BMP Trains USER MANUAL

BMP Trains 2020: a C++ and VB based model for **calculating annual removal effectiveness**.
The acronym is derived from the use of stormwater BMPs in series.

It is used to evaluate **B**est **M**anagement **P**ractice **T**reatment options based on **R**emoval using **A**nnual loadings by those **I**nterested in **N**utrients and in **S**tormwater.

Edited and Updated to Facilitate Evaluation of Most Stormwater Management Practices in Florida
By
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Download from: https://roneaglin.online/bmptrains/

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With input from user groups that include FDEP, WMDs, FDOT and Consultants.

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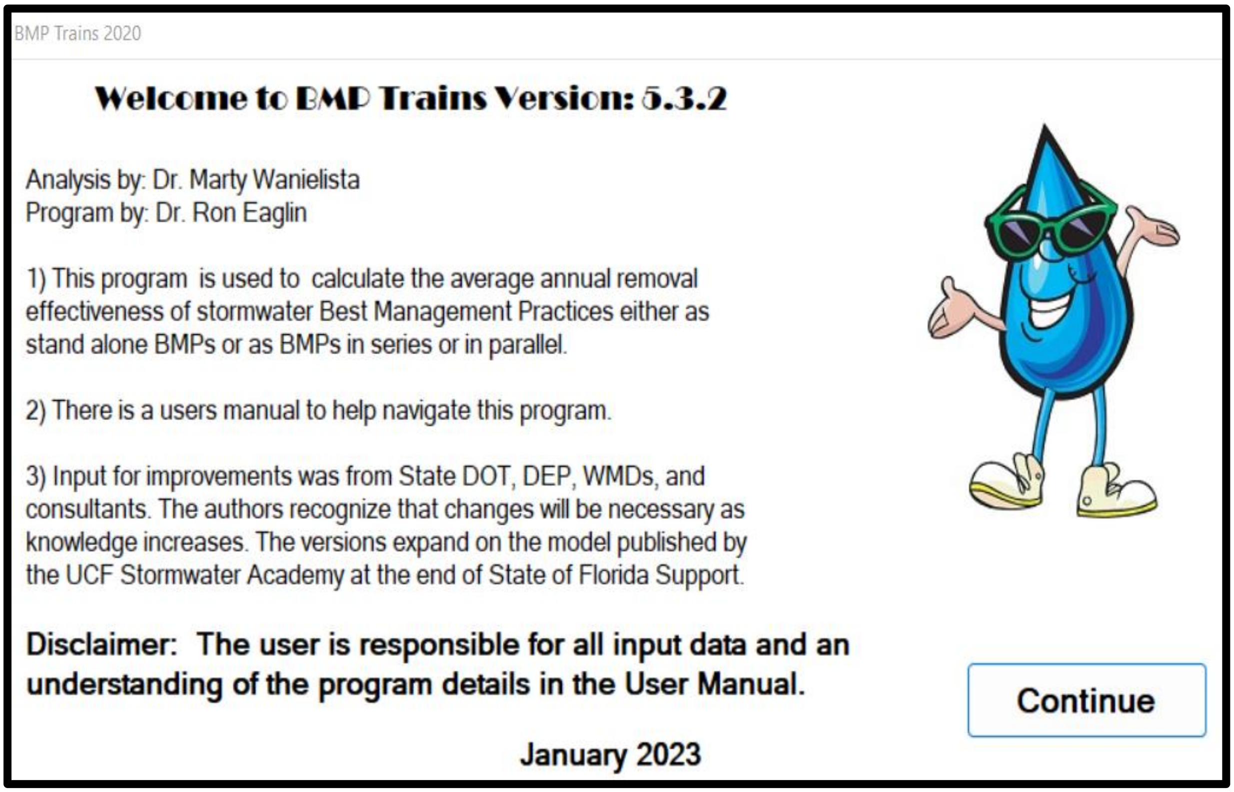
The information within this Manual is based on current (January, 2023) stormwater management practice within the State of Florida. The Manual accompanies the **BMP Trains 2020** computer program as a resource to explain current practice as well as to understand the navigation of the computer program**.** The computer program runs on the **Windows 10** operating system. It can operate in a Windows 7 environment with the addition of .net4.6. The computer program is used to assess average annual effectiveness of stormwater BMPs. The information in this Manual is based on input and review of the computer program from State agencies and consulting professionals. Many have experience in using previous versions of the computer program. Example problems are used to illustrate improved features found in **BMP Trains 2020**. All existing examples from previous versions of the Manual were executed with the new **BMP Trains 2020** program and some examples maintained in this publication as a check on accuracy and to demonstrate the use of the model. All users should visit a review agency to determine endorsement for input data to the model. **Note in this release new EMC values for rural areas as well as a new yearly rainfall map.** The authors appreciate the input from stormwater professionals in the development of the Model and this Manual.



Updating BMP Trains 2020

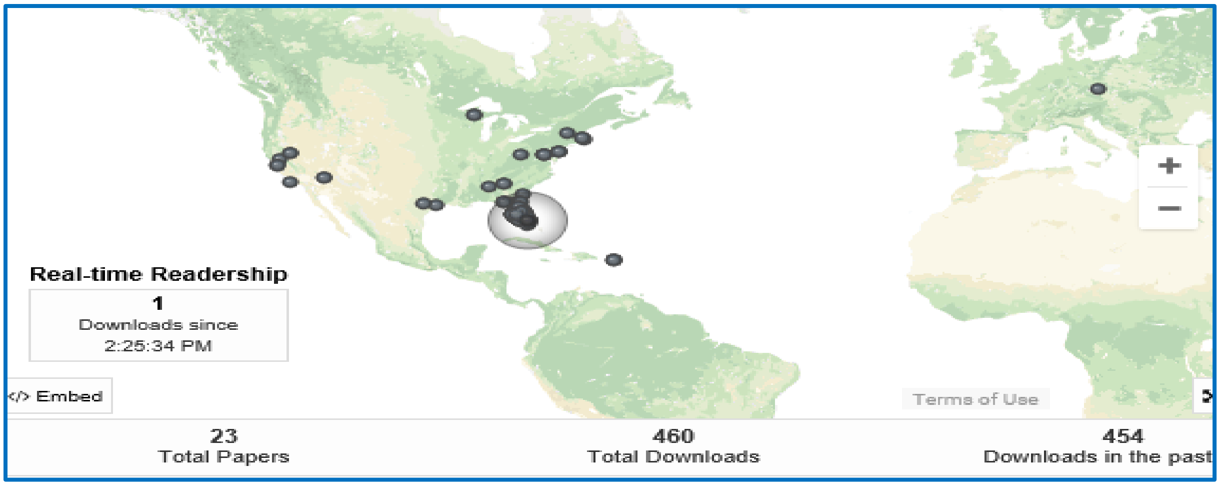
BMP Trains 2020 is a computer program featuring clarity of use, enhanced understanding of the BMP treatment train as a method for analyzing average annual removal effectiveness given stormwater BMPs. It is programmed and compiled using the C# programming language. **Windows 10** is the operating system for the program. It can operate in a Windows 7 environment with the addition of .net4.6 or .net4.7. The entire user interface and much of the internal function has been completely overhauled from the Excel version, while preserving the essential goal of quantifying pre- and post-development average annual nutrient loadings (Nitrogen and Phosphorus). The research by Dr. Harvey Harper, Dr. Marty Wanielista, Dr. Mike Hardin, Eric Livingston, and others in computing nutrient loads and BMP removal effectiveness continues to be the foundation of the program.

The program preserves the methodologies used to assess average annual effectiveness as currently used (January, 2023) by professionals within the State of Florida. Input data on site conditions must be determined before the use of the model. The manual does use data from actual permits but it must be recognized that inputs vary with region of the State. The reviewers include staff from consulting engineering and science companies as well as from the Florida Department of Transportation, Florida Department of Environmental Protection, Water Management Districts, and local review agencies. Where there are evolving concepts and products (input data), the option for user inputs has been preserved. In these cases, pre-application meetings are encouraged.

It is understood that **BMP Trains 2020** reflects current (January, 2023) state-of-the art methods that are used to determine average annual effectiveness of stormwater best management practices (BMPs). The authors appreciate the input from all reviewers and are committed to making changes as the science and engineering are approved by reviewing agencies. State fiscal support for the program ended in November 2019. Since then, the authors with user input have maintained and upgraded the program.

Improvements relative to the previous spreadsheet models in BMP Trains 2020 are:

Website: To download the latest version of the model and the user manual, proceed to: http://roneaglin.online/bmptrains/. Previous versions of BMP Trains with publications that support the model development are found on: http://stars.library.ucf.edu/bmptrains/. Support presentations and videos also can be accessed on this site. A map which shows download locations for a specific period for the model and publications is shown below to indicate the general acceptance and distribution of the model and publications.



Site/catchment topology: A catchment area is defined by runoff at a point and the possible use of a BMP. The user may include an unlimited number of catchments within an individual project model. An example is a parking lot for one catchment and wet detention or rain gardens for anther catchment. The model has been tested for up to 25 catchments and 25 BMPs. There are many different configurations of the catchments that can be used.

Multiple BMP per catchment: The user may select up to four BMPs for each individual catchment to route in series (e.g., pervious pavement to a swale, to a wet detention pond and finally to a side-bank filter). Note that the catchment area for runoff to these four BMPs does not change. Previous versions limited the user to three BMPs in each catchment.

Groundwater analysis option: For systems utilizing retention BMPs (such as exfiltration, tree wells, retention rain gardens, pervious pavement, swales, and vegetated buffers/strips as well as traditional on-site and regional retention basins) the option is provided for calculating nutrient flow into the groundwater and groundwater recharge in million gallons per year. The effectiveness of media (i.e. biosorption activated media and others) can be used as part of the calculations for average annual efficiency and annual average concentration into the ground water. Average annual concentration is defined as the annual mass into the groundwater divided by the annual runoff to the ground. This calculation was not part of the previous releases.

Multiple BMP methodology: Sites with multiple catchments and BMPs for each catchment are modeled more precisely because catchments can be divided into smaller areas. Nutrient removal from upstream inflows is calculated so that removal upstream cannot be removed twice – users can no longer wrongly assume that they can simply add up the removal efficiencies for multiple BMPs to estimate effectiveness. For example, in a site with two BMPs, the downstream BMP is a wet pond in series with an upstream BMP. The nutrient load discharged from the upstream BMP is modeled for the incremental treatment that it receives in the downstream pond (while direct inflow to the downstream pond also has its own load removal calculation).

When multiple BMPs in a catchment or in a series of catchments are used, calculations of overall effectiveness are based on the stand-alone effectiveness, thus the physical size of the stand-alone BMP must be adjusted. As an example; for wet detention effectiveness is based on the annual residence time. The annual residence time is defined as the permanent pool (ac-ft) divided by the annual runoff (ac-ft/year) and multiplied by 365 days per year. Thus, if annual flow is decreased and the residence time is maintained, then the permanent pool is decreased.

Current practice: New (2019-2022) research findings have been added for the Vegetated Filter Strips (VFS). The research verified a minimum width of the VFS. The maximum width remains at 30 feet as a width greater than 30 feet does not result in a significantly greater removal. In practice, up to 4 BMPs in one catchment may be used, thus the program was modified to permit up to 4 and responds to the need to evaluate removal for up 4 BMPs in one catchment. If there are more than 4, another catchment can be made and routing is set-up. Also, the use of the model justifies a reduction of catchment area when on-site retention is provided. An example is a rain garden catchment areas with storage from at least 4 inches of rain can be removed from the total area when considering surface nutrient discharges.

The calculations reflect the state-of-the-art understanding for nutrient removal using single and multiple catchments. The annual removal for retention adheres to the cumulative distributions of annual rainfall and the catchment configuration as well as treatment in wet detention systems adheres to the cumulative annual residence time.

With added catchments the logic is preserved for the calculations associated with many optional combinations of runoff. As an example, runoff water retained upstream has nutrients removed before downstream treatment and thus cannot be removed again. In addition, wet detention for runoff water upstream removes a fraction of the particulates and that fraction is not available for removal in another downstream wet detention pond. Thus, nutrient removal from upstream inflows is calculated so that discharge loading is more accurate – users can no longer solve separately the removal in each catchment and then wrongly assume that they can simply add up the removal efficiencies for multiple BMPs that exaggerate their effectiveness.

Permanent pool volume: That volume of a wet pond that has a Dissolved Oxygen (DO) concentration greater than 1 mg/L. The calculation of average annual wet pond residence time is made using the permanent pool volume and the annual runoff into the pond. Anoxic depth is the depth at which DO is less than 1 mg/L Thus, the permanent pool depth is the depth to the anoxic layer.

Weighted Curve Number (CCN): For the composite curve number, there is an option for the calculation with multiple land uses reflecting different soil/cover conditions. Copy and paste from a spreadsheet for large data bases is available. The calculation is weighted on the annual runoff. The weighted CCN values can be calculated for all catchments and is not limited to 4 as with the past spreadsheet version. The paste button permits a GIS interface provided the data is in a spreadsheet format. The use of this calculation is optional.

Composite Event Mean Concentration (EMC): As with CCN, another option for the calculation of a composite EMC weighted for annual runoff is available. Interface or copy of spreadsheet values with the paste button for each catchment is available. This option uses the annual runoff and the area. EMCs have been updated and a user defined option is available.

User interface: All information and worksheets within **BMP Trains 2020** have a consistent "look and feel." The font sizes and views are standard. Print and copy options are available.

Output files and reports: Input and calculated data are visible on-screen as the user completes the worksheets within **BMP Trains 2020**. On-screen reports allow the review and design professionals to check data input and different design options before selecting a final design. Every on-screen report has an accompanying printable report – as with the user interface these reports are now standardized in their font size so that nothing is omitted from a printout. A "*complete report*" button is available for review of all input data and average annual effectiveness data. All input data can be saved using the "save project" button. The file is saved in the "Documents" section and in a folder called "BMP Trains" with the ".bmpt" file extender. However, any file location can be used.

User support: The user is directed through the worksheets for calculating pre- and post-development runoff volume and nutrient loadings, selecting one or more BMPs to provide treatment, establishing the topology for the project's catchments, and then to present the results for annual calculations. An optional step allows the inclusion of life cycle cost assessment. The user has the choice of a life cycle cost analysis at both the individual BMP and project levels, and to include a number of "what if" scenarios for capital costs (land, construction) and operating and maintenance costs. Support screen captures are accessible throughout the program, using maps and tables for rainfall depths, land use types, BMP diagrams, etc. As part of the "look and feel" of the software every screen has a *"Back"* button to return the user to a previous level. The user is also provided with a unique file suffix, identified as ".bmpt" for all saved files making it easier to search and retrieve files.

Holding Basin: A holding basin is used when natural infiltration is limited. It is recognized that removal credit should be evaluated based on a filter media as well as bank and bottom infiltration (Harper, 2016). An example problem (#14) to evaluate annual effectiveness is presented.

User manual: This user manual includes information for many calculations and for navigation of the model, consistent with current design methodologies. Earlier used example problems with solutions have been updated to reflect the new **BMP Trains 2020** interface and navigation, as well as to make the example problems more representative of typical design situations throughout the State of Florida at this present time (year 2023).

Overview of BMP Trains 2020

The user interface in the model consists of data input and calculation steps (“worksheets”) for the professional to follow. The cost comparison worksheet is generally considered as optional. The worksheets and reports are:

- General Site Information Worksheet,
- Watershed Characteristics Worksheet,
- Treatment Options (selecting one or more BMPs, each with its own worksheet),
- Catchment Configuration Worksheet,
- Summary Treatment report,
- Complete Report (usually submitted for review purposes), and
- Cost Comparisons (optional).

Within this section is an explanation of each of these worksheets. The order listed above is the general sequence of input and analysis, although users may choose to return to previous steps at any time to revise values for a “what if” scenario or project modifications. The general site information data must be entered first; an example is shown in Figure 1. You cannot proceed to the treatment and other worksheets, until the catchment data are entered.

General Site Information Worksheet

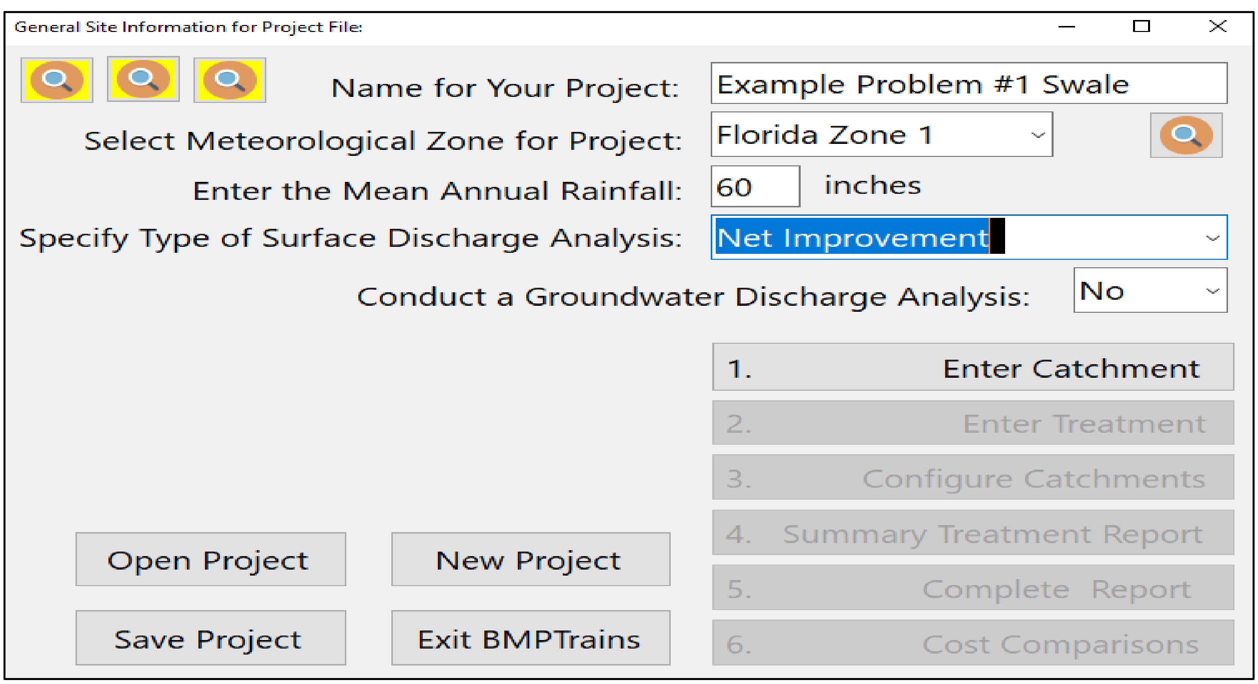


Figure 1. General Site Information Worksheet.

The **General Site Information Worksheet** prompts the user to input information related to the project, including:

- **Project name** – any set of alphanumeric characters
- **Meteorological zone** – one of the five designated zones for the state of Florida
- **Mean annual rainfall** (inches)
- **Type of analysis**:
  - BMP analysis (only post-development parameters are necessary),
  - Net improvement (compares pre- and post-development nutrient loadings),
  - 10% less than pre-development (similar to net improvement but requiring an additional 10% removal), and
  - Specified removal efficiency (based upon custom entered percentages for nutrient removal efficiency rates).
- Whether to include **groundwater analysis** of nutrient removal (optional).

In addition, the **General Site Information Worksheet** provides typical file functions (save, open, exit, and new). You can also go to "*open pre BMP*" button when there exists a BMP in a pre-condition. The "*New Project*" button allows the user to completely erase any values currently entered. Also, six buttons guide the user to frequently used worksheets in proceeding with BMP analysis (plus the sixth/optional cost analysis step). Upon beginning a new project, the user can only select button *#1 (Enter Catchment)* as the subsequent steps cannot proceed without the catchment hydrologic parameters. Upon completing step #1, the second button (*Enter Treatment*) is available, and so on. There are user assist buttons that provide information for input and analysis of data.

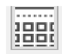
Contextual Support and Calculation Assistance:

 Support  Calculation……..  …References

In various locations throughout **BMP Trains 2020**, the user is given context-specific support, calculation options and access to references. These are identified as shown with the above icons which, when selected, will open resource documents such as rainfall distribution maps, FLUCCS code tables, calculators, User Manual, and so on. Hovering the mouse pointer over the icon will display the specific topic.

BMP Trains 2020 formatted files are given the file extension ".bmpt". The file is created when the "save" button is used. Once installed on a given Windows operating system, the user may double-click on the last six saved files to open the file (typical Windows conventions).

Watershed Characteristics Worksheet

After the user selects the "*Enter Catchment*" button, a new window opens with the **Watershed Characteristics Worksheet**. An example of this Worksheet is shown in Figure 2 and includes the hydrologic parameters for the site's catchment(s) and support icons. Included in Figure 2 is the EMC calculation assist button  and is available only for user defined inputs

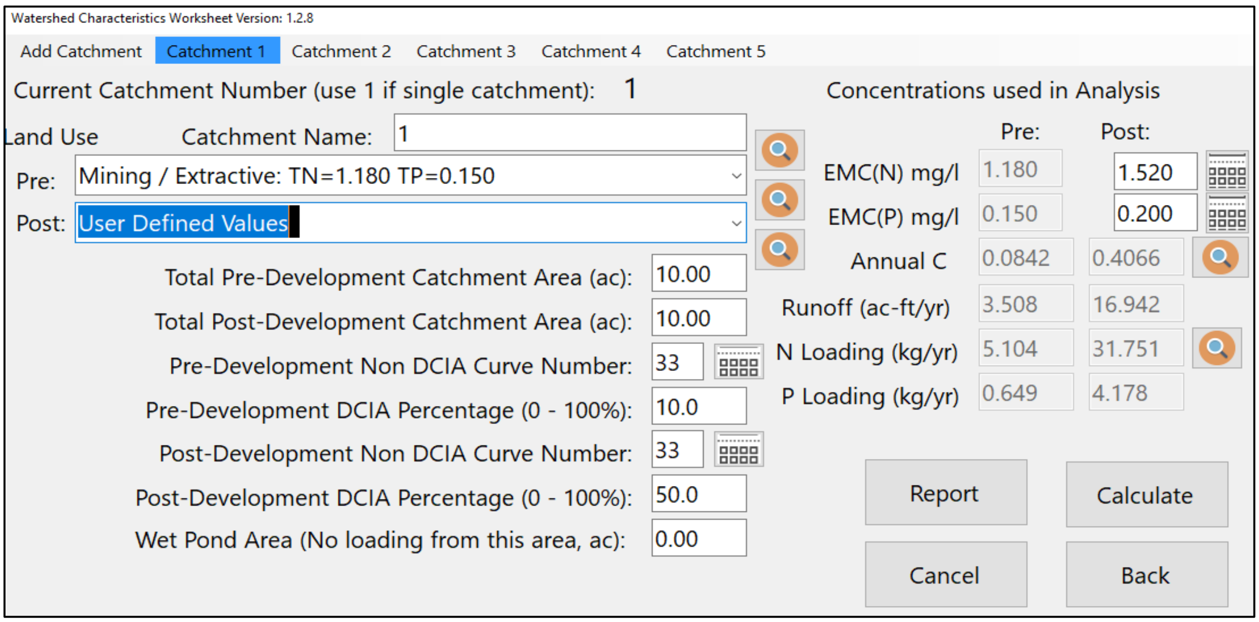
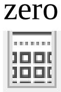


Figure 2. Watershed Characteristics Worksheet.

Upon selecting "1. Input values for the **Watershed Characteristics Worksheet** are as follows:

- **Catchment name** – Any alphanumeric text, this typically matches the stormwater professional's designation for the project site's catchment(s). For the purpose of **BMP Trains 2020**, catchments are the smallest hydrologic designation for which runoff occurs in a year and where one or more specific BMPs can provide treatment.
- **Pre- and post-development land uses** – 25 typical land use categories are available via the drop-down menu based upon current recognized values. Each has an arithmetic average EMC value (see Appendix A). A user defined category is available for other EMCs and for composite land uses. A calculator is available for a composite EMC when there are multiple land uses based on average annual runoff for each area CN value. The calculator is only visible when the "User Defined Values" is selected. For "User Defined

Values", EMC values for both Nitrogen and Phosphorus must be entered. For many land uses programmed into the model, the EMC are automatically entered.

- **Total pre-development catchment area** – the total area in acres for the catchment in the pre-development condition. The catchment is a contiguous area where all the runoff will accumulate.
- **Total post-development catchment area** – the total area in acres for the catchment defined at a point where there is a discharge as well as a place for possible BMPs in the post-development condition.
- **Pre-development Non-DCIA curve number** – the weighted runoff curve number for the portion of the catchment which is *not* directly connected impervious area. A composite weighted CN can be calculated using average annual runoff. This is an option in place of simple area averages. *If this value is below 30, the SCS/NRCS runoff curve number method is not valid and the program will change the input to 29.9.*
- **Pre-development DCIA percentage** – the percentage of the total catchment area that is directly-connected impervious area. Note, areas wet all year are not included.
- **Post-development Non-DCIA curve number** – the weighted runoff curve number for the portion of the catchment that is not directly connected impervious area in the post-development state. A composite weighted CN can be calculated using average annual runoff. This is an option in place of simple area averages. *As noted above for pre-development Non-DCIA curve numbers, if this value is below 30, the program will change the input to 29.9.*
- **Post-development DCIA** percentage – the percentage of the total catchment area that is directly-connected impervious area in the post-development state. Areas wet all year (detention ponds, wetlands) are not included in the DCIA calculation.
- **Estimated Wet Pond area –** is the area at the top of the permanent pool or at the control elevation. This area will be subtracted from the overall post-development catchment area when the wet pond area is part of the total catchment area. As an alternative, the wet pond area does not have to be included in the catchment area. Thus, no contribution of nutrient loadings is included for this area. This is normally assigned to an area which remains wet all-year. For Florida sites, the average annual runoff pond coefficient is zero because Evapotranspiration is about equivalent to rainfall on wet ponds.
-  Weighted EMC and CN calculator support buttons. Copy and paste is available.

The "*Calculate"* button will provide for calculation of pre- and post-development runoff coefficients ("C value"), the volume of annual runoff in Acre-Feet, and the Nitrogen and Phosphorus annual mass loadings in kilograms per year.

For sites with multiple catchments, the stormwater professional may create additional catchment input by using the "*Add Catchment*" button in the top left-hand corner of this Worksheet. After selecting that button, a new dialogue box opens with several options as shown in Figure 3.

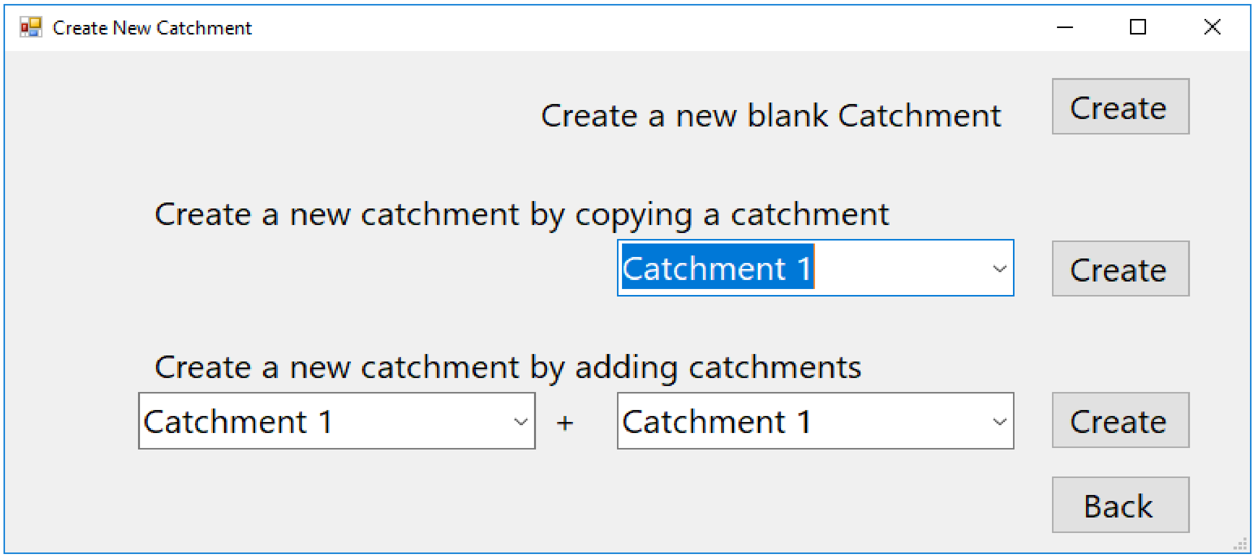


Figure 3. Create New Catchment Dialog.

There are three options for creating a second or subsequent catchments: 1) blank catchment, 2) copy an existing catchment, and 3) create a new catchment by combining two existing catchments.

The **blank catchment** option creates a new catchment which will need entry of all of the hydrologic parameters as described above. The user should enter a new and unique name for each of the new catchments.

The **copy an existing catchment** option allows the user to duplicate any existing catchment – the copy may then be edited to make it unique and distinct from the original. The only required change is to the name of the newly created catchment; any and all other values may remain identical to the original (source) catchment or they may be modified.

The **create a new catchment by adding catchments** option allows the user to use the area values for any two existing catchments to be combined into a third, new catchment.

To **copy and paste data, examples: Area, CN and EMC values,** the values must be in a spreadsheet format. When copying the values, make sure there are no additional data copied or if there are set (key in) the additional data equal to zero (0.000) as shown below.

Composite EMC Calculator - Enter Area, CN, and EMC Post-Development Total Nitrogen

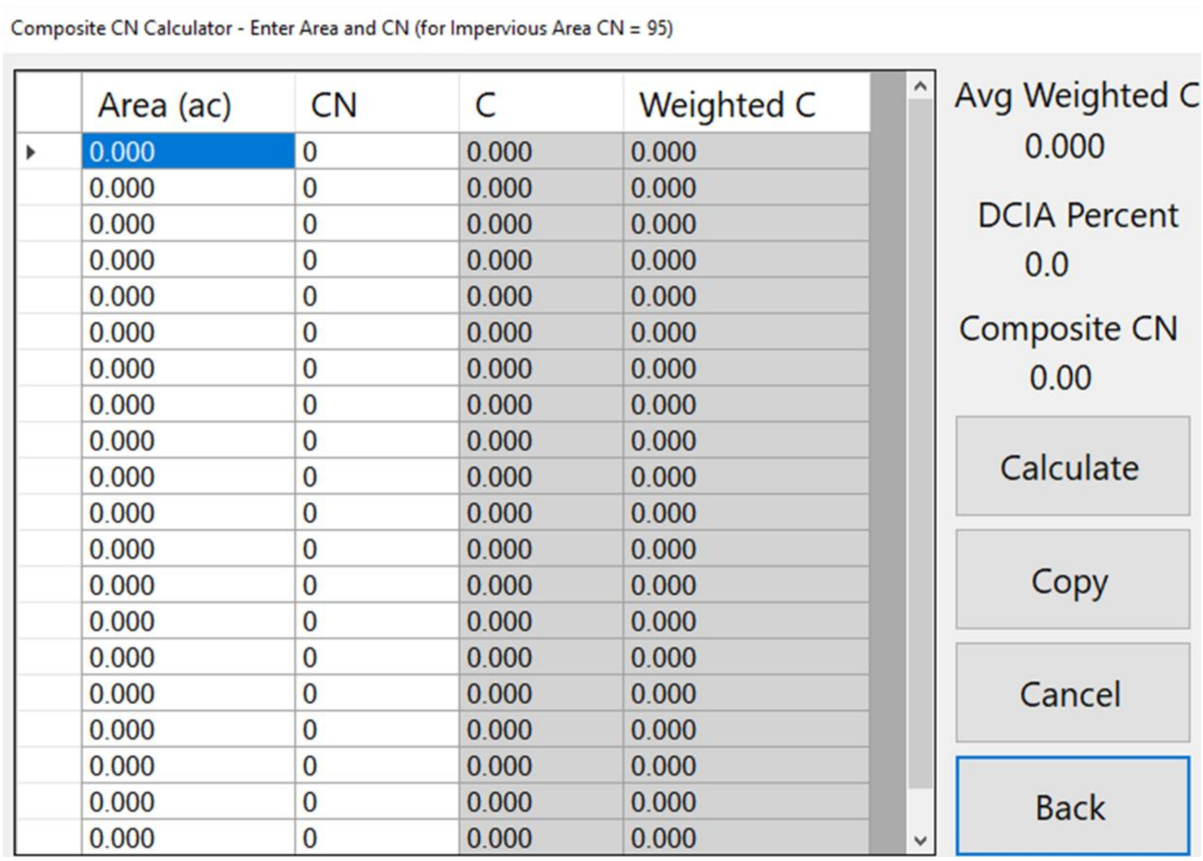
Area (ac)	EMC	CN	C	Weighted C
1.000	1.000	50	0.543	0.091
2.000	2.000	60	0.549	0.183
3.000	3.000	70	0.560	0.280
0.000	0.000	0	0.000	0.000
0.000	0.000	0	0.000	0.000

The CCN calculator worksheet is:

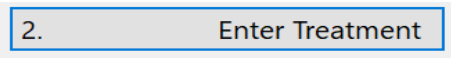
Composite Curve Number Calculator:

If the calculation icons beside the Pre- and Post-development Non-DCIA Curve Number fields are selected, this will open a new window allowing the user to calculate composite curve numbers. Input values are the individual areas (in acres) and the runoff curve number for each individual area. Up to 20 sub-areas may be entered. When the C*alculate* button is selected, runoff coefficients (C) and weighted C values are computed for each sub-area and the average weighted C and composite CN (for the non-DCIA) area also computed. A CN value of 95 to reflect impervious areas not directly connected can be used (no runoff from rainfall up to 0.1 inch is a CN of 95).

Note: these values are not automatically transferred back to the **Watershed Characteristics Workshee**t. When the *Back* button is selected, a dialog box will prompt the user to decide to transfer the calculated values



Treatment Options Worksheet



Upon selecting "2. Enter Treatment" from the **General Site Information Worksheet**, a new window opens with a selection of 13 established BMPs, a user-defined BMP, and an option for BMPs in series within a given catchment. **BMP Trains 2020** will accommodate up to four BMPs in series within a single catchment; in the unlikely event that a design includes more than four then the stormwater professional may simply split the original catchment into two new catchments and assign BMPs to each. BMP descriptions are presented in detail in Appendix C. Figure 4 (below) shows the **Select Treatment Options** worksheet:

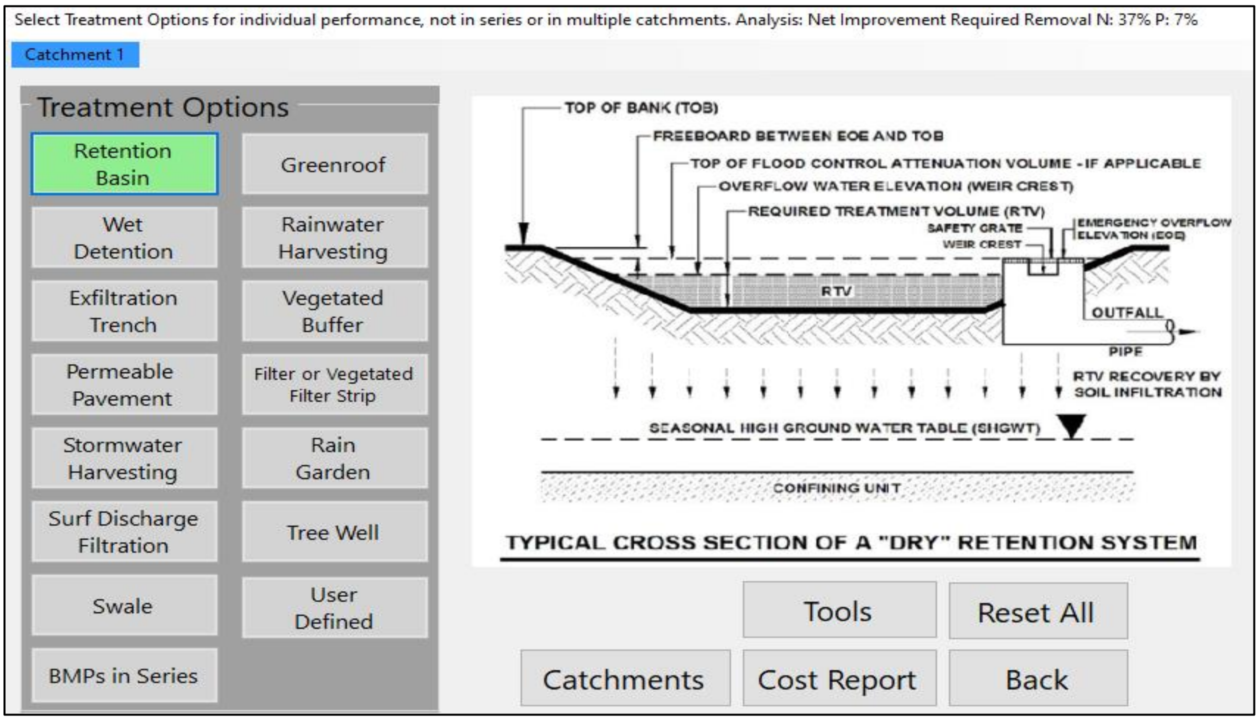


Figure 4. Select Treatment Options Worksheet.

By hovering the mouse pointer over each of the 14 BMP buttons, the user may view a detailed schematic of that particular BMP design. Design details and assumptions are presented in Appendix C. An example of a User Defined input is the use of Florida Friendly Landscaping.

This manual explains commonly used BMPs in detail, as in previous versions of BMP Trains. However, modifications for removal for the inclusion of BMP in series are new to this version. When the button for each BMP is selected, a new worksheet will open allowing the stormwater professional to enter the various parameters specific to that BMP's design. Common designs in the State are explained in Appendix C. Once one or more BMPs have been configured, their gray button on the Select Treatment Options window will turn green. After subsequent steps when a BMP is selected for routing in the **Configure Catchment Worksheet** the selected BMP's button will turn to a lighter, cyan color to indicate that this is the BMP being used for the routing and summary report. All unselected BMPs will remain gray.

Once a BMP's parameters are entered for a particular catchment, that BMP will remain active. If a designer chooses to remove all BMP inputs, there is a button to Reset All Values. This has the effect of deleting the BMP completely from the project; thus, there is no need for the user to delete individual numbers from the input fields.

The BMPs and changes from previous versions of the model are described as:

Retention Pond BMP – Rainfall depth as input, no other changes from previous versions.

Wet Detention Ponds – The user is prompted to enter the permanent pool volume. The average annual residence time (in days) is calculated from the pond's permanent pool and the average annual runoff volume. The input was changed from annual residence time in days to permanent pool (in acre-feet) to reduce the confusion between wet season and annual residence time.

Exfiltration Trench – Dimensions of trench input, no changes to input from previous versions.

Pervious Pavement – Input was reduced by providing internal calculations. The option to use traffic bearing media is added with a 3-12" depth of media. It remains a retention BMP.

Stormwater Harvesting – The weighted rational runoff is automatically calculated and the rate of use is not a calculation but an input.

Surface Discharge Filtration – The user is prompted to input the filtration media type (8 choices including none and user defined) and the treatment depth (inches).

Swale – Input was reduced by providing internal calculations thus reducing input errors.

Green Roof – Input was reduced with internal calculations thus reducing input error.

Rainwater Harvesting – Harvest rate as output not an option.

Vegetated Buffer – No changes to input from previous versions.

Filter or Vegetated Filter Strip – No changes to input from previous versions.

Rain Garden – Dimensions as input, no changes to input from previous versions.

Tree Well – Tree well dimensions as input, no changes to input from previous versions.

User Defined BMP – An update to allow additional removal at the discharge point; examples are a BMP without supporting removal data, landscape changes, or chemical treatment after a pond.

Tools Button

Upon selecting the *Tools button*, the user is presented with six calculation routines utilized for several individual BMPs. Figure 5 (below) shows those choices:

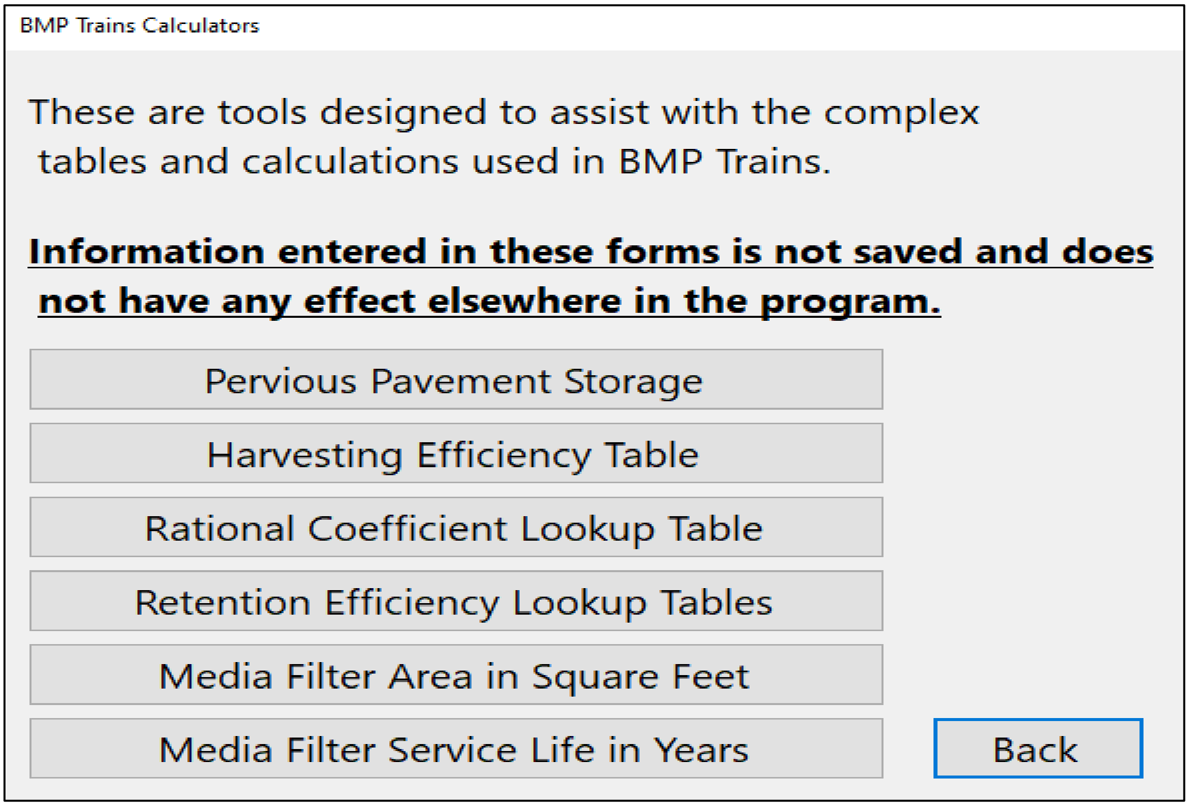


Figure 5. BMP Trains 2020 Calculators.

To remove all BMPs from an entire project, the user may select *Reset All BMPs* from the Select Treatment Options window. This will delete all BMPs and the user must now proceed to select new BMPs and enter new values. *Caution: this removal process cannot be undone (unless the BMP Trains2020 file has previously been saved)!*

If necessary from the **Routing Catchment Worksheet**, the user may "jump" back to the **Watershed Characteristics Worksheet** by selecting the Catchments button. This merely saves the step of returning to **the General Site Information Worksheet** first.

For any catchment, an option to assess effectiveness of BMPs in series where each and every BMP has the same catchment area is available by selecting the *BMPs in Series* button. The user is presented with a dialog box from which to choose up to four already-configured BMPs in one catchment and in series. Figure 6 shows an example **Multiple BMP Worksheet:**

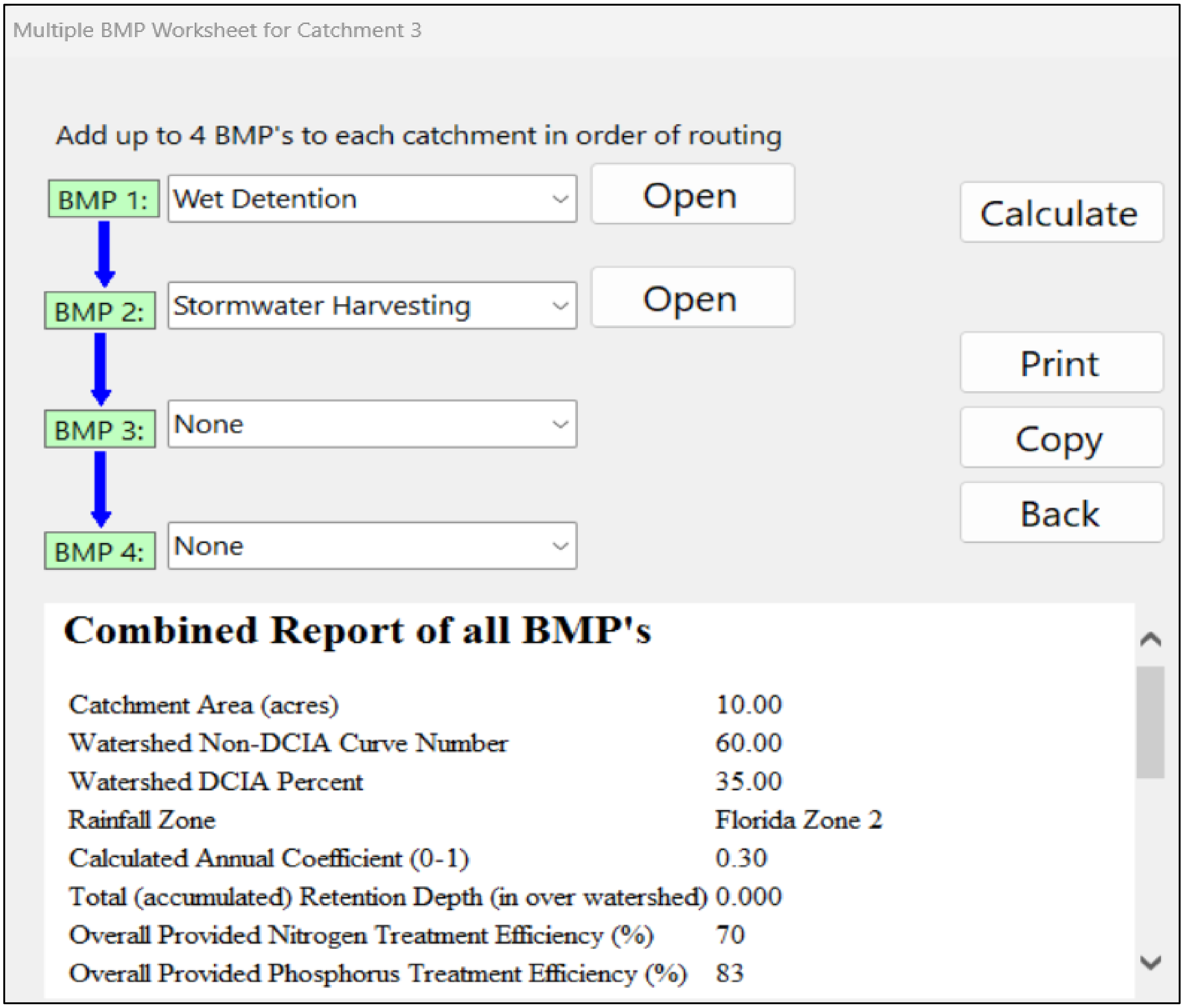
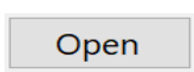
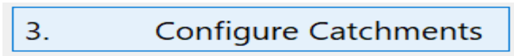


Figure 6. Multiple BMP Worksheet.

The option box 

beside each of the four BMPs may be chosen to review data for that BMP. Note that each of the individual BMPs must already be configured for them to appear in these menus. Upon clicking the *Calculate* button (or returning to the previous screen by clicking the *Back* button) the BMPs are selected for the catchment with nutrient removal and effectiveness calculated for the combined system. The on-screen report window shows all of the associated values, as well as a flow diagram indicating annual nutrient removal and discharge mass rates. When there are BMPs in series and the first one removes particulates and is followed by a wet pond, the wet pond % removal is reduced by the fraction of particulate nutrients removed in the first BMP at an assumed reduction up to 22%. This must be further monitored and may change in the future.

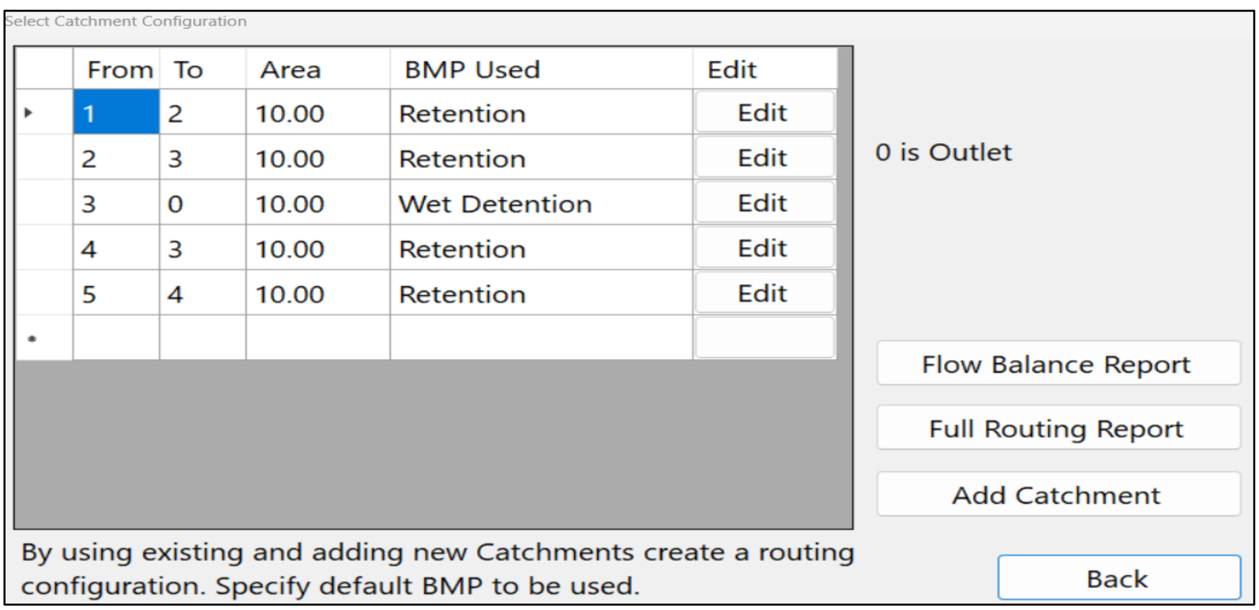
Catchment Configuration Worksheet



This step allows the stormwater professional to create any unique topology with an unlimited number of catchments. While previous versions were limited to a maximum of four catchments in 15 specific layouts, **BMP Trains 2020** has been tested with 20 catchments. This does require the user to "inform" the software as to the design layout which is input data shown in Figure 7. Calculation of average annual nutrient loading removal is based upon this configuration, as nutrient removal rates are dependent upon the configuration of the catchments and the flow of stormwater from one BMP into another.

In this step two key parameters must be set for each catchment: 1) the routing downstream to the next catchment and 2) the default BMP to be used in calculating the average annual nutrient loading removal. *For projects with only one catchment and one BMP this second parameter must still be set for subsequent calculations to be valid*.

When entered initially the Worksheet defaults to all catchments discharging directly to the outfall node (the outfall node is designated by the number "0"). In addition, no default BMP is yet selected, so if this parameter is not changed then no nutrient removal is calculated. Figure 7 shows a view of the **Select Catchment Configuration Worksheet:**


Select Catchment Configuration

From	To	Area	BMP Used	Edit
1	2	10.00	Retention	Edit
2	3	10.00	Retention	Edit
3	0	10.00	Wet Detention	Edit
4	3	10.00	Retention	Edit
5	4	10.00	Retention	Edit

0 is Outlet

Flow Balance Report

Full Routing Report

Add Catchment

By using existing and adding new Catchments create a routing configuration. Specify default BMP to be used.

Back

Figure 7. Select Catchment Configuration Worksheet.

To set up the parameters for each catchment, click on the *Edit* button to the right end of the catchment's row. A new dialog box will open:

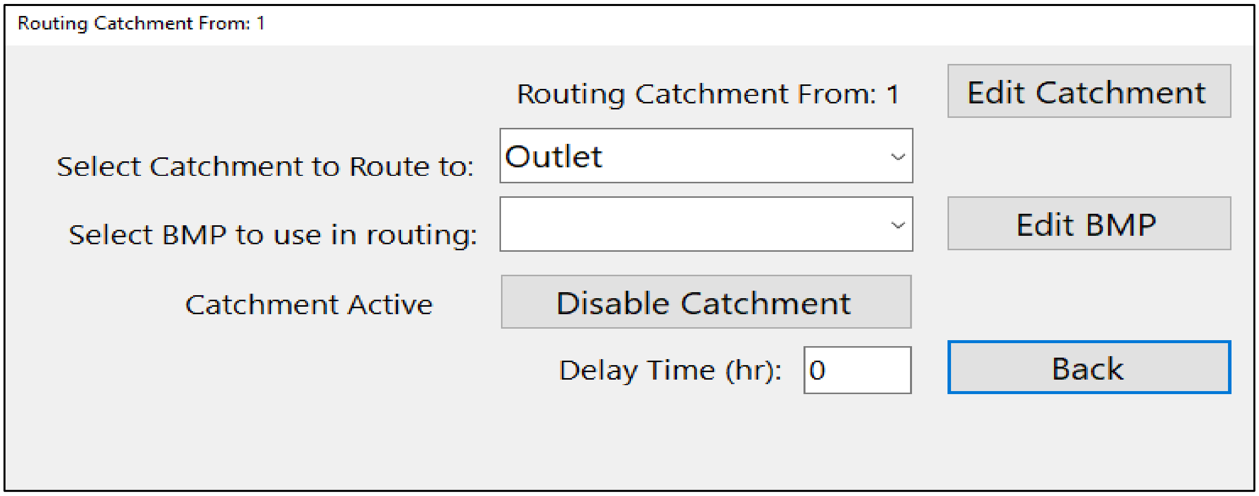


Figure 8. Routing Catchment Dialog Box.

Select the dropdown menu to the right of *Select Catchment to Route* to choose the next downstream (receiving) catchment. For a single catchment system this should remain set as Outlet. Also, for any multiple catchment system at least one catchment (or more, if in parallel) should ultimately discharge to the Outlet.

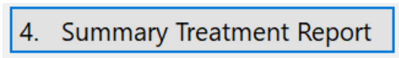
Next select the *BMP to use in routing* by choosing the dropdown menu. All configured BMPs will appear, along with the option of "None." If BMPs in Series has been configured for any catchments, this will also appear as one of the choices along with each of the individual BMPs. Any single BMP (or "None") may be chosen for "what if" analysis. To remove a catchment simply enter zeros or no data in the catchment input worksheet as well as the treatment worksheet.

An offsite catchment may have a delay time before stormwater reaches an onsite BMP. A **Delay Time** may be entered (in hours) up to a maximum of 15 hours. The increase in removal effectiveness is about 1% for each 4 hours of delay when the downstream BMP is retention. Exact increases depend on catchment characteristics (Wanielista, 2017).

For simplicity of editing, buttons to *Edit Catchment* and *Edit BMP* are included. Selecting either of these will jump directly to the previously configured pages for the catchment or BMP.

When the *Back* button is selected, the user is returned to the **Catchment Configuration Worksheet** and the appropriate parameters will now appear. The **Routing Catchment Configuration Worksheet** should be followed for each catchment until all BMPs have been properly placed. *Note that the only topology which is not allowed (and is not practically desirable) is a circular path with no discharge to an outlet.* As previously noted, at least one catchment in every project should discharge to the outlet/receiving waters. Also note to always use this worksheet after you place BMPs in series to identify the multiple BMP option.

Summary Treatment Report



After analyses for BMP designs and routing are completed, a comparison to the selected BMP analysis and groundwater analysis if chosen is available in the **Summary Treatment Report**. No additional input is needed for this report and it is visible on-screen and can be sent to the user's default printer or saved to a file. If saved, the file is in an HTML format and will appear the same as the on-screen report initially displayed. Two sections of the report show essential information for the project:

Project Summary – This section displays the name of the project and date of printing, the type of analysis, the BMP type(s), a summary of the routing among the site's catchments, and a yes/no test for whether the designed BMP(s) satisfy the surface discharge analysis requirements. The yes/no test is based on rounding to the nearest "whole" percentage. This item is not used for BMP Analysis, as a BMP analysis requires no pre-development nutrient loadings.

Summary Report for Surface Water discharge **–** This section has two identical subsections for Nitrogen and Phosphorus. Each subsection includes the total pre- and post-development average annual loadings (kg/yr), the target load reduction (%) and target discharge load (kg/yr), the percentage of load reduction (%), and the provided discharge load and load removed. The last two values are given in both kilograms per year (kg/yr) and pounds per year (lbs/yr).

