossing structures over the Puyallup River, Wapato Creek, Surprise Lake Tributary, and Hylebos Creek; compensatory wetland mitigation; and partial relocation of Surprise Lake Tributary and Hylebos Creek; and riparian restoration along Wapato Creek, Surprise Lake Tributary, and Hylebos Creek that will be implemented as an alternative to construction of large stormwater detention facilities. The riparian restoration associated with the project would control flow from three threshold discharge areas totaling 85 acres of pollution-generating impervious surface. Weigh stations and park-and-ride facilities are included for each direction of travel.

The project will create approximately 221 acres of impervious surface. Of that total, 70 acres will be in the Puyallup subbasin, 115 acres will be in the Hylebos subbasin, and 36 acres will be in the Wapato subbasin. The anticipated average daily traffic (ADT) level on the new freeway in the year 2015 is 50,000 to 70,000 vehicles per day; in 2030, it will be 75,000 to 90,000 vehicles per day.

Summary of Stormwater Quality Analysis

Because the approach used during this consultation to complete the stormwater quality analysis (as well as the other impact analyses) was generally an iterative process between the Services

and WSDOT, the USFWS biological opinion and WSDOT–FHWA analysis have been combined in the summary discussion and case studies below. WSDOT essentially supported USFWS by providing the necessary stormwater information to write their biological opinion. As was noted previously, at the time this white paper was being drafted, NMFS had not yet completed their biological opinion.

The stormwater concentration and loading analysis completed was a Level Three Stormwater Analysis, as described in the WSDOT BA Writers Guidance (WSDOT 2006b). The agencies (WSDOT and USFWS) modeled annual pollutant loading based on procedures described in FHWA (1990). To predict concentrations of project-related pollutants discharged to fresh water, the agencies used the FHWA method. To estimate concentrations that would be added to the estuarine environment, the agencies completed dilution modeling using Ecology's RIVPLUM5 and TSDCALC spreadsheets (Ludwa 2006). These concentrations were then compared to known toxicity thresholds. The background water quality conditions in which the thresholds were established were also compared to the baseline conditions present in the project area. This stormwater effects analysis was augmented by an exposure analysis for each of the project elements. The exposure analysis was technically straightforward but time-consuming to complete for each project element.

In addition, the following performance standards were assumed for the BMPs:

- Basic treatment = at least 80 percent removal of TSS
- Enhanced treatment = Basic treatment plus effluent concentrations not to exceed the following values 90 percent of the time at the point of discharge:
    - Total copper – 12 micrograms per liter
    - Dissolved copper – 7.8 micrograms per liter
    - Total zinc – 67 micrograms per liter
    - Dissolved zinc – 44.8 micrograms per liter.

The USFWS analysis examines specific toxicity thresholds for bull trout in addition to specific pathways by which pollutants could affect bull trout. The analysis specifically examines pollutant concentrations and annual loading associated with project-related runoff and how these concentrations could affect bull trout. In addition, an examination of potential for exposure (timing, duration, frequency) is provided.

Appendix B of this white paper contains a more detailed summary of stormwater-related information contained in the document.

Consultation History

Consultation on this project extended nearly 4 years. The following timeline summarizes significant issues and actions related to the history of this consultation. Preconsultation

coordination for this project began in 2003 with meetings between FHWA, WSDOT, NMFS and USFWS.

October 26, 2004: FHWA submitted a BA and requested formal consultation.

December 17, 2004: FHWA withdrew the BA and rescinded its request for consultation because a preferred option had not been identified. Preconsultation meetings began again, and the Services provided technical assistance on topics such as conducting the exposure analysis (evaluating the potential for listed fish species to be exposed to project impacts) and deconstructing the action.

September 30, 2005: FHWA forwarded a revised BA and requested formal consultation.

October 27, 2005: USFWS sent a letter to FHWA stating that the information necessary to initiate consultation had not been received.

Between October 2005 and April 2006, multiple meetings and information exchanges occurred. A collaborative approach to conducting the consultation was begun that included the Services assisting WSDOT and FHWA in deconstructing the action, completing an exposure analysis, and providing input of various effects analyses.

April 17, 2006: FHWA submitted a package of information to the Services that included a final deconstruction of the action, baseline information, action area description, and draft exposure analyses. Collaborative, preconsultation meetings continued where the Services provided guidance and input on topics such as development of stormwater flow control approaches, bull trout critical habitat analyses, and completion of the exposure analyses.

October 6, 2006: USFWS received revised exposure analyses from the project team and considered the initiation package complete. WSDOT and FHWA continued to submit revised project descriptions and effect analyses, including revised pollutant modeling results, updated in-water work plans, and responses to various questions throughout the remainder of the consultation.

January 29, 2007: A meeting was held among the Services, FHWA, and WSDOT to discuss draft Terms and Conditions that had been provided by NMFS. This meeting led to a formal elevation of particular issues by WSDOT and FHWA. Several meetings and information exchanges occurred at a result.

February 27, 2007: WSDOT provided a revised analysis of the hydrologic impacts of new impervious surface in the Puyallup River subbasin. This analysis factored in the addition of several new stormwater infiltration techniques and is

summarized in the "Effects of the Action" section of the USFWS biological opinion.

May 31, 2007: USWFS Biological opinion is completed.

Summary and Evaluation of Methodologies

The different methodologies used in the consultations summarized above varied considerably. Methods used to evaluate stormwater quality impacts included:

- Pollutant load estimation based on simple empirical runoff models
- Calculation of land-use weighted pollutant concentrations
- Dilution models (e.g., RIVPLUM)
- Multiple linear regression models as described in Kayhanian et al. (2003)
- Comparisons of toxicity thresholds to state water quality standards and/or anticipated effluent concentrations.

This white paper addresses only those methods used to evaluate water quality impacts associated with stormwater. Flow-related impacts analyzed in the consultation documents are outside the scope of this white paper. A more detailed description of each of the methods is provided in separate subsections below, with case studies that outline the data, assumptions, and outcomes from their application in specific consultations. Finally, the relative strengths and weaknesses of each methodology are summarized based on the following criteria:

- The ease of use and time and effort required for each method
- Availability of data needed to complete the analysis
- The effectiveness of the method in assessing specific stormwater pollutants of concern associated with highway runoff, considering BMP effectiveness in addressing those pollutants, and evaluating the bioavailability and effects of those pollutants on listed fish
- The effectiveness of the method in clearly conveying the extent of stormwater impacts on listed species and whether the impacts are insignificant or discountable
- The effectiveness of the method in meeting the needs of the resource agencies.

Pollutant Load Estimation from Empirical Runoff Models

This method uses simple empirical models to estimate annual stormwater pollutant loads as the product of mean pollutant concentration and annual (or storm-specific) runoff volumes for the

project area. Runoff in this relationship is calculated using the drainage area, rainfall total for the period of interest, and a runoff coefficient that predicts the fraction of rainfall that actually becomes runoff. In most applications, the runoff coefficient is estimated as a function of the area of impervious surface in the watershed. Mean pollutant concentrations are derived from representative monitoring data from local, regional, or national sources.

To estimate post-treatment impacts from highway runoff, the calculated pollutant loading estimates are adjusted downward based on the anticipated pollutant removal efficiency for the specific BMP technology that will be used on the project. These removal efficiency estimates can also be derived from monitoring data obtained from local, regional, or national sources.

While a number of different methods have been suggested for these calculations, the analyses performed for the ESA consultations described herein have generally used the FHWA method, Simple method, and the WSDOT Data–FHWA method. These methods are described in more detail below.

FHWA Method

Identified as "Method 1" in the 2003 and 2004 WSDOT Environmental Procedures Manuals (WSDOT 2003, 2004b), the FHWA method was developed by the FHWA (1990) for assessing impacts from roadway projects. It uses an empirically derived equation to predict annual pollutant loads as a function of runoff volume and pollutant concentration. The runoff volume is derived using a runoff coefficient that is estimated based on the amount of impervious cover in the watershed. The specific input parameters for the FHWA method are as follows: rainfall volume for mean storm event, watershed area, site median concentrations (SMCs), and estimated number of storm events per year. The computational steps that are performed using these variables and the FHMA method are documented in Appendix C of this white paper.

SMCs for the method were derived based on data collected between 1975 and 1985, from almost 1,000 storm events at 31 highway runoff sites in 11 states (FHWA 1990). The SMCs represent the median value from site event mean concentrations in this data set. SMCs are provided in the method for two roadway use classifications: less than 30,000 ADT volume and greater than 30,000 ADT volume. Differences between predicted loads in the method are driven primarily by differences in rainfall characteristics and this ADT distinction. The SMCs to be applied in the method are also documented in Appendix C of this white paper.

To calculate post-treatment annual pollutant loads in highway runoff, the 2003 and 2004 WSDOT Environmental Procedures Manuals provided pollutant removal efficiency estimates for various stormwater BMPs that were derived from national data sources. The post-treatment load is calculated by multiplying the pretreatment load by the appropriate removal efficiency estimate for the BMP identified for the project. The removal efficiency estimates to be applied in these calculations are documented in Appendix C of this white paper.

Unlike the simple method described below, the FHWA method was developed specifically for use in conducting highway impact assessments, and it includes additional steps for assessing impacts on streams and lakes (see FHWA 1990). However, its applicability is limited without the availability of supplemental hydrologic data specific to the project area (e.g., rainfall for mean storm event).

Simple Method

Identified as "Method 2" in the 2003 and 2004 WSDOT Environmental Procedures Manuals (WSDOT 2003, 2004b), the Simple method refers to an empirical model that was developed by Schueler (1987) for use in estimating pollutant loads from urban watersheds. The Simple method calculates loads as the product of annual runoff volume and an average pollutant concentration. The annual runoff volume is derived using the annual rainfall amount, the drainage area, and a runoff coefficient estimated based on the amount of impervious cover in the drainage area. The specific computation steps that are performed in the Simple method are documented in Appendix D of this white paper.

Average pollutant concentrations used in the Simple method can be derived from local, regional, or national data sources. The 2003 and 2004 WSDOT Environmental Procedures Manuals provided flow-weighted average concentrations for 14 parameters and six different land use types, including urban highways, to facilitate estimation of pollutant loads from highway projects using the Simple method. These concentrations were derived using data compiled in the National Urban Highway Runoff (NURP) database that was developed in the 1970s. These concentrations are also documented in Appendix D of this white paper.

In the 2003 and 2004 WSDOT Environmental Procedures Manuals, the pollutant removal efficiency estimates described above in conjunction with the FHWA method were also to be applied to pretreatment loads obtained using the Simple method to estimate post-treatment pollutant loads. As noted previously, these removal efficiency estimates are documented in Appendix C.

In general, the Simple method is most appropriate for assessing and comparing the relative storm flow pollutant load from urban developments; however, it was not specifically developed to assess pollutant loads from highway projects. Furthermore, the method is also generally not applicable to drainage areas greater than 1 square mile.

WSDOT Data–FHWA Method

Originally identified as "Method 1" in the 2005 and 2007 Environmental Procedures Manuals (WSDOT 2005d, 2007b), the WSDOT Data–FHWA method is a modification of the FHWA method such that local highway runoff data are used for computing annual pollutant loads in lieu of the SMCs discussed above. In the 2005 Environmental Procedures Manual, the local data were obtained from the WSDOT 2004 Annual National Pollutant Discharge Elimination System (NPDES) Progress Report (WSDOT 2004c). These data included concentrations for common

pollutants (i.e., total suspended solids, total phosphorus, total copper, and total zinc) measured in runoff from high ADT volume highways (90,000–160,000) in western Washington. In the 2007 Environmental Procedures Manual, updated local data from the WSDOT 2006 Annual NPDES Progress Report (WSDOT 2006c) were used as input for the method. Included were concentrations for common pollutants (i.e., TSS, total phosphorus, total and dissolved copper, and total and dissolved zinc) from a wider range of ADT volume highways (2,400–180,000) in western Washington. The annual pollutant loads for untreated highway runoff that were derived using this method are summarized in Appendix E of this white paper for the 2005 and 2007 Environmental Procedures Manuals.

To calculate post-treatment annual pollutant loads in highway runoff, data from the WSDOT 2004 and 2006 Annual NPDES Progress Reports were also used to derive average removal efficiency estimates for each pollutant identified above across all types of BMPs. These values were then applied to the annual load estimates for untreated highway runoff to calculate annual pollutant loads for treated runoff. The resultant values from these calculations are also summarized in Appendix E of this white paper for the 2005 and 2007 Environmental Procedures Manuals.

To assess potential project impacts using this method, the following steps are followed to compare pre- and postproject pollutant loads:

1. To determine preproject pollutant loads, existing untreated area is multiplied by annual pollutant load estimates for untreated runoff, and existing treated area is multiplied by annual pollutant load estimates for treated runoff. The pollutant load calculated for existing untreated areas is added to the load calculated for existing treated areas to determine the overall preproject pollutant load.

2. To determine postproject pollutant loads, postproject untreated area is multiplied by annual pollutant load estimates for untreated runoff, and postproject treated area is multiplied by annual pollutant load estimates for treated runoff. The pollutant load calculated for postproject untreated areas is added to the load calculated for postproject treated areas to determine the overall postproject pollutant load.

3. The net annual pollutant load for a project is determined by subtracting the preproject load from the postproject load.

The WSDOT Data–FHWA method also provides the basis for the Level One Stormwater Analysis that is presented in WSDOT's BA Writers Guidance for Preparing Stormwater Section of Biological Assessments (WSDOT BA Writers Guidance) (WSDOT 2006b) for evaluating impacts from highway projects. This guidance presents three consecutive levels of analysis depending on the scale of anticipated impacts. The level one analysis is the least complex and relies on annual pollutant load estimates for treated and untreated highway runoff that were derived using the WSDOT Data–FHWA method and local data obtained from the WSDOT 2005

Annual NPDES Progress Report (WSDOT 2005e). These pollutant load estimates are documented in Appendix E of this white paper. The same steps identified above for Method 1 of the 2005 and 2007 WSDOT Environmental Procedures Manuals are applied when comparing pre- and postproject pollutant loads. To expedite the stormwater quality analysis for WSDOT BAs and related consultation analysis and documents (biological opinions), a pollutant load-concentration spreadsheet, The BA Pollutant Load/Concentration Calculator (see Appendix G) was developed by WSDOT to automate some of the calculations related to these steps. The spreadsheet contains a data entry section, from which pollutant loads are calculated automatically. Calculations are made by threshold discharge area, as defined in the Highway Runoff Manual (2004 and 2006d).

The following subsections provide case studies that show how the pollutant load estimation from the empirical runoff models method was applied in actual consultations; also presented is information on the ultimate outcome.

Case Study 1: SR 524 Project Stormwater Quality Analysis

As is discussed above, the initial BA submitted for this project lacked detailed stormwater information. As a result, subsequent analyses were produced. The first FHWA method analysis was dismissed by WSDOT because it did not generate data that provided the Services with the information they requested (i.e., concentrations of pollutants for a range of storms throughout a particular month for both the current and proposed site conditions); in addition, it did not include anticipated removal efficiencies for tested BMPs.

A second analysis was prepared in May 2005. This analysis used Method 1: WSDOT Data–FHWA Method (described above) from the WSDOT 2005 Environmental Procedures Manual (WSDOT 2005d) to develop a projection of the percentage change of pollutants discharged to receiving water bodies. The projections were based on pre- vs. postdevelopment pollution-generating surface area and the efficiency of the pre- vs. postdevelopment stormwater treatment BMPs used. Projections were developed for each of the project subbasins. Results from this analysis were not used in either the NMFS' or USFWS' analysis.

Prior to commitment of no net increase in pollutants, NMFS estimated annual pollutant loading via the FHWA and Simple methods as outlined in the WSDOT Environmental Procedures Manual (WSDOT 2003). These methods provide estimates of storm pollutant export from a site, catchment, or watershed. The methods (FHWA/Simple) were used to estimate annual pollutant loads while accounting for new impervious area and installation of new BMPs. Results were calculated in annual loads of total metals per BMP.

Based on highly variable BMP efficiency data, NMFS made an assumption that wet ponds would have 60 percent pollutant removal efficiency for TSS, 15 percent for dissolved metals, and 40 percent for total metals. For wet vaults, NMFS assumed 60 percent efficiency for TSS, 5 percent for dissolved metals, and 20 percent for total metals. These numbers were near the reported means and medians of most of the literature reviewed by NMFS.

Estimates of annual pollutant loading of copper, zinc, and TSS were calculated to compare baseline and proposed annual loadings. To determine dissolved metal loadings, NMFS used the ratios of the total metal concentrations to dissolved metal concentrations from the multiple linear regression model, as described below. The estimated increases in copper, zinc, and TSS loading are summarized in Table 1 below.

Table 1. Annual pollutant loading estimates.

Pollutant	Baseline [a]	Vault [a]	Pond [a]
Total copper in kg/year	*0.26* / **0.32**	*0.58* / **0.7**	*0.43* / **0.53**
Dissolved copper in kg/year	*0.13* / **0.16**	*0.33* / **0.4**	*0.3* / **0.36**
Total zinc in kg/year	*1.61* / **1.95**	*3.52* / **4.27**	*2.64* / **3.20**
Dissolved zinc in kg/year	*0.84* / **1.02**	*2.19* / **2.65**	*1.96* / **2.37**
TSS in kg/year	*693* / **843**	*760* / **921**	*760* / **921**

[a] Italicized text indicates Simple method results. Bold text indicates FHWA method results.
Source: NMFS (2005).

These initial results indicated substantial increases in annual copper and zinc loading per BMP and a 10 percent increase in annual TSS loading or a total increase in TSS of 173 percent as a result of the new impervious surface. It was assumed that there would be a substantial increase in fine sediment above baseline conditions because the BMPs treating increased TSS resulting from new impervious surface would only remove the largest particles.

However, after this analysis was completed, NMFS and WSDOT/FHWA agreed to a no net increase performance standard for copper, zinc, and TSS. NMFS' reliance on this performance commitment as a central tenet of its analysis of potential project impacts and conclusions related to effects on listed species. As a result, the conclusions provided in the NMFS biological opinion are not ultimately substantiated by the detailed stormwater quality analysis provided in the opinion The conclusions of the biological opinion, ultimately rely on an untested performance commitment that may or may not be achievable or even feasible. In their biological opinion, NMFS states that the agency "does not understand how the no net increase commitment will be achieved."

Case Study 2: I-405 Bellevue Nickel Improvement Project Stormwater Quality Analysis

The biological assessment submitted to the Services in November 2005 had limited stormwater information and analysis. In response to questions from the Services regarding the project's contribution of pollutant loads to local receiving waters, WSDOT completed a supplemental stormwater quality analysis, which is summarized below.

In December 2005, WSDOT applied the WSDOT Data–FHWA method for calculating annual pollutant loading for the project. The results of the analysis were presented as a general comparison of the percentage change in annual loading for each pollutant from each subbasin as well as for the project as a whole.

A summary of anticipated changes in impervious surface provided in the WSDOT analysis is provided in Table 2 below.

Table 2. Summary of impervious surface change and proposed treatment by basin.

Threshold Discharge Area	Preproject Acreages		Postproject Acreages	
	PGIS [a]	Treated	PGIS	Treated
A	9.84	0	12.37	12.37
B	8.21	0	11.85	11.85
C	2.02	0	3.32	3.32
D	8.61	0	8.61 [b]	8.61
E	9.47	1.75	16.03	8.68 [b]
Totals	38.15	1.75	52.19	44.83

[a] PGIS–pollution generating impervious surface.
[b] The new impervious surface (4.14 acres) in Basin D is diverted to Basin E for water quality treatment.

The preproject pollutant loading information was based on values provided in Exhibit 431-4, Table 3 of the WSDOT 2005 Environmental Procedures Manual, for runoff *without* treatment. The pollutant loading information for treated highway pavement surfaces was also based on the values that are provided in this same table for runoff *with* treatment. BMP effectiveness assumptions were based on the WSDOT 2005 NPDES report (WSDOT 2005e), supplemented by test data from the International BMP database.

Table 3. Anticipated percent reduction in pollutant loading by basin.

Threshold Discharge Area	Pollutant		
	Total Suspended Solids	Total Copper	Total Zinc
A	94	69	70
B	93	64	66
C	92	59	61
D	95	75	76
E	1	-23	-22
Average	74	49	51

Source: WSDOT (2005c).

The new BMP design criteria described in the 2004 Highway Runoff Manual (WSDOT 2004d) were incorporated into project designs. However, insufficient time lapsed between the development of the new BMP criteria and the stormwater quality analysis completed for this project to accurately represent BMP removal efficiency. The new BMPs would presumably result in a higher removal efficiency than those built to conform to the 1997 Highway Runoff Manual (WSDOT 1997a). But data reflected in the 2005 NPDES report (WSDOT 2005e) would likely represent BMPs constructed to conform to these earlier criteria. As a result, the stormwater quality analysis for this project likely underestimated BMP effectiveness and overestimated pollutant loads.

