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WMOST
- Watershed Management Optimization Support Tool -

Hydro-Climate Automation Module (HCAM) Instructions: Version 2

Office of Research and Development
Center for Environmental Measurement and Modeling

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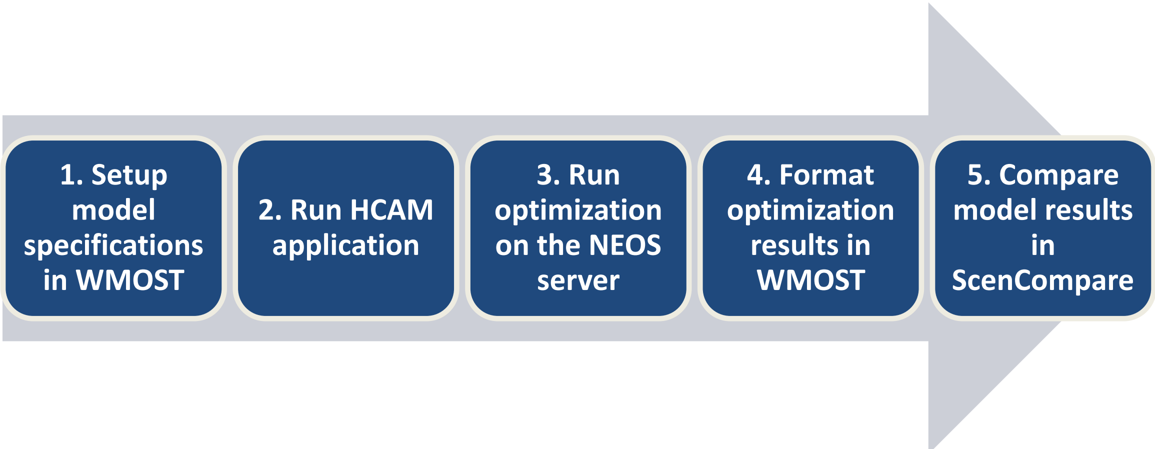
Introduction

The Watershed Management Optimization Tool (WMOST) is an Excel-based tool designed to aid decision making in integrated water resources management. It is meant to be run for small watersheds (HUC10 to HUC12 scale) and over a range of planning years. The Hydro-Climate Automation Module (HCAM) is a WMOST version 3.1 add-on that allows the user to automate the creation of runoff and recharge time series that reflect varying climate scenarios and then run WMOST scenarios using those time series sets. Following model optimization setup using HCAM, users should utilize ScenCompare, the WMOST Climate Scenario Viewer and Comparison Post Processor (EPA 2018c) to compare optimization results across climate scenarios.

The HCAM automates the functionality of the Baseline Hydrology and Stormwater Hydrology Modules within WMOST v3.1. In particular, HCAM allows the user to batch run stormwater Best Management Practice (BMP) simulations with the Storm Water Management Model (SWMM) to generate managed runoff/recharge time series over varying climate scenarios. HCAM facilitates the use of multiple watershed model runs driven by multiple scenarios of future changes in temperature and precipitation, for example, as obtained from downscaled General Circulation Models (GCMs) and prepared as time series inputs to the model. There are numerous sources for downscaled GCMs. For example, EPA provides the online LASSO tool which allows users to estimate change factors for temperature and precipitation between current and future climate scenarios across multiple GCMs (https://lasso.epa.gov/). Users would need to apply these change factors to current climate time series and rerun base watershed models with updated weather files to generate new hydrology and loading time series for use in HCAM. Such functionality is needed to support applications such as evaluating the outcome of a prescribed management strategy – e.g., a Watershed Implementation Plan (WIP) to meet Total Maximum Daily Load (TMDL) requirements – over multiple plausible future temperature and rainfall scenarios to determine under what conditions the strategy might be expected to fail to meet performance requirements. In other words, the HCAM application allows the user to evaluate the robustness of various management options in meeting hydrology or water quality targets under varying future climate conditions.

HCAM users who are unfamiliar with the WMOST model inputs and outputs should refer to the WMOST documentation (EPA, 2018a; EPA, 2018b). These instructions provide information on HCAM's software requirements (section 1), data requirements (section 2), and module usage (section 3). In order to run WMOST for varying climate or management scenarios, you will generally be using the following process.

Figure 1. HCAM Process



1. Software Requirements

The tool can be downloaded from EPA's WMOST website. After downloading the HCAM.zip folder, unzip the contents to create the HCAM folder. Within the HCAM folder, double click "StormwaterBMP.application" to install and launch HCAM. When prompted, click "Install". Once installed, HCAM can be launched by double clicking "StormwaterBMP.application".

1.1 SWMM Executable

EPA's Storm Water Management Model (SWMM)[1] simulates water runoff quantity and quality in primarily urban areas and helps to support the evaluation of reduction of runoff and harmful discharges to water bodies through infiltration and retention in stormwater control measures. The HCAM is compatible with SWMM 5[2], and an .exe file has been included in the HCAM download. Therefore, you do not need to download and install SWMM separately. However, the link below can be used to download relevant documentation.

https://www.epa.gov/water-research/storm-water-management-model-swmm

2. Data Requirements

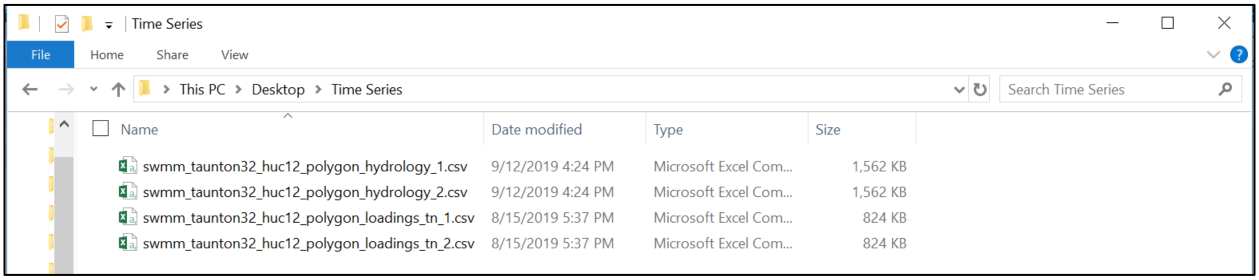
The following files are required for running the HCAM:

- WMOST Hydrology and Loadings Databases
- WMOST Log File
- WMOST Model Files (Wmodel.mod, Wdata.dat, Wcommand.amp, Wopt.opt)
- BMP Parameter File (BMP-Config.csv)
- HRU Parameter File (HRU-Config.csv)

[1] https://www.epa.gov/water-research/storm-water-management-model-swmm
[2] The HCAM is only compatible with SWMM 5.1.013, the version included in the download and is not backwards or forwards compatible with different versions of SWMM.

