

**HIGHWAY RUNOFF DILUTION AND
LOADING MODEL USER'S GUIDE**

Analysis of Highway Stormwater Runoff
Effects for Endangered Species Act
Consultations

Prepared for

Washington State Department of Transportation

January 2011

Note:

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Effects for Endangered Species Act
Consultations

Prepared for

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How the HI-RUN Model Was Developed

To support the preparation of biological assessments for Endangered Species Act (ESA) Section 7 consultations for highway and other transportation-related construction projects, a technically valid analytical approach is needed for assessing the potential water quality effects of highway runoff on ESA-listed aquatic species. This approach must be practical enough to apply at early stages in a project's design process, and provide a meaningful way to identify when potential impacts may occur and whether those impacts are likely to be significant. Furthermore, to adequately support the ESA consultation process, this approach must reflect the "best available scientific and commercial information".

To address this need, the Washington State Department of Transportation (WSDOT) initiated a joint project with the Federal Highway Administration (FHWA), the U.S. Fish and Wildlife Service (USFWS), and the National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NOAA Fisheries) to develop a mutually acceptable approach for assessing the potential water quality effects of highway runoff on ESA-listed aquatic species. To begin this process, four white papers (Herrera 2007a, 2007b; GeoSyntec 2008; Pacific EcoRisk 2008) were prepared to summarize the current state of knowledge in each of the following areas:

- Pollutants found in untreated highway runoff
- Pollutants found in treated highway runoff
- Bioavailability of pollutants in treated highway runoff and their effects on ESA-listed fish species
- Currently or recently used analytical approaches for assessing potential water quality effects of highway runoff on ESA-listed aquatic species

Agency representatives discussed these white papers at a series of workshops to review available information, promote a shared understanding of potential water quality effects of highway runoff on listed species, evaluate assessment methods, and reach consensus. These white papers and workshop discussions were the basis for identifying key attributes to incorporate into any new approach for assessing potential water quality effects of highway runoff on ESA-listed aquatic species.

To ensure adequate review and collective agreement by the involved agencies at critical milestones in the process, the development of this new approach proceeded in two phases. The first phase was development of a technical approach for estimating pollutant concentrations and loads in highway runoff at the point of discharge to receiving waters (i.e., end-of-pipe), and the second phase was development of a technical approach for quantifying pollutant concentrations in receiving waters after mixing and dilution.

This work culminated in the development of a spreadsheet model to support the consultation process for western Washington transportation projects, the Highway Runoff Dilution and Loading (HI-RUN) model. Based on feedback from the multi-agency workgroup, the HI-RUN model can:

- Be used with the limited amount of data available at the design phase of a highway project
- Be used to estimate the probability that a specific pollutant concentration will be observed at outfalls that are discharging treated or untreated highway runoff
- Be used to estimate the probability of discharge durations observed during individual storm events in any given month of the year at outfalls that are discharging treated and/or untreated highway runoff
- Be used to estimate the probability that annual pollutant loads from the proposed highway project will exceed those from baseline conditions
- Incorporate information on the treatment efficiency of specific best management practices (BMPs) for estimating pollutant loads and concentrations
- Incorporate infiltration losses of specific BMPs for estimating pollutant loads and concentrations

With these capabilities, the loadings and concentrations of select water quality constituents in highway runoff can be predicted probabilistically, and the potential effects of these constituents on ESA-listed aquatic species can now be assessed using a risk-based approach. Specifically, the HI-RUN model permits the user to determine the probability that an identified threshold of concern could be exceeded given underlying uncertainties associated with the water quality and hydrologic data that stem from natural temporal and spatial variability (e.g., variations in the size of storm events across a given region) and measurement variability (e.g., laboratory analytical imprecision). This differs from previous approaches used in ESA Section 7 consultations, which used a single representative value to determine whether a threshold of concern was exceeded while not considering data uncertainty in this prediction.

This document is the user's guide for using the HI-RUN model to assess the potential water quality effects of highway runoff on ESA-listed aquatic species. More detailed technical documentation describing the development and analytical routines of the HI-RUN model is provided in a separate document, *HI-RUN Technical Documentation* (Herrera 2008).

How the HI-RUN Model Works

The HI-RUN model provides risk-based predictions of runoff quality at the individual outfall, threshold discharge area (TDA), and project scales.

TDA's are onsite areas draining to a single natural discharge location, or multiple natural discharge locations that combine within 1/4 mile downstream (as determined by the shortest flow path). The *Highway Runoff Manual* (WSDOT 2008b) discusses TDA delineation specific to transportation-related drainage systems. The HI-RUN model can analyze the following water quality parameters:

- Total suspended solids (TSS)
- Total copper (TCu)
- Dissolved copper (DCu)
- Total zinc (TZn)
- Dissolved zinc (DZn)

The HI-RUN model can be used to conduct two types of analysis of the above parameters:

1. End-of-Pipe Loading Subroutine

Evaluation of baseline and proposed pollutant loading values from a specific TDA or the entire project area. This subroutine also provides evaluation of baseline and proposed pollutant concentrations at specific outfall discharge locations.

2. Receiving Water Dilution Subroutine

Evaluation of baseline and proposed DCu and DZn concentrations at specific outfall discharge locations after mixing in the associated receiving water. Like the concentration analysis portion of the end-of-pipe loading subroutine, the dilution analysis is conducted at a "subbasin" scale, and uses a hydraulic mixing model (RIVPLUM6) to estimate dilution factors based on the project's stormwater discharge, receiving water flow, and channel conditions/characteristics. This analysis is applicable for discharges to relatively shallow, unidirectional waters (e.g., streams and rivers). If a project discharges to a lake or estuarine water body, this subroutine is not applicable, and a separate mixing model (outside of HI-RUN) would be required to estimate mixing zone distance. (The recommended model is CORMIX, available from MixZon Inc.: <http://www.mixzon.com>.)

In this guide, *baseline conditions* means the water quality within the receiving water downstream of any discharges from the project action area and before construction of the proposed project. *Proposed conditions* are the water quality within the receiving water downstream of any

discharges from the project action area after construction of the proposed project. Finally, *background conditions* are water quality conditions upstream of any discharges originating from the action area both before and after construction of the proposed project.¹

A Risk-Based Analysis Approach

The approach for assessing potential water quality effects of highway runoff on ESA-listed aquatic species that is described in this guide is based on risk, meaning that the risk, or more precisely, the probability of a particular “undesirable event” is calculated by taking into account known variability or uncertainty associated with hydrologic and water quality conditions. In the case of highway runoff water quality, the undesirable event is a detrimental effect on an ESA-listed aquatic species.

Previous analytical approaches for assessing potential water quality effects of highway runoff on ESA-listed aquatic species (e.g., WSDOT 2008a) used a deterministic model that relied on fixed, conservative estimates of input parameters to determine whether a detrimental project-related effect is likely. However, these approaches did not provide a clear understanding of the underlying uncertainty associated with the resulting prediction. Furthermore, the cumulative effect of incorporating multiple conservative “worst-case” assumptions into the model likely caused the predicted effect to be unrealistically high.

In contrast to these previous approaches, the analytical approach presented herein uses a probabilistic model to determine the likelihood or “risk” of a detrimental effect based on the underlying uncertainty associated with the data for each input variable. The uncertainty can come from a number of different sources including natural temporal and spatial variability, and measurement variability (e.g., laboratory analytical imprecision). Once this risk has been quantified, it can be compared to a predefined threshold for determining risk acceptance.

In practice, the underlying uncertainty associated with the data for each input variable is reflected in their associated distributions. A probability distribution expresses the likelihood that a particular value will be observed for each input variable across all possible values. Figure 1 presents a graphical representation of a probability distribution for a hypothetical input variable using a histogram. To generate this histogram, individual values for the hypothetical input variable are plotted against the frequency with which they occur. In this example, the value of 0.02 was observed on approximately 60 occasions whereas the value of 0.05 was observed on 10 occasions. Therefore, values of 0.02 have a higher likelihood of occurrence in this data set relative to values of 0.05.

To determine the risk of a detrimental effect based on the underlying uncertainties and variability associated with the data for each input variable, the HI-RUN model uses a probabilistic procedure called Monte Carlo simulation. Monte Carlo simulation is a method that estimates possible outcomes from a set of random variables by simulating a process a large number of

¹ These definitions are unique to the HI-RUN model. They are not the same as those contained in the definition for *Effects of the Action* in the implementing regulations of the Endangered Species Act (50 CFR § 402.02).

times and observing the outcomes. Using Monte Carlo simulation, the HI-RUN model calculates multiple model output scenarios by repeatedly sampling (or picking) values for each input variable from computer-generated probability distributions. In this way, a probability distribution can be derived for the model output that indicates which predicted values have a higher probability of occurrence. The probability of exceeding a specific threshold for detrimental effects also can be determined using this procedure.

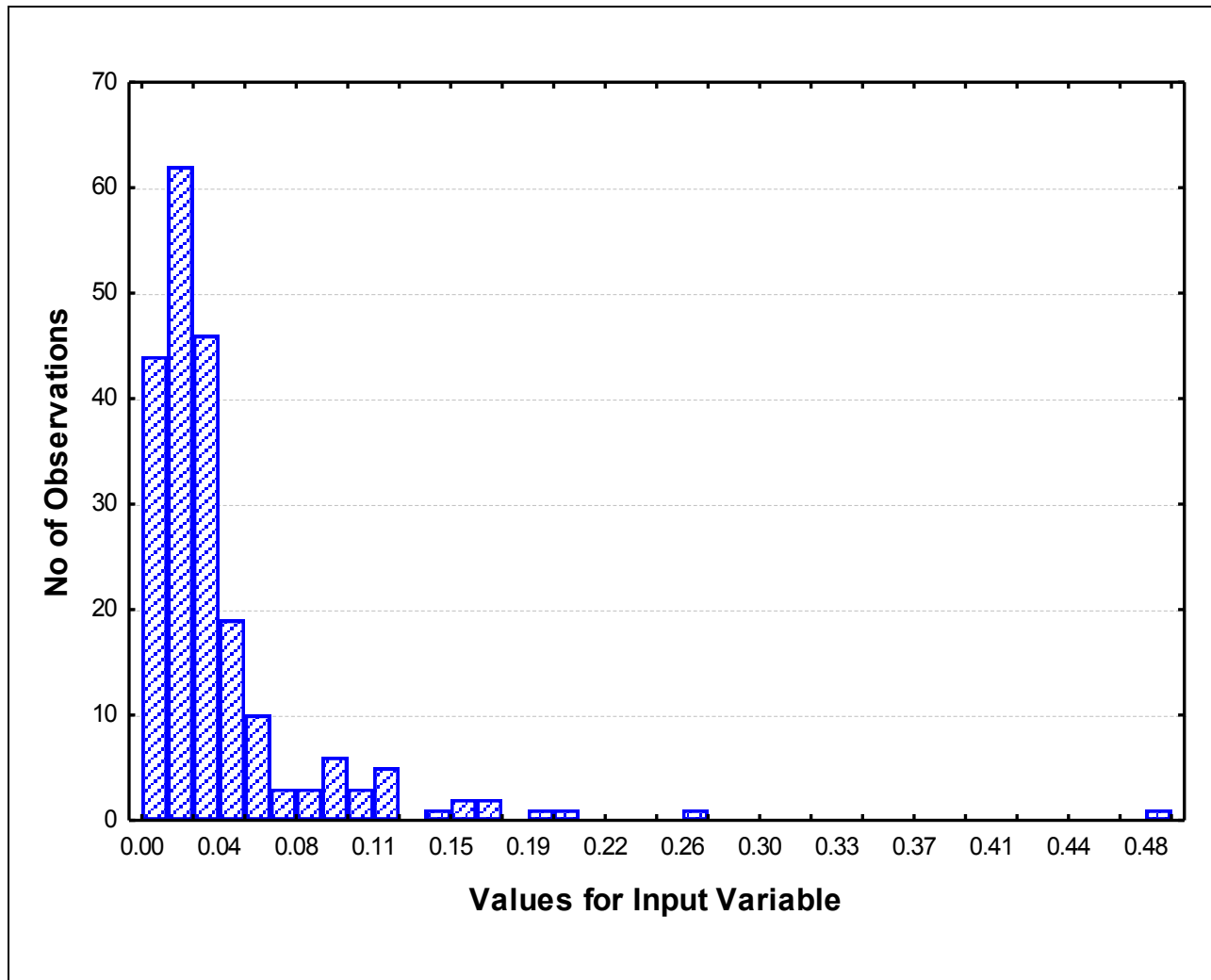


Figure 1. Graphical representation of a probability distribution for a hypothetical input variable using a histogram.

Figure 2 illustrates this approach using histograms for two hypothetical input variables to the model and a hypothetical histogram for the model output. Figure 2 also shows hypothetical input and output values superimposed on these histograms from a deterministic model that relies on fixed, conservative estimates for each input variable. As shown in this illustration, theoretical probability distributions are fit to the actual data for each input variable. These distributions are then sampled repeatedly in the Monte Carlo simulation with values having a higher likelihood of occurrence selected more often. It follows that the output from the Monte Carlo simulation will

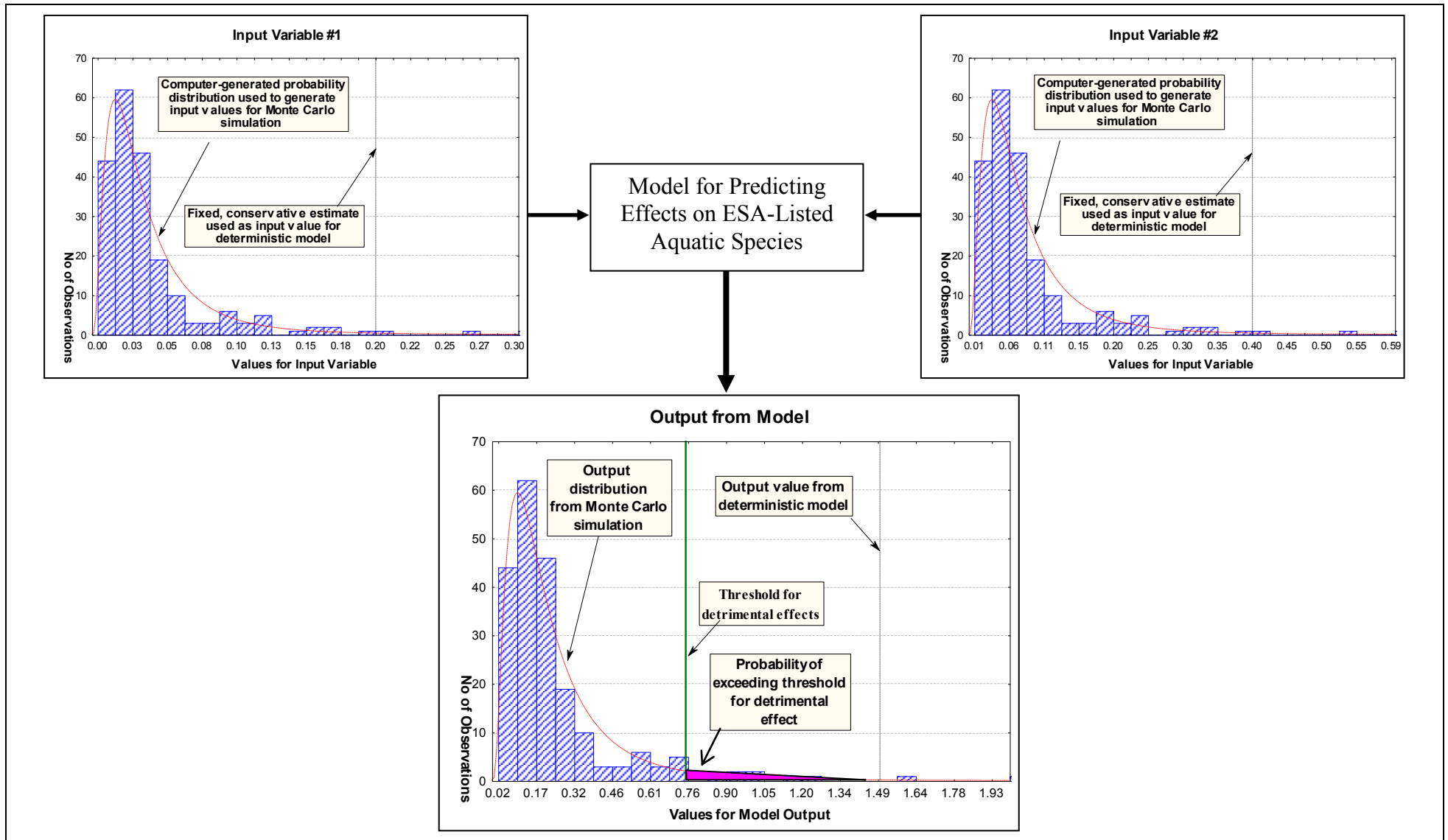


Figure 2. Simplified illustration showing risk-based modeling approach using Monte Carlo simulation versus deterministic modeling approach using fixed, conservative input variables.

also be a probability distribution that can be used to determine which output values have a higher likelihood of occurrence. The estimated risk of exceeding an actual threshold for detrimental effect can be quantified by determining the cumulative proportion of the probability distribution that exceeds this threshold (see Figure 2).

As illustrated in Figure 2, the output from a deterministic model that relies on a single value for each input variable will not capture any of the uncertainty that is reflected in the output from the probabilistic model. Furthermore, if conservative worst-case values are used for each input variable, the resultant output from the model may be unrealistically high.

In general, there is inherently a large amount of uncertainty associated with stormwater data that stems from various factors including site differences, seasonality, and storm events with different precipitation characteristics. Use of a risk-based approach for assessing water quality effects of highway runoff on ESA-listed aquatic species will ultimately improve the Section 7 consultation process because related decisions will be made based on the most probable outcome given this uncertainty in the underlying data.

Limitations

Though the HI-RUN model was specifically developed to address some of the shortcomings of previous analytical approaches used in ESA Section 7 consultations, it has limitations that should be considered in the consultation process. The most notable limitation is that pollutant concentrations in highway runoff are influenced by numerous factors, including site-specific conditions (e.g., proximity to urban areas, traffic volumes, and basin size), storm event characteristics (e.g., antecedent dry period, and precipitation depth), and regional weather patterns (Herrera 2007a). The quantity, timing, and duration of highway runoff are also influenced by similar factors. Because it is impossible to accurately predict how these factors may interact to affect highway runoff at any given site, their influence cannot be directly incorporated into the HI-RUN model.

Another limitation of the HI-RUN model is that the available water quality data used as input for the HI-RUN model were derived from a small number of monitoring locations and best management practice (BMP) types. Although these data are considered the most representative for this particular application, some extrapolation of the data is required to estimate pollutant concentrations for the full range of conditions that are likely to be encountered at highway projects in western Washington.

Given these limitations, HI-RUN model output is not intended to provide highly accurate estimates of pollutant concentrations for a specific project, but rather to provide a screening-level assessment of the risk of potential impacts on ESA-listed species due to highway runoff. When this assessment indicates that the potential risk exceeds a predefined threshold, a more detailed assessment of the project should be performed to determine if there are mitigating factors not reflected in the output of the HI-RUN model. This more detailed assessment would examine site

characteristics not accounted for in the HI-RUN model that would potentially reduce (or increase) water quality impacts (i.e., open conveyance, distance from outfall to receiving waterbody), quality and suitability of habitat for various life stages of species, and anticipated timing of discharges relative to the anticipated use and timing of species in the receiving waterbody. The Stormwater chapter in WSDOT's *Advanced Training Manual: Writing Biological Assessments for Transportation Projects* describes the process of analyzing stormwater impacts in detail.

Version History

An updated version of the HI-RUN model (version 2.0) was released in January 2011 to address issues that were raised during the first year of model implementation. This version included modifications to improve the HI-RUN model's ease of use and output clarity; however, the basic calculations that are at the core of HI-RUN model were not changed in this version relative to previous version. This guide provides detailed instructions on how to run version 2.0 of the HI-RUN model, and replaces the previous user's guide for the model (Herrera 2008b).

Basic Software Requirements

The HI-RUN model was developed using Microsoft Excel 2003 and may not work properly if run with an earlier version of this program. Because the HI-RUN model uses macro routines, the security level on the user's computer must be set to a level that allows macros to run. See the Using the HI-RUN Model section below for guidance.