The results generated by the WSDOT analysis indicated significant reductions in pollutant loading in all basins, except for Basin E. For this basin, the analysis concluded that stormwater treatments within the basin would be maximized as practicable as part of final designs. A summary of modeling results is provided in Table 3 (above).

While the above results present general estimates of annual pollutant loads, the analysis also includes the following discussion regarding its limitations:

- Impacts on fish are not based on annual averages. Impacts result from extreme events (e.g., 1-hour exceedances or acute concentration standards). This method (WSDOT-FHWA Method), however, presumes that there is a positive correlation between annual loads and discharge quality (i.e., extreme events decrease when annual loads decrease).

- Effects cannot be predicted unless baseline concentrations in the receiving waters are known. The I-405 project team conducted research to determine what existing sampling data were available for the study pollutants for Mercer Slough and Lake Washington. The closest sampling data were available through King County's monitoring point 444 in Kelsey Creek. This source provides current TSS data, but no metals data have been collected since 1992. Neither Mercer Slough nor Lake Washington is listed on Ecology's 303(d) list for metals. Therefore, unlike the analysis for the SR 524 project, it appears that there is not a known threshold of existing pollutant levels within the receiving water bodies.

- Although WSDOT will generate an analysis with this approach, not enough data are available to accurately evaluate BMP effectiveness, receiving water quality, dilution factors, or susceptibility of fish.

It was assumed that there would be a similar decline in dissolved metal pollutant loading within the receiving waters. This stormwater quality analysis stops short of extending conclusions to baseline conditions or to fish.

These WSDOT impervious surface and percentage data for pollutant reduction are incorporated into the USFWS concurrence letter (January 19, 2006). USFWS' stormwater quality-related conclusions, as they pertain to bull trout, rely on this stormwater information, accompanied by bull trout distribution data (i.e., the low likelihood of their presence in the action area) and anticipated dilution of project-related stormwater to undetectable levels in Lake Washington where bull trout could potentially be present.

Subsequently, an addendum to the BA was provided to NMFS (July 10, 2006) describing a change in roadway alignment and requesting a conference for Puget Sound steelhead. The change in alignment, stemming from Burlington Northern Santa Fe Railway's abandonment of the Wilburton Tunnel, included construction of one additional southbound lane along the existing I-405 alignment instead of creating an all-new alignment of southbound lanes into the

median of I-405. This change in alignment resulted in a reduction of stream and wetland impacts, minimized widening and excavation into the median, and allowed for water quality treatment to a greater percentage of the existing pavement. In summary, the project would add 6.6 acres of new impervious area to 37.67 acres of existing impervious area and would treat 18.89 acres of impervious surface. The project was projected, using the FHWA-WSDOT data method previously used, to reduce total suspended solids by 25 percent, total copper by 15 percent, and total zinc by 16 percent.

NMFS presented these impervious surface data (6.6 acres of new impervious surface and retrofitting 12.29 acres out of a total of 37.67 existing acres of impervious surface within the project area) in its concurrence letter (July 20, 2006) but did not include information on the projected loading reductions. After the WSDOT analysis was completed, NMFS and WSDOT/FHWA agreed to a no net increase performance standard for TSS, dissolved and total copper and zinc, and hydrocarbons for "any stormwater effluent that discharges into Mercer Slough and Lake Washington and any associated tributaries to those water bodies." The concurrence letter states, "The performance standard will ensure that stormwater treatment facilities within the action area remove contaminants to levels not harmful to PS Chinook." This rationale is extended to the conclusions pertaining to designated critical habitat for PS Chinook salmon and the PS steelhead conference conclusion. As a result, the conclusions provided in the NMFS concurrence letter are not ultimately substantiated by the stormwater quality analysis provided to NMFS by WSDOT.

Case Study 3: SR 167 Extension Project Stormwater Quality Analysis

As a portion of the stormwater quality analysis completed for the SR 167 project, WSDOT used the FHWA method as adapted in the WSDOT BA Writers Guidance (WSDOT 2006b) to predict. annual pollutant loading. The results from this modeling effort represent a Level One Stormwater Analysis method and are summarized below. FHWA method results indicated an annual pollutant loading increase in TSS, and total and dissolved copper and zinc loading in all threshold discharge areas (TDAs) with the following exceptions: TSS would decrease in the Fife Ditch (-8,356.1 lbs), Hylebos Creek (-7,231.1 lbs), and Puyallup River (-1,482 lbs) TDAs, where approximately 24 acres of pollution-generating impervious surface (PGIS) would be retrofitted. Loading of total zinc was expected to decrease in Fife Ditch (-11.07 lbs) and Hylebos Creek (-4.07 lbs). Loading of total copper was expected to decrease in Fife Ditch (-1.63 lbs) and Hylebos Creek (-0.01 lbs). Loading of dissolved zinc would decrease in Fife Ditch (-1.38 lbs). It was assumed that net increases in pollutant loading (18.59 lbs for total zinc, 29.18 lbs for dissolved zinc, 6.6 lbs for total copper, and 5.81 lbs for dissolved copper) would measurably degrade the environmental baseline during periods of high water.

Assumed standards were:

- Basic treatment = at least 80 percent removal of TSS
- Enhanced treatment = Basic treatment plus effluent concentrations not to exceed the following values 90 percent of the time at the point of discharge:

- Total copper – 12 micrograms per liter
- Dissolved copper – 7.8 micrograms per liter
- Total zinc – 67 micrograms per liter
- Dissolved zinc – 44.8 micrograms per liter

Enhanced treatment will be provided for 9 out of the 10 TDAs. The one TDA where basic treatment will likely be provided is the 3-acre TDA discharging to the Erdahl Ditch.

Strengths and Weaknesses

The strengths and weaknesses of the empirical runoff models evaluated for this white paper (Simple method, FHWA method, and WSDOT Data–FHWA method) are summarized below.

Strengths

- Empirical runoff models effectively calculate and represent relative differences in loadings between pre- and postproject conditions (i.e., baseline loading vs. postdevelopment loading).
- Empirical runoff models provide quantitative data that can clearly demonstrate if loading will increase or decrease as a result of a proposed project.
- In general, data required for empirical models are readily available:
  - Most parameters for the Simple method and WSDOT Data–FHWA method would be included in the ESA Stormwater Design Checklist completed for a project.
  - The FHWA method requires additional inputs regarding site-specific information on precipitation patterns.
- Because annual pollutant loads are the output from the models, the resultant data can be used to inform assessments of potential sediment contaminant issues.
- With the BA Pollutant Load/Concentration Calculator (see Appendix G), the WSDOT Data–FHWA method is easy to use for individuals without a technical stormwater background.
- The WSDOT Data–FHWA method uses local data as input.

Weaknesses

- Empirical runoff models do not address receiving water concentration. As a result, models cannot be used to assess toxicity in the receiving water

body based on water quality standards or other biologically significant endpoints for pollutants in the water column.

- Empirical runoff models cannot evaluate receiving water characteristics that can affect concentration (e.g., dilution), bioavailability (e.g., hardness, dissolved organic carbon), or other factors that may influence toxicity (e.g., background concentrations, mixtures, bioaccumulation, multiple stressors).

- Inputs to the models (e.g., effluent pollutant concentration, BMP performance, rainfall data) generally rely on a single measure of central tendency as derived from national or local data. Variability in these model inputs is not captured in the analysis.

- The FHWA and Simple methods generally rely on national data for effluent pollutant concentrations and BMP removal efficiency estimates. (This is why the WSDOT Data–FHWA method was subsequently developed.)

- The Simple method was not developed specifically for highway runoff analyses.

- Output from the models generally provides annual loading estimates. Potential impacts associated with short-term, intermittent, or extreme storm events or exposures cannot be assessed.

- Models are overly simplistic in that they assume the pollutant load varies only in proportion to basin size, impervious area, and precipitation amount. Other variables (e.g., ADT, first flush, antecedent dry period, proximity to urban areas, etc.) that could potentially influence pollutant load estimates are not factored into the models.

Weighted Concentration Models

This method provides the basis for the Level Two Stormwater Analysis that is presented in the BA Writers Guidance (WSDOT 2006b). A level two analysis is required if the Level One Stormwater Analysis described above cannot demonstrate that a project will result in no net increase in pollutant loading. The Level Two Stormwater Analysis is performed for projects that may result in some small increase in pollutant loading and/or flow alteration, but do not result in a net increase in pollutant concentrations.

To perform the Level Two Stormwater Analysis, the following steps are followed:

1. Determine the baseline (preproject) runoff treatment and flow control based on existing information obtained from the ESA Stormwater Design Checklist (see Appendix A) that is contained in the WSDOT Highway Runoff Manual (WSDOT 2006d).

2. Characterize existing pollutants of concern based on available monitoring data (e.g., WSDOT NPDES Progress Reports) with specific emphasis on total suspended solids, copper, zinc, lead, cadmium, chromium, and PAHs.

3. Identify if the proposed project is at moderate or high risk of producing runoff with high pollutant concentrations based on the following criteria:

   - Moderate Risk: Highway projects in this category pose a moderate risk of producing runoff with low to moderate concentrations of pollutants. Projects are characterized as moderate risk if they have an ADT less than 60,000. Average effluent concentrations, generated from WSDOT monitoring data for treated runoff, are used to represent the expected pollutant concentration for projects in this category.

   - High Risk: Highway projects in this category pose a high risk of producing runoff with high concentrations of pollutants. Projects in the high risk category have traffic levels exceeding 60,000 ADT, and have completely closed conveyance systems (with no opportunity for infiltration or passive treatment in vegetation). The 90th percentile effluent concentrations for treated WSDOT runoff are used to represent the expected concentrations for projects in this category.

4. Calculate expected effluent pollutant concentrations that would likely be generated before and after the proposed project based on representative concentrations for untreated and treated runoff that were derived from the WSDOT 2005 NPDES Progress Report (WSDOT 2005e). These data are summarized in Table 4 for moderate and high risk projects. The actual calculations involve the generation of land-use weighted concentrations for pre- and postproject effluent using the following steps:

   To calculate preproject effluent concentrations:

   a. Multiply acres of untreated impervious surface by the expected pollutant concentrations in untreated runoff from Table 4.

   b. Add the acres of existing treated impervious surface with discharge to a water body multiplied by the expected pollutant concentrations in treated runoff.

c. Divide the sum by the total acres of preproject existing treated and untreated impervious surface to determine expected concentrations.

To calculate postproject effluent pollutant concentrations:

a. Multiply acres of untreated impervious surface by the expected pollutant concentrations in untreated runoff from Table 4.

b. Add the acres of existing treated impervious surface after the project multiplied by the expected pollutant concentrations in treated runoff.

c. Divide the sum by the total acres of treated and untreated impervious surface to determine expected concentrations.

(Example calculations for these steps are provided in Appendix F. WSDOT has also developed a Pollutant Load/Concentration Calculator to facilitate these calculations [Appendix G].)

Table 4. Expected pollutant concentrations for untreated and treated runoff from the WSDOT BA Writers Guidance.

	Untreated Runoff		Treated Runoff	
Pollutant	Moderate Risk	High Risk	Moderate Risk	High Risk
TSS (mg/L)	93	192	6.4	14
Total copper (μg/L)	31	59	7	12
Dissolved copper (μg/L)	7.6	14	5	7.8
Total zinc (μg/L)	174	350	40	67
Dissolved zinc (μg/L)	62	110	27	44.8

Source: WSDOT (2006b).

The effects analysis essentially consists of a comparison of baseline conditions to postproject conditions. This analysis must evaluate or determine the following:

- How much runoff may be discharged to the receiving water body as a result of the project
- Under what conditions a storm event will result in discharges
- Level of runoff treatment and flow control employed
- Pre- vs. postproject annual pollutant loading

- Pre- vs. postproject effluent concentrations
- Effects of resulting stormwater on ESA species and critical habitat based on timing of impacts vs. species presence, types of impacts relative to life-history stages and level of use of the system by ESA species, and types of impacts relative to presence of critical habitat and primary constituent elements.

Case Study 1: SR 167 Extension USFWS Biological Opinion and SR 167 FHWA-WSDOT Stormwater Analysis

As a portion of the stormwater quality analysis completed for the SR 167 project, WSDOT used the Level Two Stormwater Analysis method as described in the WSDOT BA Writers Guidance to predict concentrations of project-related pollutants discharged to fresh water. This modeling effort assumed that the SR 167 Extension project was a high risk project. The results from this modeling effort are summarized below.

Stormwater from existing PGIS within the action area already contained concentrations of copper, zinc, cadmium, and chromium. The pre- and postproject concentrations at the point of discharge throughout the action area by threshold discharge area are summarized in Table 5 below.

In the Fife Ditch, Hylebos Creek, and Puyallup River TDAs and within all water bodies combined, the retrofit of 24 acres of existing PGIS is expected to decrease the concentrations of TSS and total and dissolved copper and zinc down to the following performance standards, which were negotiated by the Service and WSDOT during ESA consultation:

- Basic treatment = at least 80 percent removal of TSS
- Enhanced treatment = Basic treatment plus effluent concentrations not to exceed the following values 90 percent of the time at the point of discharge:
    - Total copper—12 micrograms per liter
    - Dissolved copper—7.8 micrograms per liter
    - Total zinc—67 micrograms per liter
    - Dissolved zinc—44.8 micrograms per liter.

For the remainder of the TDAs where new PGIS will be installed and there is no existing PGIS to retrofit (i.e., Erdahl Ditch, Wapato Creek, Surprise Lake Tributary, and Oxbow Lake Ditch), concentrations of pollutants are expected to meet the project's performance standards. Enhanced treatment will be provided for 9 out of the 10 TDAs. The one TDA where basic treatment will likely be provided is the 3-acre TDA discharging to the Erdahl Ditch.

A key assumption in the USFWS biological opinion effects analysis was that these performance standard concentrations exceed thresholds of effects on listed species (see the *Toxicity Threshold*

Analysis discussion, below). Another key assumption in the stormwater quality analysis regarding the potential for exposure was that mixing zones in the Puyallup River would adhere to those defined in the Puyallup Tribe's water quality standards (300 feet downstream, 100 feet upstream, 25 percent of the channel during the 7Q10 discharge [i.e., the 7 day average low flow that has a 10 percent chance of occurring in any given year]). For all other water bodies (i.e., Hylebos and Wapato creeks and Surprise Lake Tributary as well as the Fife and Erdahl ditches), Washington State water quality standards dictate the mixing zone. State mixing zone standards are identical to the Tribe's.

Table 5. Pre- and postproject pollutant concentrations of TSS, zinc (Zn), and copper (Cu) and net change by TDA.[a]

		Pollutant Concentration				
		mg/L	µg/L [e]			
TDA		TSS	Total Zn	Diss. Zn	Total Cu	Diss. Cu
Erdahl Ditch	Preproject					
	Postproject	14.00	67.00	44.80	12.00	7.80
	Net Change	**14.00**	**67.00**	**44.80**	**12.00**	**7.80**
Wapato Creek [b]	Preproject					
	Postproject	14.00	67.00	44.80	12.00	7.80
	Net Change	**14.00**	**67.00**	**44.80**	**12.00**	**7.80**
Fife Ditch [c]	Preproject	192.00	350.00	110.00	59.00	14.00
	Postproject	14.00	67.00	44.80	12.00	7.80
	Net Change	**-178.00**	**-283.00**	**-65.20**	**-47.00**	**-6.20**
Hylebos Creek [d]	Preproject	192.00	350.00	110.00	59.00	14.00
	Postproject	14.00	67.00	44.80	12.00	7.80
	Net Change	**-178.00**	**-283.00**	**-65.20**	**-47.00**	**-6.20**
Surprise Lake Tributary	Preproject					
	Postproject	14.00	67.00	44.80	12.00	7.80
	Net Change	**14.00**	**67.00**	**44.80**	**12.00**	**7.80**
Oxbow Lake Ditch	Preproject					
	Postproject	14.00	67.00	44.80	12.00	7.80
	Net Change	**14.00**	**67.00**	**44.80**	**12.00**	**7.80**
Puyallup River	Preproject	192.00	350.00	110.00	59.00	14.00
	Postproject	14.00	67.00	44.80	12.00	7.80
	Net Change	**-178.00**	**-283.00**	**-65.20**	**-47.00**	**-6.20**
All Water Bodies	Preproject	192.00	350.00	110.00	59.00	14.00
	Postproject	14.00	67.00	44.80	12.00	7.80
	Net Change	**-178.00**	**-283.00**	**-65.20**	**-47.00**	**-6.20**

[a] Table excerpted from USFWS (2007).
[b] Combines PGIS from two non-listed fish bearing TDAs. Pollutant loading from at least the downstream TDA will likely affect PS Chinook salmon inhabiting the Blair Waterway and Commencement Bay.
[c] Combines PGIS from two non-listed fish-bearing TDAs.
[d] Combines PGIS from three listed fish-bearing TDAs.
[e] The pollutant concentrations were derived from data on influent and effluent concentrations for multiple stormwater quality BMPs contained in the 2005 WSDOT NPDES Report (WSDOT 2005e).

Strengths and Weaknesses

The strengths and weaknesses of the Weighted Concentration Model (Level Two Stormwater Analysis) are summarized below.

Strengths

- The model effectively calculates and represents relative differences in concentrations between pre- and postproject conditions (i.e., baseline loading vs. postdevelopment loading).
- In general, data required for empirical models are readily available in the BA Writers Guidance.
- With the BA Pollutant Load/Concentration Calculator, the method is easy to use for individuals without a technical stormwater background.
- The method uses local data as input.
- The model can be used to estimate effluent concentrations. Therefore, results provide a more meaningful assessment of toxicity in the receiving water as compared to state water quality standards or other biologically significant endpoints for pollutants in the water column.

Weaknesses

- The model cannot evaluate receiving water characteristics that can affect concentration (e.g., dilution), bioavailability (e.g., hardness, dissolved organic carbon), or other factors that may influence toxicity (e.g., background concentrations, mixtures, bioaccumulation, multiple stressors).
- Inputs to the models (e.g., treated and untreated runoff concentration, BMP removal efficiency) generally rely on a single measure of central tendency as derived from local data. Variability in these inputs is not captured in analysis.
- Output from the model generally provides average effluent pollutant concentrations. Potential impacts associated with short-term, intermittent, or extreme storm events or exposures cannot be assessed.
- Other variables (e.g., rainfall, first flush, antecedent dry period, proximity to urban areas, etc.) influencing concentration estimates besides basin area and ADT are not factored into the model.

- Because average effluent pollutant concentrations are the output from the model, the resultant data cannot be used to inform assessments of potential sediment contaminant issues based on pollutant loads.

Dilution Models

Dilution model provides the basis for the Level Three Stormwater Analysis that is presented in the WSDOT BA Writers Guidance (WSDOT 2006b). The Level Three Stormwater Analysis essentially incorporates all of the information and analysis provided by the Level One and Two Stormwater Analyses described previously, but also uses dilution models to quantify the potential exposure of ESA species to stormwater impacts by defining how far downstream the stormwater discharge plume would extend.

Dilution models utilize computers to simulate the hydrodynamics of mixing processes within receiving waters to predict pollutant concentrations at varying distances from their point of discharge. To make these predictions, dilution models typically use complex algorithms to integrate properties related to the point of discharge (e.g., outfall configuration, size, and orientation), effluent (e.g., buoyancy and discharge rate), and receiving water (e.g., channel geometry, flow volume, and flow velocity). Dilution models can vary markedly in their complexity and suitability for different applications; however, the WSDOT BA Writers Guidance recommends that RIVPLUM5 dilution model be used for the Level Three Stormwater Analysis.

RIVPLUM5 is a simple dilution model for rivers that was developed based on concepts presented in Fischer et al. (1979). This model calculates dilution at a specified point of interest downstream from a point discharge to a river, assuming that the discharge: (1) is a single point source, which is most appropriate for single port or short diffusers, or side-bank discharges; and (2) is completely and rapidly mixed vertically, which usually only occurs in shallow rivers. A spreadsheet for running the model is available on Ecology's website (Ecology 2000) with detailed instructions regarding the required input parameters and assumptions. Although the instructions and spreadsheet simplify use of the model significantly, this model requires a large number of input parameters to be implemented effectively. For example, the effluent discharge rate and the following input parameters relating to the receiving water must be obtained to run the model: stream depth, stream velocity, channel width, and stream slope (or Manning's roughness coefficient).