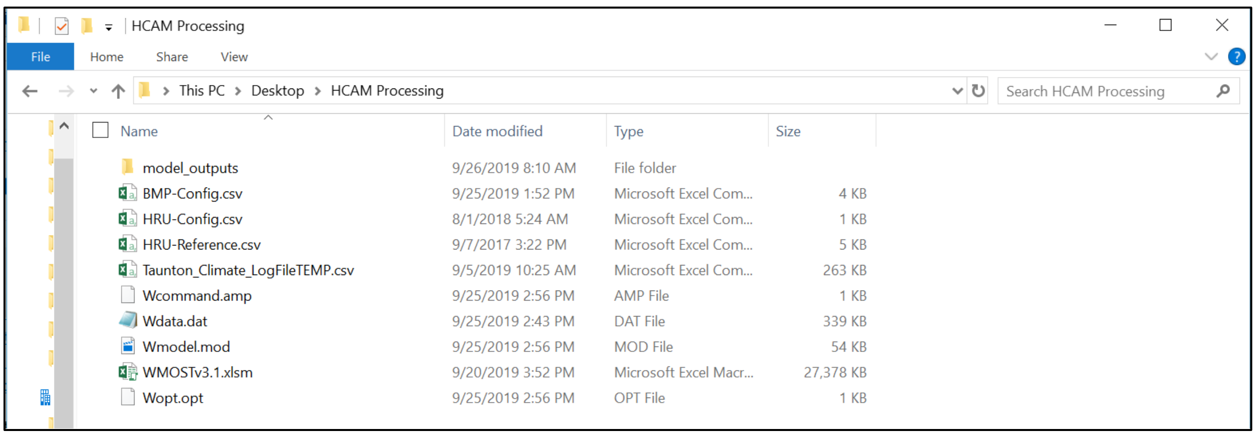
Each of these files or sets of files will be described in more detail in the subsections below. First, create a folder entitled "Time Series". This folder will hold the WMOST hydrology and loadings databases (see Figure 2.).

Figure 2. Time Series Folder and Contents



Next, create a folder entitled "HCAM Processing". This folder will hold the remaining required data[3] and will also be where the HCAM will create a "model_outputs" folder that will contain all of the model outputs (see Figure 3.).

Figure 3. HCAM Processing Directory



2.1 WMOST Hydrology and Loadings Databases

WMOST requires WMOST-formatted databases containing hourly runoff and recharge data for your study area and representing various climate scenarios. These databases are described in detail in the WMOST User Guide (EPA, 2018b) Section 3.2. There are two options for developing these databases:

1) Databases ready for input into WMOST are available online via EPA's Estuary Data Mapper (EDM) server[4], including watershed model output from current and future climate scenarios. Watersheds, land-use scenarios, and climate change scenarios covered in the EDM set are described in the edm_wmost_database_inventory.xlsx found at https://www.epa.gov/ceam/wmost-30-download-page.

2) Datasets derived from an existing or user-developed calibrated/validated simulation model run under various climate scenarios. If using outputs from a Hydrological Simulation Program Fortran (HSPF)[5] or Soil and Water

[3] Make sure there is only one version of each of the files represented in the example. HCAM will encounter errors if you have two WMOST .xlsm files, for example.
[4] The Estuary Data Mapper (EDM) application uses the Remote Sensing Information Gateway (RSIG) web servers as conduits for accessing data. The datasets that are available can be viewed through the EDM application or found on the EDM Data Inventory site, https://www.epa.gov/edm. These databases can also be accessed through the WMOST interface within the Baseline Hydrology Module (see WMOST User Guide Section 3.2).
[5] http://water.usgs.gov/software/HSPF/

Assessment Tool (SWAT)[6] model, you can reformat the outputs for use in WMOST using the HydroProcessor[7], available for download from the WMOST v3.0 download page.

If you are not using data from an existing WMOST database (option 1) nor did you use the HydroProcessor to reformat HSPF or SWAT model outputs, you will want to adjust your runoff and recharge time series to take into account the effects of evaporation. In order to avoid double counting evaporation within the HCAM, use the evaporation or potential evapotranspiration time series included with model outputs to adjust the runoff time series.

Check that the time frame (*e.g.,* length of time and actual dates) represented in the climate scenario runoff and recharge time series match the time frame of the baseline runoff and recharge time series. These climate scenario time series are typically new sets of input hourly temperature and precipitation data generated by uniformly adjusting the baseline temperature and precipitation records by the corresponding ΔT (absolute) and ΔP (percentage) values, respectively, where ΔT and ΔP are typically obtained from climate models. Using these adjusted temperature and precipitation data, hourly runoff and nutrient loading rates can then be generated for each scenario using SWMM.

These databases are required by the HCAM as the baseline and climate scenario runoff and recharge time series. Each WMOST Hydrology and associated Loadings Database should have the following characteristics[8] in the order specified as shown in the example below:

- Indication of model name: e.g., “swmm”, “swat”
- Watershed name
- Indication of the type of information included in the database: “hydrology” or “loadings”[9]
- If “loadings” data, the constituent of interest: “tn”, “tp”, “tss”, or “zn”
- A unique numerical ID as the final character in the file name

Figure 4. HCAM Processing Directory – Hydrology and Loadings Files

swmm_taunton24_huc12_polygon_hydrology_2.csv	9/8/2017 10:17 AM	Microsoft Excel Co...	7,636 KB
swmm_taunton24_huc12_polygon_loadings_tn_2.csv	9/8/2017 10:17 AM	Microsoft Excel Co...	3,946 KB
swmm_taunton32_huc12_polygon_hydrology_1.csv	9/8/2017 10:18 AM	Microsoft Excel Co...	8,024 KB
swmm_taunton32_huc12_polygon_loadings_tn_1.csv	9/8/2017 10:18 AM	Microsoft Excel Co...	4,122 KB

Double check the files to make sure there is only one runoff and recharge time series for each HRU.

2.2 WMOST Model Setup (Step 1 of Figure 1)

When you first open WMOST, you will see the familiar Excel interface with one active worksheet entitled Intro. Overall, interaction with the WMOST 3.1 interface will largely be the same as for earlier versions except for the entry of runoff and recharge hydrology and loadings time series, including the Baseline Hydrology and Stormwater Hydrology Modules.10 In order to use HCAM, you must be running a Hydrology & Loadings model analysis and follow the general steps as outlined.

1) Setup the baseline and stormwater managed runoff and recharge tables using either:
   a) “Import HRUs” button within the Baseline Hydrology Module (Figure 5) or

[6] http://swat.tamu.edu/
[7] https://www.epa.gov/ceam/wmost-30-download-page
[8] All file name characteristics are case sensitive.
[9] “loading” will cause HCAM errors.
[10] For detailed information on how to fill out the rest of the WMOST input pages, please refer to the WMOST User Guide (Sections 3.4 through 3.8).

b) “Setup Baseline Tables” and “Setup Stormwater Tables” buttons on the **Input** sheet (Figure 6).