If groundwater analysis is chosen, evaluation of effectiveness metrics are average recharge volume in million gallons (MG) per year, provided recharge load in kilograms/year and pounds/year, and average annual concentration in the recharge water (milligrams/liter). Provided recharge, load, and concentration result from the BMP designs and reflects the sum of all BMPs having discharge to the ground. Average concentration is the sum of all loadings to the ground divided by the sum of recharge volume.

The summary treatment report is designed to serve as a common format between consulting designers and permit review agencies. It is anticipated that this report will be a focus of the permit submittal package. In addition, the electronic (.bmpt) file can be shared with reviewers for their own confirmation of the modeling. Figure 9 shows an example of a summary treatment report with net improvement.

BMP Trains Reports

Copy Back

Analysis Type: Net Improvement

BMP Types:

Catchment 1 - Rain Garden retention

Total nitrogen target removal met? YES

Total phosphorus target removal met? YES

Routing Summary

Catchment 1 Routed to Outlet

Summary Report

Nitrogen

Surface Water Discharge

Total N pre load	4.37 kg/yr	
Total N post load	7.13 kg/yr	
Target N load reduction	39 %	
Target N discharge load	4.37 kg/yr	
Percent N load reduction	49 %	
Provided N discharge load	3.65 kg/yr	8.05 lb/yr
Provided N load removed	3.48 kg/yr	7.68 lb/yr

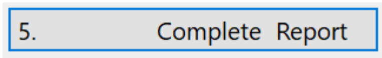
Phosphorus

Surface Water Discharge

Total P pre load	.85 kg/yr	
Total P post load	.97 kg/yr	
Target P load reduction	12 %	
Target P discharge load	.85 kg/yr	
Percent P load reduction	49 %	
Provided P discharge load	.49 kg/yr	1.09 lb/yr
Provided P load removed	.47 kg/yr	1.04 lb/yr

Figure 9. Summary Treatment Report.

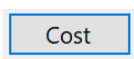
Complete Report



The *complete report* button was added to produce a summary of all input and output data usually required as a hard copy report for permit review purposes. It does not include the data and results for a cost analysis since that cost is not currently part of a permit review. If cost review is needed, then the *copy* button can be used. The complete report does include the summary report. However, it may be more advantages to minimize the time for review by submitting the electronic file (.bmpt) for each permit.

Cost Comparisons

The *Cost Comparison* button allows the preparation of one or more cost estimate scenarios. In Appendix B, helpful procedures to select cost data are presented. The data input are relevant to the site location and thus are usually different for each evaluation. An example of the input data are shown in Figure 10 and data are required for each BMP. Access to this input format is through each BMP treatment method input worksheet using the *cost* button.



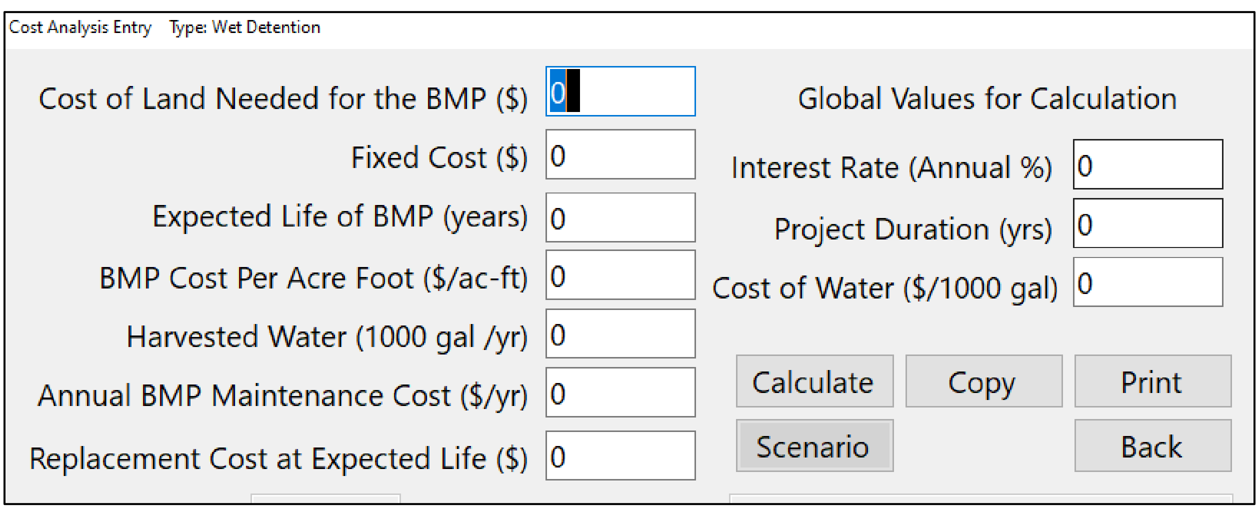


Figure 10. Cost Input Worksheet.

Comparison of BMP Trains 2020 to Other Models

There are BMP evaluation models in use in other states. These models were reviewed to determine commonly used format and input parameters so that translation of the **BMP Trains 2020** model to other states and use by others would be facilitated. The unique features of the **BMP Trains 2020** model are apparent in the sense that the use of series and parallel BMPs are facilitated with **BMP Trains 2l020**. The models reviewed and comments follow.

Jordan/Falls Lake Stormwater Nutrient Load Accounting Model

The Jordan/Falls Lake Stormwater Nutrient Load Accounting Model is an Excel spreadsheet model developed by North Carolina State University in coordination with the North Carolina Department of Environment and Natural Resources. While the original application of this tool is the Jordan Lake Nutrient Strategy, it may also be applied to any location within the State of North Carolina (Jordan/Falls Lake Stormwater Nutrient Load Accounting Tool (Version 1.0) User's Manual, 2011).

Physiographic/Geologic Region:	**Coastal**
Soil Hydrologic Group	**A**
Precipitation location:	**Fayetteville**
Pre-Development Watershed Time of Concentration (min):	**30 min**

Total Development Area (ac):	**10**
Development Name:	Stormwater BMP Selection
Model Prepared By:	Przemyslaw Kuzlo
Post-Development Watershed Time of Concentration (min):	**15**

COLUMN 1 -- NON-RESIDENTIAL LAND USES

	TN EMC (mg/L)	TP EMC (mg/L)	Pre-Development (acres)	Post-Development (acres)
COMMERCIAL				
Parking lot	1.44	0.16		4
Roof	1.08	0.15		3
Open/Landscaped	2.24	0.44		1
INDUSTRIAL				
Parking lot	1.44	0.39		
Roof	1.08	0.15		
Open/Landscaped	2.24	0.44		
TRANSPORTATION				
High Density (interstate, main)	3.67	0.43		
Low Density (secondary, feeder)	1.4	0.52		
Rural	1.14	0.47		
Sidewalk	1.4	1.16		
PERVIOUS				
Managed pervious	3.06	0.59		
Unmanaged (pasture)	3.61	1.56		
Forest	1.47	0.25	10	
LAND TAKEN UP BY BMPs	1.08	0.15		2

COLUMN 2 -- RESIDENTIAL LAND USES

	Custom Lot Size (ac)	Age (yrs)	TN EMC (mg/L)	TP EMC (mg/L)	Pre-Development (acres)	Post-Development (acres)
PART A						
⅛-ac lots	--		--	--		
¼-ac lots	--		--	--		
½-ac lots	--		--	--		
1-ac lots	--		--	--		
2-ac lots	--		--	--		
Multi-family	--		--	--		
Townhomes	--		--	--		
Custom Lot Size			--	--		
PART B						
Roadway		--	1.4	0.52		
Driveway		1	1.44	0.39		
Parking lot		--	1.44	0.39		
Roof		--	1.08	0.15		
Sidewalk/Patio		--	1.4	1.16		
Lawn		--	2.24	0.44		
Managed pervious		--	3.06	0.59		
Forest		--	1.47	0.25		

The Jordan Lake model is used to calculate the annual Total Phosphorus and Total Nitrogen mass loading produced by runoff from the existing condition and new, developed condition. Additionally, it is used to calculate nutrient removal by the stormwater BMPs chosen for a watershed. Calculations performed within the model are governed by two basic principles: Simple Method (for runoff volume and pollutant loading calculations) and the median effluent concentration BMP efficiency metric (for BMP reduction calculations) (Jordan/Falls Lake Stormwater Nutrient Load Accounting Tool (Version 1.0) User's Manual, 2011).

The structure and set up of the Jordan Lake loading tool is relatively simple and easy to follow. The first tab, entitled "Instructions," contains a description and user information for the users of the spreadsheet tool. It also contains physiographic region and annual precipitation location maps for the State of North Carolina to aid with appropriate input selection in the model. The next two worksheets are "Watershed Characteristics" and "BMP Characteristics" input tabs. On the Watershed Characteristics worksheet, users enter all information pertaining to the site of interest, including both pre- and post-development conditions (Jordan/Falls Lake Stormwater Nutrient Load Accounting Tool (Version 1.0) User's Manual, 2011). The information relevant to the type and properties of the BMPs is specified in the BMP Characteristics tab.

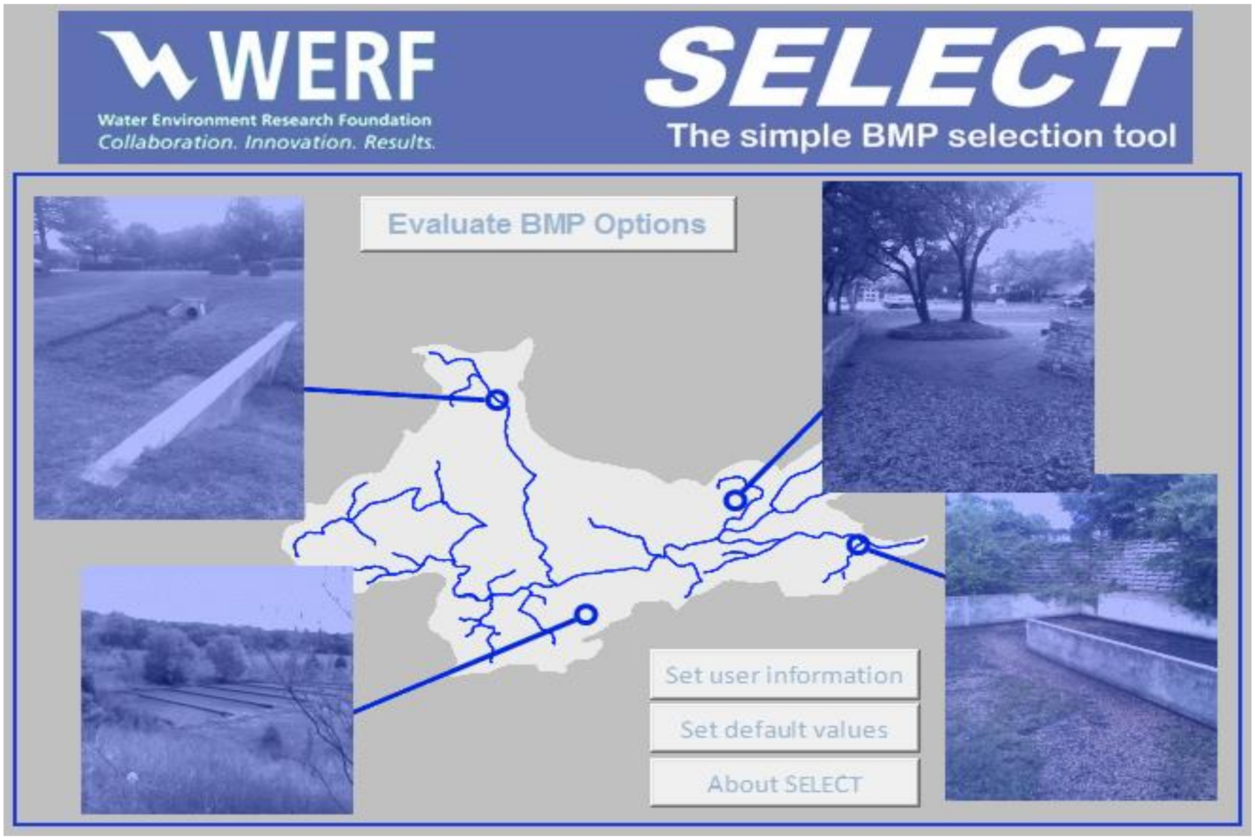
Structure of the Jordan/Falls Lake Stormwater Nutrient Load Accounting Model

The setup of the model allows the user to divide the developed watershed into as many as six catchments. Each catchment can be treated by up to three BMPs. The available BMP choices comprise of Bioretention with IWS (Internal Water Storage Zone), Bioretention without IWS, Dry Detention Pond, Grassed Swale, Green Roof, Level Spreader/Filter Strip, Pervious Pavement, Sand Filter, Water Harvesting, Wet Detention Pond, and Wetland (Jordan/Falls Lake Stormwater Nutrient Load Accounting Tool (Version 1.0) User's Manual, 2011). The summary of the analysis output is displayed in the final worksheet entitled "Development Summary".

BMP SELECT Model

The BMP SELECT Model is a Microsoft Excel based model developed on behalf of Water Environment Research Foundation (WERF) by a work group consisting of ACR, LLC, Colorado State University and the University of Utah. This software was developed by WERF in response to WERF Subscribers who desired a simple tool that could be readily applied to evaluate the relative performance and cost implications of various BMP control options (Pomeroy and Rowney, 2009).

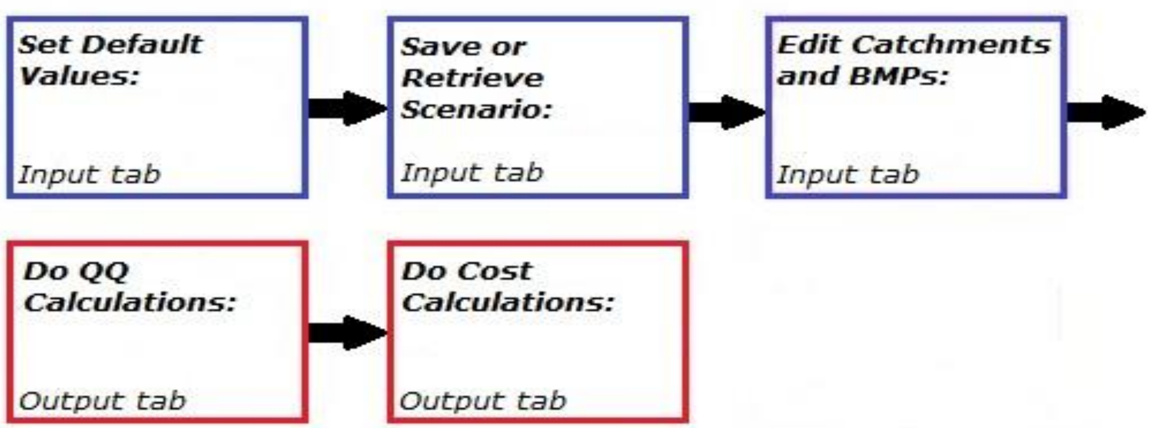
The BMP SELECT Model is a tool that has the capability of evaluating water quality parameters such as Total Suspended Solids, Total Nitrogen, Total Phosphorus and Total Zinc. It also evaluates the effectiveness of stormwater BMPs and the cost implications associated with the application of these systems. The stormwater BMPs that can be analyzed with this software include extended detention, bioretention, wetlands, swales, pervious pavement and filters.



Starting page of the BMP SELECT Model.

The BMP SELECT Model is a "planning-level" tool with a focus on limiting the extent and/or complexity of input data necessary to generate results (Pomeroy and Rowney, 2009). The input data for the model allows the user to run the calculations with limited information about the watershed characteristics, BMP types, and BMP sizes. The calculations performed by the model are focused in four major areas; watershed runoff calculations, BMP quantity calculations, pollutant load calculations, and cost calculations.

The BMP SELECT Model is relatively easy to use. Prior to beginning to work with the model, the user may change default Watershed Parameters, BMP Parameters and Meteorological Data in the "Set Default Values" window. The model has the capability of adding, saving, and retrieving multiple scenario data in the "Save or Retrieve Scenario" tab. All the information pertaining to the watershed and the BMPs is indicated in the "Edit Catchments and BMPs" tab. Once all the required input is indicated, the water quantity and quality calculations are performed in the "Do QQ Calculations" (quantity and quality) tab. The cost calculations are performed in the "Do Cost Calculations" section.



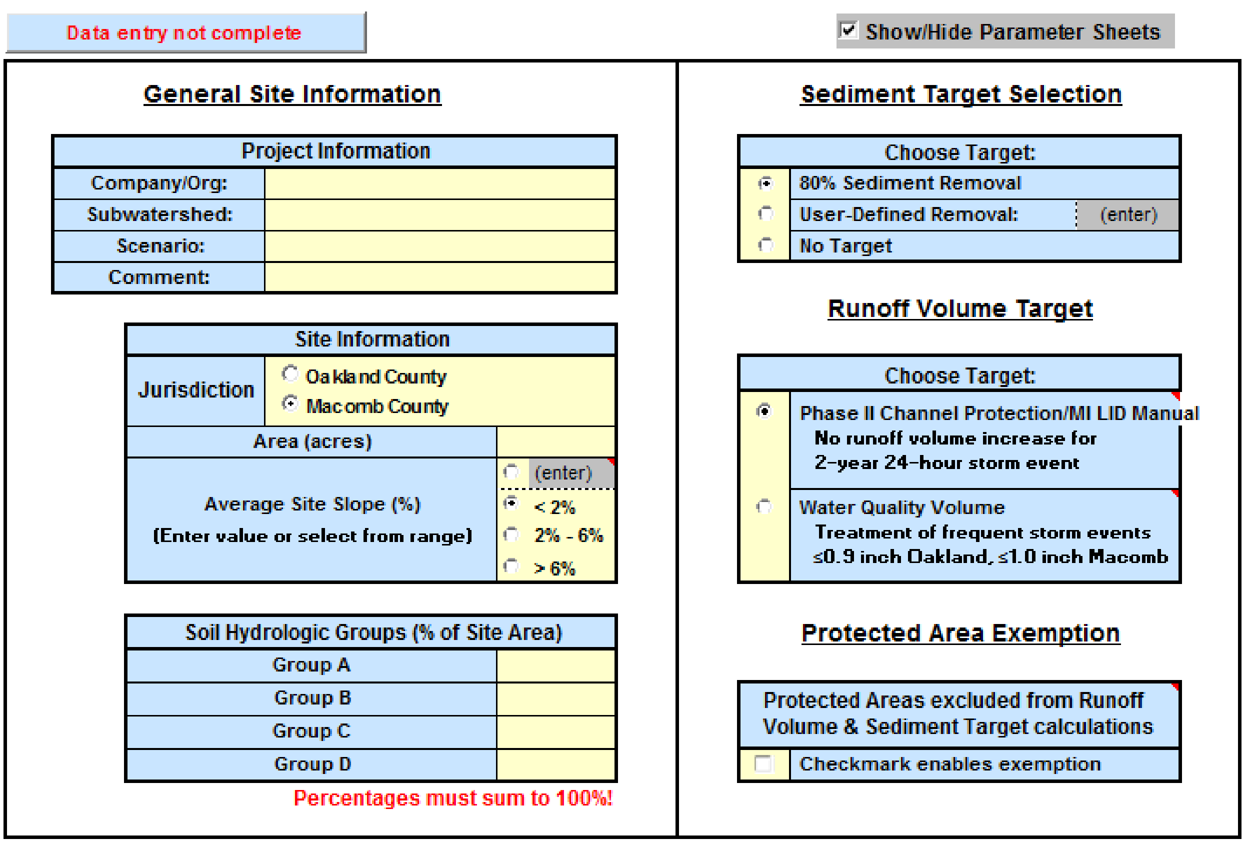
Structure of the BMP SELECT Model.

Clinton River Site Evaluation Tool (SET)

The Clinton River Site Evaluation Tool (SET) is a Microsoft Excel spreadsheet, which is designed to aid in the assessment of development plans and available Best Management Practices (BMPs) to achieve water quality objectives (Tetra Tech, 2008). Another model was developed by the U.S. EPA (2007) and Tetra Tech that is a Geographic based model called SUSTAIN for cost analysis and BMP efficiencies. The SET model is presented here.

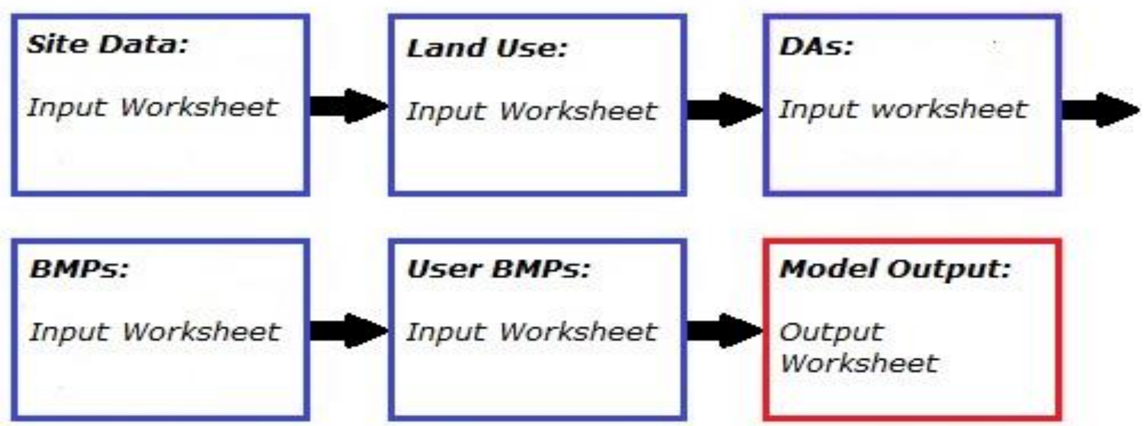
The SET model evaluates the annual pollutant loads for the Total Suspended Solids, Total Nitrogen, Total Phosphorus, E. Coli Bacteria and Copper based on the pre- and post-development watershed characteristics. The BMP selection in the model is based on achieving the annual sediment load reduction percentage or a specified runoff volume reduction target. The BMP selection in the model is not determined however by matching the pre- and post-development annual nutrient loads.

The SET spreadsheet model is very easy to use, even for first time users. The model opens with only one visible worksheet entitled "Site Data". Here, the user indicates the general site information and the type of analysis that they want to perform. The next input tab, entitled "Land Use," has input fields for the overall site land uses for both proposed and existing conditions (Tetra Tech, 2008). Input data for all drainage areas (DAs) are assigned to include proposed pervious, impervious, and stormwater management areas to their appropriate DA. Each of the respective drainage areas are then assigned to the BMPs which serve these areas in the "BMPs" worksheet.



Site Data input worksheet for the Clinton River Site Evaluation Tool

The BMPs available for analysis include extended wet detention, extended dry detention, infiltration basin, bioretention, sand filter, infiltration trench, vegetated swale, vegetated filter strip, dry well, rain barrel, cistern, green roof, porous pavement, hydrodynamic device, catch basin with sump, street sweeping and user-defined BMP. If the user cannot find an appropriate BMP from a wide selection built into the model, a custom treatment system can be specified in the “User BMP” sheet. However, the pollutant removal efficiencies and other properties of the user specified BMP must be included with this selection.



Schematic of the Clinton River Site Evaluation Tool

Virginia Runoff Reduction Method Worksheet

The Virginia Runoff Reduction Method Worksheet is a model developed on behalf of the Virginia Department of Conservation and Recreation by the Center for Watershed Protection, Inc. and the Chesapeake Stormwater Network. The spreadsheet is designed to assist users plan combinations of stormwater BMPs for a particular site in order to meet the standards in the proposed regulations within the State of Virginia (Virginia Department of Conservation and Recreation, 2011). There are two versions of the model, one for new development and one for re-development.

The Virginia Runoff Reduction Method Worksheet calculates the annual post-development Total Phosphorus and Total Nitrogen loadings and the required post-development treatment volume. The methodology used in this model is based on the calculation of the post-development pollutant loads associated with the site-specific conditions and selection of BMPs to meet the pre-determined target pollutant loads. The target pollutant load, which is only established for Total Phosphorus, is achieved by the appropriate combination of the Environmental Site Design, Runoff Reduction, and Pollutant Removal Practices.

Virginia Runoff Reduction Method Worksheet -- Revised 03/25/2011
Site Data

Project Name:
Date:

	data input cells
	calculation cells
	constant values

1. Post-Development Project & Land Cover Information

Constants

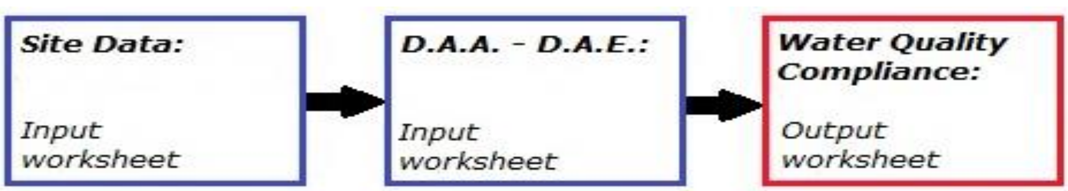
Annual Rainfall (inches)	43		
Target Rainfall Event (inches)	1.00		
Phosphorus EMC (mg/L)	0.26	Nitrogen EMC (mg/L)	1.86
Target Phosphorus Target Load (lb/acre/yr)	0.41		
Pj	0.90		

Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals
Forest/Open Space (acres) -- undisturbed, protected forest/open space or reforested land	2.00	0.00	0.00	0.00	2.00
Managed Turf (acres) -- disturbed, graded for yards or other turf to be mowed/managed	2.00	0.00	0.00	0.00	2.00
Impervious Cover (acres)	6.00	0.00	0.00	0.00	6.00

Site Data input worksheet for the Virginia Runoff Reduction Method worksheet

The Virginia Runoff Reduction Method Worksheet is a very straightforward modeling tool. In the first worksheet entitled "Site Data," the user indicates the site information such as annual rainfall and post-development land cover. The five worksheets allow the user to split the project area into five separate drainage areas. In each of the worksheets, the user may choose from a large menu of Runoff Reduction and Pollution Reduction practices and apply them to the respective drainage basins. The Runoff Reduction practices include bioretention, infiltration, green roofs, dry swales, wet swales, grass channels, extended detention ponds, pervious pavement, and impervious surface not connected to a discharge. Finally, the results of the analysis are diplayed in the "Water Quality Compliance" worksheet.



Schematic of the Virginia Runoff Reduction Method Worksheet

Department of Environmental Services (DES) Pollutant Loading Spreadsheet Model

The Simple Method Pollutant Loading Model has been developed by the New Hampshire Department of Environmental Services (NHDES) Watershed Management Bureau. This Microsoft Excel spreadsheet is based on the Simple Method that estimates pollutant loading of stormwater runoff for urban and developing areas (New Hampshire Department of Environmental Services, 2011).

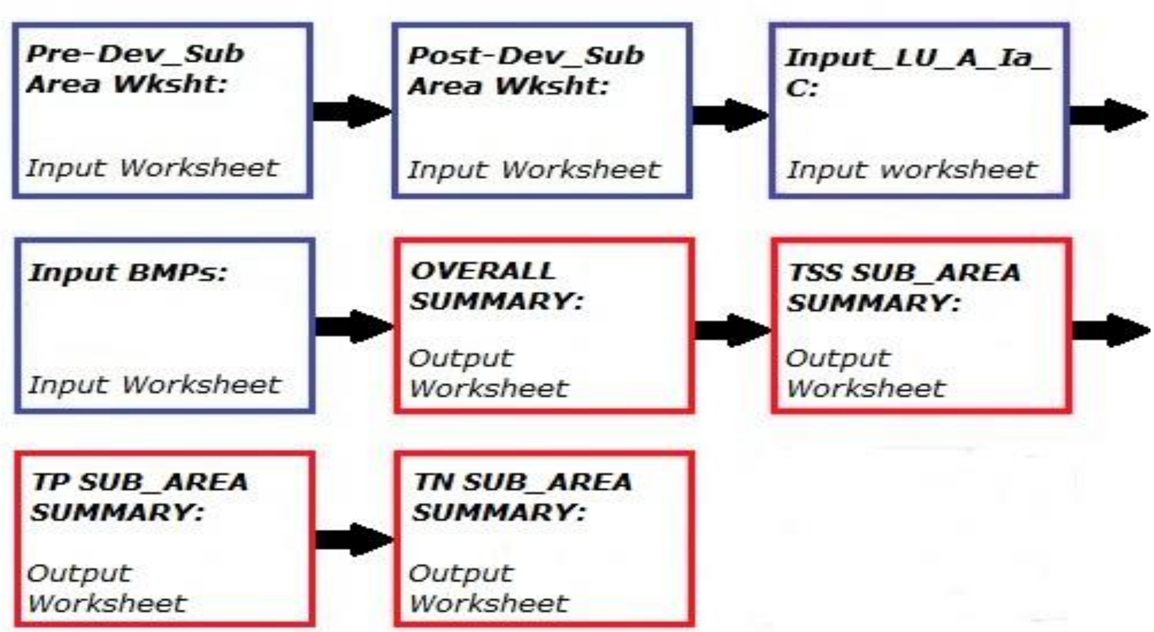
Credit for Using Low Nutrient Fertilizer: If there are managed turf areas under post development conditions that are to by providing enforceable documents (i.e., deed restrictions) requiring land owners to use low nutrient fertilizer. To get low n development for TP and TN in the table below. Low nutrient fertilizers must have application rates less than the standard fer sub-area that is managed turf that is fertilzed annually.

STANDARD FERTILIZER APPLICATION RATE (lbs/acre/year)			
PROPOSED REDUCED FERTILIZER APPLICATION RATES FOR POST-DEVELOPMENT (lbs/acre/year)			
INITIAL PERCENT REDUCTION			
PERCENT OF CITIZENS THAT WILL COMPLY WITH REDUCED APPLICATION RATES			
PERCENT OF APPLIED FERTILIZER THAT IS LOST TO RUNOFF OR PERCOLATION			
FINAL PERCENT FERTILIZER REDUCTION WITH COMPLIANCE AND RUNOFF RATES APPLIED (%FR)			
MINIMUM ASSUMED EMC = EMC_{MIN} (mg/L)			
PRE-DEVELOPMENT CONDITIONS			
	Area	**Impervious Area**	
Total Area (All Sub-Areas) (acres)	**0.00**	**0.00**	
		Insert information for 1st sub-area below	
Sub_Area_ID	**1- PRE**		
Point of Analysis (PoA) Number	**1**		
Total Area for Sub-Area (acres)	**0.00**	**0.00**	
Land Use	**Area**	**Ia**	
	(acres)	(% Impervious)	
From HWG			
Residential Roof	0.00	0.00%	
Commercial Roof	0.00	0.00%	

Input worksheet for DES Simple Method Pollutant Loading Spreadsheet Model

The methodology used in this model estimates the annual pre- and post-development Total Suspended Solids, Total Phosphorus, and Total Nitrogen loads. This technique is recommended by NHDES because of the modest amount of information it requires, which includes subwatershed drainage area and impervious cover, annual precipitation, and stormwater runoff pollutant concentrations (New Hampshire Department of Environmental Services, 2011). The Simple Method Pollutant Loading Spreadsheet Model requires the user to input the BMP removal efficiencies for all pollutants included in the analysis. This information can be obtained from the NHDES Stormwater Manual that contains BMP removal effectiveness values of different stormwater systems.

The NHDES Simple Method Pollutant Loading Spreadsheet Model is easy to navigate. The first tab contains general information about the model and instructions for the user. In the following two worksheets, the user indicates the pre- and post-development watershed information. These input worksheets require information about land use, types of pervious areas, and types of impervious areas. The next sheet requires input information about the average annual precipitation. In the last input sheet, analyzed BMPs are specified along with their pollutant removal efficiencies. It also allows the user to provide pollutant load reductions associated with the use of low nutrient fertilizers under post-development conditions (Comstock, 2010). The model does not contain any specific BMPs or the data on their associated effectiveness. Therefore, the user is required to provide this information. All results of the analysis are provided in the last worksheets.



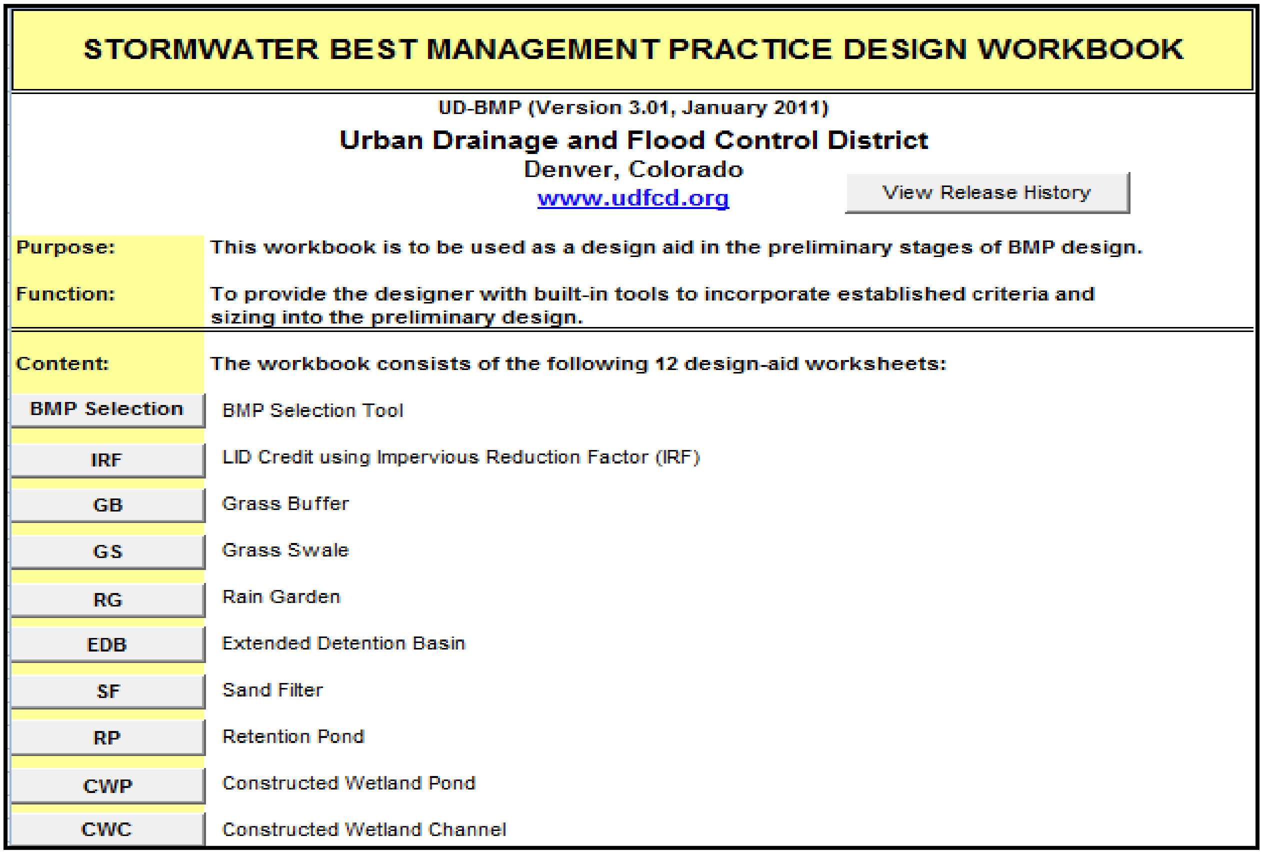
Schematic of the DES Simple Method Pollutant Loading Spreadsheet Model

Stormwater Best Management Practice Design Workbook

The Stormwater Best Management Practice Design Workbook is an Excel spreadsheet model published by the Urban Drainage and Flood Control District (UDFCD) in Denver, Colorado. This tool has been developed by the UDFCD in an effort to help users of their stormwater management manual to select BMPs that are best suited for their project. This tool is used to screen BMPs at the planning stages of development (Urban Storm Drainage Criteria Manual Volume 2).

The *UD-BMP* tool provides a list of BMPs for consideration based on site-specific conditions (Urban Storm Drainage Criteria Manual Volume 2). The BMP evaluation in the Stormwater Best Management Practice Design Workbook is based on a few steps. First, the model factors in Excess Urban Runoff Volume (EURV) reduction. Quantification of runoff volume reduction takes into account such practices as Minimizing Directly Connected Impervious Area (MDCIA), implementation of Low Impact Development (LID) practices, and other BMPs. Factoring these runoff reduction practices into the model yield total imperviousness and effective imperviousness values. These values can then be used in the assessment and sizing of the BMPs. The functions provided by BMPs may include volume reduction, treatment and slow release of the water quality capture volume (WQCV), and combined water quality/flood detention (Urban Storm Drainage Criteria Manual Volume 3, 2010). The BMP selection in the model is based on achieving the annual runoff mass reduction target. The BMP selection in the BMP TRAINS model can also be based also on a pre-determined % annual nutrient removal.

The UDFCD Stormwater Best Management Practice Design Workbook is user friendly and simple in operation. The introduction page contains general information about the function and content of the model. The model contains a helpful tab entitled “BMP Selection”. In this tab, the model identifies potential volume reduction and WQCV BMPs for the user based on general site information such as development characteristics and existing soil conditions. Volume reduction practices, such as MDCIA, can be evaluated in the following Impervious Reduction Factor (IRF) worksheet that will allow the user to obtain the effective imperviousness value. This value can be used in calculating the required WQCV for the individual BMP options. Individual BMP selections in the model include grass buffer, grass swale, rain garden, extended detention basin, sand filter, retention pond, constructed wetland pond, constructed wetland channel, and pervious pavement system.



Starting page of the Stormwater Best Management Practice Design Workbook

Stormwater Management and Design Aid (SMADA)

Stormwater Management and Design Aid (SMADA) is a set of computer models that provide a complete hydrology package. SMADA is one of the very first models that were able to estimate pollution removal as well as hydrograph shapes. These programs work together to allow hydrograph generation, pond routing, storm sewer design, statistical distribution and regression analysis, pollutant loading modeling, and other functions.

One of the calculation routines in SMADA's provides pollution loading calculation capabilities and is called PLOAD. It is a program that estimates pollutant loading on a time basis using typical watershed land uses and total rainfall (Wanielista et al., 1991).

Comparisons of BMPs

Some BMPs have regional restrictions, as an example, see the District of Columbia designs (2014), thus before the use of a model, the user should check the design. No model however allows for the combined series use of BMPs or evaluation on an average annual mass reduction basis. A listing of the BMPs used in the models is shown as:

Stormwater Model / BMPs	Retention	Dry Detention	Swale	Green Roof	Filter Strip & Buffer	Pervious Pavement	Filter	Water Harvesting	Wet Detention	Built Wetland	Rain Garden	Exfiltration
Jordan/Falls Lake Model	x	x	x	x	x	x	X	x	x	x		
BMP SELECT Model	x	x	x		x	x	X		x	x		
Clinton River SET	x	x	x	x	x	x	X		x			
Virginia Runoff Reduction	x	x	x	x		x			x			
DES Simple Method Pollutanl	x	x	x	x	x	x	X	x	x	x		
Colorado	x	x	x			x	X		x	x	x	
IDEAL	x				x		X		x		x	
D.C. Green			x		x	x					x	
SMADA	x		x					x	x			
BMP TRAINS	x	x	x	x	x	x	X	x	x		x	x

[1] Efficiency data need to be provided by user.

Example Problems and Solutions

These example problems use data from actual stormwater permits and the data are site specific. BMP designs consider runoff water for the entire catchment, but when considered together need specific evaluation methodologies. Methodology calculations are detailed in Appendix C, Section 15.

For the first time user, it is recommended to do the example problems in the order presented. Navigation of the model is more detailed with the initial examples than in later examples. However, the user with model experience may go directly to any example.

Example problem # 1 - swale – net improvement and groundwater protection

A swale (defined as a BMP for transport and infiltration) is serving a 1.2-acre highway project in Wakulla County, southwest of Tallahassee, FL in Hydrologic Soil Group B. The seasonal high water table will be at least 4 feet below the bottom of the swale. The existing pre-development land use condition is agricultural-pasture with a non-DCIA Curve Number of 80 and 0.0% DCIA. The post-development land use condition is highway with a non-DCIA Curve Number of 85 and 60% DCIA. Does the swale provide treatment sufficient to reduce the annual nutrient loading so that a net improvement is attained? There is significant area for a swale with dimensions shown in the **Swale Input worksheet** of Figure 11d. Additional concentration reduction is achieved because of the very low longitudinal slope. The infiltration rate was agreed upon to be 2.5 inch per hour or half of the reported rate using a double-ring infiltrometer.

First, annual loading analysis will be done to protect surface water. The next part of the evaluation will address groundwater protection.

1. From the introduction page click on the *Continue* button to proceed to the **General Site Information** Worksheet (Figure 11a)

   a. Enter the project name and select the meteorological zone. It is Zone 1.
   b. Input the mean annual rainfall amount, which is 60 inches.
   c. Select the *Specified Removal Efficiency* option from the type of analysis drop down menu. It is net improvement or post = pre loading.

d. Leave the *Conduct a Groundwater Discharge Analysis* selection as "No." However the next part of the problem will address the need for groundwater protection.

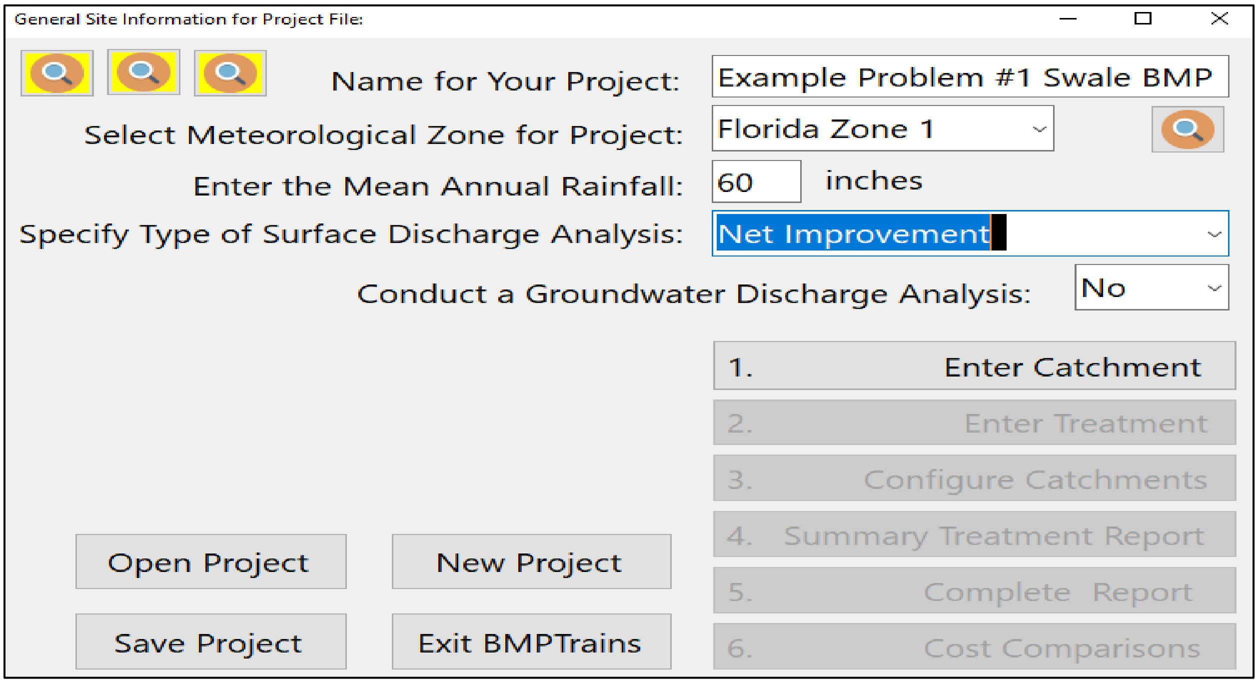


Figure 11a. General Site Information Worksheet.

After entering data on the **General Site Information Worksheet**, the catchment information has to be entered next. Thus, there is only one option button choice to proceed forward and that is the *Enter Catchment* button. Once all data are entered, there will be opportunities to enter any of the other worksheets for input or to make changes.

2. Click on the *1 button, or Enter Catchment* button to proceed to the **Watershed Characteristics Worksheet** (Figure 11b). Enter a name for this catchment and indicate the pre- and post-development conditions. Note the review agency has determined that the swale or the BMP area will contribute a mass loading, thus do not enter an area for the BMP in the cell indicated as "wet pond area" on the worksheet. Also do not include the swale area in the DCIA. Next, click on the *Calculate* button to determine pre- and post-development runoff and loadings (just above the *Calculate* button). Click on the *Back* button to return to the **General Site Information Worksheet**.

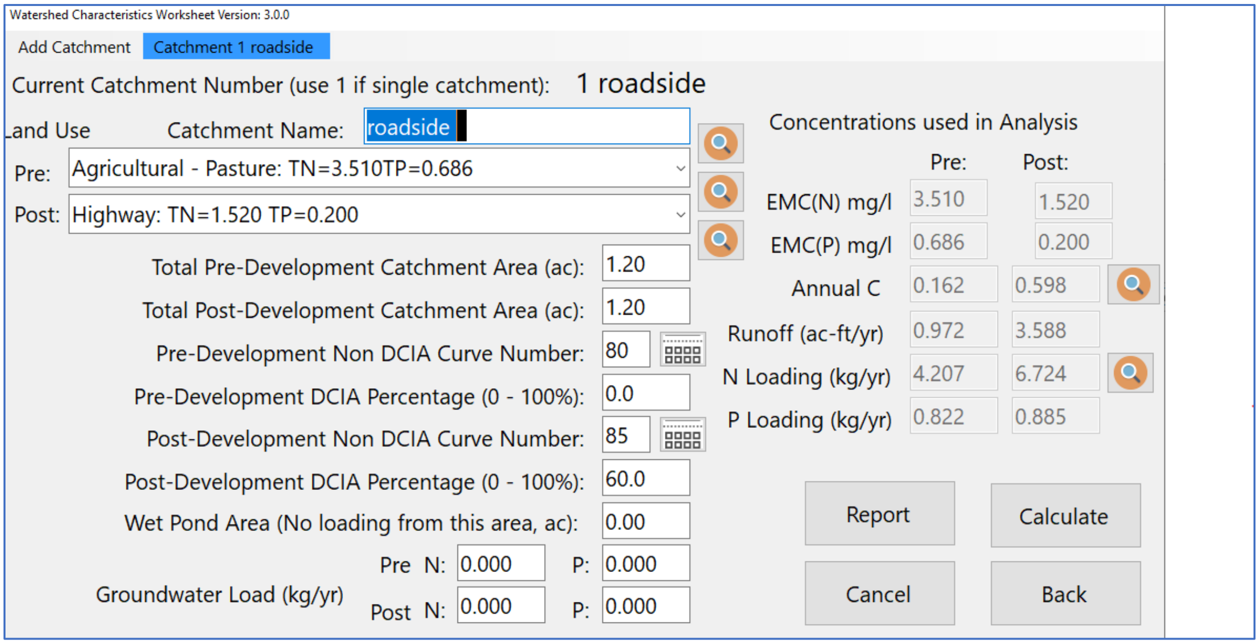


Figure 11b. Watershed Characteristics Worksheet.

3. From the **General Site Information Worksheet,** select the *2. Enter Treatment* button to proceed to the **Select Treatment Options Worksheet** (Figure 11c). Note that there are 14 treatment options and effectiveness is done as if the BMP were a stand-alone one.

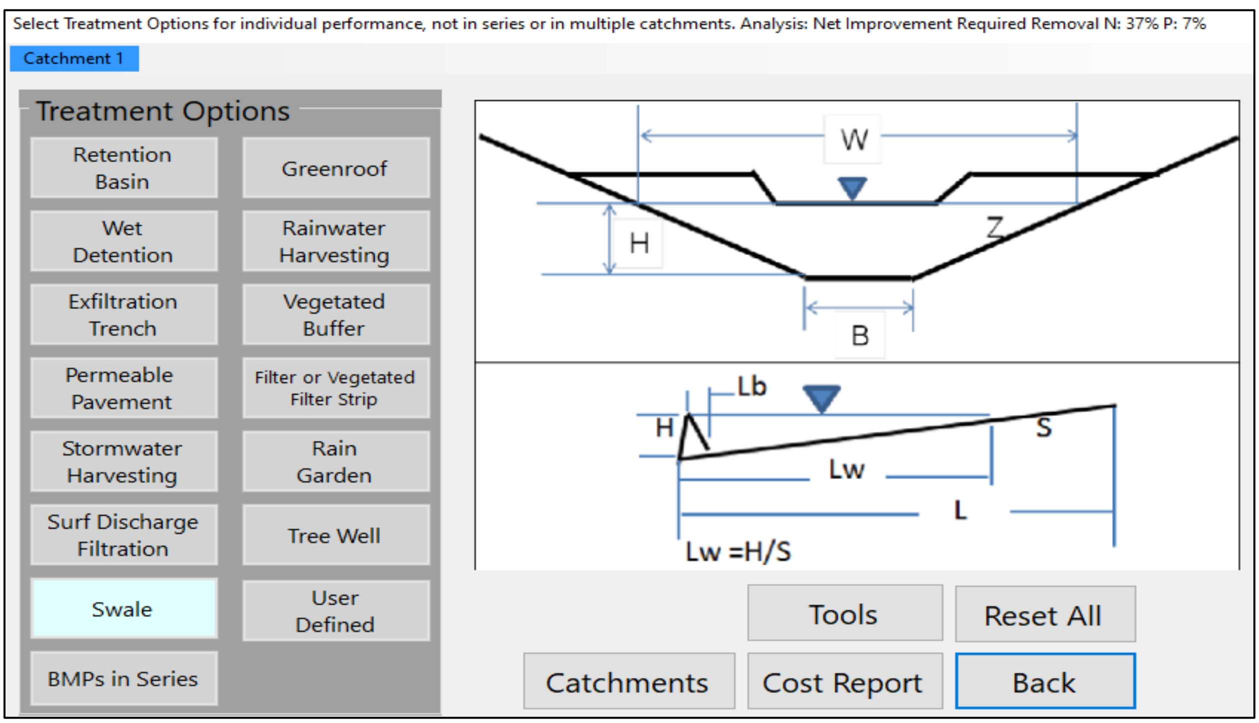


Figure 11c. Select Treatment Options Worksheet.

4. Select the *Swale* button to proceed to the **Swale Worksheet** (Figure 11d). Enter the parameters for the swale design as shown. One check on input uses the catchment area; it should be the average width times the length or {(20+40) x 871.2}/43560 = 1.2 acres. Also note across the top ribbon, the net improvement for this catchment is listed (37%, 7%).

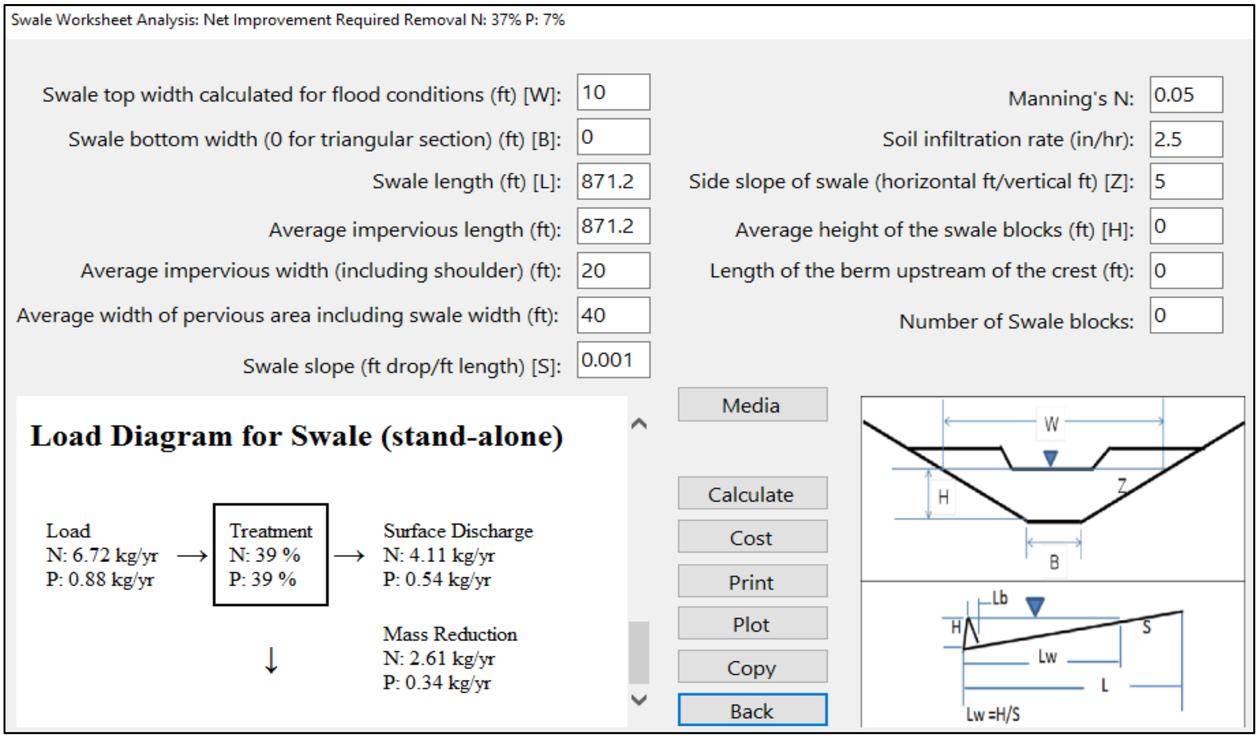


Figure 11d. Swale Worksheet.

Note, the term stand-alone is used to remind the user that the design of the swale is based on a contributing (catchment) area characteristics and annual runoff. The catchment area may increase if the swale is used with other catchments that also contribute runoff to it.

5. The design parameters for the swale are shown in Figure 11d. Of particular note is the very flat slope of 0.1% (0.001 foot drop per linear foot). For slopes less than one percent or swale blocks greater than 6 inches, there is a reduction in concentration as well as a mass reduction due to infiltration. BMP Trains 2020 accounts for the additional concentration reduction as a function of the residence time within the swales. After entering the design parameters for the swale, select the *Calculate* button to review the on-screen report. Note the required % removal is shown on the top "ribbon." Also there are buttons to copy the information to a clip board or a print button.

   a. Next, select the *Back* button to return to the **Select Treatment Options** sheet.

   b. Select the *Back* button to return to the **General Site Information Worksheet**.

c. Select the *Configure Catchments* button to enter the **Select Catchment Configuration Worksheet** (Figure 11e).

d. Select the *Edit* button and select Swale as the BMP for routing. Since this project only has a single catchment which discharges to the outlet (receiving waters) there is no need to change the value for "*Route to", "0"* means outlet.

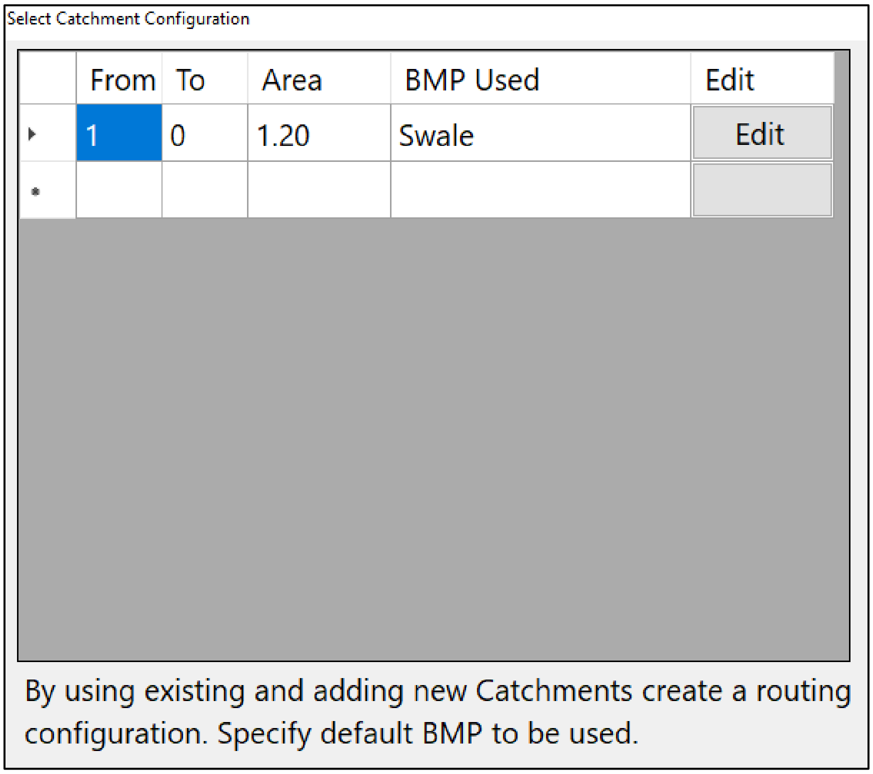


Figure 11e. Select Catchment Configuration Worksheet.