Case Study 1: SR 167 Extension USFWS Biological Opinion and SR 167 FHWA–WSDOT Stormwater Analysis

To estimate the extent of the action area as well as pollutant concentrations that would be added to the estuarine environment, WSDOT completed dilution modeling using Ecology's RIVPLUM5 and TSDCALC spreadsheets (Ludwa 2006).

The dilution analysis indicated that at the mouth of Hylebos Creek, there would be no difference between existing and proposed concentrations for copper and a slight reduction in zinc. In Oxbow Lake Ditch, there would be an increase in dissolved copper and zinc concentrations. In the Puyallup River, the distance necessary to dilute copper and zinc to within 0.5 µg/L of background conditions was calculated; for zinc, dilution distance was 25 feet under existing conditions and 235 feet under proposed conditions; for copper, the dilution distance was 1 foot under existing conditions and 6 feet under proposed conditions. These same models also determined concentrations of pollutants at tide gates. Modeling results indicated that postproject concentrations of dissolved copper at tide gates ranged from 2.1 to 2.6 µg/L, and concentrations of zinc at tide gates ranged from 4.5 to 8.3 µg/L. In addition, the modeling indicated that zinc was diluted to background levels within 2,000 feet in the Blair Waterway, and within 7,000 feet in the Hylebos Waterway.

These concentrations were then compared to known toxicity thresholds (see the *Toxicity Threshold Analysis* discussion, below). The background water quality conditions in which the thresholds were established were also compared to the baseline conditions present in the project area.

The Level Three Stormwater Analysis (i.e., the RIVPLUM and TSDCALC modeling) was difficult to complete for this project. From project e-mails, it is apparent that the difficulty associated with project modeling was exacerbated by repeated changes to assumptions and model inputs, which in turn required rerunning the project models. In addition, the piecemeal manner in which information was requested and subsequently generated seemed to make the analytical process somewhat inefficient. If inputs and assumptions were agreed upon at the outset, the pollutant concentration and annual pollutant loading models would require staff with modeling expertise to complete, but implementation of the models would be relatively straightforward.

Strengths and Weaknesses

The strengths and weaknesses of the dilution models (Level Three Stormwater Analysis) are summarized below.

Strengths

- The models can be used to estimate actual effluent concentrations in the receiving water. Therefore, results provide a more meaningful assessment of toxicity to affected aquatic species as compared to state water quality standards or other biologically significant endpoints for pollutants in the water column.

- With the RIVPLUM5 spreadsheet, the method is relatively easy to use for individuals without a technical stormwater background. The RIVPLUM5 model used for the Level Three analysis is readily accessible via

Ecology's website (Ecology 2000), along with detailed guidance for conducting mixing zone analyses (Ecology Undated).

- The method uses local data as input.

Weaknesses

- The models cannot evaluate receiving water characteristics that can affect bioavailability (e.g., hardness, dissolved organic carbon) or some factors that may influence toxicity (e.g., mixtures, bioaccumulation, multiple stressors).

- Inputs to the models (e.g., receiving water flow rate, receiving water concentration, effluent concentration, receiving water velocity) generally rely on a single measure of central tendency as derived from local or site-specific data. Variability in these inputs is not captured in the analysis.

- Output from the models generally provides average pollutant concentrations at specific dilution points of interest. Potential impacts associated with short-term, intermittent, or extreme storm events or exposures cannot be assessed.

- Because average pollutant concentrations at specific points of interest are the model output, the resultant data cannot be used to inform assessments of potential sediment contaminant issues based on pollutant loads.

- Some input parameters must be determined based on site-specific reconnaissance (e.g., channel geometry) and/or modeling (e.g., effluent flow rate) that may be difficult to obtain.

- Concentration values used as model input must conflate numerous potential influencing factors (e.g., basin area, rainfall, ADT, antecedent dry period, proximity to urban areas).

Multiple Linear Regression Models

Multiple linear regression (MLR) analyses performed by Kayhanian et al. (2003) provided the basis for the stormwater effects evaluation that was presented in the biological opinion for the SR 524 project (see the case study discussion, below). MLR is a statistical analysis procedure that examines the relation of a dependent variable (response variable) to specified independent variables (explanatory variables). From the procedure, mathematical models can be developed to estimate the value of the dependent variable based on a given value for each of the independent variables.

The specific goal of the analyses performed by Kayhanian et al. (2003) was to examine relationships between pollutant concentrations in highway runoff and ADT using data that were collected by the California Department of Transportation (CALTRANS) between 1997 and 2001. In these analyses, MLR models were developed to predict highway runoff pollutant concentrations (the response variable) as function of ADT as well as combinations of the following additional explanatory variables: total, storm event rainfall, maximum storm event rainfall intensity, antecedent dry period, seasonal cumulative precipitation, and drainage area. The specific application of these models in a biological opinion for a highway project is discussed in the following case study.

Case Study 1: SR 524 NMFS Biological Opinion

NMFS provides a detailed discussion of baseline metals concentrations based on 14 years of site-specific data. NMFS used the models developed by Kayhanian et al. (2003) to predict average pre- and postproject effluent concentrations for TSS, copper (total and dissolved), and zinc (total and dissolved) based on the representative model inputs for a fall and winter/spring rain event. To estimate postproject effluent concentrations following treatment, NMFS assumed 5 and 15 percent removal efficiencies for dissolved metals in wet vaults and wet ponds, respectively. For total metals, NMFS assumed 20 and 40 percent removal efficiencies for vaults and wet ponds, respectively. Finally, NMFS assumed a 60 percent removal efficiency for TSS in both vaults and wet ponds. The modeling results were then compared to baseline conditions, applicable water quality standards for Washington State, and ultimately to toxicity threshold information for Chinook salmon (see the *Toxicity Threshold Analysis* section below). Results from this analysis are summarized in Tables 6 and 7 below.

Table 6. Metal concentration calculations (estimates in bold)—fall rain event.

	Baseline [a]		Vault [b]		Pond [c]		Actual Swamp Conc.	Actual North Conc.	WQS Chron. Swamp	WQS Chron. North
Copper (µg/L)	**11.68d**	**22.74t**	**10.99d**	**20.68t**	**9.83d**	**15.5t**	2.65d	0.87d	6.81d	4.97d
Lead (µg/L)	**2.16d**	**12.85t**	**2.1d**	**15.91t**	**1.88d**	**9.55t**	0.081d	0.066d	0.87d	1.31d
Zinc (µg/L)	**53.73d**	**119.8t**	**49.37d**	**140.81t**	**44.2d**	**12.7t**	4.57d	1.41d	46.04d	62.97d
TSS (mg/L)	**85.89**		**41,03**		**41.03**		6d	9.04d		

d = dissolved fraction concentration; t = total metal concentration; WQS = water quality standards.
Actual creek concentrations are means. All concentration estimates (except WQS) are median.
Swamp and North creek size of storm: 0.31 inch; intensity: 0.17 in/hr; antecedent dry period: 14 days; cumulative water year precipitation: 1.18 in; road drainage area baseline: 1.38 acres; proposed drainage area: 3.78 acres; ADT baseline: 17,000; proposed ADT: 26,000.

[a] The MLR models predicted pollutant concentration in the runoff flowing into wet ponds or vaults. However, these concentrations may be reduced before runoff reached water bodies. Currently, road runoff flows into water bodies through vegetated ditches. NMFS assumed that no pollutant removal occurs in these ditches under the baseline conditions, which likely overstates baseline pollutant concentrations to some degree.

[b] Vault removal efficiencies: dissolved metals (5 percent), total metals (20 percent), TSS (60 percent).

[c] Pond removal efficiencies: dissolved metals (15 percent), total metals (40 percent), TSS (60 percent).

For the estimates above (for both fall and winter/spring storms), copper, lead, and zinc concentrations and TSS are slightly reduced from estimated baseline conditions. TSS

concentrations are reduced to a greater degree. The volume of runoff that would be routed to the drainage network (postproject) would increase by an estimated 173 percent.

Table 7. Metal concentration calculations (estimates in bold)—winter/spring rain event.

	Baseline [a]		Vault [b]		Pond [c]		Actual Swamp Conc.	Actual North Conc.	WQS Chron. Swamp	WQS Chron. North
Copper (µg/L)	**3.54d**	**7.32t**	**3.33d**	**20.68t**	**2.98d**	**4.99t**	0.92d	1.27d	6.81d	4.97d
Lead (µg/L)	**2.30d**	**3.77t**	**1.97d**	**15.91t**	**1.76d**	**2.8t**	0.054d	0.065d	0.87d	1.31d
Zinc (µg/L)	**18.86d**	**36.04t**	**15.5d**	**140.81t**	**15.5d**	**25.42t**	2.01d	1.84d	46.04d	62.97d
TSS (mg/L)	**23.78**		**11.36**		**11.36**		4.24d	7.3d		

All parameters are the same as in Table 6, except the following: Size of storm: 0.78 inch; intensity: 0.43 in/hr; antecedent dry period: 3 days; cumulative water year precipitation: 25 in.

[a] The MLR models predicted pollutant concentration in the runoff flowing into wet ponds or vaults. However, these concentrations may be reduced before runoff reaches water bodies. Currently, road runoff flows into water bodies through vegetated ditches. NMFS assumed that no pollutant removal occurs in these ditches under the baseline conditions, which likely overstates baseline pollutant concentrations to some degree.

[b] Vault removal efficiencies: dissolved metals (5 percent), total metals (20 percent), TSS (60 percent).

[c] Pond removal efficiencies: dissolved metals (15 percent), total metals (40 percent), TSS (60 percent).

The median metal concentrations estimated above could be exceeded in nearly half of the runoff events. Road runoff concentrations for the pollutants are lognormally distributed, indicating that for those concentrations that do exceed the median concentration, some will exceed the median by a large factor.

Again, the no net increase performance standard supplants this analysis for reaching a conclusion in the NMFS biological opinion. The standard allowed NMFS analysts to assume that postproject conditions would not exacerbate an already degraded baseline, whereas modeling results indicated that significant degradation would occur.

Strengths and Weaknesses

The strengths and weaknesses of the multiple linear regression models (Kayhanian et al. 2003) are summarized below.

Strength

- Variables influencing concentration such as storm size and intensity, cumulative water year precipitation, antecedent dry period, and ADT can be factored into the model.

Weaknesses

- Some specialized knowledge of statistical principles and techniques is necessary to perform the required multiple regression analyses.

- The model developed by Kayhanian et al. (2003) is based on data collected in California. Until calibration with Washington data is performed, the accuracy of this model for use in Washington projects is unknown.

- Output from the model generally provides average effluent pollutant concentrations. Potential impacts associated with short-term, intermittent, or extreme storm events or exposures cannot be assessed.

- The model cannot evaluate receiving water characteristics that can affect concentration (e.g., dilution), bioavailability (e.g., hardness, dissolved organic carbon), or other factors that may influence toxicity (e.g., background concentrations, mixtures, bioaccumulation, multiple stressors).

- Inputs to the model (e.g., storm size and intensity, cumulative water year precipitation, antecedent dry period, and ADT) generally rely on a single measure of central tendency as derived from local data. Variability in these inputs is not captured in the analysis.

- Because average effluent pollutant concentrations are the output from the model, the resultant data cannot be used to inform assessments of potential sediment contaminant issues based on pollutant loads.

Toxicity Threshold Analysis

The toxicity threshold analysis entails examination of existing literature and research results to determine lethal and sublethal levels of metals for various species of fish. Limited research was conducted on the listed species addressed in the biological opinions; as a result, the analyses include studies that address other species of salmonids as surrogate species. Documented thresholds are then compared to baseline water quality conditions, as well as projected effluent and receiving water concentrations resulting from proposed projects to determine the potential for effects on listed species.

Case Study 1: SR 524 USFWS Biological Opinion

For the water quality analysis in its SR 524 biological opinion, as it pertained to toxicity threshold for fish species, USFWS assumed the following:

- The drainage system and ponds would be designed per the Ecology Stormwater Manual (2001), WSDOT Hydraulics Manual (2001), the current WSDOT Highway Runoff Manual (WSDOT 2004d), and WSDOT instructional letter IL4020.02 (WSDOT 2002a).

- Stormwater discharge would meet state and federal requirements (Clean Water Act) and the Washington State water quality standards at the point of discharge.

The USFWS toxicity analysis essentially consisted of a literature review that relied on the 13 studies summarized in Appendix D of the SR 524 USFWS biological opinion (USFWS 2005) and Table 19 of the USFWS Brightwater biological opinion (USFWS 2004a).

Table 8 below displays the water quality standards and the minimum toxicity values that were developed in the Brightwater biological opinion (USFWS 2004a):

Table 8. The water quality standards and minimum toxicity values for subadult and adult bull trout for constituents common to roadway runoff.

Constituent	Washington State WQS (Φg/L) Acute/Chronic Dissolved	Minimum Toxicity Values (µg/L) Dissolved
Cadmium	3.7/1.0	0.786
Chromium	549/178	30
Copper	17.7/11.4	10
Lead	65/2.5	13
Zinc	114/105	5.6

WQS = water quality standards.
Source: USFWS (2005).

The chronic and acute water quality standards, with the exception of the chronic lead levels, are above levels documented to result in potentially adverse effects (avoidance, impaired growth, and reproduction) in salmonids.

Based on a number of variables (water temperature, pH, hardness, and dilution) affecting toxicity levels and uncertainties of potential exposure and duration times, USFWS was not able to determine the significance of stormwater effects on individual fish, so a general discussion describes potential adverse effects associated with long-term water quality degradation.

With regard to stormwater pollutants, a general discussion in the USFWS SR 524 biological opinion addresses numerous toxicants. More detailed information is provided for cadmium, chromium, copper, lead, and zinc, but this information is not ultimately useful in the effects analysis. A more rigorous environmental baseline discussion pertaining to these specific water quality parameters would be necessary to meaningfully incorporate minimum toxicity information into the effects analysis.

The USFWS SR 524 biological opinion generally addresses variability in the treatment effectiveness of various BMPs (ponds and wet vaults in Comings et al. [2000], WSDOT [2002b], and Ecology [2001]), but this information is not fully integrated into the analysis. Discharges anticipated for specific project-related BMPs are not addressed.

USFWS concludes that the proposed project would adversely affect bull trout but would not result in take. Adverse effects from the project would reduce the number and distribution of bull trout in the action area, as well as reduce general fitness of bull trout and their prey species through exposure to contaminants in stormwater runoff. However, affected foraging area associated with the project would be small in relation to the overall foraging habitat in the Lake Washington foraging, migration, and overwintering (FMO) habitat. Effects of the project would also not preclude use of this FMO habitat. The take conclusion relies heavily on the low use of the action area by bull trout, which in turn minimizes the potential for exposure of individual fish. These conclusions form the basis for the "not likely to jeopardize the continued existence" conclusion of the biological opinion. To address some if its concern regarding water quality effects, USFWS includes Conservation Recommendations 3 and 4 in the biological opinion to further minimize potential impacts on bull trout. Conservation Recommendation 3 encourages the inclusion of impact minimization measures to offset anticipated impacts on habitat functions. Conservation Recommendation 4 suggests that stormwater wet vaults be replaced with other techniques to treat stormwater based upon initial monitoring results that indicated wet vaults were ineffective in removing dissolved pollutants.

The project does not occur within proposed critical habitat for the species, and the action area for the project does not affect proposed critical habitat, so USFWS concluded the project would not destroy or adversely modify critical habitat.

The toxicity analysis in the USFWS SR 524 biological opinion attempts to explicitly connect the discussion of potential pollutants with specific impacts on fish and resulting take, but ultimately falls short of this goal for two reasons: (1) the environmental baseline provided in the biological opinion does not provide sufficient detail to juxtapose minimum threshold information against existing water quality conditions that might increase or decrease anticipated impacts, and (2) the inherent variability present in a natural system and associated with migratory species makes the timing and duration of exposure difficult to predict. As a result, conclusions were made at a much grosser level and relied on very general statements of potential impacts stemming from stormwater (i.e., impaired foraging behavior and opportunity, and potential sublethal impacts).

Case Study 2: SR 524 NMFS Biological Opinion

NMFS' detailed evaluation of baseline conditions in North and Swamp creeks indicates existing water quality degradation in both systems. The degraded baseline conditions in both creeks expose salmonids in these systems to sublethal and potentially lethal concentrations of pollutants and inhibits the abundance of prey, resulting in a low benthic index of biological integrity scores. The toxicity analysis related to projected concentrations associated with postproject conditions provides a discussion of general effects on fish from exposure to metals, followed by a more detailed discussion of potential effects on Chinook salmon from copper, cadmium, chromium, lead, zinc, and PAHs based on a detailed literature evaluation regarding lethal and sublethal effects. In addition, the analysis incorporates a comparison with Washington State water quality standards.

The NMFS analysis and modeling results (described previously) indicated anticipated pollutant levels and projected water quality standards that potentially exceeded the following thresholds:

- Neurotoxic (2.3–3.0 µg/L) and avoidance (0.1 µg/L [hardness of 90 mg/l]) thresholds for copper
- Sublethal thresholds for cadmium (0.78 µg/L)
- Lowest observable effect level for chromium (157 µg chromium^{+3}/L [hardness 25 mg/l])
- Reduced stamina and anemia associated with 13 µg/L and 14 µg/L lead concentrations
- Avoidance (5.6 µg/L) levels for zinc.

With the focus of the analysis on adult fish, impacts on other life-history stages are not explicitly examined. In addition, the analysis does not address mixtures of metals or effects related to multiple stressors in detail; however, it does provide a qualitative discussion of the additive, synergistic, and/or antagonistic responses generated by these factors. The conclusions in the biological opinion pertaining to potential effects ultimately rely on the no net increase performance commitment. Related to the issue of metal mixtures, the biological opinion states, "the no net increase commitment of the proposed action avoids effects that may be additive, synergistic, and/or antagonistic."

NMFS concludes that the proposed action will adversely affect the Puget Sound Evolutionarily Significant Unit (ESU) of Chinook salmon via diverse mechanisms that are anticipated to alter habitat in the short and long term. Short-term impacts include alterations of stream channels and riparian areas, as well as sediment discharge from earthwork near the channel. Alterations of water volumes are expected to occur on an indefinite basis. Because individuals of the Puget Sound Chinook ESU were considered likely to be present in the action area when some of the projected effects of the proposed action would occur (specifically, altered volumes of water delivered to the channel and increased delivery of water quality contaminants), NMFS concludes that take will occur. However, NMFS' final conclusion is that the project would not likely jeopardize the continued existence of Puget Sound Chinook salmon. As part of its conclusion, NMFS states, "The commitment of no net increase invalidates NMFS' initial conclusions that the originally proposed action would have appreciably reduced habitat functions and population viability of Sammamish River Chinook."

The biological opinion states, "NMFS dos not understand how the no net increase commitment will be achieved." NMFS attempts to address this uncertainty with Reasonable and Prudent Measures #1 and Terms and Conditions #1, both of which address minimization of water quality degradation. Reasonable and prudent measure #1 states that "The FHWA shall minimize adverse effects from water quality degradation to Swamp and North Creeks." Terms and Conditions #1 requires quantitative evidence that the proposed action will not increase average

annual loading. NMFS' reliance on the no net increase performance commitment is a central tenet of its analysis of potential project impacts and conclusions related to effects on listed species.

In summary, the conclusions provided in this biological opinion are not ultimately substantiated by the detailed stormwater and toxicity analysis provided in the opinion. Instead, they rely upon the no net increase standard.

Critical habitat is not addressed in the biological opinion.

Case Study 3: SR 167 Extension USFWS Biological Opinion and SR 167 FHWA–WSDOT stormwater quality analysis

The USFWS biological opinion and the WSDOT–FHWA analysis is thorough in its examination of specific toxicity thresholds for bull trout in addition to specific pathways by which pollutants could affect bull trout. The analysis explicitly examines pollutant concentrations and annual loading associated with project-related runoff as well as how loads and concentrations could affect bull trout. In addition, the examination of potential for exposure (timing, duration, frequency) is more rigorous in this analysis than the other consultation documents examined for this paper.

The USFWS analysis examines proposed stormwater effluent concentrations in relation to the following thresholds:

- Neurotoxic (2.3–3.0 µg/L) and avoidance (0.1 µg/L [hardness of 90 mg/l]) thresholds for copper
- Sublethal thresholds for cadmium (0.78 µg/L)
- Chromium toxicity level bounded by a 30 µg/L no observed adverse effect level and an unacceptable toxic concentration level of 157 µg chromium^{+3}/L [hardness 25 mg/l])
- Avoidance (5.6 µg/L over background levels between 3.0 µg/L and 13.0 µg/L) levels for zinc.