Figure 5. Baseline Hydrology Module

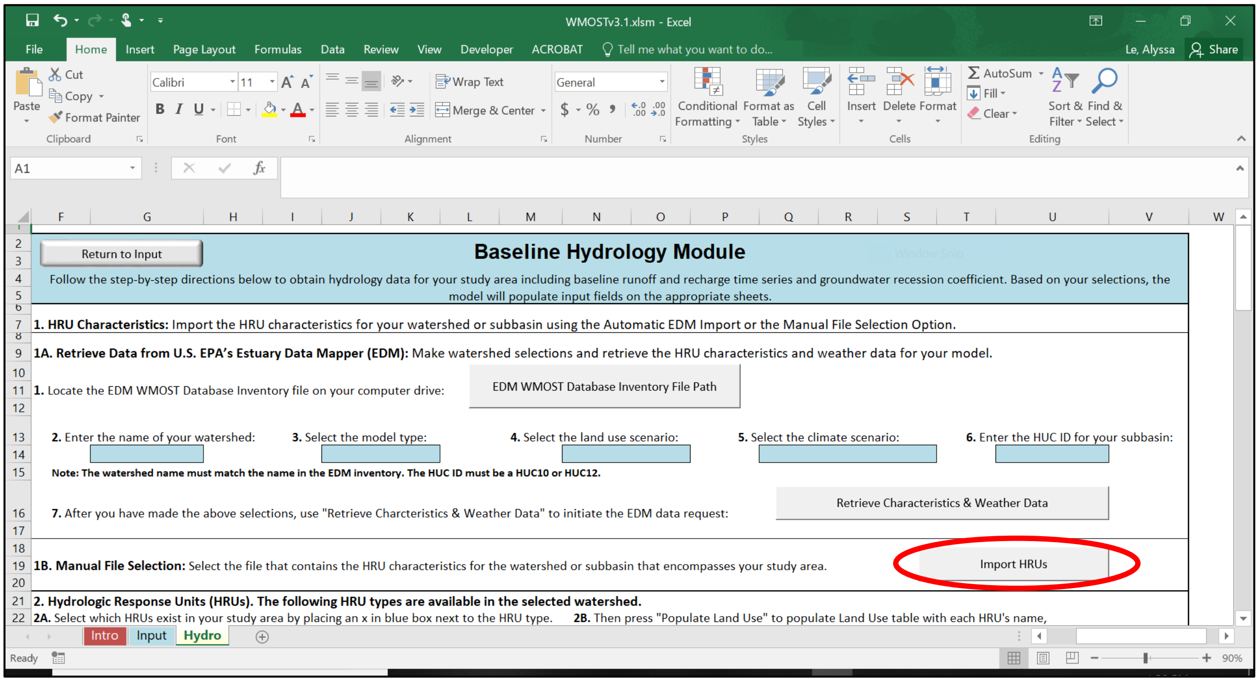
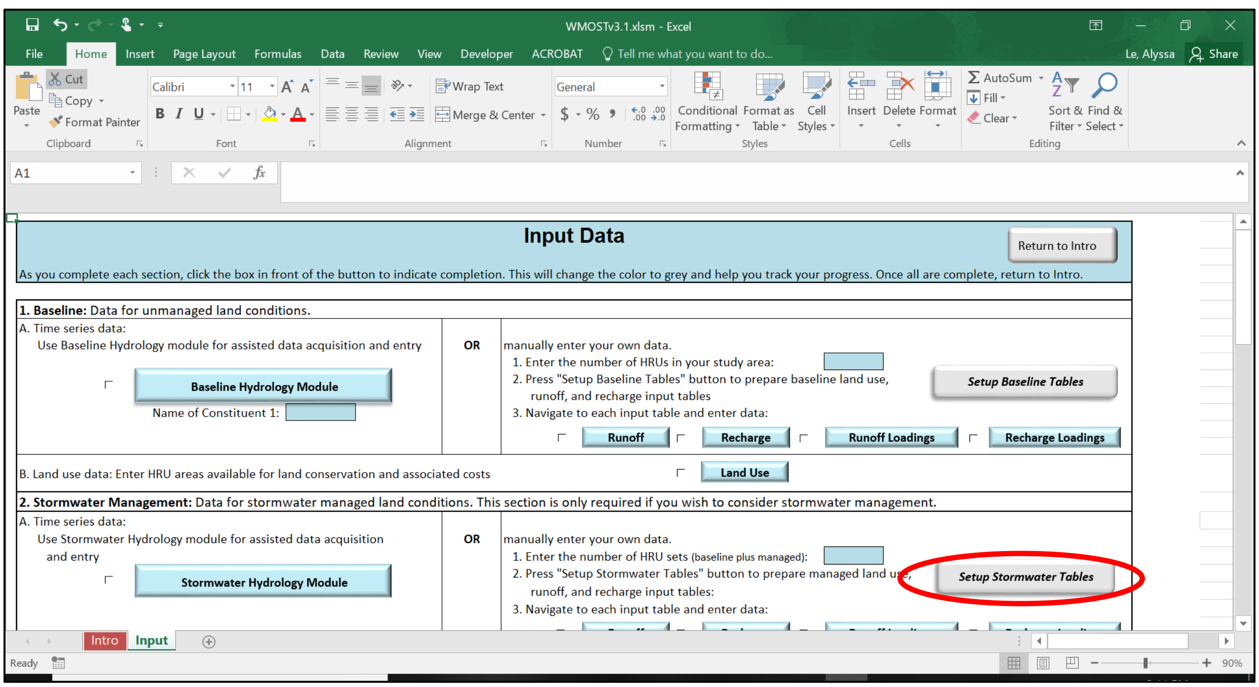