6. Now select the *Back* button to return to the **General Site Information Worksheet**.

7. At this point in the analysis, the evaluation may be completed and a summary of input and results may be needed. Otherwise a cost analysis can be completed. For a summary of input and results, select button #4 (**Summary Treatment Report**). See Figure 11f for the results.

BMP Types:
Catchment 1 - (roadside) Swale
Based on % removal values to the nearest percent
Total nitrogen target removal met? **Yes**
Total phosphorus target removal met? **Yes**

Routing Summary
Catchment 1 Routed to Outlet

Summary Report

Nitrogen

Surface Water Discharge

Total N pre load	4.21 kg/yr	
Total N post load	6.72 kg/yr	
Target N load reduction	37 %	
Target N discharge load	4.21 kg/yr	
Percent N load reduction	39 %	
Provided N discharge load	4.11 kg/yr	9.07 lb/yr
Provided N load removed	2.61 kg/yr	5.76 lb/yr

Phosphorus

Surface Water Discharge

Total P pre load	.822 kg/yr	
Total P post load	.885 kg/yr	
Target P load reduction	7 %	
Target P discharge load	.822 kg/yr	
Percent P load reduction	39 %	
Provided P discharge load	.541 kg/yr	1.19 lb/yr
Provided P load removed	.344 kg/yr	.758 lb/yr

Figure 11f. Summary Treatment Report

For this example, the swale as designed satisfies net improvement based on both Nitrogen and Phosphorus removal. The annual removal of both Nitrogen and Phosphorus is 39%.

Continuation of Example Problem #1 – groundwater protection

For this project, there is a need to focus on groundwater protection and to determine the reduction of Phosphorus and Nitrogen before entering the groundwater. This can be done by using a pollution control media in the bottom of the swale. Two feet of B&G CTS media is selected. Starting from the General Site Information page, select *Conduct a Groundwater Discharge Analysis* as shown in Figure 11g. The use of a pre-mixed media is accepted below the swale but above the seasonal high water table. The homogeneity of a pre-mix is acceptable to provide for a more uniform infiltration and contact time, and thus is part of the minimum separation needed between the swale bottom and the seasonal high water table level.

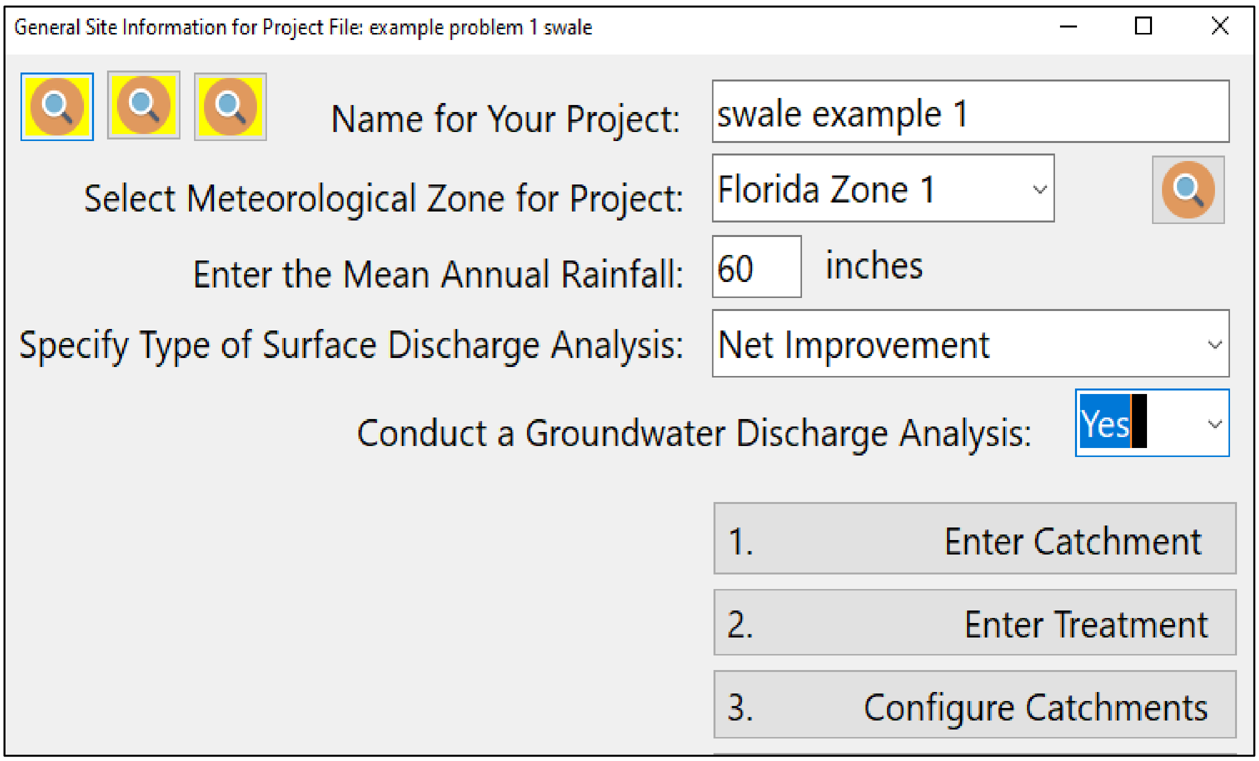


Figure 11g. General Site Information groundwater protection

The catchment data from the surface water discharge analysis are the same, and if the file was saved, then the data in the file can be reused. However, if the treatment data have to be re-entered, first reset the values (see Figure 11h). When a new data set is used, then simply enter the swale and media data. Enter the *Media* button to select the type of pollution control media as shown in Figure 11i.

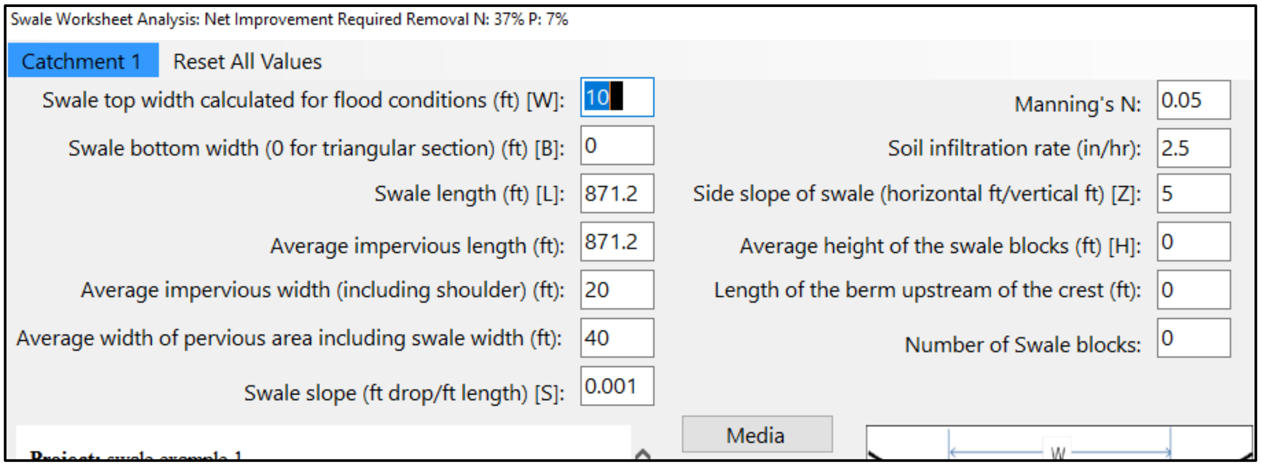


Figure 11h. Reset and Media Function Buttons on the Swale Treatment Worksheet

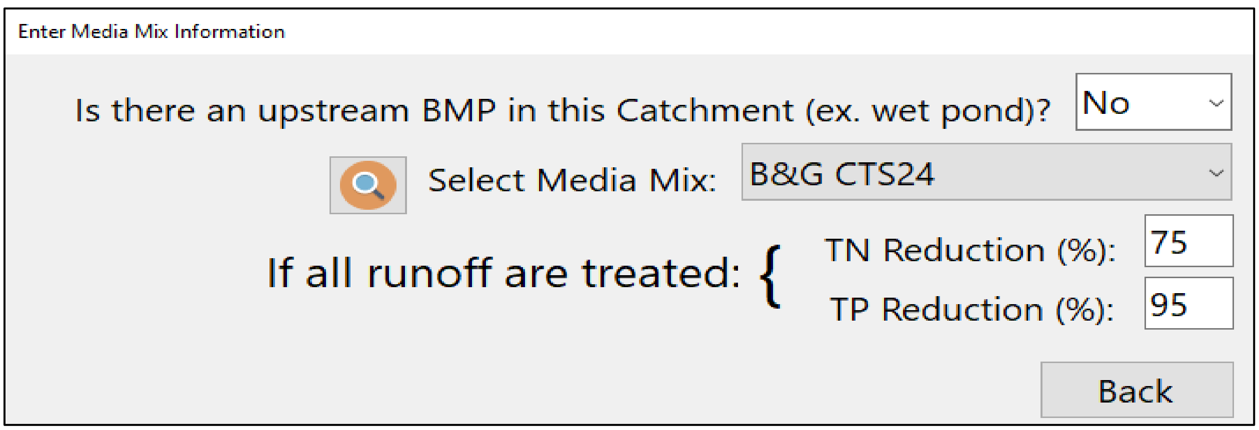


Figure 11i. Media Selection

The reduction % values shown in Figure 11i are for runoff water passing through the filter media. They are specific for the type of media selected. However, not all of the annual discharge water passes through the filter, and for this swale design, the capture effectiveness is 39% as shown in the **Swale Treatment Worksheet** report. The program calculates the removal of only that water passing through the filter. The overall annual removal efficiency for surface discharge is a weighted average of the concentration of water not passing the filter and water passing through the filter. The concentration of that entering the groundwater is based on that water passing through the filter.

Select the *Back* button to return to the **Swale Worksheet Analysis**. On this worksheet is a listing of input and results with summary load diagrams. The following are summary diagrams for the removal of TN and TP from surface discharge (Figure 11j) and as collected in the media before discharge to the groundwater (Figure 11k).

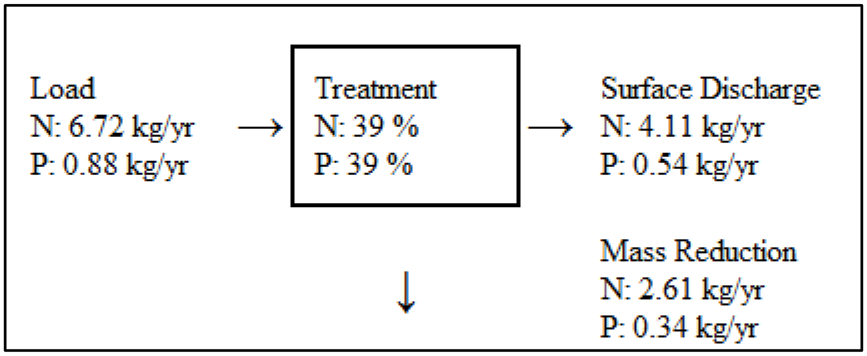


Figure 11j. Surface Discharge Load Diagram for Input, Mass Reduction and Discharge

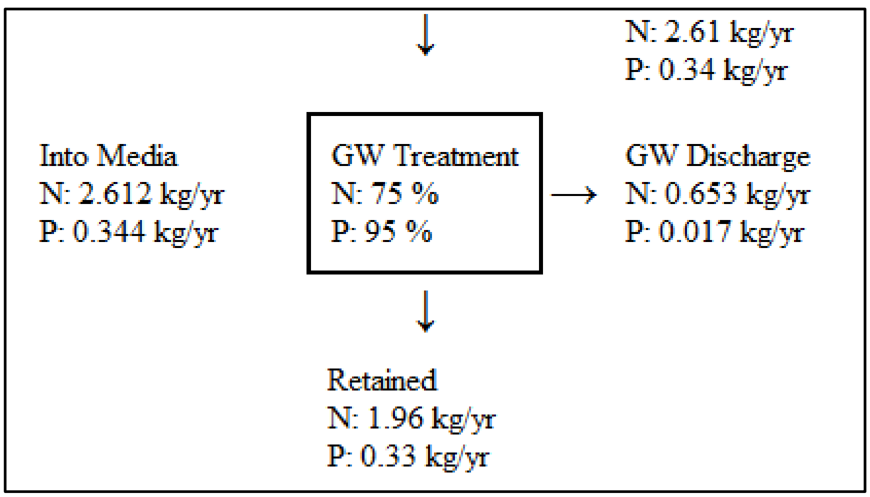


Figure 11k. Groundwater Discharge Load Diagram For Input, Retained Mass and Discharge

From the **Summary Treatment Report**, the average annual recharge is 0.454 MG/year, with an average nitrogen concentration of 0.38 mg/L and an average phosphorous concentration of 0.01 mg/L. The calculation of average annual recharge is annual runoff in acre-feet (Figure 11b) multiplied by the fraction of annual runoff captured (Figure 11d) times a conversion factor, or:

Recharge = 3.588 (ac-ft) x 0.39 (capture) x 0.3258724 (MG/ac-ft) = 0.454 MG/yr and,

TN concentration is the EMC of 1.52 mg/L x fraction not removed (1-0.75) = 0.38 mg/L.

Example problem # 2 - retention basin: pre- vs. post-development loading

This example problem includes the step-by-step procedure to input information for retention basin average annual effectiveness. Retention basins also are identified as infiltration cells, retention ponds, and infiltration basins. They are used for regional and on-site treatment.

Another purpose of the example problem is to demonstrate an option of comingling compared to by-pass of offsite runoff. The **BMP Trains 2020** method for evaluating effectiveness is based on the results of annual simulations (Wanielista, et.al., 2017). The problem description is for a retention basin serving a 2-acre highway with an option to by-pass or treat an equivalent offsite area. Another 2 acres with 50% directly connected impervious roadway owned by another transportation entry has the option to by-pass or be treated with the existing onsite retention basin. The site is located in Marion County, near Ocala FL, with 50 inches of annual rainfall on Hydrologic Soil Group C. A non-DCIA Curve Number (CN) of 80 describes the soil conditions of both areas. Thus, the rainfall excess is the same from each roadway.

The onsite retention basin must provide treatment for 80% removal. This is the regulatory requirement for the area. The usual retention design depth for this area is a rainfall depth of 1 inch. Thus, the volume of the retention basin is 7,260 CF (1-inch x 2 acres x 43,560 SF/Acre / 12 inches/foot). The retention depth for the 1 inch of treatment is on the average 3 feet. Thus, the area at design depth of 1 inch over the watershed is 2420 SF (7260 CF/3ft) or 0.056 acres. The retention area is part of the catchment area. The depth of retention (inches) is calculated from the volume of the retention basin and the catchment area. The catchment area may change if there is additional runoff to the retention basin from another catchment area as an example.

There is no additional treatment volume onsite that can result from a deeper basin because of water table depth. Also, no additional area can be used within the right-of-way. The **BMP Trains 2020** program is used to analysis one inch of treatment depth. The analysis option selected is the BMP analysis. The question is to determine if the 1-inch size of retention results in 80% removal. We could have also picked the specified removal effectiveness of 80% and checked to see if we achieved it. BMP analysis does not require pre-development land use data.

1. From the introduction page click on the *Continue* button to proceed to the **General Site Information Worksheet** (Figure 12a).

   a. Enter the project name and select the meteorological zone.

   b. Input the mean annual rainfall amount.

   c. Select the *BMP Analysis* option from the type of analysis drop down menu.

   d. Leave the *Conduct a Groundwater Discharge Analysis* selection as “No.”

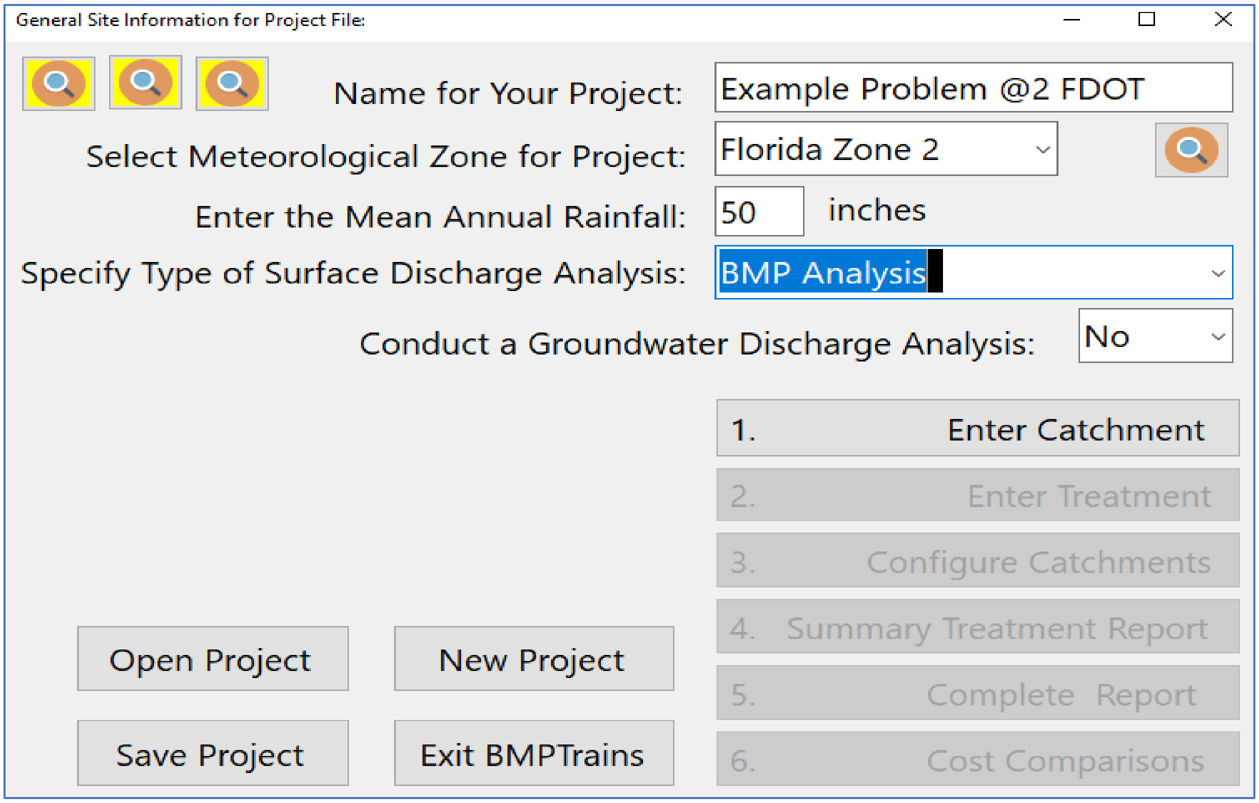


Figure 12a. General Site Information Worksheet.

2. Click on the *1. Enter Catchment* button to proceed to the **Watershed Characteristics** W**orksheet** (Figure 12b). Enter a name for this catchment and enter the post-development conditions. Only the post condition data need to be entered because this is a BMP analysis which is done to determine the annual effectiveness of a design BMP for the post condition. Click on the *Calculate* button to determine pre- and post-development runoff and loadings (just above the *Calculate* button). After the data are entered, click on the *Back* button to return to the **General Site Information Worksheet**.

Note: In the pre-condition, there may already be a small BMP that cannot be expanded, and in the post condition the removal has to meet 80% average annual removal. In this case, run the model with the post condition and the size of the existing BMP to determine the existing effectiveness. Then run the model in the post condition with another BMP to make up the difference in the removal to achieve 80%. This may have to be done with 2 different catchments or with one catchment and two BMPs. For any scenario, the existing effectiveness has to be considered.

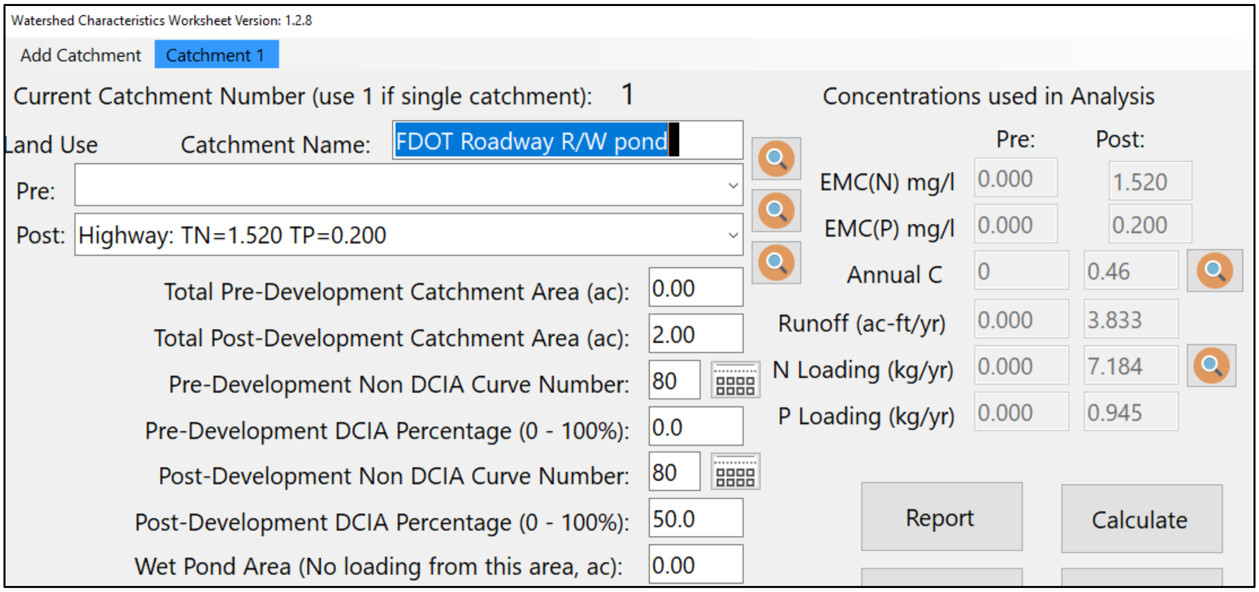


Figure 12b. Watershed Characteristics Worksheet for BMP Analysis.

4. Select the *2. Enter Treatment* button to proceed to the **Select Treatment Options Worksheet** (Figure 12c).

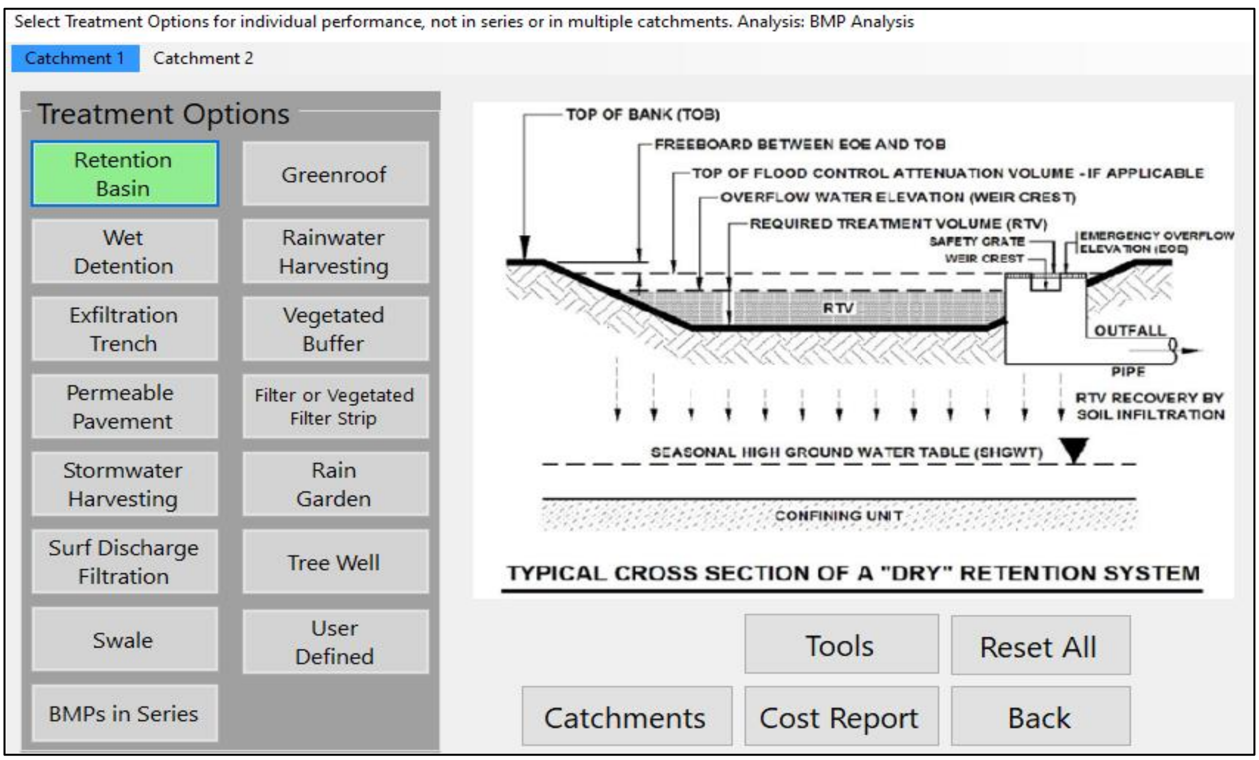


Figure 12c. Select Treatment Options Worksheet.

5. Select the *Retention Basin* button to proceed to **Retention Basin Worksheet** (Figure 12d).
   a. The **Retention Basin Worksheet** shows a retention depth of 1 inch which results in an average annual effectiveness of 81% or a different depth in the cell "Provided Retention Depth (in over Catchment)". Click the *Calculate* button and review the input and results.

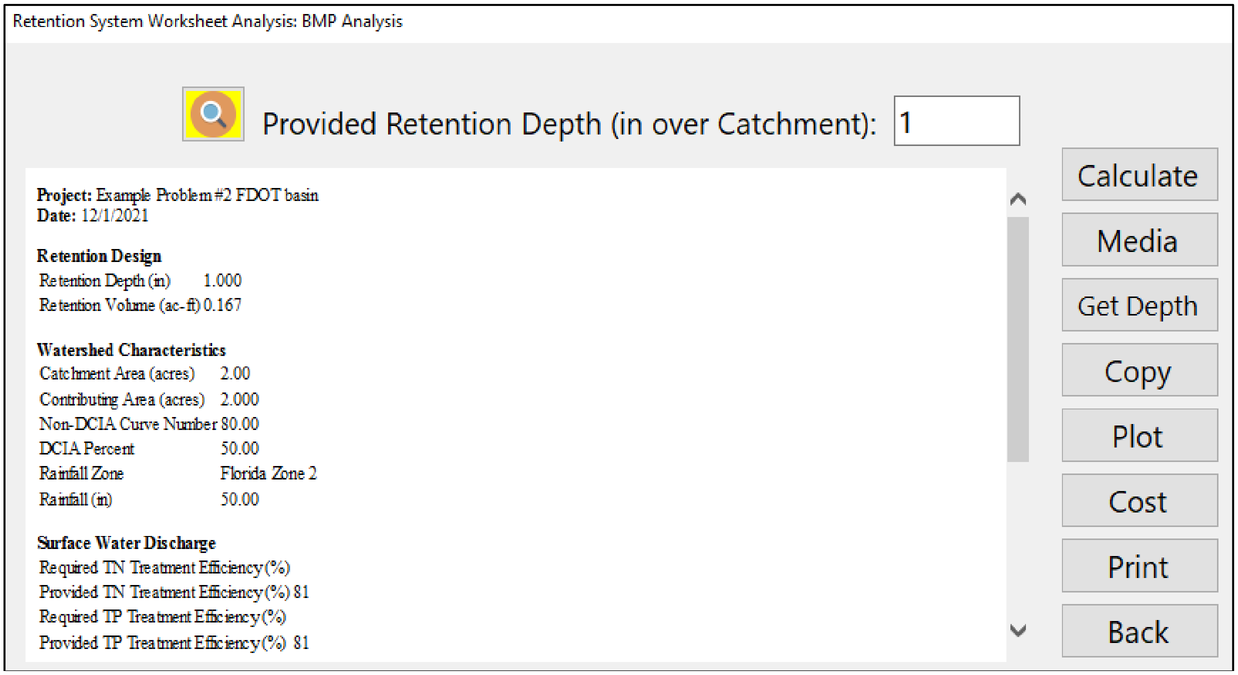


Figure 12d. Retention Basin Worksheet.

   b. The analysis includes the rate of change in annual capture (effectiveness) as a function of the size (depth) of retention using the *PLOT* button in Figure 12e (a). Or, given a percent capture, the retention depth (*Get Depth button*) can be used (b) in Figure 12e.

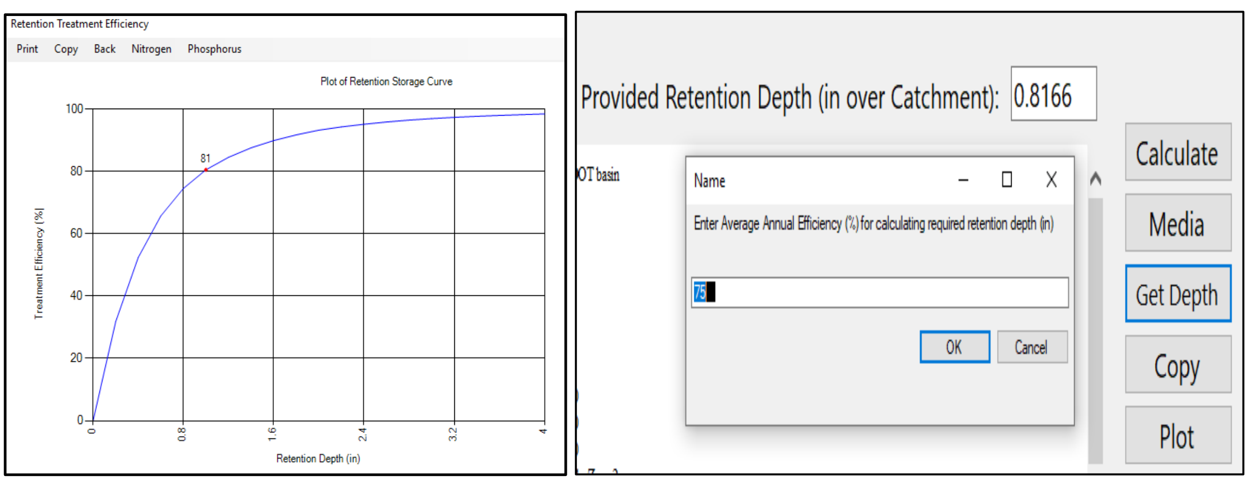


Figure 12e. (a) Annual Capture with Retention Depth. (b) Depth for 70% Capture (Effectiveness).

A load diagram as part of the on-screen results is also displayed. Scroll down to the bottom of the results window as shown in Figure 12f. Note, the term stand-alone is used to remind the user that the effectiveness of the retention basin is based on a catchment area CN for the pervious area and the DCIA. The volume of treatment or inches over the catchment = treatment volume Ac-ft x 12in/ft/catchment area (ac). The catchment area will increase if the retention basin is used with other catchments that contribute runoff to it and thus the effectiveness may decrease for a physical size of retention.

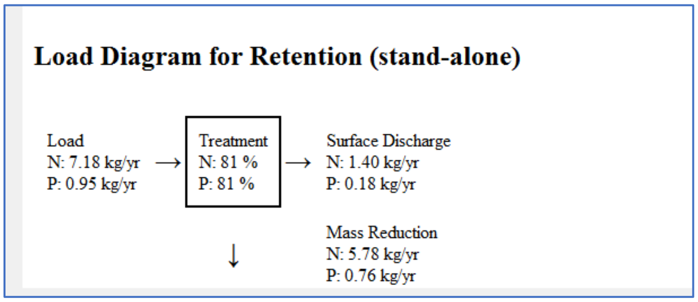


Figure 12f. Load Diagram.

c. Click the *Back* button to return to the **Select Treatment Options Worksheet**.
d. Click the *Back* button to return to the **General Site Information Worksheet**.
e. Click the *Configure Catchments* button to enter the **Select Catchment Configuration** Worksheet (Figure 12g). For each evaluation, catchment configuration must be selected.

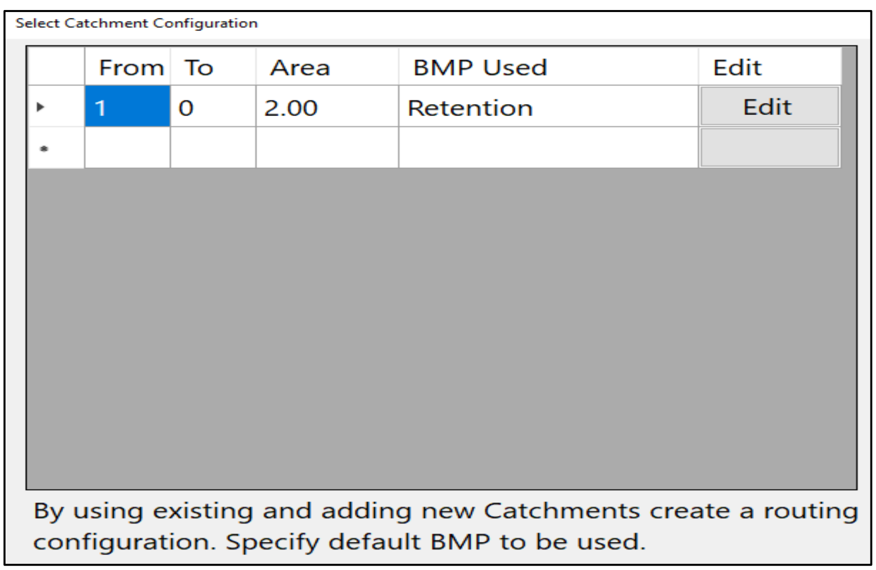


Figure 12g. Edited Catchment Configuration Worksheet.

6. To edit the **Catchment Configuration Worksheet**, click on the *Edit* button. You may now select “Retention” as the BMP for routing as shown in Figure 12h by using the dropdown menu. Since this project only has a single catchment which discharges to the outlet (receiving waters) there is no need to change the value for **Select Catchment to Route to**.

Select the catchment to route to. If only one catchment the routing is to the outlet. If there are other catchment, choices in the drop down menu will be given. The same logic applies to the selection of the BMP. In this case it is either none or retention.

You must make use of this worksheet before you can proceed to get a summary result. You can also add another catchment from this worksheet.

After you select the routing and the BMP, select the *Back* button to return to the **General Site Information Worksheet**.

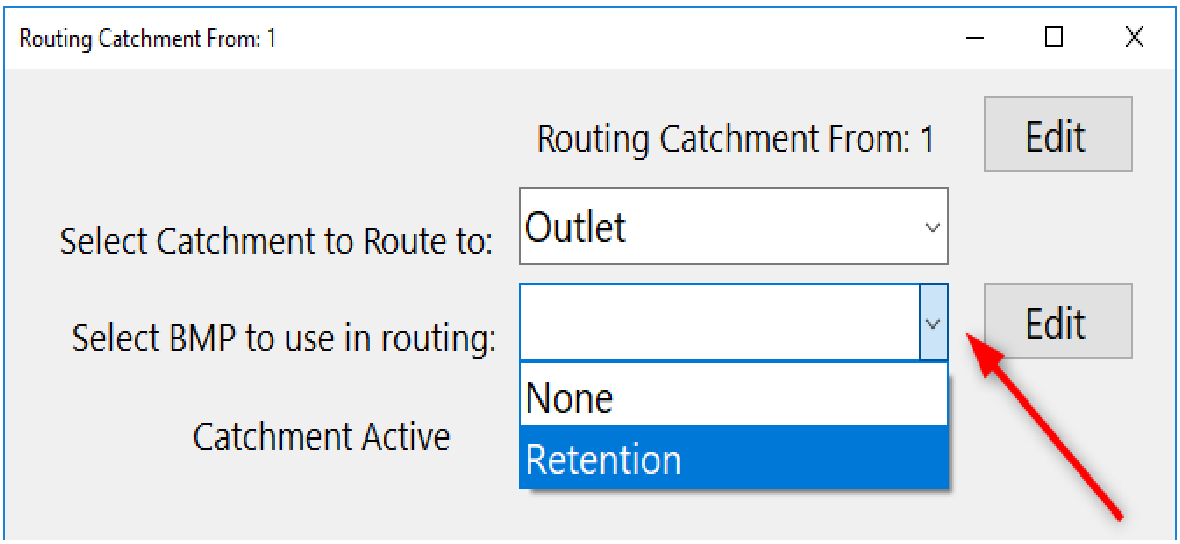


Figure 12h. Routing Worksheet.

7. When at the **General Site Information Worksheet,** Select button #4 (**Summary Treatment Report**). There is also a selection for a cost comparison. Data must be entered in the cost worksheets for each BMP used before cost comparisons can be done. Note also that a “complet report” button is available and is a listing of input data and results. The comple report doe not include cost data.

8. The summary treatment report is shown in Figure 12i. Since this is a BMP analysis (see Figure 12a) and in this case, an assesment of the annual effectivness of a 1 inch retention design, there is not printed a target or reguired effectiveness. The target values are printed when net improvement, a specified removal, or 10% less than pre loadings are specified as the type of analysis.

Project: Example Problem #2 FDOT basin

Analysis Type: BMP Analysis

BMP Types:

Catchment 1 - (FDOT Roadway R/W pond) Retention

Based on % removal values to the nearest percent

Routing Summary

Catchment 1 Routed to Outlet

Summary Report

Nitrogen

Surface Water Discharge

Total N post load	7.18 kg/yr	
Percent N load reduction	81 %	
Provided N discharge load	1.4 kg/yr	3.09 lb/yr
Provided N load removed	5.78 kg/yr	12.75 lb/yr

Phosphorus

Surface Water Discharge

Total P post load	.945 kg/yr	
Percent P load reduction	81 %	
Provided P discharge load	.184 kg/yr	.41 lb/yr
Provided P load removed	.761 kg/yr	1.678 lb/yr

Figure 12i. Summary Treatment Report.

With the retention basin design, the average annual effectiveness has been calculated at 81%, which is slightly higher than a commonly used 80% target. The average annual discharge and removal loads have been calculated. This is for a retention basin within the right-of-way.

Now for an adjacent catchment, what is the expected annual treatment effectiveness if the adjacent county roadway drainage is routed through the existing retention basin. The existing retention basin area and storage volume will not change. The adjacent catchment area has the same land use characteristics as the on-site catchment. This example continues.

Continuation of Example Problem # 2 – Comingling of Off-Site Drainage

Flow from a county roadway (off-site) can be either routed around the existing retention basin or comingled within the existing basin. The off-site roadway has a delayed time of 8 hours before the runoff water enters into the existing on-site basin. This delay allows for additional runoff water to infiltrate in the retention basin. The off-site drainage is upstream and in series with the on-site retention basin. No treatment is done for the off-site catchment.

The general site information for rainfall and catchment characteristics remain the same (see Figure 12a). The upstream catchment information is added as shown in Figure 12j. This information is for catchment one and it flows into catchment 2. Catchment 1 is identified as off-site and upstream.

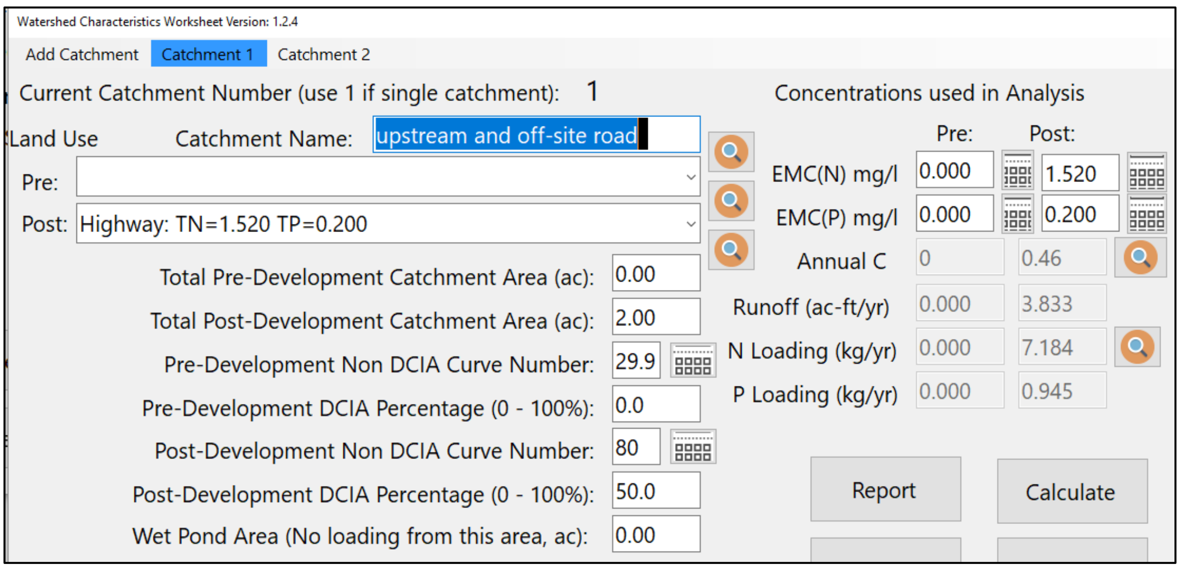


Figure 12j. Upstream Catchment Information.

Next, add the downstream on-site FDOT catchment information. In Figure 12j note there is a button in the upper left corner called "Add Catchment" that is highlighted with the curser and navigates to the **Create New Catchment Worksheet** (Figure 12k).

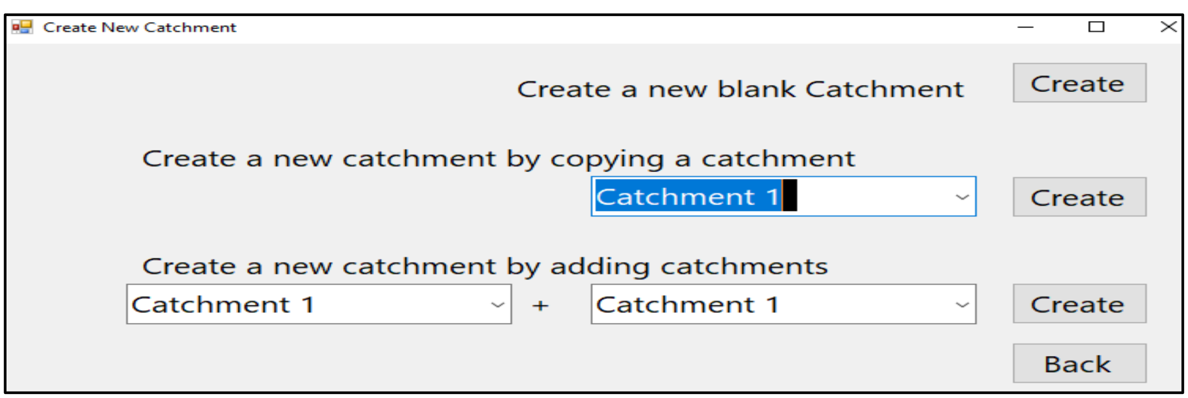


Figure 12k. Create a new Catchment by clicking on the Create Button.

The downstream catchment characteristics and the land use data as shown in Figure 12L.

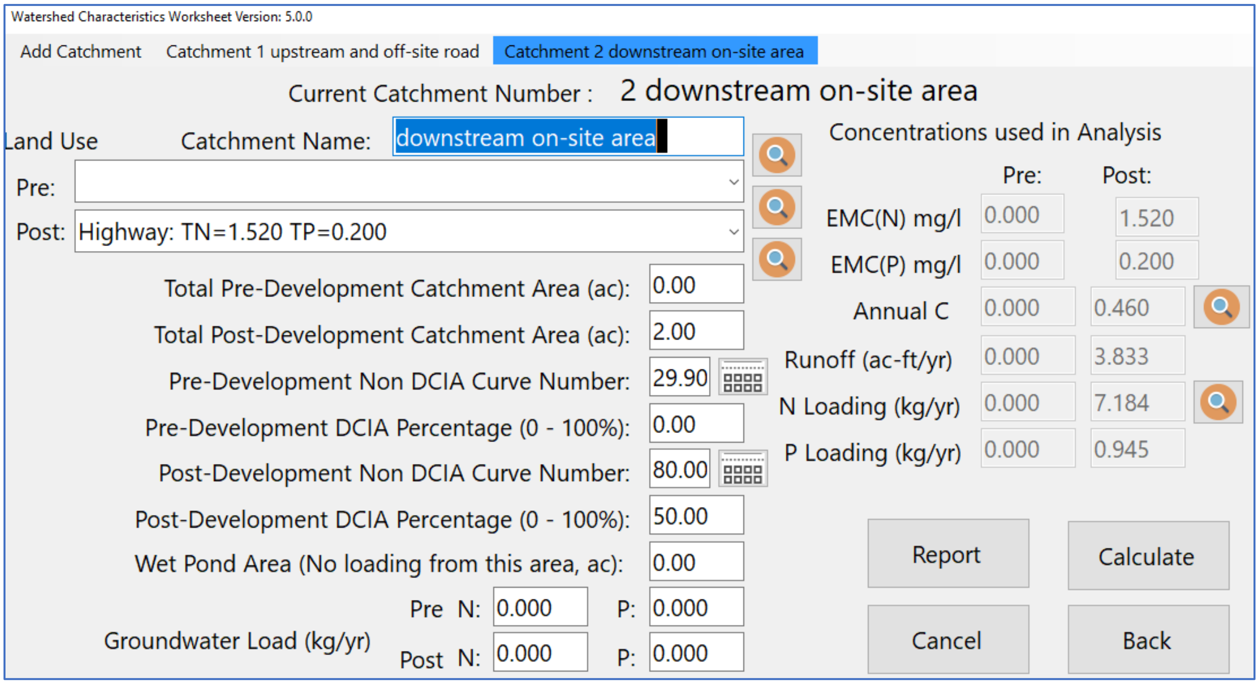
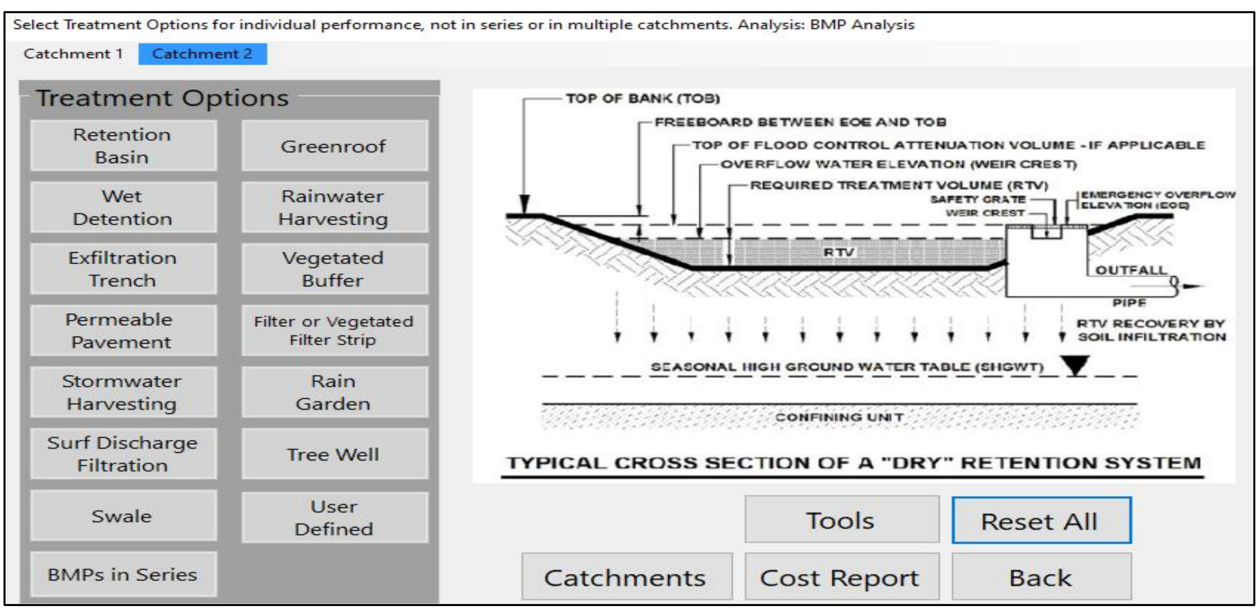


Figure 12L. Catchment 2 Downstream Data.

Go back to the **General Site Information Worksheet** and click on the *2. Enter Treatment* Button. There is no treatment for the upstream off-site catchment # 1 but there is treatment in the downstream on-site catchment (catchment # 2). After the treatment depth is added, the retention basin button on the **Select Treatment Options Worksheet** will appear in a different color (see Figure 12m or the next two screen captures).



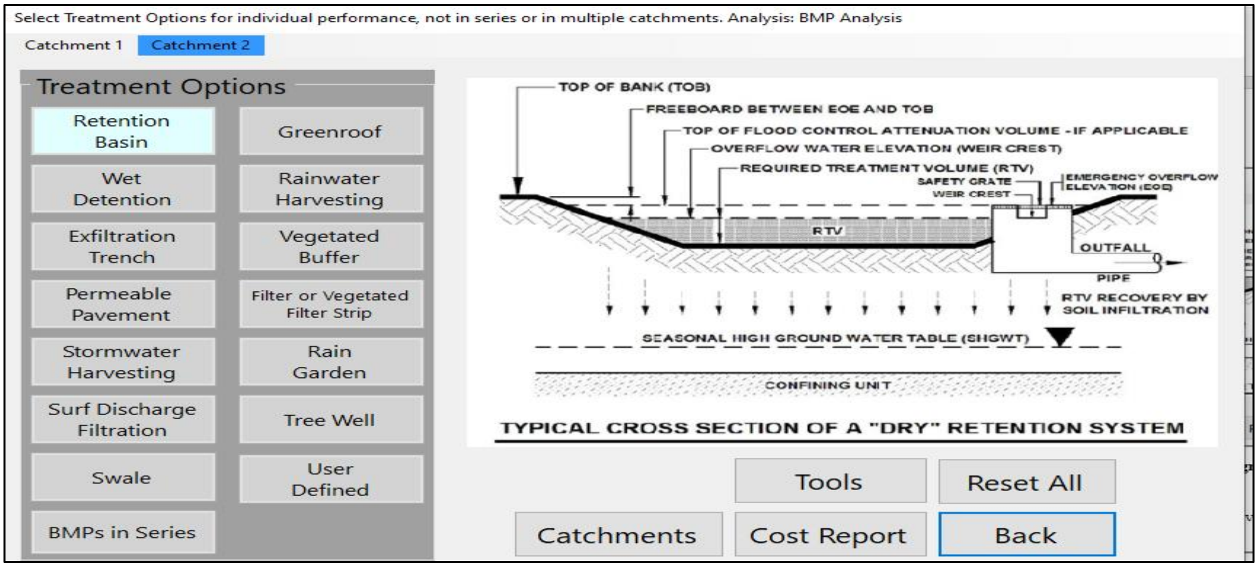


Figure 12m. Select Treatment Options, Retention Basin before and after Retention Basin Selection.

The retention depth used is the same used to attain 81% removal as if the basin were treating only the on-site runoff. This is equivalent to one inch or 0.167 ac-ft shown in Figure 12n. However, when off-site runoff enters, the removal will decrease because of additional runoff and no increase in retention pond size. But, the removal will also increase because the off-site runoff takes longer to enter, or 8 hours before entering the basin in this example.

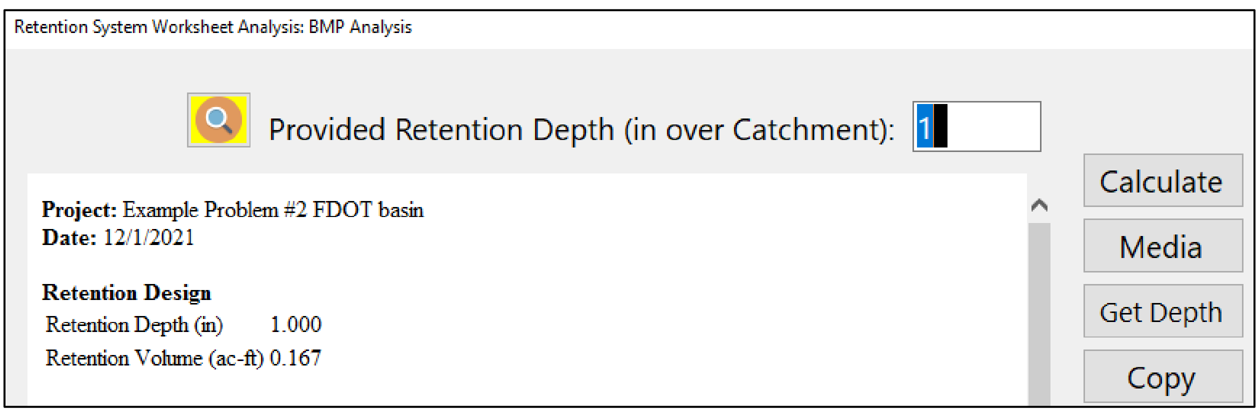


Figure 12n. Retention Basin Designed for One Inch Capture from the Downstream On-site Basin.

Go back using the *Back* button to the **General Site Information Worksheet** to configure the catchments (click on 3). Initially the **Catchment Configuration Worksheet** appears as shown in Figure 12o. The *Edit* button is used to make changes or enter new data. The edited **Catchment Configuration Worksheet** is shown in Figure 12p.

	From	To	Area	BMP Used	Edit
▸	1	0	2.00		Edit
	2	0	2.00		Edit
*					

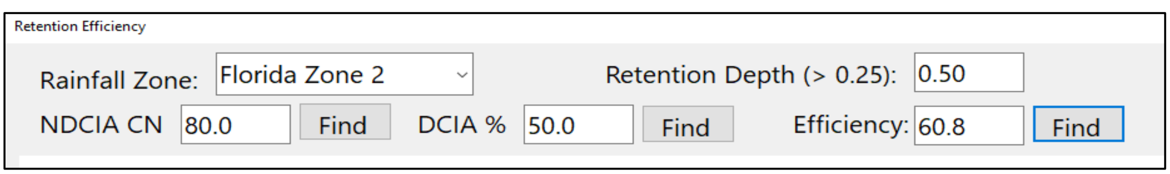
Figure 12o. Catchment Configuration for Initial Data Entry.

Select Catchment Configuration

	From	To	Area	BMP Used	Edit
▸	1	2	2.00	None	Edit
	2	0	2.00	Retention	Edit
*					

Figure 12p. Catchment Configuration with Topology Data Added.

The program will calculate the removal without the delay of runoff from catchment 1 as 60.8%. This can also be calculated using the "**tools**" menu, *Retention Efficiency Lookup Tables* with the retention depth of 0.5 inches or 0.167 ac-ft x 12 (in/ft)/4 acres.



The delay from the upstream catchment to the downstream catchment in hours is added from the **Routing Catchment Worksheet** as shown in Figure 12q. The delay is 8 hours and applies to the up-stream catchment. This delay allows more water to infiltrate. In this example, the delay increased the effectiveness with no delay by 2%. After the delay is entered, the *Back* buttons are again used to return to the **General Site Information Worksheet**.