Under the proposed action, stormwater effluent concentrations of 7.8 µg/L dissolved copper would be 3.4 times higher than the lower limit of the neurotoxic effects threshold. These levels would be exceeded within the mixing zones defined above and could impact fish with exposure time as short as 10 minutes. WSDOT modeling in the Blair and Hylebos waterways indicated concentrations below the 3.0 µg/L upper threshold but above the 2.3 µg/L lower neurotoxic threshold. Under the proposed action, stormwater effluent concentrations of 44.8 µg/L dissolved zinc would be 8 times higher than the behavioral avoidance threshold for rainbow trout. In the absence of research on bull trout, rainbow trout were used as a surrogate for bull trout for the USFWS and FHWA_WSDOT analysis. These levels would be exceeded within the mixing

zones defined above. WSDOT dissolved zinc modeling in the Blair and Hylebos waterways indicated concentrations that could potentially exceed this same threshold. The cadmium and chromium analysis is limited by the lack of baseline information and uncertainty regarding the project's contribution of these pollutants when stormwater is discharged post-treatment.

The analysis does not address mixtures of metals or effects related to multiple stressors in detail; however, a qualitative discussion is provided. The qualitative analysis examines the potential for different life-history stages to be affected differently and also examines the spatial and temporal extent of potential exposure, ultimately concluding that the project will adversely affect all adult and subadult bull trout and their critical habitat in the lower Puyallup River core area. Long-term impacts associated with stormwater would continue in perpetuity but would be sublethal, affecting the productivity of all fish in the lower Puyallup River core area.

USFWS also concluded that take will occur in the form of harm and harassment. Individual adult and subadult bull trout exposed to the effluent plume (several times over the course of their individual lives) at each stormwater outfall in the Puyallup River and at the mouth of Oxbow Lake Ditch will be when concentrations exceed the thresholds listed above. Adult and subadult bull trout would experience harassment through significant disruption of normal foraging and migrating behavior resulting from the discharge of stormwater effluent in the lower Puyallup River (in the form of avoidance of mixing zones for a period of days for migrating individuals, or in perpetuity for individuals overwintering or foraging in the lower river).

USFWS ultimately concluded that the project is "not likely to jeopardize the continued existence of Coastal-Puget Sound bull trout." Specific to long-term impacts (i.e., stormwater), USFWS concluded that the effects would not measurably affect productivity in the Puyallup River core area in its entirety, which consists of five local populations of bull trout. With regard to the recovery of the distinct population segment (DPS) as a whole, the Puyallup River core area is one of 14 other core areas defined for the Puget Sound recovery unit in the draft recovery plan (USFWS 2004b). With regard to critical habitat, bull trout would not be prohibited for accessing critical habitat by the project; in addition, although several primary constituent elements (PCEs) would be affected by the project, none would be altered to the extent that the PCE's conservation role for bull trout was compromised. As a result, USFWS concluded that the project would not destroy or adversely modify critical habitat for bull trout. Similar to the NMFS SR 524 biological opinion, USFWS includes reasonable and prudent measures (BT II, BT III) and their implementing Terms and Conditions to ensure that stormwater-related impacts are minimized. Reasonable and prudent measure BT II states that harassment of bull trout, from the addition of new impervious surface in the lower-Puyallup subbasin, will be minimized. Reasonable and prudent measure BT III states that harm and harassment of bull trout from impacts on their prey base from stormwater-related pollutants will be minimized.

Strengths and Weaknesses

The strengths and weaknesses of toxicity threshold analysis are summarized below.

Strengths

- The approach attempts to link stormwater modeling and environmental baseline results to biologically meaningful endpoints.

- The approach attempts to quantify impact analyses that were historically qualitative in nature.

Weaknesses

- The approach relies on research conducted largely in laboratory settings. Results from this research may or may not be transferable to the natural environment where a complex interplay of variables would affect toxicity.

- The approach frequently relies on information generated from studies involving surrogate species rather than the species potentially affected by project impacts.

- Sublethal impacts are difficult to measure at the individual, core population, or recovery population scale. As a result, most documentation is necessarily qualitative in nature and lacks specificity.

Conclusion

In the SR 524 consultation, WSDOT and FHWA used the FHWA method and subsequently used Method 1:WSDOT Data–FHWA method to complete the stormwater quality analysis. In this same consultation USFWS relied upon a toxicity analysis based upon assumptions related to project-generated water quality. However, because of uncertain exposure and duration of exposure, USFWS was unable to determine the significance of stormwater impacts on individual fish. As a result, the USFWS documentation presented a discussion of general effects associated with long-term water quality degradation. The consultation with USFWS extended over a 15-month period. NMFS used several methods in its stormwater analysis including: multiple linear regression modeling, FHWA method, Simple method, and finally a performance commitment in addition to providing more detailed baseline information and timing information. The conclusions of the NMFS biological opinion ultimately rely upon the assumed performance standard of no net increase of for copper, zinc, and TSS. The consultation with NMFS extended over a 20-month period.

In the I-405 consultation, WSDOT and FHWA ultimately used the WSDOT Data–FHWA method to compare pre- and post-project pollutant loads. USFWS downgraded this consultation to an informal consultation, and its concurrence letter relied upon the information provided by WSDOT in December 2005. The consultation with USFWS extended 3 months. NMFS also downgraded this consultation to an informal consultation; however, the NMFS concurrence letter relied upon information provided in July 2006 by WSDOT in an addendum to the BA. In addition, NMFS' conclusions relied upon a performance standard of no net increase for TSS, dissolved and total copper and zinc, and hydrocarbons. The consultation with NMFS extended 9 months.

For the SR 167 consultation, WSDOT, FHWA, and USFWS worked collaboratively to complete the stormwater analysis for the project. In this consultation, the agencies used the FHWA method (adapted in the WSDOT BA Writers Guidance) to predict annual pollutant loading. The agencies used the Level Two Stormwater Analysis, as described in the WSDOT BA Writers Guidance, to predict concentration of project-related pollutants discharged to freshwater. To estimate concentrations that would be added to the estuarine environment, the agencies completed dilution modeling. Consultation with USFWS extended nearly 4 years. The consultation completed with NMFS is not included in this white paper.

In each consultation examined for this white paper, generally no single analytical method was employed to evaluate potential impacts associated with stormwater. Multiple methods were used in order to generate a more complete picture of the array of potential stormwater effects. Table 9 below summarizes the analytical method types used for stormwater quality impact analyses in the documents that were reviewed for this white paper.

Table 9. Methods used to assess stormwater impacts.

	Empirical Runoff Models	Weighted Concentration Models	Dilution Models	Multiple Linear Regression Models	Toxicity Threshold Analysis
SR 524- BA	x				
SR 524 USFWS					x
SR 524 NMFS [a]	x			x	x
I-405- BA	x				
I-405- USWFS	x				
I-405- NMFS	x				
SR 167[b]	x	x	x		x

[a] Assumed a "no net increase" performance standard.
[b] Includes analysis completed by WSDOT, FHWA, and USFWS. Does not include NMFS analysis.

None of the models used present a panacea for evaluating the range of potential effects associated with stormwater. Each of the models have marked strengths and weaknesses that are summarized below. In combination, the use of multiple models potentially offsets the inherent weaknesses of some of the model types and provides a more thorough analysis of potential stormwater impacts and potential effects to species and baseline conditions.

The strengths of empirical runoff models include the ability to effectively calculate and quantitatively represent relative differences in loadings between pre- and post-project conditions. The data needed for empirical models is readily available, and can use local data as input. In addition, the WSDOT BA Pollutant Load/Concentration Calculator can be used to complete these calculations. Empirical models also provide annual pollutant load outputs, so the resultant data can be used to inform potential sediment contaminant issues. Weaknesses of these models include the inability to assess toxicity based on water quality standards or other biologically significant endpoints and variability in potential concentrations, bioavailability or toxicity resulting form different receiving water characteristics. In addition, models are overly simplistic in that they address a limited number of variables, and inputs to the models generally rely on a single measure of central tendency. Output for empirical models provides annual loading estimates and does not account for impacts associated with short-term, intermittent, or extreme storm events. In addition, some of the empirical models used rely on national data sets rather than local data.

The strengths of weighted concentration models include the ability to calculate and represent relative differences in concentrations between pre- and post-project conditions. Local data is generally used for inputs and data needed is readily available. In addition, the WSDOT BA Pollutant Load/Concentration Calculator can be used to complete these calculations. Finally, the model can estimate effluent concentrations which can be meaningfully used in toxicity assessments of the receiving water as compared to water quality standards or biologically significant endpoints for pollutants in the water column. Weaknesses of the model include the inability of the model to evaluate receiving water characteristics that can influence concentration, bioavailability and toxicity and their reliance upon inputs that reflect a single measure of central

tendency without consideration of input variability of these inputs or other variables that influence concentration. Output for empirical models provides average effluent pollutant concentrations so impacts associated with short-term, intermittent, or extreme storm events cannot be assessed and resultant data cannot be used to inform assessments of potential sediment contamination.

The strengths of dilution models include the ability to use the models to estimate effluent concentrations in the receiving water that in turn can inform toxicity assessments. With the RIVPLPUM5 spreadsheet, modeling is relatively straightforward and inputs are based upon local data. Weaknesses of dilution modeling include an inability to evaluate receiving water characteristics that can affect bioavailability or toxicity. Inputs rely on a measure of central tendency and do not accurately reflect the potential for variability in these inputs. Outputs of the models (average pollutant concentrations at specific dilution points of interest) do not capture potential impacts associated with short-term, intermittent or extreme storm events or exposures. Outputs cannot be used to inform assessments of potential sediment contaminant issues. Some input parameters must be determined based on site- specific reconnaissance and or modeling that may be difficult to obtain. Concentration values used as model inputs conflate numerous influencing factors (basin area, rainfall, ADT, antecedent dry period, proximity to urban areas).

Multiple linear regression models account for multiple variables influencing concentration (storm size and intensity, cumulative water year precipitation, antecedent dry period and ADT). Model weaknesses include the requirement of some specialized knowledge of statistical principles and techniques to perform the analyses. Model output provides average effluent pollutant concentrations and does not account for impacts associated with short-term, intermittent or extreme storm events or exposures. The model cannot evaluate receiving water characteristics that can affect concentration or toxicity, nor can the outputs be used to inform assessments of potential sediment contamination. Inputs to the model rely on a measure of central tendency derived from local data that cannot capture the potential for variability in the model inputs. In addition, the Kayhanian model has not yet been calibrated with Washington data.

Toxicity threshold analysis attempts to quantitatively link stormwater modeling and environmental baseline results to biologically meaningful endpoints. However, the approach relies on research conducted largely in laboratory settings and studies involving surrogate species. In addition, sublethal impacts are difficult to measure at the individual, core population, or recovery population scale. As a result, sublethal documentation is generally qualitative.

References

Baldwin, D.H., J.F. Sandahl, J.S. Labenia, and N.L. Sholz. 2003. Sublethal effects of copper on coho salmon: impacts on nonoverlapping receptor pathways in the peripheral olfactory nervous system. Environmental Toxicology and Chemistry 22 (10):2266-74.

Beyerlein, D. 1999. Why standard stormwater mitigation doesn't work proceedings: Watershed Management to Protect Declining species. Pages 477-479 *in* American Water Resources Association, Annual Water Resources Conference, Seattle, Washington.

City of Bellevue. 2000. GIS Land use and development coverage. City of Bellevue Planning and Community Development Department.

Comings, K.J., D.B. Booth, and R.R. Horner. 2000. Stormwater pollutant removal by two wet ponds in Bellevue, Washington. Center for Urban Water Resources Management, University of Washington. Seattle, Washington. 24 p.

CUWRM. 1999. Center for Urban Water Resource Management. <http://140.142.16.146/cuwrm>. Fall 1999.

Ecology. 2000. Spreadsheets for Water Quality-Based NPDES Permit Calculations. Washington State Department of Ecology. Updated March 2000, by Greg Pelletier. Available at Washington State Department of Ecology website at: <http://www.ecy.wa.gov/programs/eap/mixzone/app6-1/pwspread.html>.

Ecology. 2001. Stormwater Management Manual for Western Washington. Volumes 1-5. Publication number 99-11. Available at Washington State Department of Ecology website at: <http://www.ecy.wa.gov/biblio/9911.html>.

Ecology. 2004. Washington State Department of Ecology 2002/2004 303(d) list. Available at Washington State Department of Ecology website at: <http:www.ecy.wa.gov/programs/wq/303d>.

Ecology. 2007. 303(d) listings for state water resources. Available at Washington State Department of Ecology website at: <http://www.ecy.wa.gov/Programs/wq/303d/index.html>. Accessed on August 8, 2007.

Ecology. Undated. Guidance for Conducting Mixing Zone Analyses. Available at Washington State Department of Ecology website at: <http://www.ecy.wa.gov/programs/eap/mixzone/mixzone.doc>. 47 pp.

FHWA. 1990. Pollutant Loadings and Impacts from Highway Stormwater Runoff. Volume 1: Design Procedure. Publication No. FHWA-RD-88-006. Federal Highway Administration. April 1990.

Fischer, Hugo B., E. John List, Robert C.Y. Koh, Jörg Imberger, and Norman H. Brooks. 1979. *Mixing in Inland and Coastal Waters*. Academic Press, San Diego, California.

Hansen, J.A., P.G. Welsh, J. Lipton, and M.J. Suedkamp. 2002. Relative sensitivity of bull trout (*Salvelinus confluentus*) and rainbow trout (*Oncorhynchus mykiss*) to acute exposures of cadmium and zinc. Environmental Toxicology and Chemistry 21(1):67-75.

Kayhanian, M. Sing, A. Suverkropp, S. Borroum, and M.K. Stestrom. 2003. Impact of annual average daily traffic on highway runoff pollutant concentrations. Journal of Environmental Engineering. Vol. No. 11.

KCDNR. 2003. Kelsey Creek Subarea. Water Resource Inventory Area (WRIA) 8 Lake Washington/Cedar/Sammamish Watershed. King County Department of Natural Resources. Available on agency website at: <http://dnr.metrokc.gov/Wrias/8/subarea_kelsey_creek.htm>. Accessed on July 15, 2003.

Ludwa, K. 2006. Technical Memorandum to Rae Bennett (WSDOT) regarding SR 167 Extension Pollutant Dilution Modeling.

May, C.W. 1996. Assessment of cumulative effects of urbanization on small streams of the Puget Sound lowland ecoregion: Implications for salmonid resource management. Ph.D. thesis, Department of Engineering, University of Washington.

Niyogi, S., P. Couture, G. Pyle, D.G. McDonald, and C.M. Wood. 2004. Acute cadmium biotic ligand model characteristics of laboratory-reared and wild yellow perch (*Perca flavescens*) relative to rainbow trout (*Oncorhynchus mykiss)*. Canadian Journal of Fish and Aquatic Sciences 61:942-953.

NMFS. 2005. Endangered Species Act Section 7 Consultation Biological Opinion. State Route 524 Widening Project in Snohomish County. National Marine Fisheries Service, Lacey, Washington. July 11, 2005.

NMFS. 2006. Endangered Species Act Section 7 Informal Consultation and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation: Interstate 405 Congestion Relief and Bus Rapid Transit Projects—Bellevue Nickel Improvement, King County, Washington. HUC, 171100120302. Tracking No. 2005/06144.

Schueler, T.R. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Council of Governments, Washington, D.C.

Scott, J., C.R. Steward., and Q.J. Stober. 1982. Impacts of urban run-off on fish populations in Kelsey Creek, Washington.

Snohomish County. 2004. Appendix F from SR 524 Environmental Impact Statement. Provided by Dave Campbell at Snohomish County to Brian Bigler at WSDOT for the SR 524 stormwater analysis via e-mail on February 11, 2004.

U.S. EPA. 1980. Ambient Water Quality Criteria for Copper. Publication 440/5-80-036. Criteria and Standards Division, Office of Water Regulations and Standards, U.S. Environmental Protection Agency, Washington, D.C.

USFWS. 2004a. Biological Opinion on the Brightwater Treatment Systems in King, Snohomish, Pierce, Douglas, and Yakima Counties, Washington. Reference No. 1-3-04-F-0496. U.S. Fish and Wildlife Service Office, Lacey, Washington.

USFWS. 2004b. Draft Recovery Plan for the Coastal-Puget Sound Distinct Population Segment of Bull Trout (*Salvelinus confluentus*). Volumes I and II: Puget Sound Management Unit. U.S. Fish and Wildlife Service, Portland, Oregon. 389 + xvii pp.

USFWS. 2005. Endangered Species Act Section 7 Consultation Biological Opinion. State Route 524 Widening Project in Snohomish County. U.S. Fish and Wildlife Service, Lacey, Washington. February 15, 2005.

USFWS. 2006. Concurrence letter regarding Interstate 405 Bellevue Nickel and Implementation Projects in King County, Washington. January 19, 2006.

USFWS. 2007. Endangered Species Act Section 7 Consultation Biological Opinion. State Route 167 Extension Project. U.S. Fish and Wildlife Service, Lacey, Washington. May 31, 2007.

WSDOT. 1997a. Highway Runoff Manual. Washington State Department of Transportation, Olympia, Washington.

WSDOT. 1997b. WSDOT Hydraulics Manual M23-03. Washington State Department of Transportation, Olympia, Washington. Current version is available on agency website at: <http://www.wsdot.wa.gov/publications/manuals/fulltext/M23-03/HydraulicsManual.pdf>.

WSDOT. 2001. Hydraulics Manual. Washington State Department of Transportation, Olympia, Washington.

WSDOT. 2002a. Endangered Species Act Stormwater Guidance. Instructional Letter No. IL4020.02. Washington State Department of Transportation, Olympia, Washington.

WSDOT. 2002b. 2002 NPDES Progress Report Cedar-Green, Island-Snohomish, and South Puget Sound Water Quality Management Areas. Washington State Department of Transportation, Olympia, Washington. September 2004. Available at agency website: http://www.wsdot.wa.gov/NR/rdonlyres/B926F625-1900-4C1D-B2A7-C7107C60FFF0/0/2002NPDESProgressReport.pdf.

WSDOT. 2003. Environmental Procedures Manual. Technical Manual. Washington State Department of Transportation, Olympia, Washington.

WSDOT. 2004a. Endangered Species Act Section 7 Consultation Biological Assessment for State Route 524 Widening Project in Snohomish County. Prepared by Jones & Stokes for Washington State Department of Transportation, Olympia, Washington. March 2004.

WSDOT. 2004b. Environmental Procedures Manual. Technical Manual. Washington State Department of Transportation, Olympia, Washington.

WSDOT. 2004c. 2004 NPDES Progress Report Cedar-Green, Island-Snohomish, and South Puget Sound Water Quality Management Areas. Washington State Department of Transportation, Olympia, Washington. September 2004. Available at agency website: <http://www.wsdot.wa.gov/NR/rdonlyres/8ACA3D6C-9EEE-4A9C-A8F0-86DE75DD987A/0/2004NPDESProgressRpt.pdf>.

WSDOT. 2004d. Highway Runoff Manual. Washington State Department of Transportation, Olympia, Washington. Available at agency website: <http://www.wsdot.wa.gov/Environment/WaterQuality/Runoff/HighwayRunoffManual.htm>.

WSDOT. 2005a. Endangered Species Act Section 7 Consultation Biological Assessment for State Route I-405, I-90 to SR-520 – Bellevue Nickel Improvement Project. Prepared by Urban Corridors, Washington State Department of Transportation, Seattle, Washington. November 2005.

WSDOT. 2005b. Approach to compare the pre versus prost development pollutant discharges: I-405 Bellevue Nickel Improvement Project: I-90 vicinity to SE 8th Street interchange. Memorandum sent to NMFS and USFWS from WSDOT dated December 6, 2005.

WSDOT. 2005c. Analysis to compare pre versus post development pollutant discharges: I-405 Bellevue Nickel Improvement Project: I-90 vicinity to SE 8th Street Interchange. Memorandum sent to NMFS and USFWS from WSDOT dated December 28, 2005.

WSDOT. 2005d. Environmental Procedures Manual. Washington State Department of Transportation, Olympia, Washington. Previously available at agency website: <http://www.wsdot.wa/gov/fasc/EngineeringPublications/Manuals/EPM/431.pdf>.

WSDOT. 2005e. 2005 NPDES Progress Report Cedar-Green, Island-Snohomish, and South Puget Sound Water Quality Management Areas. Washington State Department of Transportation, Olympia, Washington. September 2005. Available at agency website: <http://www.wsdot.wa.gov/NR/rdonlyres/A294F2F6-C2F9-465F-89EF-27DF1185A932/0/2005NPDES.pdf>.

WSDOT. 2006a. Project Addendum to I-405 Bellevue Nickel Improvement Project Biological Assessment; request to conference on Puget Sound steelhead. Letter to NMFS from WSDOT dated July 10, 2006.