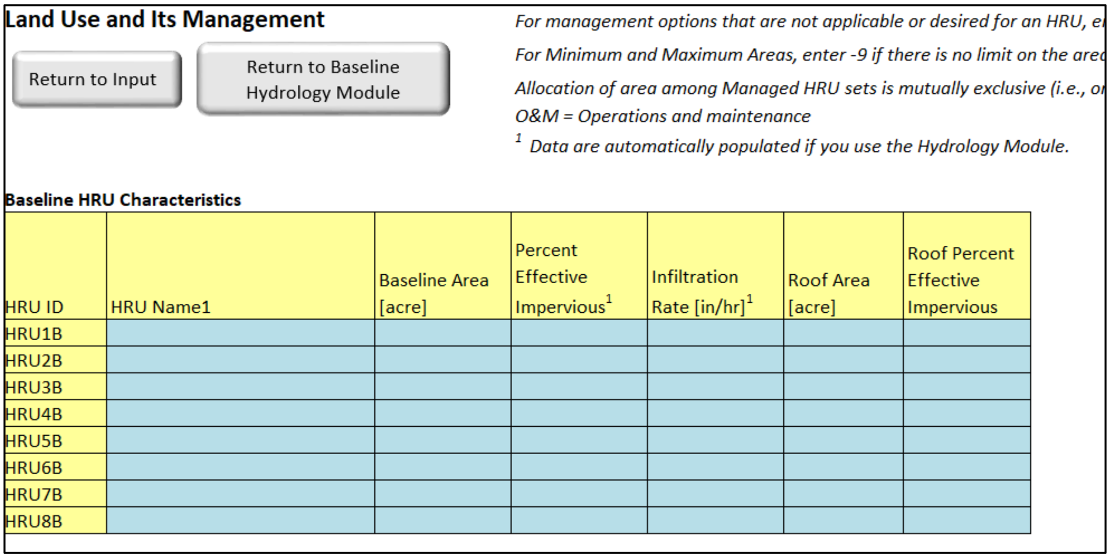
Figure 6. Input Data



The fields in the baseline and stormwater managed runoff and recharge tables will be left blank. In a later step, you will fill out the time period column on the **Runoff** sheet.

2) Provide the baseline and managed set land use data for the tables on the **Land Use** sheet. If you are modeling green roofs, be sure to include nonzero values for roof area and roof percent effective impervious. If you are not modeling green roofs, you may enter "-9" for all HRUs.

Figure 7. Baseline HRU Characteristics


Land Use and Its Management

Return to Input

Return to Baseline Hydrology Module

For management options that are not applicable or desired for an HRU, e

For Minimum and Maximum Areas, enter -9 if there is no limit on the area

Allocation of area among Managed HRU sets is mutually exclusive (i.e., o

O&M = Operations and maintenance

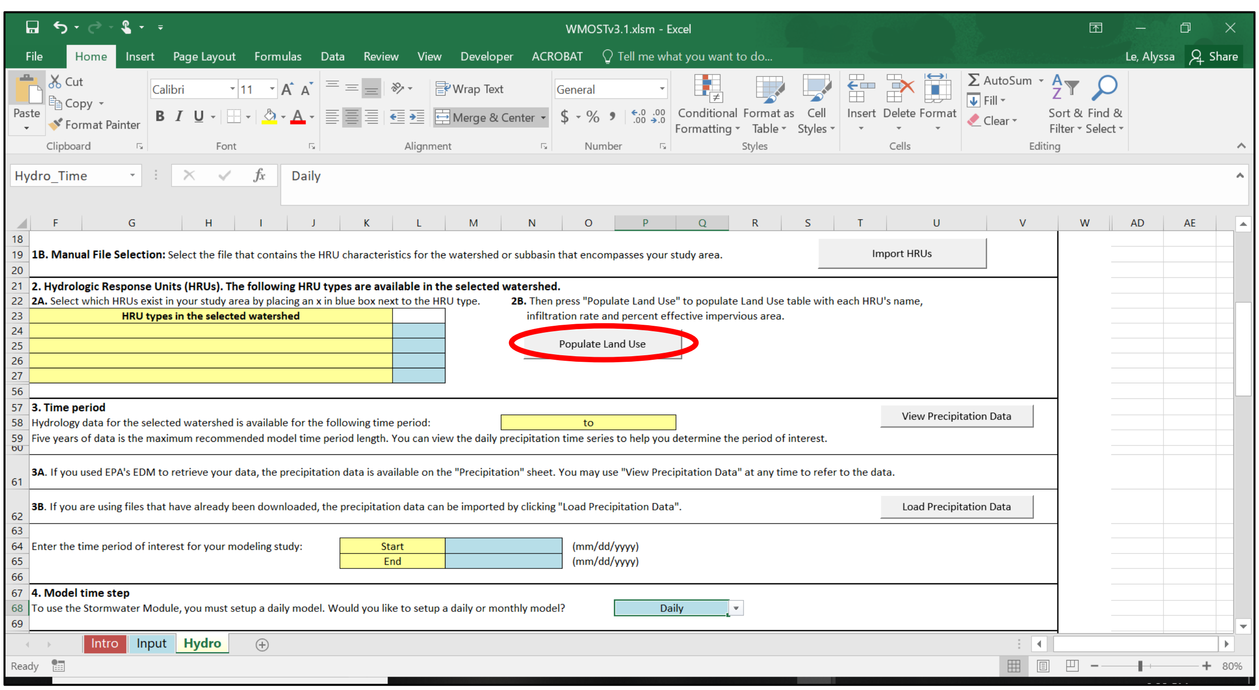
[1] Data are automatically populated if you use the Hydrology Module.

Baseline HRU Characteristics

HRU ID	HRU Name1	Baseline Area [acre]	Percent Effective Impervious[1]	Infiltration Rate [in/hr][1]	Roof Area [acre]	Roof Percent Effective Impervious
HRU1B						
HRU2B						
HRU3B						
HRU4B						
HRU5B						
HRU6B						
HRU7B						
HRU8B						

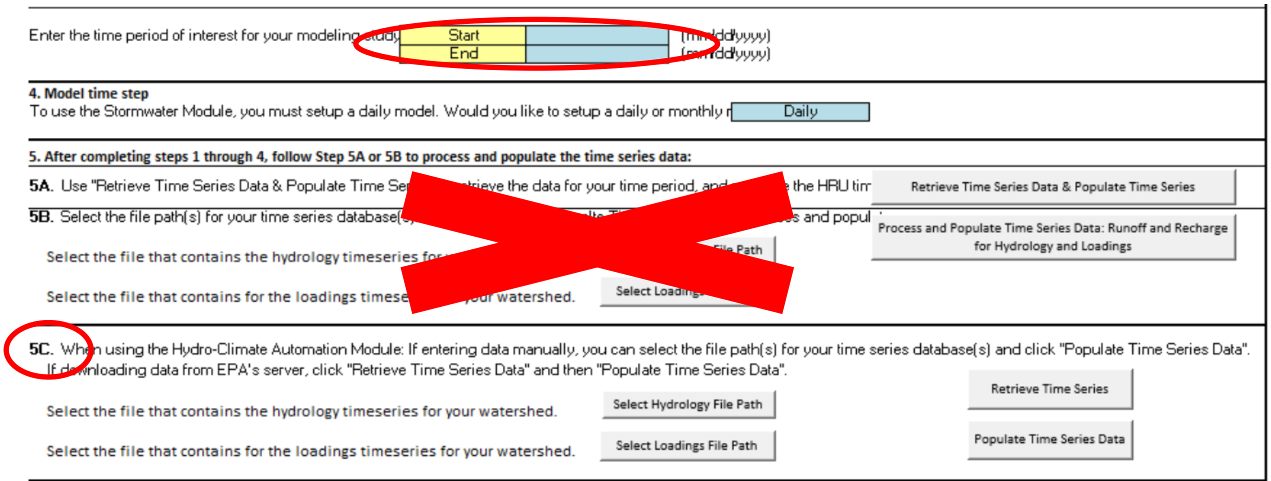
You can do this manually using your own data, or with the assistance of the Baseline Hydrology Module. If you are using the Baseline Hydrology Module, follow Steps 1-4 as usual, including using the "Populate Land Use" button.

