Appendix 2-B

WWHM – Information, Assumptions and Computation Steps for WWHM3

Western Washington Hydrology Model – Information, Assumptions, and Computation Steps for WWHM~~3~~

Because the WWHM3 is no longer allowed for use in Clark County, Appendix 2-B is removed from the Clark County Stormwater Manual. Please refer to the 2019 SWMMWW Volume III, Chapter 2 for the most current information on the WWHM. a

~~This appendix describes some of the information and assumptions used in the Western Washington Hydrology Model, Version 3 (WWHM3).~~

~~However, since the first version of WWHM was developed and released to public in 2001, WWHM program has gone through several upgrades incorporating new features and capabilities. WWHM 2012 has added low impact development (LID) modeling capability. LID flow modeling guidance for both WWHM3 and WWHM 2012 is given in Appendix 2-C of this manual. WWHM users should periodically check Ecology's WWHM web site for the latest releases of WWHM, user manual, and any supplemental instructions. The web address is: http://www.ecy.wa.gov/programs/wq/stormwater/wwhmtraining/index.html.~~

~~WWHM Limitations~~

~~WWHM has been created for the specific purpose of sizing stormwater control facilities for new development and redevelopment projects in Western Washington. WWHM can be used for a range of conditions and developments; however, certain limitations are inherent in this software. These limitations are described below.~~

~~The WWHM uses the EPA HSPF software program to do all of the rainfall-runoff and routing computations. Therefore, HSPF limitations are included in the WWHM. For example, HSPF does not explicitly model backwater or tailwater control situations. This is also true in the WWHM.~~

~~WWHM Information and Assumptions~~

~~1. Precipitation data.~~

~~Length of record.~~

~~The WWHM uses long-term (50 - 70 years) precipitation data to simulate the potential impacts of land use development in western Washington. A minimum period of 20 years is sufficient to simulate enough peak flow events to produce accurate flow frequency results. A 40 to 50-year record is preferred. The actual length of record of each precipitation station varies, but all exceed 50 years.~~

~~Rainfall distribution.~~

~~The precipitation data are representative of the different rainfall regimes found in western Washington. More than 17 precipitation stations are used. These stations represent rainfall at elevations below 1500 feet. WWHM does not include snowfall and melt.~~

~~The primary source for precipitation data is National Weather Service stations. The secondary source is precipitation data collected by local jurisdictions. During development of WWHM, county engineers at 19 western Washington counties were contacted to obtain local precipitation data.~~

~~Earlier versions of the WWHM used hourly data from the precipitation stations in the table below to generate precipitation timeseries for use in WWHM. For WWHM 2012, more recent precipitation data have been used to generate precipitation timeseries in 15-minute time steps.~~

~~Precipitation Station~~	~~Years of Data~~	~~County Coverage~~
~~Astoria, OR~~	~~1955-1998 = 43~~	~~Wahkiakum~~
~~Blaine~~	~~1948-1998 = 50~~	~~Whatcom, San Juan~~
~~Burlington~~	~~1948-1998 = 50~~	~~Skagit, Island~~
~~Clearwater~~	~~1948-1998 = 50~~	~~Jefferson (west)~~
~~Darrington~~	~~1948-1996 = 48~~	~~Snohomish (northeast)~~
~~Everett~~	~~1948-1996 = 48~~	~~Snohomish (excluding northeast)~~
~~Frances~~	~~1948-1998 = 50~~	~~Pacific~~
~~Landsburg~~	~~1948-1997 = 49~~	~~King (east)~~
~~Longview~~	~~1955-1998 = 43~~	~~Cowlitz, Lewis (south)~~
~~McMillian~~	~~1948-1998 = 50~~	~~Pierce~~
~~Montesano~~	~~1955-1998 = 43~~	~~Grays Harbor~~
~~Olympia~~	~~1955-1998 = 43~~	~~Thurston, Mason (south), Lewis (north)~~
~~Port Angeles~~	~~1948-1998 = 50~~	~~Clallam (east)~~
~~Portland, OR~~	~~1948-1998 = 50~~	~~Clark, Skamania~~

~~Quilcene~~	~~1948-1998 = 50~~	~~Jefferson (east), Mason (north), Kitsap~~
~~Sappho~~	~~1948-1998 = 50~~	~~Clallam (west)~~
~~SeaTac~~	~~1948-1997 = 49~~	~~King (west)~~