WSDOT. 2006b. BA Writers Guidance for Preparing the Stormwater Section of Biological Assessments. Washington State Department of Transportation, Olympia, Washington. November 2006.

WSDOT. 2006c. 2006 Stormwater Report. Washington State Department of Transportation, Olympia, Washington. September 2006. Available at agency website: <http://www.wsdot.wa.gov/NR/rdonlyres/09450DED-E0BC-4568-BFF6-341BD96434C9/0/2006StormwaterReport.pdf>.

WSDOT. 2006d. Highway Runoff Manual. Washington State Department of Transportation, Olympia, Washington. Available at agency website: <http://www.wsdot.wa.gov/Environment/WaterQuality/Runoff/HighwayRunoffManual.htm>.

WSDOT. 2007a. Supplemental information provided to USFWS for SR 167 consultation. Includes e-mails, reports, modeling data, etc. Provided to Herrera Environmental Consultants, Inc., by Washington State Department of Transportation on March 7, 2007.

WSDOT. 2007b. Environmental Procedures Manual. Washington State Department of Transportation, Olympia, Washington. Available at agency website: <http://www.wsdot.wa.gov/fasc/EngineeringPublications/Manuals/EPM/EPM.htm>.

APPENDIX A

ESA Stormwater Design Checklist

Endangered Species Act Stormwater Design Checklist

Project Name: _____

Project Location: _____

General Project Information

1. Will work occur outside existing pavement or gravel shoulders? ☐ Yes ☐ No

   If *yes*, describe the nature and extent of the work:
   _____
   _____
   _____
   _____

Existing Impervious Surface and Stormwater Facilities (Preproject)

2. Is there any existing impervious surface within the project area? ☐ Yes ☐ No

   If *yes*, for each threshold discharge area (TDA), identify the amount of existing impervious surface within the project limits:
   _____ (square feet, acres)

   If *no*, go to #11.

3. For each TDA, identify the total area of existing impervious surface currently receiving runoff treatment:
   _____ (square feet, acres)

4. Will any existing impervious surface receive runoff treatment (i.e., retrofit)? ☐ Yes ☐ No

   If *yes*, for each TDA, identify how much of the existing impervious surface will be retrofitted for runoff treatment _____ (square feet, acres), and the level(s) of treatment:

   ☐ *Basic* ☐ *Enhanced* ☐ *Oil Control* ☐ *Phosphorous Control*

5. For each TDA, identify the total area of existing impervious surface currently receiving flow control:
   _____ (square feet, acres)

6. Will any existing impervious surface receive flow control (i.e., retrofit)? ☐ Yes ☐ No

   If *yes*, how much of the existing impervious surface in each TDA will be retrofitted for flow control? _____ (square feet, acres)

7. Is any of the runoff from the existing impervious surface infiltrated? ☐ Yes ☐ No

   If *yes*, what percentage of the runoff from the existing impervious surface in each TDA is infiltrated? _____%.

   How much of the runoff volume does this represent? _____ (acre-feet)

8. Identify the type(s), location(s), footprint(s), and receiving area/water body for each runoff treatment and flow control BMP. If available, provide a map depicting TDA boundaries and BMP locations.

   _____
   _____
   _____
   _____
   _____

9. Describe the nature of the stormwater conveyance (drainage) system (e.g., pipe, culvert, channel, ditch, swale, sheet flow). If available, provide a map of the system depicting TDA boundaries.

   _____
   _____
   _____
   _____
   _____

10. Is off-site stormwater being treated/controlled by WSDOT stormwater facilities prior to initiation of the project? ☐ Yes ☐ No

    If *yes*, will this stormwater continue to be treated/controlled to the same level? ☐ Yes ☐ No

    If off-site stormwater will not continue to be treated/controlled to the same level, explain why not:

    _____
    _____
    _____
    _____
    _____

New Impervious Surface and Stormwater Facilities (Proposed Project)

11. Will the project create a net gain in impervious surface? ☐ Yes ☐ No

    If *yes*, for each TDA, identify how much net-new impervious surface the project will create:
    _____ (square feet, acres)

    If *no*, will the project result in a net decrease in impervious surface? ☐ Yes ☐ No

    If *yes*, for each TDA, identify how much net loss will result:
    _____ (square feet, acres)

12. Will the project require runoff treatment? ☐ Yes ☐ No

    If *yes*, for each TDA, identify the total area of new impervious surface treated:
    _____ (square feet, acres) and identify the level(s) of treatment required:

    ☐ *Basic* ☐ *Enhanced* ☐ *Oil Control* ☐ *Phosphorous Control*

13. Will the project require flow control? ☐ Yes ☐ No

    If *yes*, for each TDA, identify the total area of new impervious surface to receive flow control:
    _____ (square feet, acres)

14. Will any of the runoff from the new impervious surface be infiltrated? ☐ Yes ☐ No

    If *yes*, what percentage of the runoff from the new impervious surface in each TDA will be infiltrated?
    _____%

    How much of the runoff volume does this represent? _____ (acre-feet)

15. Are any of the project's TDAs exempt from the flow control requirement? ☐ Yes ☐ No

    If *yes*, identify the exempt TDA(s):
    _____
    _____
    _____
    _____
    _____

    If *no*, and the project is petitioning for an exemption, has a hydrologic analysis supporting the exemption been approved by Ecology? ☐ Yes ☐ No

If *yes*, provide a summary of the analysis as an attachment to this checklist.

If *no*, a hydrologic analysis justifying the exemption must be submitted to Ecology for approval, or flow control must be provided.

16. If applicable, identify the type(s), location(s), and footprint(s) for each runoff treatment and flow control BMP. If available, provide a map of depicting TDA boundaries and BMP locations.

_____
_____
_____
_____
_____

17. Describe the nature of the stormwater conveyance (drainage) system (e.g., pipe, culvert, channel, ditch, swale, sheet flow). If available, provide a map of the system depicting TDA boundaries.

_____
_____
_____
_____
_____

18. Will the project require construction of a new stormwater outfall structure or a new point of discharge to any water body? ☐ Yes ☐ No

If *yes*, identify the receiving water body, and describe areas of permanent and temporary clearing or grading, types of vegetation to be removed, amount of riprap, diameter of outfall pipe(s), and all maintenance/access roads to be constructed. If available, provide a map of outfall locations.

_____
_____
_____
_____
_____

19. If the project is not infiltrating all of the runoff from the new impervious surface and is unable to provide the required runoff treatment or flow control for the entire new impervious surface, explain why not. (Documentation should include a completed copy of the *Engineering and Economic Feasibility (EEF) Evaluation Checklist*.)

_____
_____
_____
_____
_____

20. What stormwater management design standards were applied?

- ☐ WSDOT *Highway Runoff Manual*, version _____
  (1995, 2004, 2006, etc.)

- ☐ Ecology's *Stormwater Management Manual*(s), version _____
  (2001, 2005 Western Washington; 2003, 2004 Eastern Washington, etc.)

- ☐ Other: _____

- ☐ Not Applicable

Prepared by_____ Phone_____ Date_____

Project Engineer_____ Office Location_____

APPENDIX B

Summary of Stormwater Information in Consultation Documents

Appendix B–Summary of Stormwater Information in Consultation Documents

The stormwater related information and analysis contained in each of the biological assessments and biological opinions examined for this white paper is provided below. A complete synopsis of all stormwater related information has been provided because the consultation process requires an examination of the proposed project elements, the environmental baseline conditions and performance standards or assumptions, as well as cumulative effects in order to fully assess anticipated project impacts and effects to listed species.

SR 524 USFWS Biological Opinion

The stormwater analysis for this project generated considerable discourse between FHWA-WSDOT and the Services. The stormwater analysis in the USFWS biological opinion for SR 524 consists of the following elements and assumptions:

- Assumption that stormwater discharge will meet the Washington State water quality standards at the point of discharge
- An *Environmental Baseline* section that consists of the following elements and assumptions:
  - Quantification of existing (12.47 acres) impervious surface area
  - Quantification of existing (16,000 vehicles per day)
  - Description of land cover and development patterns within the action area defined for the project (4,667 acres total, of which 2,134 acres are already developed, 455 are undevelopable, and 2,070 acres are buildable).
  - Description of poor water quality conditions in North Creek (303[d] list for Dissolved Oxygen and Temperature and high metals levels [lead, copper, and zinc] according to Snohomish County data) and Swamp Creek (303[d] list for Fecal coliform and high metals levels [lead, and copper] according to Snohomish County data).
    - According to Snohomish County data, fungicides and herbicides were detected, albeit not above state water quality standards, in both creeks.
- An *Effects of the Proposed Action* section that consists of the following elements and assumptions:

- Comparison of existing (12.47 acres) vs. new (25.91 acres) impervious surface area

- Characterization of proposed treatment and flow control measures (installation of 6 stormwater ponds and 4 enclosed vaults for detention of stormwater per the 2001 DOE Stormwater Manual, the WSDOT Hydraulic Manual [2001], the WSDOT Highway Runoff Manual, and the WSDOT instructional letter IL4020.02).

- Discussion of impacts to forest cover (removal of 25 acres of forested, pasture and grassland), wetlands (8.83 acres of wetlands impacts, 7.12 acres of which relate to wetland buffers) and surface runoff from new impervious areas resulting in disruptions to hydrologic regime.

- Quantification of how much water will be intercepted and conveyed (3,827,969 cubic feet [ft^3]) on new impervious surface areas based upon assumption of average annual precipitation (40.7 inches) of rain per year (Beyerlein 1999).

- Comparison of annual runoff volumes associated with forest and impervious land use to determine anticipated increase in surface runoff (3,194,845 ft^3), decrease in interflow by 789, 910 ft^3, ground water recharge by 1,259,077 ft^3, and evapotranspiration by 1,765, 526 ft^3 in the action area.

- Assumption that indirect effects associated with accommodating planned growth in action area (2000+ acres) will result in additional reduction in forest cover, wetland fill, and increased surface runoff and in turn, additional hydrologic disruptions.

- Calculation of the anticipated annual runoff from future development in action area by comparing annual runoff volumes associated with forest, lawn and suburban land uses. Planned development will increase annual surface runoff (67,753,583 ft^3) and interflow by 6,026,770 ft^3, and decrease ground water recharge by 38,390,417 ft^3, and evapotranspiration by 35,389,936 ft^3 in the action area.

- General discussion of potential for increased peak flow frequency, volume and duration, even with proposed detention facilities, and related effects to stream channel and aquatic habitat conditions resulting from new impervious area.

- General discussion regarding significance of channel morphology impacts, depending upon the relative baseline conditions of existing streams (i.e. heavily impacted streams will experience insignificant impacts, functioning streams will experience measurable impacts).

- General discussion on channel destabilization resulting from altered flow regimes and related impacts to channel substrates and their suitability for prey species spawning.

- General discussion of incremental declines in bull trout numbers resulting from gradual changes to aquatic biodiversity and biological assemblages resulting from changes in base flows.

- General discussion of probability of bull trout exposure to stormwater contaminants as a result of the timing of storm events (fall, winter, spring) coinciding with cooler water temperatures, when bull trout could be present.

- General discussion impacts associated with discharge from outfalls. Six outfalls discharge stormwater to wetlands and contaminants would not extend to North and Swamp creeks. As a result, impacts from these outfalls are assumed to be insignificant. For the remaining 4 outfalls, discharging directly to tributaries of North and Swamp creeks, at the point of discharge contaminant concentrations are assumed to be measurable. Outfall locations associated with future development are unknown, impacts associated with these outfalls we assumed to be measurable in the analysis.

- Brief discussion of removal efficiency for various BMPs.

- WSDOT pollutant loading analysis data provided in the biological assessment were too limited to be used in the USFWS analysis to assess potential impacts of stormwater pollutants on bull trout. The following information was included in the USFWS analysis:

    - General discussion of lethal and sublethal effects of pollutants or stormwater constituents.

    - Assumption that facilities adhere to federal and state regulations

- Comparison of state water quality standards with minimum toxicity levels established in Brightwater BO for copper, lead, zinc, chromium-total, and cadmium.

- Brief discussion of factors affecting the potential toxicity of many constituents (temperature, hardness, duration of exposure, etc.).

- Conclusion that USFWS unable to determine significance of the effects of stormwater contaminants on individual bull trout due to number of influential variables and uncertainties. Assume long-term additive decrease in water quality will contribute to long-term declines in bull trout numbers and distribution resulting from impaired foraging behavior and opportunity.

SR 524 NMFS Biological Opinion

The stormwater analysis for this project generated considerable discourse between FHWA-WSDOT and the Services. Ultimately, FHWA-WSDOT and NMFS agreed to a performance standard based approach. The stormwater analysis contained in the NMFS biological opinion for SR 524 consists of the following elements and assumptions:

- Commitment to performance standard that stormwater discharge will result in no net increase performance standard for total suspended solids, and the total and dissolved forms of copper, lead, and zinc for both Swamp and North Creeks.

- Conclusion of the biological opinion relies on achieving the no net increase performance standard, which in turn relies on demonstrating the effectiveness of all BMP types for all phases of the project.

- Assumption that proposed stormwater systems were designed to meet Snohomish County Engineering Design and Development Standards that require effective impervious surfaces (those where runoff flows directly to a stream) not be placed within 300 feet of waters bearing ESA-listed fish or Fish and Wildlife Conservation Areas.

    - Development activities are also assumed to meet this requirement, provided the stormwater system is capable of infiltrating the portion of the 2-year, 24-hour storm event from any impervious surface placed within 300 feet of listed species habitat.

- An *Environmental Baseline* section that consists of the following elements and assumptions:

  - General discussion of location and environmental conditions in Sammamish River, Lake Washington and Swamp and North Creeks.

  - Quantification of dimensions of sub-basins for North Creek (30 square miles, 45 miles of channel) and Swamp Creek (25 square miles, 36 miles of channel).

  - Quantification of percent impervious surface area in North Creek (49 percent) and Swamp Creek (52 percent) sub-basins.

  - Quantification of percent forest cover in North Creek (15-20 percent) and Swamp Creek (<20 percent) sub-basins.

  - General description of hydrograph in North Creek: current 2-year flood discharge exceeds the historical 100-year discharge, groundwater recharge has likely been reduced, resulting in lower summer flows.

  - General description of hydrograph in Swamp Creek: current 2-year flood discharge exceeds the historical 100-year discharge, groundwater recharge has likely been reduced, resulting in lower summer flows.

  - Discussion of poor water quality conditions in North Creek including low dissolved oxygen, high summer temperature, and periodic elevated levels of nutrients, turbidity and toxic metals [lead, copper, and zinc] according to Snohomish County data. Frequent and severe exceedances of state Water Quality standards, 303(d) listed for dissolved oxygen and temperature.

  - Discussion of pesticide and other toxin concentrations. Concentrations have not been assessed in North Creek- assumption that results from Swamp Creek are applicable to North Creek due to location and similar development histories.

  - Assumption that salmonids in North Creek experience sublethal effects from heavy metals based on dissolved copper levels in area creeks, durations required to impair nervous function, inability or avoid high metals concentrations.

- Benthic index of biological integrity score for North Creek 16-28 (22 median)(Snohomish County 2005) and 16-22 (18 median)(EVS Environmental Consultants 2004).

- Discussion of poor water quality conditions in Swamp Creek including erosion and sedimentation resulting from high stormwater flows, and low summer flows resulting in low dissolved oxygen and high temperature. Discussion of periodic elevated levels of nutrients, turbidity, and toxic metals [lead, copper, chromium and zinc] according to Snohomish County data. Detection of 12 pesticides in creek based on a King County data. Frequent and severe exceedances of state Water Quality standards, 303(d) listed for dissolved oxygen, fecal coliform and temperature.

- Assumption that salmonids in Swamp Creek experience sublethal effects from heavy metals based on dissolved copper levels in area creeks, durations required to impair nervous function, inability or avoid high metals concentrations.

- Benthic index of biological integrity score for Swamp Creek 16-30 (22 median)(Snohomish County 2005) and 16-28 (22 median)(EVS Environmental Consultants 2004).

- An *Effects of the Proposed Action* section that includes the following elements and assumptions:

  - Discussion of impacts to forest cover (removal of 25 acres of forested, pasture and grassland), wetlands (8.83 acres of wetlands impacts, 7.12 acres of which relate to wetland buffers), and surface runoff from new impervious areas resulting in disruptions to hydrologic regime.

  - Characterization of proposed treatment and flow control measures: retain 100 percent of existing impervious surface and 100 percent of new impervious surface, resulting in retrofitting of 12.47 acres that did not previously receive treatment.

  - Quantification of how much water will be intercepted and conveyed (3,827,969 cubic feet [ft^3]) on new impervious surface areas based upon assumption of average annual precipitation (40.7 inches) of rain per year (Beyerlein 1999).

  - Comparison of annual runoff volumes associated with forest and impervious land use to determine anticipated increase in surface runoff (3,194,845 ft^3), decrease in interflow by 789, 910 ft^3,

ground water recharge by 1,259,077 ft^3, and evapotranspiration by 1,765, 526 ft^3 in the action area.

- General discussion of potential for increased peak flow frequency, volume and duration, even with proposed detention facilities, and related effects to stream channel, aquatic habitat conditions, migration timing, and displacement of Chinook from preferred habitats resulting from new impervious area.

- General discussion regarding significance of groundwater recharge reductions resulting in reduced flows during low flow periods (summer), potential reduction of rearing habitats, and increased temperatures.

- General discussion on channel destabilization resulting from altered flow regimes and related impacts to channel substrates and habitat quality or suitability.

- General discussion of performance commitment of no net increase of pollutants (TSS, total and dissolved copper, lead and zinc) to North and Swamp creeks. "*Prior to the issuance of this opinion, NMFS has not received revised infrastructure designs, or plans to facilitate the achievement of this performance commitment. Therefore, NMFS does not understand how the no net increase commitment will be achieved*."

- Outline of steps that are necessary to achieve no net increase of pollutants listed above. 1) proper analysis of removal efficiencies must be used as a framework to design facilities to achieve the goal, proper analysis would entail the use of the Simple or FHWA method…2) proper maintenance of stormwater facilities needs to occur for the life of the project to avoid reduced efficiencies over time.

- General discussion about the proposed wet vaults and wet ponds being insufficient for avoiding pollutant loading from the proposed project. The conclusions of the opinion rely on the no net increase commitment.

- Brief discussion of timing of pollutant exposure relative to presence of different life stages (eggs and juveniles October through May), adults (September through November in North and Swamp Creeks).

- Discussion of the relationship between pollutant concentrations and Average Daily Traffic, road area, watershed characteristics, and surrounding land use (Kayhanian et al. 2003) and use of multiple linear regression model equations to describe two different types of storm events: a late summer/fall "first flush" event (during adult spawning), and a winter storm event (during egg development and juvenile rearing/outmigration).

- Brief discussion of modeling results for metals concentrations. For the Fall and Winter/Spring estimates developed by NMFS, copper, lead, zinc concentrations and TSS are slightly reduced from estimated baseline conditions. But the volume of polluted runoff that is routed to the drainage network and new stormwater facilities will increase by 173 percent. This additional runoff coupled with increased average daily traffic will result in a net increase in pollutant loading to the new stormwater treatment facilities. To meet the no net increase commitment, the BMPs will need to effectively remove total and dissolved metals because background waters are assumed to not have the capacity to dilute introduced metals.

- Brief summary of NMFS' BMP effectiveness research. Most relevant BMP data was for total metals which is a poor predictor of effects on Chinook compared to dissolved metals (metal toxicity studies are based on dissolved fractions of metals because they best approximate the immediately bio-available fraction and toxicity).

  - Due to variability between sites and variability in removal effectiveness among storm events at the same pond, NMFS determined that 60 percent for TSS and 40 percent for total metals were reasonable mid-range estimates of removal efficiencies for wet ponds.

  - For wet vaults, given the limited information available and the expectation that vaults will be less effective at metals removal than ponds (because biological uptake and processing of metals is limited in vaults compared to ponds) NMFS used 60 percent for TSS and 20 percent for total metals removal.

- Prior to commitment of no net increase in pollutants, NMFS estimated annual pollutant loading via two methods outlined in WSDOT's Environmental Procedure Manual (2003): the FHWA method and the Simple method. These methods provide estimates of storm pollutant export from a site, catchments or watershed. The

models were used to estimate annual pollutant loads while accounting for new impervious area and installation of new BMPs. Results are calculated in annual loads of total metals per BMP. To determine dissolved metal loadings, NMFS used the ratios of the total metal concentrations to dissolved metal concentrations from the concentration model. These initial results indicated substantial increases in annual copper and zinc loading per BMP and a 10 percent increase in annual TSS loading. It was assumed there would be a substantial increase in fine sediment above baseline conditions because the BMPs treating increased TSS resulting from new impervious surface would only remove the largest particles.