Figure 8. Hydro Tab – Populate Land Use



3) Enter the model start dates on the **Hydro** sheet (Baseline Hydrology Module). Whether you are using the Baseline Hydrology Module or not, skip steps 5A and 5B and go to step 5C to finish downloading the hydrology and loadings data and enter the time period onto the **Runoff** sheet (as referred to in Step 1).

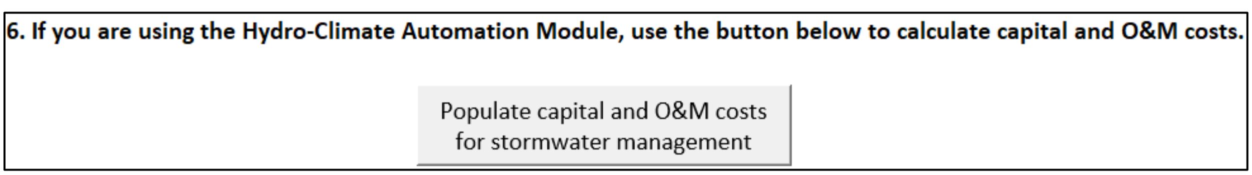
Figure 9. Hydro Tab – Time Period of Interest



If you are entering data manually, select the file paths for your time series databases and click "Populate Time Series Data". If downloading data from EPA's server, click "Retrieve Time Series Data" and then "Populate Time Series Data".

4) Specify BMPs[11] on the **Stormwater** sheet (Stormwater Hydrology Module) and enter their characteristics for design depth and constituent removal rate
5) If desired, use the "Populate capital and O&M costs for stormwater management" button on the **Stormwater** sheet to automatically populate the stormwater costs for each BMP set. Otherwise, be sure to enter your own stormwater BMP costs on the **Land Use** sheet.

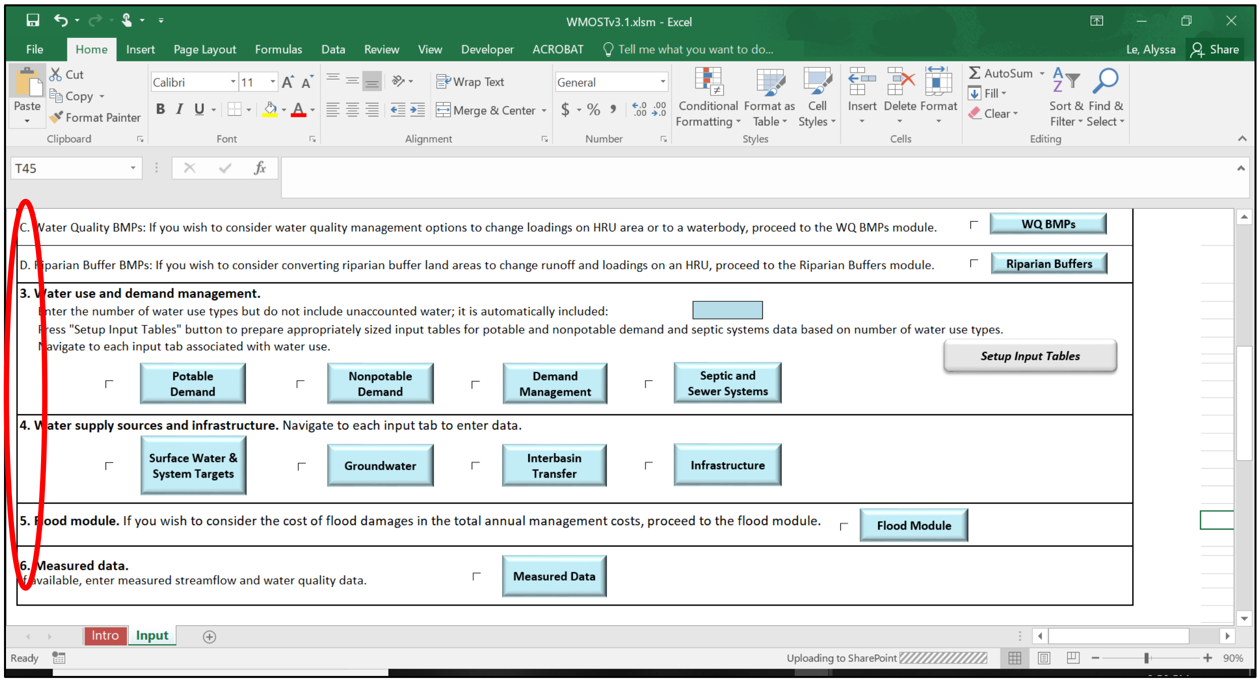
Figure 10. Calculate Capital and O&M Costs



[11] The HCAM application cannot be used to model agricultural BMPs as it is only calculating BMP performance based on runoff from impervious surfaces, which do not exist for agricultural BMPs.