Using the HI-RUN Model

Opening HI-RUN

To begin running HI-RUN, download the program from the WSDOT Biological Assessment Guidance web site at:

<http://www.wsdot.wa.gov/Environment/Biology/BA/BAguidance.htm#Stormwater> and save it to a local hard drive. HI-RUN is a Microsoft Excel spreadsheet application, so simply open the file to get started. Because HI-RUN uses Visual Basic macros to run, security settings within Excel may need to be changed. Graphical instructions on how to allow the macros to run will be visible on the “Instructions” tab when HI-RUN is opened. Figure 3 shows the screen as it appears to the user when HI-RUN is first opened. Note that there are three tabs at the bottom of the screen: “Instructions”, which explains how to enable macros; “Loading”, which is used to run the end-of-pipe loading subroutine; and “Dilution”, which is used to run the receiving water dilution subroutine. The instructions for enabling macros are repeated in the sections below.

Allowing Macros to Run on Excel 2003

In Microsoft Excel 2003, the appropriate security setting can be selected by navigating to the “Tools/Macros/Security” window and selecting a “Medium” security level. At this security level, the program will prompt the user for permission to run any macros. Simply select “enable macros” when prompted, and HI-RUN will function correctly.

Allowing Macros to Run on Excel 2007/2010

In Microsoft Excel 2007, the user will be prompted with a “Security Warning” banner at the top of the window (see Figure 3). Click the **Options...** button, and select “Enable this content” in the Microsoft Office Security Options window. In Microsoft Excel 2010, the user will be prompted with a banner at the top of the window that is similar to that in Excel 2007; click the **Enable Content** button to begin using the model.

Alternately, the user can navigate to the Microsoft Excel “Trust Center” to enable macros using the following steps:

1. Select the Microsoft button in the upper left hand corner of the Excel window (the button is round with a 4-color symbol)
2. Select the “Excel Options” button at the bottom of the drop-down menu
3. Select “Trust Center” on the left side of the Excel Options window
4. Select “Macro Settings” on the left side of the Trust Center window

5. Select “Enable all macros” temporarily while running HI-RUN. If you choose to select this, be sure that you reset the previous macro setting to protect your computer.

Managing Input and Output Files

Project information entered into the HI-RUN model can be saved for future use.

- **To save inputs** from the “Loading” sheet or from the “Dilution” sheet, click the **Save Inputs** button at the top of the page. Input settings are stored within the HI-RUN spreadsheet, not in separate files.
- **To retrieve saved inputs**, click the **Load Inputs** button. Note that inputs for the end-of-pipe loading calculator are saved separately from inputs for the receiving water dilution calculator.
- **To delete saved input settings**, click the **Load Inputs** button, select the desired setting, then click the **Delete Selected Settings** button.

The end-of-pipe loading calculator and the receiving water dilution calculator are run using the **Run Loading Model** and **Run Dilution Model** buttons at the top of the input sheets. Each time the model is run, the resulting output data is saved to a separate file, and you are prompted to save this data.

Using the End-of-Pipe Loading Subroutine

As described above, you can use the end-of-pipe loading subroutine to estimate baseline and proposed pollutant loading values from a specific TDA or the entire project area. The subroutine can also be used to estimate baseline and proposed pollutant concentrations at specific outfall discharge locations. Below are step-by-step instructions for running the end-of-pipe loading subroutine. The *Case Studies* section of this document provides examples of these steps.

Entering Inputs

To begin running the End of Pipe Loading subroutine, select the “Loading” sheet by clicking on the “Loading” tab at the bottom of the page. This sheet provides cells and menus for the users to enter model input values. The user can clear all inputs on the sheet using the **Clear TDA Inputs** button at the top of the screen. Previously saved input settings can also be retrieved using the **Load Inputs** button (see *Managing Input and Output Files* section above).

An example input page for the end-of-pipe loading subroutine is shown in Figure 4. In practice, many of these required inputs for the HI-RUN model will be obtained from the project hydraulic

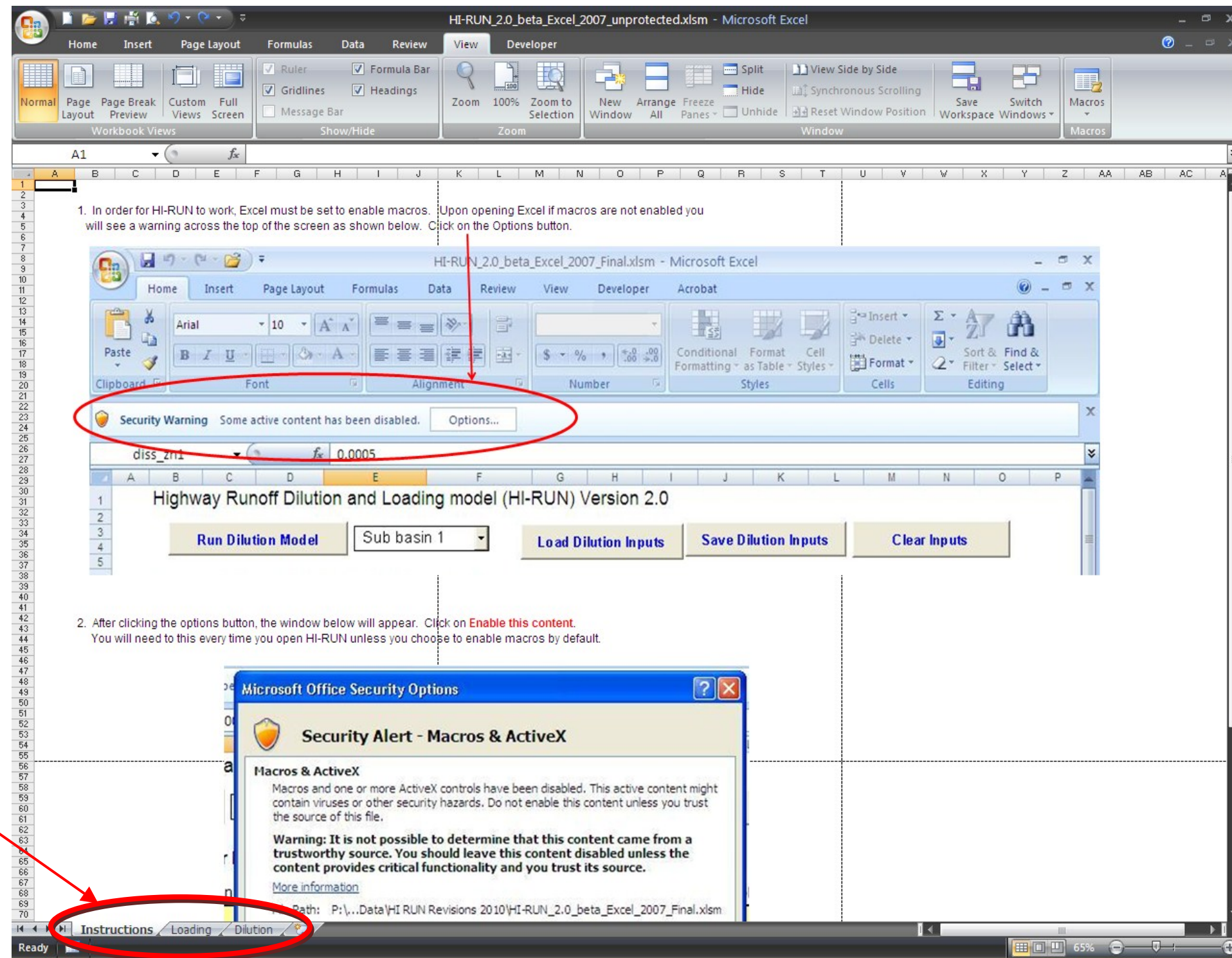


Figure 3. Instructions sheet in the HI-RUN model.

Highway Runoff Dilution and Loading model (HI-RUN) Version 2.0 For Excel 2007

This model is for stormwater analysis associated with biological assessments, and is not a design tool

Run Loading Model
Load Inputs
Save Inputs
Clear TDA Inputs

Data Inputs - End-of-Pipe Loading Subroutine

Description: This model provides risk-based predictions of stormwater quality at the outfall and Threshold Discharge Area (TDA) scale. The Highway Runoff Manual provides a thorough discussion of TDA delineation specific to transportation drainage systems. The analysis of water quality concentrations is conducted at a subbasin scale, with subbasins being divisions of TDAs that have discrete discharge points in the receiving water. If a TDA has only one discharge point, data need only be entered under Subbasin 1. The analysis of pollutant loadings is done at the TDA scale only. Water quality parameters analyzed by this tool are Total Suspended Solids (TSS), Total Copper (TCu), Dissolved Copper (DCu), Total Zinc (TZn), and Dissolved Zinc (DZn).

Press to Run

Project/TDA ID:

Precipitation Timeseries: Puget West 56 View Region Map

Water Quality Parameters

- All
- TSS
- Copper - Total
- Copper -Dissolved
- Zinc - Total
- Zinc - Dissolved

Month

- January
- February
- March
- April
- May
- June
- July
- August
- September
- October
- November
- December

TDA Information - Baseline Conditions							
Treatment Type	Level of Incidental Infiltration (%)	Subbasin Area (acres)					TDA Impervious Area (acres)
		1	2	3	4	5	
Basic	0						0
	20						0
	40						0
	60						0
	80						0
Enhanced	0						0
	20						0
	40						0
	60						0
Infiltration BMP	100						0
None	0	10					10
Total		10	0	0	0	0	10

TDA Information - Proposed Conditions							
Treatment Type	Level of Incidental Infiltration (%)	Subbasin Area (acres)					TDA Impervious Area (acres)
		1	2	3	4	5	
Basic	0						0
	20						0
	40						0
	60	2					2
	80						0
Enhanced	0						0
	20						0
	40						0
	60						0
Infiltration BMP	100	4					4
None	0	9					9
Total		15	0	0	0	0	15

Figure 4. Sample input page for the end-of-pipe loading subroutine of the HI-RUN model.

designer/engineer in the form of the *Endangered Species Act Stormwater Design Checklist*. However, the Biological Assessment author may need to work in coordination with the project hydraulic designer/engineer to generate all of the required inputs. This checklist should be downloaded from the WSDOT Biological Assessment Guidance web page, as it will be updated periodically. For reference, this checklist is provided in Appendix B along with additional detailed guidance on where to obtain the required input values.

Step 1. Enter Project/TDA Identification

Enter project location/identification in text box. Identify the project by state route (SR) and milepost (MP). An identifier for the TDA analyzed can also be included when multiple TDAs will be analyzed for a given project. This information should be provided on the *Endangered Species Act Stormwater Design Checklist*.

Step 2. Select Precipitation Timeseries

Select the precipitation time series most applicable to the project location in the pull-down menu. Options include Extended Precipitation Timeseries and individual rain gauge series. These timeseries match those used in the MGSFlood hydrologic model and can be determined by identifying the project location on a map included in the HI-RUN spreadsheet (press the **View Region Map** button) and in Appendix A.

On the precipitation map, the user will first determine whether the project is located in one of the three Extended Precipitation Timeseries zones (Puget West, Puget East, and Vancouver). If so, the user will then identify the nearest isopluvial line to the project location. The number displayed on the isopluvial line (the user may need to zoom into the graphic to read the numbers) is mean annual precipitation at 4-inch increments. The user then exits the precipitation map by pressing the **Go Back to Data Input Sheet** button, and selects the precipitation time series associated with the zone and mean annual precipitation of the project location (e.g., Puget East 40). If the project is located outside of the Extended Precipitation Timeseries zones, the user will identify the appropriate rain gauge for use at the project site (e.g., Montesano), then exit the precipitation map and select the appropriate precipitation time series/rain gauge.

Step 3. Select Water Quality Parameters

Select the water quality parameters of interest in the analysis. Any combination of one or more of these can be selected from a list box, using the **Shift** or **Ctrl** keys to choose more than one. The end-of-pipe loading subroutine can analyze TSS, TCu, DCu, TZn, and DZn; and loads for all five should be estimated and reported in the project Biological Assessment. However, the current stormwater quality effects analysis process is based on DCu and DZn only. The Biological Assessment should discuss how estimated loads of all five parameters change from baseline to proposed conditions, but this comparison should be more detailed and quantitative for DCu and DZn than for the other three parameters. The receiving water dilution subroutine analyzes DCu and DZn only.

Step 4. Select Months

Select the months of interest for which the HI-RUN subroutine will be run. To determine the months of interest, the user must determine when ESA-listed aquatic species could occur in the vicinity of the project. By running the routine for only the months of interest, the number of output data tables generated can be reduced. (Note: this affects the end-of-pipe concentration results and receiving water dilution subroutine results, but not the end-of-pipe loading estimates.)

Multiple months of interest can be selected from the list box using the **Shift** or **Ctrl** keys. The months of interest are those months during which fish could be present and potentially exposed to stormwater discharges. For species that do not show distinct seasonality (i.e., bull trout) or that are present within a system year-round (i.e., steelhead, residual Chinook), analyzing multiple months will be necessary. To determine what months are of interest, the biologist has to determine what life stages could occur in the vicinity of the project. The biologist can determine what life stages could potentially be affected by a project by determining the suitability of the habitat in the action area (area affected by the proposed project) for those life stages. In addition, the biologist should determine the timing of various life stages in the action area by reviewing available literature and reports, and contacting local tribal, agency, or jurisdictional biologists.

Step 5. Enter Baseline TDA Conditions

Enter the areas (in acres) of baseline (existing) impervious surfaces, according to the type of runoff treatment that is provided for stormwater from the areas (basic, enhanced, or no treatment), and the level of incidental infiltration associated with the treatment BMP (0, 20, 40, 60, or 80 percent). Incidental infiltration is characterized at these 20 percent increments to provide a level of flexibility to the model user while still reducing the level of effort required to develop the HI-RUN model. The *HI-RUN Model Technical Documentation* (Herrera 2008) provides more detail on the pre-processing work involved in developing the model.

Step 6. Enter Proposed TDA Conditions

Similar to the information provided in Step 5, enter areas of the proposed impervious drainage subbasin according to treatment BMP type and incidental infiltration rate. This information should be provided on the *Endangered Species Act Stormwater Design Checklist*.

Interpreting Outputs

Step 7. Run End-of-Pipe Loading Subroutine

After entering all of the above information into the input page, run the end-of-pipe loading subroutine by clicking the **Run Loading Model** button. The user will be asked whether flow control (detention) should be applied to the project TDA. If only one subbasin has values entered, the user simply selects “Yes” or “No”. If multiple subbasins have values entered, the user is prompted to select the subbasin in which the detention facility will be located. Select “No” or check the “No Flow Control” box if a detention facility is not planned. If a detention basin is to be constructed in the TDA, click “Yes” or select the subbasin in which it will be

located from the dropdown menu. Once the flow control information has been completed, click the **Run Analysis** button.

Before HI-RUN conducts the end-of-pipe loading analysis, an additional window (“Confirm Input Parameters”) will appear to prompt the user to review input data and provide text describing the model run as needed. The text entered in this box will be included in the output file to assist with documentation of results, and can include initials of the analyst and notes and assumptions associated with the input data entered.

When the analysis has been completed, HI-RUN will prompt the user to save the output file. The end-of-pipe loading subroutine output file consists of a “Results” summary sheet and individual sheets with concentration results for each subbasin analyzed. The loading results include the following summary statistics for each selected parameter for baseline and proposed conditions in the project TDA:

- Maximum load (pounds per year [lb/yr])
- 75th percentile load (lb/yr)
- Median load (lb/yr)
- 25th percentile load (lb/yr)
- Minimum load (lb/yr)

The maximum values provide a worst-case load estimate for comparing the baseline and proposed conditions. The percentile values provide an indication of the overall distribution of the loading estimates. For example, the 75th percentile value represents the load estimate at which 75 percent of the values will be lower and 25 percent will be higher. For reference, Figure 5 provides an example of this summary table with data from a hypothetical TDA.

In addition, the model compares numerous individual loading estimates from the Monte Carlo simulation to determine the probability that loading for the proposed project will exceed loading for the baseline condition. This probability is referred to as the P(exceed) value in the summary table for the model output (see Figure 5). By way of example, a P(exceed) value of 0.07 for a specific parameter indicates that the loading estimate for the proposed project was lower than the loading estimate for baseline conditions in approximately 93 percent of these comparisons, and higher in 7 percent. Thus, P(exceed) values of less than 0.5 generally indicate that loadings for the proposed project are likely lower than those for the baseline conditions. It follows that P(exceed) values greater than 0.5 indicate that loadings for the proposed conditions are likely higher than those for baseline conditions. Finally, loadings for the baseline and proposed conditions are essentially equivalent with a P(exceed) value of 0.5.

It should also be noted that the end-of-pipe loading subroutine also outputs this same summary table for baseline and proposed pollutant concentration values based on the combined input from all the outfalls in a specific TDA (see Figure 5). However, this concentration summary table is provided for information purposes only and is generally not required to complete the formal analysis for ESA Section 7 consultations (see discussion in next section).

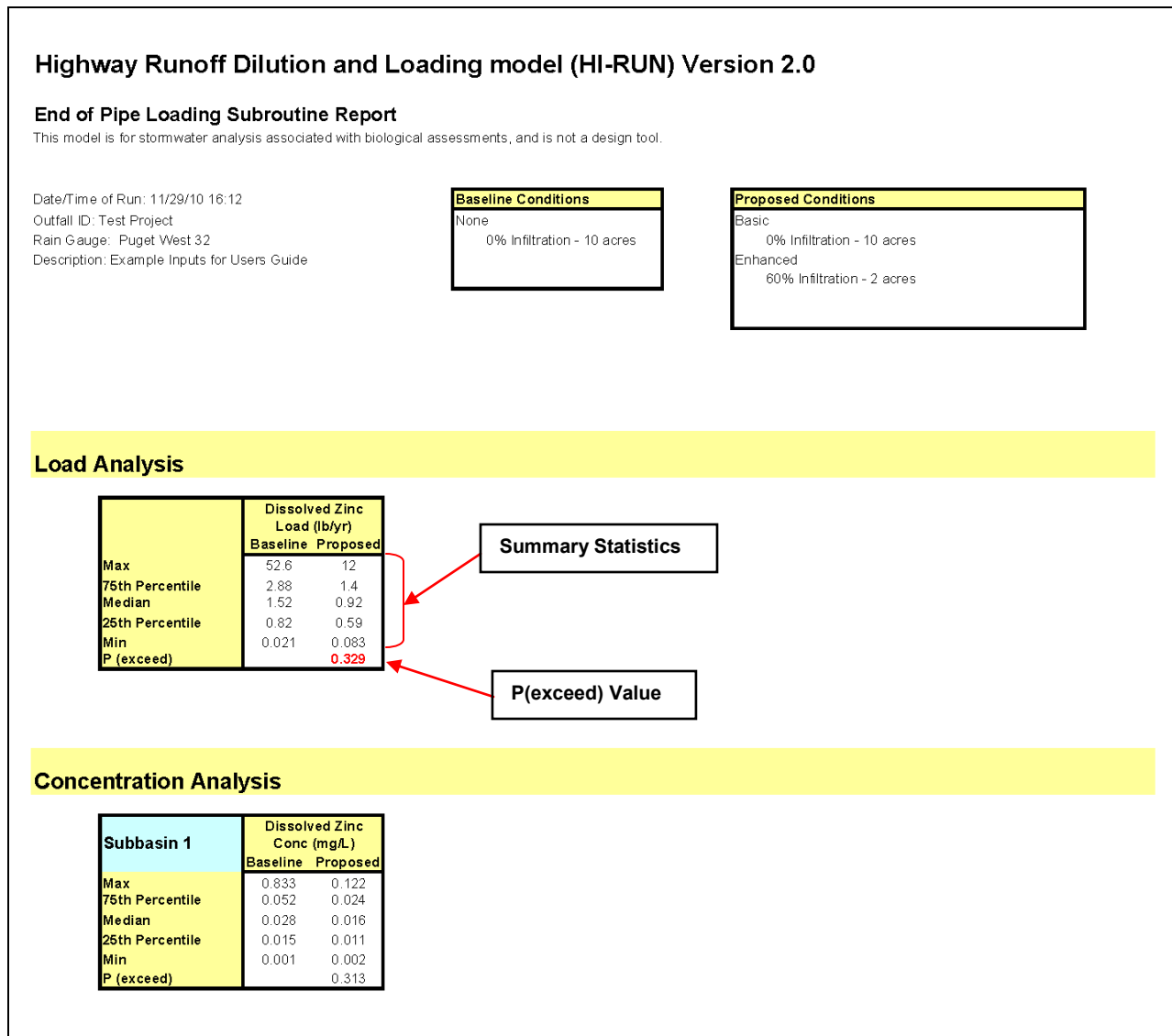


Figure 5. Sample “Results” output page for the end-of-pipe loading subroutine of the HI-RUN model.