- Discussion of three known physiological pathways of metal exposure and uptake within salmonids: 1)gill surfaces and uptake metal ions which are rapidly delivered to biological proteins (Niyogi 2004); 2) olfaction receptor neurons, and; 3) dietary uptake.

  - Discussion of copper toxicity studies and literature, lethal and sublethal responses of fish in general and more specifically salmonids (coho, rainbow trout, Atlantic salmon, and brook trout).

  - Discussion of cadmium toxicity studies and literature, lethal and sublethal responses of fish in general and more specifically salmonids (bull trout, rainbow trout, and brown trout).

  - Brief discussion of variability in chromium sensitivity, toxicity effects and literature.

  - Discussion of lead toxicity studies and literature, lethal and sublethal responses of fish in general and more specifically salmonids (rainbow trout).

  - Discussion of zinc toxicity studies and literature, lethal and sublethal responses of fish in general and more specifically salmonids (juvenile and adult rainbow trout).

  - Discussion of polycyclic aromatic hydrocarbons toxicity studies and literature lethal and sublethal responses of fish.

  - Discussion of effects of individual metals and metal mixtures and the potential for two or more pollutants

resulting in toxicological interactions resulting in additive or synergistic or antagonistic responses.

- Discussion of sublethal effects of stormwater on Chinook salmon (reduction of growth or immune system functions) and the exacerbation of these effects resulting from overall poor water quality in Salmon and North Creeks, the Sammamish River and Lake Washington.

- Brief discussion of water volume changes resulting from project: loss of infiltration capacity affecting base flows, and increased stormwater volumes affecting channel habitat conditions.

  - Comparison of annual runoff volumes associated with forest and impervious land use to determine anticipated increase in surface runoff (3,194,845 ft^3), decrease in interflow by 789, 910 ft^3, ground water recharge by 1,259,077 ft^3, and evapotranspiration by 1,765, 526 ft^3 in the action area.

SR 524 FHWA-WSDOT Biological Assessment

The stormwater analysis in the SR 524 biological assessment (March 2004) consists of the following elements and assumptions:

- A description of anticipated clearing limits, new impervious surface, and acreage of propose stormwater ponds in the Road Improvements subsection of the *Project Design and Construction* section of the BA.

- A description of the proposed facilities locations, general points of discharge, and the design standards to which the facilities would be built (Ecology's 2001 Stormwater Manual, WSDOT HRM, WSDOT Instructional Letter 4020.02, Snohomish County Title 30, Snohomish County Code 31.10, and the Snohomish County Engineering Design and Development Standards) in the *Stormwater Detention and Outfall Location* subsection of the *Project Design and Construction* section of the BA.

- Additional information on *Measures Addressing Stormwater Volume and Quality of Stormwater Runoff from the Construction Operation and Maintenance of the Project Corridor* in the *Additional Project Design*

Features subsection of the *Project Design and Construction* section of the BA. General discussion of routing all project stormwater to proposed stormwater detention facilities, erosion and sediment control measures, fencing to protect wetlands and to demarcate clearing limits, etc.

- Environmental Baseline information in the BA includes standard Diagnostic Pathways and Indicators water quality information (temperature, sediment/turbidity, chemical contaminants/nutrients) and flow/hydrology information (changes in peak/base flows, drainage network increase).

  - Temperatures in both Swamp and north Creeks were considered "not properly functioning" and have periodically exceeded state standards throughout their respective basins, primarily during the summer months. Temperatures in north Creek exceeded 16 degrees Celsius 26 percent of the time and 18 degrees Celsius four percent of the time. In swamp creek, temperatures have exceeded 16 degrees Celsius 34 percent of the time and 18 degrees Celsius for four percent of the time. Tributary streams that intersect North and Swamp creeks are assumed to be similar.

  - Sediment/Turbidity in Swamp and north creeks stem from a high level of bank disturbance and scouring resulting from hydromodifications that restrict channel migration. Fine sediments in these systems and their tributary stream have resulted in substrate embeddedness and pool filling as well as impacts to macroinvertebrate communities.

  - Chemical Contaminants/Nutrients have resulted in 303(d) listing of North Creek for dissolved oxygen and temperature. Swamp Creek has been listed for fecal coliform. In addition the Snohomish County studies that addressed metals and pesticides referenced in the NMFS and USFWS biological opinions are referenced and summarized in the BA. The BA also states that nitrate and phosphorous levels in Swamp Creek exceed Environmental Protection Agency recommendations.

  - Flow/Hydrology: Current two-year flood discharge in both basins exceeds the historical 100-year discharge. Loss of wetlands and floodplain connectivity and the quantity of impervious surface area (52 percent in Swamp Creek and 49 percent in North Creek watersheds have resulted in lower summer flows, increased flashiness, peak flows with greater intensity and duration, over widening of channels, bank erosion, and scour of the streambeds. Road density is high in both basins (14.81 miles/ square mile in

Swamp Creek and 15.77 miles/square mile in North Creek) which has lead to an increase in drainage network.

- An *Analysis of Effects* section consisting of the following subsections:
  - Direct Effects. The topics addressed in this section that pertain to stormwater include, a discussion on the impacts associated with Impervious Surface Area and Stormwater and a discussion on Stream Impacts.
    - The Impervious Surface Area and Stormwater discussion focuses on the introduction of 25.91 acres of new impervious surface, of which 4.39 acres will consist of stormwater detention ponds. The project will treat all new impervious surface and retrofit the existing 12.47 acres of impervious surface (existing stormwater is conveyed via ditches directly to surface waters). Aside from referencing the standards that will inform design of the facility and general descriptions of minimizing stormwater related impact through stormwater detention and treatment, no detailed analysis is provided.
    - The Stream Impacts discussion states that HEC_RAS Water Surface profiles Version 2.2 and HY-8 Model hydraulic analyses were reformed to evaluate proposed bridge designs, culverted stream crossings, and inlet spacing calculations. A detailed summary of modeling results is not provided. For two of the drainage basins in the project corridor (West Basin and Martha Creek) a brief description of proposed stormwater treatment and facilities is provided.
  - The *Indirect Effects* section concludes the proposed action could increase the rate at which additional growth occurs, but is not likely to increase the amount or pattern of growth which is governed by the Comprehensive Plan or generate other activities and related impacts that would not otherwise occur without the completion of the project.

I-405 Bellevue Nickel Improvement Project FHWA-WDOT Biological Assessment

This biological assessment was written using a biological assessment template form developed by WSDOT in 2005. The information in the report is very concise and provided in a checklist style format. The stormwater related information provided in this biological assessment consists of the following:

- A *General Project Description* section, a portion of which is particularly relevant (the *Project Footprint* subsection).
  - Project will increase pollution generating impervious surface by 450,410 square feet.
  - Project will retrofit 76,666 square feet of existing impervious surface.
  - 3.63 acres of existing impervious surface will be removed.
  - The new roadway will be constructed over 500 feet from the Median Stream (which does not contain federal listed species). Construction over the culvert that connects Mercer Slough and Kelsey Creek will occur- but will not affect the culvert and will remain 100 feet from either water body.
  - Project will convert I-405 median habitats which include three wetlands, Median Stream, and a mix of upland and riparian vegetation.
  - The project will use Enhanced Treatment BMPs to treat the stormwater from all of the new and some of the existing pavement surfaces per WSDOT Highway Runoff Manual (2004). "Stormwater will remain separated from the environment until it is conveyed through quality treatment facilities prior to discharge."
  - Stormwater flow control facilities will be designed according to WSDOT Highway Runoff Manual (2004). Four combined stormwater treatment wetland/detention ponds and one Ecology embankment will be used. Flow control will not be provided when discharge is made directly to Mercer Slough due to its connection with lake Washington. Flow control will be provided for discharges to tributary watercourses or storm drains. The peak rate and duration of discharge will be controlled to match the theoretical flows from the Project area prior to the start of

construction . Infiltration is a non-viable method due to low permeability soils. Facilities A, B, C will discharge to existing storm drain or cross-drain pipes after treatment. Facility D, the Ecology embankment, will collect (in underdrains) and pipe treated water to spreader trenches where runoff will sheet flow into a wetland. Drainage facility E will discharge to an existing outfall.

- An *Avoidance and Minimization Measures* section of which the *Performance Standards* subsection is particularly relevant.
  Very general language is provided for stormwater management measures that will be implemented during construction and project activities to minimize water quality impacts.

- A *Project Action Area* section of which the *Aquatic Considerations* subsection is particularly relevant.
  An increase in stormwater discharge will only affect Mercer Slough immediately at the discharge location. Mercer Slough is a backwater of Lake Washington and the level of these water bodies is regulated by the Hiram M. Chittenden Locks.

- An *Effects Analysis for Impervious Surface Area/Stormwater* section consisting of the following elements:

  - Quantification of new impervious surface area (10.34 acres). This increase is a 29 percent increase in impervious surface area over the existing impervious area associated with I-405.

  - General discussion of impacts associated with installation of new impervious surface including the following topics: removal of vegetation, impacts to water quality, impacts to water quantity and impacts to wetlands.

    - Removal of Vegetation: general discussion lists potential effects including: increased stream temperatures, reduced LWD recruitment potential and contribution of organic material for macroinvertebrates, elimination of over-stream cover and decreased bank stability. Project will not permanently impact riparian buffers of water bodies with listed species.

    - Water Quality: general discussion summarizes potential impacts including increased exposure to hazardous materials, increased stormwater runoff, and decreased water quality in the streams within the action area. Contaminants and petrochemicals from vehicle traffic and

stormwater runoff could enter streams potentially affecting salmonids through absorption across the gills or bioaccumulation as a result of consuming contaminated prey or incidental consumption of sediment particles to which contaminants have adhered. Enhanced treatment via Ecology embankments and stormwater ponds will effectively remove suspended solids in addition to targeting dissolved pollutants. Water quality will meet state water quality standards in accordance with the Highway Runoff Manual.

- Water Quantity: general discussion summarizes impacts resulting from new impervious surface including, increased velocity and flow, with concomitant impacts on habitat and fish and decreased groundwater, resulting in decreased surface water recharge and lower summer flows, which in turn results in fish stranding and increased in-stream temperatures. Areas where impacts would most likely occur include Kelsey Creek and Mercer Slough. The new stormwater system will provide peak flow control for all new impervious surface in addition to10.34 additional acres (an equivalent area) of existing impervious surface. Because of this additional treatment, it is assumed no negative effects to base flows would result.

- Wetlands: The project will permanently affect 3 wetlands via partial filling. None of the wetlands provide Chinook or bull trout rearing habitat or refugia. Functions provided by the wetlands include stormwater retention, improved water quality, and groundwater recharge.

- An *Effect Determinations* section including the following information that is particularly pertinent for the stormwater analysis as it pertains to ESA listed species and critical habitat:

  - Short-term water quality impacts include construction-related turbidity and sedimentation at stormwater outlets to Kelsey Creek and Mercer Slough. This could result in smothering of salmon eggs in gravels, decreased micro- and macroinvertebrate survival and a result of reduced dissolved oxygen, reduced ability for visual predators to capture prey, damaged gills and increased risk of anoxia, behavioral changes or stress that can lead to fish mortality. However, project-related turbidity and sedimentation

impacts are expected to be avoided and minimized by the use of appropriate conservation measures and BMPs.

- Long-term water quality and quantity impacts are not expected to affect Kelsey Creek and Mercer Slough as a result of stormwater flow control facilities and enhanced water quality treatment for the new impervious surface area.

- *Appendix E: Environmental Baseline*. This section provides information on the Diagnostic Pathways and Indicators parameters for Kelsey creek and Mercer Slough:

  - Kelsey Creek- the following baseline information is provided:

    - Kelsey Creek watershed contains more than 19 miles of streams

    - Kelsey Creek is used by Chinook and assumed to be used by bull trout

    - Temperature: Kelsey Creek is on Ecology's 303(d) list for temperature based on unpublished data from King County showing temperature criterion were exceed all years between 1998 and 2002. Summer temperatures range between 61 and 63 degrees Fahrenheit (CUWRM 1999). Kelsey Creek showed a statistically significant increase in baseflow temperature values between 1979 and 1999 at to King County water quality sampling sites (KCDNR 2000).

    - Sediment turbidity: Fine sediments have been identified as a limiting factor in Kelsey Creek with fine sediment comprising 22 percent of the spawning substrate (Scott et al. 1982)/ In a 1995-96 study, fine sediment amounts as high as 29 percent were observed (May 1996).

    - Chemical Contamination/Nutrients: Kelsey Creek is on Ecology's 303(d) list for dissolved oxygen, fecal coliform bacteria, and three pesticides (Dieldrin, Heptachlor Epoxide, and Dichlorodiphenyltrichloroethane (DDT). Seven

percent of King County's baseflow samples from 1998-2003 exceeded the upper limit of the State pH water quality standard, baseflow phosphorous concentrations were above the median, and ammonia and nitrate concentrations were within the median range.

- Road density and location: Kelsey Creek water shed is 42 percent impervious (City of Bellevue 2000). Impervious surfacing from roads equate to 1,413 acres or 13 percent of the 10,870 acre watershed.

- Basin is considered to have reached built-out conditions and future development will consist of redevelopment of existing properties.

- Mercer Slough – the following baseline information is provided:

  - Mercer Slough is currently listed on Ecology's 303(d) list for exceeding minimum water quality criteria for fecal coliform, pH, and dissolved oxygen, though dissolved oxygen exceedances may be the result of natural decomposition within the marsh.

  - Temperature: Mercer Slough is on Ecology's 303(d) list for temperature based on unpublished data from King County showing temperature criterion were exceed all years between 1998 and 2002.

  - Chemical contamination/Nutrients: Based on city of Bellevue monitoring data, copper was noted as exceeding acute toxicity criteria in 50 or more of the stormwater samples taken. Zinc exceeded EPA's acute toxicity criteria 61 percent of the time in storm flows. USGS research identified 18 pesticides in the West tributary and Mercer Slough, some at levels potentially detrimental to aquatic life (Kerwin 2001).

SR 167 USFWS Biological Opinion

The stormwater analysis in the SR 167 Biological Opinion consists of the following elements and assumptions:

- A *Description of the Proposed Action* section that provides:
  - Quantification of new impervious surface (221 acres). Of this acreage, 70 acres will be located in the Puyallup River sub-basin, 115 acres will be in the Hylebos Creek sub-basin, and 36 acres will be in the Wapato Creek sub-basin.
  - Anticipated average daily traffic levels on the new freeway in 2015 is 50,000 to 70,000 vehicles, and in 2030, it will be 75,000 to 90,000 vehicles.
  - During construction, water quality mixing zones will not exceed 300 ft in the Puyallup river, 200 feet in Hylebos and Wapato Creek and 100 feet in Surprise lake Tributary, in accordance with the implementing agreement (Appendix C).
  - Temporary and permanent stormwater best management practices will be constructed for water quality treatment and flow control consistent with the most recent version of the WSDOT Highway Runoff Manual.
    - Water Quality treatment: Treatment of all new impervious (221 acres of pollution generating impervious surface).
      - Hylebos sub-basin treatment includes 88 acres of PGIS in four threshold discharge areas with will discharge above ordinary high water mark through 11 outfalls of Hylebos Creek or Surprise Lake tributary then into an area intended to provide flow control (Riparian Restoration Project). Depending upon the water quality BMP that precedes discharge, treated stormwater may sheet flow or be collected and conveyed. 27 acres of PGIS in two threshold discharge areas will discharge through 6 outfalls to Fife Ditch, discharging approximately 1 mile downstream into Hylebos Creek and then into the Hylebos Waterway.

- Wapato sub-basin treatment includes 3 acres of PGIS in one threshold discharge area discharging into Erdahl Ditch and 9 acres of PGIS in one threshold discharge area discharging to lower Wapato Creek. Both discharge one mile downstream to the Port Industrial Waterway. 24 acres will discharge between river mile 7 and 8.

- Puyallup sub-basin treatment includes 70 acres of PGIS in two TDAs discharging through 3 outfalls. Two of these outfalls discharge to the Puyallup River, via the 2,300-foot long Old Oxbow ditch, and one discharges directly to the Puyallup River.

- WSDOT will retrofit 24 acres of existing PGIS along northbound I-5.

- Enhanced treatment will be provided for 9 out of the 10 TDAs. The one TDA where basic treatment will likely be provided is the 3 acre TDA discharging to the Erdahl Ditch.

- BMPs will meet the following performance standards:

    - Basic treatment = at least 80 percent removal of TSS

    - Enhanced treatment = Basic treatment plus effluent concentrations not to exceed the following values 90 percent of the time at the point of discharge:

    - Total copper – 12 micrograms per liter.

    - Dissolved copper 7.8 micrograms per liter

    - Total zinc 67 micrograms per liter

    - Dissolved zinc 44.8 micrograms per liter

- Flow control and riparian restoration includes the following elements and assumptions:

- No flow control provided in a 3 acre TDA discharging to Hylebos creek.

- No flow control provided for a total of 30 acres of PGIS in three TDAs discharging to non-fish bearing Erdahl and Fife Ditches.

- No flow control will be provided for 9 acres of PGIS in a 9 acre TDA that discharges to lower Wapato Creek.

- No flow control management is proposed for 52 acres PGIS in one TDA discharging directly to the Puyallup River.

- WDOE Flow Duration Standard will be used to design facilities for 18 acres of PGIS in a 18 acre TDA that discharges into Oxbow Lake Ditch. Compost amended filter strips (an experimental BMP type) are proposed for this TDA.

- In the Hylebos subbasin, WSDOT is proposing riparian restoration as an alternative to the construction of large detention facilities from the three TDAs totaling 85 acres PGIS. The Riparian Restoration Project will be applied to 87 acres of riparian area adjacent to Hylebos Creek, 29 acres adjacent to Surprise lake Tributary, and 73 acres adjacent to Wapato Creek.

- Conventional flow control BMPs will be installed at the Valley Avenue Interchange.

- The *Status of the Species* section provides general information on the threats to bull trout in the Puyallup Core Area including:

  - The development and disturbance history in the area that has affected habitat complexity and quality

  - Dams and diversions inhibiting migration,

  - Historic recreational fisheries affecting overall population size

  - Water quality degradation form municipal and industrial effluent discharges and stormwater discharges. (Impervious surface in the

Puyallup watershed increased by 12 percent between 1990 and 2001.)

- Major flood events in 2006 significantly affected instream habitat and bull trout brood success for the year.

- In November 2006 an 18,000 gallon spill for diesel fuel affected a bull trout spawning area within the watershed.

- The *Status of Bull Trout Critical Habitat* section provides general information on the habitats that have been designated as critical habitat for bull trout, current range-wide condition of critical habitat, and condition of designated critical habitat in the Puget Sound. Also within this section, a detailed Environmental Baseline discussion is provided

  - The Environmental Baseline Section provides the following information:

    - A detailed discussion of Lower Puyallup River and Commencement Bay Foraging, Migratory, and Over-wintering (FMO) habitat, including use and abundance information, location distribution and condition of the habitat.

      - Limited numbers of anadromous individuals (50) are present today within the Puyallup system, migrating to and from Commencement Bay.

      - The number of fluvial bull trout in the system is assumed to be approximately 50 individuals.

      - Lower Puyallup River is the primary FMO habitat supporting bull trout in the Puyallup watershed. Their use is concentrated near the outlets of tributary streams where they forage or find thermal refugia.

      - Extensive urban growth, heavy industry, dredging, agriculture, and revetments and levees have altered habitat complexity in the lowermost reaches of the Puyallup River. These changes have also affected the natural hydrology in these areas, resulting in increased peak flows and reduced base flows. Instream minimum flows established at the Puyallup River gauge are 1,000 cubic feet per

section. From 1980 to 1993, instream flows were not met an average of 35 days annually.

- Less than 5 percent of the lower reaches of the mainstem Puyallup River retain high quality riparian habitat.

- Listed on the 2004 303(d) list for fecal coliform (ranging from 120/100ml to 270/100 ml) and mercury violations. Low levels of dissolved oxygen, elevated temperatures, and elevated levels of copper, lead, and turbidity were also identified as concerns. Some of the turbidity in the system can be attributed to its glacial origins, however surrounding land uses also contribute.

- Temperatures at station number 10A070 range from 10.3 degrees Celsius in October through December, 6.8 degrees Celsius January through march, 11.8 degrees Celsius April through June, and 14.0 degrees Celsius July through September.

- In Commencement Bay, bull trout use shallow nearshore waters <10meters. Less than 10 percent of the historic intertidal mudflat and 2 percent of the original salt marsh remain.