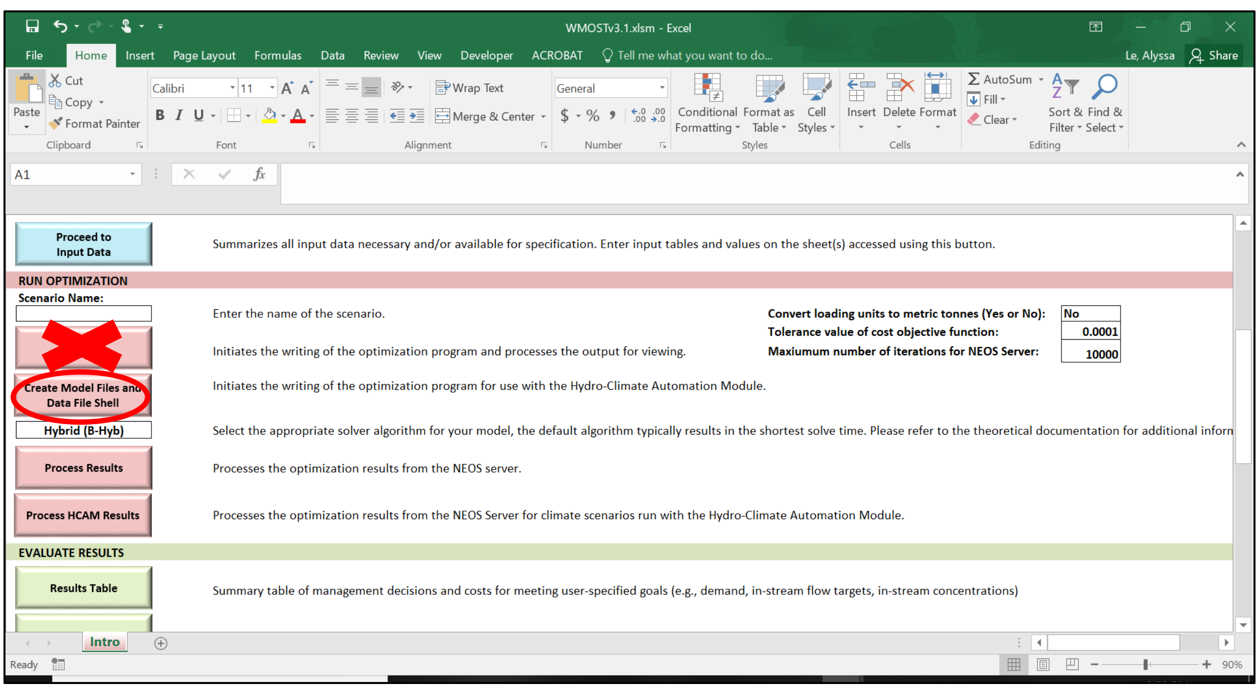
Just as a reminder, you do *not* need to process or enter any runoff/recharge time series data or create any managed sets. However, you should fill in all of the other WMOST input pages, such as the Potable and Nonpotable Demand pages and Infrastructure page (WMOST User Guide Sections 3.3 through 3.8, Sections 2c through 6 on the **Input** sheet).

Figure 11. Input Tab



After you have input the necessary data, press the “Create Model Files and Data File Shell” button on the **Intro** sheet. You do not need to press the “Optimize” button anymore.

Figure 12. Intro Tab – Create Model Files and Data File Shell



Pressing the button will create five files: 1) a model file, 2) a command file, 3) a data file, 4) an options file, and 5) an input data log file (a csv file ending in "LogFileTEMP"). The data file (Wdata.dat) and log file will both be updated by the HCAM.

If you entered your HRU and hydrology and loadings data manually, check the log file to make sure all of the required data is there. In particular, check the *Units* column for the "NLuName" variables and make sure that the integer listed in the *Units* column corresponds to the HRU ID in your model characteristics file and hydrology and loadings databases (refer to the following example).

Table 2. NLuName Variables in Hydrology and Loadings Log File

NLuName	1	forest sand	1
NLuName	2	open nonres sand	2
NLuName	3	MLD res sand	3
NLuName	4	MHHD resid sand	6
NLuName	5	comindtr sand	7
NLuName	6	ag sand	8
NLuName	7	forest till	9
NLuName	8	open nonres till	10
NLuName	9	MLD res till	11
NLuName	10	MHHD resid till	14
NLuName	11	comindtr till	15
NLuName	12	ag till	16
NLuName	13	cranberry bog	17
NLuName	14	forested wetland	18
NLuName	15	nonforested wetlnd	19
NLuName	16	water	100

2.3 BMP Parameters

Included in the download of the HCAM is a file entitled BMP-Config.csv that includes parameters associated with the BMPs available in WMOST. These are default BMP design parameters that were originally set by the EPA Region 1 office during development of the Opti-Tool (EPA, 2017). In some cases, the BMP design parameters from Opti-Tool were adjusted to be compatible with SWMM BMP parameter requirements (see Appendix A). A data dictionary is included within the file beginning on row 21.

These BMP parameters can be edited within the .csv file itself or within the HCAM application. However, it is highly recommended that parameters are only edited within the HCAM application itself to minimize data input errors.

2.4 HRU Parameters

Included in the download of the HCAM is a file entitled HRU-Reference.csv that can be used to set buildup and washoff coefficient values[12] by HRU in the HRU-Config.csv file when running a WMOST "Hydrology and Loadings" optimization run. The HRU-Reference.csv file includes parameter values for a variety of different pollutant, land use types, and infiltration types beginning in column G. Use this information to fill out the HRU-Config.csv file (columns B through E). If you have regionally-specific values for your study area, fill in columns B through E in the HRU-Config.csv file with the appropriate values for your WMOST model's HRUs to replace the default values derived for New England. The SWMM water quality reference manual (EPA, 2016) includes a table summary of linear buildup rates and methodology for developing watershed-specific washoff functions. A crosswalk of HRU-Config.csv column and parameters name is summarized Table 2.

Table 2. HRU References for Column and Parameter Names

Column Name	Parameter Name
bup1	Maximum Buildup (lbs/ac)
bup2	Buildup Rate (1/day)
wsh1	Washoff Coefficient
wsh2	Washoff Exponent

These HRU parameters can only be edited within the HRU-Config.csv file itself.

[12] SWMM defines pollutant buildup and washoff for each land use category. The buildup and washoff functions are described in detail in Chapter 3 Section 3.3.9 of the SWMM user guide (EPA, 2015) and Chapters 3 and 4 of SWMM's water quality reference manual (EPA, 2016).

3. HCAM Usage

3.1. HCAM Steps

Once installed, HCAM can be launched by double clicking “StormwaterBMP.application”.
The following section walks through the steps of the HCAM (Steps 2 and 3 in Figure 1).

Step 1: Welcome to the Hydro-Climate Automation Module.

The tool will ask for the file path for the folder holding the WMOST Hydrology and Loadings Databases and the file path for the HCAM Processing folder. See Section 2 for a detailed description of these folders and associated file contents. Click on Folder Path buttons to navigate to directory of interest. The HCAM processing folder must also contain the HRU-Config.csv file and the BMP-Config.csv file.

Step 2: Confirm the HRU buildup/washoff parameter values.

HCAM includes default buildup/washoff parameter values in the HRU-Config.csv file. Users should confirm values and edit if necessary. The HRU buildup/washoff parameter values can only be set in the HRU-Config.csv file so if the parameters are incorrect, close the application, and return to the HRU-Config .csv file to make the necessary changes. Close the HRU-Config.csv before returning to HCAM.

Step 3: Confirm the BMP specifications.

The BMP specifications summarized in the table can be edited within the application in the lower table. However, it is important to keep parameter values within acceptable ranges as designated by the SWMM documentation[13]. If you are modeling green roofs, you can adjust the nutrient rain concentration on this page as well.

Step 4: Summary of data processing specifications.

This page allows you to verify your data processing specifications before proceeding to run SWMM. Make note of the baseline database names and corresponding Wdata#.dat file names to ensure that you understand which model run is associated with each scenario.