~~The records were reviewed for length, quality, and completeness of record. Annual totals were checked along with hourly maximum totals. Using these checks, data gaps and errors were corrected, where possible. A "Quality of Record" summary was produced for each precipitation record reviewed.~~

~~The reviewed and corrected data were placed in multiple WDM (Watershed Data Management) files. One WDM file was created per county and contains all of the precipitation data to be used by the WWHM for that particular county. A local government that believes that it has a more accurate precipitation record to use with the WWHM should petition Ecology to allow use of that record, and to possibly incorporate that record into the WWHM. This may be more easily done in the future if the WWHM is upgraded to allow use of custom precipitation time series.~~

~~Computational time step.~~

~~The computational time step used in the earlier versions of WWHM has been one hour. The one-hour time step was selected to better represent the temporal variability of actual precipitation than daily data. WWHM 2012l incorporates 15-minute precipitation time series.~~

~~2. Precipitation multiplication factors.~~

~~Precipitation multiplication factors increase or decrease recorded precipitation data to better represent local rainfall conditions. This is particularly important when the precipitation gage is located some distance from the study area.~~

~~Precipitation multiplication factors were developed for western Washington. The factors are based on the ratio of the 24-hour, 25-year rainfall intensities for the representative precipitation gage and the surrounding area represented by that gage's record. The 24-hour, 25-year rainfall intensities were determined from the NOAA Atlas 2 (*Precipitation-Frequency Atlas of the Western United States, Volume IX – Washington, 1973*).~~

~~These multiplication factors were created for the Puget Sound lowlands plus all western Washington valleys and hillside slopes below 1500 feet elevation. The factors were placed in the WWHM database and linked to each county's map. They are transparent to the general user and the default range is set to 0.8 – 2. The advanced user will have the ability to change the precipitation multiplication factor for a specific site. However, such changes will be recorded in the WWHM output.~~

~~3. Pan evaporation data.~~

~~Pan evaporation data are used to determine the potential evapotranspiration (PET) of a study area. Actual evapotranspiration (AET) is computed by the WWHM based on PET and available moisture supply. AET accounts for the precipitation that returns to the atmosphere without becoming runoff. Soil moisture conditions and runoff are directly influenced by PET and AET.~~

~~Evaporation is not highly variable like rainfall. Puyallup pan evaporation data are used for all of the 19 western Washington counties.~~

~~Pan evaporation data were assembled and checked for the same time period as the precipitation data and placed in the appropriate county WDM files.~~

~~Pan evaporation data are collected in the field, but PET is used by the WWHM. PET is equal to pan evaporation times a pan evaporation coefficient. Depending on climate, pan evaporation coefficients for western Washington range from 0.72 to 0.82.~~

~~NOAA Technical Report NWS 33, *Evaporation Atlas for the Contiguous 48 United States*, was used as the source for the pan evaporation coefficients. Pan evaporation coefficient values are shown on Map 4 of that publication.~~

~~As with the precipitation multiplication factors, the pan evaporation coefficients have been placed in the WWHM database and linked to each county's map. They will be transparent to~~

~~the general user. The advanced user will have the ability to change the coefficient for a specific site. However, such changes will be recorded in the WWHM output.~~

4. ~~Soil data.~~

~~Soil type, along with vegetation type, greatly influences the rate and timing of the transformation of rainfall to runoff. Sandy soils with high infiltration rates produce little or no surface runoff; almost all runoff is from ground water. Soils with a compressed till layer slowly infiltrate water and produce larger amounts of surface runoff during storm events.~~

~~WWHM uses three predominant soil types to represent the soils of western Washington: till, outwash, and saturated~~

~~Till soils have been compacted by glacial action. Under a layer of newly formed soil lies a compressed soil layer commonly called "hardpan". This hardpan has very poor infiltration capacity. As a result, till soils produce a relatively large amount of surface runoff and interflow. A typical example of a till soil is an Alderwood soil (SCS class C). Where field infiltration tests indicate a measured initial infiltration rate less than 0.30 in/hr., the user may model the site as a class C soil.~~