- Much of the shallow nearshore has been converted via dredging to develop industrial waterways. In addition, shoreline protection measures have armored the shoreline (77 percent of shoreline is armored). These changes have reduced the suitability of the habitat for bull trout and eradicated habitats for their prey species (forage fish).

- Temperatures in Commencement Bay (at Browns Point) range from 8.88 degrees Celsius in April to 13.52 degrees Celsius in August.

- Commencement Bay was a federal Superfund site in 1981. Upland cleanup has occurred at 63 of the 70 identified sites. The Hylebos, Middle and Thea Foss waterways remain Superfund sites and have ongoing cleanup actions.

- Clean up efforts in Blair and Hylebos waterways have significantly reduced levels of dissolved metals.
    - Median concentrations for Blair Waterway includes 0.81 micrograms per liter for copper, 3.7 micrograms per liter for zinc, and 1.3 micrograms per liter for arsenic.
    - For the Hylebos Waterway, median values were 1.6 micrograms per liter for copper, 11.6 micrograms per liter for zinc, and 2.1 micrograms per liter for arsenic.
    - These levels, with the exception of zinc in the Hylebos Waterway, are above the olfactory inhibition and behavioral effects/modifications thresholds.
    - Also detected in the Hylebos Waterway at levels that could potentially affect salmonid reproductions, growth and survival, were chlorinated pesticides, DDT, Polycyclic Aromatic hydrocarbons , and Polychlorinated Biphenyls.
- Hylebos Creek habitat conditions are highly degraded. Bull trout are not known to occur in the creek, but it provides a forage base for fish in Commencement Bay.
    - In Hylebos Creek there is a general lack of habitat complexity, temperatures could support migration and rearing but may limit salmonid spawning, and levels of dissolved copper reached 2.47 micrograms per liter (which could inhibit olfactory function in salmonids), and fecal coliform levels have exceeded state standards.
- Surprise Lake Tributary does not contain bull trout because it lacks suitable habitat for the species, but provides bull trout prey base.

- Wapato Creek has been generally degraded by land use practices. In addition fish passage barriers inhibit movement of fish in the system. Bull trout do not occur in the system due to lack of suitable habitat, but Wapato does support a run of coho. As a result, the system contributes to bull trout prey base.

    - Listed on the 2004 303(d) list for fecal coliform and reduced dissolved oxygen. Tribal data indicate state standards for dissolved oxygen, pH and temperature do not meet water quality standards during late summer. In addition ,turbidity levels, nitrate/nitrite and phosphorous concentrations were also elevated.

    - B-IBI score is 18, indicating impairment of biological processes.

    - Flood flows are generally diverted to the Puyallup river.

- The *Effects Of the Action* section addresses the following impacts in detail:

    - Effects of Increased Impervious Surface Section includes:

        - Conversion of 220 acres currently vacant/undeveloped land (~105 acres) and agricultural land (~112 acre) to impervious surface.

        - 214 acres of vegetation will be permanently removed.

            - In Puyallup Sub-basin: 1,010,118 cubic yards of fill, 70 acres new impervious surface, 73 acres of permanent vegetation removal.

            - In Hylebos Sub-basin: 2,257,067 cubic yards of fill, 115 acres of new impervious surface, 81.9 acres of permanent vegetation removal.

            - In Wapato Sub-basin: 447,856 cubic yards of fill, 36 acres of new impervious surface, 59.4 acres of permanent vegetation removal.

- General discussion provided regarding conversion of land to impervious surface affecting the natural hydrograph, groundwater recharge, and subsurface water exchange. Subsequent reductions in base flows could result in increased temperatures, degraded habitat conditions for bull trout and their prey base.

- Effect of Increased Impervious Surface to Hyporheic Function in the Lower Puyallup River includes:

  - Summary of FHWA and WSDOT data indicating impacts to hyporheic function will be minor due to degraded existing condition of the system and soils types. However a detailed description of existing conditions was not provided to FWS by these agencies. As a result FWS concluded there was not enough information available to determine the extent or condition of remaining hyporheic function in the action area.

- Effects of Increased Impervious Surface on Subsurface Water Exchange and Groundwater Recharge provides the following information:

  - Impervious surface in the Puyallup-White River increased 12 percent between 1991 and 2001.

  - General discussion regarding placement of fill compressing substrates that overlay the shallow groundwater table in the project area, and subsequent potential effects to subsurface water flow and possible interruption of bull trout homing behavior that is keyed in to the chemical signature of groundwater.

  - General discussion regarding increased impervious surface resulting in lower base flows and subsequently higher temperatures.

  - General discussion of impervious surfaces increasing temperatures by collecting and heating runoff prior to discharge.

  - Precipitation in the action area averages 38 inches a year, of which 14 inches enters the groundwater system as recharge.

- Based on data in Beyerlein (1999), the addition of 70 acres of new impervious surface will affect 10,348,985 cubic feet of water. Estimated volumes associated with conversion of pasture to impervious surface, FWS predicts an increase in surface runoff (+8,586, 553), a decrease in subsurface flow (-3,369,630), decrease in groundwater recharge (-2,580,002) and a decrease in evapotranspiration (-2,636,921).

  - To address these impacts, WSDOT added compost amended vegetated filter strips and flow dispersion BMPs to the Puyallup River sub-basin and developed a revised hydrologic analysis. This analysis was based on Beyerlein data coupled with a pre and post-project comparison using a Hydrological Simulation Program- FORTRAN. This modeling effort concluded the annual infiltration volume would be equivalent.

    - WSDOT analyzed 170.8 acres (including lands that would be replanted and impervious areas instead of only 70 acres impervious surface.

    - WSDOT modified the land use category described by Beyerlein (pasture) to "tilled farmland."

    - WSDOT assumes a very high effectiveness rating for the CAVFS.

  - FWS concluded that the WSDOT model overestimates the effectiveness of the CAVFS, there is a lack of monitoring information related to CAVFS' effectiveness, and that despite installation of CAVFS, there would likely be some reduction to subsurface water exchange resulting from the project. .

- Effects of Increased Impervious Surface on Bull Trout

  - General discussion provided regarding anticipated degradation of bull trout foraging , migrating, and overwintering habitat as a result of increased impervious surface. Loss of vegetation, placement of fill, and

conversion of land cover to impervious surface will impact the hydrologic function of the lower Puyallup River, which in turn will increase water temperatures and reduce the quality of thermal refugia, the foraging effectiveness of bull trout by affecting prey base, and result in increased energetic costs for bull trout.

- Similar impacts are cited for Wapato and Hylebos sub-basins. However, these impacts are assumed to be partially offset by the proposed Riparian Restoration project.

- Direct Effects of Stormwater Discharge on Bull trout:
  - Traffic residue contains several metals including iron, zinc, lead, cadmium, nickel, copper and chromium.
  - Urban areas deliver PAHs to surface water bodies via runoff, and roads can introduce pesticides to surface waters.
  - Performance standards will be implemented for all BMPs. BMPs will meet the following performance standards:
    - Basic treatment = at least 80 percent removal of TSS
    - Enhanced treatment = Basic treatment plus effluent concentrations not to exceed the following values 90 percent of the time at the point of discharge:
      - Total copper – 12 micrograms per liter.
      - Dissolved copper – 7.8 micrograms per liter
      - Total zinc – 67 micrograms per liter
      - Dissolved zinc – 44.8 micrograms per liter
    - Performance standard concentrations exceed thresholds of effects to listed species.
      - Copper
        - To predict concentrations of project-related pollutants, WSDOT used the FHWA method.

- Post-project stormwater BMP concentrations of dissolved copper were estimated to be 7.8 micrograms per liter.

- Under the proposed action, concentrations of 7.8 micrograms per liter 90 percent of the time at the point of discharge would be 3.4 times the lower limit of the documented neurotoxic threshold (Baldwin et al. 2003). These levels would be exceeded in the mixing zone of the two outfalls (300 feet downstream) in the lower Puyallup River.

- Estimated dissolved copper levels also exceed the LC10 concentration for rainbow trout (based on 200 hours of exposure) (EPA 1980). However, the duration of potential exposure in the lower Puyallup River will likely be much shorter, and would therefore not result in mortality.

- To estimate concentrations that would be added to the estuarine environment, WSDOT completed dilution modeling using Ecology's RIVPLUM and TSDCALC spreadsheets (Ludwa 2006).

  - Spreadsheets do not account for pollutant mixtures or synergistic effects of multiple pollutants- as a result estimates are likely low.

- Model uses 2-year discharge in receiving water body and 10-year discharge off the project's PGIS.

- Modeling results indicated dissolved copper concentrations in the upper reaches of the Blair and Hylebos Waterways would exceed the lower limit for the neurotoxic threshold. However, concentrations will likely be diluted below the 2.3 micrograms per liter effects threshold to bull trout within a short distance of entering these waterways due to their size and tidal exchange.

- Zinc

  - To predict concentrations in the lower Puyallup River, WSDOT used NPDES monitoring data.

  - Estimated pre-project concentrations of zinc were up to 110.0 micrograms per liter. Post-project concentrations were 44.8 micrograms per liter.

  - Under the proposed action, concentrations of 44.8 micrograms per liter 90 percent of the time at the point of discharge will be 8 times higher than the behavioral avoidance concentration in rainbow trout (5.6 micrograms per liter) (Hansen et al. 2002).

  - These concentrations exceed the LC50 concentration of juvenile bull and rainbow trout (with applicable pH, hardness, and temperatures).

However, the duration of potential exposure will likely be much shorter than originally tested (120-days), and would therefore not result in mortality.

- For estuarine areas, WSDOT predicted dissolved zinc concentrations in the upper reaches of the Blair and Hylebos Waterways

  would exceed the behavioral avoidance concentration.

- Cadmium and Chromium

  - Baseline levels of these pollutants are not known in the lower Puyallup River.

  - Post-project, post-treatment contribution of these pollutants is unknown.

  - BMP effectiveness monitoring indicates reduction in total cadmium ranges from 36 to 86 percent and dissolved cadmium ranged from increased concentrations to reductions of up to 68 percent.

- Much of the toxicity data only available for other salmonid species. Majority of data is for rainbow trout.

- Most toxicity studies focus on dissolved metals because this is the closest approximation of the bio-available fraction of the metals.

  - Three known pathways of exposure and uptake: 1) absorption of metal ions through the gill surfaces, 2) olfaction receptor neurons, 3) dietary uptake.

- For metals, relative toxicity is affected by pH, water hardness, water temperature, organic content, phosphate concentration, suspended solids, and presence of other metals.
    - As hardness increases, metals become less bio-available via gill surfaces. Data is not as clear for olfactory function.

- Anticipated concentrations were modeled by WSDOT using the FHWA method.
    - FHWA method uses estimates of average pollutant concentrations that are based on a limited dataset to develop general estimates of plausible stormwater pollutant concentrations at the TDA scale
    - Modeling indicates that in the Fife Ditch, Hylebos Creek, and Puyallup River threshold discharge areas, with the retrofit of approximately 24 acres of existing PGIS, will decrease concentrations of TSS, and total and dissolved copper and zinc down to the performance standards.
    - In the remainder of TDAs where new PGIS will be installed and none retrofitted, concentrations are anticipated to meet performance standards.

- Annual pollutant loading was modeled by WSDOT using the FHWA method.
    - Modeling results indicate an increase in TSS, total and dissolved copper and zinc loading in all the TDAs with the following exceptions:
        - TSS will decrease in Fife Ditch, Hylebos Creek, and Puyallup River TDAs, as well for all water bodies combined.

        - Loading of total zinc and copper are expected to decrease in Fife Ditch and Hylebos Creek.
        - Loading of dissolved zinc will decrease in Fife Ditch.
    - Net increase in pollutant loading will measurably degrade the environmental baseline during periods of high water.
- Bull trout potentially exposed to project-related stormwater in outfall mixing zones. Individuals may pass though lower Puyallup River up to 20 times in a 10-year life span.
    - Risk of exposure is greatest during periods of low flow when water quality is poor and temperatures are high. Adults pass through lower Puyallup River to access upstream spawning areas in June and July. However, stormwater discharge is unlikely during the dry months.

□ *Effects of Pollutant Exposure on Bull Trout*:

- Bull trout will be exposed to a greater level of pollutants as a result of the project.
- Effects of the project may be additive, synergistic and or antagonistic.
- A general discussion of potential effects associated with metals toxicity and water quality degradation is provided (i.e. effects may include reduced growth, fecundity, avoidance, reduced stamina, neurophysiological and histological effects on the olfactory system, suppressed immune systems).
- Mixing zones in the Puyallup River must adhere to those defined in the Puyallup Tribe's water quality standards (300 feet downstream, 100 feet upstream, 25 percent of the channel during the 7Q10 discharge (7 day average low flow that has a 10 percent chance of occurring in any given year).

- For all other water bodies- Hylebos and Wapato Creeks and Surprise Lake Drain, as well as the Fife and Erdahl Ditches, Washington State Water Quality standards dictate the mixing zone. State mixing zone standards are identical to the Tribe's.

- The *Indirect Effects* section of the biological assessment provides a very general discussion regarding development of transportation corridors leading to changes in lad use and subsequent changes in impervious surface. Impact associated with increased impervious surface are addressed above.

- Effects to Bull trout Critical Habitat

  - Temperatures in the lower Puyallup River are at the high end of the range that bull trout tolerate. The loss of vegetation, placement of fill, and conversion of undeveloped lands to impervious surface will negatively impact hydrologic function of the river, and over time will result in warmer water temperatures.

    - In the Blair and Hylebos waterways, impacts from stormwater runoff are not expected to be measurable.

  - Puyallup River flow is currently impacted due to significant development within the basin. Additional significant increases in impervious surface are likely to have measurable impact on peak and base flows (as a result of increased runoff and decreased infiltration and groundwater recharge) in the lower reaches of the river.

  - The loss of vegetation, placement of fill, and conversion of undeveloped lands to impervious surface will negatively impact hydrologic function of the river. The project will decrease groundwater recharge and reduce subsurface flow to loss of cold water refugia could present an impediment to migration.

  - The loss of vegetation, placement of fill, and conversion of undeveloped lands to impervious surface will result in increased runoff and decreased infiltration, and subsequently decreased groundwater recharge and loss of subsurface flow. These impacts will result in a reduced prey base.

- Increased runoff from new impervious surface is expected to further degrade water quality, primarily within the mixing zones associated with outfalls.

    - In the Blair and Hylebos waterways, stormwater discharge is expected to contain contaminants such as copper, zinc, other metals, and sediment. However, effects are anticipated to be insignificant with regard to bull trout migration and significant with regard to bull trout prey base reduction and normal bull trout reproduction, growth and survival.

- *Appendix A* provides detailed exposure-response matrices that identified project elements, where they will occur, pathways of exposure for bull trout, anticipated response to impacts, and applicable minimization measure or performance standards that will address and potentially reduce identified impacts. Within these matrices, several rows are dedicated to project activities potentially affecting water quality via stormwater.

- *Appendix C* provides a summary of proposed conservation measures. Pertaining to stormwater, several conservation measures are listed for stormwater outfalls.

- *Appendix D* provides background information and a protocol for assessing sediment impacts.

SR 167 Extension FHWA-WDOT Stormwater Analysis

Stormwater analysis prepared by FHWA and WSDOT for SR 167 included preliminary studies, biological assessment data, letters and email correspondence between USFWS, NMFS, consultants and FHWA and WSDOT. Much of the information was incorporated into the USFWS biological opinion summarized above.

The analysis and information that was provided to NMFS specifically, has not yet been incorporated into a biological opinion that has been released to the public. For this reason, this data, in particular a draft Incidental Take Statement, will not be summarized here because the analysis is still a work in progress.

The biological assessment that was originally submitted was ultimately supplanted by a performance based, iterative process that provided information to the Services as needed to support their analysis and completion of their biological opinions. Ultimately the stormwater analysis consisted essentially of a Level Three analysis, as described in the *WSDOT BA Writers*

Guidance for Preparing the Stormwater Section of Biological Assessments. Data provided to the Services included the following:

- Final deconstruction of the action
  - This deconstruction is conveyed in the Description of the Proposed Action section of the USFWS Biological Opinion.
- Final baseline conditions
  - Summarized above in USFWS Biological Opinion.
  - Some information provided by FHWA and WSDOT in supplemental materials was not incorporated, including:
    - Dissolved copper in Hylebos Creek ranges from <0.01 to 0.015 milligrams per liter. Dissolved zinc ranged from 0.01 to 0.03 milligrams per liter.
    - Hylebos Creek benthic index of biological integrity ranges from 14 to 22.
    - Action area was expanded to include, Hylebos waterway, so additional baseline information was provided to the Services including that information. Some of this baseline information was incorporated into the USFWS Biological Opinion.
- Final action area
  - Within the action area defined for the project, stormwater related effects are limited to the 300 foot mixing zones as described above in USFWS Biological Opinion.
- Final indirect effects analysis
  - Incorporated in the USFWS Biological Opinion
- Final definition of performance measures
  - The performance standard for stormwater underwent several iterations (August 21,2006 and September 7, 2006). The final standard is summarized above in the USFWS Biological Opinion.

- A final listing of minimization measures and performance standards and final universal minimization measures was provided by WSDOT to USFWS and NMFS on September 28, 2006 (a previous version had been sent March 28, 2006). These measures were incorporated into the USFWS Biological Opinion in the Description of the Proposed Action section and are also listed in their entirety in Appendix C of the opinion.

- Final stormwater management report

  - Provides an overview of existing conditions, 303(d) listing information, additional water quality background information, and proposed approach. This document also outlines the proposed Riparian Restoration Project for stormwater flow control. All of this information is incorporated into the USFWS biological opinion.

  - The management report also provides a detailed discussion of stormwater runoff impacts.

    - This section of the report addresses erosion and sedimentation (generally), pollutant loading (by presenting modeling results from the Water Resource Discipline Report (EnviroVision 2005), temperature and ph (generally), and impervious surface (by providing a detailed discussion of highway runoff contaminant sources and modeling results), median percent removal efficiencies assumed for the pollutant loading analysis, and also provides a general discussion on effects to listed fish (flow alterations, base flow alterations, hyporheic movements alteration, erosion and sedimentation, temperature, and contaminants.

    - An appendix of this report provides clarification on the modeling results presented in the report.

      - The assumptions associated with and the results from the models presented in this report were subsequently replaced by other models that analyzed concentrations and loading by threshold discharge area. See Appendix A for the Concentration and Load calculator that was developed by WSDOT.

      - In addition, several iterations of dilution models were subsequently run by WSDOT using Ecology's

RIVPLUM and TSDCALC spreadsheets to determine extent of impacts within surface waters (mixing zones) in the action area. The results for these newer models were incorporated into the USFWS Biological Opinion.

- Dilution modeling results were submitted to the Services in December 4, 2006. Additional analysis was provided to the Services on December 19, 2006 in Hylebos Creek and Hylebos Waterway. An update was sent on February 26, 2007 for analyses in Hylebos Creek and the Puyallup River.

- 2nd and 3rd drafts of the project Pathways of Exposure matrix
  - The final matrix are contained in the USFWS biological opinion Appendix A.

- Annual infiltration volume before and after the project (including proposed compost amended filter strips).
  - This analysis initially did not account for evapotranspiration. As a result, infiltration was initially over-estimated.
  - To account for evapotranspiration, the analysis was repeated, incorporating runoff, interflow and infiltration values from Beyerlein (1999). As is summarized above in the USFWS biological opinion. The analysis completed by WSDOT differs from that completed by USFWS. The results and assumptions of the WSDOT analysis are summarized below:
    - Annual infiltration is approximately equivalent before (120.1 acre-feet) and after (122.5 acre-feet) the project with CAVFS and flow dispersion BMPs.
      - In the Puyallup River sub-basin a small decrease in infiltration volume from 223.4 ac-ft to 196.2 ac-ft (27.3 ac0ft) is anticipated.
    - All unit water balance values are from the Beyerlein paper except “Impervious with Dispersion or Overland Flow.”
    - Impervious with Dispersion or Overland Flow values are from WSDOT’s MSG Flood model of impervious area

discharging to a 24-foot CAVFS on 6H:1V slopes with 1-foot soil amendment depth over till. The flow onto the CAVFS is preceded by a 2-foot wide gravel shoulder. The model of CAVFS indicates 88% of runoff will be infiltrated (4,825 ac-ft out of 5,400 ac-ft total inflow volume are infiltrated).

  - MSG Flood modeling results were also provided to the services with these results.

- Beyerlein paper modeled 40.70 inches of rainfall per year on till soils.

  - There were several emails sent clarifying if in fact it could be assumed that the Beyerlein paper was based on till and also that till soils were present in the action area. The paper does not explicitly identify the soil type as till but it is evident from the runoff until values that till soils were used (email dated March 5, 2007 from Ken Ludwa to Emily Teachout). A soil type assessment confirmed that classifying project area soils as till in the hydrologic model was justified. Type B and C soils were present in the project area. The WSDOT MSG Flood manual classifies these soil types as till for modeling purposes.