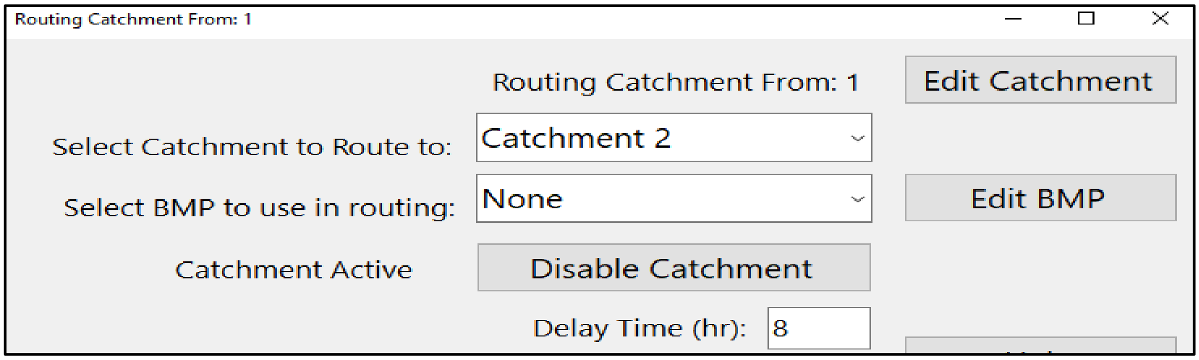
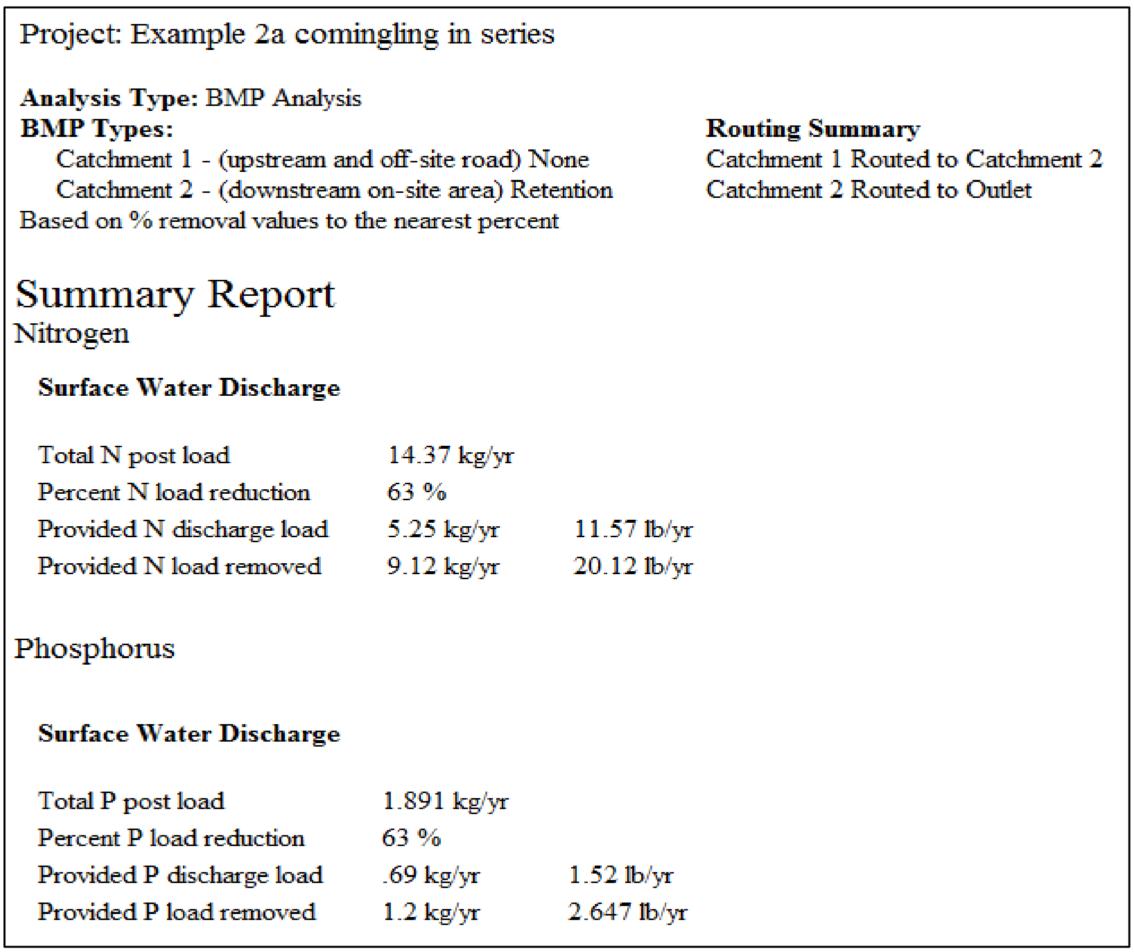


Figure 12q. Routing Catchment 1 Information with Delay of 8 Hours.

From the **General Site Information Worksheet**, click on button *4*, *Summary Treatment Report*. The results show when comingling the off-site drainage into an existing on-site retention basin, the TN and TP removed are 20.12 and 2.65 pounds/year respectively (Figure 12r) compared to 12.75 and 1.68 pounds/year respectively when there is no comingling (Figure 12i).


Project: Example 2a comingling in series

Analysis Type: BMP Analysis

BMP Types:

Catchment 1 - (upstream and off-site road) None

Catchment 2 - (downstream on-site area) Retention

Based on % removal values to the nearest percent

Routing Summary

Catchment 1 Routed to Catchment 2

Catchment 2 Routed to Outlet

Summary Report

Nitrogen

Surface Water Discharge

Total N post load	14.37 kg/yr	
Percent N load reduction	63 %	
Provided N discharge load	5.25 kg/yr	11.57 lb/yr
Provided N load removed	9.12 kg/yr	20.12 lb/yr

Phosphorus

Surface Water Discharge

Total P post load	1.891 kg/yr	
Percent P load reduction	63 %	
Provided P discharge load	.69 kg/yr	1.52 lb/yr
Provided P load removed	1.2 kg/yr	2.647 lb/yr

Figure 12r. Summary Results with Comingling of Off-Site with On-Site Flows and 8 Hour Delay.

Another treatment option is to by-pass flow from the off-site catchment so that it is not comingled with the on-site treatment basin. The information in the series configuration can be modified. Or a new model flow path can be constructed. See Figures 12s for the modifications and Figure 12t for the summary results. Note the percent removal in this parallel treatment option is only 40% (Figure 12t) compared to 63% with comingling (Figure 12r).

Select Catchment Configuration

	From	To	Area	BMP Used	Edit
▸	1	0	2.00	None	Edit
	2	0	2.00	Retention	Edit
*					

Figure 12s. Catchment Configuration Modification for Parallel Discharge.

Project: Example 2 in parallel

Analysis Type: BMP Analysis
BMP Types:
Catchment 1 - (upstream and off-site road) None
Catchment 2 - (downstream on-site area) Retention
Based on % removal values to the nearest percent

Routing Summary
Catchment 1 Routed to Outlet
Catchment 2 Routed to Outlet

Summary Report
Nitrogen

Surface Water Discharge

Total N post load	14.37 kg/yr	
Percent N load reduction	40 %	
Provided N discharge load	8.59 kg/yr	18.93 lb/yr
Provided N load removed	5.78 kg/yr	12.75 lb/yr

Phosphorus

Surface Water Discharge

Total P post load	1.891 kg/yr	
Percent P load reduction	40 %	
Provided P discharge load	1.13 kg/yr	2.49 lb/yr
Provided P load removed	.761 kg/yr	1.678 lb/yr

Figure 12t. Summary Assessment for By-Pass of On-Site Treatment – Parallel Discharge.

Example problem # 3 - retention basin - specified removal efficiency of 75%

A 1-acre shallow retention basin is serving within an 11.0-acre residential subdivision. The development site is located in East Hillsborough County near Tampa, FL on Hydrologic Group Soil A. The existing land use condition is assumed to be agricultural-pasture with a non-DCIA Curve Number of 50 and 0.0% DCIA. The post-development land use condition is a residential subdivision with a non-DCIA Curve Number of 65 and 25% DCIA. The retention basin is to provide treatment sufficient for 75% reduction of the post-development annual nutrient loads. One-acre has been set as the area for a retention basin. No mass loading is expected from this one acre which is part of the catchment area because it is located in an undisturbed area. Thus, it is a depression area that exists for retention before development. Note, loading from regional retention is determined on a site by site basis.

1. From the introduction page click on the *Continue* button to proceed to the **General Site Information Worksheet** (Figure 13a).
   a. Enter the project name and select the meteorological zone.
   b. Input the mean annual rainfall amount.
   c. Select the *BMP Analysis* option from the type of analysis drop down menu.
   d. Leave the *Conduct a Groundwater Discharge Analysis* selection as “No.”

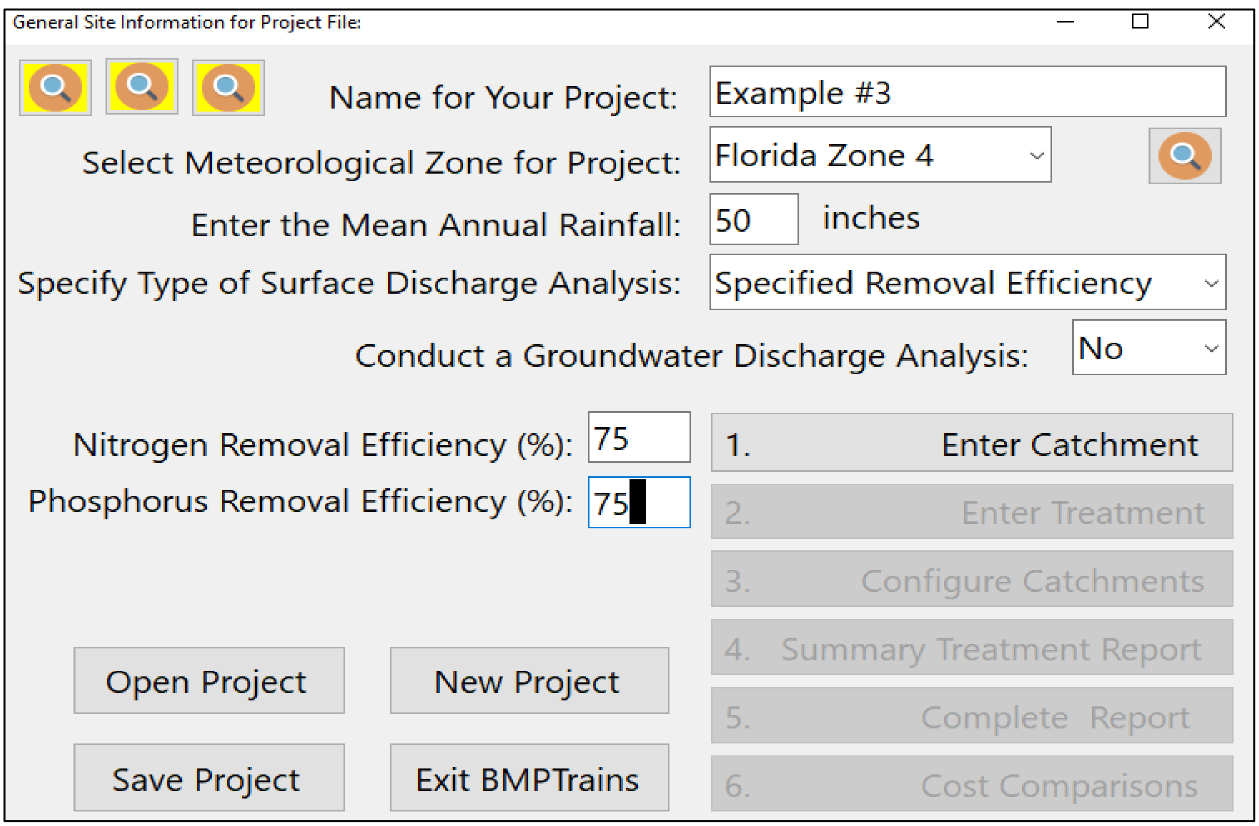


Figure 13a. General Site Information Worksheet.

2. Click on *1. Enter Catchment* button to proceed to the **Watershed Characteristics Worksheet** (Figure 13b). Enter a name for this catchment and indicate the pre- and post-development conditions. **Note** there is no wet area since treatment is by retention. Click on the *Calculate* button to determine pre- and post-development runoff and loadings (just above the *Calculate* button). Click on the *Back* button to return to the **General Site Information Worksheet**

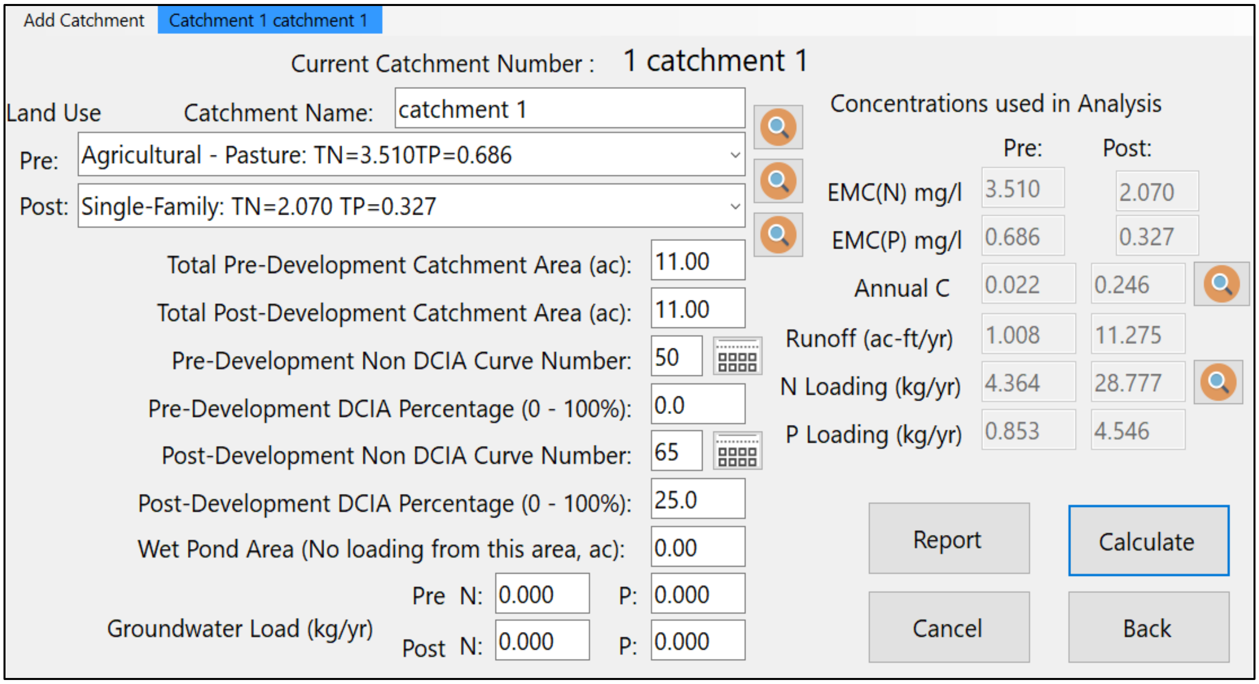


Figure 13b. Watershed Characteristics Worksheet.

3. Select the *2. Enter Treatment* button to go to the **Select Treatment Options Worksheet**. Select the *Retention Basin* button to proceed to the **Retention Basin Worksheet**. On the **Retention Basin Worksheet,** enter the depth of retention or 0.552 inches and key the "calculator" button the retrieve the effectiveness. (Figure 13c) shows the retention depth used to meet the required efficiency of 75% and in this case is 0.552 inches over the catchment watershed. The physical volume of retention is 0.552 inches times the catchment area (11 Acres) divided by 12 in/ft or 0.506 ac-ft. As another calculation option, the user can calculate a treatment depth (Get Depth) for an annual removal effectiveness. This is convenient when seeking a depth given an annual removal.

Note that the treatment depth is over the entire catchment site. As noted in the problem description, this is a shallow undisturbed area for retention. It is important to note that the retention depth is converted to traditional units of volume by multiplying the depth by the total catchment area and then expressed in acre feet. The volume of retention is depth in inches divided by 12 inches per foot times the catchment area in acres.

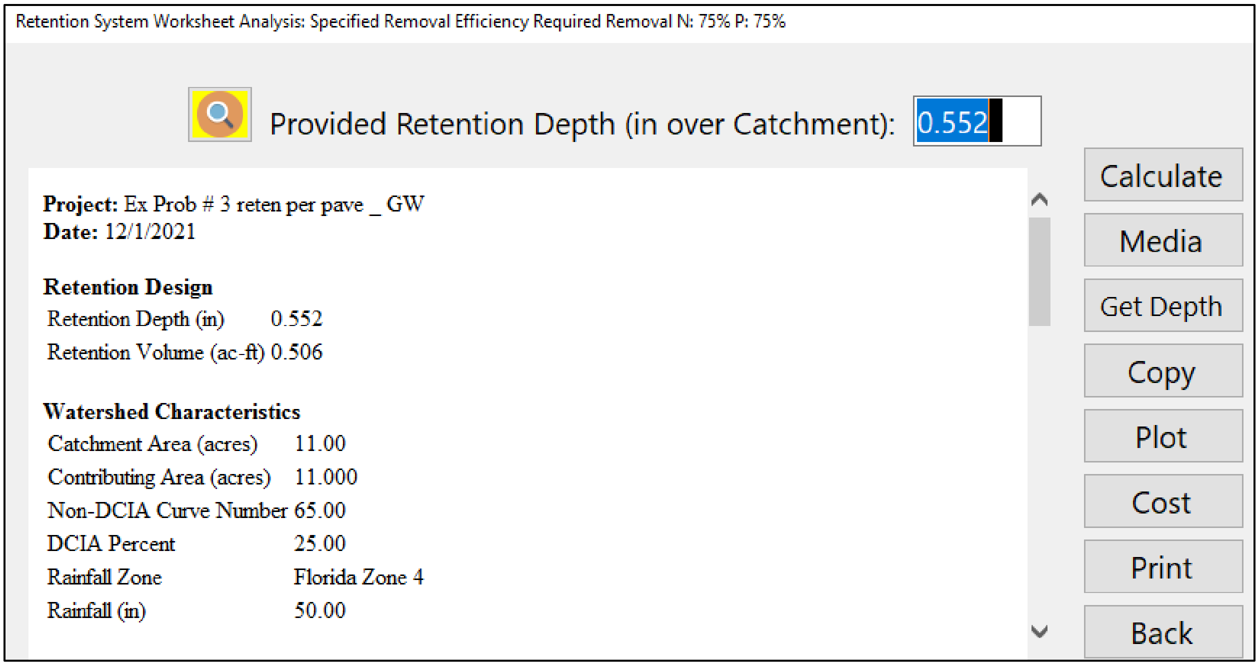


Figure 13c. Retention System Worksheet.

The bottom of the window information is shown in Figure 13d, which is a load diagram of annual average mass in the influent, effluent and as captured (reduction). Note that the size of the font used in these output windows can be changed to extract only information of interest.

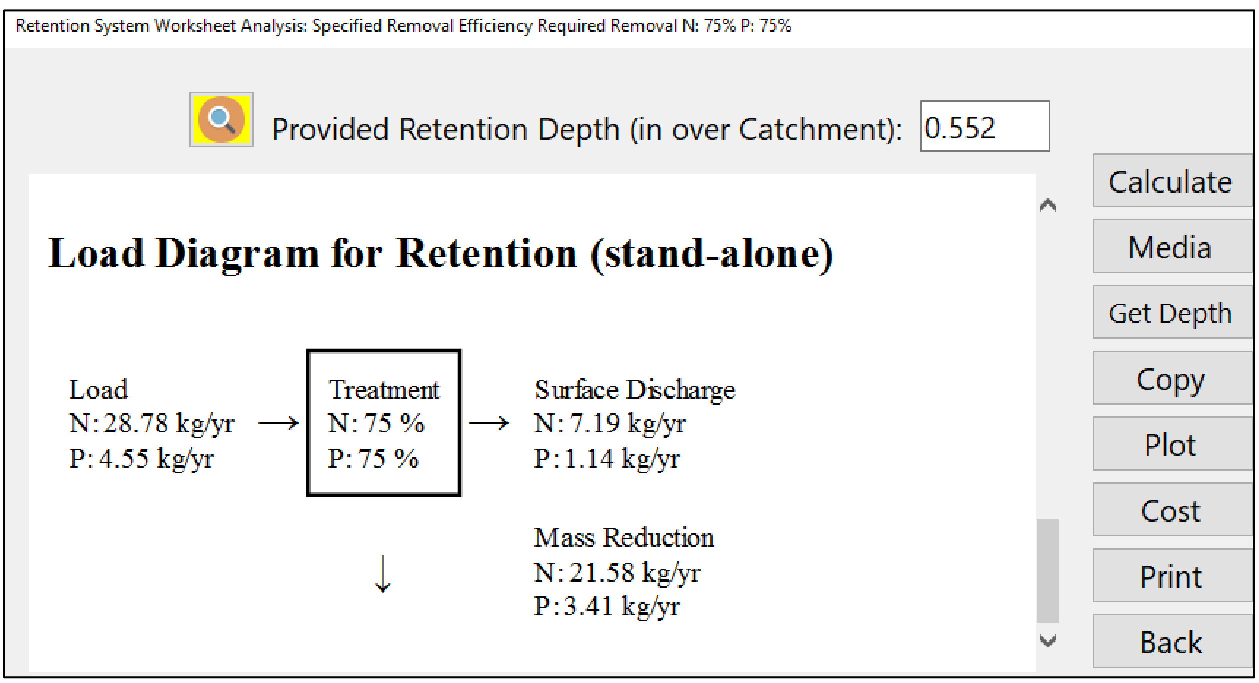


Figure 13d. Retention System Worksheet with Annual Load Diagram.

4. Using the *Back* button return go to **Retention System** and **Select Treatment Options**, to return to the **General Site Information** window. Click on *3. Configure Catchments* to proceed to the **Select Catchment Configuration Worksheet.**

5. On the **Select Catchment Configuration Worksheet**, click on the *Edit* button as shown on Figure 13e:

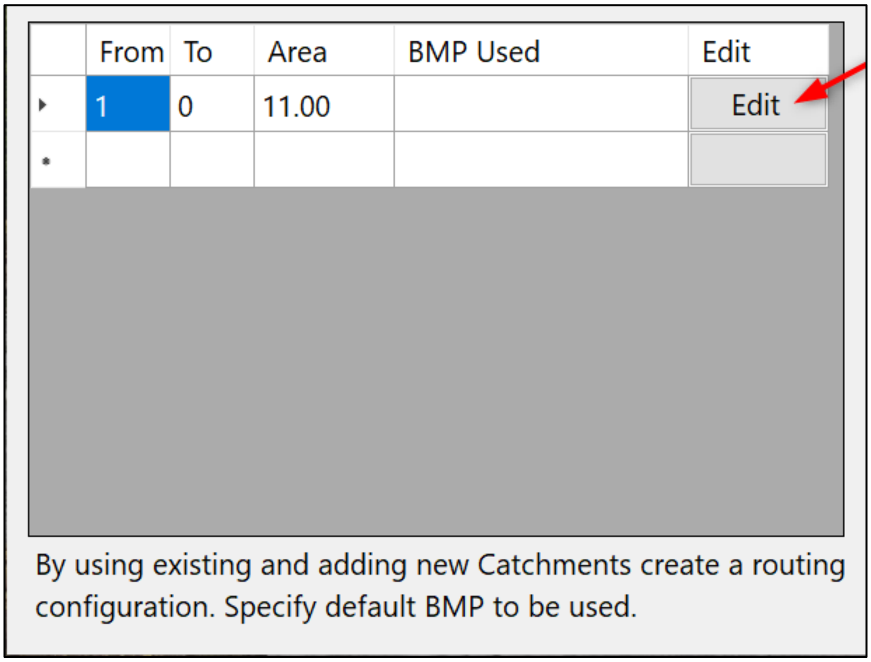


Figure 13e. Select Catchment Configuration Worksheet.

6. Select the BMP to use in routing by clicking on the dropdown menu. Since this project has only a single catchment which discharges to the outlet (receiving waters) the input is simply to define the outlet and the BMP.

Choose Retention for the BMP as shown on Figure 13f, then click on the *Back* button to return to the **Select Catchment Configuration Worksheet** and *Back* again to return to the **General Site Information Worksheet.**

Note the catchment information may be **disabled**, if so the information on the **Select Catchment Configuration Worksheet** will show with a dark color. The catchment can be enabled again if needed.

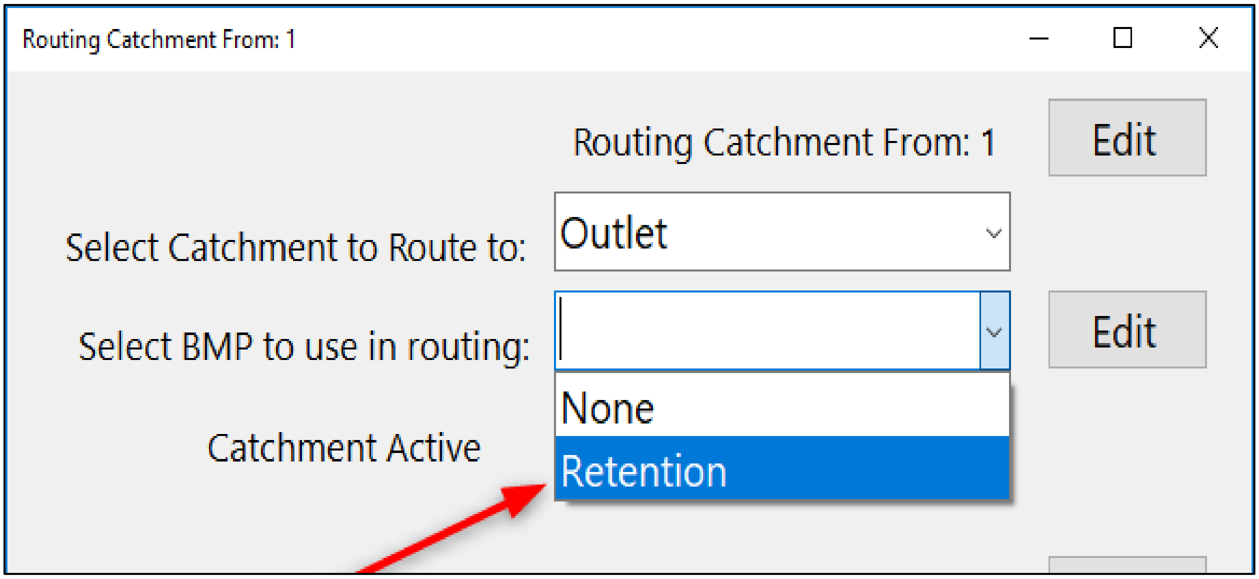
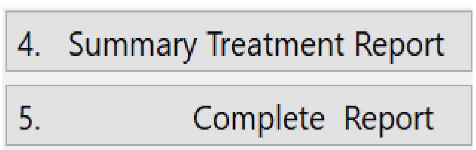


Figure 13f. Routing Catchment menu.

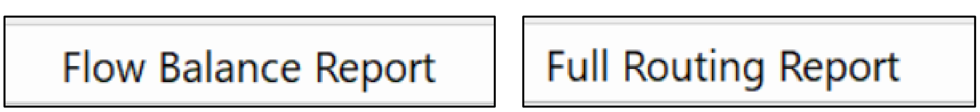
Return to the General Site Information and Navigation Page, You may now view a summary of the treatment achieved or the complete report button.



For the specified site conditions and BMP used, select the *4. Summary Treatment Report* button to proceed to the **Summary Treatment Report,** which is shown below**.**

Note that in this example, the desired removal efficiencies for both Nitrogen and Phosphorus have been met. If not met (as an example, 80% removal needed) or if there is more removal than required, the program can be used to evaluate a different size of retention as well as various other BMPs or combination of BMPs.

For multiple catchments, it is possible to view the flow at each catchment as well as the loadings. This is done from the Select Configuration Catchment Worksheet (see Figure 7) and using the buttons as shown below:



BMP Trains Reports

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Summary Treatment Report Version: 4.1.0

Project: Example Problem # 3

Analysis Type: Specified Removal Efficiency
BMP Types:
Catchment 1 - (catchment 1) Retention
Based on % removal values to the nearest percent
Total nitrogen target removal met? **Yes**
Total phosphorus target removal met? **Yes**

Routing Summary
Catchment 1 Routed to Outlet

Summary Report

Nitrogen

Surface Water Discharge

Total N pre load	4.36 kg/yr	
Total N post load	28.78 kg/yr	
Target N load reduction	75 %	
Target N discharge load	7.19 kg/yr	
Percent N load reduction	75 %	
Provided N discharge load	7.19 kg/yr	15.86 lb/yr
Provided N load removed	21.58 kg/yr	47.59 lb/yr

Phosphorus

Surface Water Discharge

Total P pre load	.853 kg/yr	
Total P post load	4.546 kg/yr	
Target P load reduction	75 %	
Target P discharge load	1.136 kg/yr	
Percent P load reduction	75 %	
Provided P discharge load	1.136 kg/yr	2.51 lb/yr
Provided P load removed	3.41 kg/yr	7.518 lb/yr

Figure 13g. Summary Treatment Report.

Example problem # 4 - wet detention - pre- vs. post-development loading with harvesting

A half-acre wet detention pond is serving a 5.5-acre highway expansion from one lane in each direction to two lanes in each direction. The existing portion of highway is not served by any treatment system. The existing and proposed portion of the highway will be treated in the post-development condition. The site is located in West Palm Beach, FL on Hydrologic Soil Group D. The existing land use condition is assumed to be a highway with a non-DCIA Curve Number of 80 and 40% DCIA. The post-development land use condition is a highway with a non-DCIA Curve Number of 80 and 85% DCIA (pavement of 4.675 acres and a wet pond area of 0.50 acres which is not part of the DCIA). The analysis will be a net improvement analysis using a wet detention pond which will utilize a littoral zone (assumed 10% removal efficiency credit) in the design. The permanent pool is 2.472 acre-feet. After net improvement is assessed, a stormwater harvesting operation is being considered to provide irrigation water to an adjacent 3 acres of land water when available. How much more Nitrogen removal can be expected from the harvesting operation?

1. From the introduction page click on the *Continue* button to proceed to the **General Site Information Worksheet** (Figure 14a).

   a. Enter the project name and select the meteorological zone.
   b. Input the mean annual rainfall amount.
   c. Select the *Net Improvement* option from the type of analysis drop down menu.
   d. Leave the *Conduct a Groundwater Discharge Analysis* selection as “No.”

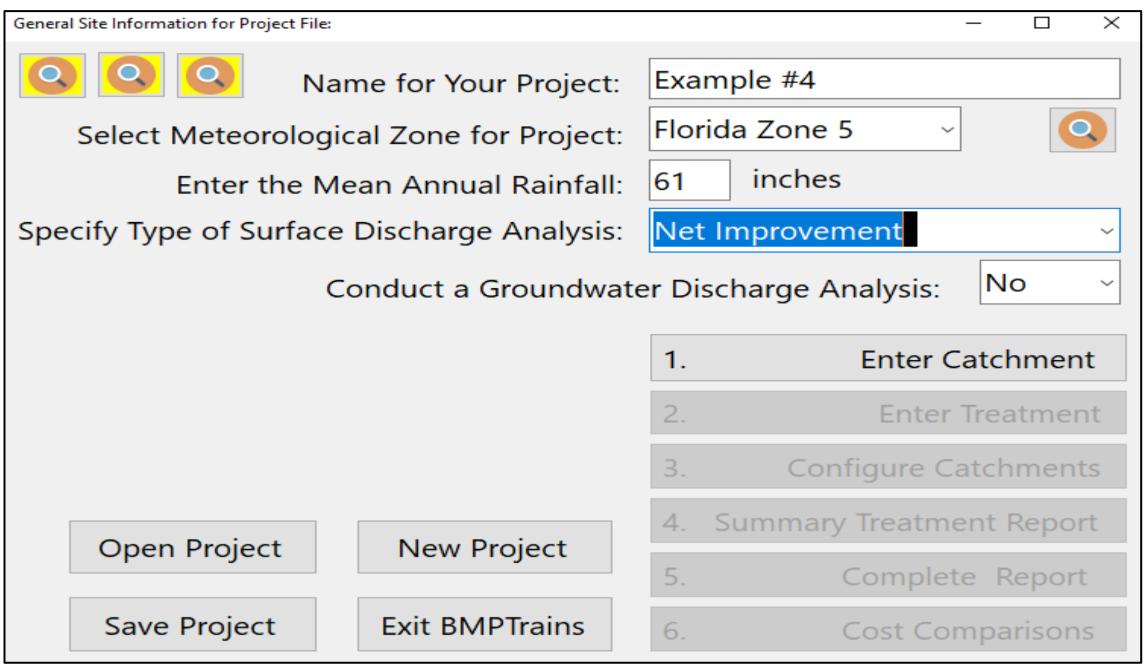

Figure 14a. General Site Information Worksheet.

2. Select the *Enter Catchment* button to proceed to the **Watershed Characteristics Worksheet** (Figure 14b). Indicate the catchment configuration, pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage. Click on the *Calculate* button to review the annual C value, annual runoff (in acre-feet/yr), and the Nitrogen and Phosphorus loadings (in kg/yr). Click on the *Calculate* button to determine pre- and post-development runoff and loadings (just above the *Calculate* button). Click on the *Back* button to return to the **General Site Information Worksheet**.

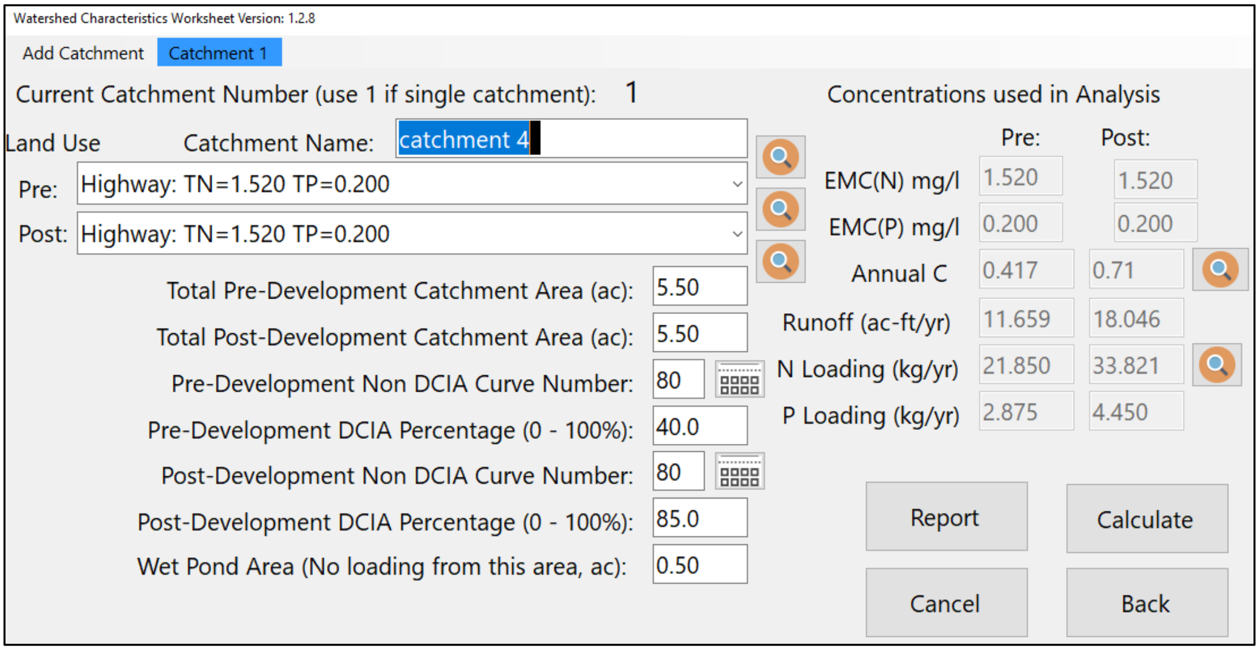

Figure 14b. Watershed Characteristics Worksheet.

3. Select the *Enter Treatment* button to proceed to the **Stormwater Treatment Analysis Worksheet**.

4. Select the *Wet Detention* button to proceed to the **Wet Detention Worksheet** (Figure 14c).

   a. Specify the permanent pool volume in acre-feet, so that **BMP Trains 2020** will calculate the average annual residence time. Since littoral zone is used in the pond, indicate the 10% efficiency credit associated with it. No managed aquatic plants (MAPS) are used in this project, so you may leave the associated credit at 0%.

   b. Click on the *Calculate* button to review the results in the on-screen report. You may also *Print* or *Copy* the results or *Plot* effectiveness as a function of annual residence time. An option is also available to calculate *Anoxic Depth* (depth to the anoxic layer).

   c. Click the *Back* button to return to the **Select Treatment Options Worksheet** and then click the *Back* button again to return to the **General Site Information Worksheet**.

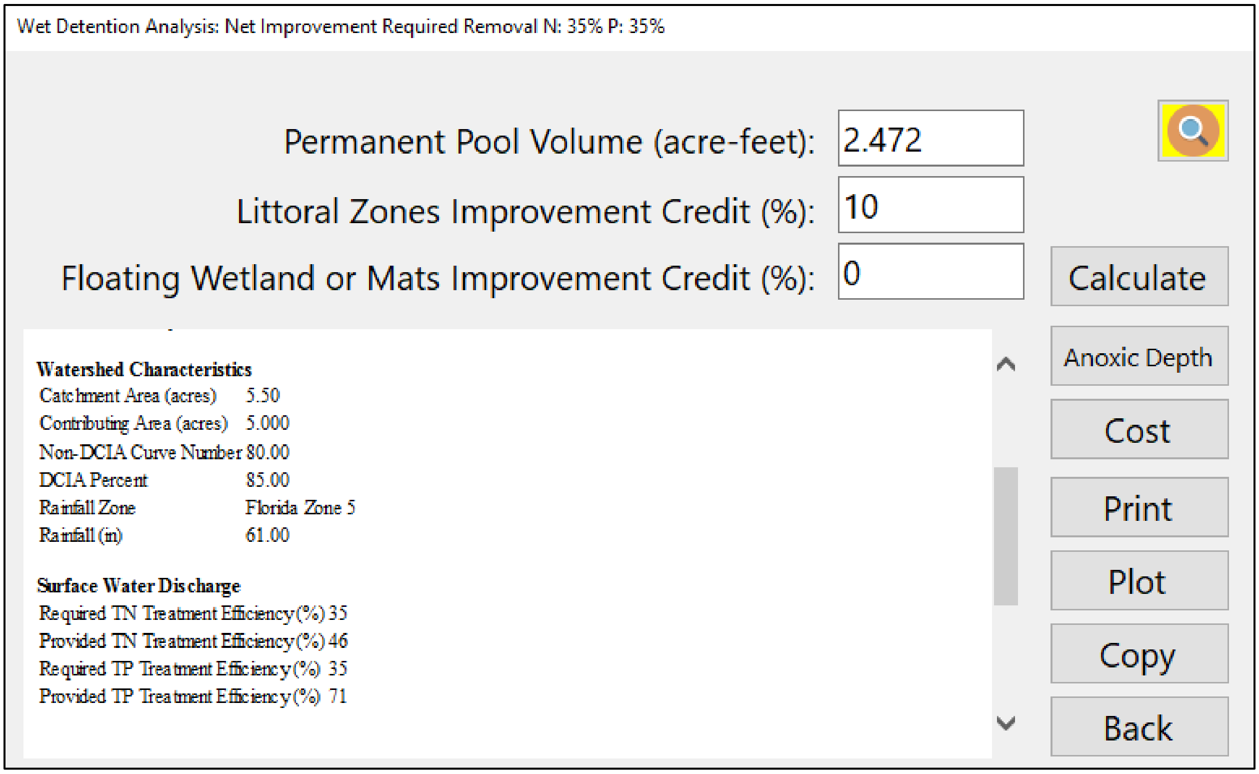

Figure 14c. Wet Detention Worksheet.

5. Click on the *Configure Catchments* button and proceed to the **Select Catchment Configuration Worksheet**. Select the *Edit* button to open the **Routing Catchment Worksheet** as shown in Figure 14d. In the drop-down menu **Select BMP to use in routing,** select Wet Detention. Since this project only has a single catchment which discharges to the outlet (receiving waters) there is no need to change the value for **Select Catchment to Route to**. Click the *Back* button to return to the **Select Catchment Configuration Worksheet** and then click *Back* again to return to the **Site Information Worksheet.**

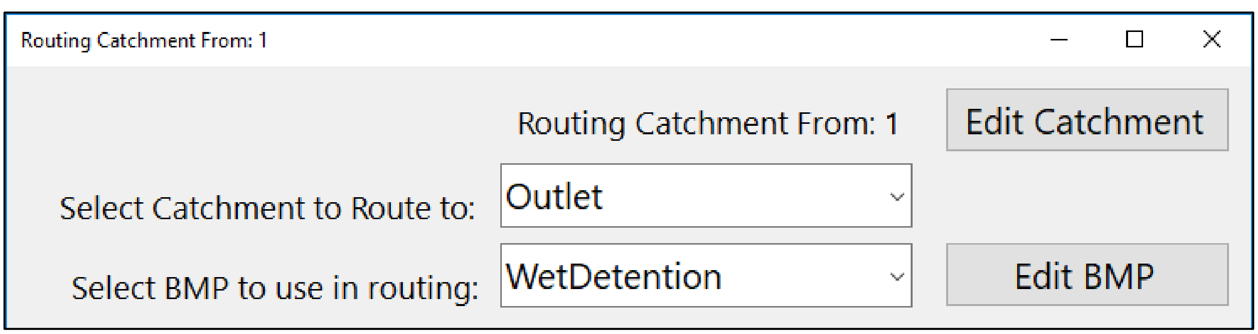

Figure 14d. Routing Catchment Worksheet.

6. You may now view a summary of the treatment achieved for the specified site conditions and BMP used by selecting the *Summary Treatment Report* button. The report opens in a new window (see Figure 14e).

Project: 2 to 4 Lane Higway Example #4

Analysis Type: Net Improvement
BMP Types:
Catchment 1 - (catchment 4) Wet Detention with Littoral Shelf
Based on % removal values to the nearest percent
Total nitrogen target removal met? **Yes**
Total phosphorus target removal met? **Yes**

Routing Summary
Catchment 1 Routed to Outlet

Summary Report

Nitrogen

Surface Water Discharge

Total N pre load	21.85 kg/yr	
Total N post load	33.82 kg/yr	
Target N load reduction	35 %	
Target N discharge load	21.85 kg/yr	
Percent N load reduction	46 %	
Provided N discharge load	18.19 kg/yr	40.12 lb/yr
Provided N load removed	15.63 kg/yr	34.46 lb/yr

Phosphorus

Surface Water Discharge

Total P pre load	2.875 kg/yr	
Total P post load	4.45 kg/yr	
Target P load reduction	35 %	
Target P discharge load	2.875 kg/yr	
Percent P load reduction	71 %	
Provided P discharge load	1.269 kg/yr	2.8 lb/yr
Provided P load removed	3.181 kg/yr	7.014 lb/yr

Figure 14e. Summary Treatment Report.

9. Continuation of example problem 4 is to understand how harvesting of stormwater can be assessed in terms of average annual removal. Stormwater harvesting assessment is based on the assumptions for design and operation as listed in Appendix C. The understanding is that harvesting is added to an already designed wet detention pond but without a bleed-down orifice for the water quality volume. The harvested water has to be irrigated over an area and at an average annual weekly rate (inches). The irrigation area is 3 acres and the average rate of irrigation is 0.8 inches per week. The volume of water available for harvesting from the pond is 1.0 acre-feet. To determine the average annual effectiveness, navigate **BMP Trains 2020** to the Stormwater Harvesting option from the **Select Treatment Options Worksheet.** The selection of the stormwater harvesting BMP is shown in Figure 14f.

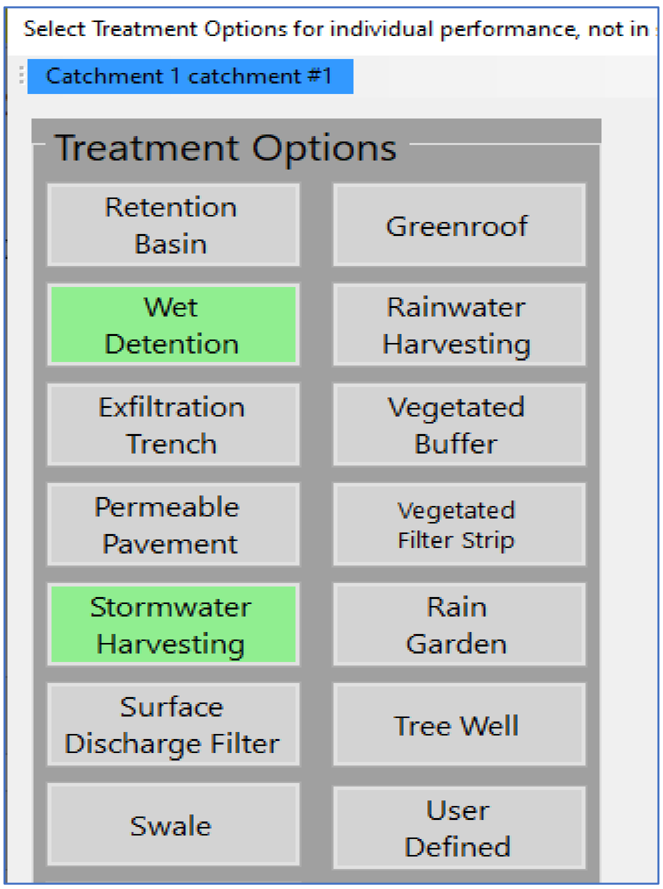

Figure 14f. Navigating to Stormwater Harvesting.

10. From the **Stormwater Harvesting Worksheet**, enter the design parameters as shown in Figure 14g. The total catchment area includes the pond area.

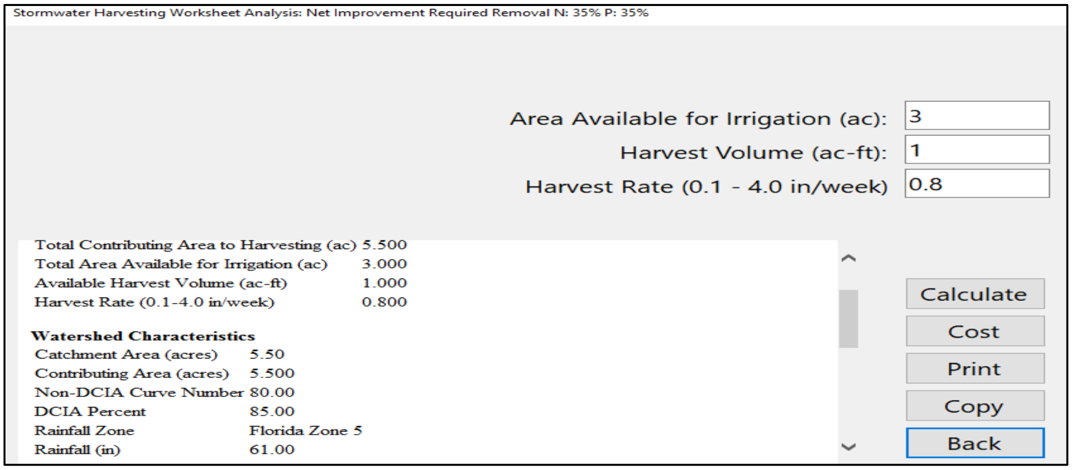

Figure 14g. Input data for Stormwater Harvesting.

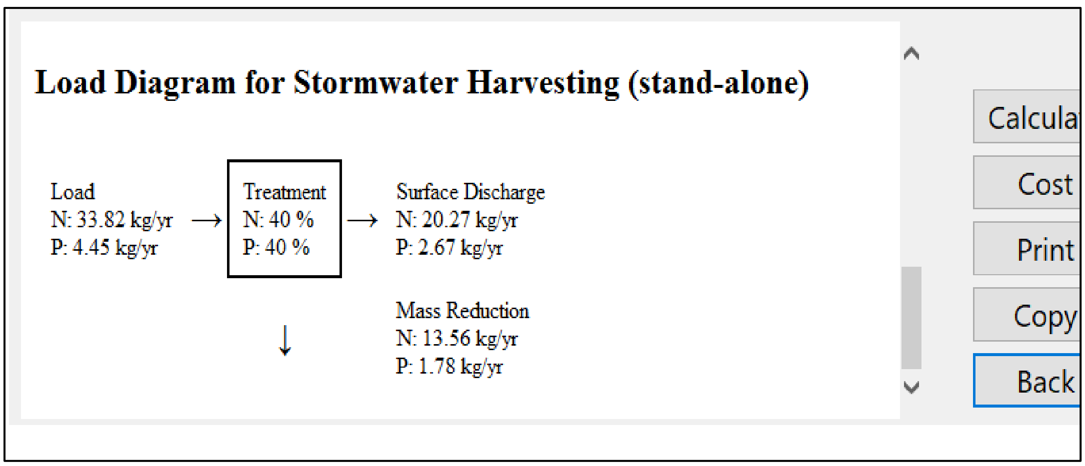

Figure 14h. Mass Diagram for Removal using Stormwater Harvesting.

The mass reduction in the load diagram of Figure 14h is the average annual volume reduction and for a stand-alone operation. It does not include the effectiveness of the wet detention pond and if a pond is used, the removal is based on the remaining concentration in the pond.

11. The wet detention pond and stormwater harvesting BMPs are obviously receiving runoff water from the same catchment. The BMPs are in series within the catchment. Proceed to the **Stormwater Treatment Options Worksheet** and select the **BMP in series** button (Figure 14i). The selection is to calculate the series effectiveness as shown in Figure 14j. It is important to note that the BMPs must be in the order of flow and there cannot be a selection of "**none**" between BMPs. For this example, wet detention for BMP1, must be followed by BMP2 for stormwater harvesting. This is the standard acceptable calculation at this time (January, 2023). The rational is that the water must be collected and stored before it is harvested. Also note that the series calculation is used because there is no catchment input between the BMPs.

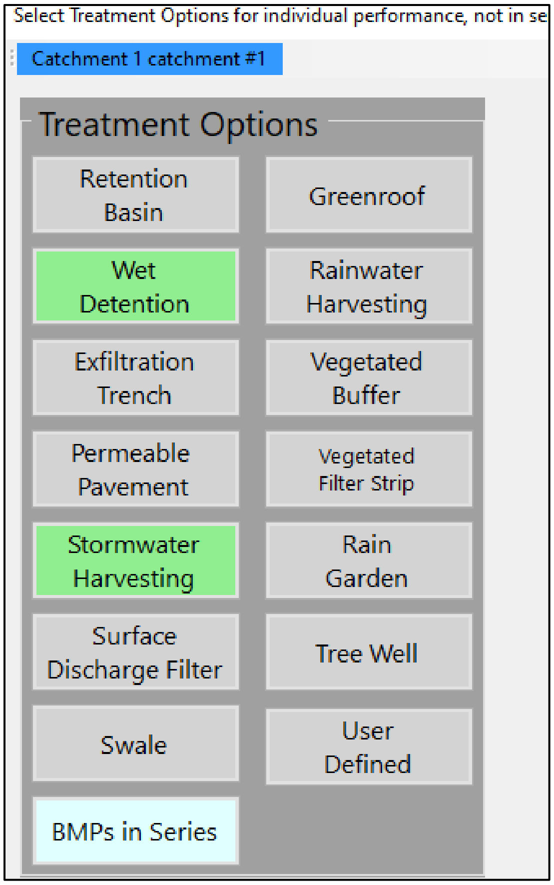

Figure 14i. Select *BMP in Series* Adding Wet Detention and Stormwater Harvesting.

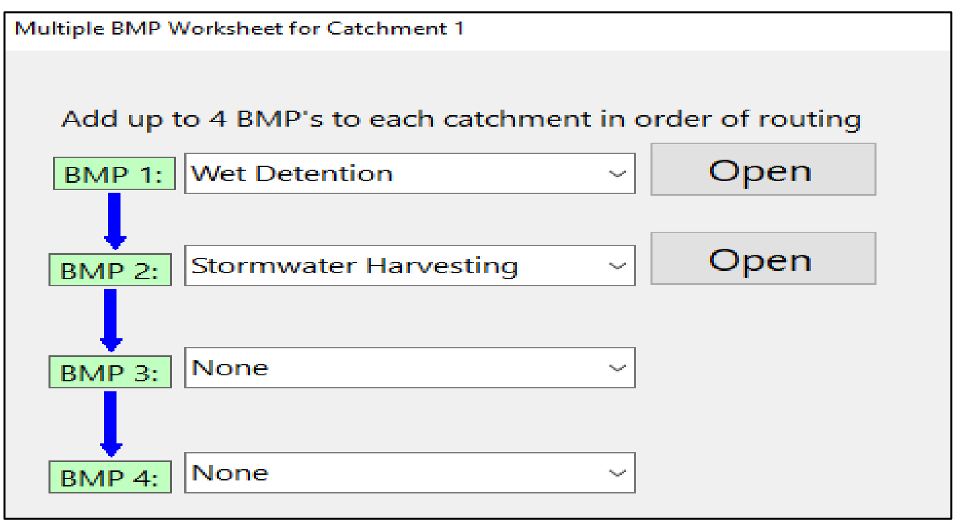

Figure 14j. Multiple BMP Worksheet Showing a Series of BMPs (note: do not "skip" an entry)

The Load diagram for each of the BMPs as if they were stand-alone BMPs as well as the combined result are shown in Figure 14k. The cumulative TN load reduction (in series) is 22.92 kg/yr or 68% ((22.92/33.82)x100). This assumes that the wet detention pond removes the loading before harvesting . Thus the harvesting removal (40% in this case) is applied to the remaining wet pond concentration.

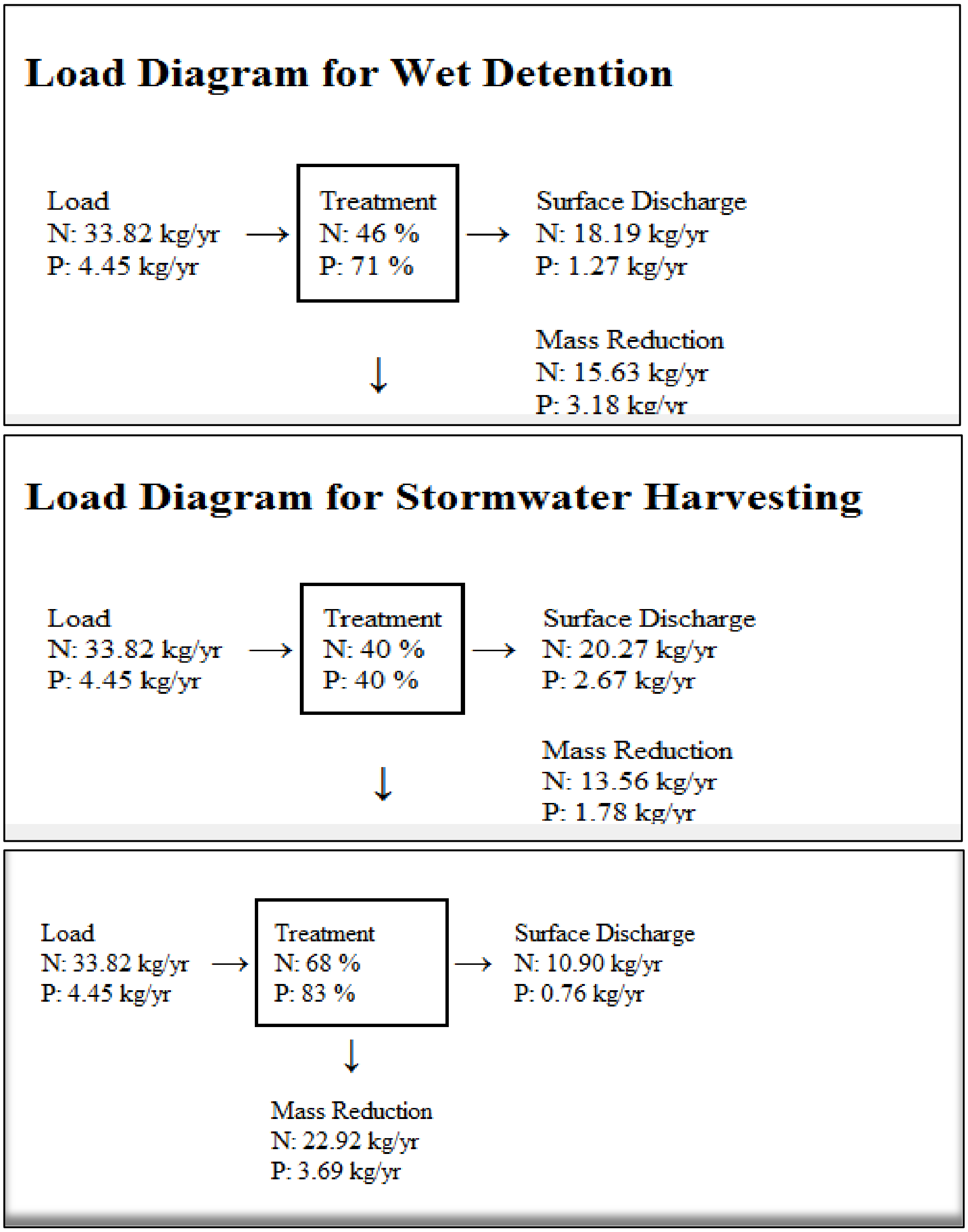

Figure 14k. Load Diagrams for Wet Detention, Stormwater Harvesting, and Combined.

12. Proceed to The **Summary Treatment Report** in Figure 14L. The additional removal of Nitrogen due to the use of stormwater harvesting is 16.08 pounds per year (50.54 from Figure 14L - 34.46 from Figure 14e).

BMP Trains Reports

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Analysis Type: Net Improvement
BMP Types:
Catchment 1 - Multiple BMP
Total nitrogen target removal met? YES
Total phosphorus target removal met? YES

Routing Summary
Catchment 1 Routed to Outlet

Summary Report

Nitrogen

Surface Water Discharge

Total N pre load	21.85 kg/yr	
Total N post load	33.82 kg/yr	
Target N load reduction	35 %	
Target N discharge load	21.85 kg/yr	
Percent N load reduction	68 %	
Provided N discharge load	10.9 kg/yr	24.04 lb/yr
Provided N load removed	22.92 kg/yr	50.54 lb/yr

Phosphorus

Surface Water Discharge

Total P pre load	2.88 kg/yr	
Total P post load	4.45 kg/yr	
Target P load reduction	35 %	
Target P discharge load	2.88 kg/yr	
Percent P load reduction	83 %	
Provided P discharge load	.76 kg/yr	1.68 lb/yr
Provided P load removed	3.69 kg/yr	8.14 lb/yr

Figure 14L. Summary Treatment Report for Wet Detention and Stormwater Harvesting in Series.