~~Outwash soils have a high infiltration capacity due to their sand and gravel composition. Outwash soils have little or no surface runoff or interflow. Instead, almost all of their runoff is in the form of ground water. An Everett soil (SCS class A) is a typical outwash soil.~~

~~Outwash soils over high ground water or an impervious soil layer have low infiltration rates and act like till soils. Where ground water or an impervious soil layer is within 5 feet from the surface, outwash soils may be modeled as till soils in the WWHM.~~

~~Saturated soils are usually found in wetlands. They have a low infiltration rate and a high ground water table. When dry, saturated soils have a high storage capacity and produce very little runoff. However, once they become saturated they produce surface runoff, interflow, and ground water in large quantities. Mukilteo muck (SCS class D) is a typical saturated/wetland soil.~~

~~The user will be required to investigate actual local soil conditions for the specific development planned. The user will then input the number of acres of outwash (A/B), till (C/D), and saturated/wetland soils for the site conditions.~~

~~Alluvial soils are found in valley bottoms. These are generally fine-grained and often have a high seasonal water table. There has been relatively little experience in calibrating the HSPF model~~

~~to runoff from these soils, so in the absence of better information, these soils may be modeled as till soils.~~

~~Additional soils will be included in the WWHM if appropriate HSPF parameter values are found to represent other major soil groups.~~

~~The three predominant soil types are represented in the WWHM by specific HSPF parameter values that represent the hydrologic characteristics of these soils. More information on these parameter values is presented below.~~

~~5. Vegetation data.~~

~~As with soil type, vegetation types greatly influence the rate and timing of the transformation of rainfall to runoff. Vegetation intercepts precipitation, increases its ability to percolate through the soil, and evaporates and transpires large volumes of water that would otherwise become runoff.~~

~~WWHM represents the vegetation of western Washington with three predominant vegetation categories: forest, pasture, and lawn (also known as grass).~~

~~Forest vegetation represents the typical second growth Douglas fir found in the Puget Sound lowlands. Forest has a large interception storage capacity. This means that a large amount of precipitation is caught in the forest canopy before reaching the ground and becoming available for runoff. Precipitation intercepted in this way is later evaporated back into the atmosphere. Forest also has the ability to transpire moisture from the soil via its root system. This leaves less water available for runoff.~~

~~Pasture vegetation is typically found in rural areas where the forest has been cleared and replaced with shrub or grass lots. Some pasture areas may be used to graze livestock. The interception storage and soil evapotranspiration capacity of pasture are less than forest. Soils may have also been compressed by mechanized equipment during clearing activities. Livestock can also compact soil. Pasture areas typically produce more runoff (particularly surface runoff and interflow) than forest areas.~~

~~Lawn vegetation is representative of the suburban vegetation found in typical residential developments. Soils have been compacted by earth moving equipment, often with a layer of topsoil removed. Sod and ornamental bushes replace native vegetation. The interception storage and evapotranspiration of lawn vegetation is less than pasture, more runoff results.~~

~~Predevelopment default land conditions are forest, although the user has the option of specifying pasture if there is documented evidence that pasture vegetation was native to the predevelopment site. If this option is used, the change will be recorded in the WWHM output.~~

~~Forest vegetation is represented by specific HSPF parameter values that represent the forest hydrologic characteristics. As described above, the existing regional HSPF parameter values for forest are based on undisturbed second-growth Douglas fir forest found today in western Washington lowland watersheds.~~

~~Postdevelopment vegetation will reflect the new vegetation planned for the site. The user has the choice of forest, pasture, and landscaped vegetation. Forest and pasture are only appropriate for postdevelopment vegetation in parcels separate from standard residential or non-standard residential/commercial developments. Development areas must only be designated as forest or pasture where legal restrictions can be documented that protect these areas from future disturbances. WWHM assumes the pervious land portion of developed areas is covered with lawn vegetation, as described above.~~

~~6. Development land use data.~~

~~The WWHM user must enter land use information for the pre-developed condition and the proposed development condition into the model. WWHM users must select the appropriate land use category and slope, where slope of 0-5% is flat, 5-15% is moderate, and greater than 15% is steep. The land use categories include: Impervious areas such as Roads, Roof, Driveways, Sidewalks, Parking, Ponds; and Pervious areas such as Lawn (this includes lawn, garden, areas with ornamental plants, and any natural areas not legally protected from future disturbance), Forest, and Pasture. The soils types available are A/B (outwash), C (Till), and Saturated (wetland).~~