- Unit value for Impervious with Standard BMPs is conservative, as it does not account for infiltration that would occur in treatment wetlands, open ponds and ditches.

- Surface runoff and interflow are counted together as direct runoff – runoff that occurs shortly after a precipitation event and reaches receiving waters quickly rather than infiltrating.

- Unit infiltration values account for evapotranspiration.

- It will be possible to treat more of the impervious area with dispersion and overland flow BMPs than previously thought.

- Not all infiltrated water is expected to be expressed as streamflow. In an HSPF calibration of 3 basins in Pierce County, a portion of infiltrated water joined a deeper aquifer rather than contributing to stream flow.

APPENDIX C

FHWA Method

Appendix C–FHWA Method

Computational steps for estimating annual pollutant loading using the FHWA Method are as follows:

Step 1: Convert SMC to average event mean concentration:

$$C_m = C_{med} * (1+CV_2)_{0.5}$$

Where:

C_m = Average Event Mean Concentration
C_{med} = Site Median Pollutant Concentration (From Table C1)
CV = Coefficient of Variation of Event Mean Concentration (See Note.)

(Note: According to FHWA (1996), a CV value of 0.75 is generally a good estimate for all highway sites and all pollutants. A value of 0.71 may be used for urban highways, while a value of 0.84 may be used for rural locations.)

Step 2: Calculate site runoff volume:

$$V_{ms} = Rv \; x \; H_{ms} \; x \; A \; x \; 10$$

Where:

V_{ms} = Volume of runoff for mean storm event (m_3)
Rv = Runoff coefficient, which is equal to 0.007 x I + 0.10, where I is the percent impervious area
H_{ms} = Rainfall volume for mean storm event (mm), for the Seattle area this value is 11.7 mm
A = Area (hectares)

Step 3: Calculate the mean event mass pollutant load:

$$L_m = C_m \; x \; (V_{ms}/1000)$$

Where:

L_m = Mean pollutant mass loading (Kg per event)
C_m = Average Event Mean pollutant concentration (mg/L)
V_{ms} = Volume of rainfall for mean storm event (m_3)

Step 4: Calculate the annual load:

$$L_a = L_m \times N_s$$

Where:

L_m = Mass load for mean event (Kg per event)
N_s = Number of storms per year (For the Seattle area this value is 86.7)
L_a = Annual mass loading of pollutant (kg/yr)

Table C1. Site median concentrations (in mg/L) for pollutants in highway runoff.

Pollutant	Percent of sites having a median EMC less than indicated concentration				
	10% of Sites	20% of Sites	50% of Sites	80% of Sites	90% of Sites
Urban (>30,000 ADT)					
TSS	68	88	142	230	295
TKN	1.06	1.27	1.83	2.62	3.17
PO4-P	0.15	0.21	0.40	0.76	1.06
Copper	0.025	0.032	0.054	0.091	0.119
Zinc	0.192	0.231	0.329	0.469	0.564
Rural (<30,000 ADT)					
TSS	12	19	41	90	135
TKN	0.34	0.47	0.87	1.59	2.19
PO4-P	0.06	0.08	0.16	0.33	0.48
Copper	0.010	0.013	0.022	0.038	0.050
Zinc	0.035	0.046	0.080	0.139	0.185

Source: FHWA 1990.
TSS: Total suspended solids
TKN: Total Kjeldahl nitrogen
PO4-P: Phosphate
mg/L: milligrams/liter

Table C2. Pollutant removal efficiencies for various urban BMP designs.

BMP/Design		Susp. Sediment	Total Phosphorus	Total Nitrogen	Oxygen Demand	Trace Metals	Bacteria	Overall Removal Capability
Extended Detention Pond	Design 1	60-80	20-40	20-40	20-40	40-60	Unknown	Moderate
	Design 2	80-100	40-60	20-40	40-60	60-80	Unknown	Moderate
	Design 3	80-100	60-80	40-60	40-60	60-80	Unknown	High
Wet Pond	Design 4	60-80	40-60	20-40	20-40	20-40	Unknown	Moderate
	Design 5	60-80	40-60	20-40	20-40	60-80	Unknown	Moderate
	Design 6	80-100	60-80	40-60	40-60	60-80	Unknown	High
Infiltration Trench	Design 7	60-80	40-60	40-60	60-80	60-80	60-80	Moderate
	Design 8	80-100	40-60	40-60	60-80	80-100	60-80	High
	Design 9	80-100	60-80	60-80	80-100	80-100	80-100	High
Infiltration Basin	Design 7	60-80	40-60	40-60	60-80	40-60	60-80	Moderate
	Design 8	80-100	40-60	40-60	60-80	80-100	60-80	High
	Design 9	80-100	60-80	60-80	80-100	80-100	80-100	High
Porous Pavement	Design 7	40-60	60-80	40-60	60-80	40-60	60-80	Moderate
	Design 8	80-100	60-80	60-80	60-80	80-100	60-80	High
	Design 9	80-100	60-80	60-80	80-100	80-100	80-100	High
Water Quality Inlet	Design 10	0-20	Unknown	Unknown	Unknown	Unknown	Unknown	Low
Filter Strip	Design 11	20-40	0-20	0-20	0-20	20-40	Unknown	Low
	Design 12	80-100	40-60	40-60	40-60	80-100	Unknown	Moderate
Grassed Swale	Design 13	0-20	0-20	0-20	0-20	0-20	Unknown	Low
	Design 14	20-40	20-40	20-40	20-40	0-20	Unknown	Low

Design 1: First-flush runoff volume detained for 6-12 hours.
Design 2: Runoff volume produced by 25 mm (1.0 in) detained 24 hours.
Design 3: As in Design 2, but with shallow marsh in bottom stage.
Design 4: Permanent pool equal to 13 mm (0.5 in) storage per impervious acre.
Design 5: Permanent pool equal to 2.5 (Vr); where Vr = mean storm runoff.
Design 6: Permanent pool equal to 4.0 (Vr); approximately 2-week retention.
Design 7: Facility exfiltrates first-flush; 13 mm (0.5 in) runoff/impervious acre.
Design 8: Facility exfiltrates 25 mm (1 in) runoff volume per impervious acre.
Design 9: Facility exfiltrates all runoff, up to the 2-yr design storm.
Design 10: 11 m3 (400 ft^3) wet storage per impervious acre.
Design 11: 6 m (20 ft) wide turf strip. Design 12: 30 m (100 feet) wide forested strip, with level spreader.
Design 13: High-slope swales with no check dams. Design 14: Low-gradient swales with check dams.
Source: Schueler 1987

APPENDIX D

Simple Method

Appendix D–Simple Method

Computational steps for estimating annual pollutant loading using the Simple method are as follows:

Step 1: Calculate runoff depth:

$$R = (H \times P_j \times R_v)/12 \times (A)$$

Where:

$R_v = 0.05 + 0.009\ (I)$
R = Runoff depth (acre-feet) over the defined time interval
H = Rainfall amount over time interval or for defined storm event (inches). (Use the average annual precipitation when calculating annual loads.)
P_j = Percentage of storms over time interval that produce runoff
R_v = Runoff Coefficient (Ratio of runoff to rainfall)
12 = Conversion factor (inches to feet)
A = Drainage area (acres)
I = Percent Impervious

For this method the runoff coefficient is calculated from the impervious area. The most troublesome part of this equation is often the Pj value. This parameter provides a means of correcting for those rainfall events that do not produce runoff. A reasonable conservative assumption can be made for this value. A value of 0.9 is recommended for seasonal or annual calculations (Schueler 1987). In the case of a highway that is entirely impervious and a discipline study where the analyst may want to err on the conservative side, a value of 1.0 could also be justified. If the equation is used to estimate runoff for a single storm event, that is larger than 0.5 inches in size, Pj should also equal 1.0.

Step 2: Runoff depth can be converted to discharge:

$$Q = (R)\ (0.504)$$

Where:

Q = Discharge (ft^3/sec/day)
0.504 = Conversion factor

Step 3: Calculate the pollutant load:

$$L=(Q)\ (C) \times 5.39$$

Where:

L = Mass load over time interval (pounds)
C = Flow-weighted mean concentration of the pollutant in the runoff (mg/L) (refer to Table D1)
5.39 = Conversion factor

If runoff depth and discharge are not required, these equations can be simplified to one equation for pollutant load:

$$L=((H \times P_j \times R_v)/12) \times (C)*2.72$$

To convert to metric units use the following conversions:

Q (ft^3/sec) * 0.028 = Q (m^3/sec)
L (pounds) * 0.454 = L (kg)

Table D1. Urban C values (in mg/L) for use with the Simple Method.

Pollutant	National Urban Highway Runoff	New Suburban NURP Sites (Wash., D.C.)	Older Urban Areas (Baltimore)	Central Business District (Wash., D.C.)	National NURP Study Average	Hardwood Forest (Northern Virginia)
Phosphorus						
Total	--	0.26	1.08	--	0.46	0.15
Ortho	--	0.12	0.26	1.01	--	0.02
Soluble	0.59	0.16	--	--	0.16	0.04
Organic	--	0.10	0.82	--	0.13	0.11
Nitrogen						
Total	--	2.00	13.6	2.17	3.31	0.78
Nitrate	--	0.46	8.9	0.84	0.96	0.17
Ammonia	--	0.26	1.1	--	--	0.07
Organic	--	1.25	--	--	--	0.54
TKN	2.72	1.51	7.2	1.49	2.35	0.61
COD	124.0	--	163		90.8	>40.0
BOD (5-day)	--	--	--	36	11.9	--
Metals						
Zinc	0.380	0.037	.397	0.250	0.176	--
Copper	--	--	0.105	--	0.47	--

TKN: Total Kjeldahl nitrogen
COD: Chemical oxygen demand
BOD: Biological oxygen demand
mg/L: milligrams/liter
Source: Schueler 1987.

APPENDIX E

Annual Pollutant Loads for Untreated Highway Runoff from the 2005 and 2007 WSDOT Environmental Procedures Manuals

Appendix E–Annual Pollutant Loads for Untreated Highway Runoff from the 2005 and 2007 WSDOT Environmental Procedures Manuals

Table E1. Annual pollutant loads from untreated and treated highway from the 2005 Environmental Procedures Manual (WSDOT 2005b).

Pollutant	Mean Load for Untreated Runoff (pounds/acre/year)	Mean Load for Treated Runoff (pounds/acre/year)
Total Suspended Solids	878 (range 350 - 2,000)	41 (range 40- 42)
Total Phosphorus	1.3 (range 0.6 – 2.9)	0.3 (range 0.26 – 0.32)
Total Copper	0.2 (range 0.1 – 0.3)	0.05 (range 0.045 – 0.055)
Total Zinc	1.1 (range 0.5 – 1.8)	0.25 (range 0.23 – 0.29)

Table E2. Annual pollutant loads from untreated and treated highway from the 2007 Environmental Procedures Manual (WSDOT 2007b).

Pollutant	Mean Load for Untreated Runoff (pounds/acre/year)	Mean Load for Treated Runoff (pounds/acre/year)
Total Suspended Solids	825	58
Total Phosphorus	1.2	0.3
Total Copper	0.2	0.05
Dissolved Copper	0.05	0.03
Total Zinc	1.1	0.25
Dissolved Zinc	0.35	0.17

Table E3. Annual pollutant loads from untreated and treated highway from the WSDOT BA Writers Guidance for Preparing Stormwater Section of Biological Assessments (WSDOT 2006).

Pollutant	Mean load from Untreated runoff	Mean load from Treated runoff
Total Suspended Solids	565	45
Total Zinc	1.1	0.28
Dissolved Zinc	0.4	0.2
Total Copper	0.2	0.065
Dissolved Copper	0.053	0.035

APPENDIX F

Example of Weighted Concentration Method

Appendix F–Example of Weighted Concentration Model

Example Calculation for the Level Two Stormwater Analysis as described in the *BA Writers Guidance for Preparing the Stormwater Section of Biological Assessments* (WSDOT 2006b):

> Project with 4 acres of existing impervious surface, 1 acre of which is currently infiltrated, 1 acre is treated and discharged to a surface water body, and 2 acres are untreated. The project will retrofit 1 acre of existing impervious and add 1.5 acres of new impervious, all of which will be treated prior to discharge into a water body. Treatment is consistent with HRM 'enhanced' treatment. ADT is 30,000 (moderate risk).
>
> *The pre-project pollutant concentration for TSS is:*
>
> (2 acres untreated * 93 mg/l) + (1 acre treated * 6.4 mg/l) / 3 acres = 64.13 mg/l
>
> *The post-project pollutant concentration for TSS is:*
>
> (1 acre untreated * 93 mg/l) + (3.5 acres treated * 6.4 mg/l) / 4.5 acres = 25.64 mg/l
>
> *The pollutant concentration reduction for TSS is:*
>
> 25.64 mg/l - 64.13 mg/l = -38.49 mg/l
>
> This example has a net concentration reduction for TSS as well as total copper, total zinc, dissolved copper, and dissolved zinc (not shown).

APPENDIX G

Pollutant Loading and Concentration Calculator

DATA ENTRY - enter acreages into yellow cells, look at 'load' and 'concentration' tabs for results

	THRESHOLD DISCHARGE AREA (TDA)										*TOTAL (acres)*
	1	2	3	4	5	6	7	8	9	10	
EXISTING IMPERVIOUS											
PRE-PROJECT											
Existing **treated** impervious surface **with discharge** to waterbody (acres)											*0.00*
Existing impervious surface **infiltrated** (acres)											*0.00*
Existing **untreated** impervious surface (acres)											*0.00*
Total existing impervious surface (acres)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
POST-PROJECT											
Existing impervious surface **retrofitted** for treatment **with discharge** to waterbody (acres)											*0.00*
Existing impervious surface **retrofitted for infiltration** (acres)											*0.00*
NEW IMPERVIOUS											
New **treated** impervious surface **with discharge** to waterbody (acres)											*0.00*
New impervious surface **infiltrated** (acres)											*0.00*
New **untreated** impervious surface (acres)											*0.00*
Total new impervious surface (acres)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*0.00*
TOTAL IMPERVIOUS											
Total impervious surface area **untreated** post-project (acres)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Total impervious surface area **treated** post-project with discharge to waterbody (acres)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Total impervious surface area **infiltrated** (acres)	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*

Revised September 2006

LOAD CALCULATIONS

LOAD RATES	TSS	TOTAL ZINC	DISSOLVED ZINC	TOTAL COPPER	DISSOLVED COPPER
Mean annual load from untreated surfaces (lbs/acre)	565	1.1	0.4	0.2	0.053
Mean annual load from treated surfaces (lbs/acre)	45	0.28	0.2	0.065	0.035

PROJECT TOTAL	TSS	TOTAL ZINC	DISSOLVED ZINC	TOTAL COPPER	DISSOLVED COPPER
Annual effluent load from existing impervious surfaces prior to project (lbs)	0.00	0.00	0.00	0.00	0.00
Annual effluent load from new and existing impervious surfaces after project (lbs)	0.00	0.00	0.00	0.00	0.00
NET CHANGE in pollutant loads between pre- and post-project conditions (lbs)	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

TDA BREAKDOWN	TSS	TOTAL ZINC	DISSOLVED ZINC	TOTAL COPPER	DISSOLVED COPPER
TDA 1					
Annual effluent load from existing impervious surfaces prior to project (lbs)	0.00	0.00	0.00	0.00	0.00
Annual effluent load from new and existing impervious surfaces after project (lbs)	0.00	0.00	0.00	0.00	0.00
NET CHANGE (lbs)	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
TDA 2					
Annual effluent load from existing impervious surfaces prior to project (lbs)	0.00	0.00	0.00	0.00	0.00
Annual effluent load from new and existing impervious surfaces after project (lbs)	0.00	0.00	0.00	0.00	0.00
NET CHANGE (lbs)	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
TDA 3					
Annual effluent load from existing impervious surfaces prior to project (lbs)	0.00	0.00	0.00	0.00	0.00
Annual effluent load from new and existing impervious surfaces after project (lbs)	0.00	0.00	0.00	0.00	0.00
NET CHANGE (lbs)	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
TDA 4					
Annual effluent load from existing impervious surfaces prior to project (lbs)	0.00	0.00	0.00	0.00	0.00
Annual effluent load from new and existing impervious surfaces after project (lbs)	0.00	0.00	0.00	0.00	0.00
NET CHANGE (lbs)	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
TDA 5					
Annual effluent load from existing impervious surfaces prior to project (lbs)	0.00	0.00	0.00	0.00	0.00
Annual effluent load from new and existing impervious surfaces after project (lbs)	0.00	0.00	0.00	0.00	0.00
NET CHANGE (lbs)	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
TDA 6					
Annual effluent load from existing impervious surfaces prior to project (lbs)	0.00	0.00	0.00	0.00	0.00
Annual effluent load from new and existing impervious surfaces after project (lbs)	0.00	0.00	0.00	0.00	0.00
NET CHANGE (lbs)	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
TDA 7					
Annual effluent load from existing impervious surfaces prior to project (lbs)	0.00	0.00	0.00	0.00	0.00
Annual effluent load from new and existing impervious surfaces after project (lbs)	0.00	0.00	0.00	0.00	0.00
NET CHANGE (lbs)	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
TDA 8					
Annual effluent load from existing impervious surfaces prior to project (lbs)	0.00	0.00	0.00	0.00	0.00
Annual effluent load from new and existing impervious surfaces after project (lbs)	0.00	0.00	0.00	0.00	0.00
NET CHANGE (lbs)	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
TDA 9					
Annual effluent load from existing impervious surfaces prior to project (lbs)	0.00	0.00	0.00	0.00	0.00
Annual effluent load from new and existing impervious surfaces after project (lbs)	0.00	0.00	0.00	0.00	0.00
NET CHANGE (lbs)	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
TDA 10					
Annual effluent load from existing impervious surfaces prior to project (lbs)	0.00	0.00	0.00	0.00	0.00
Annual effluent load from new and existing impervious surfaces after project (lbs)	0.00	0.00	0.00	0.00	0.00
NET CHANGE (lbs)	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

CONCENTRATION CALCULATIONS - Moderate Risk Projects

	TSS (mg/L)	TOTAL ZINC (ug/L)	DISSOLVED ZINC (ug/L)	TOTAL COPPER (ug/L)	DISSOLVED COPPER (ug/L)
Expected pollutant concentrations for UNTREATED runoff	93	174	62	31	7.6
Expected pollutant concentrations for TREATED runoff	6.4	40	27	7	5

PROJECT TOTAL	TSS (mg/L)	TOTAL ZINC (ug/L)	DISSOLVED ZINC (ug/L)	TOTAL COPPER (ug/L)	DISSOLVED COPPER (ug/L)
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE in pollutant concentration between pre- and post-project conditions					

TDA BREAKDOWN	TSS (mg/L)	TOTAL ZINC (ug/L)	DISSOLVED ZINC (ug/L)	TOTAL COPPER (ug/L)	DISSOLVED COPPER (ug/L)
TDA 1					
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE					
TDA 2					
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE					
TDA 3					
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE					
TDA 4					
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE					
TDA 5					
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE					
TDA 6					
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE					
TDA 7					
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE					
TDA 8					
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE					
TDA 9					
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE					
TDA 10					
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE					

CONCENTRATION CALCULATIONS - High Risk Projects

	TSS (mg/L)	TOTAL ZINC (ug/L)	DISSOLVED ZINC (ug/L)	TOTAL COPPER (ug/L)	DISSOLVED COPPER (ug/L)
Expected pollutant concentrations for UNTREATED runoff	192	350	110	59	14
Expected pollutant concentrations for TREATED runoff	14	67	44.8	12	7.8

PROJECT TOTAL	TSS (mg/L)	TOTAL ZINC (ug/L)	DISSOLVED ZINC (ug/L)	TOTAL COPPER (ug/L)	DISSOLVED COPPER (ug/L)
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE in pollutant concentration between pre- and post-project conditions					

TDA BREAKDOWN	TSS (mg/L)	TOTAL ZINC (ug/L)	DISSOLVED ZINC (ug/L)	TOTAL COPPER (ug/L)	DISSOLVED COPPER (ug/L)
TDA 1					
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE					
TDA 2					
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE					
TDA 3					
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE					
TDA 4					
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE					
TDA 5					
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE					
TDA 6					
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE					
TDA 7					
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE					
TDA 8					
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE					
TDA 9					
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE					
TDA 10					
Pollutant concentation for runoff PRE-project					
Pollutant concentation for runoff POST-project					
NET CHANGE					