Note. Storage for harvesting without wet detention can also be assessed for annual removal. An example is an underground vault. In this assessment, only BMP used is harvesting. This is also a popular option when the harvested water is used for other than irrigation. For this example and with a one acre foot vault, the removal efficiency is 40% (Figure 14h), which is greater than the required 35%. Thus, a smaller vault size should be evaluated.

Example problem # 5 - wet pond after retention. This example demonstrates that two catchments (one for a downstream wet pond) are recommended for analysis because wet ponds usually have a catchment or area contributing to the pond.

A half-acre wet detention pond preceded by a half-acre of retention pre-treatment is serving a new highway. The 6-acre watershed is located in West Palm Beach, FL on mainly Hydrologic Soil Group D. The existing land use condition is classified as Wet Flatwoods with a non-DCIA Curve Number of 80 and 0% DCIA. The post-development land use condition is a highway where the non-DCIA Curve Number is 80 and DCIA is 60% (no pond area included). The target removal efficiency for Nitrogen is 70% and Phosphorus is 80%. The wet detention pond permanent pool can be up to 3.809 ac-ft. The retention volume is 0.75 inch over the catchment. The wet detention pond also will utilize a littoral zone (a 10% removal efficiency credit is allowed). Higher efficiencies are allowed for different designs and maintenance conditions.

1. From the introduction page click on the *Continue* button to proceed to the **General Site Information Worksheet** (Figure 15a).

   a. Enter the project name and select the meteorological zone.
   b. Input the mean annual rainfall amount.
   c. Select the *Specified Removal Efficiency* option from the drop down menu.
   d. Leave the *Conduct a Groundwater Discharge Analysis* selection as “No.”
   e. Specify the desired removal efficiency (80% for both Nitrogen and Phosphorus).

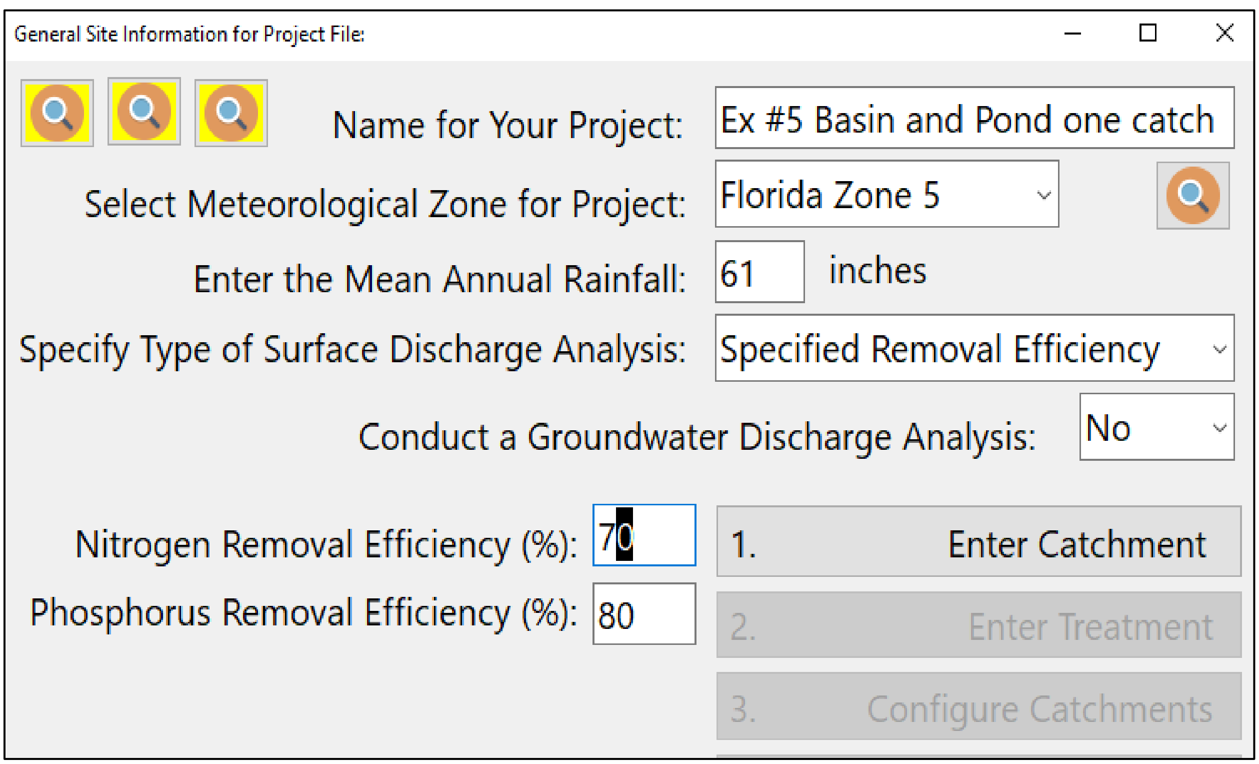

Figure 15a. General Site Information Worksheet.

2. For a one catchment analysis, Select the *Enter Catchment* button to proceed to the **Watershed Characteristics Worksheet** (Figure 15b). Indicate the catchment configuration, pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage. Click on the *Calculate* button to view the annual C value, annual runoff (in acre-feet/yr), and the Nitrogen and Phosphorus loadings (in kg/yr). Click on the *Calculate* button to determine pre- and post-development runoff and loadings (just above the *Calculate* button). Click on the *Back* button to return to the **General Site Information Worksheet**.

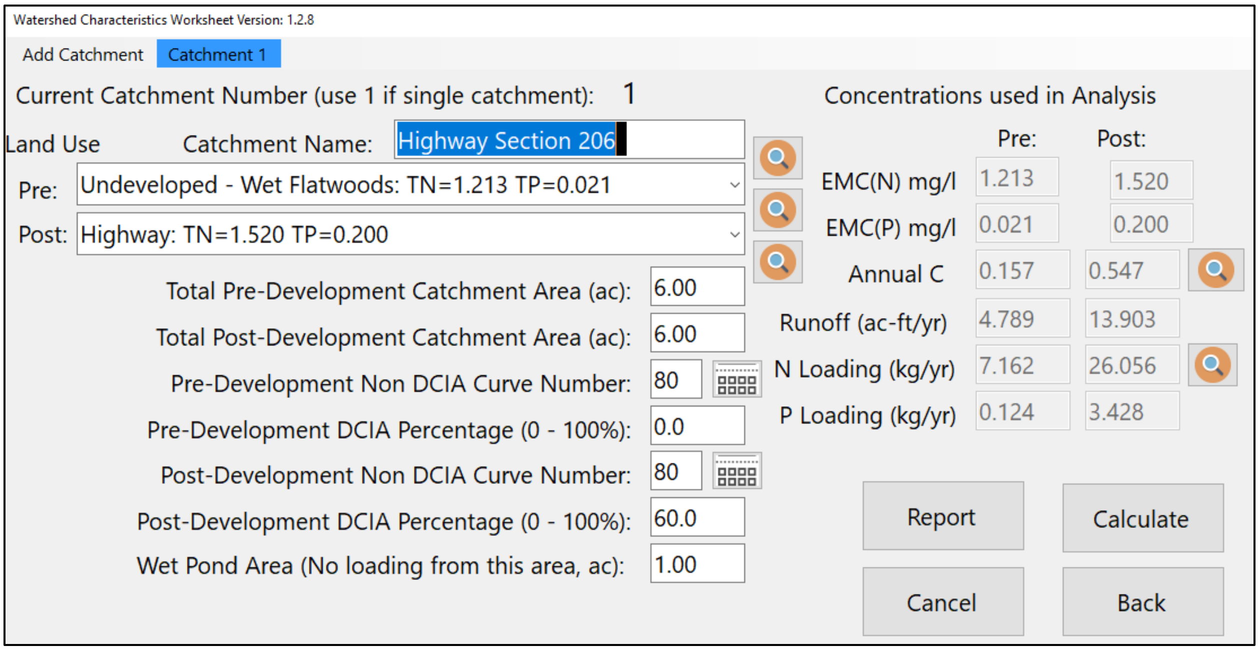

Figure 15b. Watershed Characteristics Worksheet.

3. Select *Enter Treatment* button to proceed to **Stormwater Treatment Analysis Worksheet**.

4. Select *Wet Detention* button to proceed to **Wet Detention Worksheet** (Figure 15c).

   a. Specify the permanent pool volume in acre-feet, and **BMP Trains 2020** will calculate the average annual residence time based on the annual flow for that catchment (stand-alone). Since littoral zone is used in the pond, enter the 10% efficiency credit associated with it. No floating wetlands/mats are used in this project, so leave the associated credit at 0%. Floating wetlands and littoral zone are not recommended to be used together.

   b. Click on the *Calculate* button and you may review the results in the on-screen report. You many also click on the *Anoxic Depth* button.

   c. Click the *Back* button to return to the **Select Treatment Options Worksheet**. Now select the *Retention Basin* button as a second BMP (Figure 15d).

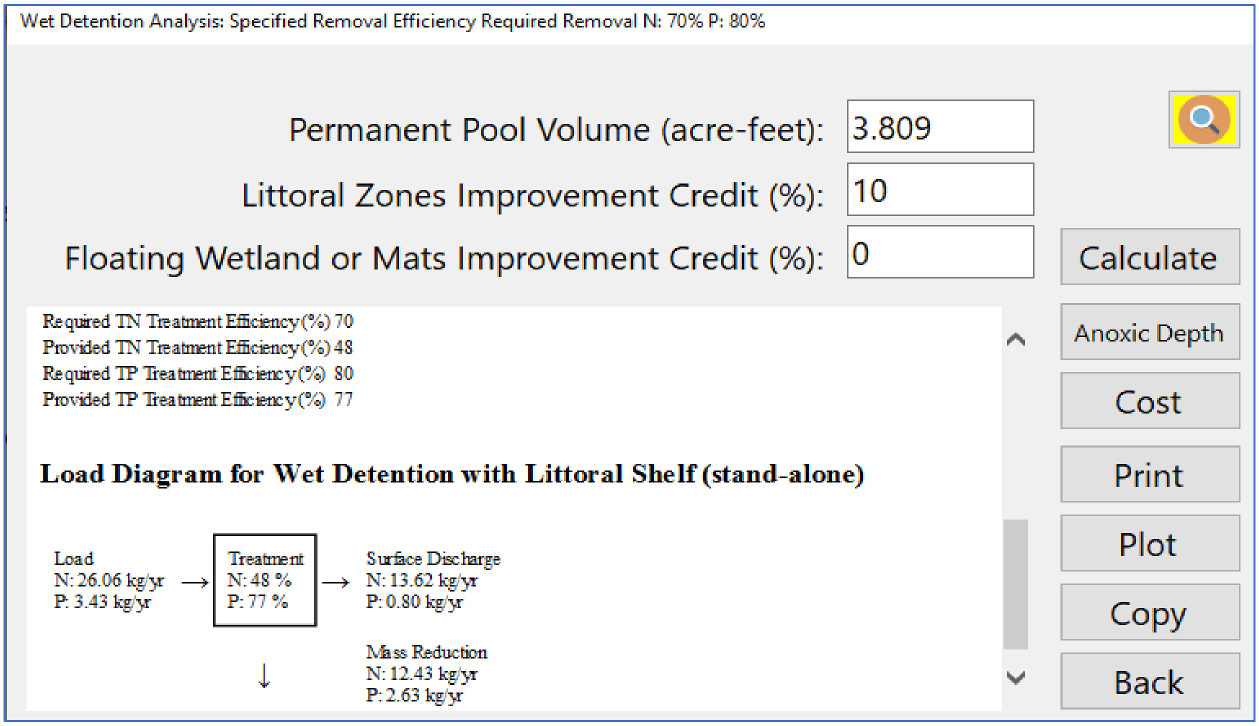

Figure 15c. Wet Detention Worksheet with 100 days Annual Residence Time and 13.903 Ac-ft per year runoff. The size of the wet pond is 3.809 Ac-Ft as a stand-alone pond.

5. Enter the provided retention depth in the **Retention Basin Worksheet** (Figure 15d).

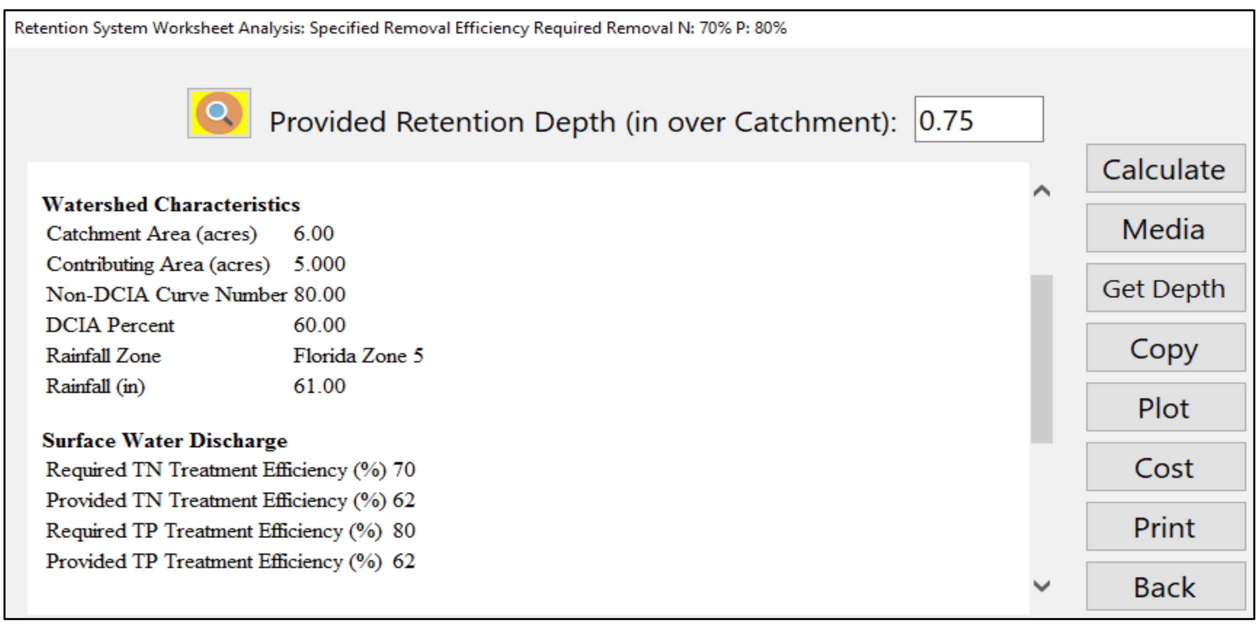

Figure 15d. Retention Basin Worksheet.

Because you have chosen two BMPs in series in the same catchment, you will now configure them together. Select the *BMPs in Series* button on the **Treatment Options**

Worksheet to open the **Multiple BMP Worksheet** for Catchment (see figure 15e). For BMP 1 choose Retention from the drop-down menu and for BMP 2 choose Wet Detention from the drop-down menu. Note the effectiveness of the wet detention pond is reduced because of the removal of particulate matter in retention that is removed by wet detention if there is a stand-alone wet detention BMP. Select the *Calculate* button to view the results in the on-screen report.

Note if anoxic depth is needed after you calculate, the A*noxic Depth* button 

will appear. The wet detention pond must be the last in series to calculate anoxic depth. Next, select the *Back* button to return to the **Select Catchment Configuration Worksheet** and select *Back* button again to return to the **Site Information Worksheet.**

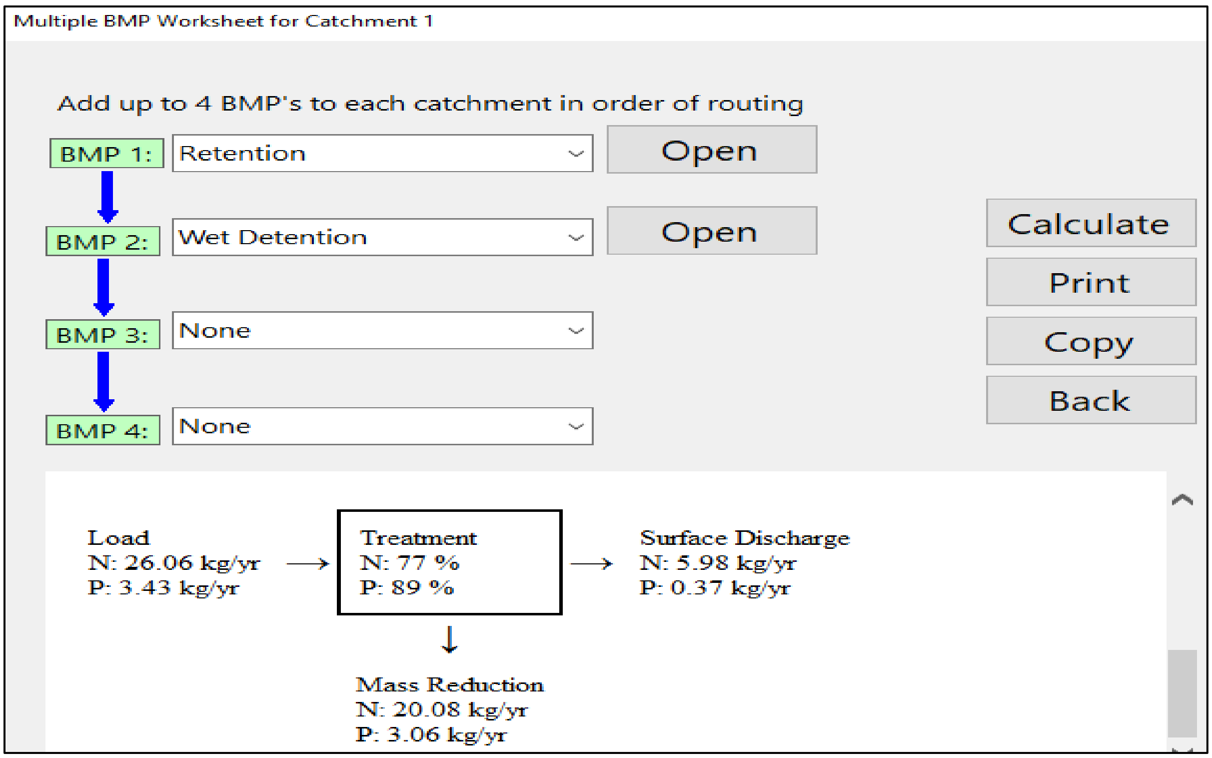

Figure 15e. Multiple BMP Worksheet for Catchment.

6. Go to the **Routing Catchment Worksheet** by way of the **Selection Configuration Worksheet** and edit the BMPs so that *Multiple BMP* is selected (see Figure 15f).

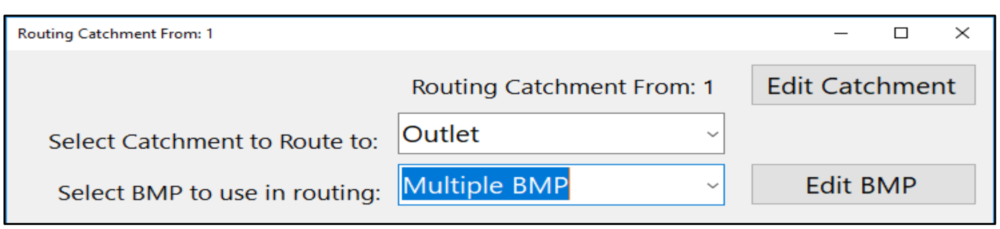

Figure 15f. Edit the Routing Catchment and Selection Configuration Worksheet, One Catchment.

A more accurate analysis uses two catchments. Flood control for the pond specifies a minimum of 1.447 ac-ft to meet post = pre peak discharge. The calculation for annual residence time is residence time = permanent pool divided by the annual flow. For this case the reduced runoff after retention is 6.13 ac-ft/yr and the permanent pool is 1.447 ac-ft. The reduce flow is found in the Catchment Configure Worksheet and using the Flow Balance Report Thus, the annual residence time is 86 days. Also, a comparison between one and two catchment analysis with two wet pond sizes is shown in the Summary 0utputs of Figure 15g. Summary Output a) is for one catchment with retention and pond, and b) is for two catchments (one is 4.5 acres with retention, and the second is 1.5 acre to include the pond (1.447 ac-ft permanent pool). The retention basin size remains at 0.75 inches for both analysis. Most ponds have an adjacent runoff area and thus a two catchment configuration is generally more accurate. Note, the EMC value for the pond catchment is usually the same as with the upstream catchment. For a wet pond after retention, it is recommended to use more than one catchment for analysis.

7. View a summary of the average annual treatment achieved for existing site conditions using one and two catchments by selecting the *Summary Treatment Report* button (see Figure 15g). The constraint of 70% and 80% removal are meet with both designs and if possible the sizes of the BMPs can be further reduced because the load reductions are greater than the targets.

Project: Ex # 5 basin & pond one catch

Analysis Type: Specified Removal Efficiency
BMP Types:
Catchment 1 - (Highway Section 206) Multiple BMP
Based on % removal values to the nearest percent
Total nitrogen target removal met? **Yes**
Total phosphorus target removal met? **Yes**

Summary Report
Nitrogen

Surface Water Discharge

Total N pre load	7.16 kg/yr	
Total N post load	26.06 kg/yr	
Target N load reduction	70 %	
Target N discharge load	7.82 kg/yr	
Percent N load reduction	77 %	
Provided N discharge load	5.98 kg/yr	13.18 lb/yr
Provided N load removed	20.08 kg/yr	44.27 lb/yr

Phosphorus

Surface Water Discharge

Total P pre load	.124 kg/yr	
Total P post load	3.428 kg/yr	
Target P load reduction	80 %	
Target P discharge load	.686 kg/yr	
Percent P load reduction	89 %	
Provided P discharge load	.372 kg/yr	.82 lb/yr
Provided P load removed	3.056 kg/yr	6.739 lb/yr

a) One Catchment with Retention & Pond

Project: Ex # 5 basin & pond two catch

Analysis Type: Specified Removal Efficiency
BMP Types:
Catchment 1 - (Highway Section 206) Retention
Catchment 2 - (Catchment 0) Wet Detention
Based on % removal values to the nearest percent
Total nitrogen target removal met? **Yes**
Total phosphorus target removal met? **Yes**

Summary Report
Nitrogen

Surface Water Discharge

Total N pre load	7.16 kg/yr	
Total N post load	26.06 kg/yr	
Target N load reduction	70 %	
Target N discharge load	7.82 kg/yr	
Percent N load reduction	73 %	
Provided N discharge load	6.91 kg/yr	15.25 lb/yr
Provided N load removed	19.14 kg/yr	42.21 lb/yr

Phosphorus

Surface Water Discharge

Total P pre load	.124 kg/yr	
Total P post load	3.428 kg/yr	
Target P load reduction	80 %	
Target P discharge load	.686 kg/yr	
Percent P load reduction	85 %	
Provided P discharge load	.508 kg/yr	1.12 lb/yr
Provided P load removed	2.921 kg/yr	6.44 lb/yr

b) Two Catchments with Retention & Pond

Figure 15g. Summary Treatment Reports: Both ponds are 1.447 Acre-Feet.

Example problem # 6 – Multiple BMPs in one watershed and cost analysis

This example illustrates multiple BMPs in one catchment and a cost analysis. The details for the catchment, BMPs treatment, and the configuration will be introduced by the screen captures. The cost data is dependent on site conditions as well as local labor conditions and represent one combination of time and labor and should not be used as a general indicator.

1. From the introduction page click on the *Continue* button to proceed to the **General Site Information Worksheet** (Figure 16a).

   a. Enter the project name and select the meteorological zone.
   b. Input the mean annual rainfall amount.
   c. Select the *Specified Removal Efficiency* option from the drop down menu.
   d. Leave the *Conduct a Groundwater Discharge Analysis* selection as "No."
   e. Specify net improvement (this automatically is for both Nitrogen and Phosphorus).

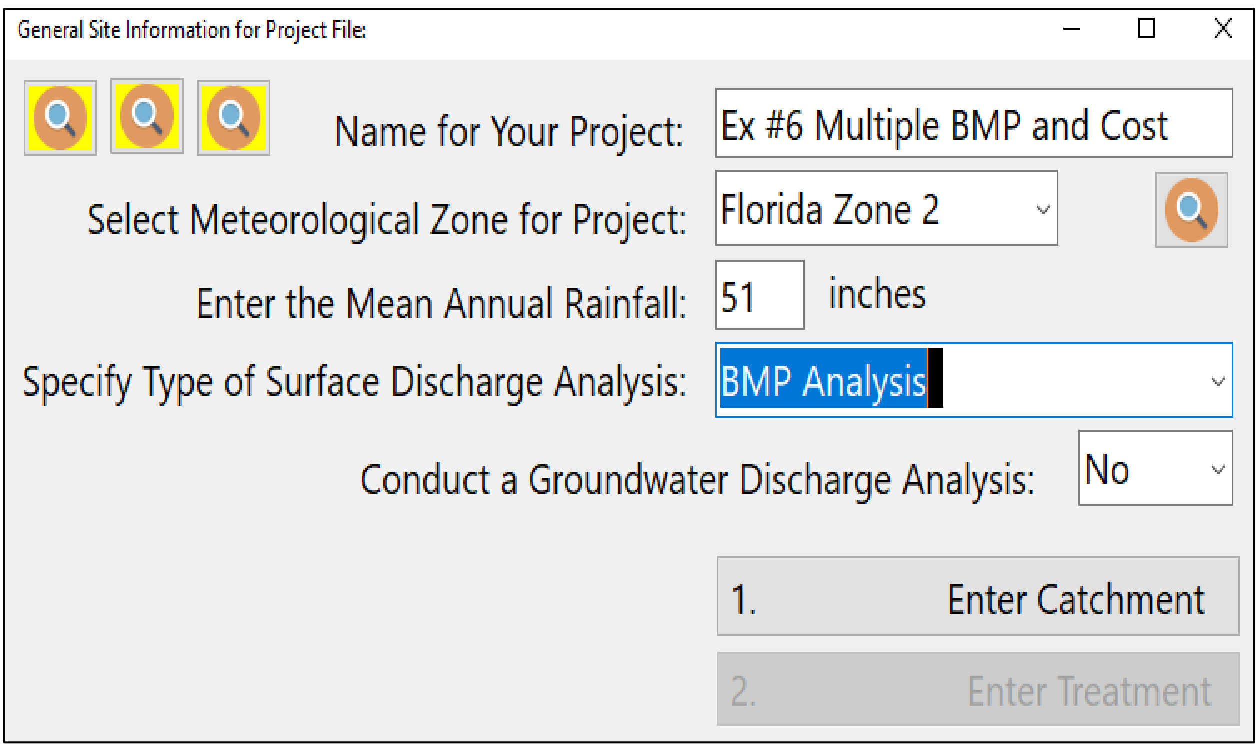

Figure 16a. Site Information Input.

2. Select the *Enter Catchment* button to proceed to the **Watershed Characteristics Worksheet** (Figure 16b). Indicate the catchment configuration, pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage. Click on the Calculate button to view the annual C value, annual runoff (in acre-feet/yr), and the Nitrogen and Phosphorus loadings (in kg/yr). Click on the *Back* button to return to the **General Site Information Worksheet**.

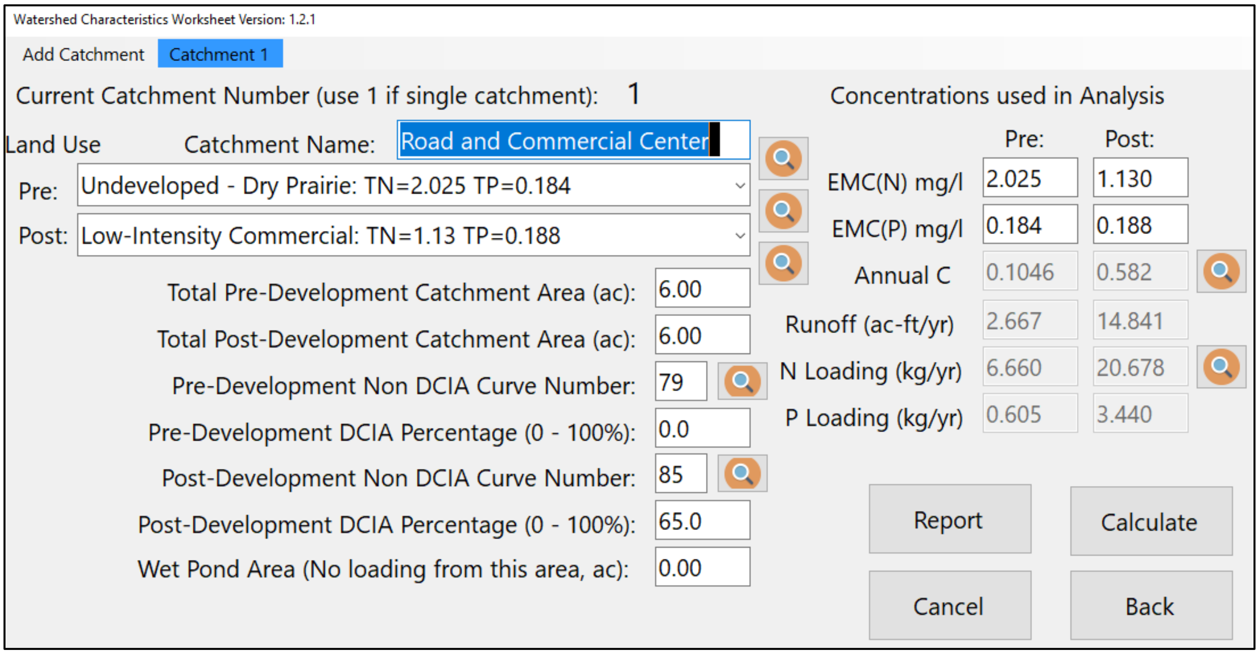

Figure 16b. Watershed Characteristics.

3. Select the *Enter Treatment* button to proceed to the **Stormwater Treatment Analysis Worksheet**.

4. Select the *Retention* button to proceed to the **Retention Worksheet** (Figure 16c).

   a. Specify the treatment depth in inches over the catchment, so that **BMP Trains 2020** will calculate the average annual removal. The depth is determined by the BMP volume available and the catchment area. The volume for this site is 0.50 ac-ft and the area is 6 acres, thus the depth of treatment is 0.50 ac-ft x 12 in/ft / 6 acres or 1.0 inch.
   b. Click on the *Calculate* button and review the results in the on-screen report. This BMP is not sufficient to meet net improvement. The ribbon across the top of each BMP screen print specifies the desired surface discharge removal if the BMP were used alone and is the overall surface discharge removal target.
   c. Click the *Back* button to return to the **Select Treatment Options Worksheet**. Now select the *Exfiltration* button as another BMP.

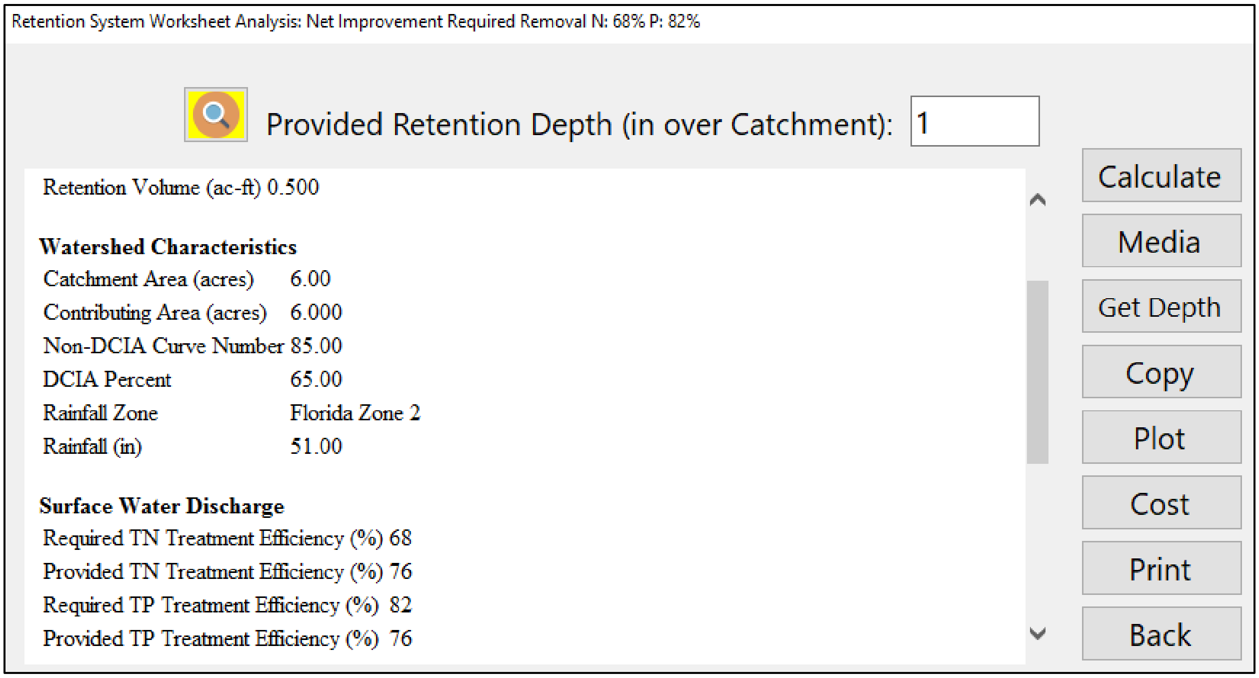

Figure 16c. Retention Basin Analysis.

The required removal % for surface discharge is based on net improvement and it is 68% for TN and 82% for TP. The provided annual removal with the one inch of retention is 76%. Thus, options for increasing TP removal include making the retention basin larger (but this is not desired or possible), adding within the catchment other BMPs (tree wells are planned but no credit has been calculated, as well as the addition of Exfiltration pipe after the retention area). A greenroof and stormwater harvesting are also possible but not considered within this example. The exfiltration pipe in this case can also be used to transport specified flood flow rate. Thus the exfiltration pipe credit as well as the tree well credit will be added to the treatment train.

5. Go to the **Exfiltration Systems Worksheet** and enter the exfiltration pipe dimensions (see Figure 16d). Note the aggregate void fraction cannot be greater than one. If a value greater than one is entered, the void fraction will be set to one for exfiltration volume calculations. For this example, the exfiltration pipe provides a capture efficiency of 19% in a retention configuration as if they were a stand-alone treatment. However the overall effectiveness of all retention is based on the sum of the retention volumes of all the retention BMPs and will be calculated when the exfiltration system is placed in a treatment train.

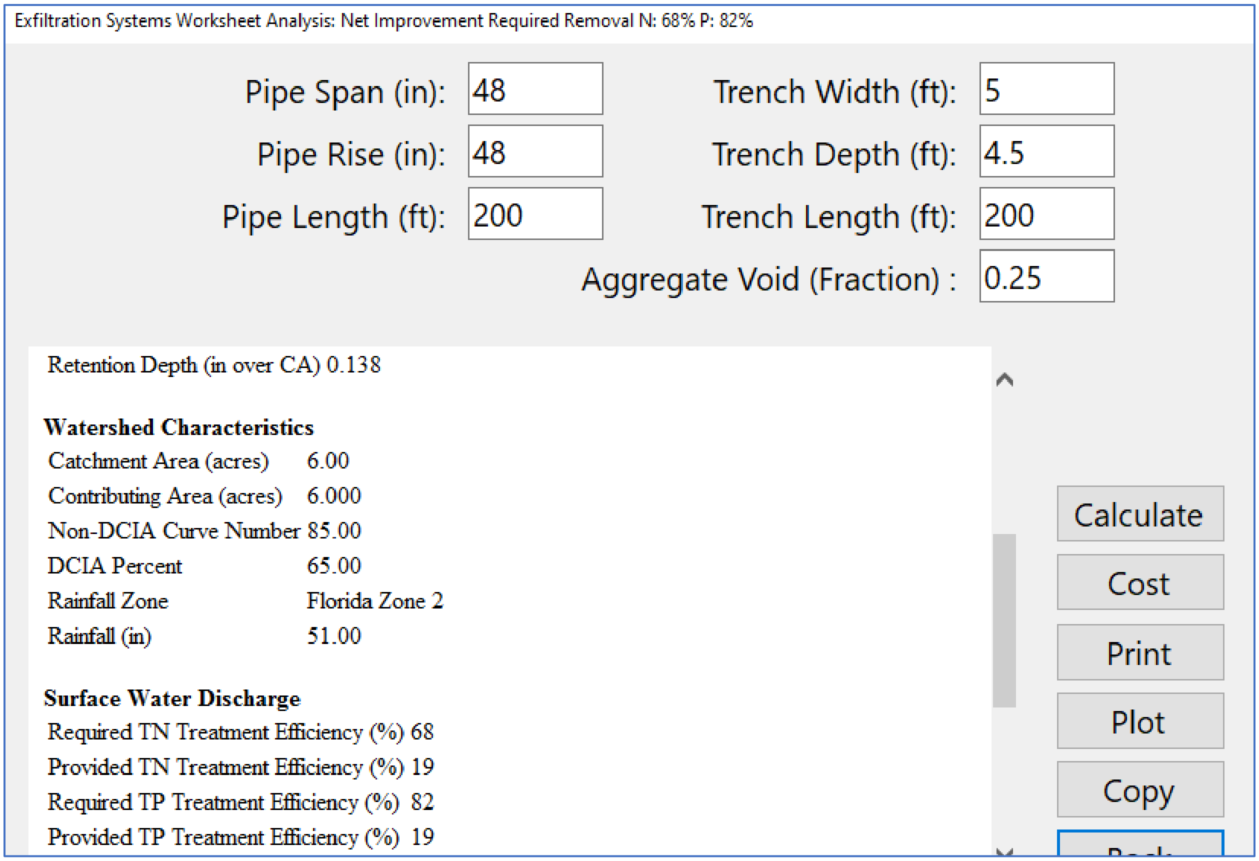

Figure 16d. Exfiltration Pipe Input Calculator and Analysis Worksheet.

Return to the **Select Treatment Options Worksheet**, and it will have highlighted the two BMPs already selected as shown in Figure 16e.

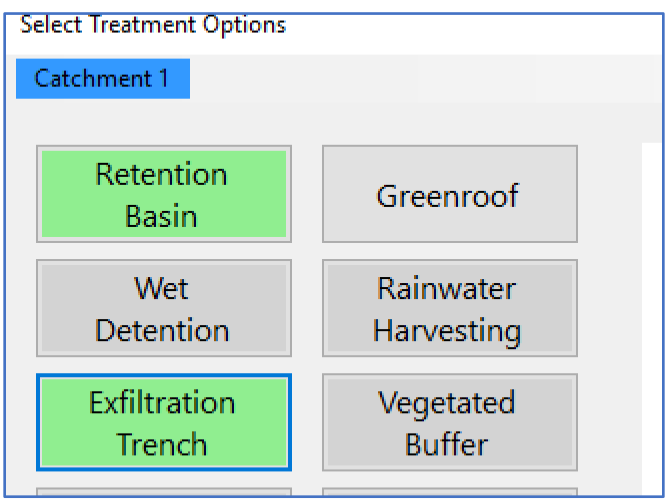

Figure 16e. Example of BMPs in use within the Catchment in Select Treatment Option Worksheet.

Add another BMP, tree wells as shown in the attached **Tree Well Worksheet** (Figure 16f). The input data for the tree wells are shown. The water entering into the tree wells is retained. The annual capture volume is 19% (see Provided TN Treatment Efficiency).

There is no media selected because there is no need for groundwater assessment. If "conduct a groundwater discharge analysis" is selected on the **General Site Information Worksheet**, then the selection of media can be made. The selected media must be sufficient to provide structural support for the vegetation. In this case the tree support will need 2 feet of CTS media, or the selection of B&G CTS24. The TN discharge to the groundwater with the addition of the CTS24 media for this case is 0.960 kg/yr (this is not shown as a screen capture). The remainder of the example problem does not use pollution control media in the tree well.

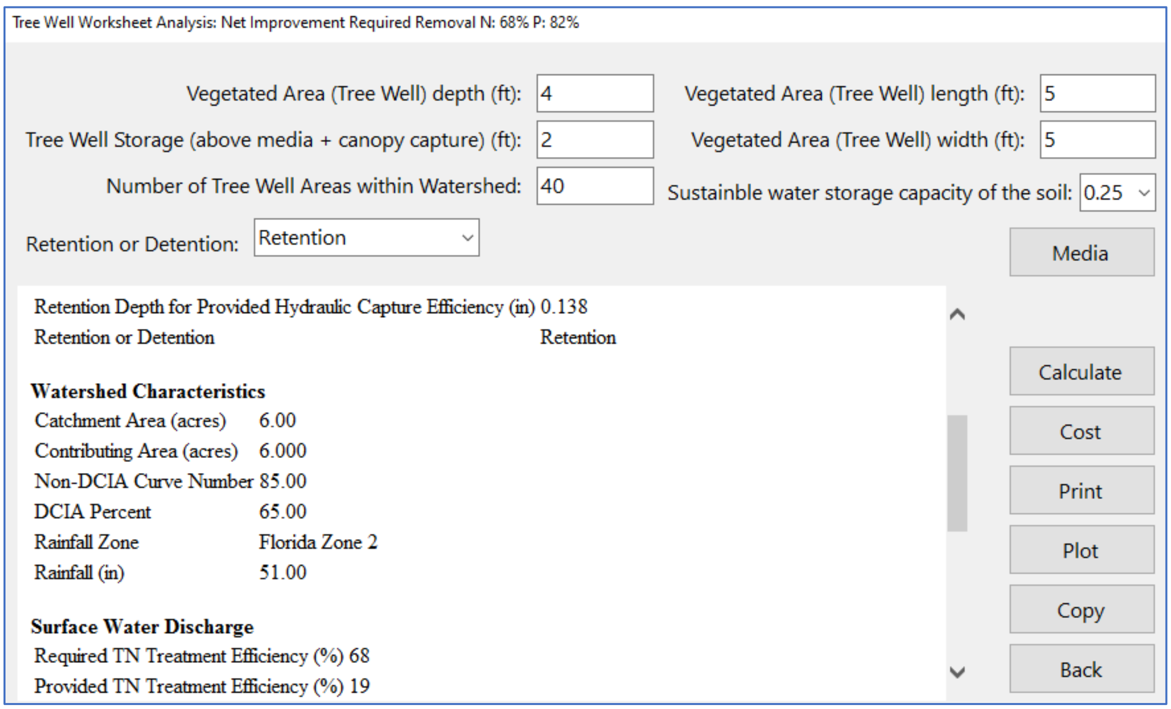

Figure 16f. Tree Well Input and Analysis Worksheet.

6. Return to the **Select Treatment Options Worksheet, (** Figure 16g). Because there are three BMPs in series in the **same catchment**, the program can configure them together or there is no need to define three catchments. Select the *BMPs in Series* button to open the **Multiple BMP Worksheet** for the same Catchment (see Figure 16h).

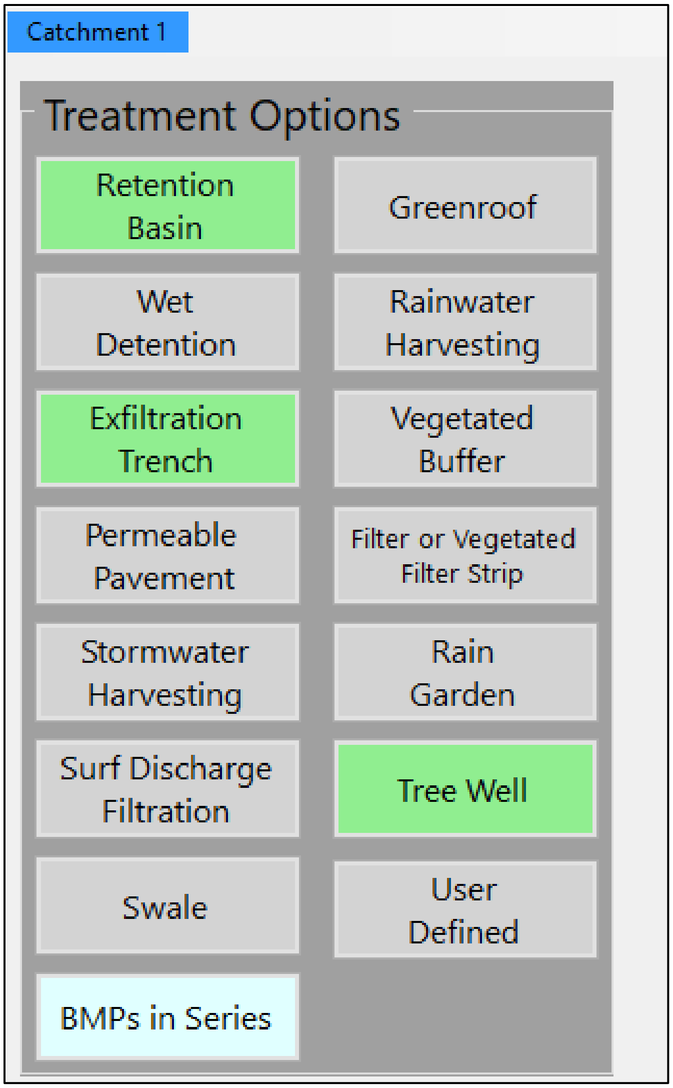

Figure 16g. In Select Treatment Options Worksheet, Select BMPs in Series (within the same catchment).

The **Multiple BMP Worksheet** is shown in Figure 16h for BMP in series. The runoff water flows into tree wells (small depression areas with trees), then to an exfiltration pipe and finally to a retention basin. All are infiltration or retention BMPs. Thus the sum of the retention volumes (depth) is used to calculate annual removal effectiveness. There is a drop down menu for the selection of BMP in the appropriate order of flow. Select the *Calculate* button; to view the results in the on-screen report. The overall average annual removal is 82% for both TN and TP. The target annual average removal based on net improvement was 68% for TN and 82% for TP. Thus, the BMPs as designed for this single catchment meets the net improvement criteria.

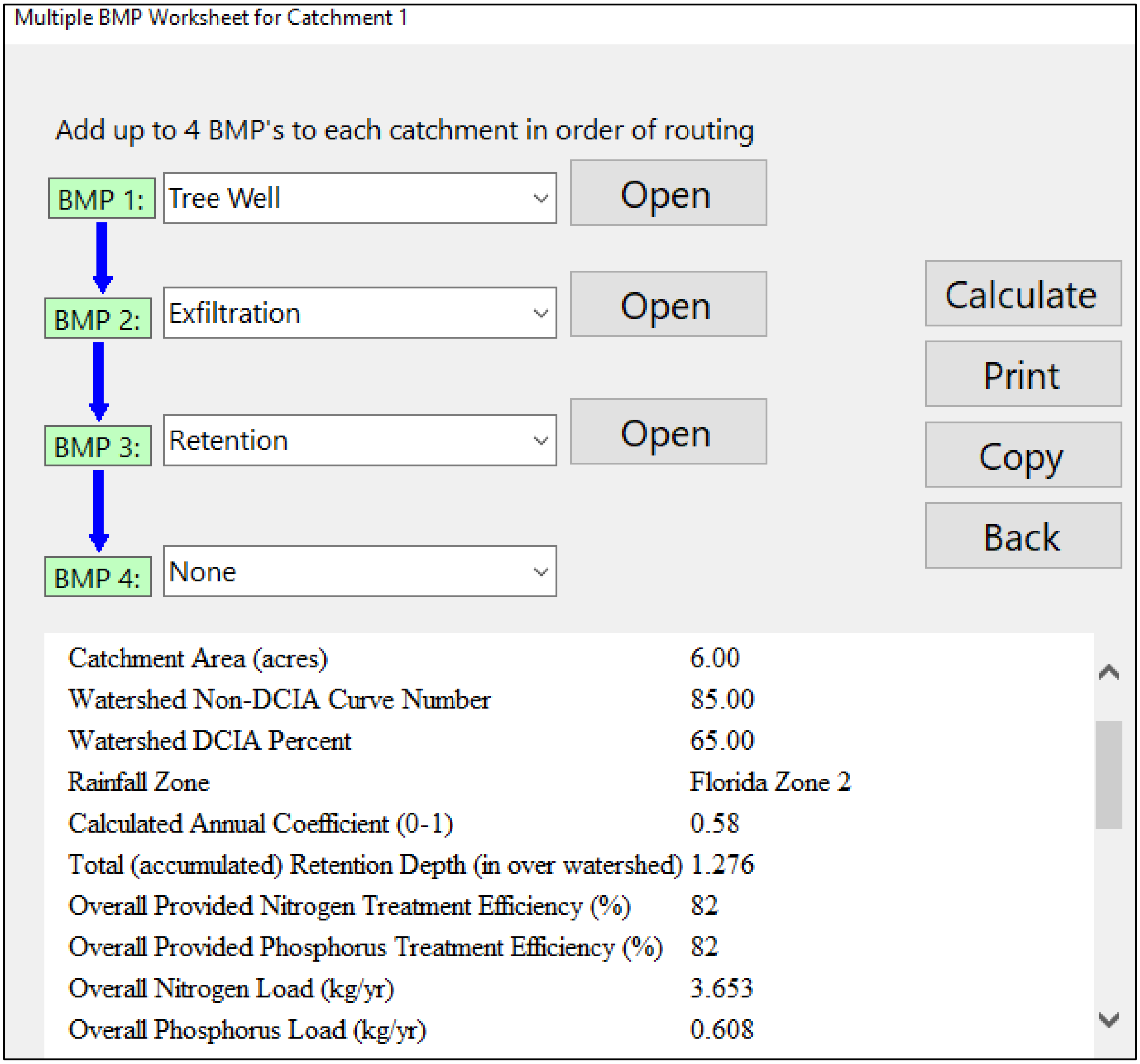

Figure 16h. In the Multiple BMP Worksheet, the BMPs are Selected in the Order of Flow.

7. Continue the analysis by selecting the *Back* button to return to the **Select Catchment Configuration Worksheet** and select *Back* again to return to the **Site Information Worksheet.** Next select the *Configure Catchment* button as shown in Figure 16i.

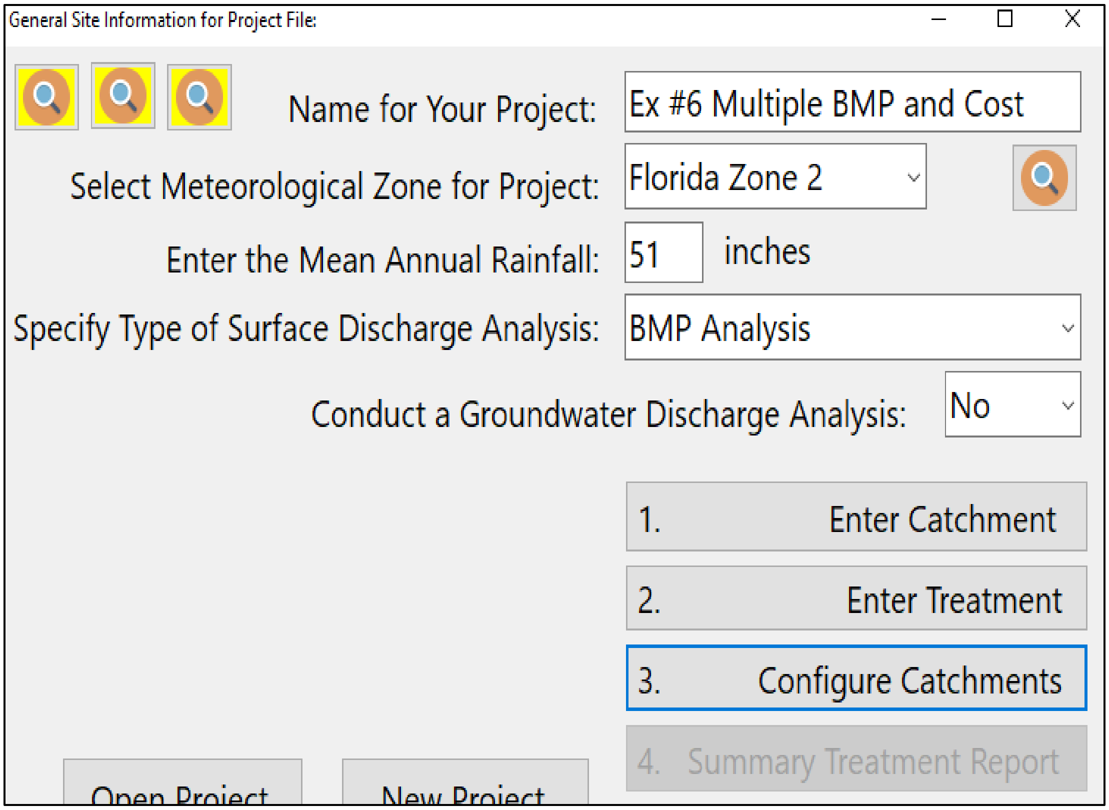

Figure 16i. Selection of the *Configure Catchments* button.

8. Edit the **Routing Catchment Worksheet** as shown in Figure 16j.

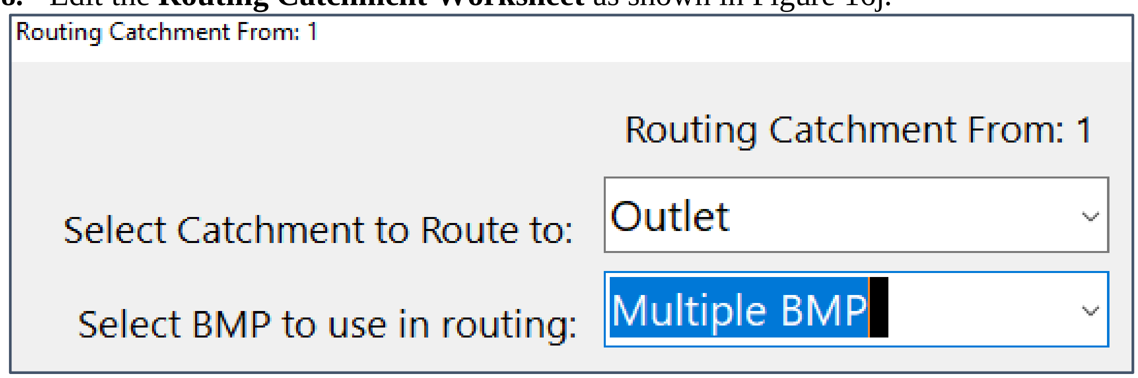

Figure 16j. Edit to Enter Multiple BMPs as shown in the Routing Catchment Worksheet.

9. Return to the **General Site information Worksheet and** click on the *Summary Treatment Report* Button of the **General Site Information Worksheet**

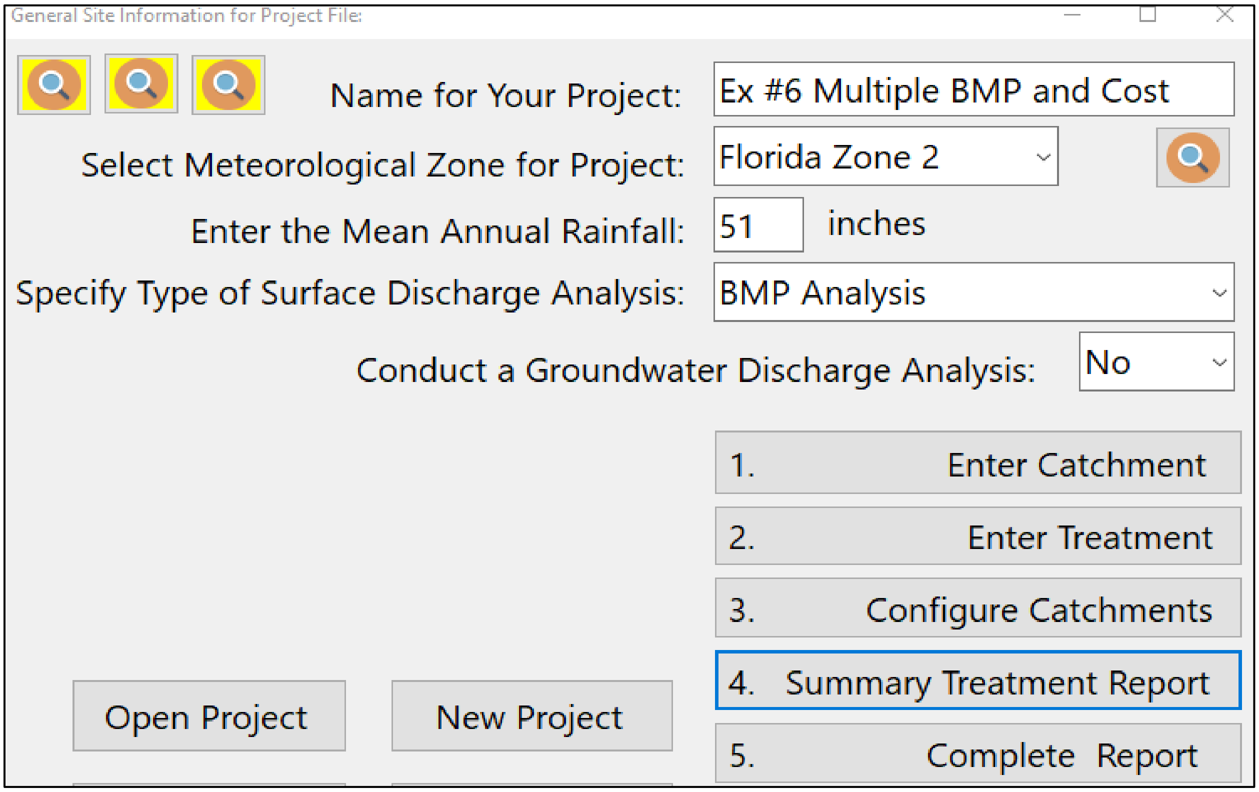

Figure 16k. Enter the Summary Treatment Report.