Step 5: Run SWMM Simulations.

When SWMM begins to run, you will see an additional screen pop up that gives you an indication of model processing. In the meantime, if you hover your cursor over the HCAM application, it will give you an indication of if it is still processing. You will be informed when SWMM simulations are complete, SWMM outputs have been processed, and optimization data files have been written. The following outputs from SWMM and the HCAM will be written to the folder *model_outputs* within the HCAM Processing folder.

- SWMM outputs
  - Detailed summary text files (detailed_out_*managementset#_HRU#*.txt)
  - SWMM output files (swmm_*managementset#*.out)
  - SWMM report files (swmm_*managementset#*.rpt)
- Updated WMOST data file (Wdata_*scenario#*.dat)
- Updated WMOST log file

This folder will be rewritten if the HCAM is used to run alternative climate scenarios.

Step 6: Run Optimization (Step 3 in Figure 1)

[13] https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100N3J6.txt

When you pressed the “Create Model Files and Data File Shell” button within WMOST, you generated one equations file (.MOD file), one AMPL commands file (.AMP file), and one options file (.OPT file). HCAM generated several data files (.DAT file), one for each climate scenario. These files need to be uploaded to the NEOS server for optimization. You will run NEOS once for each unique data (.dat) file. See Section 4.1 in the WMOST Users Guide for more detailed instructions on submitting model files to the NEOS server.

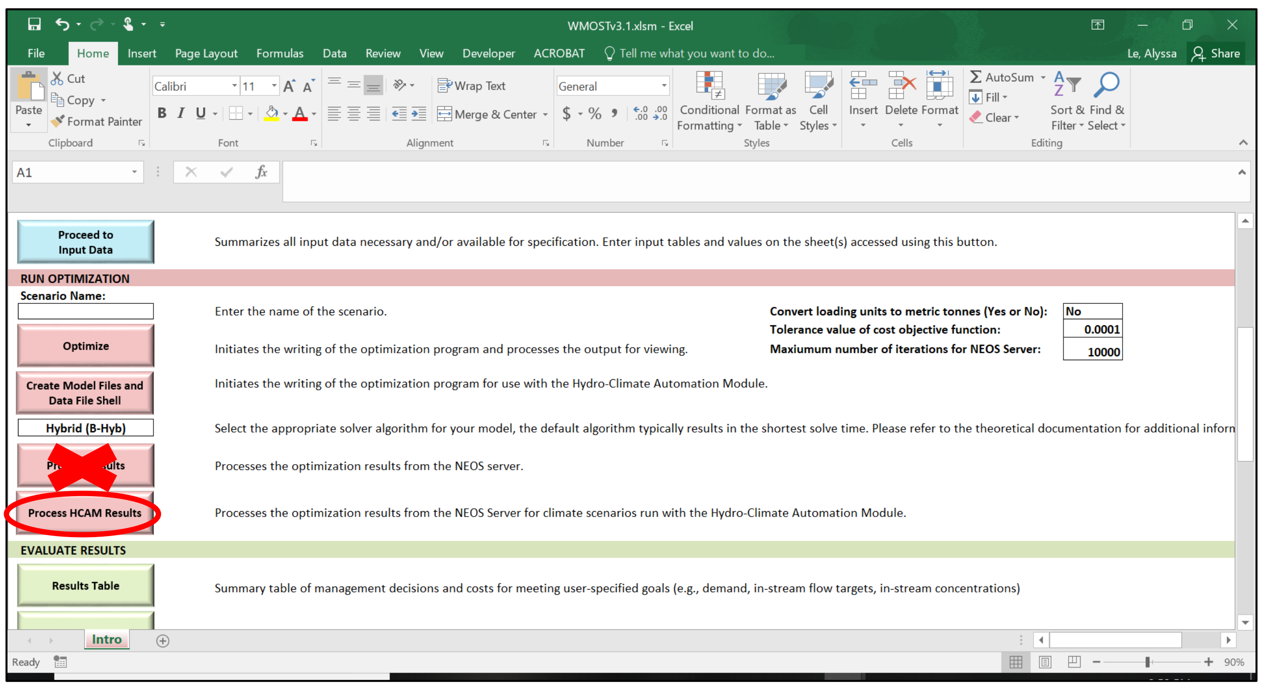
Step 7: Results Processing

The NEOS server will send you an email when your model run has completed. The optimization results must be copied into a new text file so it can be evaluated within WMOST. See Section 4.1 in the WMOST User Guide for more detailed instructions on processing results from the NEOS server.

3.2 Post-HCAM WMOST Steps

HCAM produces a log file for each scenario (saved to the HCAM Processing folder with the names in the form of “[*StudyAreaName*]_[*ScenarioName*]_SpecsResults_[ScenarioID].csv), which contain the input data and monthly runoff and recharge hydrology and loading statistics for each scenario.

WMOST must complete the processing of the SpecsResults file to include the climate statistics (average annual precipitation and average temperature for the time period) and the results from each scenario input by the user (Step 4 in Figure 1). To do this, open your WMOST file and select the “Process HCAM Results” button on the **Intro** sheet.



This button initiates the writing of the climate statistics and appends the results for each scenario in its corresponding scenario log file based on the file paths of the hydrology database file and scenario log files in the “outFiles.txt” file saved to the folder *model_outputs*. WMOST will prompt you to select the results file path for each scenario log file, and then uses that file to append the results to the scenario log file. When the scenario log file processing is complete, a message box appears that says “HCAM Scenario Log File processing complete”. At this point, you can view and analyze your results in the WMOST ScenCompare[14] tool (Step 5 in Figure 1).

[14] https://www.epa.gov/ceam/wmost-301-download-page

References

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United States Environmental Protection Agency (U.S. EPA). 2018b. “Watershed Management Optimization Support Tool (WMOST) v3: User Guide.” Publication No. EPA/600/R-17/255).

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Appendix A

The following tables indicate where the BMP-Config.csv BMP parameters have been updated from the default Opti-Tool values. References are linked in the footnotes. Parameter units are listed within the BMP-Config.csv file for reference.