~~Forest and pasture vegetation areas are only appropriate for separate undeveloped parcels dedicated as open space, wetland buffer, or park within the total area of the standard residential development.~~ ***~~Development areas must only be designated as forest or pasture where legal restrictions can be documented that protect these areas from future disturbances.~~***

~~Impervious, as the name implies, allows no infiltration of water into the pervious soil. All runoff is surface runoff. Impervious land typically consists of paved roads, sidewalks, driveways, and parking lots. Roofs are also impervious.~~

~~For the purposes of hydrologic modeling, only effective impervious area is categorized as impervious. Effective impervious area (EIA) is the area where there is no opportunity for surface~~

~~runoff from an impervious site to infiltrate into the soil before it reaches a conveyance system (pipe, ditch, stream, etc.). An example of an EIA is a shopping center parking lot where the water runs off the pavement and directly goes into a catch basin where it then flows into a pipe and eventually to a stream. In contrast, some homes with impervious roofs collect the roof runoff into roof gutters and send the water down downspouts. When the water reaches the base of the downspout it can be directed into an infiltration system. If roof runoff is infiltrated according to the requirements of BMP T5.10A or B, the roof area can be considered ineffective impervious area. The roof area may then be discounted from the project area entered into WWHM.~~

~~The non-effective impervious area uses the adjacent or underlying soil and vegetation properties. Vegetation often varies by the type of land use. The assumption is made in the WWHM that the EIA equals the TIA (total impervious area). This is consistent with King County's determination of EIA acres for new developments. Where appropriate, the TIA can be reduced through the use of runoff credits (more on that below).~~

~~Earlier versions of WWHM (WWHM1 and WWHM2) provided the 2 optional features below for modeling of Standard Residential development and obtaining flow credits for incorporating low impact development (LID) techniques. Later upgrades to WWHM have provided for direct input of the standard residential development details by the WWHM users. WWHM 2012 enables direct modeling of some LID techniques through use of new LID Elements. Other LID techniques will continue to be modeled in accordance with Appendix 2-C of this manual.~~

~~**Standard Residential:** For housing developments where lot-specific details (e.g., size of roof and driveway) are not yet determined, the earlier versions of WWHM provided a set of default assumptions about the amount of impervious area per lot and its division between driveways and rooftops under the "Standard Residential" development land use type. Later versions of WWHM (e.g., WWHM3, WWHM 2012) do not have this option programmed in the model but the land use assumptions for the "Standard Residential" development are given below.~~

~~Ecology has selected a standard impervious area of 4200 square feet per residential lot, with 1000 square feet of that as driveway, walkways, and patio area, and the remainder as rooftop area. The rest of the lot acres will be assumed to be landscaped area (including lawn). The user inputs the number of residential lots and the total acreage of the residential lots (public right-of-way acreages and non-residential lot acreages excluded). The number of residential lots and the associated number of acres will be used to compute the average number of residential lots per acre. This value together with the number of residential lots and the impervious area in the public right-of-way will be used by the model to calculate the TIA for the proposed~~

~~development. The areas covered by streets, parking areas, and sidewalk areas are input separately by the user.~~

~~**Runoff Credits:** Please note that the modeling of runoff credits using some of the low impact development techniques described in Appendix 2-C have been updated. WWHM 2012 provides LID modeling capabilities in accordance with this manual. The following LID credit modeling is based on modeling in earlier versions of WWHM (WWHM2 and WWHM3).~~

~~Runoff credits can be obtained using any or all of the low impact development methods listed below. The WWHM has an automated procedure for taking credits for infiltrating or dispersing roof runoff - methods #1 and #2 below. Credits for using methods 3,4,8, and 9 must be taken by following the guidance in Appendix 2-C. Methods 5, 6, and 10 also have guidance in Appendix 2-C for taking credits. However, the new LID Elements in WWHM 2012 allow direct modeling of methods 4, 5, 6, and 10 and would better represent how they function to reduce surface runoff. Roof areas using method 7 - rainwater harvesting systems designed in accordance with the guidance in Appendix 2-C need not be entered into the model. Also, if using method 11 – full dispersion – the runoff model need not be used for the area that meets the criteria in Appendix 2-C.~~