The summary treatment report is shown in Figure 16L. The BMP design meets the net improvement target average annual removal for surface discharges. Since the BMPs are retention in series, the cumulative retention volume is used to calculate the annual average surface discharge % removal of 82%.

Project: Example 6 Multiple BMP & Cost

Analysis Type: Net Improvement
BMP Types:
Catchment 1 - Multiple BMP
Total nitrogen target removal met? YES
Total phosphorus target removal met? YES

Routing Summary
Catchment 1 Routed to Outlet

Summary Report

Nitrogen

Surface Water Discharge

Total N pre load	6.66 kg/yr	
Total N post load	20.68 kg/yr	
Target N load reduction	68 %	
Target N discharge load	6.66 kg/yr	
Percent N load reduction	82 %	
Provided N discharge load	3.65 kg/yr	8.05 lb/yr
Provided N load removed	17.03 kg/yr	37.54 lb/yr

Phosphorus

Surface Water Discharge

Total P pre load	.61 kg/yr	
Total P post load	3.44 kg/yr	
Target P load reduction	82 %	
Target P discharge load	.61 kg/yr	
Percent P load reduction	82 %	
Provided P discharge load	.61 kg/yr	1.34 lb/yr
Provided P load removed	2.83 kg/yr	6.25 lb/yr

Figure 16L. Summary Treatment Report.

10. Continue the analysis for a cost estimate. The cost data are entered for each BMP treatment system (for retention see Figures 16m and 16n). There is a *cost* button on each BMP treatment worksheet that allows the cost input data for that BMP.

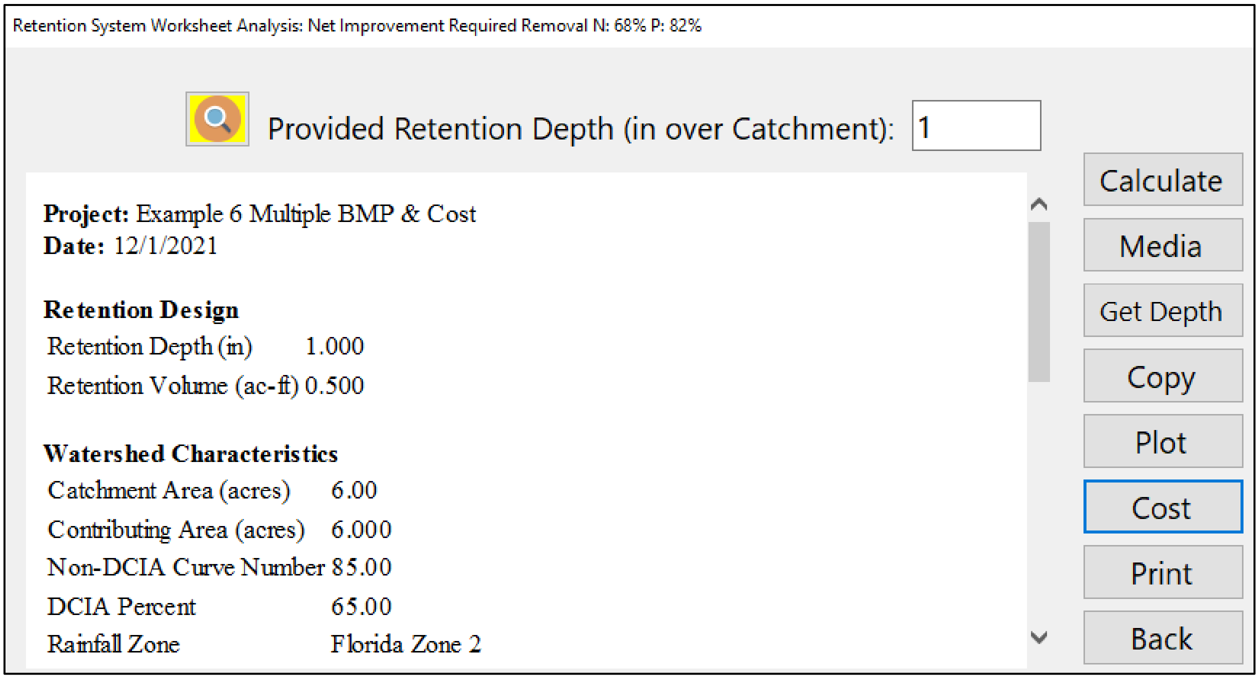

Figure 16m. Enter the Cost data from the Treatment BMP.

11. The cost data entered for the retention basin BMP are shown in Figure 16n. Once all data are entered, the *Calculate* button is clicked.

    First, general remarks about cost data can be helpful. Cost data are site specific and as such require input that usually is different for each particular location. The cost data input allows the inclusion of set up cost as a fixed cost or it can be included within the unit cost. Also land cost can be included or not included. There is also an option for revenue generation, as an example from harvesting operations. Harvesting of water under retention basins is an option in some locations, and thus it is included as input.

    For retention basins, the construction cost is based on the volume of retention and the units as shown are in acre-feet. Note that this unit cost in acre-feet may have economies of scale and thus should be calculated for the approximated or exact size of the retention basin in acre-feet. Interest rates can be expected to change over time and thus reference to local conditions is again required for a more accurate projection of cost. The resulting cost are calculated as construction and present value (PV) to provide a means of comparing BMP options as well as budget allocations for construction and annual operation.

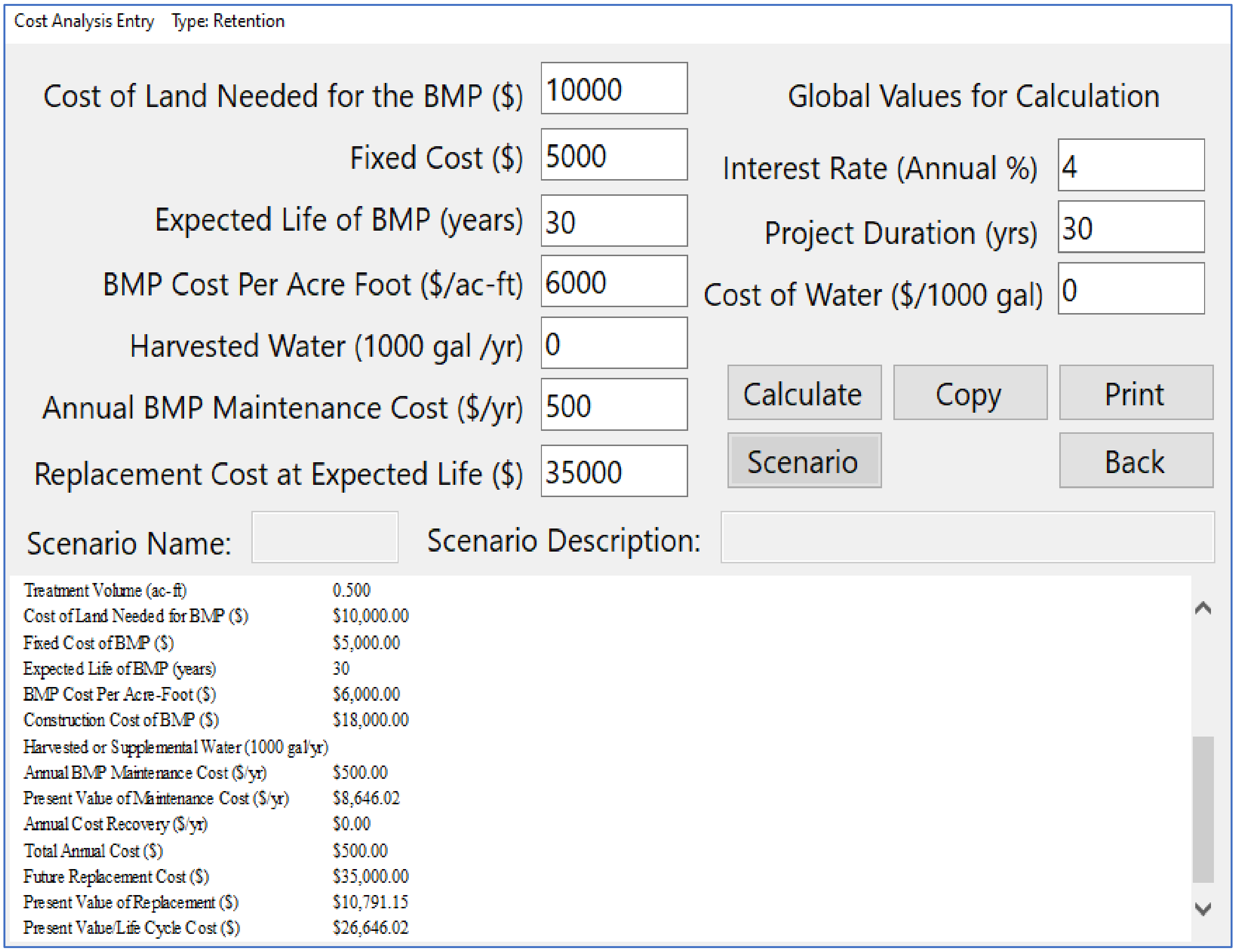

Figure 16n. Cost Analysis for Retention Worksheet with Calculations.

Note that the present value calculation results are shown. For this particular situation, the present value over the 30 year life cycle is $26, 646.02.

12. Using a parallel navigation procedure for other input cost data, the cost data are entered for exfiltration and for tree wells as shown in Figure 16o and Figure 16p respectively.

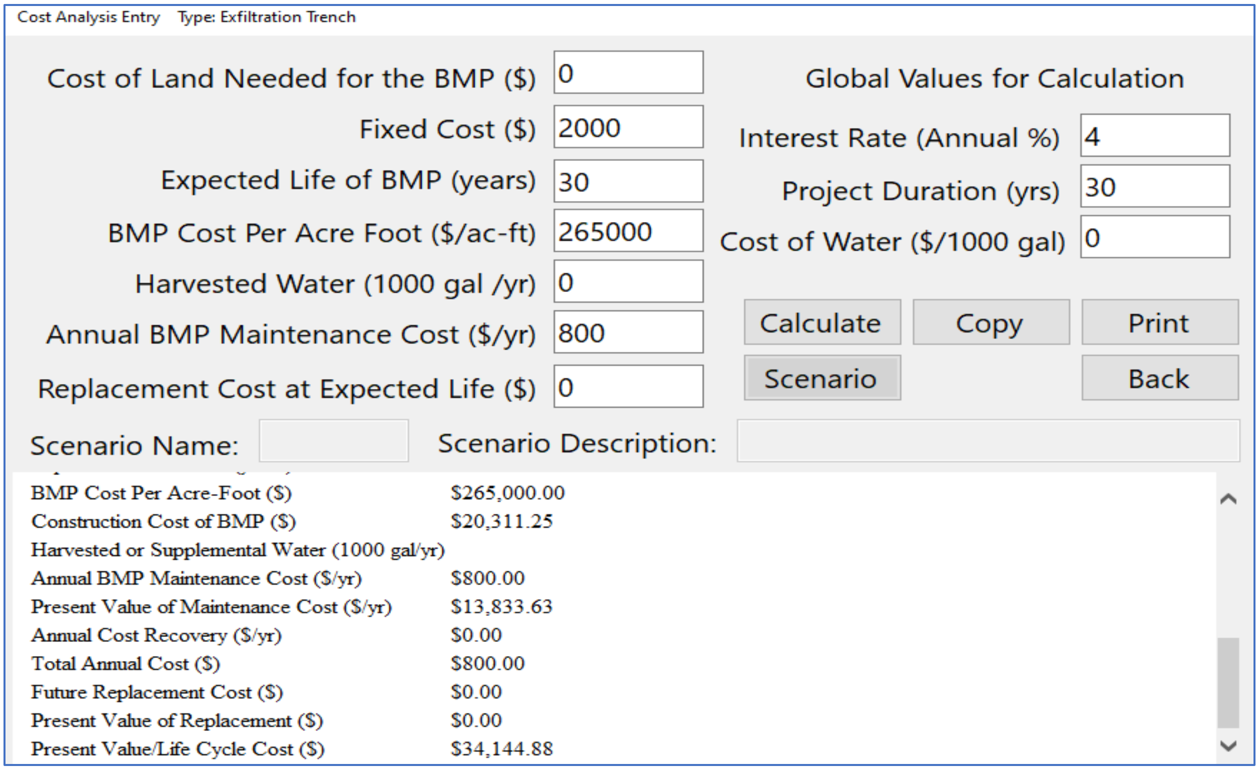

Figure 16o. Cost Analysis for Exfiltration Worksheet with Calculations.

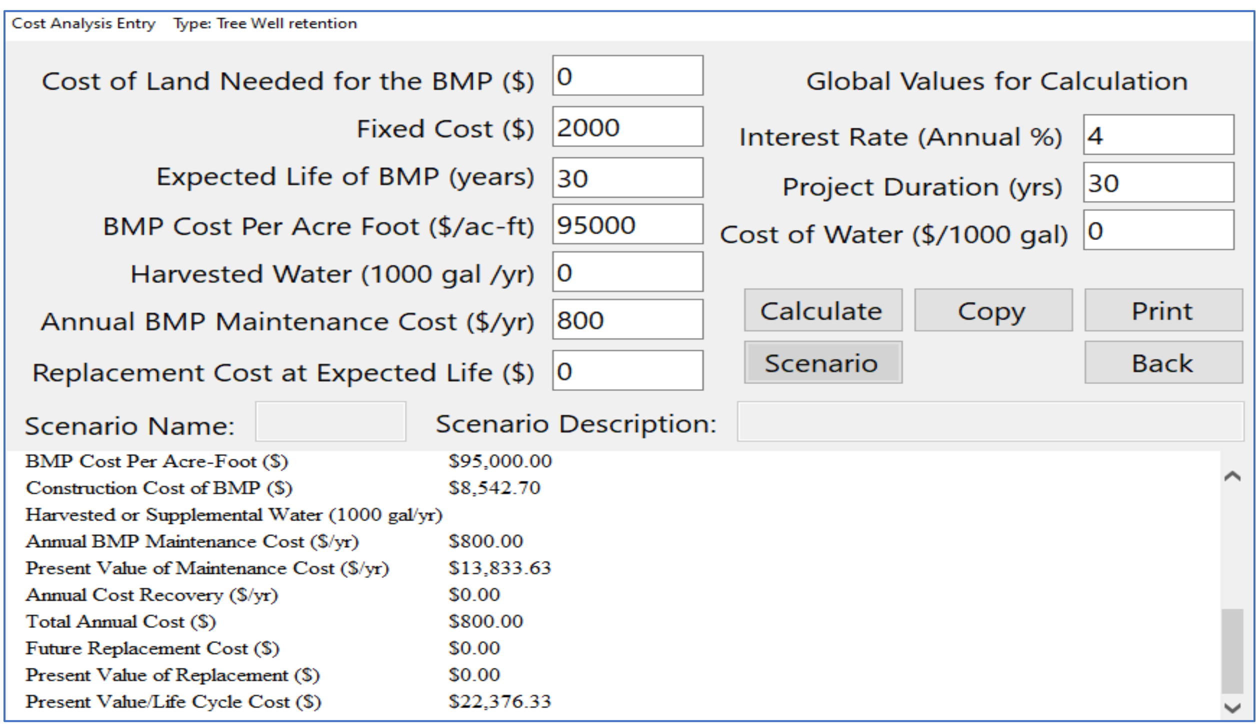

Figure 16p. Cost Analysis for Tree Wells Worksheet with Calculations.

13. Navigate using the *Back* button three times to the **General Site Information Worksheet** and click on *Cost Comparisons* button. On the **Cost Scenario Management Sheet**, the user has the opportunity to name the scenario (which can be done if there are other comparisons) or simply get a *full cost report*. The comparison data for cost analysis is shown in Figure 16q. The output is divided into two screens so that the print information is larger.

Project: Example 6 Multiple BMP & Cost

Date: 01/06/2019

Summary Cost Report

Interest Rate (%)	4.000
Project Duration (yr)	30.000
Cost of Water ($ /1000 gal)	0.000

Road and Commercial Center (Catchment #1)

BMP Type	Treatment Volume (ac-ft)	Land Cost ($)	Expected Life (yr)	Fixed Cost ($)	BMP Cost ($/ac-ft)	Initial BMP Cost ($)	BMP Maintenance ($/yr)	Annual Recovery ($/yr)	Total Annual Cost ($/yr)
Retention	0.50	10,000	30	5,000	6,000	18,000	500	0	500
Exfiltration	0.07	0	30	2,000	265,000	20,311	800	0	800
Tree Well	0.07	0	30	2,000	95,000	8,543	800	0	800
Multiple BMP	0.64	10,000	0	9,000	0	46,854	2,100	0	2,100

Total Annual Cost ($/yr)	Future Replace Cost ($)	Present Value to Replace ($)	Present Value/Life Cycle Cost ($)	Nitrogen Mass Reduction (lb/yr)	Phosphorus Mass Reduction (lb/yr)	PV Cost per Pound N Removed ($/lb)	PV Cost per Pound P Removed ($/lb)
500	35,000	10,791	26,646	34.61	5.76	25.67	154.27
800	0	0	34,145	8.49	1.41	134.00	805.41
800	0	0	22,376	8.47	1.41	88.11	529.57
2,100	0	10,791	83,167	37.54	6.25	73.85	443.86

Figure 16q. Cost Analysis for all BMPs with Comparisons.

Example problem # 7 – Rain Gardens

This example problem demonstrates the use of the rain garden BMP, user defined media, and user defined data for EMCs in the post condition. In addition, 2 options for treatment, namely retention and detention are presented.

Rain gardens made from depression storage have been proposed as a BMP for a 2.0-acre roadway near a commercial development in Lee County, FL. The pre-development land use condition is agricultural-pasture with a Curve Number of 78 and 0% DCIA. The post-development land use condition in a similar location has been monitored and EMCs approved by the review agency. Thus, the EMCs are *User Defined* as 1.16 mg/L TN and 0.157 mg/L TP with a non-DCIA Curve Number of 78 and DCIA of 65%. The review agency required an annual rainfall of 52 inches should be used. Net improvement is needed for surface discharge. Media will be used in the rain garden to better reduce Nitrogen and Phosphorus going into a nearby estuary either by ground or runoff waters. Assume the media in the rain garden is to have dimensions of 160 ft by 15 ft with a depth of 2 foot, thereby making the volume of the media in the rain garden to be 4800 cubic feet. The water storage above the rain garden is 2088 cubic feet. The sustainable void ratio for the media is 0.25. The problem solution is divided into parts for training purposes, first as a retention BMP and second as a detention one. The detention option can use a sorption media and one locally available one is composed of clay, tire crumb, and sand (CTS). The media has a sustainable void ratio of 0.25 and a depth of 24 inches. The review agency has approved the values for TN and TP average annual removal, noting that the removal is only for the media location after wet detention. The seasonal high water table is below the media.

1. From the introduction page click on the *Continue* button to proceed to the **General Site Information Worksheet** (Figure 17a).

    a. Enter the project name
    b. Select the meteorological zone.
    c. Input the mean annual rainfall amount.
    d. Select the *Net Improvement* option from the drop down menu.
    e. Leave the *Conduct a Groundwater Discharge Analysis* selection as “No.”

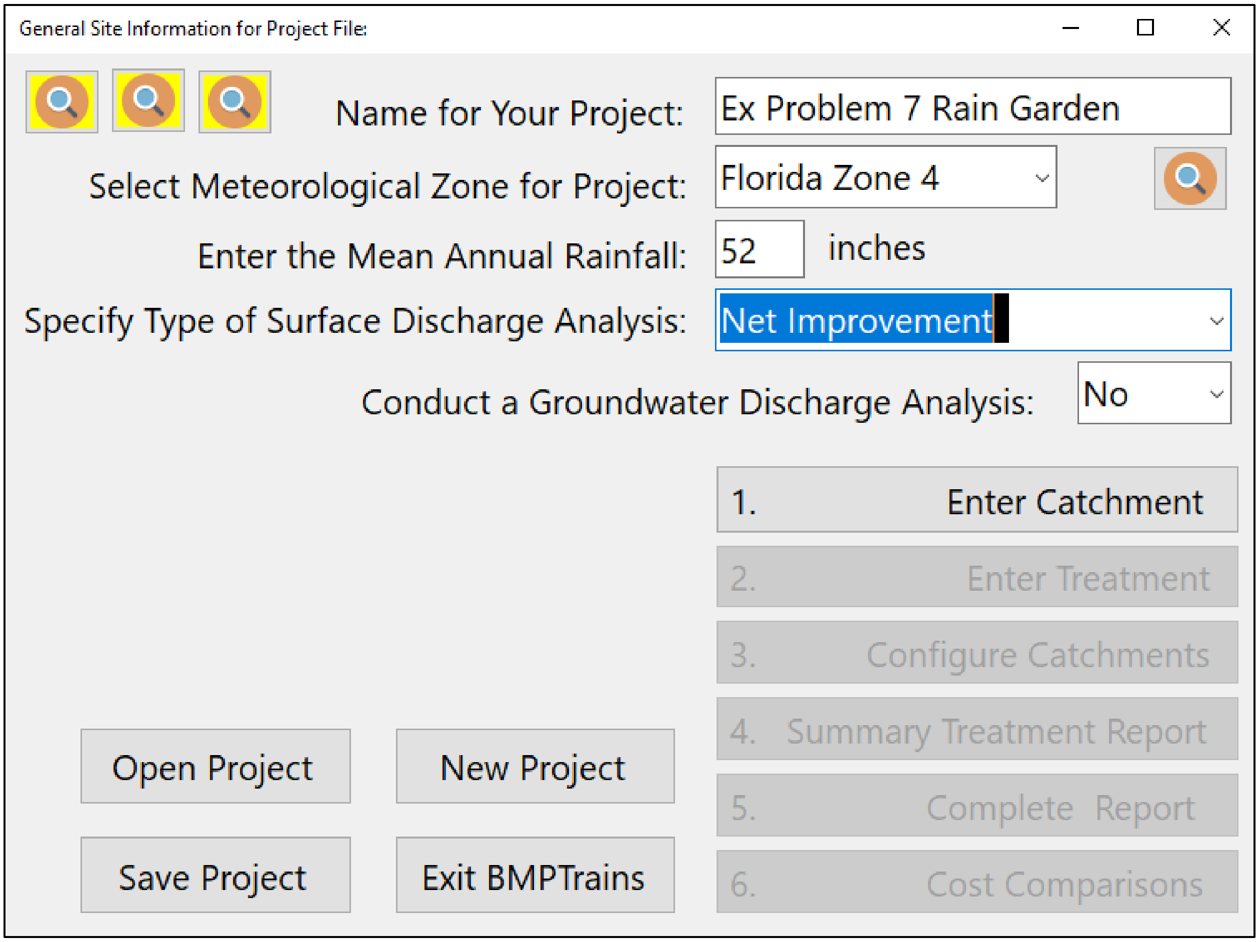

Figure 17a. Site Information Input.

2. Select the *Enter Catchment* button to proceed to the **Watershed Characteristics Worksheet** (Figure 17b). Enter the catchment configuration, pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage. Note that the land use in the post condition is user defined because of the site specific EMC data. Click on the *Calculate* button to view the annual C value, annual runoff (in acre-feet/yr), and the Nitrogen and Phosphorus loadings (in kg/yr). Click on the *Back* button to return to the **General Site Information Worksheet**.

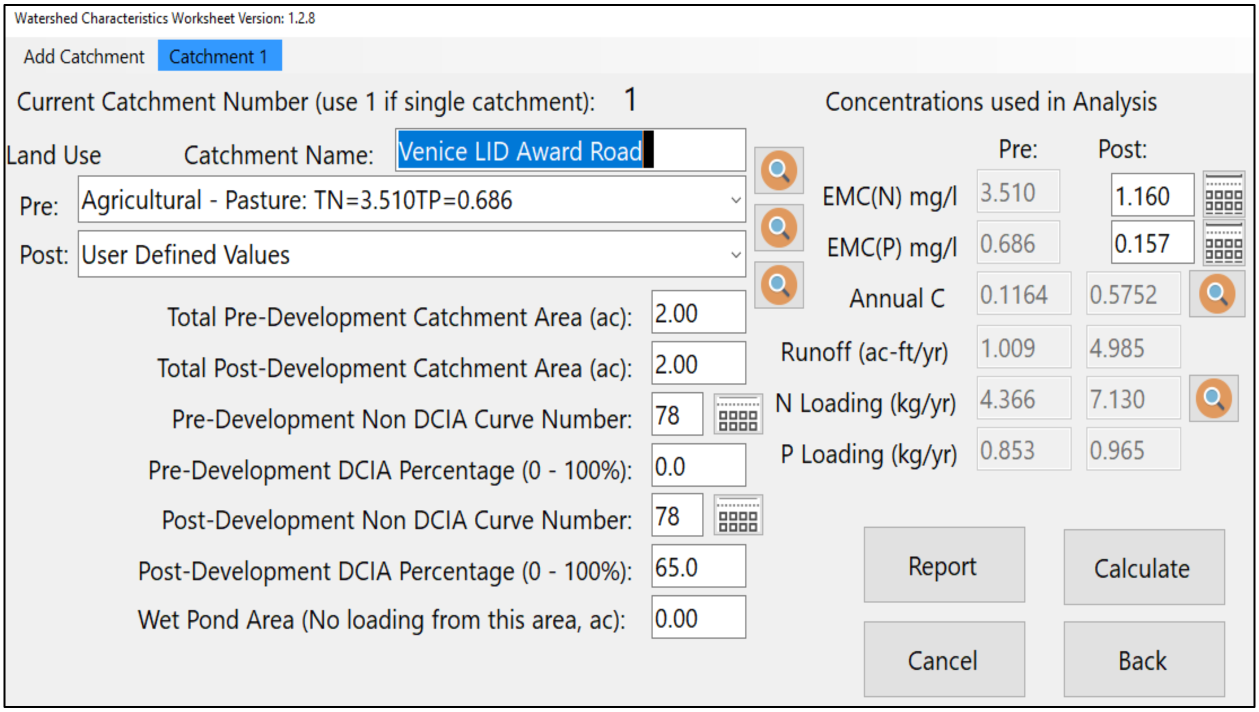

Figure 17b. Watershed Characteristics.

3. You are at the **General Information Worksheet**, Select the *Enter Treatment* button to proceed to the **Stormwater Treatment Analysis Worksheet**.

4. Select the *Rain Garden* button to proceed to the **Rain Garden Analysis Worksheet** (Figure 17c). The screen report is a partial output display in Figure 17c. Other input data and mass diagram information is also available on this screen output. Groundwater analysis was not chosen on the **General Site Information Worksheet,** thus no calculations for recharge and average concentration discharged to the ground. The media filter area is an input so that a check can be made to verify the area is greater than that required to drain the media in 72 hours. A print of that “minimum” area is provided in the on-screen report as well as the average annual removal effectiveness (shown in “rectangular boxes” in Figure 17c).

   a. Specify the input data for the rain garden, so that **BMP Trains 2020** will calculate the average annual removal effectiveness.
   b. Input data include the selection of retention or detention, media type, media volume, type of media, and storage of water above the media. There is an option to use no media or a user defined media. All media used must be approved by the reviewing agency.
   c. Click on the *Calculate* button and review the results in the on-screen report.
   d. Click the *Back* button to return to the **Select Treatment Options Worksheet**.

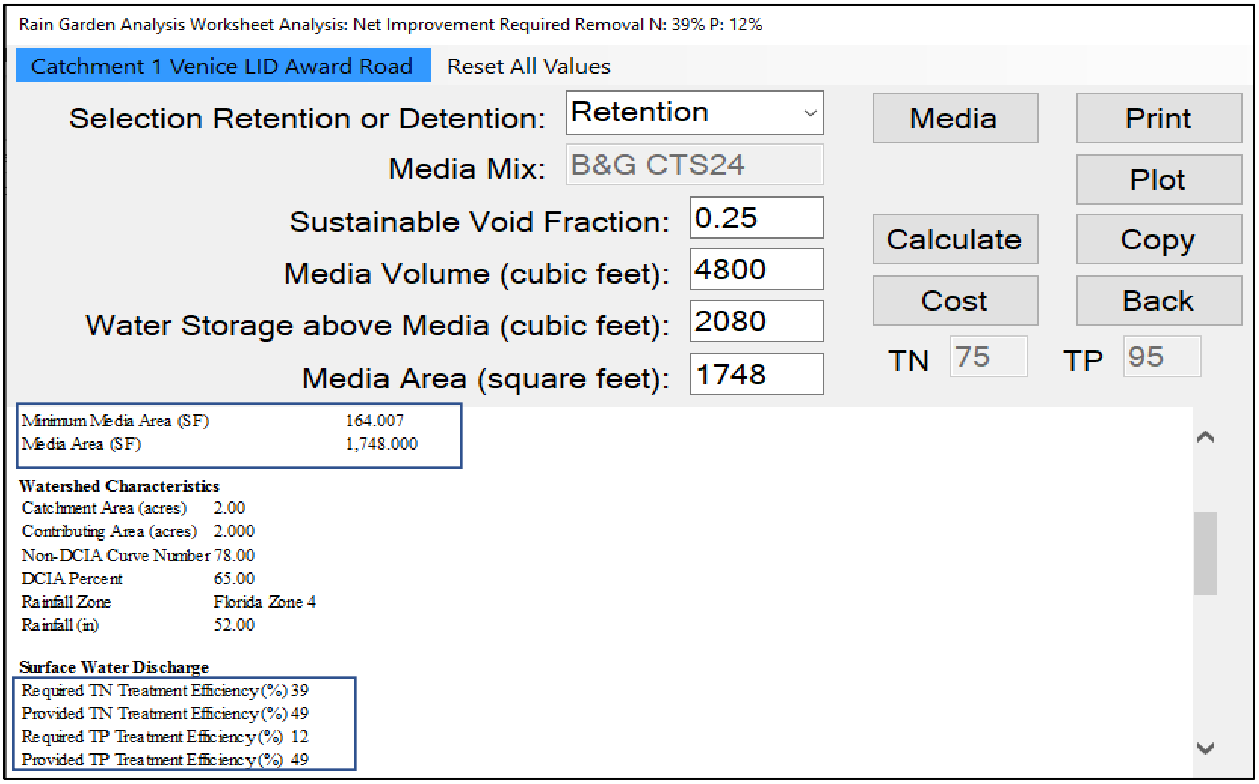

Figure 17c. Rain Garden Analysis.

1. Continue the analysis by selecting the *Back* button to return to the **Site Information Worksheet.** Next select the *Configure Catchment* button to select the routing and the BMP to use in the analysis using the *edit* button (see Figures 17d and 17e).

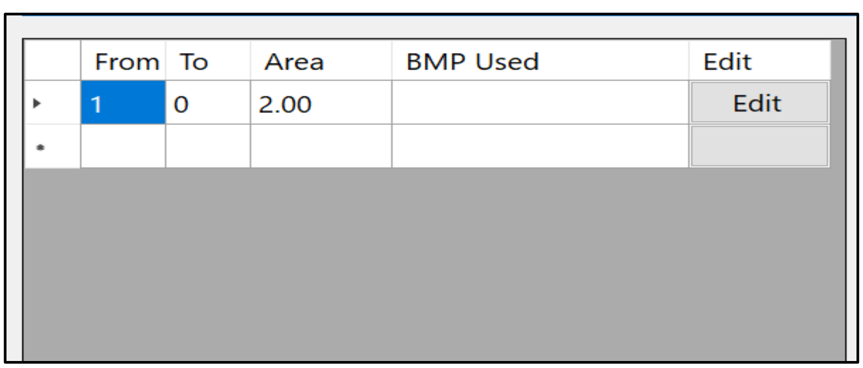

Figure 17d. Select Catchment Configuration and *Edit* to add the BMP called Rain Garden.

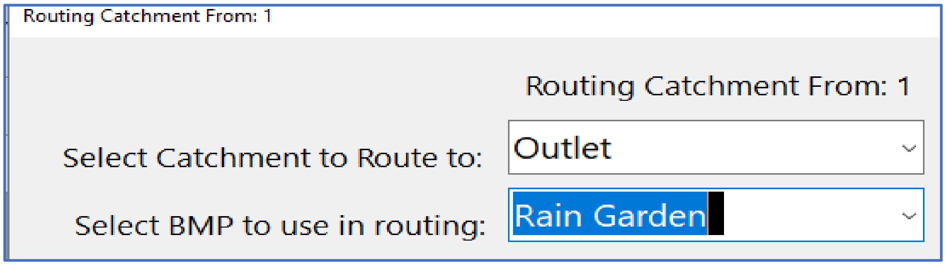

Figure 17e. Select Routing to the Outlet and BMP called Rain Garden.

2. Continue the analysis by selecting the *Back* button to return to the **Site Information Worksheet (**see Figure 17f) and select the *Summary Treatment Report* button. Figure 17g shows the summary report.

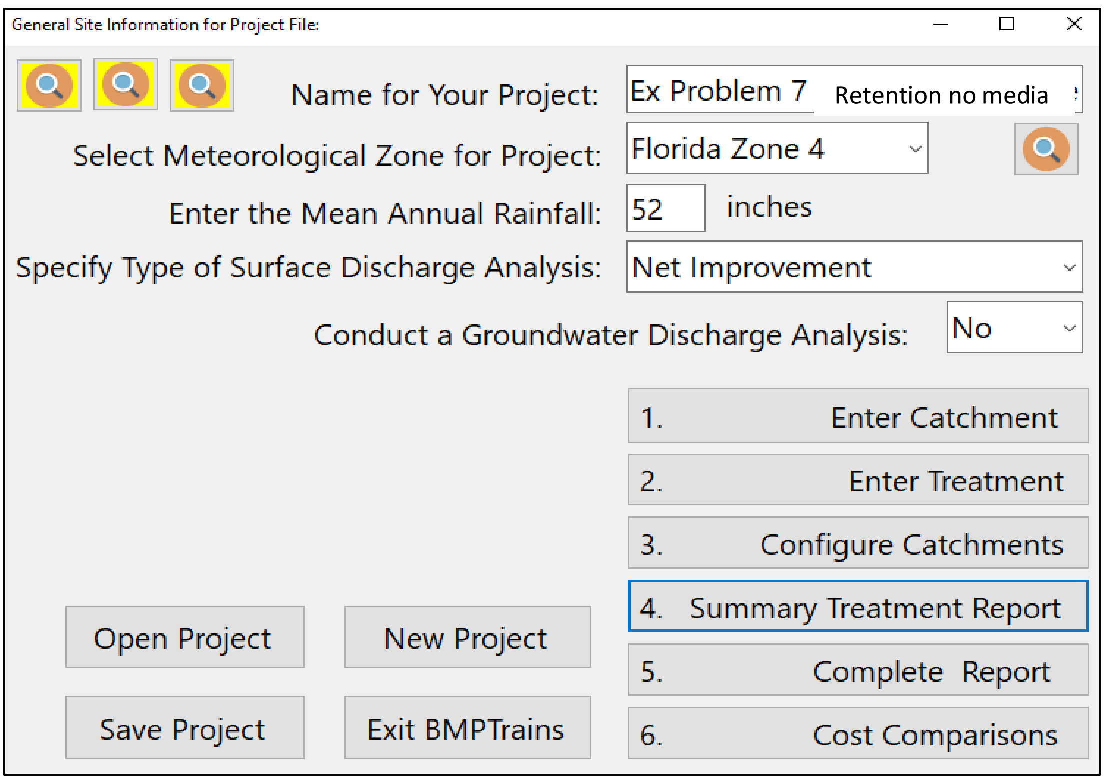

Figure 17f. Select Summary Treatment Report.

BMP Trains Reports

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Summary Treatment Report Version: 4.2.1

Project: Ex Problem 7 Retention no media

Analysis Type: Net Improvement
BMP Types:
Catchment 1 - (Venice LID Award Road) Rain Garden retention
Based on % removal values to the nearest percent
Total nitrogen target removal met? **Yes**
Total phosphorus target removal met? **Yes**

Routing Summary
Catchment 1 Routed to Outlet

Summary Report

Nitrogen

Surface Water Discharge

Total N pre load	4.37 kg/yr	
Total N post load	7.13 kg/yr	
Target N load reduction	39 %	
Target N discharge load	4.37 kg/yr	
Percent N load reduction	49 %	
Provided N discharge load	3.65 kg/yr	8.05 lb/yr
Provided N load removed	3.48 kg/yr	7.68 lb/yr

Phosphorus

Surface Water Discharge

Total P pre load	.853 kg/yr	
Total P post load	.965 kg/yr	
Target P load reduction	12 %	
Target P discharge load	.853 kg/yr	
Percent P load reduction	49 %	
Provided P discharge load	.494 kg/yr	1.09 lb/yr
Provided P load removed	.471 kg/yr	1.039 lb/yr

Figure 17g. Summary Report Surface Water Discharge Analysis.

3. Continue with this rain garden BMP example. However, there is no option for ground water recharge or retention. This condition can result from a high groundwater table which limits discharge to the ground. Net improvement for surface water discharge is still required. Resume the analysis by selecting again the *Rain Garden* treatment option. Within the ***Rain Garden Worksheet*** **(**see Figure 17h) select the option for **Detention** as shown with the other inputs and press the C*alculate* button. A pollution control media must be used to reduce the Nitrogen and Phosphorus load in the surface discharge. The amount of water through the media and the volume of media should be adjusted if needed to meet the net improvement. It was decided to increase the volume of media to 5800 CF for pollution control.

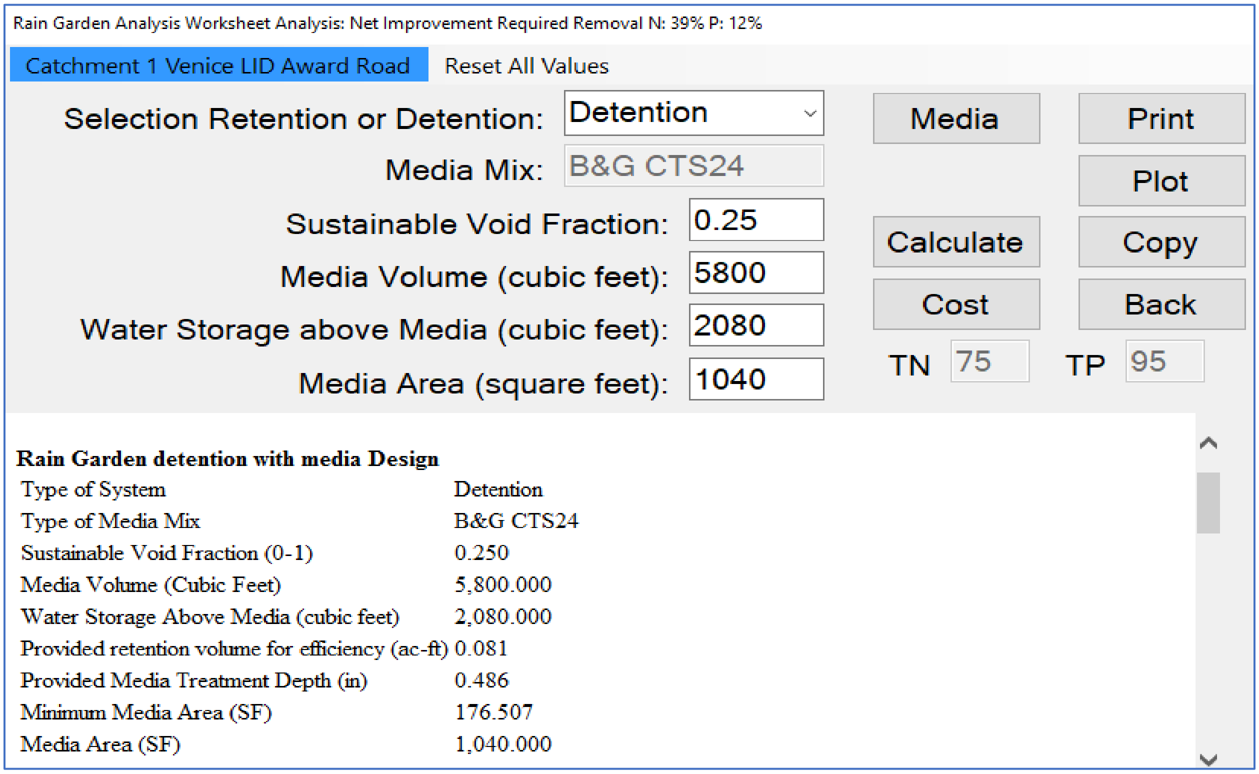

Figure 17h. Rain Garden Worksheet with Detention Option and Media Input Selection.

4. With the detention option for treatment, there is an increase in discharge volume compared to retention because there is no runoff volume discharged to the ground. However, a pollution control media is being used to remove mass of nutrients, namely CTS media at a 24 inch depth to treat discharge from the rain garden. Continue the analysis by selecting the *back* button to the **General Site Information Worksheet** and select the *Summary Treatment Report* button. The percent reduction in TN and TP for a rain garden with detention and 5800 CF of media for pollution control meets net improvement for TN (Figure 17i). More media (as an example 5800 CF vs. 4800 CF) was used in the rain garden relative to retention to meet the required removal of TN. More media results in a higher storage volume capture. If possible, more water storage could also be added.

Summary Treatment Report Version: 4.2.3

Project: Ex Problem 7 Detention with media

Analysis Type: Net Improvement

BMP Types:

Catchment 1 - (Venice LID Award Road) Rain Garden detention with media

Based on % removal values to the nearest percent

Routing Summary

Catchment 1 Routed to Outlet

Total nitrogen target removal met? **Yes**

Total phosphorus target removal met? **Yes**

Summary Report

Nitrogen

Surface Water Discharge

Total N pre load	4.37 kg/yr	
Total N post load	7.13 kg/yr	
Target N load reduction	39 %	
Target N discharge load	4.37 kg/yr	
Percent N load reduction	39 %	
Provided N discharge load	4.37 kg/yr	9.64 lb/yr
Provided N load removed	2.76 kg/yr	6.08 lb/yr

Phosphorus

Surface Water Discharge

Total P pre load	.853 kg/yr	
Total P post load	.965 kg/yr	
Target P load reduction	12 %	
Target P discharge load	.853 kg/yr	
Percent P load reduction	49 %	
Provided P discharge load	.492 kg/yr	1.08 lb/yr
Provided P load removed	.473 kg/yr	1.043 lb/yr

Figure 17i. Summary Treatment Report for a Detention Rain Garden with Media BMP.

5. The example is continued with the retention option for treatment and with a groundwater discharge analysis. In this catchment the groundwater is tributary to an estuary and treatment is required for any retained water that percolates to the estuary. Proceed to the **General Site Information Worksheet** and select *Conduct a Groundwater Discharge Analysis* as shown in Figure 17j.

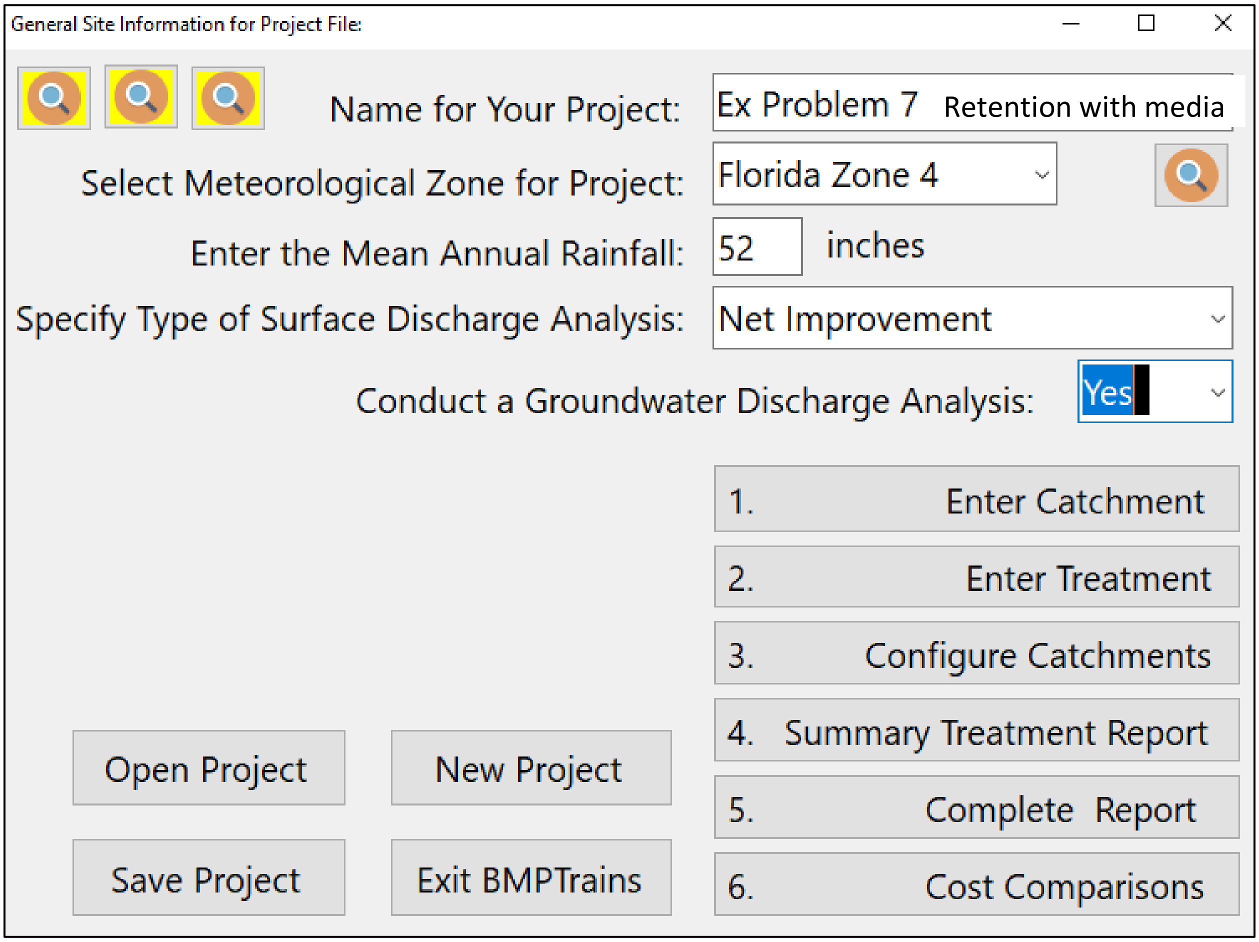

Figure 17j. Conduct a Groundwater Discharge Analysis Selection.

6. The volume of media is 4800 CF and 2080 CF of water storage above (same as before). Be certain that the retention option is chosen on the **Rain Garden Worksheet** along with a pollution control media type (in this case B&G CTS 24) and proceed to the **Summary Treatment Report** (see Figure 17k). The groundwater discharge analysis shows a recharge volume per year, average annual loading to the ground and average annual concentration data. Note that there may be an irreducible concentration of TN and TP. The irreducible concentrations may be checked against those in the discharge. If the discharge is below, the irreducible amount, the % removed may be adjusted and the fixed removal set by specifying that removal only. The surface water discharges can also be viewed in the summary report.

Total nitrogen target removal met? **Yes**
Total phosphorus target removal met? **Yes**

Summary Report

Nitrogen

Surface Water Discharge

Total N pre load	4.37 kg/yr	
Total N post load	7.13 kg/yr	
Target N load reduction	39 %	
Target N discharge load	4.37 kg/yr	
Percent N load reduction	49 %	
Provided N discharge load	3.65 kg/yr	8.05 lb/yr
Provided N load removed	3.48 kg/yr	7.68 lb/yr

Groundwater Discharge

Average Annual Recharge	.793 MG/yr	
Provided N recharge load	.87 kg/yr	1.92 lb/yr
Provided N Concentration	.29 mg/l	

Phosphorus

Surface Water Discharge

Total P pre load	.853 kg/yr	
Total P post load	.965 kg/yr	
Target P load reduction	12 %	
Target P discharge load	.853 kg/yr	
Percent P load reduction	49 %	
Provided P discharge load	.494 kg/yr	1.09 lb/yr
Provided P load removed	.471 kg/yr	1.039 lb/yr

Groundwater Discharge

Average Annual Recharge	.793 MG/yr	
Provided P recharge load	.0236 kg/yr	.0519 lb/yr
Provided P Concentration	.0078 mg/l	

Figure 17k. Summary - Groundwater Protection using Rain Gardens.

Example problem # 8 – A Vegetated Filter Strip (VFS)

A VFS with BAM is typically placed in a highway shoulder/embankment or in an area adjacent to a parking lot. It is designed to infiltrate and then percolate runoff through BAM. With the typical highway application, the groundwater table can direct the filtered water to a nearby surface waterbody, most likely a roadside ditch, and occurs within a day after a runoff event. In these applications, the seasonal high water table is usually no deeper than 3 feet below the surface. On the site information worksheet, the button “to conduct a groundwater Discharge Analysis” is set as **No** (Figure 18a). However, for other site considerations, the percolated water may not appear in surface waters for a long period of time (usually greater than a week). Thus a groundwater analysis many be done. If runoff infiltrates into the ground, an estimate of average annual recharge volume and concentration can be obtained (see end of this example problem).

A VFS must use a stand-alone catchment; thus the area of the roadway section must include the VFS area.

In Florida meteorological zone 4, a roadway has a shoulder that can accommodate a VFS and the seasonal high water table is 3 feet below the surface of the proposed VFS with a six inch soil cover for vegetation and one foot of BAM. It is proposed to design a VFS along this roadway to reduce the surface mass loadings to meet net improvement. In Figure 18a the site information is shown with the selection of **No** for *Conduct a Groundwater Discharge Analysis.*

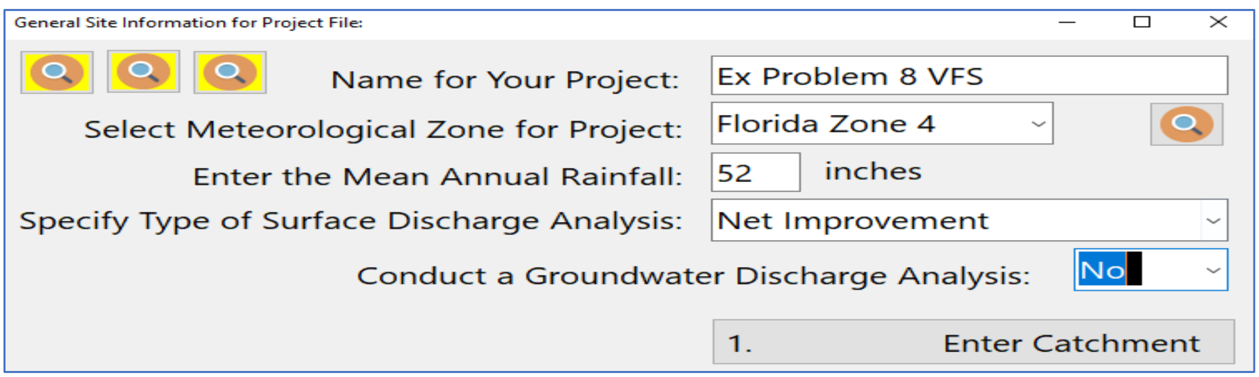

Figure 18a. Site Information Input.

2. Select the *Enter Catchment* button to proceed to the **Watershed Characteristics Worksheet** (Figure 18b). Enter the catchment configuration, pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage. The land use in the post condition is user defined because of site specific EMC data. The EMC data for the user defined EMCs must be entered by the professional after approval from the review agency. Click on the *Calculate* button to view the annual C value, annual runoff (in acre-feet/yr), and the Nitrogen and Phosphorus loadings (in kg/yr). Click on the *Back* button to return to the **General Site Information Worksheet**.

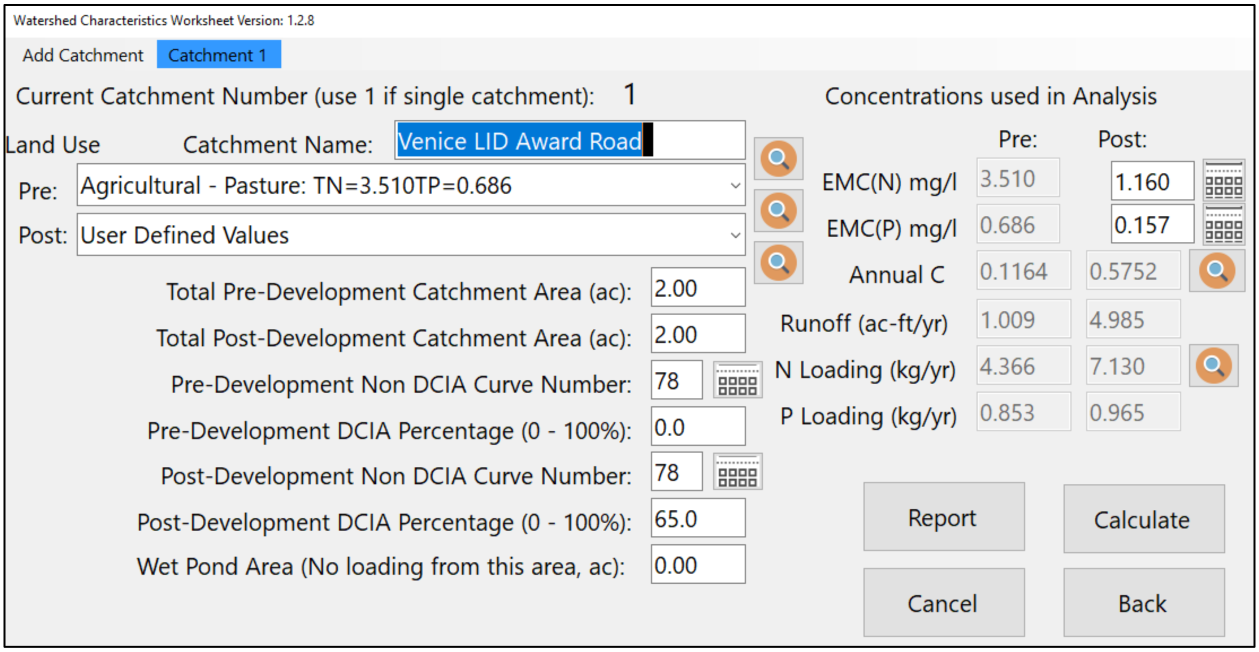

Figure 18b. Watershed Characteristics.

3. You are at the **General Information Worksheet**, Select the *Enter Treatment* button to proceed to the **Stormwater Treatment Analysis Worksheet**.

4. Select the *Filter or Vegetated Filter Strip (VFS)* button to proceed to the **Filter or Vegetated Filter Strip Worksheet**. First select the media. All VFS must have media (Figure 18c).

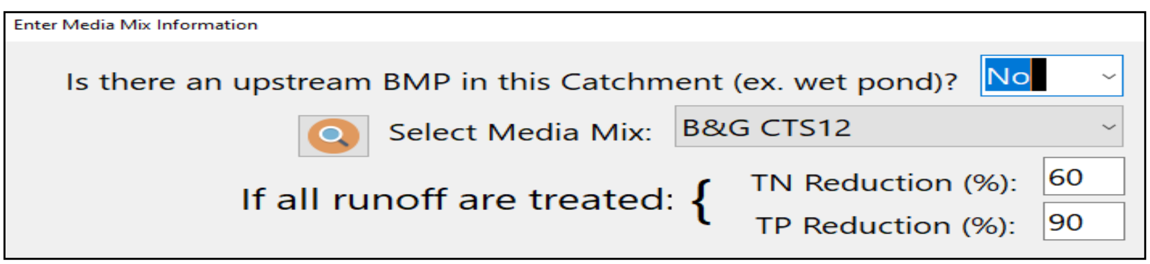

Figure 18c. VFS Media Selection.

a. Next, specify the design data for the VFS, so that **BMP Trains 2020** will calculate the average annual surface discharge removal. The screen report of Figure 18d is a partial output display. Other input data and mass diagram information are available on this screen output but are not shown.

b. Input data include the depth of media, VFS length, an equivalent width of DCIA (a.k.a. overland flow width), VFS storage capacity (usually 0.2 for media), and slope of the VFS. If the slope is less than 2%, set equal to 2%. Any slope over 20% or less than 2% are not an option to calculated effectiveness. There is an option to use no media or a user defined media. All media used must be approved by the reviewing agency. If no media are specified, there is no credit for nutrient reduction in runoff water. Note the equivalent DCIA plus the VFS swale area times the length must equal the catchment area (2 acres in this case). Thus, a stand-alone catchment. Also, an estimate of nutrient removal for natural soil (user defined, based on site soil characteristics) must be made along with certification for mixing consistency.

c. Click the *Calculate* button and view the results in the on-screen report.

d. Click the *Back* button to return to the **Select Treatment Options Worksheet**.