WMOST BMP Name	StorVolume	BermH	VegVol	SurfRough	SurfSlope	SwaleSlope	SoilThick	SoilPor	SoilFC	SoilWP
Biofiltration w/ UD		MA Stormwater Guidance Manual[15]	SWMM User Manual[16]		SWMM User Manual[15]	SWMM User Manual[15]	MA Stormwater Guidance Manual[14]		SWMM WQ Reference[17]	SWMM WQ Reference[17]
Bioretention Basin		MA Stormwater Guidance Manual[14]			SWMM User Manual[15]	SWMM User Manual[15]			SWMM WQ Reference[17]	SWMM WQ Reference[17]
Enhanced Biofiltration w/ ISR			SWMM User Manual[15]		SWMM User Manual[15]	SWMM User Manual[15]			SWMM WQ Reference[17]	SWMM WQ Reference[17]
Extended Dry Detention Basin			SWMM User Manual[15]		SWMM User Manual[15]	SWMM User Manual[15]			SWMM WQ Reference[17]	SWMM WQ Reference[17]
Grass Swale w/D			SWMM User Manual[15]	SWMM WQ Reference[17]	SWMM WQ Reference[17]	SWMM WQ Reference[17]	WMOST Theoretical Documentation[17]	WMOST Theoretical Documentation[16]	SWMM WQ Reference[17]	SWMM WQ Reference[17]
Gravel Wetland			SWMM User Manual[15]		SWMM User Manual[15]	SWMM User Manual[15]			SWMM WQ Reference[17]	SWMM WQ Reference[17]
Green Roof		SWMM WQ Reference[18]	SWMM User Manual[15]		Literature review[19]	SWMM User Manual[15]	SWMM WQ Reference[17]	SWMM WQ Reference[17]	SWMM WQ Reference[17]	SWMM WQ Reference[17]
Infiltration Basin			SWMM User Manual[15]		SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]
Infiltration Chamber			SWMM User Manual[15]		SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]
Infiltration Trench			SWMM User Manual[15]		SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]

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WMOST BMP Name	StorVolume	BermH	VegVol	SurfRough	SurfSlope	SwaleSlope	SoilThick	SoilPor	SoilFC	SoilWP
Porous Pavement w/ SI		SWMM WQ Reference[17]	SWMM User Manual[15]		UNH Stormwater Center[20]	SWMM User Manual[15]		SWMM WQ Reference[17]	SWMM WQ Reference[17]	SWMM WQ Reference[17]
Porous Pavement w/ UD		SWMM WQ Reference[17]	SWMM User Manual[15]		UNH Stormwater Center[19]	SWMM User Manual[15]		SWMM WQ Reference[17]	SWMM WQ Reference[17]	SWMM WQ Reference[17]
Sand Filter w/ UD			SWMM User Manual[15]		SWMM User Manual[15]	SWMM User Manual[15]			SWMM WQ Reference[17]	SWMM WQ Reference[17]
Wet Pond			SWMM User Manual[15]		SWMM User Manual[15]	SWMM User Manual[15]			SWMM WQ Reference[17]	SWMM WQ Reference[17]

WMOST BMP Name	SoilCond	SoilCondSlope	SoilSH	StorThick	StorVR	StorCF	FlowCoeff	FlowExp	FlowOH	PaveThick	PaveVR
Biofiltration w/ UD		SWMM WQ Reference[17]	SWMM Hydro Reference[20]			SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]	WMOST Theoretical Documentation[16]		
Bioretention Basin		SWMM WQ Reference[17]	SWMM Hydro Reference[20]	SWMM User Manual[15]							
Enhanced Biofiltration w/ ISR		SWMM WQ Reference[17]	SWMM Hydro Reference[20]			SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]	WMOST Theoretical Documentation[16]		
Extended Dry Detention Basin			SWMM Hydro Reference[20]			SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]	WMOST Theoretical Documentation[16]		
Grass Swale w/D	WMOST Theoretical Documentation[16]	SWMM WQ Reference[17]	SWMM Hydro Reference[20]			SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]			
Gravel Wetland		SWMM Hydro Reference[21]	SWMM Hydro Reference[20]			SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]			

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WMOST BMP Name	SoilCond	SoilCondSlope	SoilSH	StorThick	StorVR	StorCF	FlowCoeff	FlowExp	FlowOH	PaveThick	PaveVR
Green Roof	SWMM WQ Reference[17]	SWMM WQ Reference[17]	SWMM Hydro Reference[20]			SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]			
Infiltration Basin			SWMM Hydro Reference[20]			SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]			
Infiltration Chamber			SWMM Hydro Reference[20]			SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]			
Infiltration Trench			SWMM Hydro Reference[20]			SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]			
Porous Pavement w/ SI	SWMM WQ Reference[17]	SWMM Hydro Reference[20]	SWMM Hydro Reference[20]	UNH Stormwater Center[19]		SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]		MA Stormwater Guidance Manual[14]	
Porous Pavement w/ UD	SWMM WQ Reference[17]	SWMM Hydro Reference[20]	SWMM Hydro Reference[20]	UNH Stormwater Center[19]		SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]			
Sand Filter w/ UD		SWMM Hydro Reference[20]	SWMM Hydro Reference[20]			SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]	WMOST Theoretical Documentation[16]		
Wet Pond		SWMM WQ Reference[17]	SWMM Hydro Reference[20]			SWMM User Manual[15]	SWMM User Manual[15]	SWMM User Manual[15]			

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WMOST BMP Name	PavePerm	PaveCF	MatThick	MatVR	MatRough	PercentRem_TN	PercentRem_TP	PercentRem_TSS	PercentRem_ZN
Biofiltration w/ UD									
Bioretention Basin									
Enhanced Biofiltration w/ ISR									
Extended Dry Detention Basin									
Grass Swale w/D									
Gravel Wetland									
Green Roof			SWMM WQ Reference[17]	SWMM WQ Reference[17]	SWMM WQ Reference[17]				
Infiltration Basin									
Infiltration Chamber									
Infiltration Trench									
Porous Pavement w/ SI									
Porous Pavement w/ UD									
Sand Filter w/ UD									
Wet Pond									

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WMOST BMP Name	RainConc_TN	RainConc_TP	RainConc_TSS	RainConc_ZN
Biofiltration w/ UD				
Bioretention Basin				
Enhanced Biofiltration w/ ISR				
Extended Dry Detention Basin				
Grass Swale w/D				
Gravel Wetland				
Green Roof				
Infiltration Basin				
Infiltration Chamber				
Infiltration Trench				
Porous Pavement w/ SI				
Porous Pavement w/ UD				
Sand Filter w/ UD				
Wet Pond				

[15] https://www.mass.gov/files/documents/2016/08/qi/v2c2.pdf
[16] https://www.epa.gov/sites/production/files/2019-02/documents/epaswmm5_1_manual_master_8-2-15.pdf
[17] https://www.epa.gov/sites/production/files/2018-02/documents/2018_wmostv3_theoreticaldoc_epa600r17_220final508.pdf
[18] https://nepis.epa.gov/Exe/ZyPDF.cgi/P100P2NY.PDF?Dockey=P100P2NY.PDF
[19] Berndtsson, J. C. 2010. Green roof performance towards management of runoff water quantity and quality: A review. Ecological Engineering, 36, 351-360.
[20] https://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/pubs_specs_info/unhsc_pa_spec_10_09.pdf
[21] https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100NYRA.txt