1. ~~Infiltrate roof runoff~~
2. ~~Disperse roof runoff~~
3. ~~Disperse driveway and other hard surface runoff~~
4. ~~Porous pavement for driveways and walks~~
5. ~~Porous pavement for roads and parking lots~~
6. ~~Vegetated Roofs~~
7. ~~Rainwater Harvesting~~
8. ~~Reverse slope sidewalks~~
9. ~~Low impact foundations~~
10. ~~Bioretention Areas~~
11. ~~Full dispersion~~

1. ~~Infiltrate Roof Runoff~~

~~Credit is given for disconnecting the roof runoff from the development's stormwater conveyance system and infiltrating on the individual residential lots. The WWHM assumes that~~

~~this infiltrated roof runoff does not contribute to the runoff flowing to the stormwater detention pond site. It disappears from the system and does not have to be mitigated.~~

~~2. Disperse Roof Runoff~~

~~Credit is also given for disconnecting the roof runoff from the development's stormwater conveyance system and dispersing it on the lawn/landscaped surface of individual lots. If the runoff is dispersed using a dispersion trench on single-family lots greater than 22,000 square feet, and the vegetative flow path of the runoff is 50 feet or longer through undisturbed native or compost-amended soils, the roof area can be entered into the model as landscaped area rather than impervious surface.~~

~~3. Disperse driveway and other hard surface runoff:~~

~~If runoff is dispersed in accordance with the guidance in BMP T5.11 or BMP T5.12, the driveway or other hard surface may be modeled as landscaped area.~~

~~4. & 5. Permeable pavement~~

~~The third option for runoff credit is the use of permeable pavement for private driveways, sidewalks, streets, and parking areas. The LID credit guidance in Appendix 2-C was developed before WWHM 2012, with the capability of directly modeling permeable pavements, became available. The LID credit guidance in Appendix 2-C will direct you to enter a certain percentage of the pervious pavement area into the landscaped area category rather than the street/sidewalk/parking lot category. Even though WWHM 2012 has other methods for calculating the impacts of permeable pavement, the methods described in Part 1 are appropriate to use where the permeable pavement does not have a significant depth of base course for storage.~~

~~Follow similar procedures for vegetated roofs, reverse slope sidewalks, and low impact foundations. The LID credit guidance of Appendix 1-F directs how these surfaces should be entered into the model. If you do not know the specific quantities of the different land cover types for your development (e.g., the individual lots will be sold to builders who will determine layout and size of home), you should start with the assumption of 4200 sq. ft. of impervious area per lot – including 1,000 sq. ft. for driveways, and begin making adjustments in those totals as allowed in the LID guidance of Appendix 1-F.~~

~~Other Development Options and Model Features~~

~~WWHM allows the flexibility of bypassing a portion of the development area around a flow control facility and/or having off-site inflow that is entering the development area pass through the flow control facility.~~

~~Bypass occurs when a portion of the development does not drain to a stormwater detention facility. On-site runoff from a proposed development project may bypass the flow control facility provided that all of the following conditions are met.~~

1. ~~Runoff from both the bypass area and the flow control facility converges within a quarter-mile downstream of the project site discharge point.~~
2. ~~The flow control facility is designed to compensate for the uncontrolled bypass area such that the net effect at the point of convergence downstream is the same with or without bypass.~~
3. ~~The 100-year peak discharge from the bypass area will not exceed 0.4 cfs.~~
4. ~~Runoff from the bypass area will not create a significant adverse impact to downstream drainage systems or properties.~~
5. ~~Water quality requirements applicable to the bypass area are met.~~

~~Off-site Inflow occurs when an upslope area outside the development drains to the flow control facility in the development. The bypass of off-site runoff must be designed so as to achieve both of the following:~~

1. ~~Any existing contribution of flows to an on-site wetland must be maintained.~~
2. ~~Off-site flows that are naturally attenuated by the project site under predeveloped conditions must remain attenuated, either by natural means or by providing additional on-site detention so that peak flows do not increase.~~