The end-of-pipe loading subroutine also outputs estimated baseline and proposed pollutant concentrations for specific outfall discharge locations to more detailed tables. Separate tables are provided for each month of interest identified in the data input page for the end-of-pipe loading subroutine of the HI-RUN model. For reference, Figure 6 provides an example of these tables with data from a hypothetical outfall discharge location. In this example, the HI-RUN model was used to analyze DZn concentrations in the month of February. Individual cells within this table indicate the combined probability of obtaining a specific pollutant concentration in conjunction with a specific discharge duration for the modeled outfall. For example, Figure 6 shows a value of 0.043 in the cell corresponding to a concentration range of 0.02 to 0.03 mg/L and a 3- to 6-hour discharge duration within the table for baseline conditions. This means that there is approximately a 4 percent chance of obtaining a DZn concentration in this range in conjunction with a 3- to 6-hour discharge from the outfall during any given storm event in the month of February.

The values in the first shaded column in the tables for the baseline and proposed conditions can also be used to determine the probability of obtaining a pollutant concentration in any of the specified ranges without regard to discharge duration. In the example table for baseline conditions that is shown in Figure 6, a value of 0.171 is presented in this column for the DZn concentration range of 0.02 to 0.03 mg/L. This indicates there is approximately a 17 percent chance of obtaining a DZn concentration in this range without regard to discharge duration. Similarly, values in the first shaded row in the tables for the baseline and proposed conditions can also be used to determine the probability of obtaining a discharge duration in any of the specified ranges without regard to concentration. In the example table for baseline conditions that is shown in Figure 6, a value of 0.252 is presented in this row for the discharge duration range of 3 to 6 hours. This indicates there is approximately a 25 percent chance of obtaining a discharge duration in this range without regard to concentration.

The process used to perform risk-based water quality effects analyses for ESA Section 7 consultations using these outputs from the HI-RUN model is described in the next major section of this user's guide. Two case studies are also provided in the *Case Studies* section to demonstrate the specific data input steps and provide examples for interpreting this output in the consultation process.

Using the Receiving Water Dilution Subroutine

As described above, the receiving water dilution subroutine of the HI-RUN model can be used to evaluate baseline and proposed dissolved copper and dissolved zinc concentrations at specific outfall discharge locations after mixing and dilution within the associated receiving water. To obtain this output, you must supply all of the inputs described above in the connection with the end-of-pipe loading subroutine, plus additional input values that pertain to the receiving water.

Entering Inputs

To begin running the receiving water dilution subroutine, select the "Dilution" sheet by clicking on the "Dilution" tab at the bottom of the page. This sheet provides cells for the users to enter

Highway Runoff Dilution and Loading model (HI-RUN) Version 2.0

End of Pipe Loading Subroutine Concentration Report - Subbasin 1

This model is for stormwater analysis associated with biological assessments, and is not a design tool.

Date/Time of Run: 11/29/10 16:12
 Outfall ID: Test Project
 Rain Gauge: Puget West 32
 Description:

Baseline Condition
None
0% Infiltration - 10 acres

Proposed Condition
Basic
0% Infiltration - 10 acres
Enhanced
60% Infiltration - 2 acres with detention

Downstream Distance (ft) = 0

Dissolved Zinc - February - Probability of Occurrence																											
Conc. (mg/L)	Baseline Conditions									Proposed Conditions																	
	> 0.1	0.09 - 0.1	0.08 - 0.09	0.07 - 0.08	0.06 - 0.07	0.05 - 0.06	0.04 - 0.05	0.03 - 0.04		0.02 - 0.03	0.01 - 0.02	0 - 0.01	> 0.1	0.09 - 0.1	0.08 - 0.09	0.07 - 0.08	0.06 - 0.07	0.05 - 0.06	0.04 - 0.05	0.03 - 0.04	0.02 - 0.03	0.01 - 0.02	0 - 0.01				
	0-3	3-6	6-12	12-24	24-48	48-96	96-192	>192		0-3	3-6	6-12	12-24	24-48	48-96	96-192	>192		0-3	3-6	6-12	12-24	24-48	48-96	96-192	>192	
> 0.1	0.083	0.006	0.021	0.03	0.019	0.006	0.001	0	0	0.001	0	0	0	0	0	0	0	0	0.001	0	0	0.001	0	0	0	0	0
0.09 - 0.1	0.019	0.001	0.005	0.007	0.005	0.001	0	0	0	0.001	0	0	0.001	0	0	0	0	0	0.001	0	0	0.001	0	0	0	0	0
0.08 - 0.09	0.019	0.001	0.005	0.007	0.005	0.001	0	0	0	0.003	0	0.001	0.001	0.001	0	0	0	0	0.003	0	0.001	0.001	0.001	0	0	0	0
0.07 - 0.08	0.032	0.002	0.008	0.012	0.008	0.002	0	0	0	0.004	0	0.001	0.002	0.001	0	0	0	0	0.004	0	0.001	0.002	0.001	0	0	0	0
0.06 - 0.07	0.042	0.003	0.011	0.015	0.01	0.003	0	0	0	0.014	0.001	0.004	0.005	0.003	0.001	0	0	0	0.014	0.001	0.004	0.005	0.003	0.001	0	0	0
0.05 - 0.06	0.06	0.004	0.015	0.022	0.014	0.004	0.001	0	0	0.03	0.002	0.008	0.011	0.007	0.002	0	0	0	0.03	0.002	0.008	0.011	0.007	0.002	0	0	0
0.04 - 0.05	0.084	0.006	0.021	0.03	0.02	0.006	0.001	0	0	0.083	0.006	0.021	0.03	0.019	0.006	0.001	0	0	0.083	0.006	0.021	0.03	0.019	0.006	0.001	0	0
0.03 - 0.04	0.113	0.008	0.029	0.041	0.026	0.008	0.001	0	0	0.21	0.016	0.052	0.075	0.048	0.016	0.003	0	0	0.21	0.016	0.052	0.075	0.048	0.016	0.003	0	0
0.02 - 0.03	0.171	0.012	0.043	0.061	0.04	0.013	0.002	0	0	0.432	0.032	0.108	0.155	0.099	0.033	0.005	0	0	0.432	0.032	0.108	0.155	0.099	0.033	0.005	0	0
0.01 - 0.02	0.23	0.016	0.056	0.082	0.054	0.017	0.003	0	0	0.213	0.016	0.053	0.076	0.049	0.016	0.003	0	0	0.213	0.016	0.053	0.076	0.049	0.016	0.003	0	0
0 - 0.01	0.142	0.01	0.036	0.051	0.033	0.01	0.002	0	0	0.073	0.016	0.053	0.076	0.049	0.016	0.003	0	0	0.073	0.016	0.053	0.076	0.049	0.016	0.003	0	0
	0.069	0.252	0.358	0.234	0.071	0.011	0	0		0.073	0.249	0.358	0.228	0.074	0.012	0	0		0.073	0.249	0.358	0.228	0.074	0.012	0	0	0

Figure 6. Sample detailed output page for the end-of-pipe loading subroutine.

model input values. The user can clear all inputs on the sheet using the **Clear Inputs** button at the top of the screen. Previously saved input settings can also be retrieved using the **Load Dilution Inputs** button (see *Managing Input and Output Files* section above).

An example data input page for the receiving water dilution subroutine is shown in Figure 7. In practice, most of these required inputs described below will be obtained from the project hydraulic designer/engineer in the form of the *Endangered Species Act Stormwater Design Checklist*. The Biological Assessment author may need to work in coordination with the project hydraulic designer/engineer to generate the remaining inputs required to run the modeling routine. The most current version of the checklist is available for download on the WSDOT Biological Assessment Guidance web page. An example checklist is shown for reference purposes in Appendix B along with additional detailed guidance on where to obtain the required input values.

Step 1. Background Concentrations

Enter representative receiving water background DCu and DZn concentrations. When values are available from more than one data source, use values that represent conditions in the receiving water that prevail where stormwater runoff is also discharging from the project site.

Step 2. Enter Receiving Water Depth

Enter an estimate of the average water depth from a representative location immediately downstream of the outfall of interest. If the stream can be waded, this value can be obtained through direct measurement; otherwise, it must be determined from other available data sources. If possible, representative stream depths should be entered for each month of interest identified in the data input page for the end-of-pipe loading subroutine.

Step 3. Enter Stream Velocity

Enter an estimate of the average stream velocity from a representative location immediately downstream of the outfall of interest. If the stream is can be waded, this value can be obtained through direct measurement; otherwise, this value must be determined from other available data sources.

If possible, representative stream velocities should be entered for each month of interest identified in the data input page for the end-of-pipe loading subroutine. If adequate data are available from a continuous gauging station or hydrologic model, the stream velocity used as input should be derived from the 25th percentile flow rate for each month of interest.

Step 4. Enter Channel Width

Enter an estimate of the average stream width from a representative location immediately downstream of the outfall of interest. If the stream can be waded, this value can be obtained through direct measurement; otherwise, this value must be determined from other available

Highway Runoff Dilution and Loading model (HI-RUN) Version 2.0 For Excel 2007

Inputs for Receiving Water Dilution Subroutine

Dilution subroutine analysis is only conducted on pollutants that have an established biological effects threshold (dissolved copper and zinc)

Subbasin 1

	Background Concentration (mg/L)	
TSS	<input type="text"/>	Enter short description of simulation (optional)
Copper - Total	<input type="text"/>	
Zinc - Total	<input type="text"/>	
Copper -Dissolved	0.001	
Zinc - Dissolved	0.004	

	January	February	March	April	May	June	July	August	September	October	November	December
Stream Depth (ft)		1										
Stream Velocity (fps)		0.25										
Channel Width (ft)		10										
Slope <input type="text" value=""/>		0.005										
Discharge Distance into Water Body From Nearest Shoreline (ft)		0										

Figure 7. Sample input page for the receiving water dilution subroutine.

data sources. If possible, representative stream widths should be entered for each month of interest identified in the data input page for the end-of-pipe loading subroutine.

Step 5. Enter Slope or Roughness

The receiving water dilution subroutine can be run using either channel slope or hydraulic roughness. Select which parameter will be used with the drop-down menu, and enter an estimate of the parameter value from a representative location immediately downstream of the outfall of interest. Slope can be measured using an autolevel or hand level. Representative Manning's roughness values can be obtained from standard reference documents for hydrology.

Step 6. Enter Outfall Distance from Shoreline

Enter the distance that the outfall extends into the receiving water from the nearest shoreline. This value can be measured for existing outfalls, or estimated from plans for proposed outfalls.

Interpreting Outputs

Step 7. Determine Mixing Distance Downstream for Baseline and Proposed Conditions

The receiving water dilution subroutine conducts an iterative analysis of downstream extent of potential water quality effects for both baseline and proposed conditions using an automated routine. Simply click the **Run Dilution Model** button on the "Dilution" sheet (see Figure 7), select the subbasin to analyze, and indicate whether detention BMPs will be applied in the subbasin (if prompted).

The results tables generated by the receiving water dilution subroutine includes a summary results table displaying results for all months of interest and detailed tables of pollutant concentrations in three intervals for DCu and DZn:

- Greater than biological effects threshold
- Background to biological effects threshold
- Less than background

Detailed tables will be generated for each combination of pollutant analyzed, month of interest, and condition (baseline and proposed). The "greater than biological effects threshold" probability value will be highlighted in each of the detailed tables. This is the probability value (less than or equal to the project effects limit of 0.05) for the related downstream distance value in the summary table. After running the receiving water dilution subroutine, save the results file for reference.

Figure 8 shows a hypothetical example of the summary results sheet generated by the receiving water dilution subroutine. This sheet displays a summary of the model inputs and the summary table displaying the predicted downstream distances (in feet) for each combination of pollutant, month, and condition. In this example, it is estimated that the biological effects threshold for

Highway Runoff Dilution Summary Results

INPUTS

Project: Test Project
 Precipitation Series: Puget West 32
 Description:

Background Concentrations (mg/L)
 Dissolved Copper: 0.001
 Dissolved Zinc: 0.004

Discharge Area
 Baseline Conditions: 10 acres
 No Treatment Infiltration 0% - 10 acres

Proposed Conditions: 12 acres
 Enhanced Treatment Infiltration 60% - 2 acres with detention
 Basic Treatment Infiltration 0% - 10 acres

Stream Inputs

	Feb
Depth (ft)	1
Velocity (fps)	0.25
Width (ft)	10
Slope	0.005
Discharge Dist (ft)	0

Results

		Distance Downstream in feet to Meet Biological Threshold											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dissolved Copper	Baseline		2										
	Proposed		< 1										
Dissolved Zinc	Baseline		16										
	Proposed		3										

Figure 8. Sample summary output page for the receiving water dilution subroutine.

dissolved copper will be reached with up to a 5 percent probability within 2 feet of the outfall under baseline conditions and less than 1 foot under proposed conditions in the month of February. Similarly, it is estimated that the biological effects threshold for dissolved zinc will be reached with up to 5 percent probability within 16 feet of the outfall under baseline conditions and 3 feet under proposed conditions, indicating an improvement in water quality conditions resulting from the project.

Figure 9 shows a hypothetical example of separate detailed results tables for each combination of pollutant, month, and condition. In this example, the HI-RUN model was used to analyze DCu and DZn concentrations in the month of February. Similar to the detailed output tables described above for the end-of-pipe loading subroutine, individual cells within this summary table indicate the combined probability of obtaining a specific pollutant concentration in conjunction with a specific discharge duration for the modeled outfall. However, these estimates are for concentrations within the receiving water at the specified distance from the outfall. The highlighted cells in each table report the project risk value calculated for exceeding the biological effects threshold for each condition. For example, the highlighted cell in the uppermost table shows a project risk value of 0.039 for exceeding the dissolved copper biological effects threshold value of 0.003 mg/L under baseline conditions at 2 feet downstream of the outfall during February. This value is associated with the “2” in the summary results table shown in Figure 8.

It should be noted that the receiving water dilution subroutine will estimate dilution distances between 1 foot and 1,000 feet. Resulting values less than 1 foot suggest near instantaneous dilution to below the biological effects threshold, and providing a finer resolution in the result would not improve the accuracy of the estimate. Resulting values greater than 1,000 feet suggest inadequate dilution capacity in most receiving waters. If adequate dilution capacity exists in the receiving water, the model should converge on the result within a reasonable distance. This reasonable distance would be within 100 to 200 feet for many small streams. A maximum value of 1,000 feet was chosen for HI-RUN so that it could be applied to a wider range of stream sizes.

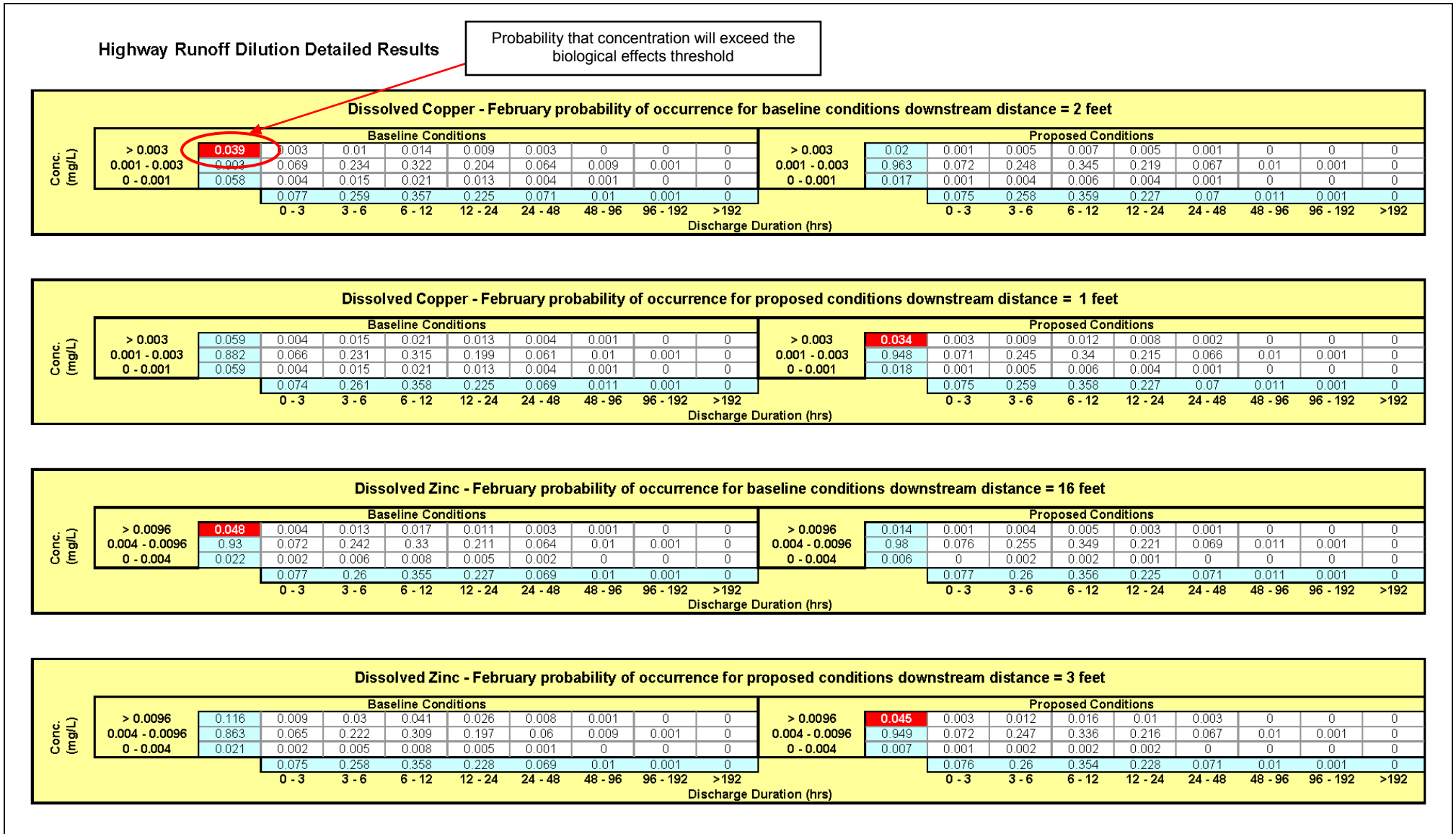


Figure 9. Sample detailed output table for the receiving water dilution subroutine of the HI-RUN model.

The Stormwater Quality Effects Analysis Process

In the ESA Section 7 consultation process, analyses must be performed to determine the potential for threatened or endangered species to be adversely impacted by stormwater from a proposed transportation project. Stormwater quality impacts are related to project runoff concentrations and loads, level of treatment and means of stormwater management, receiving water quality, and the run timing or residency of ESA-listed fish when stormwater discharges occur. The HI-RUN model allows users (primarily authors of biological assessments) to evaluate the potential stormwater quality effects of a proposed project on threatened and endangered species.

As a first step, the end-of-pipe loading subroutine is run using DZn as the parameter of interest to determine whether a proposed project will result in a significant increase in pollutant loading over the baseline condition that would warrant additional analyses with the receiving water dilution subroutine. DZn was chosen for this initial screening step because monitoring data compiled by WSDOT for this parameter have generally shown it is a good indicator of stormwater treatment system performance (DCu was not used as a predictor because existing monitoring data suggests that concentrations of this parameter in highway runoff are so low as to be untreatable with BMPs that are currently used in highway settings). The process used for this initial screening step is summarized in Figure 10 and discussed below.

The first step in this screening process is to compare the P(exceed) value that is obtained from the end-of-pipe loading subroutine for DZn to a threshold value of 0.45 to determine whether a proposed project is likely to result in a significant increase in pollutant loading over the baseline condition. If the P(exceed) value exceeds this threshold, analyses using the receiving water dilution subroutine are required by default. Because this threshold value is less than 0.5, it represents conditions under which runoff quality is expected to improve. The threshold value was selected to provide a level of confidence that proposed conditions would not be degraded when compared to background given the inherent uncertainty and variability in the data.