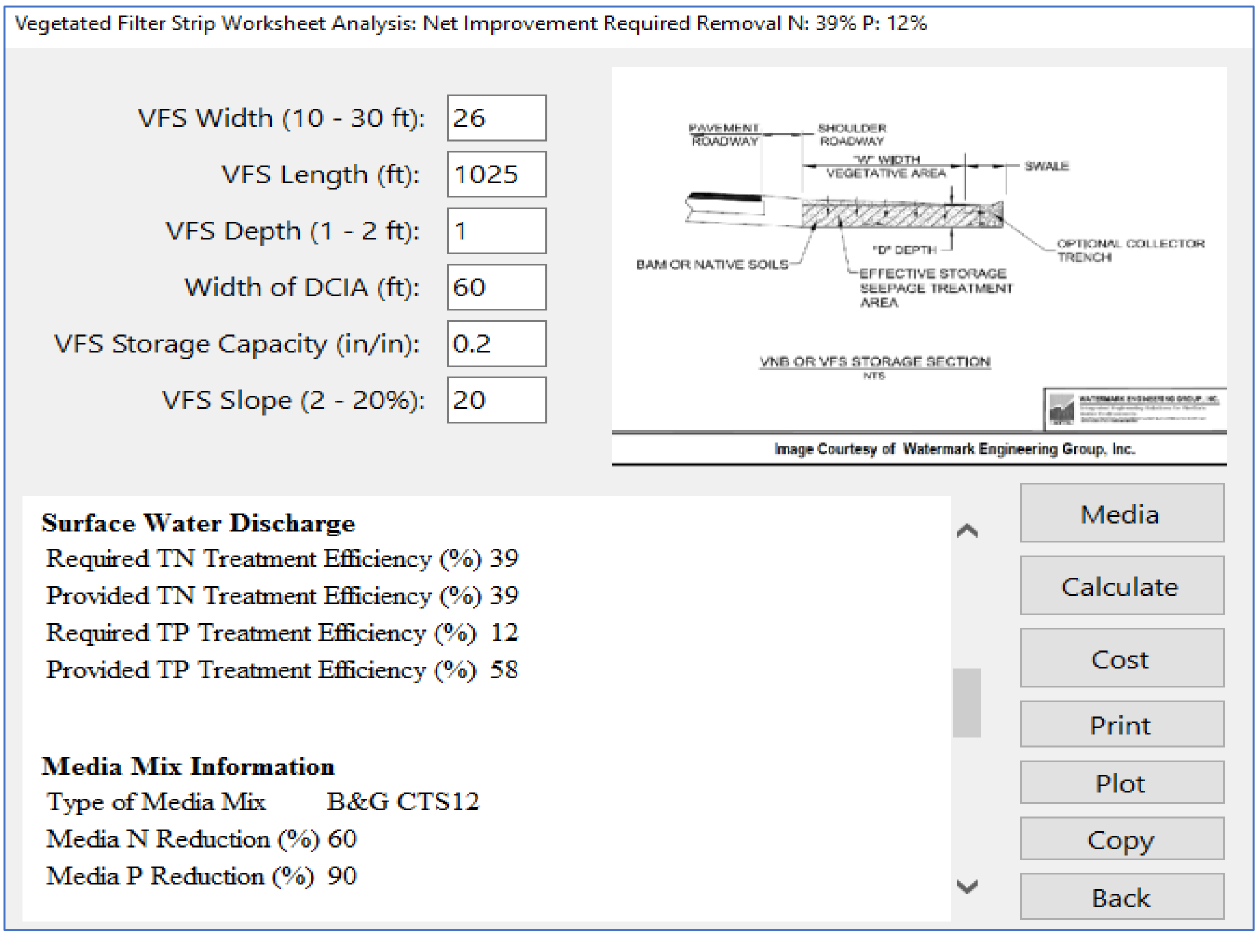

Figure 18d. Vegetated Filter Strip Analysis.

7. Continue the analysis by selecting the *Back* button to return to the **Site Information Worksheet.** Next click the *Configure Catchment* button to select the routing and the BMP to use in the analysis using the *edit* button (see Figure 18e).

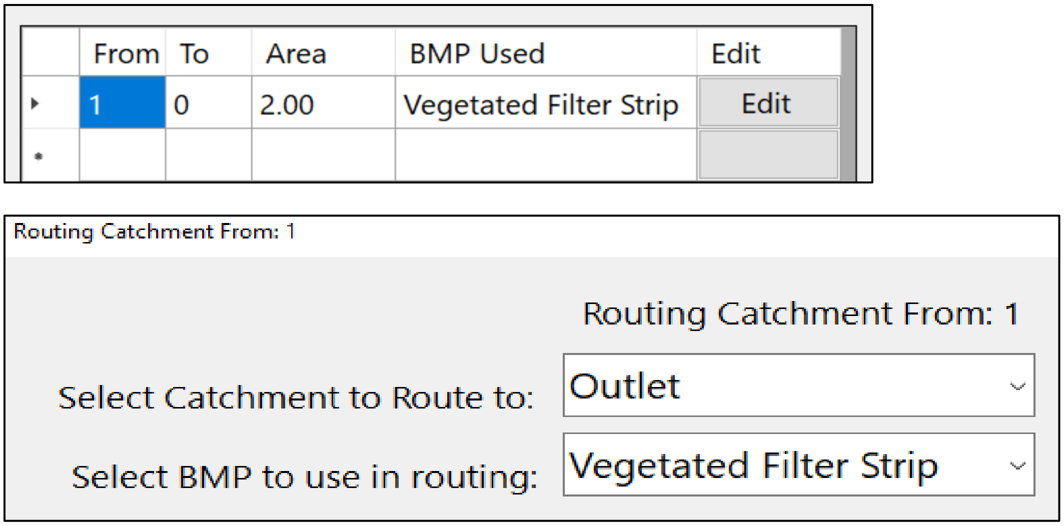

Figure 18e. Select Routing to the Outlet and Vegetated Filter Strip.

8. Continue the analysis by selecting the *Back* button to return to the **Site Information Worksheet** and select the *Summary Treatment Report* button. Figure 18f shows the summary report for surface water discharge after development. The net improvement criteria are met. Total Nitrogen removal is required to be 39% and the VFS provides for 39% removal. While total Phosphorus removal required is 12% and the VFS provides for 58% removal.

The typical application for a VFS is for infiltration of runoff through BAM resulting in the percolated water appearing as treated runoff water in the ditch adjacent to the VFS. However, the runoff water may percolate from the VFS and not immediately appear in the surface water. This could occur in areas with a very low water table. For deep percolation, the program calculates the average yearly groundwater average recharge volume in Million Gallons (MG) per year based on the capture volume of the VFS physical design. For a selected media, the residual mass and average concentration is calculated as the mass divided by the recharge volume. For the data of this problem, the yearly recharge volume is 1.046 MG/year. The average annual concentration to the ground water for TN is 0.464 mg/L. The equation for average annual concentration into the ground water (mg/L) is annual mass load into the ground (kg/yr) / annual recharge (MG/yr) / 3.7854 L/G x 1,000,000 mg/kg / 1,000,000 G/MG and in a simple equation form:

Annual average concentration (mg/L) = annual mass (kg)/annual recharge (MG)/3.78541 (L/G).

BMP Types:
Catchment 1 - (Venice LID Award Road) Vegetated Filter Strip with media

Routing Summary
Catchment 1 Routed to Outle

Total nitrogen target removal met? **Yes**
Total phosphorus target removal met? **Yes**

Summary Report
Nitrogen

Surface Water Discharge

Total N pre load	4.37 kg/yr	
Total N post load	7.13 kg/yr	
Target N load reduction	39 %	
Target N discharge load	4.37 kg/yr	
Percent N load reduction	39 %	
Provided N discharge load	4.37 kg/yr	9.65 lb/yr
Provided N load removed	2.76 kg/yr	6.08 lb/yr

Phosphorus

Surface Water Discharge

Total P pre load	.853 kg/yr	
Total P post load	.965 kg/yr	
Target P load reduction	12 %	
Target P discharge load	.853 kg/yr	
Percent P load reduction	58 %	
Provided P discharge load	.406 kg/yr	.89 lb/yr
Provided P load removed	.559 kg/yr	1.234 lb/yr

Figure 18f. Selected output from Summary Treatment Report.

Example problem # 9 – Three (3) Catchments in Series

This is an example where there is a catchment area between each of the BMPs. For Catchment 1, the BMP is retention. The outflow from this retention BMP flows into another retention BMP downstream and there is flow from that catchment, namely #2. Then the flow from retention area 2 goes into a wet detention pond and the wet pond also receives flow from another catchment, namely #3. All catchments are under the management of one entity. Net improvement is required. The site characteristics information are shown in Figure 19a.

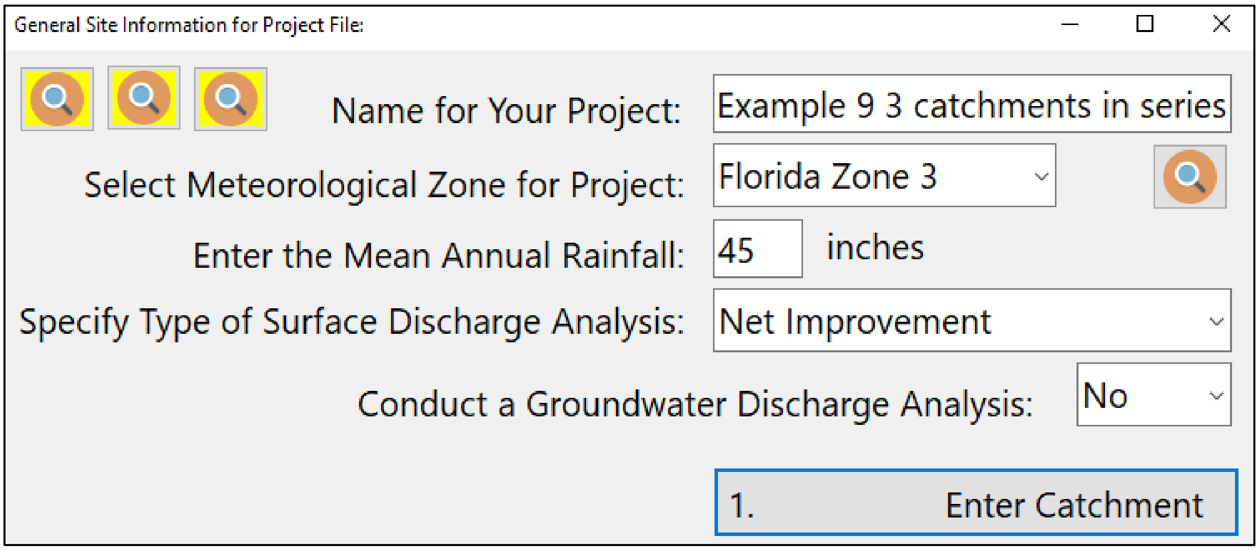

Figure 19a. Site Information Input.

1. Select the *Enter Catchment* button to proceed to the **Watershed Characteristics Worksheet** (Figure). Enter the catchment configuration, pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage. There are three catchments, thus data are entered for all three. After the data for each catchment are entered, click on the *Calculate* button to view the annual C value, annual runoff (acre-feet/yr), and the Nitrogen and Phosphorus loadings (kg/yr). For catchment 3, the wet detention area is outside of the 10 acre catchment and thus there is no wet pond area identified within catchment 3.

   After the data are entered and the calculate button pressed, the data for the next catchment are entered using the ribbon across the top (*add catchment*). If the information for each catchment is similar, then the data set can be easily copied. The data for each catchment are shown in Figure 19b.

   Click on the *Back* button to return to the **General Site Information Worksheet**.

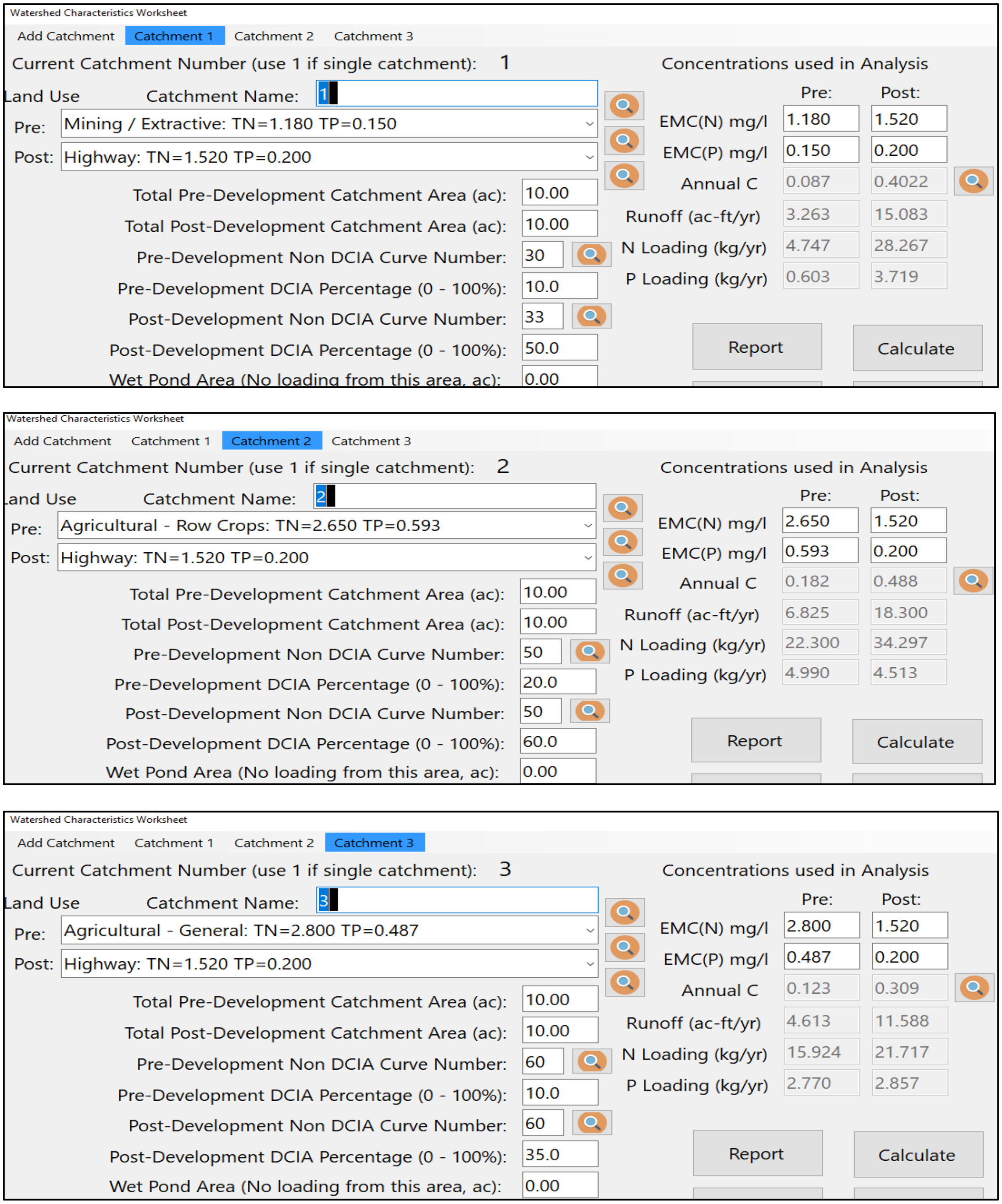

Figure 19b. Watershed Characteristics for all Three Catchments.

2. Go to the **Select Treatment Options Worksheet** to enter data for the BMP in each catchment. If the same BMP is in more than one catchment, highlighted catchment will be shown (see partial screen outputs Figure 19c).

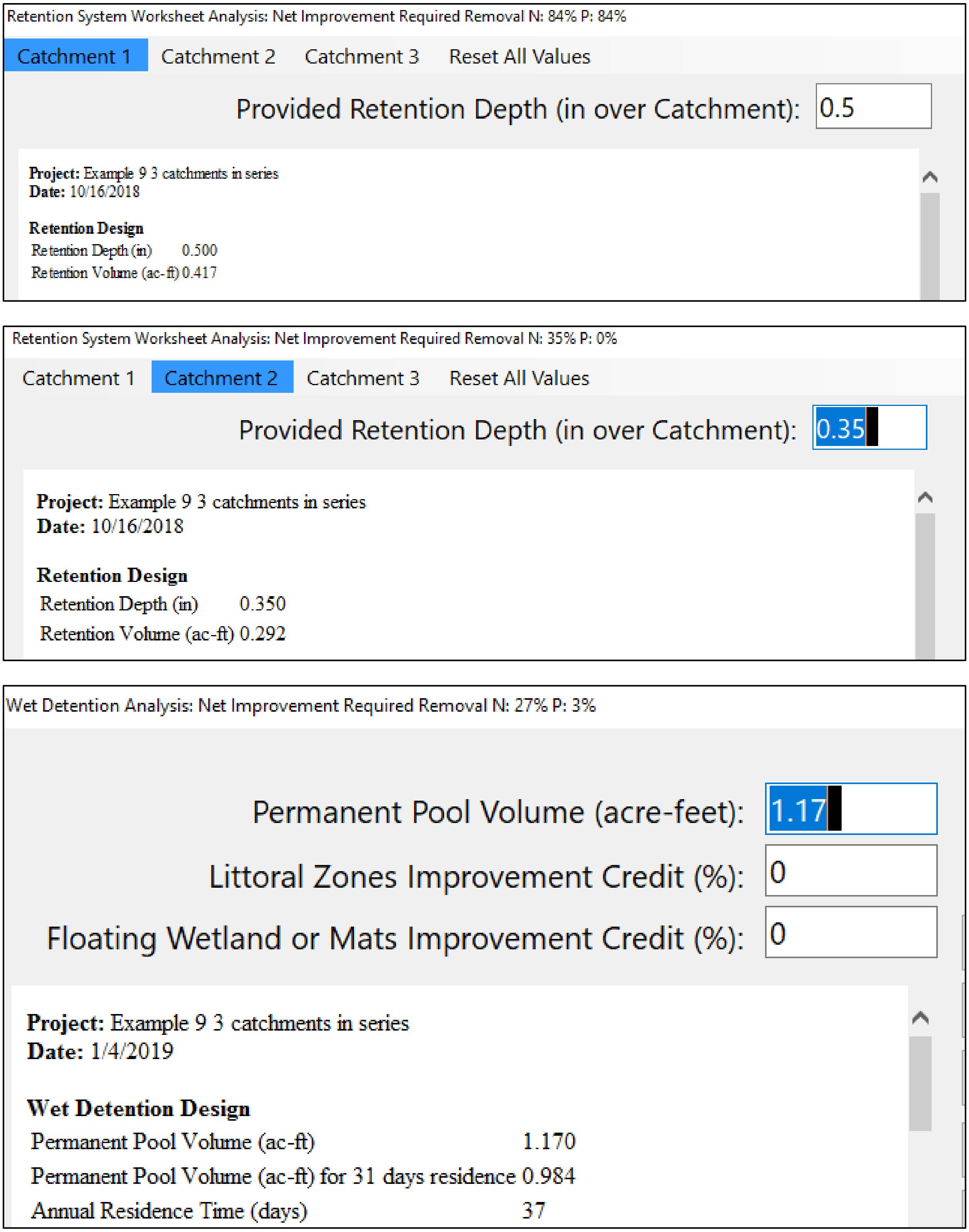

Figure 19c. Partial Screen Data for a BMP in each Catchment.

3. Continue the analysis by selecting the *Back* button to return to the **Site Information Worksheet.** Next click the "***Configure Catchment"*** button to select the routing and the BMP to use in the analysis using the *edit* button (see Figures 19d).

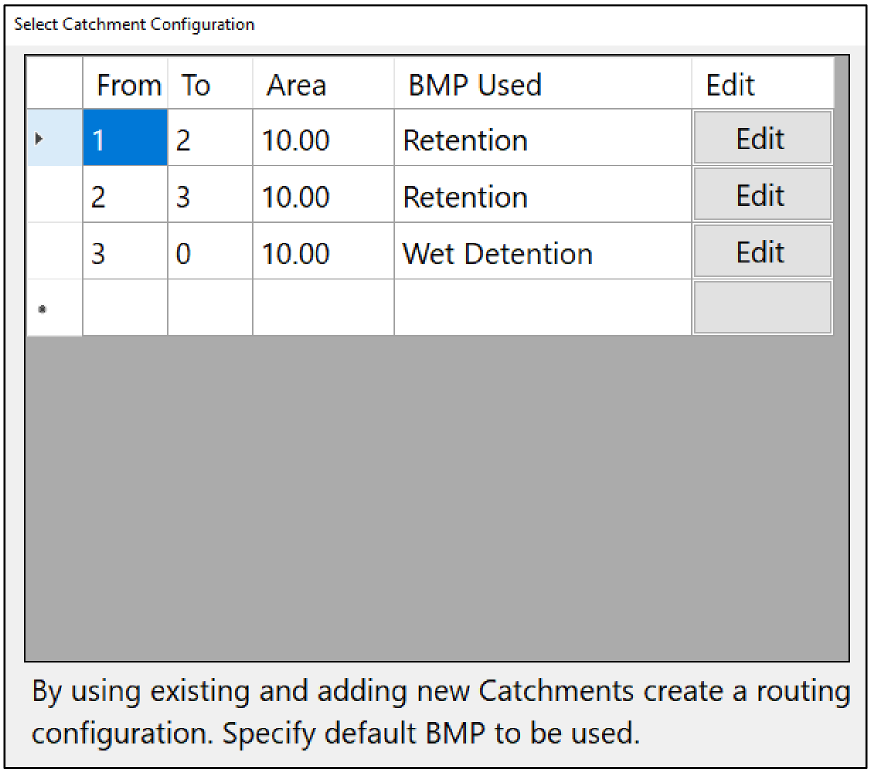

Figure 19d. Select Routing to the Outlet and BMP.

4. Continue the analysis by selecting the *Back* button to return to the **Site Information Worksheet** and select the *Summary Treatment Report* button. Figure 19e shows the summary report.

For the three catchments in series, each with a BMP required for each, the selection of BMPs meets the net improvement criteria for surface water discharge. The percent load reduction provided by the BMPs treatment train is greater than the net improvement required. This is an example of how a downstream BMP can be used to enhance the removal of flow from an upstream BMP that by itself (for the catchment) may not meet net improvement for that catchment alone. Of course each and every situation will be different. This is an application where the three catchments are under the management of the same entity.

BMP Trains Reports

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Summary Treatment Report Version: 4.2.1

Project: Example 9 3 catchments in series

Analysis Type: Net Improvement
BMP Types:
Catchment 1 - (1) Retention
Catchment 2 - (2) Retention
Catchment 3 - (3) Wet Detention
Based on % removal values to the nearest percent
Total nitrogen target removal met? **Yes**
Total phosphorus target removal met? **Yes**

Routing Summary
Catchment 1 Routed to Catchment 2
Catchment 2 Routed to Catchment 3
Catchment 3 Routed to Outlet

Summary Report

Nitrogen

Surface Water Discharge

Total N pre load	42.97 kg/yr	
Total N post load	84.28 kg/yr	
Target N load reduction	49 %	
Target N discharge load	42.97 kg/yr	
Percent N load reduction	62 %	
Provided N discharge load	32.14 kg/yr	70.86 lb/yr
Provided N load removed	52.14 kg/yr	114.98 lb/yr

Phosphorus

Surface Water Discharge

Total P pre load	8.363 kg/yr	
Total P post load	11.09 kg/yr	
Target P load reduction	25 %	
Target P discharge load	8.363 kg/yr	
Percent P load reduction	76 %	
Provided P discharge load	2.694 kg/yr	5.94 lb/yr
Provided P load removed	8.396 kg/yr	18.513 lb/yr

Figure 19e. Output from Summary Treatment Report.

Example problem # 10 – Five (5) Catchments

This is an example of a routing among 5 catchments in which there is a catchment or area contributing runoff between each BMP. The site information data are shown in Figure 20a.

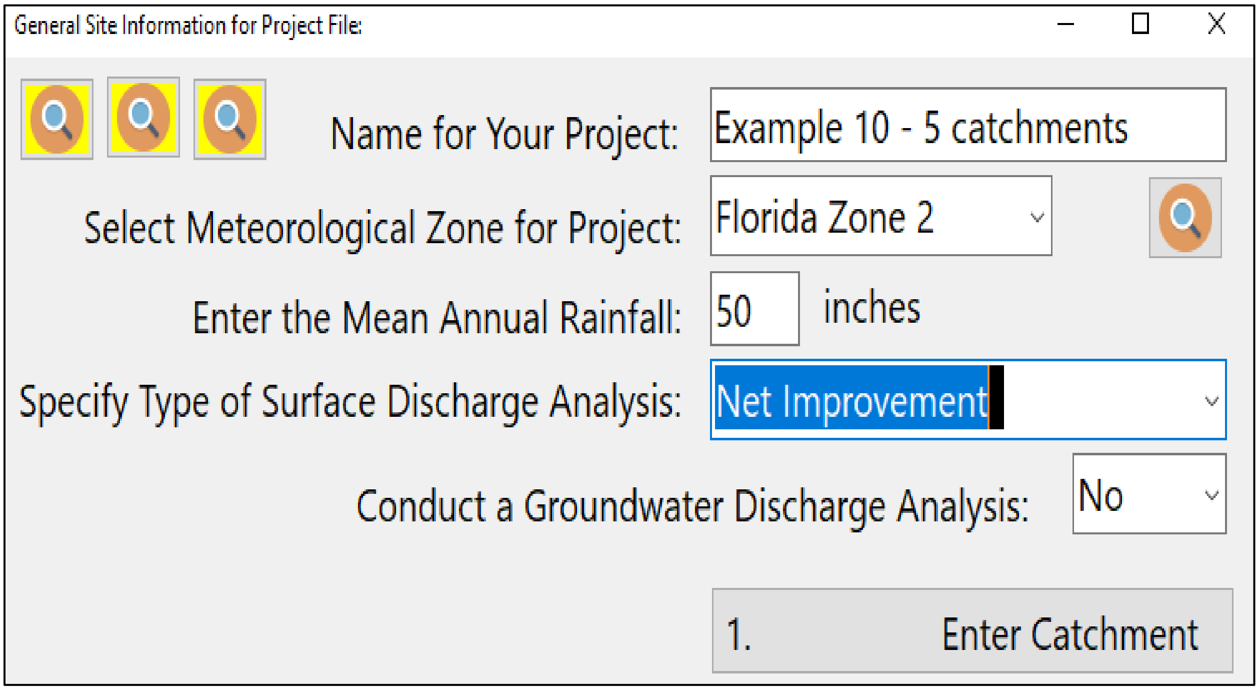


Figure 20a. Site Information Input.

1. Select the *Enter Catchment* button to proceed to the **Watershed Characteristics Worksheet** (Figure). Enter the catchment configuration, pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage. There are five catchments, thus data are entered for all five. After the data for the catchment are entered, click on the *Calculate* button to view the annual C value, annual runoff (acre-feet/yr), and the Nitrogen and Phosphorus loadings (kg/yr). The data for catchment 1 are shown in Figure 20b.

After the data are entered and the calculate button pressed, the additional catchment cinfiguration must be entered since this is for five catchments.

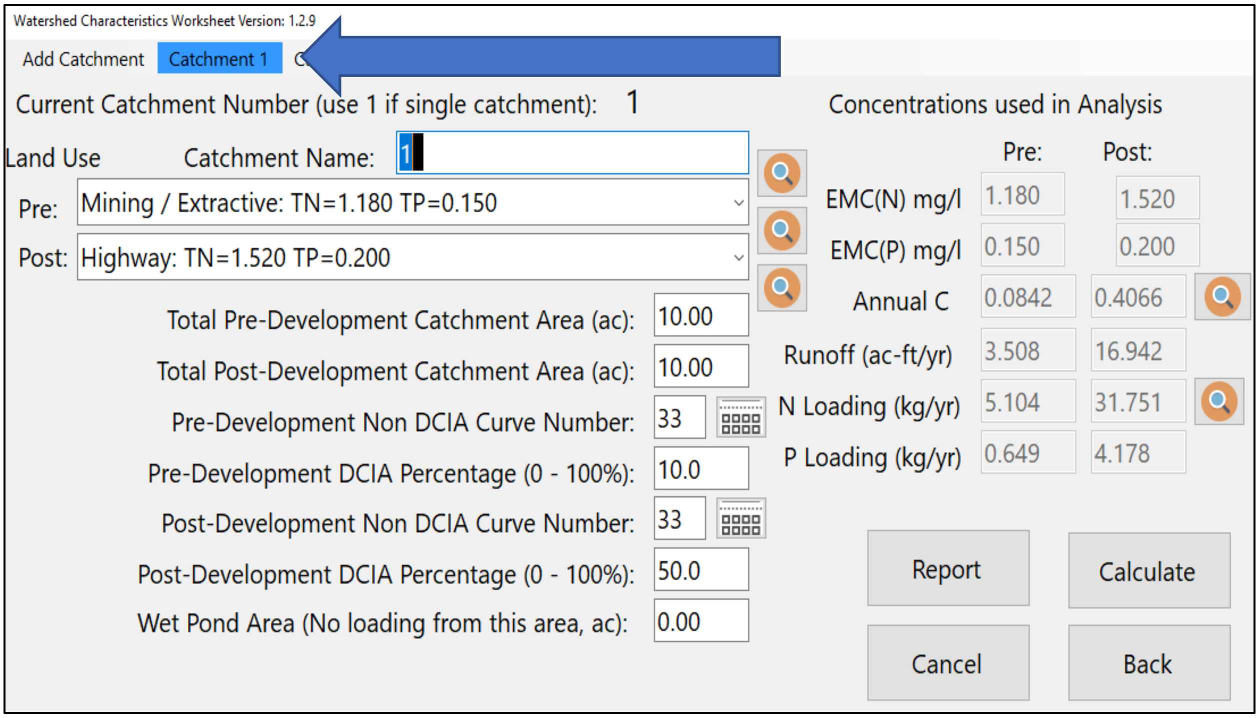
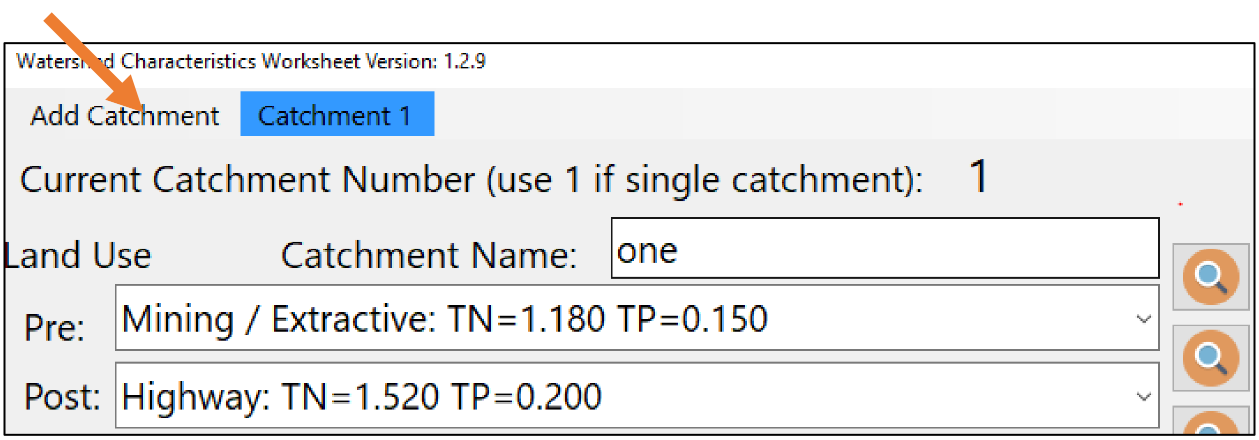
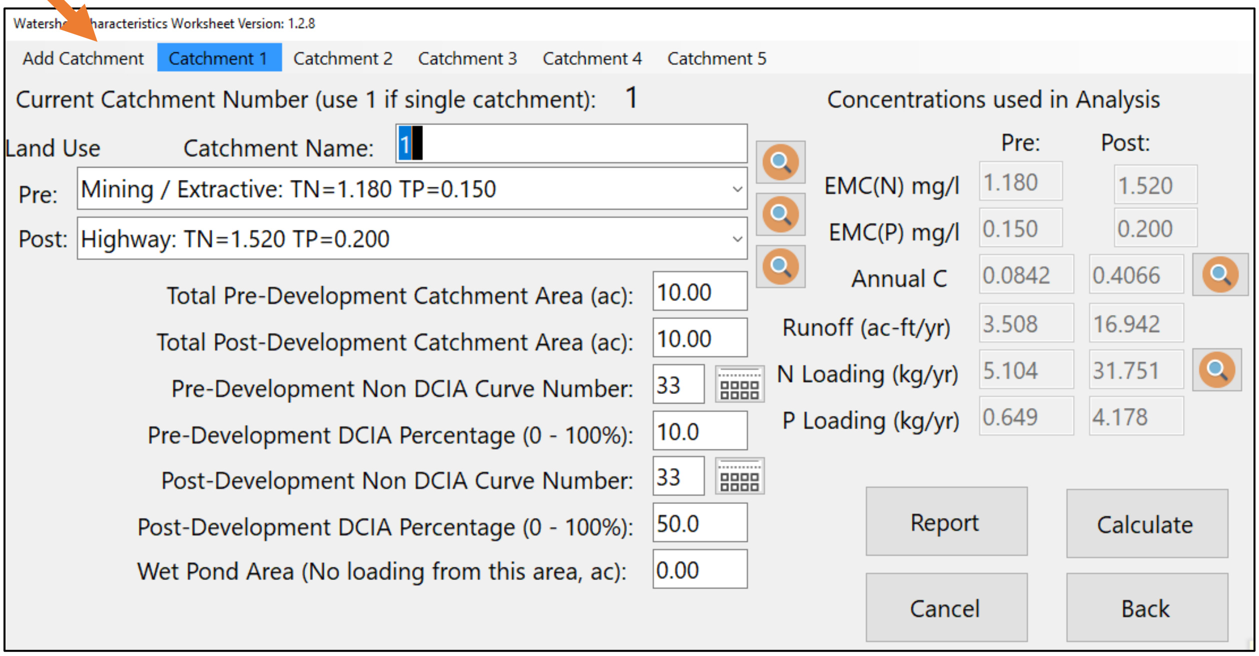


Figure 20b. Watershed Characteristics for the First of Five Catchments.

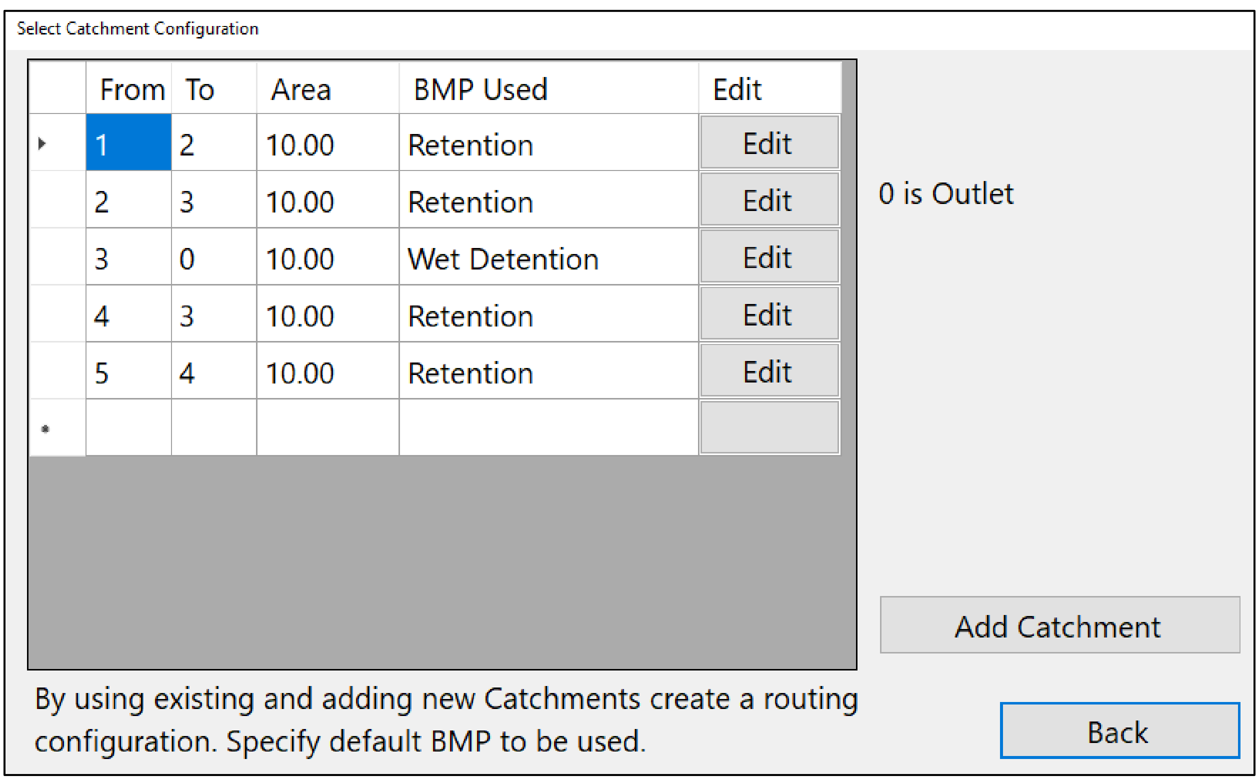
2. Since this is a routing for 5 catchments, click the button "Add Catchment" on the **Watershed Characteristics Worksheet.**



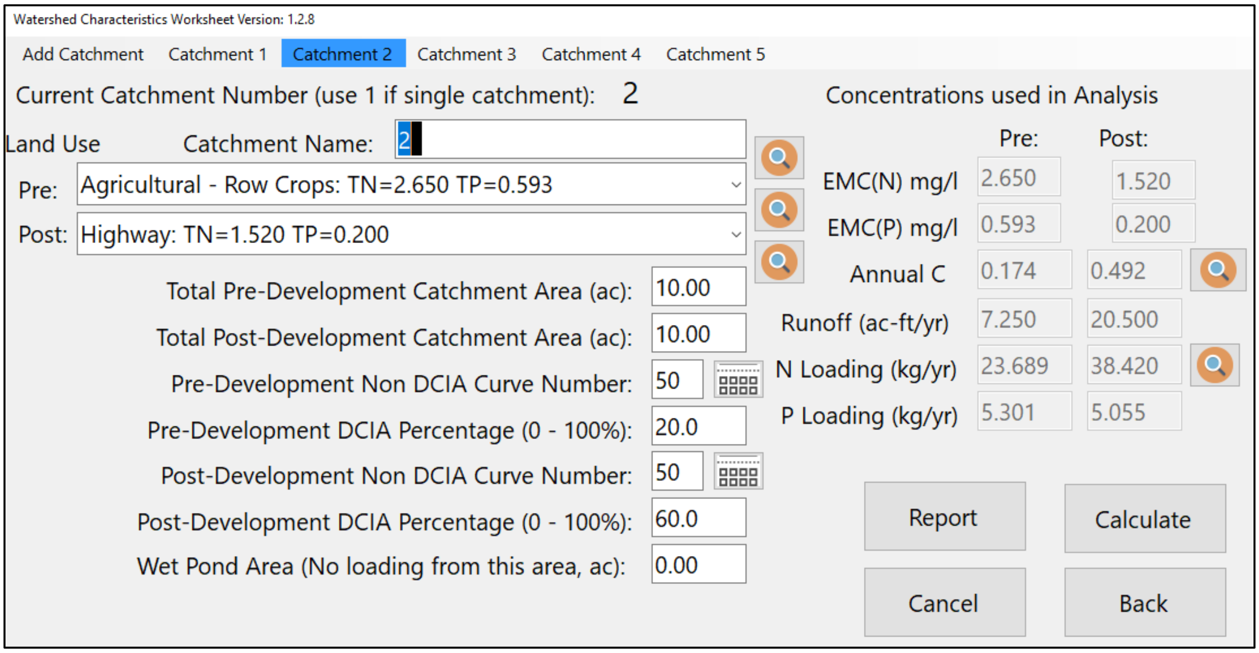
3. Continue adding catchments up to 5 as shown below

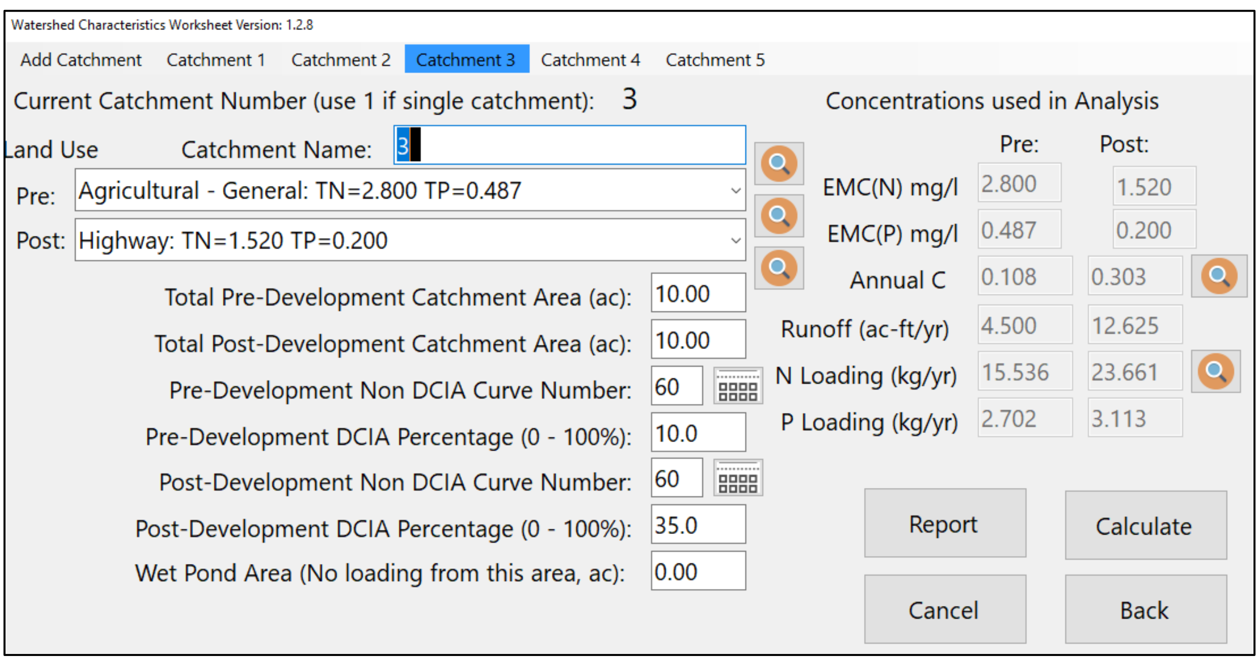


After all 5 catchments and treatment have been identified, go to the **3. Select Catchment Configuration worksheet,** from the **General Site Information worksheet**.

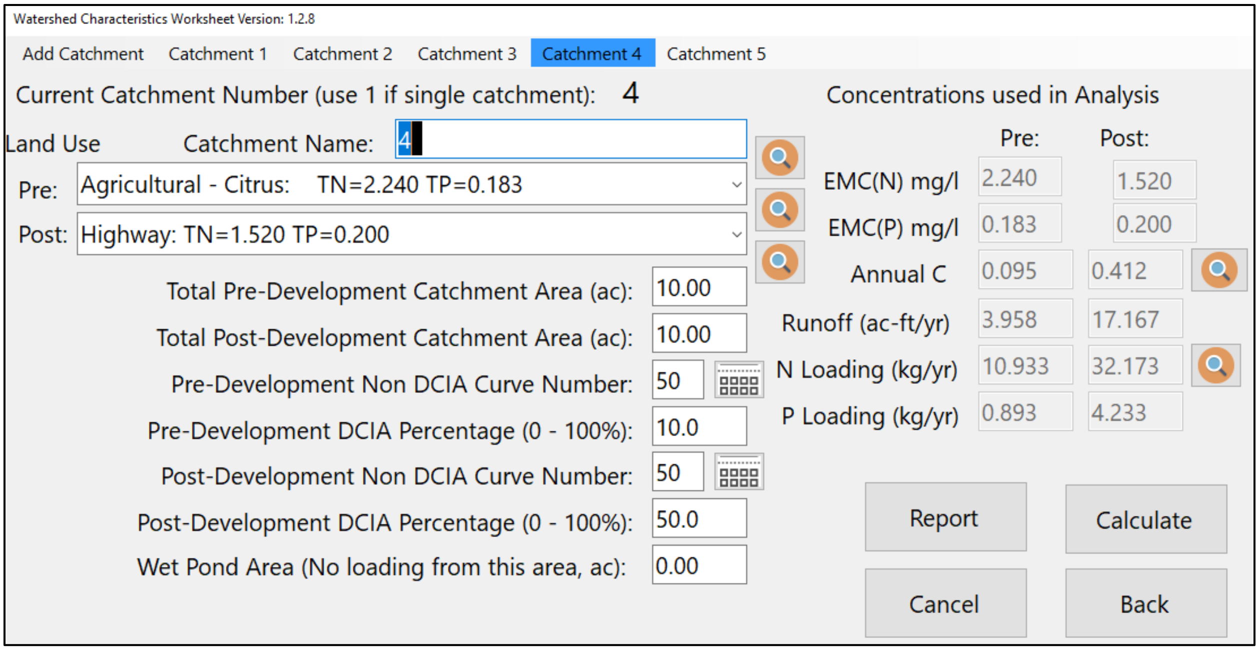


The data for the remaining 4 catchments are shown in Figure 20c. Note, add the BMP treatment for each of the catchments before entering the **Select Catchment Configuration Worksheet**.





Continued for the next two catchments on the next page



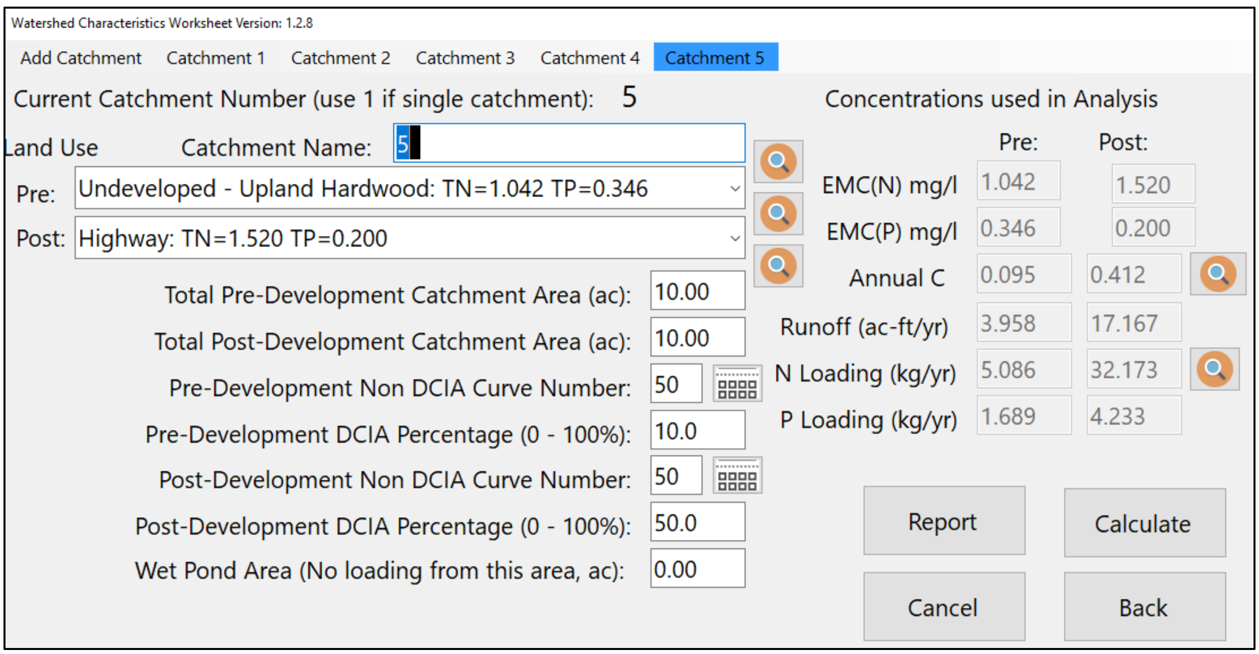
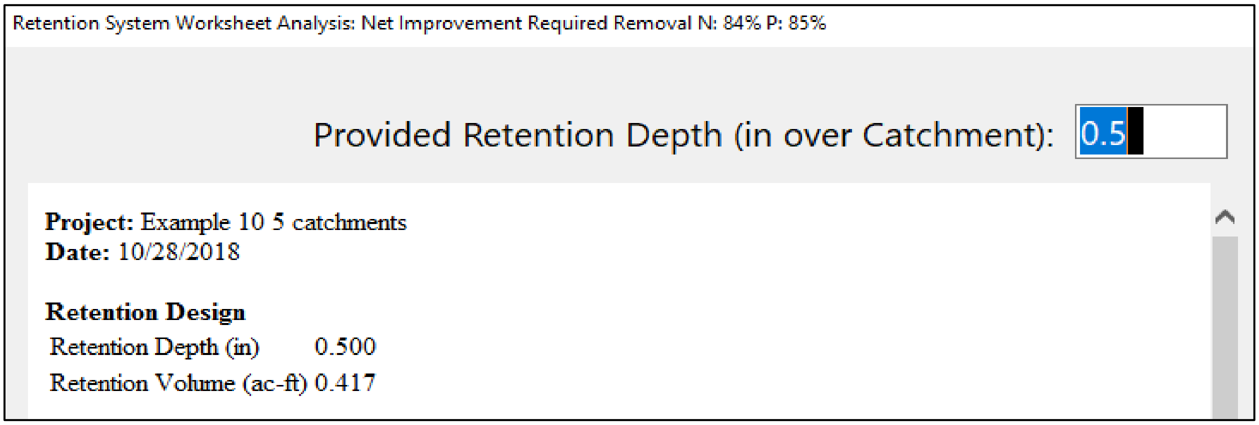


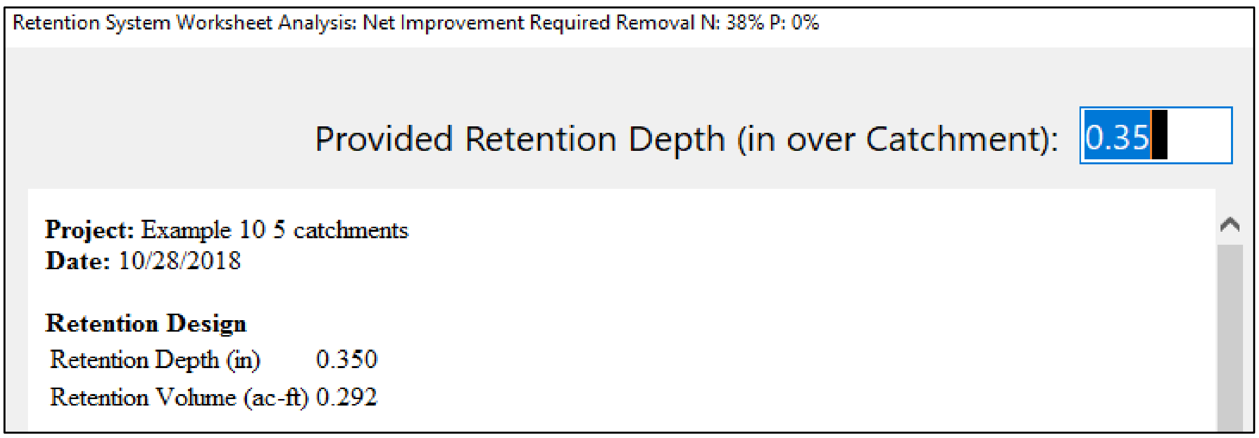
Figure 20c. Watershed Characteristics for all Five Catchments

4. Go to the **Select Treatment Options Worksheet** to enter data for the BMP in each catchment. Partial on-screen prints to illustrate input and some of the output are shown in Figure 20d. Required treatment for each catchment is printed on the ribbon across the top of the worksheet.

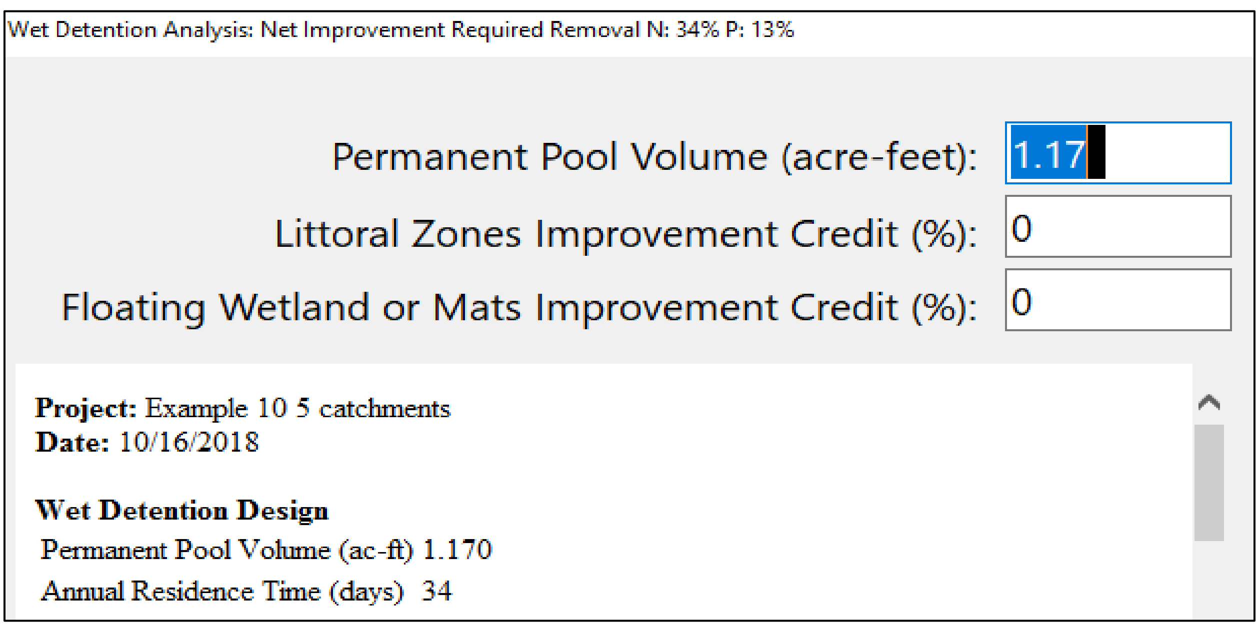
Catchment 1



Catchment 2

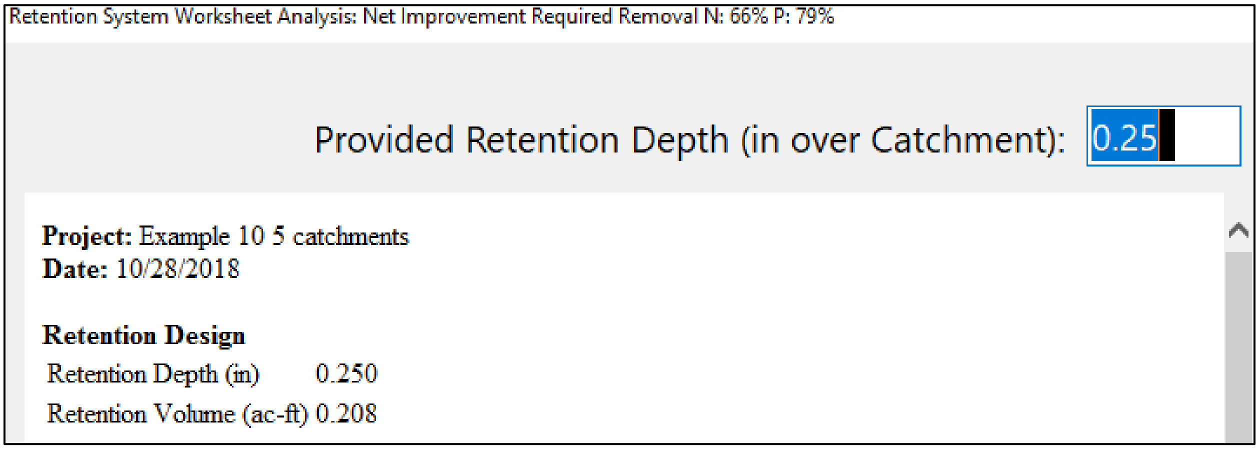


Catchment 3



Continued for the next two BMPs on the next page.