~~Application of WWHM in Re-developments Projects~~

~~WWHM allows only forest or pasture as the predevelopment land condition in the Design Basin screen. This screen does not allow other types of land uses such as impervious and landscaped areas to be entered for existing condition. However, WWHM can be used for redevelopment projects by modeling the existing developed areas that are not subject to the flow control requirements of Book 1 as off-site areas. For the purposes of predicting runoff from such an existing developed area, enter the existing area in the Off-site Inflow screen. This screen is designed to predict runoff from impervious and landscaped areas in addition to the forest and pasture areas. If the existing 100-year peak flow rate from the existing developed areas that are not subject to flow control is greater than 50% of the 100-year developed peak flow rate (undetained but subject to the flow control requirements of Book 1), then the runoff from the off-site area must not be allowed to flow to the on-site flow control facility.~~

~~7. PERLND and IMPLND parameter values.~~

~~In WWHM (and HSPF) pervious land categories are represented by PERLNDs; impervious land categories (EIA) by IMPLNDs. An example of a PERLND is a till soil covered with forest vegetation. This PERLND has a unique set of HSPF parameter values. For each PERLND there are 16 parameters that describe various hydrologic factors that influence runoff. These range from interception storage to infiltration to active ground water evapotranspiration. Only four parameters are required to represent IMPLND.~~

~~PERLND parameters:~~

~~LZSN = lower zone storage nominal (inches)~~
~~INFILT = infiltration capacity (inches/hour)~~
~~LSUR = length of surface overland flow plane (feet)~~
~~SLSUR = slope of surface overland flow plane (feet/feet)~~
~~KVARY = ground water exponent variable (inch^{-1})~~
~~AGWRC = active ground water recession constant (day^{-1})~~
~~INFEXP = infiltration exponent~~
~~INFILD = ratio of maximum to mean infiltration~~
~~BASETP = base flow evapotranspiration (fraction)~~
~~AGWETP = active ground water evapotranspiration (fraction)~~
~~CEPSC = interception storage (inches)~~
~~UZSN = upper zone storage nominal (inches)~~
~~NSUR = roughness of surface overland flow plane (Manning's n)~~
~~INTFW = interflow index~~
~~IRC = interflow recession constant (day-1)~~
~~LZETP = lower zone evapotranspiration (fraction)~~

~~A more complete description of these PERLND parameters is found in the HSPF User Manual (Bicknell et al, 1997).~~

~~PERLND parameter values for other additional soil/vegetation categories will be investigated and added to the WWHM, as appropriate.~~

~~IMPLND Parameters~~

	~~EIA~~
~~Name~~	
~~LSUR~~	~~400~~
~~SLSUR~~	~~0.01~~
~~NSUR~~	~~0.10~~
~~RETSC~~	~~0.10~~

~~IMPLND parameters:~~

~~LSUR = length of surface overland flow plane (feet)~~
~~SLSUR = slope of surface overland flow plane (feet/feet)~~

NSUR = roughness of surface overland flow plane (Manning's n)
RETSC = retention storage (inches)

A more complete description of these IMPLND parameters is found in the HSPF User Manual (Bicknell et al, 1997).

The PERLND and IMPLND parameter values will be transparent to the general user. The advanced user will have the ability to change the value of a particular parameter for that specific site. However, the only PERLND and IMPLND parameters that are authorized to be adjusted by the user are LSUR, SLSUR, and NSUR. These are parameters whose values are observable at an undeveloped site, and whose values can be reasonably estimated for the proposed development site. Any such changes will be recorded in the WWHM output.

Earlier versions of WWHM (WWHM1 and WWHM2) provided only one category of moderate land slope (typically 5-15% slopes). In more recent versions of WWHM (WWHM3 and WWHM 2012), two additional land categories have been added to account for the flat (0-5%) and steep (15-25%) land slopes.

Surface runoff and interflow will be computed based on the PERLND and IMPLND parameter values. Ground water flow can also be computed and added to the total runoff from a development if there is a reason to believe that ground water would be surfacing (such as where there is a cut in a slope). However, the default condition in WWHM assumes that no ground water flow from small catchments reaches the surface to become runoff. This is consistent with King County procedures (King County, 1998).

8. Guidance for flow-related standards.

Use flow-related standards to determine whether or not a proposed stormwater facility will provide a sufficient level of mitigation for the additional runoff from land development. Guidance is provided on the standards that must be met to comply with the Minimum Requirements.