If the P(exceed) value that is obtained from the end-of-pipe loading subroutine for DZn is less than or equal to the 0.45 threshold value identified above, the approach presented in Figure 10 identifies a second P(exceed) threshold value of 0.35 for determining when an alternate, less rigorous “land-area based” dilution analysis must be performed. To perform the land-area based dilution analysis, the impervious area for the TDA being analyzed is compared to the total contributing basin area to the receiving water upstream of the project discharge. If the TDA represents 5 percent or less of the total upstream basin area, it is assumed that the receiving water will have sufficient dilution capacity to mitigate potential impacts from the project if background water quality conditions are not degraded.

Finally, the process presented in Figure 10 requires an examination of water quality indicators for the receiving water (temperature, sediment, and chemical contamination per the *NOAA Fisheries and USFWS Matrices of Pathways and Indicators*) to determine whether analyses using the receiving water dilution subroutine are still warranted. These water quality indicators

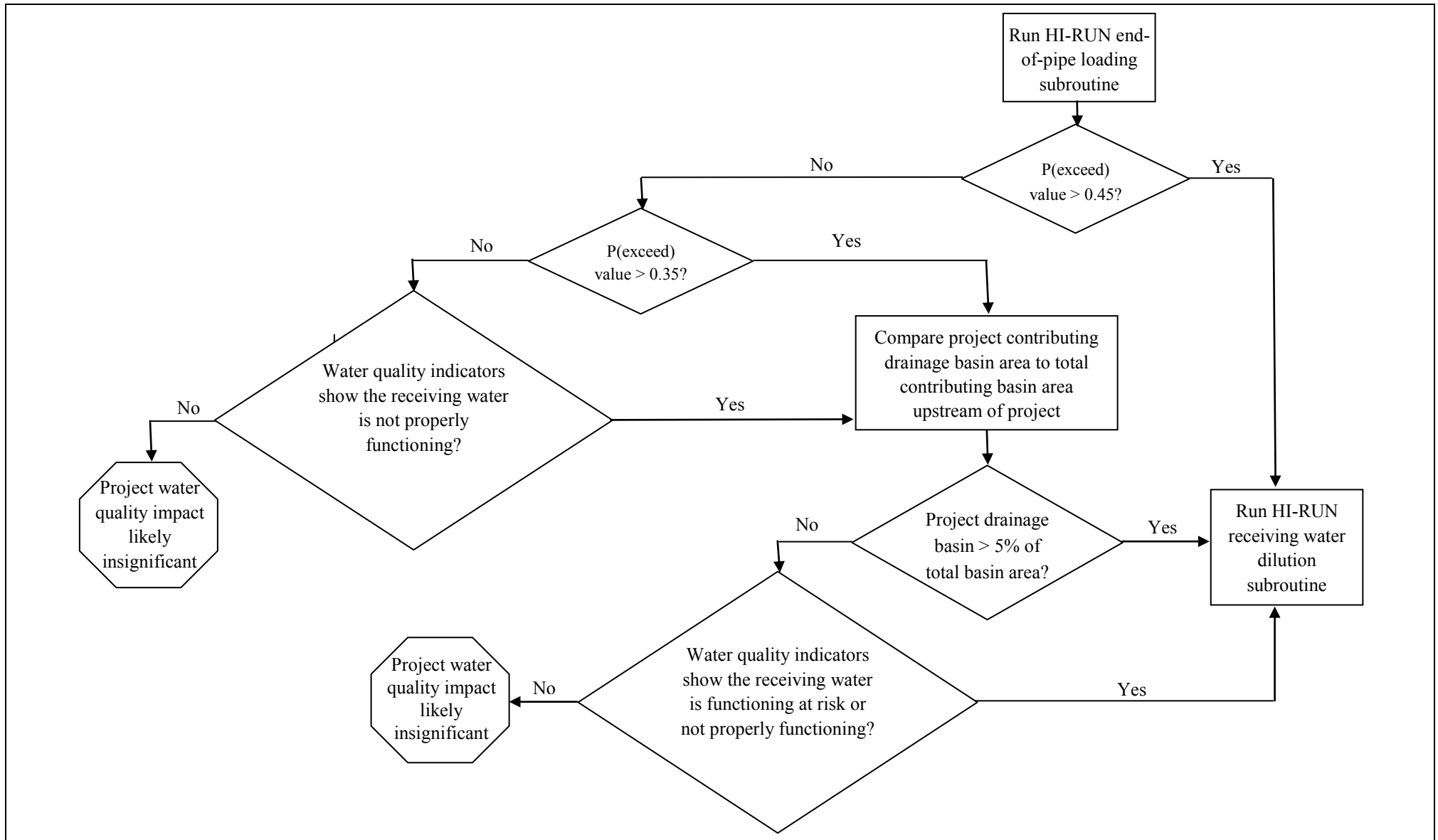


Figure 10. Process for applying output from the end-of-pipe loading subroutine in ESA Section 7 consultations.

and criteria for determining their functionality are summarized in Appendix C. For projects with P(exceed) values that are equal to or below the 0.45 threshold but above the 0.35 threshold identified above, analyses using the receiving water dilution subroutine would still be required if the water quality indicators show the receiving water is functioning at risk or not properly functioning. Similarly, for projects with P(exceed) values that are equal to or below the 0.35 threshold, the land-area based dilution analysis would still be required if the water quality indicators show the receiving water is not properly functioning.

Once a determination is made using the process shown in Figure 10 that additional analyses with the receiving water dilution subroutine are warranted, these analyses would be performed for both the baseline and proposed conditions using DZn and DCu as the parameters of interest. The specific goal of these analyses is to determine the maximum distance downstream from an outfall's point of discharge where the following thresholds for potential water quality effects on ESA-listed aquatic species are exceeded within the receiving water:

- A 0.0056 mg/L increase in DZn over the receiving water's background concentration due to stormwater discharges from the outfall
- A 0.002 mg/L increase in DCu over the receiving water's background concentration due to stormwater discharges from the outfall.

In keeping with a risk-based approach for assessing potential water quality effects from highway projects, these thresholds for potential effects would be assessed based on a predefined "project risk limit." In most cases, this default project risk limit will be a 5 percent probability of exceeding each effect threshold.

The receiving water dilution subroutine iteratively computes the distance downstream where the biological effects threshold is exceeded for each month of interest based on the specified project risk limit. This process is performed separately for the baseline and proposed conditions. The distance downstream calculated for the proposed condition defines the area within which listed species could be exposed to pollutant concentrations above the biological effects threshold. The case studies presented in the following section demonstrate the specific steps that are required to perform these analyses using the receiving water dilution subroutine.

Case Studies

Two case studies are presented herein to demonstrate use of the HI-RUN model in the stormwater quality effects analysis process. Case Study #1 involves using the end-of-pipe loading subroutine, but not the receiving water dilution subroutine. Case Study #2 involves the use of both routines. Guidance on selection and generation of hydrologic, hydraulic, and water quality input data is provided in Appendix B.

You can find additional guidance on how to use HI-RUN at the following website:
http://www.wsdot.wa.gov/NR/rdonlyres/5362821F-24A4-4FF9-80EE-7378273176CE/0/BA_HiRunFAQ.pdf.

This guidance is provided in the form of questions and answers for more complex or challenging project scenarios. Refer to the WSDOT Biological Assessment Guidance web page for further assistance and resources.

Case Study #1: End-of-Pipe Loading Subroutine

The first example provides an illustration of how to input data and interpret results using the HI-RUN end-of-pipe loading subroutine. In this example, a full receiving water dilution analysis is not necessary for evaluation of project stormwater quality effects. For an example that illustrates the use of both the end-of-pipe loading subroutine and the receiving water dilution subroutine, see Case Study #2.

The hypothetical project evaluated in Case Study #1 has the following characteristics:

Project Site Assumptions

- Existing roadway area: 10 acres
- Existing treatment: none
- Proposed roadway area: 12 acres (2 additional acres)
- Proposed treatment: biofiltration swale (sized for 2 acres) and media filter drain (previously referred to as ecology embankments) sized for 4 additional acres (retrofit)
- Outfall: All runoff in the TDA discharges through a single outfall (only one subbasin)
- Incidental infiltration: Due to sufficient separation between the base of the media filter drain and the seasonal high water table elevation, it is determined that the facility will achieve approximately 60 percent

infiltration on an annual runoff volume basis. The biofiltration swale is not expected to have substantial incidental infiltration.

- Detention: Detention is not planned for this TDA because the receiving water is exempt from flow control requirements.

Receiving Water Assumptions

- ESA-listed fish species present in the project receiving water include Puget Sound Chinook salmon and Puget Sound steelhead. An analysis will be performed to evaluate the potential water quality effects of highway runoff on rearing steelhead in the month of February.
- Receiving water quality indicators are functioning properly.

Figure 11 shows an example data input page for the end-of-pipe loading subroutine that has been populated with the requisite input values to reflect these characteristics. The specific procedures required to input these values, run the subroutine, and interpret the associated output are described below.

Running End-of-Pipe Loading Subroutine

The project biologist describes stormwater management plans in the biological assessment based on the information presented by the project engineer in the *Endangered Species Act Stormwater Design Checklist* and project plans. The *Endangered Species Act Stormwater Design Checklist* also provides the information needed for HI-RUN model inputs. The project biologist may request the project engineer to provide this checklist. The most recent version of the checklist is available for download from the WSDOT Biological Assessment Guidance web page. An example of the checklist is shown for reference in Appendix B along with guidance on selecting or generating the input values. Step-by-step instructions for inputting information contained in the checklist to the data input page for the end-of-pipe loading subroutine are as follows:

Step 1. Enter Project/Threshold Discharge Area Location

Instructions – Enter project location/identification in text box. Identify the project by state route (SR) and milepost (MP). An identifier for the TDA analyzed can also be included when multiple TDAs will be analyzed for a given project. This information should be provided on the *Endangered Species Act Stormwater Design Checklist*.

Case Study #1 – The sample input page shown in Figure 11 displays the following information for Case Study #1: “SR 13, MP 12.2, TDA 3.”

Highway Runoff Dilution and Loading model (HI-RUN) Version 2.0 For Excel 2007

This model is for stormwater analysis associated with biological assessments, and is not a design tool

Data Inputs - End-of-Pipe Loading Subroutine

Description: This model provides risk-based predictions of stormwater quality at the outfall and Threshold Discharge Area (TDA) scale. The Highway Runoff Manual provides a thorough discussion of TDA delineation specific to transportation drainage systems. The analysis of water quality concentrations is conducted at a subbasin scale, with subbasins being divisions of TDAs that have discrete discharge points in the receiving water. If a TDA has only one discharge point, data need only be entered under Subbasin 1. The analysis of pollutant loadings is done at the TDA scale only. Water quality parameters analyzed by this tool are Total Suspended Solids (TSS), Total Copper (TCu), Dissolved Copper (DCu), Total Zinc (TZn), and Dissolved Zinc (DZn).

Project/TDA ID:

Precipitation Timeseries:

Water Quality Parameters

- All
- TSS
- Copper - Total
- Copper - Dissolved
- Zinc - Total
- Zinc - Dissolved

Month

- January
- February
- March
- April
- May
- June
- July
- August
- September
- October
- November
- December

TDA Information - Baseline Conditions							
Treatment Type	Level of Incidental Infiltration (%)	Subbasin Area (acres)					TDA Impervious Area (acres)
		1	2	3	4	5	
Basic	0						0
	20						0
	40						0
	60						0
	80						0
Enhanced	0						0
	20						0
	40						0
	60						0
	80						0
Infiltration BMP	100						0
None	0	10					10
Total		10	0	0	0	0	10

TDA Information - Proposed Conditions							
Treatment Type	Level of Incidental Infiltration (%)	Subbasin Area (acres)					TDA Impervious Area (acres)
		1	2	3	4	5	
Basic	0	2					2
	20						0
	40						0
	60						0
	80						0
Enhanced	0						0
	20						0
	40						0
	60	4					4
	80						0
Infiltration BMP	100						0
None	0	6					6
Total		12	0	0	0	0	12

Figure 11. End-of-pipe loading subroutine input page – Case Study #1.

Step 2. Select the Precipitation Time Series

Instructions – Select the precipitation time series most applicable to the project location in the pull-down menu. Options include Extended Precipitation Timeseries and individual rain gauge series. These times series match those used in MGSFlood and can be determined by identifying the project location on the figure in Appendix A. This precipitation map is also available by selecting the **Precipitation Map** button on the data input page of the HI-RUN model. On the precipitation map, the user will first determine whether the project is located in one of the three Extended Precipitation Timeseries zones (Puget West, Puget East, and Vancouver). If so, the user will then identify the nearest isopluvial line to the project location. The number displayed on the isopluvial line (the user may need to zoom into the graphic to read the numbers) is mean annual precipitation at 4-inch increments. The user then exits the precipitation map by pressing the **Go Back to Data Input Sheet** button, and selects the precipitation time series associated with the zone and mean annual precipitation of the project location (e.g., Puget East 40). If the project is located outside of the Extended Precipitation Timeseries zones, the user will identify the appropriate rain gauge for use at the project site (e.g., Montesano), then exit the precipitation map and select the appropriate precipitation time series/rain gauge.

Case Study #1 – The sample input page shown in Figure 11 indicates the “Puget East 40” time series will be used in the model for Case Study #1.

Step 3. Select Water Quality Parameters

Instructions – Select the water quality parameters of interest in the analysis. Any combination of one or more of these can be selected from a list box, using the “Shift” or “Ctrl” buttons on the keyboard to choose more than one. The end-of-pipe loading subroutine can analyze TSS, TCu, DCu, TZn, and DZn; and loads for all five should be estimated and reported in the project Biological Assessment. The current stormwater quality effects analysis process is based on Dcu and DZn only. The Biological Assessment should discuss how estimated loads of all five parameters change from baseline to proposed conditions, but this comparison should be more detailed and quantitative for DCu and DZn than for the other three parameters. The receiving water dilution subroutine analyzes DCu and DZn only.

Case Study #1 – The sample input page shown in Figure 11 indicates that DCu, and DZn will be analyzed for Case Study #1.

Step 4. Select Months

Instructions – Select the months of interest for which the HI-RUN subroutine will be run. To determine the months of interest, the user must determine when ESA-listed aquatic species could occur in the vicinity of the project. By running the routine for only the months of interest, the number of output data tables generated can be reduced. (Note: this affects the end-of-pipe concentration results and receiving water dilution subroutine results, but not the end-of-pipe loading estimates.)

Multiple months of interest can be selected from the list box using the “Shift” or “Ctrl” keys on the keyboard. The months of interest are those months during which fish could be present and potentially exposed to stormwater discharges. For species that do not show distinct seasonality (i.e., bull trout) or that are present within a system year-round (i.e., steelhead, residual Chinook), analyzing multiple months will be necessary. To determine what months are of interest, the biologist has to determine what life stages could occur in the vicinity of the project. The biologist can determine what life stages could potentially be affected by a project by determining the suitability of the habitat in the action area (area affected by the proposed project) for those life stages. In addition, the biologist should determine the timing of various life stages in the action area by reviewing available literature and reports, and contacting local tribal, agency, or jurisdictional biologists.

Case Study #1 – As described above, Case Study #1 assumes that analyses are being performed to evaluate the potential water quality effects of highway runoff on rearing steelhead in the month of February. Accordingly, the sample input page shown in Figure 11 indicates that February has been selected.

Step 5. Enter Baseline TDA Conditions

Instructions – Enter the areas (in acres) of baseline (existing) impervious surfaces, according to the type of runoff treatment that is provided for stormwater from the areas (basic, enhanced, or no treatment), and the level of incidental infiltration associated with the treatment BMP (0, 20, 40, 60, or 80 percent). Incidental infiltration is characterized at these 20 percent increments to provide a level of flexibility to the model user while still reducing the level of effort required to develop the HI-RUN model. The *HI-RUN Model Technical Documentation* (Herrera 2008) provides more detail on the pre-processing work involved in developing the model.

Case Study #1 – 10 acres is entered in the “no treatment” row for Case Study #1 (see Figure 11).

Step 6. Enter Proposed TDA Conditions

Instructions – Similar to the information provided in Step 5, enter areas of the proposed impervious drainage subbasin according to treatment BMP type and incidental infiltration rate. This information should be provided on the *Endangered Species Act Stormwater Design Checklist*.

Case Study #1 – The proposed conditions of Case Study #1 have the following drainage subbasin attributes: 2 acres draining to a biofiltration swale (Basic Treatment); 4 acres draining to media filter drains (Enhanced Treatment) that achieve approximately 60 percent infiltration on an annual runoff volume basis; and 6 acres with no treatment. This information is reflected in the “Outfall Information – Proposed Conditions” table on the input page for Case Study #1 (see Figure 11).

Step 7. Run End-of-Pipe Loading Subroutine

Instructions – After entering all of the above information into the input page, run the end-of-pipe loading subroutine by clicking the **Run Loading Model** button. The user will be asked whether flow control (detention) should be applied to the project TDA. If only one subbasin has values entered, the user simply selects “Yes” or “No”. If multiple subbasins have values entered, the user is prompted to select the subbasin in which the detention facility will be located. The user should select “No” or check the “No Flow Control” box if a detention facility is not planned. If a detention basin is to be constructed in the TDA, the user will click “Yes” or select the subbasin in which it will be located from the dropdown menu. Once the flow control information has been completed, the user will click the **Run Analysis** button. This information should be provided on the *Endangered Species Act Stormwater Design Checklist*.

Before HI-RUN conducts the end-of-pipe loading analysis, an additional window (“Confirm Input Parameters”) will appear to prompt the user to review input data and provide text describing the model run as needed. The text entered in this box will be included in the output file to assist with documentation of results, and can include initials of the analyst and notes and assumptions associated with the input data entered.

Case Study #1 – No detention facilities are planned, so the “No” is selected in the flow control window (see Figure 12). In the “Confirm Input Parameters” window, a note regarding the input data are entered (see Figure 13).

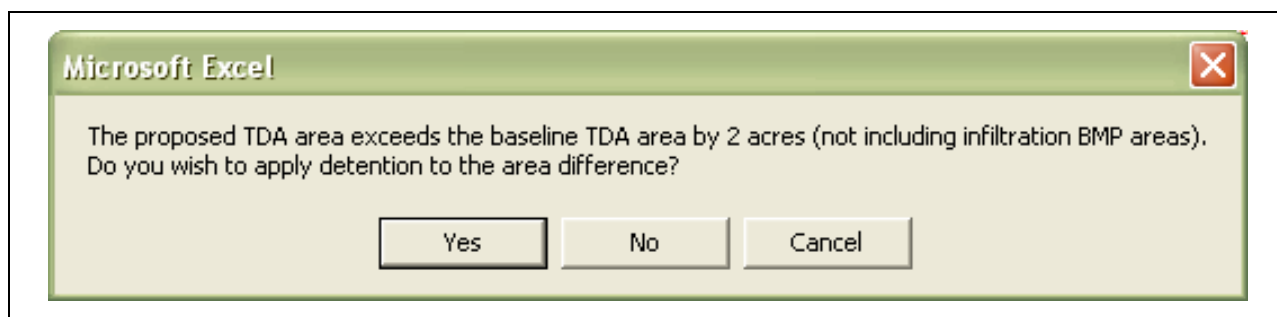


Figure 12. Flow control dialog box – Case Study #1.

Interpreting End-of-Pipe Loading Subroutine Results

Instructions – When the analysis has been completed, HI-RUN will prompt the user to save the output file. The end-of-pipe loading subroutine output file consists of a “Results” summary sheet and individual sheets with concentration results for each subbasin analyzed. The loading statistics presented on the “Results” sheet will be reviewed by the user to determine whether further analysis is needed to assess water quality effects on the receiving water. The loading results include the following statistics for each selected parameter for baseline and proposed conditions in the project TDA:

- Maximum load (pounds per year [lb/yr])
- 75th percentile load (lb/yr)

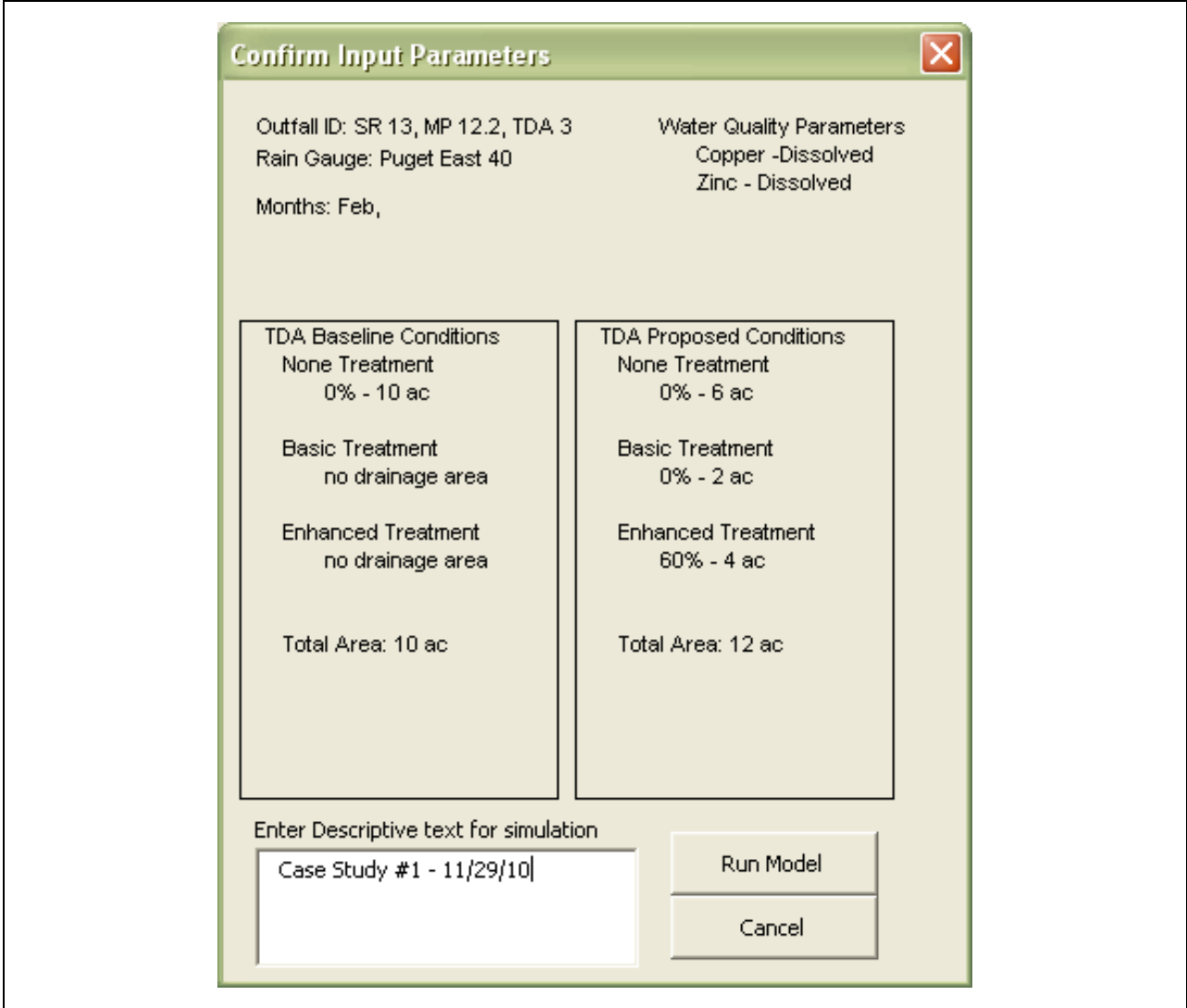


Figure 13. Confirm input parameters dialog box – Case Study #1.

- Median load (lb/yr)
- 25th percentile load (lb/yr)
- Minimum load (lb/yr)

The maximum values provide a worst-case load estimate for comparing the baseline and proposed conditions. The percentile values provide an indication of the overall distribution of the loading estimates. For example, the 75th percentile value represents the load estimate at which 75 percent of the values will be lower and 25 percent will be higher.

In addition, a P(exceed) value is provided for each parameter. As discussed in the *Stormwater Quality Effects Analysis Process* section above, the P(exceed) values associated with the loading estimates represent the probability that loads will be greater in the proposed condition than in the baseline condition and are the statistics of interest in the water quality effects evaluation. **The TDA P(exceed) value for DZn must be compared to the thresholds identified in Figure 10 to help determine the need for conducting a detailed dilution analysis using the receiving water dilution subroutine.** For guidance, see the *Stormwater Quality Effects Analysis Process* section of this user's guide.

In addition to the loading results described above, the end-of-pipe loading subroutine also provides information on pollutant concentrations at the project outfall. This information is provided for additional understanding of project water quality conditions, but is not specifically used in the stormwater quality effects analysis process shown in Figure 10. Guidance on the interpretation of these concentration results is provided in the *Using the HI-RUN Model* section of this user's guide.

Case Study #1 – The P(exceed) value for DZn is 0.438 (see Figure 14). The evaluation flow chart (Figure 10) is used to determine what level of analysis (if any) is needed of water quality effects in the receiving water. The resulting P(exceed) value (0.438) is less than the upper threshold value of 0.45, but greater than the lower threshold value of 0.35. Therefore, a simplified dilution analysis must be conducted as a next step.

Simplified Dilution Analysis

Instructions – Estimate the area (in square miles or acres) of the receiving water drainage basin upstream of the project discharge point. The simplified dilution analysis consists of a simple comparison of the project drainage area to this greater receiving water drainage basin. If the impervious area of the TDA being analyzed represents more than 5 percent of the receiving water drainage basin, then the receiving water dilution analysis must be conducted (see Case Study #2 for step-by-step instructions). If not, a final check of receiving water indicators must be conducted. Receiving water drainage basin area can be estimated using StreamStats, an online tool developed by USGS (<http://water.usgs.gov/osw/streamstats/Washington.html>).

Case Study #1 –The drainage basin area estimate for the Case Study #1 receiving water is 23 square miles. The proposed subbasin area of 12 acres represents less than 5 percent of the receiving water drainage basin.

Highway Runoff Dilution and Loading model (HI-RUN) Version 2.0 End of Pipe Loading Subroutine Report

This model is for stormwater analysis associated with biological assessments, and is not a design tool.

Input Summary	

Run Date/Time: 12/30/10 13:56	
Outfall ID: SR 13, MP 12.2, TDA 3	
Rain Gauge: Puget East 40	
Description: Case Study #1 - 11/29/10	

Discharge Areas	
Subbasin 1 - Baseline Conditions - 10 acres no treatment - 0% infiltration - 10 acres	
Subbasin 1 - Proposed Conditions - 12 acres basic treatment - 0% infiltration - 2 acres enhanced treatment - 60% infiltration - 4 acres no treatment - 0% infiltration - 6 acres	

Load Analysis

	Dissolved Copper Load (lb/yr)		Dissolved Zinc Load (lb/yr)	
	Baseline	Proposed	Baseline	Proposed
Max	8.75	5.6	126	30
75th Percentile	0.464	0.36	3.77	2.7
Median	0.268	0.24	2	1.6
25th Percentile	0.154	0.16	1.05	1
Min	0.005	0.031	0.033	0.18
P (exceed)		0.463		0.438

Concentration Analysis

Subbasin 1	Dissolved Copper Conc (mg/L)		Dissolved Zinc Conc (mg/L)	
	Baseline	Proposed	Baseline	Proposed
Max	0.061	0.062	0.929	0.74
75th Percentile	0.006	0.005	0.05	0.039
Median	0.004	0.004	0.027	0.024
25th Percentile	0.002	0.003	0.014	0.016
Min	0	0.001	0.001	0.004
P (exceed)		0.51		0.476

Figure 14. End-of-pipe loading subroutine results – Case Study #1.

Receiving Water Quality Indicator Check

Instructions – If receiving water quality indicators are determined to be functioning at risk or not properly functioning (per the *NOAA Fisheries and USFWS Matrices of Pathways and Indicators* [see Appendix C]), the HI-RUN receiving water dilution subroutine must be used to assess water quality effects. Otherwise, no additional analysis of stormwater quality effects is necessary.

Case Study #1 – Receiving water quality indicators for the Case Study #1 receiving water were determined to be properly functioning. No additional dilution analysis is required for determination of stormwater quality effects for this project.

Case Study #2: End-of-Pipe and Receiving Water Dilution Subroutines

This second example provides an illustration of how to input data and interpret results using both the end-of-pipe loading subroutine and the receiving water dilution subroutine. The hypothetical project evaluated in Case Study #2 has the following characteristics:

Project Site Assumptions

- Existing roadway area: 24.8 acres
- Existing treatment: biofiltration swale (sized for 4.3 acres)
- Proposed roadway area: 31.1 acres (6.3 additional acres)
- Proposed treatment: media filter drain (previously referred to as ecology embankments) sized for 6.3 new acres. Existing biofiltration swale remains (sized for 4.3 acres).
- Outfall: All runoff in the TDA discharges through a single outfall (only one subbasin).
- Incidental infiltration: Due to sufficient separation between the base of the media filter drain and the seasonal high water table elevation, it is determined that the facility will achieve approximately 60 percent infiltration on an annual runoff volume basis. The biofiltration swale is not expected to have substantial incidental infiltration.
- Detention: Detention is planned for this TDA to meet the *Highway Runoff Manual* flow control requirements.

Receiving Water Assumptions

- ESA-listed fish species present in the project receiving water includes Puget Sound Chinook salmon. An analysis will be performed to evaluate the potential water quality effects of highway runoff on rearing Chinook salmon in the months of August and September.
- Background water quality data from a site upstream of the project outfall is available from a previous watershed assessment effort. The median values for DCu and DZn are 0.002 and 0.003 mg/L, respectively.
- Receiving water quality indicators are properly functioning.

Figure 15 shows an example data input page for the end-of-pipe loading subroutine that has been populated with the requisite input values to reflect these characteristics. The specific procedures required to input these values, run the subroutine, and interpret the associated output are described below.

Running End-of-Pipe Loading Subroutine

Step 1. Enter Project/Threshold Discharge Area Location

Instructions – Enter project location/identification in text box. Identify the project by state route (SR) and milepost (MP). An identifier for the TDA analyzed can also be included when multiple TDAs will be analyzed for a given project. This information should be provided on the *Endangered Species Act Stormwater Design Checklist*.

Case Study #2 – The sample input page shown in Figure 15 displays the following information for the hypothetical Case Study #2: “SR 13, MP 15.5, TDA 1.”

Step 2. Select Precipitation Time Series

Instructions – Select the precipitation time series most applicable to the project location in the pull-down menu. Options include Extended Precipitation Timeseries and individual rain gauge series. These times series match those used in MGSFlood, and can be determined by identifying the project location on the figure in Appendix A. This precipitation map is also available by selecting the **Precipitation Map** button on the data input page of the HI-RUN model. On the precipitation map, the user will first determine whether the project is located in one of the three Extended Precipitation Timeseries zones (Puget West, Puget East, and Vancouver). If so, the user will then identify the nearest isopluvial line to the project location. The number displayed on the isopluvial line (the user may need to zoom into the graphic to read the numbers) is mean annual precipitation at 4-inch increments. The user then exits the precipitation map by pressing the **Go Back to Data Input Sheet** button, and selects the precipitation time series associated with the zone and mean annual precipitation of the project location (e.g., Puget East 40). If the project is located outside of the Extended Precipitation Timeseries zones, the user will identify the appropriate rain gauge for use at the project site (e.g., Montesano), then exit the precipitation map and select the appropriate precipitation time series/rain gauge.

Highway Runoff Dilution and Loading model (HI-RUN) Version 2.0 For Excel 2007

This model is for stormwater analysis associated with biological assessments, and is not a design tool

Data Inputs - End-of-Pipe Loading Subroutine

Description: This model provides risk-based predictions of stormwater quality at the outfall and Threshold Discharge Area (TDA) scale. The Highway Runoff Manual provides a thorough discussion of TDA delineation specific to transportation drainage systems. The analysis of water quality concentrations is conducted at a subbasin scale, with subbasins being divisions of TDAs that have discrete discharge points in the receiving water. If a TDA has only one discharge point, data need only be entered under Subbasin 1. The analysis of pollutant loadings is done at the TDA scale only. Water quality parameters analyzed by this tool are Total Suspended Solids (TSS), Total Copper (TCu), Dissolved Copper (DCu), Total Zinc (TZn), and Dissolved Zinc (DZn).

Project/TDA ID:

Precipitation Timeseries:

Water Quality Parameters

- All
- TSS
- Copper - Total
- Copper - Dissolved
- Zinc - Total
- Zinc - Dissolved

Month

- January
- February
- March
- April
- May
- June
- July
- August
- September
- October
- November
- December

TDA Information - Baseline Conditions							
Treatment Type	Level of Incidental Infiltration (%)	Subbasin Area (acres)					TDA Impervious Area (acres)
		1	2	3	4	5	
Basic	0	4.3					4.3
	20						0
	40						0
	60						0
	80						0
Enhanced	0						0
	20						0
	40						0
	60						0
Infiltration BMP	100						0
None	0	20.5					20.5
Total		24.8	0	0	0	0	24.8

TDA Information - Proposed Conditions							
Treatment Type	Level of Incidental Infiltration (%)	Subbasin Area (acres)					TDA Impervious Area (acres)
		1	2	3	4	5	
Basic	0	4.3					4.3
	20						0
	40						0
	60						0
	80						0
Enhanced	0						0
	20						0
	40						0
	60						6.3
Infiltration BMP	100						0
None	0	20.5					20.5
Total		31.1	0	0	0	0	31.1

Figure 15. Receiving water dilution subroutine input page – Case Study #2.

Case Study #2 – The sample input page shown in Figure 15 indicates the “Montesano” time series will be used in the model for Case Study #2.

Step 3. Select Water Quality Parameters

Instructions – Select the water quality parameters of interest in the analysis. Any combination of one or more of these can be selected from a list box, using the “Shift” or “Ctrl” buttons on the keyboard to choose more than one. The end-of-pipe loading subroutine can analyze TSS, TCu, DCu, TZn, and DZn; and loads for all five should be estimated and reported in the project Biological Assessment. The current stormwater quality effects analysis process is based on Dcu and DZn only. The Biological Assessment should discuss how estimated loads of all five parameters change from baseline to proposed conditions, but this comparison should be more detailed and quantitative for DCu and DZn than for the other three parameters. The receiving water dilution subroutine analyzes DCu and DZn only.

Case Study #2 – The sample input page shown in Figure 15 indicates that DCu and DZn will be analyzed for Case Study #2.

Step 4. Select Months

Instructions – Select the months of interest for which the HI-RUN subroutine will be run. To determine the months of interest, the user must determine when ESA-listed aquatic species could occur in the vicinity of the project. By running the routine for only the months of interest, the number of output data tables generated can be reduced. (Note: this affects the end-of-pipe concentration results and receiving water dilution subroutine results, but not the end-of-pipe loading estimates.)

Multiple months of interest can be selected from the list box using the “Shift” or “Ctrl” keys on the keyboard. The months of interest are those months during which fish could be present and potentially exposed to stormwater discharges. For species that do not show distinct seasonality (i.e., bull trout) or that are present within a system year-round (i.e., steelhead, residual Chinook), analyzing multiple months will be necessary. To determine what months are of interest, the biologist has to determine what life stages could occur in the vicinity of the project. The biologist can determine what life stages could potentially be affected by a project by determining the suitability of the habitat in the action area (area affected by the proposed project) for those life stages. In addition, the biologist should determine the timing of various life stages in the action area by reviewing available literature and reports, and contacting local tribal, agency, or jurisdictional biologists.

Case Study #2 – As described above, Case Study #2 assumes that analyses are being performed to evaluate the potential water quality effects of highway runoff on rearing Chinook salmon in the months of August and September. Accordingly, the sample input page shown in Figure 15 indicates that these months have been selected.

Step 5. Enter Baseline TDA Conditions

Instructions – Enter the areas (in acres) of baseline (existing) impervious surfaces, according to the type of runoff treatment that is provided for stormwater from the areas (basic, enhanced, or no treatment), and the level of incidental infiltration associated with the treatment BMP (0, 20, 40, 60, or 80 percent). Incidental infiltration is characterized at these 20 percent increments to provide a level of flexibility to the model user while still reducing the level of effort required to develop the HI-RUN model. The *HI-RUN Model Technical Documentation* (Herrera 2008) provides more detail on the pre-processing work involved in developing the model.

Case Study #2 – 20.5 acres is entered in the “no treatment” row for Case Study #2. In addition, 4.3 acres is entered under Basic Treatment, 0% Infiltration to represent the portion of the project area that drains to the biofiltration swale (see Figure 15).

Step 6. Enter Proposed TDA Conditions

Instructions – Similar to the information provided in Step 5, enter areas of the proposed impervious drainage subbasin according to treatment BMP type and incidental infiltration rate. This information should be provided on the *Endangered Species Act Stormwater Design Checklist*.

Case Study #2 – The proposed conditions of Case Study #2 have the following drainage subbasin attributes: 4.3 acres draining to a biofiltration swale (Basic Treatment); 6.3 acres draining to media filter drains (Enhanced Treatment) that achieve approximately 60 percent infiltration on an annual runoff volume basis; and 20.5 acres with no treatment. This information is reflected in the “Outfall Information – Proposed Conditions” table on the input page for Case Study #2 (see Figure 15).

Step 7. Run End-of-Pipe Loading Subroutine

Instructions – After entering all of the above information into the input page, run the end-of-pipe loading subroutine by clicking the **Run Loading Model** button. The user will be asked whether flow control (detention) should be applied to the project TDA. If only one subbasin has values entered, the user simply selects “Yes” or “No”. If multiple subbasins have values entered, the user is prompted to select the subbasin in which the detention facility will be located. The user should select “No” or check the **No Flow Control** box if a detention facility is not planned. If a detention basin is to be constructed in the TDA, the user will click “Yes” or select the subbasin in which it will be located from the dropdown menu. Once the flow control information has been completed, the user will click the “Run Analysis” button. This information should be provided on the *Endangered Species Act Stormwater Design Checklist*.

Before HI-RUN conducts the end-of-pipe loading analysis, an additional window (“Confirm Input Parameters”) will appear to prompt the user to review input data and provide text describing the model run as needed. The text entered in this box will be included in the output file to assist with documentation of results, and can include initials of the analyst and notes and assumptions associated with the input data entered.

Case Study #2 – Because detention facilities are planned, "Yes" is selected in the flow control window (see Figure 16). In the "Confirm Input Parameters" window, the initials of the analyst and a note regarding the source of input data are entered (see Figure 17).

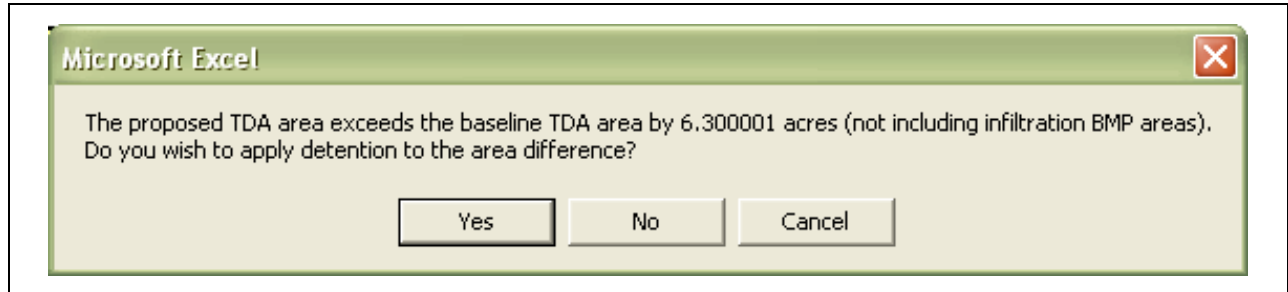


Figure 16. Flow control dialog box – Case Study #2.