There are three flow-related standards stated in Book 1: Minimum Requirement #5 - On-site Stormwater Management; Minimum Requirement #7 - Flow Control and Minimum Requirement #8 - Wetlands Protection.

Minimum Requirement #5 allows the user to demonstrate compliance with the LID Performance Standard of matching developed discharge durations to pre-developed durations for the range of pre-developed discharge rates from 8% of the 2-year peak flow to 50% of the 2-year peak flow. If the post-development flow duration values exceed any of the

~~predevelopment flow levels between 8% and 50% of the 2-year predevelopment peak flow values, then the LID performance standard not been met.~~

~~Minimum Requirement #7 specifies that stormwater discharges to streams shall match developed discharge durations to predeveloped durations for the range of predeveloped discharge rates from 50% of the 2-year peak flow up to the full 50-year peak flow. In general, matching discharge durations between 50% of the 2-year and 50-year will result in matching the peak discharge rates in this range.~~

~~WWHM uses the predevelopment peak flow value for each water year to compute the predevelopment 2- through 100-year flow frequency values. The postdevelopment runoff 2-through 100-year flow frequency values are computed from the outlet of the proposed stormwater facility. The user must enter the stage-surface area-storage-discharge table (HSPF FTABLE) for the stormwater facility. The model then routes the postdevelopment runoff through the stormwater facility. As with the predevelopment peak flow values, the model will select the maximum developed flow value for each water year to compute the developed 2-through 100-year flow frequency.~~

~~The actual flow frequency calculations are made using the federal standard Log Pearson Type III distribution described in Bulletin 17B (United States Water Resources Council, 1981). This standard flow frequency distribution is provided in U.S. Geological Survey program J407, version 3.9A-P, revised 8/9/89. The Bulletin 17B algorithms in program J407 are included in the WWHM calculations.~~

~~Minimum Requirement #7 is based on flow duration. WWHM will use the entire predevelopment and post-development runoff record to compute flow duration. The standard requires that post-development runoff flows must not exceed the flow duration values of the predevelopment runoff between the predevelopment flow values of 50 percent of the 2-year flow and 100 percent of the 50-year flow.~~

~~Flow duration is computed by counting the number of flow values that exceed a specified flow level. The specified flow levels used by WWHM in the flow duration analysis are listed below.~~

1. ~~50% of the 2-year predevelopment peak flow.~~
2. ~~100% of the 2-year predevelopment peak flow.~~
3. ~~100% of the 50-year predevelopment peak flow.~~

~~In addition, flow durations are computed for 97 other incremental flow values between 50 percent of the 2-year predevelopment peak flow and 100 percent of the 50-year predevelopment peak flow.~~

There are three criteria by which flow duration values are compared:

1. If the postdevelopment flow duration values exceed any of the predevelopment flow levels between 50% and 100% of the 2-year predevelopment peak flow values (100 Percent Threshold) then the flow duration requirement has not been met.
2. If the postdevelopment flow duration values exceed any of the predevelopment flow levels between 100% of the 2-year and 100% of the 50-year predevelopment peak flow values more than 10 percent of the time (110 Percent Threshold) then the flow duration requirement has not been met.
3. If more than 50 percent of the flow duration levels exceed the 100 percent threshold then the flow duration requirement has not been met.

The results are provided in the WWHM report.

Minimum Requirement #8 specifies that total discharges to wetlands must not deviate by more than 20% on a daily basis, and must not deviate by more than 15% on a monthly basis. Flow components feeding the wetland under both Pre-and Post-development scenarios are assumed to be the sum of the surface, interflow, and ground water flows from the project site. The WWHM is being revised to more easily allow this comparison.

~~References for Western Washington Hydrology Model~~

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~~Dinicola, R.S. 1990. Characterization and Simulation of Rainfall-Runoff Relations for Headwater Basins in Western King and Snohomish Counties, Washington. Water-Resources Investigations Report 89-4052. U.S. Geological Survey. Tacoma, WA.~~

~~King County. 1998. Surface Water Design Manual. Department of Natural Resources. Seattle, WA.~~

~~United States Water Resources Council. 1981. Guidelines for Determining Flood Flow Frequency. Bulletin #17B of the Hydrology Committee. Washington, DC.~~