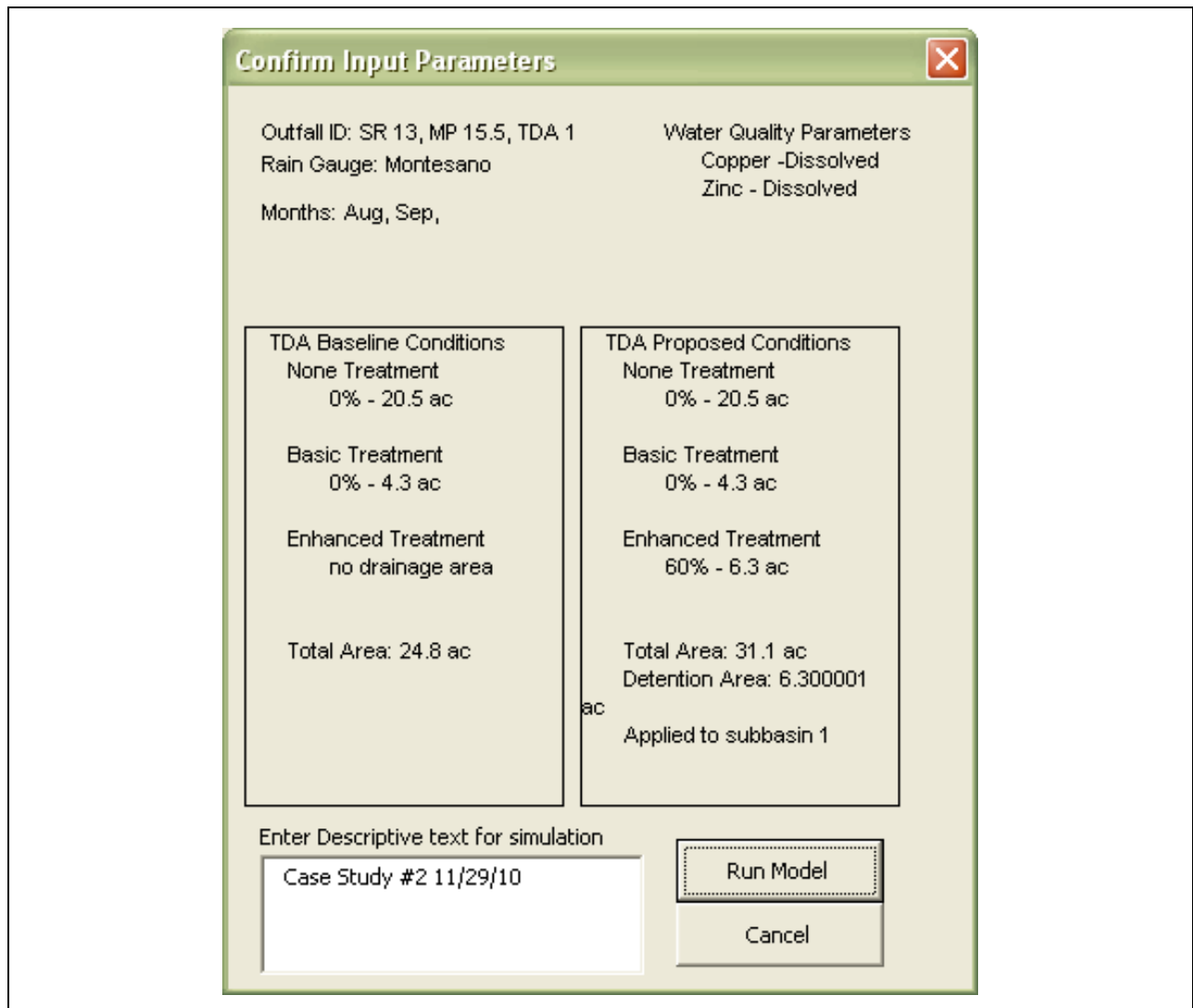


Figure 17. Confirm input parameters dialog box – Case Study #2.

Interpreting End-of-Pipe Loading Subroutine Results

Instructions – When the analysis has been completed, HI-RUN will prompt the user to save the output file. The end-of-pipe loading subroutine output file consists of a “Results” summary sheet and individual sheets with concentration results for each subbasin analyzed. The loading statistics presented on the “Results” sheet will be reviewed by the user to determine whether further analysis is needed to assess water quality effects on the receiving water. The loading results include the following statistics for each selected parameter for baseline and proposed conditions in the project TDA:

- Maximum load (pounds per year [lb/yr])
- 75th percentile load (lb/yr)
- Median load (lb/yr)
- 25th percentile load (lb/yr)
- Minimum load (lb/yr)

The maximum values provide a worst-case load estimate for comparing the baseline and proposed conditions. The percentile values provide an indication of the overall distribution of the loading estimates. For example, the 75th percentile value represents the load estimate at which 75 percent of the values will be lower and 25 percent will be higher.

In addition, a P(exceed) value is provided for each parameter. As discussed in the *Stormwater Quality Effects Analysis Process* section above, the P(exceed) values associated with the loading estimates represent the probability that loads will be greater in the proposed condition than in the baseline condition and are the statistics of interest in the effects evaluation. **The TDA P(exceed) value for DZn must be compared to the thresholds identified in Figure 10 to help determine the need for conducting a detailed dilution analysis using the receiving water dilution subroutine.** For guidance, see the *Stormwater Quality Effects Analysis Process* section of this user's guide.

In addition to the loading results described above, the end-of-pipe loading subroutine also provides information on pollutant concentrations at the project outfall. This information is provided for additional understanding of project water quality conditions, but is not specifically used in the stormwater quality effects analysis process shown in Figure 10. Interpretation of these concentration results is provided in the *Using the HI-RUN Model* section of this user's guide.

Case Study #2 – The P(exceed) value for dissolved zinc is 0.514 (see Figure 18). The evaluation flow chart (Figure 10) is used to determine what level of analysis (if any) is needed of water quality effects in the receiving water. The resulting P(exceed) value (0.514) is greater than 0.45. Therefore, a detailed dilution analysis using the receiving water dilution subroutine must be conducted as a next step. The specific procedures required to run the subroutine and interpret the associated output are described in the following subsection.

Highway Runoff Dilution and Loading model (HI-RUN) Version 2.0 End of Pipe Loading Subroutine Report

This model is for stormwater analysis associated with biological assessments, and is not a design tool.

Input Summary	

Run Date/Time: 12/14/10 16:45	
Outfall ID: SR 13, MP 15.5, TDA 1	
Rain Gauge: Montesano	
Description:	

Discharge Areas	
Subbasin 1 - Baseline Conditions - 24.8 acres	
basic treatment - 0% infiltration - 4.3 acres	
no treatment - 0% infiltration - 20.5 acres	
Subbasin 1 - Proposed Conditions - 31.1 acres	
basic treatment - 0% infiltration - 4.3 acres	
enhanced treatment - 60% infiltration - 6.3 acres	
no treatment - 0% infiltration - 20.5 acres	

Load Analysis

	Dissolved Copper Load (lb/yr)		Dissolved Zinc Load (lb/yr)	
	Baseline	Proposed	Baseline	Proposed
Max	27.4	30	289	280
75th Percentile	2.05	2.1	15.7	16
Median	1.22	1.3	8.47	8.9
25th Percentile	0.741	0.81	4.88	5.2
Min	0.048	0.075	0.232	0.51
P (exceed)		0.521		0.514

Concentration Analysis

Subbasin 1	Dissolved Copper Conc (mg/L)		Dissolved Zinc Conc (mg/L)	
	Baseline	Proposed	Baseline	Proposed
Max	0.077	0.062	0.956	1.101
75th Percentile	0.006	0.006	0.046	0.044
Median	0.004	0.004	0.026	0.026
25th Percentile	0.002	0.002	0.015	0.016
Min	0	0.001	0.002	0.003
P (exceed)		0.5		0.5

Figure 18. End-of-pipe loading subroutine results – Case Study #2.

Running Receiving Water Dilution Subroutine

The receiving water dilution subroutine is used to estimate the distance downstream of a discharge point where dissolved copper (DCu) and dissolved zinc (DZn) in runoff have the potential to impact ESA-listed salmonids. This distance is predicted iteratively by estimating the probability that pollutant concentrations will exceed biological effects thresholds. The distance values are varied until a distance is determined where the probability of exceeding the biological effects thresholds is less than a predefined project risk limit. In most cases, this default project risk limit will be a 5 percent probability of exceeding each effect threshold. This analysis is conducted for baseline and proposed conditions to estimate both the downstream distance of potential impact, and determine how the proposed project may change water quality conditions in the receiving water relative to baseline conditions.

Step 1. Background Concentrations

Instructions – Enter representative receiving water background DCu and DZn concentrations in the Dilution Inputs page. This information should be provided on the *Endangered Species Act Stormwater Design Checklist*.

Case Study #2 – 0.002 and 0.003 are entered for dissolved copper and dissolved zinc, respectively (see Figure 19).

Steps 2 - 6. Receiving Water Characteristics

Instructions – Enter channel dimensions, including Stream Depth, Stream Velocity, Channel Width, and Slope or Manning's Roughness. In addition, enter the outfall discharge distance from nearest shoreline. All of these parameters should be provided on the *Endangered Species Act Stormwater Design Checklist*. Note that in some cases, channel measurements may not be available for all months of interest. The best information available must be used to characterize channel conditions.

Case Study #2 – The receiving water for Case Study #2 is small and wadeable. Therefore, the field channel measurements displayed in Table 1 were collected for each month of interest.

Table 1. Field channel measurements collected for Case Study #2 receiving water.

Parameter	August Measurement	September Measurement
Discharge (cfs)	8.6	7.5
Average Velocity (ft/s)	0.53	0.5
Maximum Depth (ft)	2.1	2
Average Depth (ft)	1.55	1.5
Top Width (ft)	14	13.5
Water Surface Slope (ft/ft)	0.004	0.004
Outfall Distance from Bank (ft)	0	0

Highway Runoff Dilution and Loading model (HI-RUN) Version 2.0 For Excel 2007

Run Dilution Model

Sub basin 1

Load Dilution Inputs

Save Dilution Inputs

Clear Inputs

Inputs for Receiving Water Dilution Subroutine

Dilution subroutine analysis is only conducted on pollutants that have an established biological effects threshold (dissolved copper and zinc)

Subbasin 1

Background
Concentration
(mg/L)

TSS
Copper - Total
Zinc - Total
Copper -Dissolved
Zinc -Dissolved

0.002
0.003

Enter short description of simulation (optional)

	January	February	March	April	May	June	July	August	September	October	November	December
Stream Depth (ft)								1.55	1.5			
Stream Velocity (fps)								0.53	0.5			
Channel Width (ft)								10.5	10			
Slope								0.004	0.004			
Discharge Distance into Water Body From Nearest Shoreline (ft)								0	0			

Figure 19. Receiving water dilution subroutine input window.

Based on these field measurements, average channel width values of 10.5 and 10 feet were calculated (discharge divided by the velocity and average depth). The depth, velocity, width, slope, and distance from nearest shoreline are entered in the appropriate columns for the months of interest (see Figure 19).

Step 7. Determine Mixing Distance Downstream for Baseline and Proposed Conditions

Instructions – The receiving water dilution subroutine conducts an iterative analysis of downstream extent of potential water quality effects for both baseline and proposed conditions using an automated routine. The user simply clicks the **Run Dilution Model** button on the dilution inputs page, selects the subbasin to analyze, and indicates whether detention BMPs will be applied in the subbasin (if prompted).

The results tables generated by the receiving water dilution subroutine includes a summary results table displaying results for all months of interest and detailed tables of pollutant concentrations in three intervals for DCu and DZn: (1) less than background, (2) background to biological effects threshold, and (3) greater than biological effects threshold. Detailed tables will be generated for each combination of pollutant analyzed, month of interest, and condition (baseline and proposed). The “greater than biological effects threshold” probability value will be highlighted in each of the detailed tables. This is the probability value (less than or equal to the project effects limit of 0.05) for the related downstream distance value in the summary table.

After running the receiving water dilution subroutine, save the results file for reference and continue to Step #8.

Case Study #2 – The receiving water subroutine was run by clicking the **Run Dilution Model** button. At the prompt, subbasin 1 was selected for analysis. Since a detention BMP is planned for this subbasin, “yes” was selected at the prompt.

Step 8. Interpreting Receiving Water Dilution Subroutine Results

Instructions – Review summary results table to determine the estimated downstream distance for potential water quality effects from runoff generated in the analyzed subbasin. Results are shown for baseline and proposed conditions so that a general indication of how the project could alter receiving water conditions can be made. In addition, the extent of potential effects can be seen on a monthly interval during the period(s) when ESA-listed fish may be present.

The maximum downstream distance of potential water quality effect calculated for the proposed condition defines the area within which ESA-listed aquatic species could be affected. This information should then be considered by the author of the biological assessment when making a stormwater related effect determination during an ESA Section 7 consultation. However, it must be stressed that this output is intended to provide a screening-level assessment of the risk of impact on ESA-listed species from highway runoff. Where this screening-level assessment indicates a potential risk exists, a more detailed assessment (quantitative or qualitative) of the

project should be performed to determine whether there are mitigating factors that are not reflected in the output of the HI-RUN model.

Case Study #2 – Figure 20 provides a summary table of the receiving water dilution subroutine results for the selected months of August and September. The distance downstream where the biological effects threshold will be met for DCu is within 1 foot for both baseline and proposed conditions in both months. This is indicated by “<1” in the summary table. For DZn, the estimated distance downstream where the biological effects threshold will be met is 7 feet for August under both the baseline and proposed condition, and 17 feet in September under both the baseline and proposed condition.

Highway Runoff Dilution Summary Results

INPUTS

Project: SR 13, MP 15.5, TDA 1
 Precipitation Series: Montesano
 Description: Case Study #2 Dilution

Background Concentrations (mg/L)
 Dissolved Copper: 0.002
 Dissolved Zinc: 0.003

Discharge Area
 Baseline Conditions: 24.8 acres
 Basic Treatment Infiltration 0% - 4.3 acres
 No Treatment Infiltration 0% - 20.5 acres

Proposed Conditions: 31.1 acres
 Enhanced Treatment Infiltration 60% - 6.3 acres with detention
 Basic Treatment Infiltration 0% - 9.536743E-07 acres with detention
 Basic Treatment Infiltration 0% - 4.299999 acres
 No Treatment Infiltration 0% - 20.5 acres

Stream Inputs

	Aug	Sep
Depth (ft)	1.55	1.5
Velocity (fps)	0.53	0.5
Width (ft)	10.5	10

		Distance Downstream in feet to Meet Biological Threshold											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dissolved Copper	Baseline								< 1	< 1			
	Proposed								< 1	< 1			
Dissolved Zinc	Baseline								7	17			
	Proposed								7	17			

Figure 20. Receiving water dilution subroutine summary results – Case Study #2.

References

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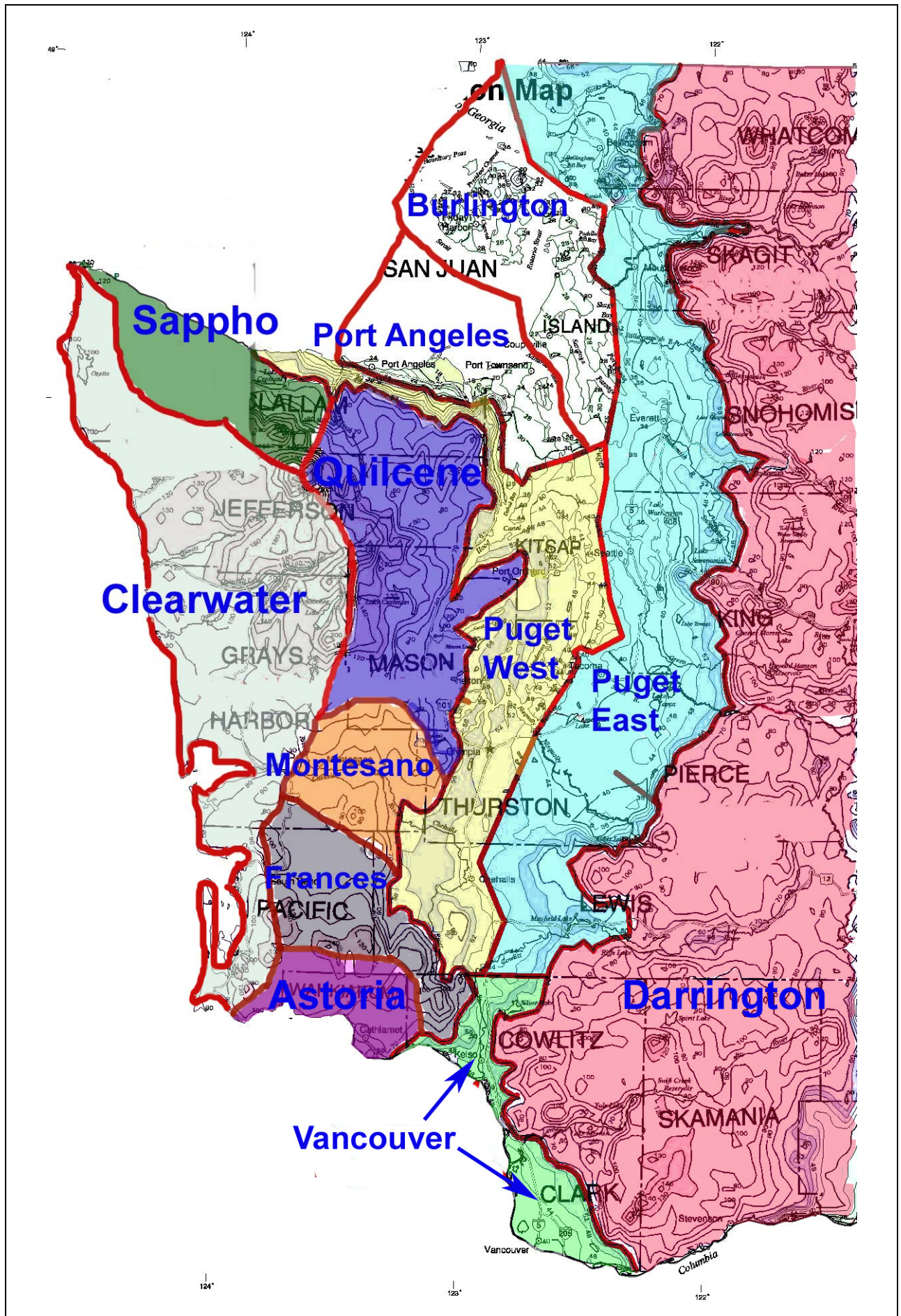
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APPENDIX A

Extended Precipitation Time Series Zones Used by MGSFlood in Western Washington



APPENDIX B

Example Endangered Species Act Stormwater Design Checklist and Guidance

**Endangered Species Act
Stormwater Design Checklist**

For Western Washington

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Endangered Species Act Stormwater Design Checklist

Purpose and Use of the Checklist

The Stormwater Design Checklist assists project designers in providing pertinent information about a project's stormwater treatment facilities to biologists responsible for preparing biological assessments required for consultation under Section 7 of the Endangered Species Act. The use of this checklist is necessary to aid in developing biological assessments and promoting consistency in the content provided in the agency's biological assessments.

It is possible that the specific conditions of some projects may warrant modifying or adding certain checklist items. However, to maintain consistency in the type and amount of information collected and submitted for the environmental permitting process, the checklist should be modified only if necessary.

Endangered Species Act Stormwater Design Checklist

Project Name: _____

Project Location: _____

Part 1

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:

2. 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:

3. If MGS-Flood was used to analyze flows and size stormwater facilities, enter the precipitation timeseries used:

Existing Stormwater Facilities (Pre-project)

4. How many TDAs exist within in the project area, how many outfalls or discharge point(s) are located in each TDA, and what are the receiving waterbodies?

Existing TDA Number	Number of Discharge Points/Outfalls	Receiving Waterbody

5. For each existing TDA/outfall (subdivide TDAs if there are multiple outfalls), identify total TDA area, area of impervious surface, area of impervious surface receiving runoff treatment, the runoff BMP type(s), area of impervious surface not receiving runoff treatment, area of impervious surface receiving flow control, the flow control BMP type(s), area of impervious surface being infiltrated via an infiltration BMP, and area of impervious surface not receiving flow control. If available, provide a map depicting drainage basin boundaries for TDAs and subbasins for individual outfalls within a TDA (if applicable), and BMP locations. This information can be summarized in the following table for each TDA/outfall. Some of this information can be provided in the table below, and some written description(s) may be necessary:

Existing TDA/Outfall Number	Total Area (acres)	Total Impervious Surface Area (acres)	Area w/ Runoff Treatment (acres)	Runoff Treatment BMP Type(s)	Area w/ No Runoff Treatment (acres)	Area w/ Flow Control (acres)	Flow Control BMP Type(s)	Area to Infiltration BMP (acres)	Area w/ No Flow Treatment (acres)
Project Totals									

6. Describe the nature of the existing stormwater conveyance (drainage) system (e.g., pipe, culvert, channel, ditch, swale, sheet flow), including the drainage distance from project

right-of-way to project receiving waterbody. If available, provide a map of the conveyance system depicting TDA/outfall subbasin boundaries.

7. To facilitate stormwater modeling efforts, for each TDA, fill out the Pre-project section of Form A (Inputs for End-of-Pipe Calculation).

Proposed Stormwater Facilities (Proposed Project)

8. How many TDAs have been identified in the project area, how many outfalls or discharge point(s) are located in each TDA, and what are the receiving waterbodies?

Proposed TDA Number	Number of Discharge Points/Outfalls	Receiving Waterbody

9. For each proposed TDA/outfall (subdivide TDAs if there are multiple outfalls), identify total TDA area, area of impervious surface, area of impervious surface receiving runoff treatment, the runoff BMP type(s), area of impervious surface not receiving runoff treatment, area of impervious surface receiving flow control, the flow control BMP type(s), area of impervious surface being infiltrated via an infiltration BMP, and area of impervious surface not receiving flow control. If available, provide a map depicting drainage basin boundaries for TDAs and subbasins for individual outfalls within a TDA (if applicable), and BMP locations. This information can be summarized in the following table for each TDA/outfall. Some of this information can be provided in the table below, and some written description(s) may be necessary:

Existing TDA/ Outfall Number	Total Area (acres)	Total Impervious Surface Area (acres)	Area w/ Runoff Treatment (acres)	Runoff Treatment BMP Type(s)	Area w/ No Runoff Treatment (acres)	Area w/ Flow Control (acres)	Flow Control BMP Type(s)	Area to Infiltration BMP (acres)	Area w/ No Flow Treatment (acres)
Project Totals									

10. If no runoff treatment or flow control BMPs are proposed for a TDA, provide justification.

11. Describe the nature of the proposed stormwater conveyance (drainage) system (e.g., pipe, culvert, channel, ditch, swale, sheet flow), including the drainage distance from project right-of-way to project receiving waterbody. If available, provide a map of the conveyance system depicting TDA/outfall subbasin boundaries.

12. For each TDA, fill out the Proposed Project section of Form A (Inputs for End-of-Pipe Calculation).

13. Are any of the project's proposed TDAs exempt from the flow control requirement per the most recent version of the *Highway Runoff Manual*? Yes No

If yes, identify the exempt TDA(s) and basis for exemption:

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.

Note: For some receiving waterbodies, the project biologist may need to acquire more detailed information flow related impacts.

14. For each non-exempt TDA, identify the total area of new impervious surface to receive flow control and for western Washington, the predeveloped land cover design standard (grass, pasture, or forested):

TDA Number	Square Feet, Acres	Predeveloped Land Cover Design Standard (western Washington only)

15. Will any existing impervious surface be retrofitted for flow control? Yes No

If yes, identify the total area of the existing impervious surface in each TDA will be retrofitted for flow control and for western Washington, the predeveloped land cover design standard (grass, pasture, or forested):

TDA Number	Square Feet, Acres	Predeveloped Land Cover Design Standard (western Washington only)

16. For western Washington, is the project able to provide all the required flow control for new impervious surfaces within the project limits to the historic land cover standard?

Yes No

If *no*, identify where and how this project-triggered retrofit obligation will be met off-site, including the location(s) and the applicable land cover design standard (grass, pasture, or forested):

On-Site/Off-Site Location TDA Numbers	Volumetric Difference Between Off-site and On-site Volume Detained	Land Cover Design Standard (western Washington only)

17. Is the project able to provide all the required flow control for replaced impervious surfaces within the project limits? Yes No

If *yes*, for each TDA, identify total area of the replaced pollution-generating impervious surface to receive flow control and for western Washington, the predeveloped land cover design standard (grass, pasture, or forested):

TDA Number	Square Feet, Acres	Predeveloped Land Cover Design Standard (western Washington only)

If *no*, identify where and how this project-triggered retrofit obligation will be met off-site, including the location(s) and the applicable land cover design standard (grass, pasture, or forested):

Off-Site Location TDA Number	Square Feet, Acres	Land Cover Design Standard

18. Does the project transfer water between watersheds? Yes No

19. 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.

20. 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* (Appendix 2A).

21. What stormwater management design standards were applied?

WSDOT *Highway Runoff Manual*, version _____
(1995, 2004, 2006, 2007, 2008, etc.)

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

Other: _____

Not Applicable

22. Will project require dilution modeling? *The project biologist will determine this for each project TDA by completing the End-of-Pipe loading analysis from HI-RUN Model, based upon the information provided in this checklist.* Yes No Not Determined

If no, or not determined, this form is complete.

If *yes*, the project biologist will contact the project engineer/designer and request that **Part 2** be filled out for each discharge point/outfall in the TDA(s) of interest: If not determined, do not continue on to Part 2, until the project biologist(s) determine if it is necessary.

Prepared by _____ Phone _____ Date _____

Project Engineer _____ Office Location _____

Part 1 (continued)

Form A – TDA _____

Inputs for HI-RUN Model End-of-Pipe Loading Subroutine

Baseline (i.e., Pre-Project) Stormwater Facilities

<i>Treatment Type</i>	<i>Level of Infiltration ^a</i>	<i>Subbasin 1 Impervious Area (acres)</i>	<i>Subbasin 2 Impervious Area (acres)</i>	<i>Subbasin 3 Impervious Area (acres)</i>	<i>Subbasin 4 Impervious Area (acres)</i>	<i>Subbasin 5 Impervious Area (acres)</i>
<input type="checkbox"/> Basic OR <input type="checkbox"/> Phosphorus <i>(Check one)</i>	0%					
	20%					
	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%					
	80%					
None						
Infiltration BMP	100%					

^a Level of infiltration relates to the amount of incidental infiltration that can be expected, expressed as a percentage of annual average flow volume. If no incidental infiltration can be assumed, enter area in the row corresponding to “0%”.

Proposed (i.e., Post Project) Stormwater Facilities

<i>Treatment Type</i>	<i>Level of Infiltration ^a</i>	<i>Subbasin 1 Impervious Area (acres)</i>	<i>Subbasin 2 Impervious Area (acres)</i>	<i>Subbasin 3 Impervious Area (acres)</i>	<i>Subbasin 4 Impervious Area (acres)</i>	<i>Subbasin 5 Impervious Area (acres)</i>
<input type="checkbox"/> Basic OR <input type="checkbox"/> Phosphorus <i>(Check one)</i>	0%					
	20%					
	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%					
	80%					
None						
Infiltration BMP	100%					

^a Level of infiltration relates to the amount of incidental infiltration that can be expected, expressed as a percentage of annual average flow volume. If no incidental infiltration can be assumed, enter area in the row corresponding to “0%”.

See HI-RUN Users Guide for instructions on completing these tables.

Part 2

Form B – TDA _____

Inputs for HI-RUN Model Receiving Water Dilution Subroutine

Stormwater Parameter	Background Concentration (mg/L)
<i>Total Suspended Solids</i>	
<i>Copper – Total</i>	
Copper – Dissolved	
<i>Zinc – Total</i>	
Zinc – Dissolved	

Values for parameters shown in italics are for information only, and are not used in the HI-RUN analysis

Drainage Subbasin # _____

Receiving Water Characteristics Downstream from Discharge	Month											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept	Oct.	Nov.	Dec.
Stream depth (ft)												
Stream velocity (fps)												
Channel width (ft)												
<input type="checkbox"/> Stream slope (ft/ft) OR <input type="checkbox"/> Manning’s roughness “n” (Check one)												
Discharge distance into receiving waterbody from nearest shoreline												

Drainage Subbasin # _____

Receiving Water Characteristics Downstream from Discharge	Month											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept	Oct.	Nov.	Dec.
Stream depth (ft)												
Stream velocity (fps)												
Channel width (ft)												
<input type="checkbox"/> Stream slope (ft/ft) OR <input type="checkbox"/> Manning’s roughness “n” (Check one)												
Discharge distance into receiving waterbody from nearest shoreline												

See HI-RUN Users Guide for instructions on completing these tables.

Endangered Species Act Stormwater Design Checklist

This section presents the Endangered Species Act (ESA) Stormwater Design Checklist and provides guidance on the selection or generation of HI-RUN input data that is included in the checklist.

The ESA Stormwater Design Checklist assists project designers in providing pertinent information about a project's stormwater treatment facilities to biologists responsible for preparing biological assessments required for consultation under Section 7 of the ESA. The use of this checklist is necessary to aid in developing biological assessments and promoting consistency in the content provided in the agency's biological assessments.

It is possible that the specific conditions of some projects may warrant modifying or adding certain checklist items. However, to maintain consistency in the type and amount of information collected and submitted for the environmental permitting process, modifications to the checklist should only occur if necessary.

Form A – Project Impervious Areas

Selection of input data for the end-of-pipe loading subroutine is primarily addressed in the HI-RUN User's Guide. The determination of treatment type and level of incidental infiltration is discussed below.

TDA Information – Baseline Conditions and Proposed Conditions

TDA's and Subbasins

A project site is first divided into Threshold Discharge Areas (TDAs) using guidance from the *Highway Runoff Manual* (WSDOT 2008b). A TDA is composed of one or more drainage subbasins, each of which discharge to a receiving water from a distinct outfall or location. TDAs and subbasins are determined during the design of site stormwater drainage and are documented in the project Hydraulic Report. If a Hydraulic Report has not yet been generated, the hydraulic engineer should be consulted to provide the most current site information. If it has not been determined if a TDA will be served with more than one outfall or discharge point, it should be assumed that stormwater will discharge to the receiving water at a single point/outfall.

Treatment Type

For the purposes of the HI-RUN model analysis, runoff treatment BMPs are divided into two groups: basic and enhanced. Enhanced BMPs are distinguished by their expected performance in removing dissolved metals from stormwater. These groups correspond to the level of treatment that individual stormwater BMPs are credited with in the *Highway Runoff Manual* (WSDOT 2008b):

Basic Treatment BMPs

- RT.02 – Vegetated Filter Strip
- RT.04 – Biofiltration Swale
- RT.05 – Wet Biofiltration Swale
- RT.06 – Continuous Inflow Biofiltration Swale
- RT.12 – Wet Pond (basic).

Enhanced Treatment BMPs

- RT.02 – Compost-Amended Vegetated Filter Strip
- RT.07 – Media Filter Drain (previously named Ecology Embankment)
- RT.13 – Constructed Stormwater Treatment Wetland.

For the purposes of the HI-RUN model, phosphorus treatment BMPs are considered basic treatment.

Level of Incidental Infiltration

Some runoff treatment BMPs have demonstrated a substantial ability to infiltrate runoff to shallow groundwater, effectively removing this water from the surface water drainage system. At the time the HI-RUN model was developed, two BMPs could be credited with incidental infiltration: media filter drains (previously named ecology embankments) could be credited with up to 62 percent infiltration (on an average annual volume basis), and compost-amended vegetated filter strips (CAVFS) could be credited with up to 80 percent infiltration. The level of infiltration that can be credited to a specific treatment BMP installation will be affected by depth to the groundwater table and specific soil characteristics at the project site. In general, if there is greater than 1 foot of separation between the base of the treatment facility and the seasonal high groundwater table, and the facility is not lined, then the full infiltration rate credit could be applied. If there is less separation, less or no infiltration should be applied to the BMP. Native site soils may also have an influence on infiltration rate, but media filter drains and CAVFS are typically configured to infiltrate through a constructed road embankment with different soil properties. For this reason, infiltration may be applied in most cases where native underlying soils are not conducive to infiltration. The HI-RUN model user should consult with the project designer when determining an appropriate level of infiltration to apply to BMPs. Justification for use of incidental infiltration rates must be provided in documentation of the stormwater effects analysis.

Note that the HI-RUN model also does not explicitly account for stormwater management facilities that use infiltration for flow control purposes. If a project has an infiltration facility that effectively removes all of the runoff generated in a portion of the site from the surface water drainage system, the HI-RUN user can account for this by subtracting (or not including) the drainage area contributing to the facility in the model input. If the HI-RUN user does this, it is important that it is documented in the Model Run Description text box so that it is understood by others reviewing model results.

Form B – Receiving Water Information

Selection of background pollutant concentrations and receiving water characteristics used as inputs to the HI-RUN receiving water dilution subroutine are described in this section.

Background Pollutant Concentrations

Background concentrations of pollutants in receiving waters may be obtained from existing sources, or may require the collection and analysis of samples. Where possible, data should meet the following minimum quality standards:

- Sample collection in accordance with Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies (Ecology 2004).
- Analysis conducted by laboratory accredited by the Washington State Department of Ecology (<<http://www.ecy.wa.gov/programs/eap/lab-accreditation.html>>).

In the interest of using data that is representative of water that will mix with project runoff, data sources and collection locations are listed below in order of preference:

1. Existing data from sampling immediately upstream of the project.
2. Existing data from sampling some distance upstream from the project but in areas with similar drainage basin land use characteristics.
3. Existing data from sampling upstream of the project, regardless of the drainage land use characteristics.
4. Existing data from sampling immediately downstream of the project.
5. Existing data from some distance downstream from the project but in areas with similar drainage basin land use characteristics.
6. Existing sampling data from downstream of the project, regardless of the drainage land use characteristics.
7. Data from another nearby stream with similar land use characteristics and flow volumes.
8. Data from a regional water quality database.
9. New data from sampling immediately upstream of the project.

Where data are available from more than one sampling event from these sources, the median value should be used as input for the receiving water dilution subroutine.

The Washington State Department of Ecology's (Ecology's) Environmental Information Management (EIM) database (<<http://www.ecy.wa.gov/eim/>>) is an excellent source for existing data on receiving water background concentrations. Water quality data for surface waters around the state are stored in this database, and can be accessed on-line. Additional sources of receiving water concentration data include the following web accessible databases:

- King County Stream and River Water Quality Monitoring:
<<http://dnrp.metrokc.gov/wlr/waterres/streamsdata/>>
- Snohomish County Surface Water Quality Online Data:
<http://web5.co.snohomish.wa.us/spw_swhydro/wq-search.asp>
- USGS Washington Water Science Center:
<<http://wa.water.usgs.gov/data/qw/>>.

Receiving Water Characteristics

Inputs for the receiving water dilution calculator should be obtained through one or more field measurements in receiving waters that are considered wadeable (for guidance on determining whether a stream is safely wadeable, refer to *Safety in Field Activities* [Lane and Fay 1997]). To obtain these measurements, a current meter is used in conjunction with the following procedure for measuring stream discharge:

1. Extend a measuring tape at right angles to the direction of flow and measure the width of the cross section. Record measurements on a data sheet. Leave the tape strung across the stream.
2. Divide the width into segments using at least 20 points of measurement. If previous flow measurements have shown uniform depth and velocity, fewer points may be used. *Smaller streams may also require fewer points.* Measuring points should be closer together where depths or velocities are more variable. Cross sections with uniform depth and velocity can have equal spacing.
3. Record the distance from the initial starting bank and the depth at each observation point.
4. Record the current velocity at each observation point (see Figure B-1). Horizontal (from right to left bank) and vertical (top to bottom) variation of stream velocity may influence stream flow measurements. To correct for vertical differences, hydrologists have determined depths that can yield acceptable estimates of the mean velocity over a vertical profile. If the depth exceeds 0.8 m (2.5 feet), it is recommended that velocities be measured at 20 percent and 80 percent of full depth and averaged to estimate mean velocity. In the depth range 0.1 to 0.8 m (0.3 to 2.5 feet), take the velocity at

60 percent of the full depth (measured from the surface) as an estimate of the mean over the profile. Measuring velocity in water shallower than 0.1 m (0.3 feet) is difficult with conventional current meters.

5. Use Equation 1 to calculate total stream discharge.

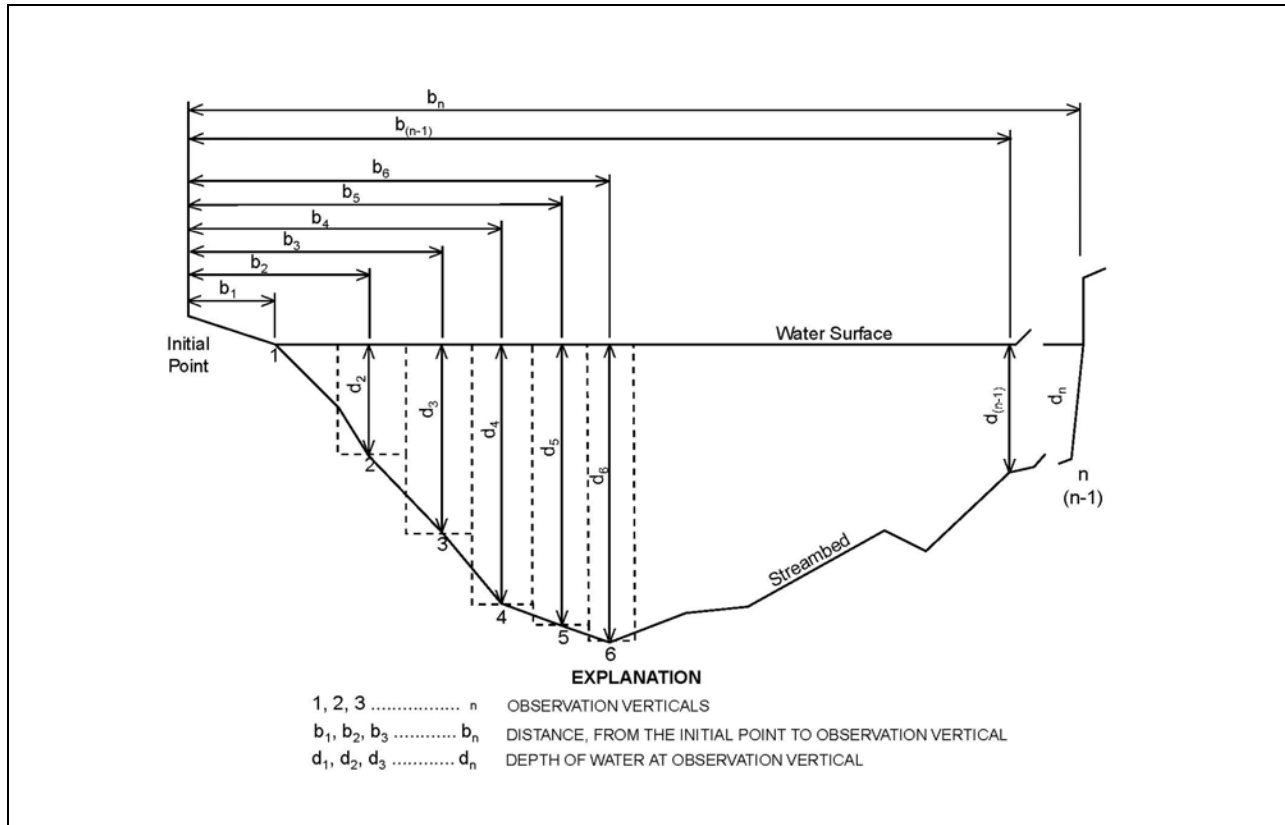


Figure B-1. Sketch of midsection method of computing cross section area for discharge measurements.

Calculate flow as a summation of flows in partial areas using the following equation:

Equation 1

$$Q_n = V_n \times d_n \left(\frac{b_{n+1} - b_{n-1}}{2} \right)$$

- Where:
- b_{n-1} = distance from initial point to the preceding point (m or ft)
 - b_{n+1} = distance from the initial point to the following point (m or ft)
 - d_n = mean depth at location n (m or ft)
 - V_n = mean velocity at location n (m/sec or ft/sec)
 - Q_n = discharge through partial section n (m³/sec or ft³/sec).

Average stream depth, velocity, and width can be calculated as follows based on these data:

- Stream Depth: Average stream depth (ft) is calculated by averaging all the values for d_n that were measured during the channel cross-section survey.
- Stream Velocity: Average stream velocity (ft/sec) would be calculated by averaging all the values for V_n that were measured during the channel cross-section survey.
- Channel Width: An average width (ft) can be calculated by dividing the discharge calculated using Equation 1 by both the average velocity and average depth.

Additional guidance on stream discharge calculations can be found in *Stream Channel Reference Sites: An Illustrated Guide to Field Technique* (Harrelson et al. 1994).

To the extent possible, these measurements would be made during each month of interest for consultation process. However, it is conceivable that a single field measurement might be applied to more than 1 month if flows are expected to remain relatively constant over the intervening period. For example, a measurement made during low flow conditions in July might also be applied to August and September. It may not be feasible to collect measurements during every month of interest, or even during a suitable month of interest. Effort must be made to collect the best data possible, but professional judgment may be need to be exercised to relate measured data to parameters during the months of interest.

For larger streams and rivers that are not considered wadeable, there is a greater likelihood that continuous time series flow data from a gauging station or modeling effort will be available. The 25th percentile (1st quartile) flow rate for each month of interest is to be used to develop input parameters for the receiving water dilution calculator. Physical characteristics of these systems can be determined using predetermined channel cross-sections and rating curves at established stream gauges (contact agency that maintains the gauge). Potential sources for these data in larger streams and rivers include:

- USGS stream gauge data (<<http://wa.water.usgs.gov/data/>>)
- Ecology stream gauge data (<<https://fortress.wa.gov/ecy/wrx/wrx/flows/regions/state.asp>>)
- Stream gauge data from local agencies such as King County (<<http://dnrp.metrokc.gov/wlr/waterres/hydrology/>>)
- FEMA floodplain modeling and mapping studies. County floodplain managers should be contacted for this information.
- Project or site-specific studies. If restoration or other design projects have occurred in the vicinity of the project, hydrologic monitoring and/or modeling may have already been conducted. Check with agencies, tribes, community organizations in the project vicinity to determine if data exists.

If the sources above do not provide useful data, estimation methods such as those listed below can be employed:

- Basin scaling and translation – In cases where stream gauge data exists for a given receiving water, but the gauge is not located near the outfall, flow statistics from that gauge can be scaled using the relative contributing basin area and other watershed parameters. If stream gauge data exists for a different water body with similar watershed characteristics, discharge may be estimated using the scaling methods described above.
- Flood frequency regression equations (USGS) – Existing relationships developed and published by USGS (Sumioka et al. 1998; <http://wa.water.usgs.gov/pubs/wrir/flood_freq/>) can be used to estimate peak discharge values for ungauged streams in Washington. There is an on-line tool called StreamStats that automates this calculation (<<http://water.usgs.gov/osw/streamstats/Washington.html>>). This method gives extreme peak flow values only. To use this information to estimate monthly flow values, it would be necessary to apply relationships between peak discharge values and monthly mean values on different stream systems where these data are available.

The HI-RUN receiving water dilution subroutine requires channel slope or channel roughness, which can be measured or estimated as described below:

Slope

Channel slope can be measured using an autolevel or hand level. It is important that channel slope be measured between two points of similar geomorphic character (e.g., riffle crests). Slope can be measured at the water surface rather than at the channel thalweg, but the same consideration holds: if the channel consists of pool-riffle sequences, it is important to measure slope at similar points in the sequence.

Manning Roughness

Guidance on estimating roughness values for natural channels can be found at: <<http://www.fhwa.dot.gov/bridge/wsp2339.pdf>>.

Calculations

Channel discharge, average velocity, and average depth are calculated from water depth and velocity inputs (Harrelson et al. 1994). In addition, an “average” width can be calculated as the flow area divided by the average depth. The average depth and width values would then be used as inputs to the HI-RUN receiving water dilution subroutine.

APPENDIX C

Water Quality Indicators and Criteria

Table 1. Water quality indicators identified in the NOAA Fisheries matrix of pathways and indicators.

	Indicators ^a	Properly Functioning	At Risk	Not Properly Functioning
Water Quality	Temperature	50–57°F ^b	57-60° (spawning) 57-64° (migration & rearing) ^c	> 60° (spawning) > 64° (migration & rearing) ^c
	Sediment/turbidity	<12% fines (<0.85 mm) in gravel ^d , turbidity low	12-17% (west-side) ^d , 12-20% (east-side) ^c , turbidity moderate	>17% (west-side) ^d , >20% (east side) ^c fines at surface or depth in spawning habitat ^c , turbidity high
	Chemical contamination and nutrients	Low levels of chemical contamination from agricultural, industrial and other sources, no excess nutrients, no Clean Water Act 303(d) designated reaches	Moderate levels of chemical contamination from agricultural, industrial and other sources, some excess nutrients, one Clean Water Act 303(d) designated reach ^e	High levels of chemical contamination from agricultural, industrial and other sources, high levels of excess nutrients, more than one Clean Water Act 303(d) designated reach ^e

^a The ranges of criteria presented here are not absolute; they may be adjusted for unique watersheds.

^b Bjornn, T.C. and D.W. Reiser, 1991. Habitat Requirements of Salmonids in Streams. American Fisheries Society Special Publication 19:83-138. Meehan, W.R., ed.

^c Biological Opinion on Land and Resource Management Plans for the: Boise, Challis, Nez Perce, Payette, Salmon, Sawtooth, Umatilla, and Wallowa-Whitman National Forests. March 1, 1995.

^d Washington Timber/Fish Wildlife Cooperative Monitoring Evaluation and Research Committee, 1993. Watershed Analysis Manual (Version 2.0). Washington Department of Natural Resources.

^e A Federal Agency Guide for Pilot Watershed Analysis (Version 1.2), 1994.

Table 2. Water quality indicators identified in the USFWS matrix of pathways and indicators.

Diagnostic or Pathway	Indicators	Functioning Appropriately	Functioning at Risk	Functioning at Unacceptable Risk
Water quality	Temperature	7-day average maximum temperature in a reach during these life history stages: ^{b, c} Incubation 2 – 5°C Rearing 4 – 12°C Spawning 4 – 9°C Also, temperatures do not exceed 15°C in areas used by adults during migration (no thermal barriers).	7 day average maximum temperature in a reach during the following life history stages: ^{b, c} Incubation <2°C or 6°C Rearing <4°C or 13 - 15°C Spawning <4°C or 10°C Also, temperatures in areas used by adults during migration sometimes exceeds 15°C.	7 day average maximum temperature in a reach during the following life history stages: ^{b, c} Incubation <1°C or >6°C Rearing >15°C Spawning <4°C or >10°C Also temperatures in areas used by adults during migration regularly exceed 15°C (thermal barriers present).
	Sediment (in areas of spawning and incubation; address rearing areas under <i>substrate embeddedness</i>)	Similar to Chinook salmon, ^b for example: <12% fines (<0.85 mm) in gravel, ^d ≤20% surface fines ≤6 mm. ^{e, f}	Similar to Chinook salmon: ^b e.g., 12-17% fines (<0.85mm) in gravel, ^d e.g., 12-20% surface fines. ^g	Similar to Chinook salmon ^b : e.g., >17% fines (<0.85mm) in gravel; ^d e.g., >20% fines at surface or depth in spawning habitat. ^g
	Chemical contamination and nutrients	Low levels of chemical contamination from agricultural, industrial, and other sources; no excess nutrients; no Clean Water Act 303(d) designated reaches. ^h	Moderate levels of chemical contamination from agricultural, industrial and other sources, some excess nutrients, one Clean Water Act 303(d) designated reach. ^h	High levels of chemical contamination from agricultural, industrial and other sources, high levels of excess nutrients, more than one Clean Water Act 303(d) designated reach. ^h

^a The values of criteria presented here are not absolute; they may be adjusted for local watersheds given supportive documentation.

^b Rieman, B.E. and J.D. McIntyre. 1993. Demographic and habitat requirements for conservation of bull trout. USDA Forest Service, Intermountain Research Station, Boise, Idaho.

^c Buchanan, D.V. and S.V. Gregory. 1997. Development of water temperature standards to protect and restore habitat for bull trout and other cold water species in Oregon. In W.C. Mackay, M.K. Brewin, and M. Monita, eds. Friends of the Bull Trout Conference Proceedings. P8.

^d Washington Timber/Fish Wildlife Cooperative Monitoring Evaluation and Research Committee. 1993. Watershed Analysis Manual (Version 2.0). Washington Department of Natural Resources.

^e Overton, C.K., J.D. McIntyre, R. Armstrong, S.L. Whitewell, and K.A. Duncan. 1995. User's guide to fish habitat: descriptions that represent natural conditions in the Salmon River Basin, Idaho. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Gen Tech. Rep. INT-GTR-322.

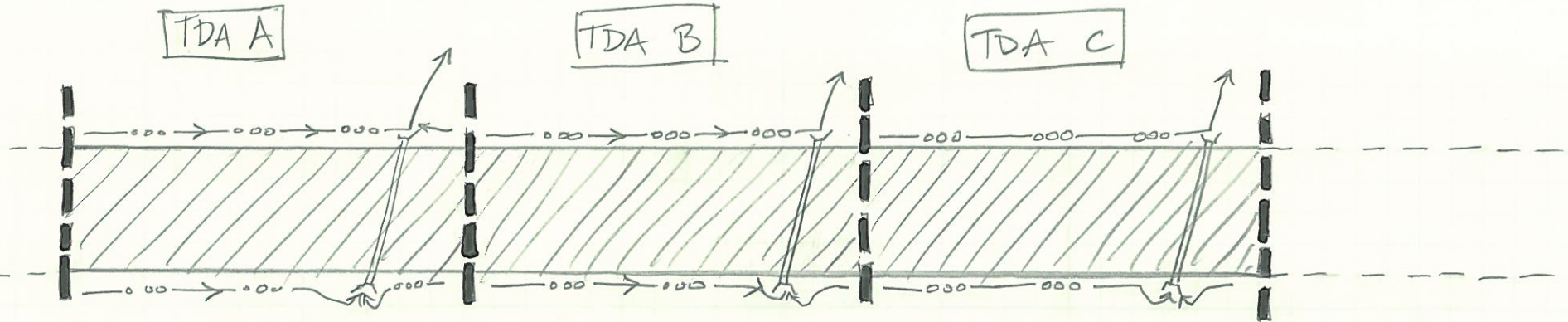
^f Overton, C.K., S.P. Wollrab, B.C. Roberts, and M.A. Radko. 1997. R1/R4 (Northern/Intermountain regions) Fish and Fish Habitat Standard Inventory Procedures Handbook. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Gen Tech. Rep. INT-GTR-346.

^g Biological Opinion on Land and Resource Management Plans for the: Boise, Challis, Nez Perce, Payette, Salmon, Sawtooth, Umatilla, and Wallowa-Whitman National Forests. March 1, 1995.

^h A Federal Agency Guide for Pilot Watershed Analysis (Version 1.2), 1994.

APPENDIX D

Example TDA Delineation Sketches and Stormwater Design Checklist Tables



Impervious Area = 1 acre

No Flow Control
No Treatment

Impervious Area = 1 acre

No Flow Control
No Treatment

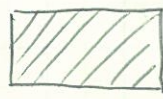
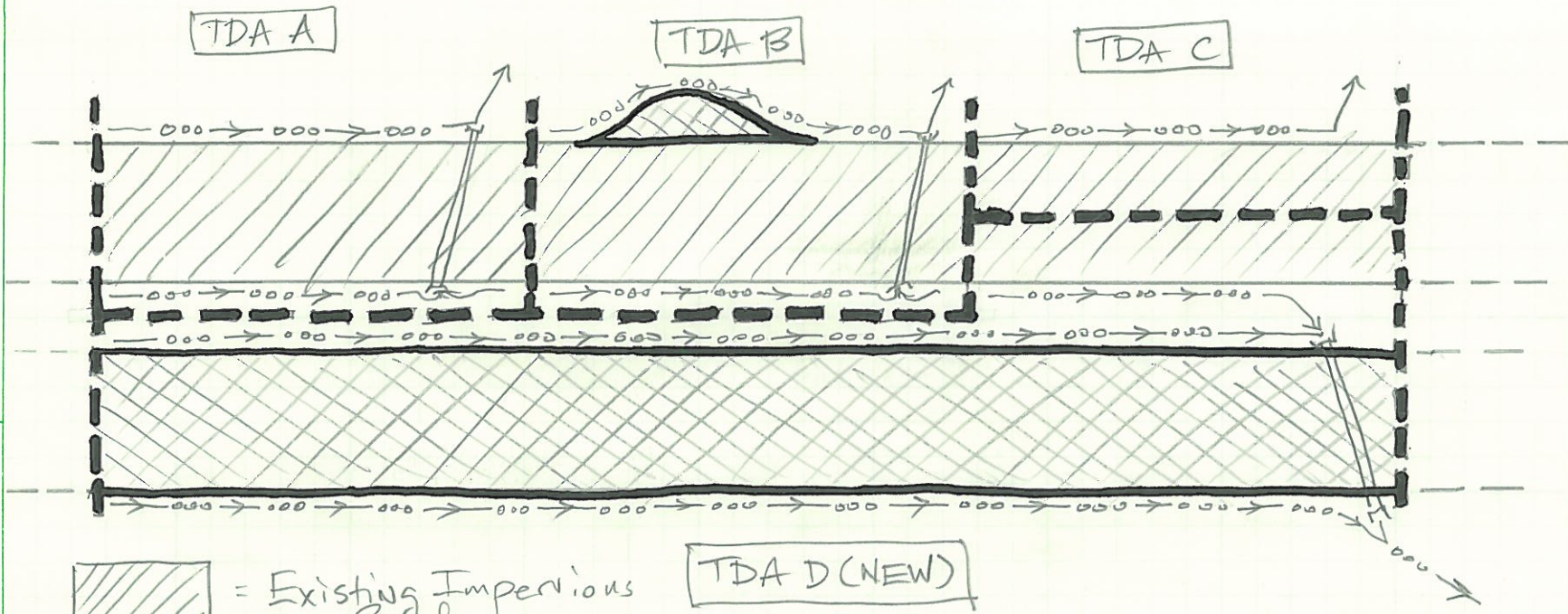
Impervious Area = 1 acre

No Flow Control
No Treatment

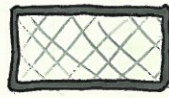
EXISTING CONDITION

 = Impervious Roadway

Example case for illustration of ESA stormwater effects evaluation using western Washington stormwater checklist.



= Existing Impervious Roadway



= New Impervious Roadway

TDA D (NEW)

PROPOSED CONDITION

- Add 3 acres new separated roadway that discharges to different water body
- Add 0.25 acres impervious area to TDA B
- Divert 0.5 acres of existing impervious area in TDA C to new outfall
- Flow control & treatment for all new impervious area

Example case for illustration of ISA stormwater effects evaluation using western Washington stormwater checklist

MB 3/26/09

2 of 2

Part 1 (continued)

Form A – TDA A

Inputs for HI-RUN Model End-of-Pipe Loading Subroutine

Baseline (i.e., Pre-Project) Stormwater Facilities

<i>Treatment Type</i>	<i>Level of Infiltration^a</i>	<i>Subbasin 1 Impervious Area (acres)</i>	<i>Subbasin 2 Impervious Area (acres)</i>	<i>Subbasin 3 Impervious Area (acres)</i>	<i>Subbasin 4 Impervious Area (acres)</i>	<i>Subbasin 5 Impervious Area (acres)</i>
<input type="checkbox"/> Basic OR	0%					
<input type="checkbox"/> Phosphorus <i>(Check one)</i>	20%					
	40%					
	60%					
	80%					
	Enhanced	0%				
	20%					
	40%					
	60%					
	80%					
None						
Infiltration BMP	100%					

^a Level of infiltration relates to the amount of incidental infiltration that can be expected, expressed as a percentage of annual average flow volume. If no incidental infiltration can be assumed, enter area in the row corresponding to "0%".

Proposed (i.e., Post Project) Stormwater Facilities

<i>Treatment Type</i>	<i>Level of Infiltration^a</i>	<i>Subbasin 1 Impervious Area (acres)</i>	<i>Subbasin 2 Impervious Area (acres)</i>	<i>Subbasin 3 Impervious Area (acres)</i>	<i>Subbasin 4 Impervious Area (acres)</i>	<i>Subbasin 5 Impervious Area (acres)</i>
<input type="checkbox"/> Basic OR	0%					
<input type="checkbox"/> Phosphorus <i>(Check one)</i>	20%					
	40%					
	60%					
	80%					
	Enhanced	0%				
	20%					
	40%					
	60%					
	80%					
None						
Infiltration BMP	100%					

Part 1 (continued)

Form A – TDA B

Inputs for HI-RUN Model End-of-Pipe Loading Subroutine

Baseline (i.e., Pre-Project) Stormwater Facilities

Treatment Type	Level of Infiltration ^a	Subbasin 1 Impervious Area (acres)	Subbasin 2 Impervious Area (acres)	Subbasin 3 Impervious Area (acres)	Subbasin 4 Impervious Area (acres)	Subbasin 5 Impervious Area (acres)
<input type="checkbox"/> Basic OR <input type="checkbox"/> Phosphorus (Check one)	0%					
	20%					
	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%					
	80%					
None		1				
Infiltration BMP	100%					

^a Level of infiltration relates to the amount of incidental infiltration that can be expected, expressed as a percentage of annual average flow volume. If no incidental infiltration can be assumed, enter area in the row corresponding to "0%"

Proposed (i.e., Post Project) Stormwater Facilities

Treatment Type	Level of Infiltration ^a	Subbasin 1 Impervious Area (acres)	Subbasin 2 Impervious Area (acres)	Subbasin 3 Impervious Area (acres)	Subbasin 4 Impervious Area (acres)	Subbasin 5 Impervious Area (acres)
<input type="checkbox"/> Basic OR <input type="checkbox"/> Phosphorus (Check one)	0%	0.25				
	20%					
	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%					
	80%					
None		1				
Infiltration BMP	100%					

Part 1 (continued)

Form A – TDA C

Inputs for HI-RUN Model End-of-Pipe Loading Subroutine

Baseline (i.e., Pre-Project) Stormwater Facilities

<i>Treatment Type</i>	<i>Level of Infiltration^a</i>	<i>Subbasin 1 Impervious Area (acres)</i>	<i>Subbasin 2 Impervious Area (acres)</i>	<i>Subbasin 3 Impervious Area (acres)</i>	<i>Subbasin 4 Impervious Area (acres)</i>	<i>Subbasin 5 Impervious Area (acres)</i>
<input type="checkbox"/> Basic OR <input type="checkbox"/> Phosphorus <i>(Check one)</i>	0%					
	20%					
	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%					
	80%					
None		1				
Infiltration BMP	100%					

^a Level of infiltration relates to the amount of incidental infiltration that can be expected, expressed as a percentage of annual average flow volume. If no incidental infiltration can be assumed, enter area in the row corresponding to "0%"

Proposed (i.e., Post Project) Stormwater Facilities

<i>Treatment Type</i>	<i>Level of Infiltration^a</i>	<i>Subbasin 1 Impervious Area (acres)</i>	<i>Subbasin 2 Impervious Area (acres)</i>	<i>Subbasin 3 Impervious Area (acres)</i>	<i>Subbasin 4 Impervious Area (acres)</i>	<i>Subbasin 5 Impervious Area (acres)</i>
<input type="checkbox"/> Basic OR <input type="checkbox"/> Phosphorus <i>(Check one)</i>	0%					
	20%					
	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%					
	80%					
None		0.5				
Infiltration BMP	100%					

Part 1 (continued)

Form A – TDA D

Inputs for HI-RUN Model End-of-Pipe Loading Subroutine

Baseline (i.e., Pre-Project) Stormwater Facilities

<i>Treatment Type</i>	<i>Level of Infiltration^a</i>	<i>Subbasin 1 Impervious Area (acres)</i>	<i>Subbasin 2 Impervious Area (acres)</i>	<i>Subbasin 3 Impervious Area (acres)</i>	<i>Subbasin 4 Impervious Area (acres)</i>	<i>Subbasin 5 Impervious Area (acres)</i>
<input type="checkbox"/> Basic OR <input type="checkbox"/> Phosphorus <i>(Check one)</i>	0%					
	20%					
	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%					
	80%					
None		0				
Infiltration BMP	100%					

^a Level of infiltration relates to the amount of incidental infiltration that can be expected, expressed as a percentage of annual average flow volume. If no incidental infiltration can be assumed, enter area in the row corresponding to "0%"

Proposed (i.e., Post Project) Stormwater Facilities

<i>Treatment Type</i>	<i>Level of Infiltration^a</i>	<i>Subbasin 1 Impervious Area (acres)</i>	<i>Subbasin 2 Impervious Area (acres)</i>	<i>Subbasin 3 Impervious Area (acres)</i>	<i>Subbasin 4 Impervious Area (acres)</i>	<i>Subbasin 5 Impervious Area (acres)</i>
<input type="checkbox"/> Basic OR <input type="checkbox"/> Phosphorus <i>(Check one)</i>	0%	3.5				
	20%					
	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%					
	80%					
None						
Infiltration BMP	100%					