Catchment 4



Catchment 5

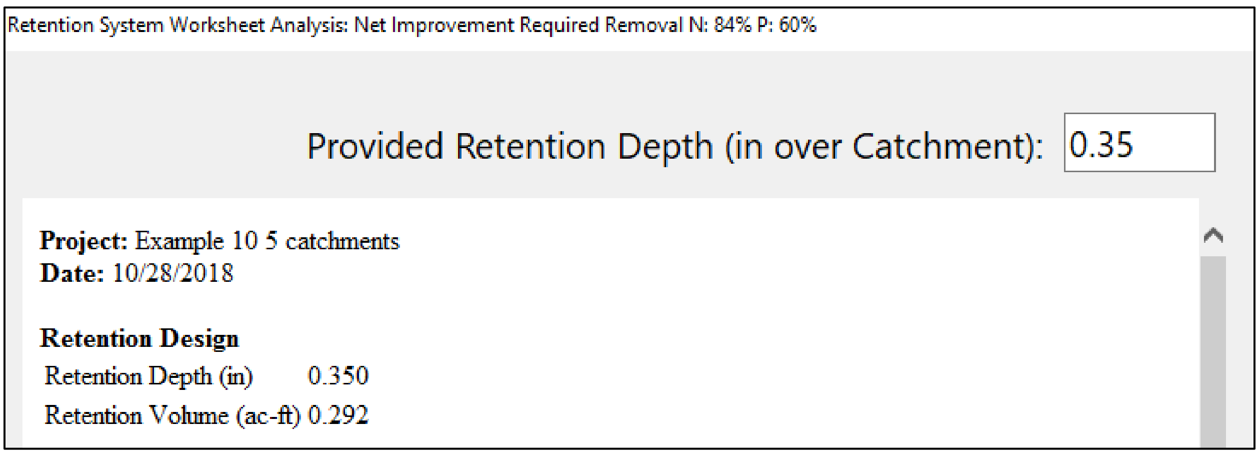
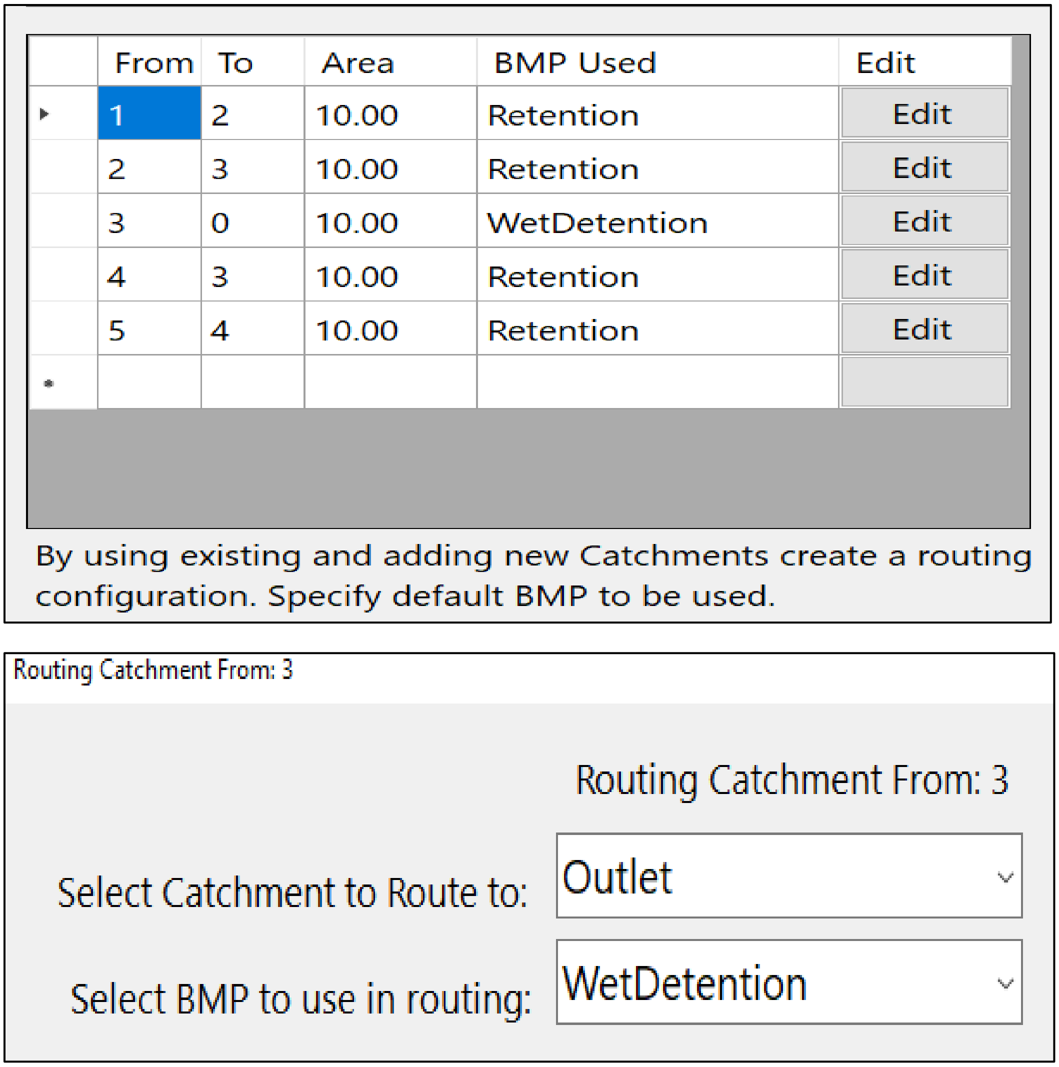


Figure 20d. Partial Screen Data for a BMP in each of the 5 Catchments.

5. Continue the analysis by selecting the *Back* buttons to return to the **Site Information Worksheet.** Next click the *Configure Catchment* button to select the routing and the BMP to use in the analysis using the *edit* button (see Figure 20e). There is no standard picture for this user defined topology (catchment configuration). Up to 4 catchments have a standard picture showing routing options. For more than 4 catchments, the routing of flow is determined by the user. In this example, catchments one and two are routed to catchment 3 which discharges to the surface water. In addition, catchments 4 and 5 are touted to catchment 3. Catchments 1,2,4 and 5 have a retention system for treatment, while catchment 3 has a wet detention pond.



From	To	Area	BMP Used	Edit
1	2	10.00	Retention	Edit
2	3	10.00	Retention	Edit
3	0	10.00	WetDetention	Edit
4	3	10.00	Retention	Edit
5	4	10.00	Retention	Edit

Figure 20e. Routing to the Outlet, BMP and an Example of Routing for Catchment 3.

4 Continue the analysis by selecting the *Back* button to return to the **Site Information Worksheet** and select the *Summary Treatment Report* button. Figure 20f shows the summary report.

BMP Trains Reports

Copy Back

Summary Treatment Report Version: 4.2.1

Project: Example 10 5 catchments & harvesting

Analysis Type: Net Improvement

BMP Types:

Catchment 1 - (1) Retention
Catchment 2 - (2) Retention
Catchment 3 - (3) Wet Detention
Catchment 4 - (4) Retention
Catchment 5 - (5) Retention

Based on % removal values to the nearest percent

Total nitrogen target removal met? **Yes**

Total phosphorus target removal met? **Yes**

Routing Summary

Catchment 1 Routed to Catchment 2
Catchment 2 Routed to Catchment 3
Catchment 3 Routed to Outlet
Catchment 4 Routed to Catchment 3
Catchment 5 Routed to Catchment 4

Summary Report

Nitrogen

Surface Water Discharge

Total N pre load	60.35 kg/yr	
Total N post load	158.18 kg/yr	
Target N load reduction	62 %	
Target N discharge load	60.35 kg/yr	
Percent N load reduction	66 %	
Provided N discharge load	53.91 kg/yr	118.87 lb/yr
Provided N load removed	104.27 kg/yr	229.91 lb/yr

Phosphorus

Surface Water Discharge

Total P pre load	11.234 kg/yr	
Total P post load	20.813 kg/yr	
Target P load reduction	46 %	
Target P discharge load	11.234 kg/yr	
Percent P load reduction	78 %	
Provided P discharge load	4.53 kg/yr	9.99 lb/yr
Provided P load removed	16.283 kg/yr	35.905 lb/yr

Figure 20f. Summary Report Routing to the Outlet and BMP Design for Five Catchments.

6. A stormwater harvesting operation is possible at catchment 3. The surface water body receiving discharge from catchment 3 has been reclassified to the status of an outstanding water body. With harvesting, can the average annual removal of Nitrogen be increased from 66% to meet this outstanding water body target of 95%? There are available from the 50 acres (sum of all catchments), 15 acres for irrigation.
7. In the **Select Treatment Options Worksheet**, select "stormwater harvesting" as shown in Figure 20g.

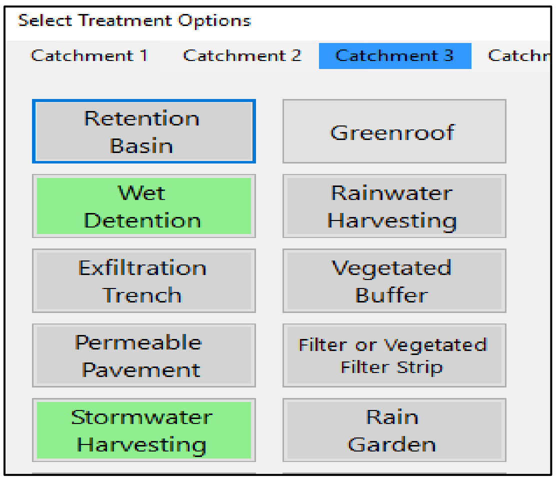


Figure 20g. Add Stormwater Harvesting in to Wet Detention in Catchment 3.

8. The harvesting input data are in Figure 20h and results in a capture of 81% if stand-alone.

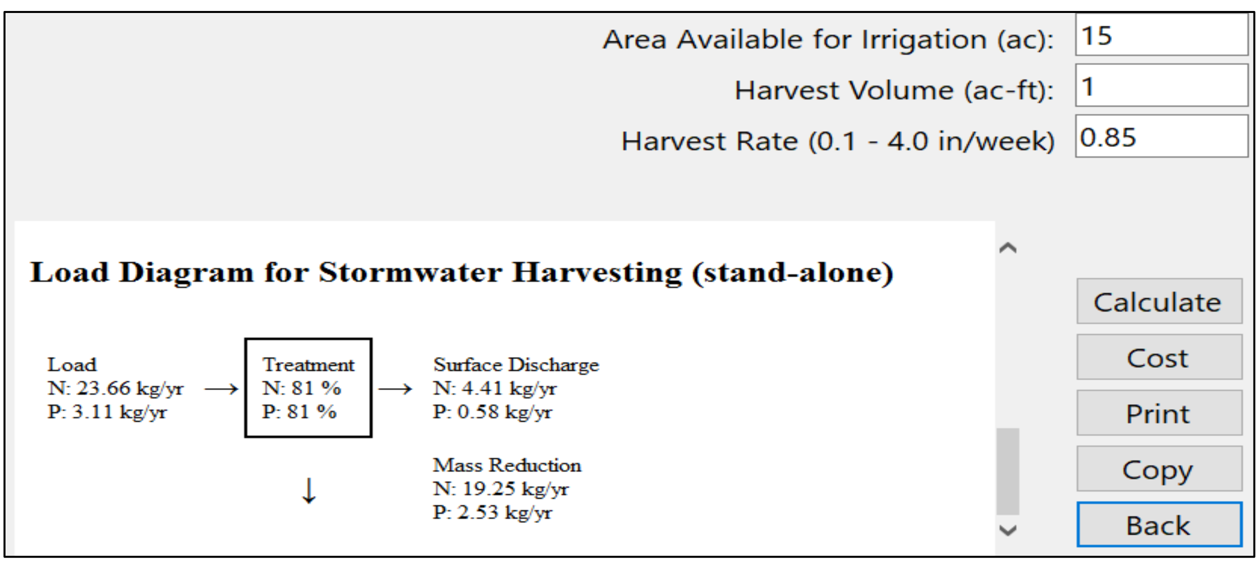


Figure 20h. Stormwater Harvesting Input Data and Capture Efficiency in Catchment 3.

9. Go to the **Select Treatment Options Worksheet and** select the "BMPs in series" button to recognize that harvesting is with wet detention and there is no additional catchment input between the 2 BMPs. Wet detention appears first in the series because the water must be detained before harvesting (Figure 20i and Figure 20j.

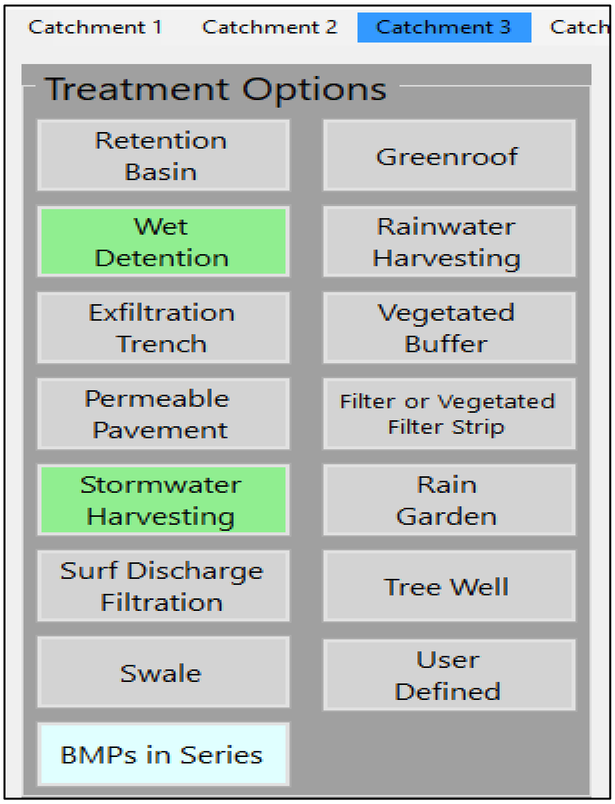


Figure 20i. Select BMPs in Series for Harvesting with Wet Detention in Catchment 3.

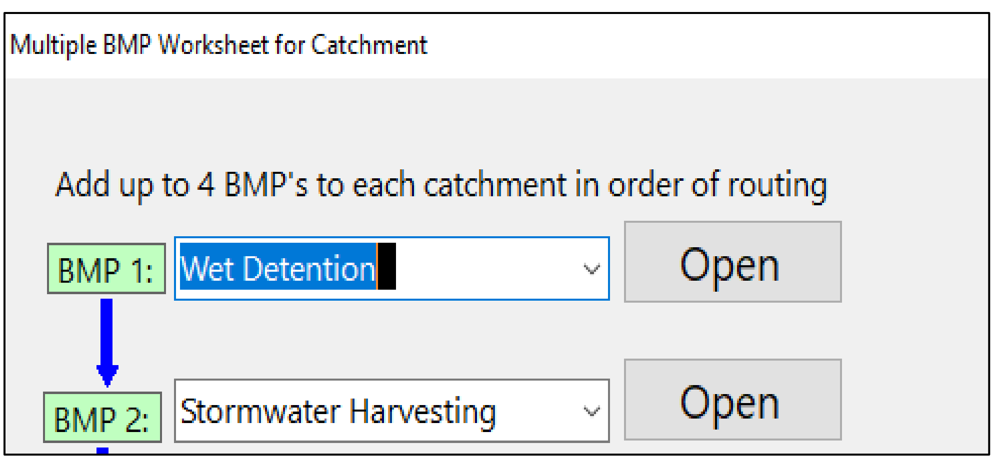


Figure 20j. BMP Selection for Stormwater Harvesting and Wet Detention in Catchment 3.

10. **In the Select Catchment Configuration Worksheet,** select for catchment 3 the multiple BMP option as shown in Figure 20k. Always go to this worksheet before going to the summary worksheet.

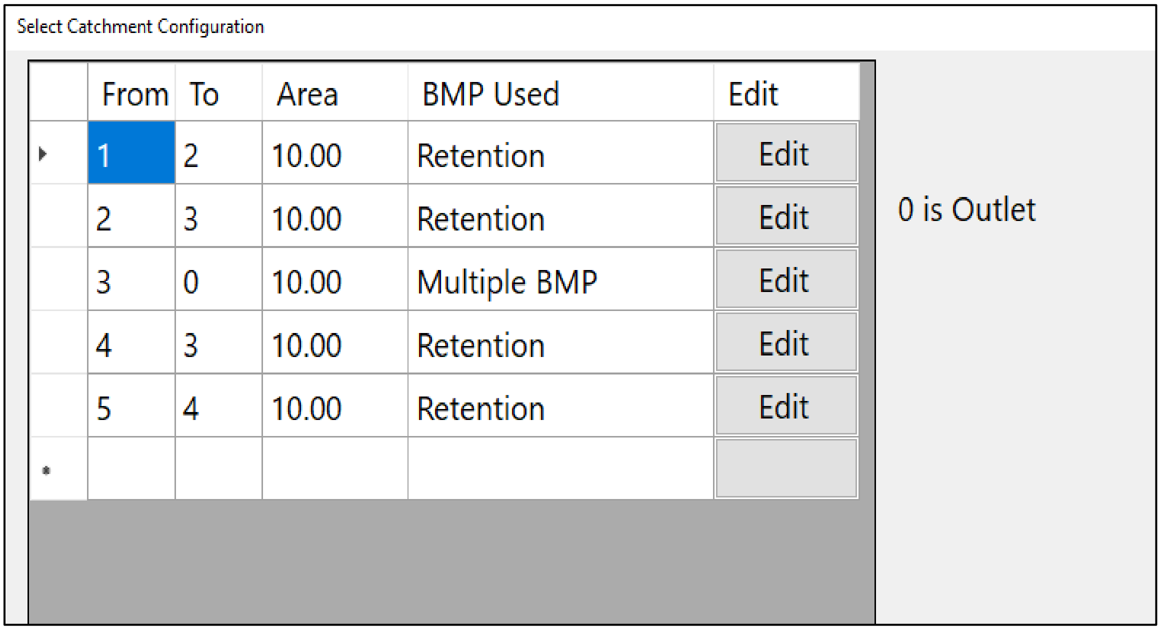


Figure 20k. Multiple BMP in Catchment 3.

This example problem demonstrates a TP and TN average annual effectiveness evaluation for a watershed with 5 catchments. Adding an additional BMP to a catchment is possible. If an option exists to change the input data for any treatment BMP including the series configurations on any worksheet, always come back to the "**Configuration Catchment**" button on the " "**General Site Information**" worksheet and enter the BMP used (note differences in Figure 20k (Multiple BMP vs. Figure 20e (Wet Detention).

With this example, the addition of a BMP, namely stormwater harvesting to an existing ".bmpt" file is demonstrated. This demonstrates the flexibility of adding BMPs to an existing file. The summary data after the addition of harvesting are shown in Figure 20L. The average annual removal TN and TP removal was increased to meet an outstanding water body criteria. However, note marginal changes in effectiveness with increases in BMP sizes should be expected once approximately 90% effectiveness has been achieved.

BMP Trains Reports

Copy Back

Summary Treatment Report Version: 4.2.1

Project: Example 10 5 catchments & harvesting

Analysis Type: Net Improvement

BMP Types:

Catchment 1 - (1) Retention
Catchment 2 - (2) Retention
Catchment 3 - (3) Multiple BMP
Catchment 4 - (4) Retention
Catchment 5 - (5) Retention

Based on % removal values to the nearest percent

Total nitrogen target removal met? **Yes**

Total phosphorus target removal met? **Yes**

Routing Summary

Catchment 1 Routed to Catchment 2
Catchment 2 Routed to Catchment 3
Catchment 3 Routed to Outlet
Catchment 4 Routed to Catchment 3
Catchment 5 Routed to Catchment 4

Summary Report

Nitrogen

Surface Water Discharge

Total N pre load	60.35 kg/yr	
Total N post load	158.18 kg/yr	
Target N load reduction	62 %	
Target N discharge load	60.35 kg/yr	
Percent N load reduction	95 %	
Provided N discharge load	8.59 kg/yr	18.93 lb/yr
Provided N load removed	149.59 kg/yr	329.85 lb/yr

Phosphorus

Surface Water Discharge

Total P pre load	11.234 kg/yr	
Total P post load	20.813 kg/yr	
Target P load reduction	46 %	
Target P discharge load	11.234 kg/yr	
Percent P load reduction	97 %	
Provided P discharge load	.642 kg/yr	1.41 lb/yr
Provided P load removed	20.171 kg/yr	44.478 lb/yr

Figure 20L. Summary Report adding Stormwater Harvesting in Catchment 3.

Example problem # 11 – User Defined BMP Option

This is an example for the evaluation of a BMP that is not one of the 13 BMPs defined in appendix B or does not have currently commonly acceptable design features and annual removal effectiveness. The User Defined BMP option is demonstrated to illustrate input and output. Note that the User Defined BMP usually is the first in a series or the last in a series in a catchment. It can be the second or third in series. It also is frequently associated with flow-through devices that reduce concentration rather than those that reduced volume of runoff, such as those used for non-retention BMPs. Others may be developed that eliminate these constraints and additional program changes will be necessary. Site information data are shown in Figure 21a.

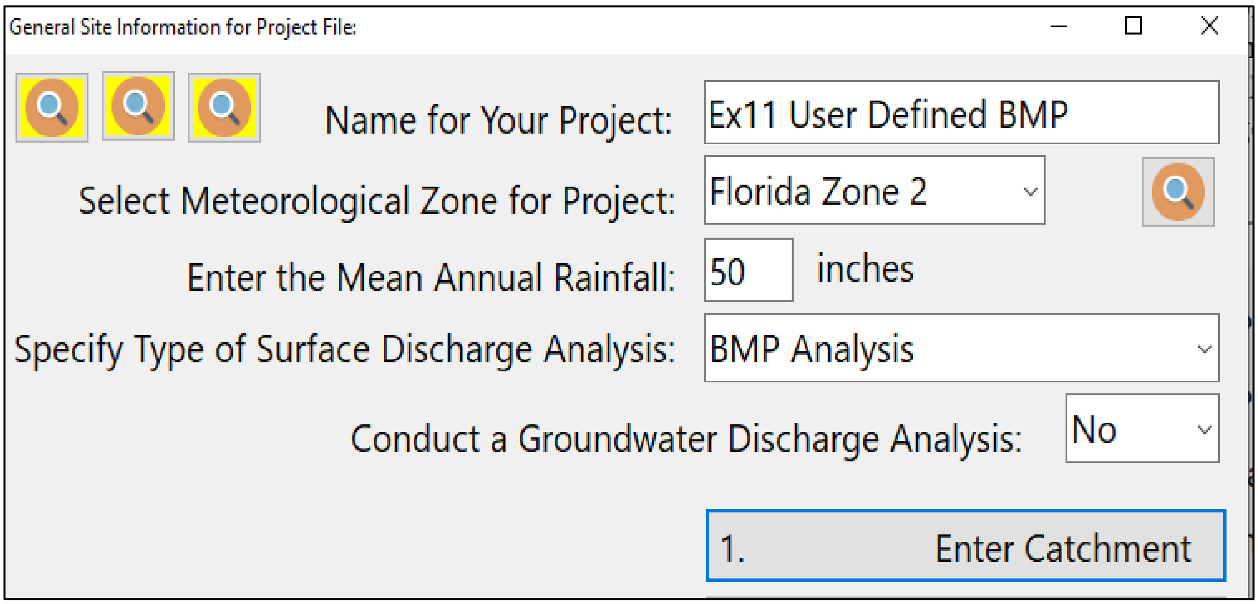


Figure 21a. Site Information Input.

1. Select the *Enter Catchment* button to proceed to the **Watershed Characteristics Worksheet** (Figure). Since this is an effectiveness analysis for a BMP, enter the catchment configuration post-development land use, post catchment area, post non-DCIA Curve Number and post DCIA percentage. It is not necessary to enter the preconditions for a BMP analysis. Note that the watershed also has User Defined EMC values, After the data for the catchment are entered, click on the *Calculate* button to view the annual C value, annual runoff (acre-feet/yr), and the Nitrogen and Phosphorus loadings (kg/yr).

   After the data are entered and the calculate button pressed, proceed to **Select Treatment Options Worksheet** and select "User Defined" BMP as shown in Figure 21c.

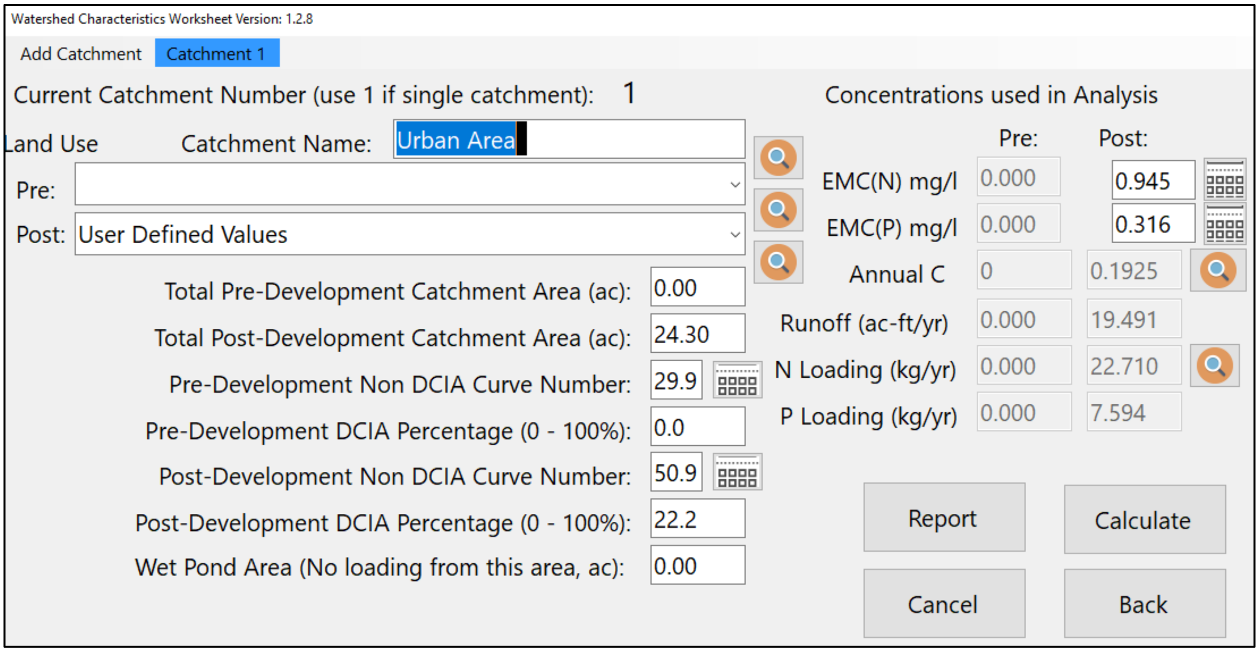


Figure 21b. Catchment Characteristics with User Defined EMC for a BMP Analysis.

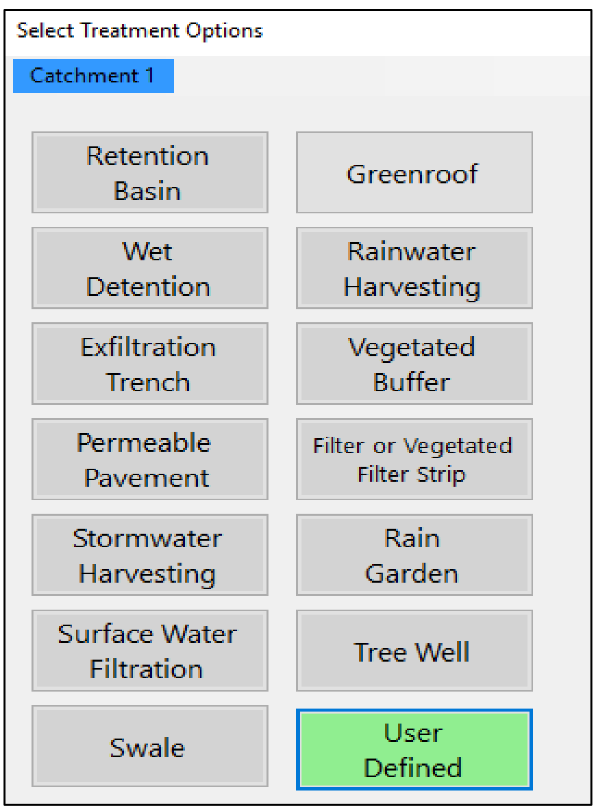


Figure 21c. User Defined BMP Selection.

2. Enter the input data for the User defined BMP as shown in Figure 21d. The User Defined BMP must be either the first or last in series within a catchment. Groundwater removal cannot be entered from this User Defined BMP option. User Defined BMPs are those without field or lab verified data. Examples would be a new solids separation device and Florida Friendly Landscape. Acceptable efficiencies need verified support data once the BMP is moved to a commonly used BMP.

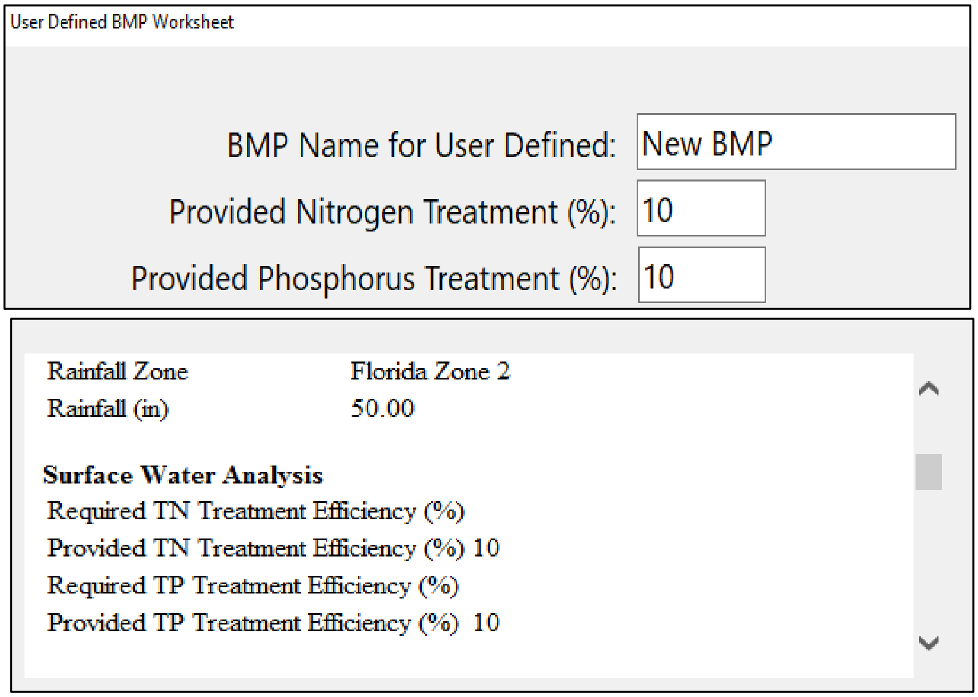


Figure 21d. User Defined BMP Data Entry for a BMP Analysis.

3. Proceed to the **Configure Catchments Worksheet** and enter the routing and BMP used as shown in Figure 21e.

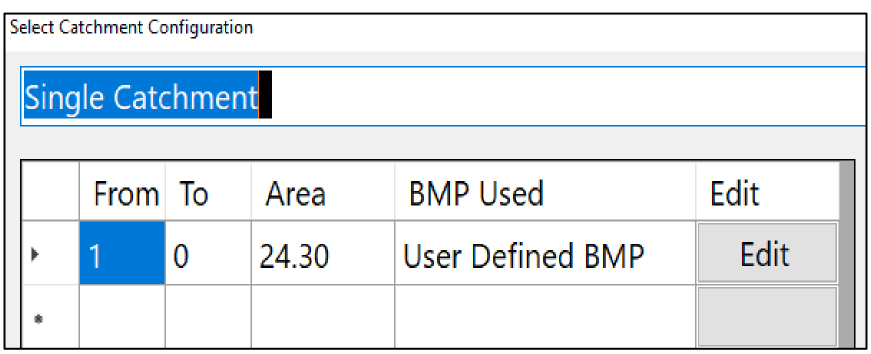


Figure 21e. Configure Catchment Worksheet with User Defined BMP Selection.

4. From the **General Site Information Worksheet**, proceed to the **Summary Treatment Report** to review the results. The report is shown in Figure 21f.

BMP Trains Reports

Copy Back

Project: Ex 11 User Defined BMP

Analysis Type: BMP Analysis
BMP Types:
Catchment 1 - User Defined BMP

Routing Summary
Catchment 1 Routed to Outlet

Summary Report

Nitrogen

Surface Water Discharge

Total N post load	22.71 kg/yr	
Percent N load reduction	10 %	
Provided N discharge load	20.44 kg/yr	45.07 lb/yr
Provided N load removed	2.27 kg/yr	5.01 lb/yr

Phosphorus

Surface Water Discharge

Total P post load	7.59 kg/yr	
Percent P load reduction	10 %	
Provided P discharge load	6.83 kg/yr	15.07 lb/yr
Provided P load removed	.76 kg/yr	1.67 lb/yr

Figure 21f. User Defined BMP Summary Treatment Report.

Note again that when analyzed in series in a single catchment the User Defined BMP is one that is a flow-through device.

5. As an example of a User Defined BMP in series with another BMP, a baffle box can be followed by an up-flow filter. Thus, as a continuation of this example problem, an up-flow filter is added after the User Defined BMP. The filter is designed to capture the runoff from the 0.25 inch of runoff and is in series with the User Defined BMP for surface water discharge. Treatment volume of 0.25 inch is calculated knowing the storage volume in the BMP and delivery pipe before overflow of the upflow filter divided by the total watershed area. The worksheets are shown in Figure 21g.

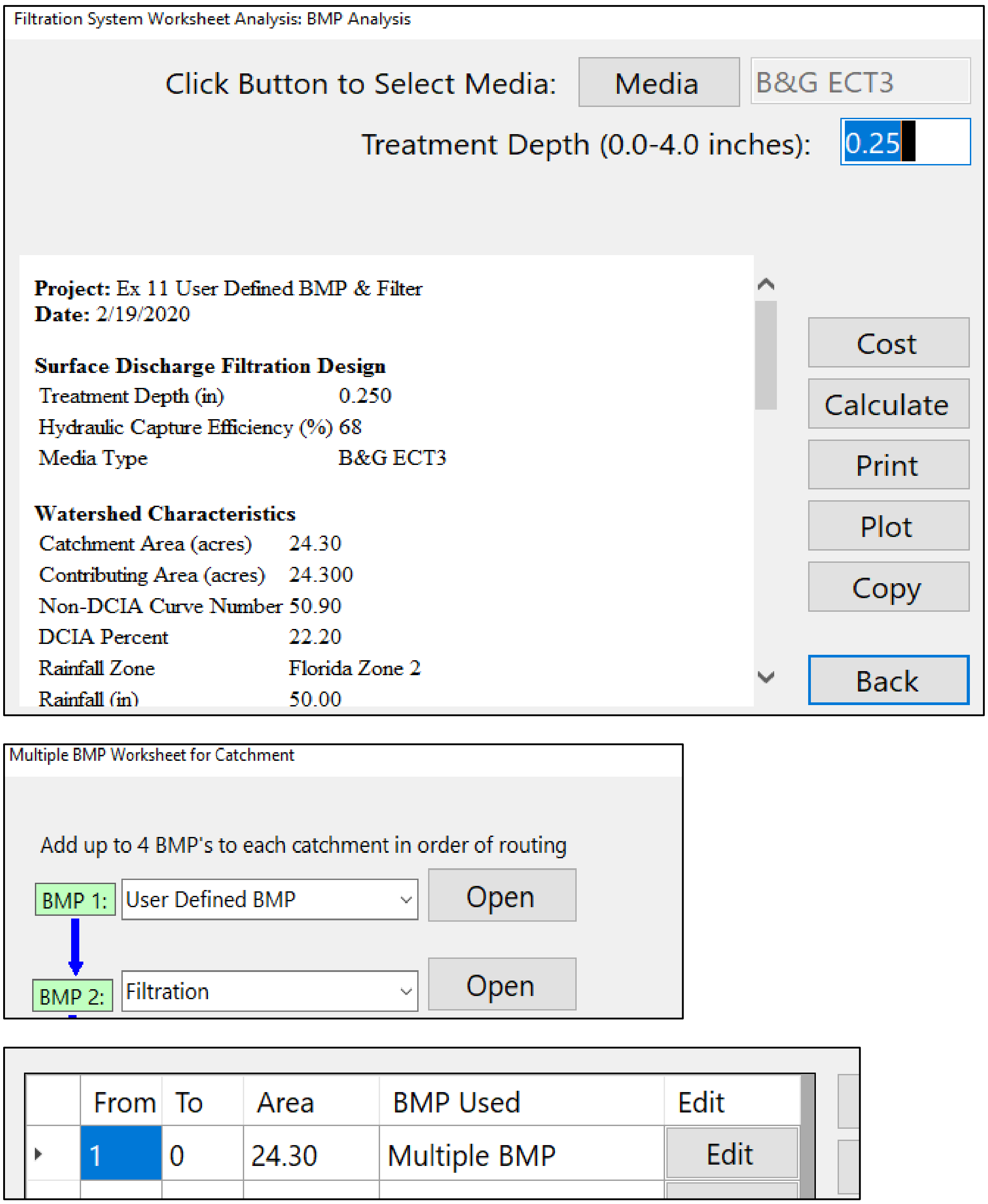


Figure 21g. Worksheets for the Addition of a Filter in Series with a User Defined BMP.

6. From the **General Site Information Worksheet,** proceed to the **Summary Treatment Report** to review the results. The report is shown in Figure 21h.

Project: Ex 11 User Defined BMP & Filter

Analysis Type: BMP Analysis
BMP Types:
Catchment 1 - (Urban Area) Multiple BMP
Based on % removal values to the nearest percent

Routing Summary
Catchment 1 Routed to Outlet

Summary Report
Nitrogen

Surface Water Discharge

Total N post load	22.71 kg/yr	
Percent N load reduction	37 %	
Provided N discharge load	14.2 kg/yr	31.31 lb/yr
Provided N load removed	8.51 kg/yr	18.77 lb/yr

Phosphorus

Surface Water Discharge

Total P post load	7.594 kg/yr	
Percent P load reduction	37 %	
Provided P discharge load	4.748 kg/yr	10.47 lb/yr
Provided P load removed	2.846 kg/yr	6.275 lb/yr

Figure 21h. User Defined BMP and Filter Summary Report.

Example problem # 12 – Wet Detention and Filtration

This is an example for the average annual removal of a wet detention pond in series with a side-bank filter. This is a net improvement effectiveness analysis for a BMP Treatment Train. The professional needs to know the average annual removal so that the post development condition is not discharging to a surface water body more Nitrogen and Phosphorus than in the pre-condition. The combination is typically used because the wet detention frequently does not provide sufficient removal by itself. It is located on the southwest area of Florida, in meteorological zone 4. Site information data are shown in Figure 22a.

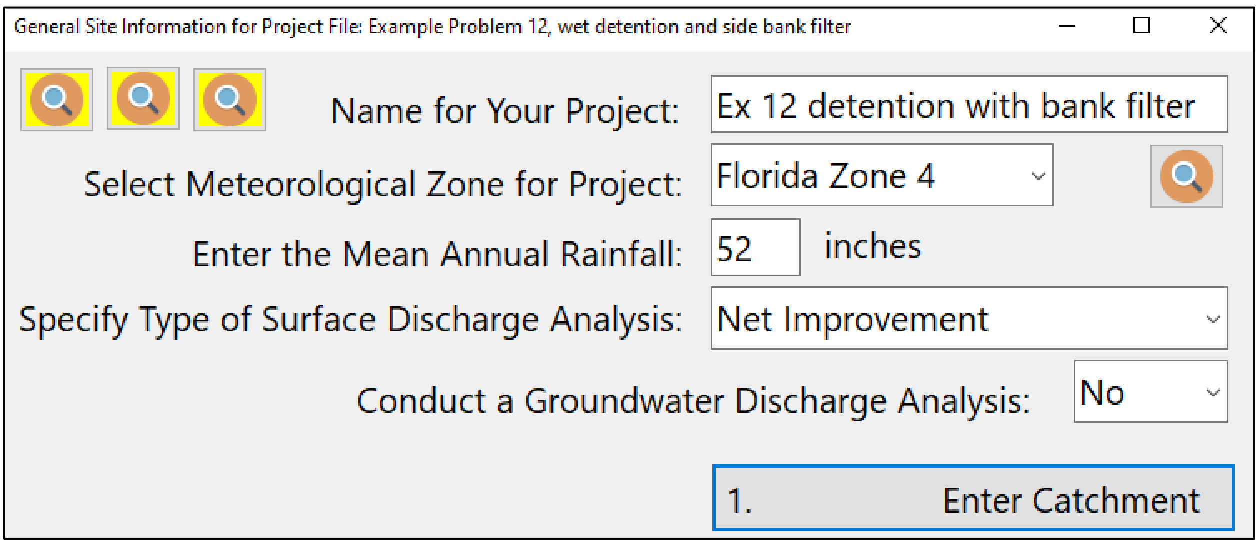


Figure 22a. General Site Information Worksheet.

1. Select the *Enter Catchment* button to proceed to the **Watershed Characteristics Worksheet** (Figure 22b). Enter the catchment configuration pre- and post-development land use, catchment area, non-DCIA Curve Number and post DCIA percentage. The watershed area is in citrus and will be converted to single family residential. These land use values have associated EMC values. The wet pond area at the permanent pool elevation is 0.5 acres and the review agency agrees that there is no net contribution of loading from this area. Thus, the area is subtracted for loading calculations. The permanent pool elevation is usually the average groundwater elevation unless there is backwater or other condition which changes the elevation. After the data for the catchment are entered, click on the *Calculate* button to view the annual C value, annual runoff (acre-feet/yr), and the Nitrogen and Phosphorus loadings (kg/yr).

   After the data are entered for the catchment and the calculate button pressed, proceed to **Select Treatment Options Worksheet** and select "Wet Detention" BMP and proceed to enter the data for a wet pond as shown in Figure 22c.

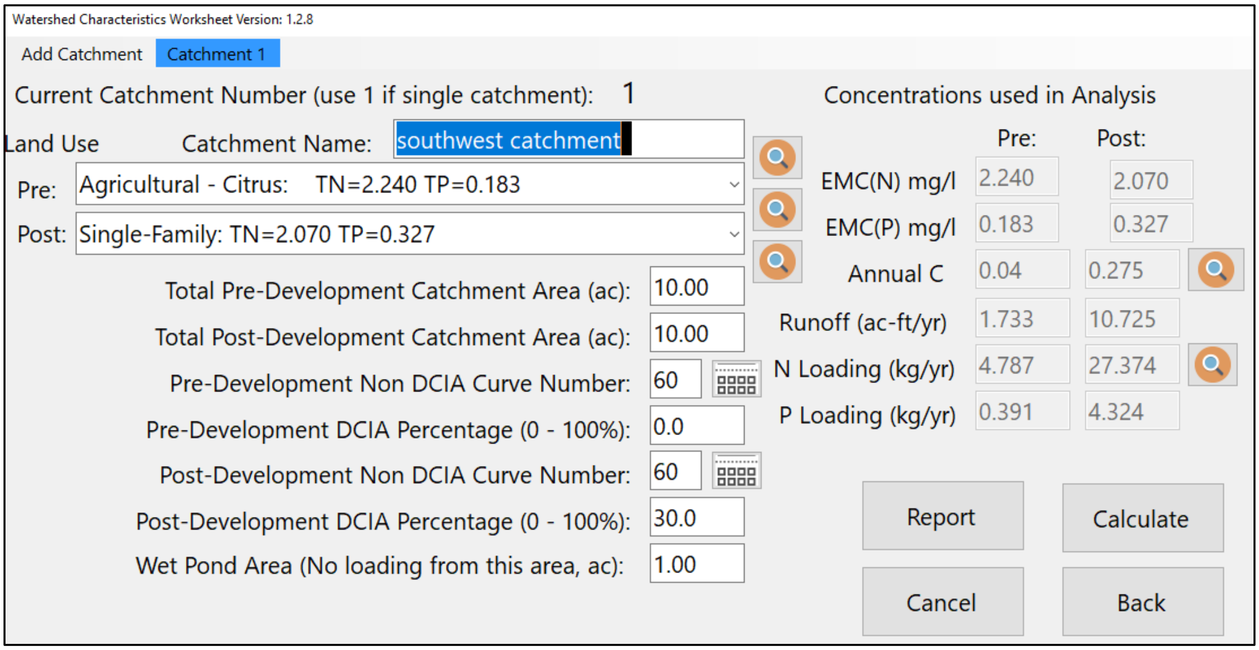


Figure 22b. Watershed Characteristics.

2. Enter the input data for the wet detention pond (see Figure 22c. The permanent pool volume is 5 acre-feet, which results in an annual residence time of 170 days. The target net improvement is 83% N and 91% P, however the pond design results in 43% N and 78% P removal. Additional treatment is required or other BMP options are examined.

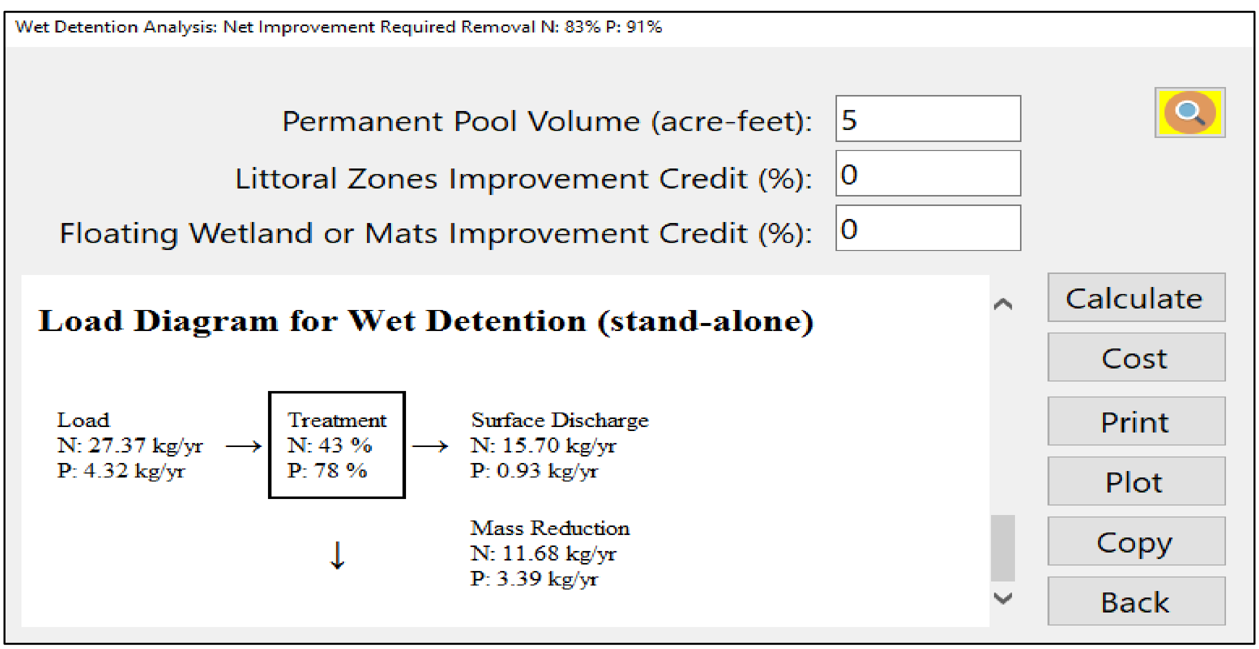


Figure 22c. Wet Detention Pond BMP Data Entry and Results.

3. The annual average effectiveness of the wet detention pond is less than required for net improvement. As an option to meet net improvement, a side bank filter is added to the wet pond. Proceed to the **Surface Filtration Worksheet** (Figure 22d) and enter the design volume of water that can be treated by the filter. In this case, the design volume is 1.75 inches and the treatment is for the effluent of a wet detention pond. The volume of treatment was chosen so as when added to the effectiveness of the wet pond, the overall removal will meet net improvement. The depth of the media for residence time must be 2 feet above the top of the side bank drain. CTS 24 media was used and its design filtration and removal rates with saturated weight are saved for calculating media area and service life in the "tools menu". The media average annual effectiveness is 75% Nitrogen and 95% Phosphorus, but not all the runoff water in a year passes through the media. The average annual effectiveness, considering the bypass water is 71% N and 89% P.

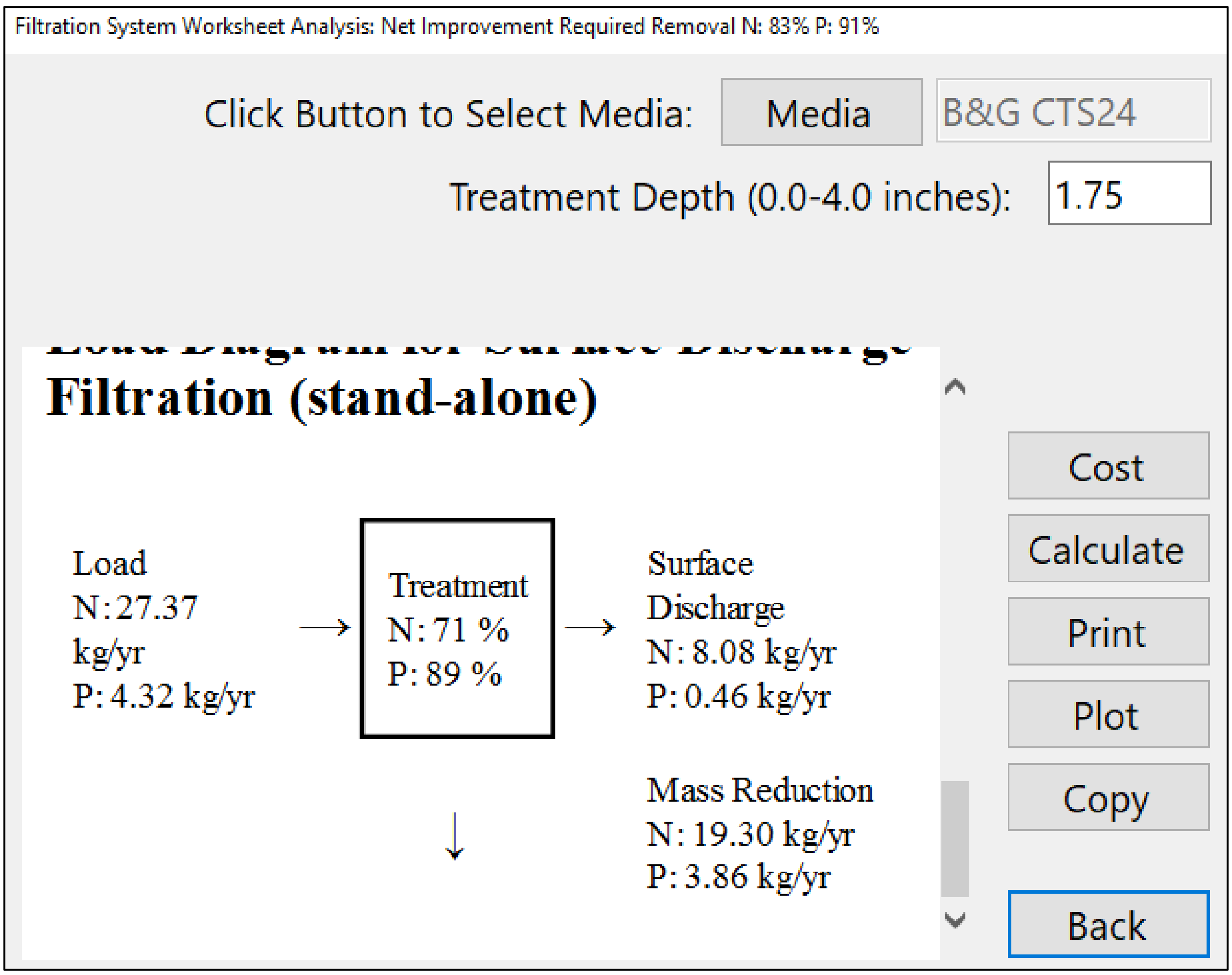


Figure 22d. Surface Filtration Data Entries and Results.

4. Proceed to the "**BMP in Series**" button on the bottom of the **Select Treatment Option Worksheet** as well as the "**Configure Catchment**" button before proceeding to the surface area calculation (see sections 7 and 8 of this example below). The area of the filter in SF and service life are calculated. The minimum surface area is based on a treatment rate for the media in units of gallons per minute per square feet, the maximum volume that is captured by the filter, and the need to drain half the captured volume in the wet detention pond in the first day. The captured volume is the treatment depth or the amount of rainfall from the effective impervious area (EIA). The product of the treatment depth and EIA with conversion factors results in a volume measure in the more traditional units of gallons, acre-feet or cubic feet. The EIA is that area from which the treatment volume at design rainfall will drain to the filter. The Directly Connected Impervious Area (DCIA), rainfall excess from the pervious area, and the pond area at permanent pool are considered to drain all of the treatment volume. As an example, for a treatment rate of 0.052 GMP/SF, the minimum surface area is calculated using EIA(acres) x TD (in) x 181.185. For a treatment rate of 1 GMP/SF, the surface area is EIA x TD x 9.425. These calculations are completed with the "tools" button on the **Select Treatment Options Worksheet**. The **BMP Trains calculator selection page** is shown in Figure 22e. The calculation worksheet for the media filter area is highlighted.

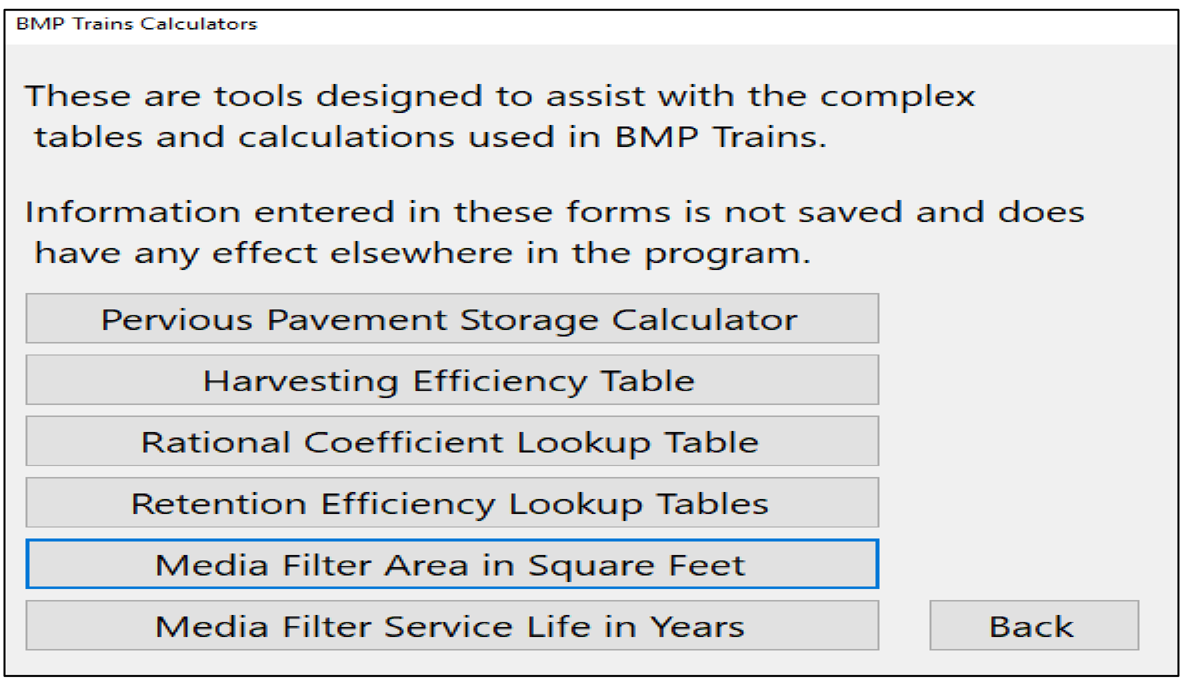


Figure 22e. BMP Trains Calculators Selection Page.

5. To calculate the minimum media filter area; the catchment characteristics, filtration rate and treatment depth are input, as shown in Figure 22f. No need to re-enter all the catchment data as it has already been done. You can also enter an effective impervious area for trail runs when no catchment is selected. For this example, the pond bank side slope is such that there is room for a 10-feet wide filter to maintain a minimum filter media depth of 2 feet. The area of the filter is calculated as 1201.58 square feet; thus the length of the filter was set at 120 feet (1201.58/10). Drawdown time must be checked and the filter size may be larger to accommodate a drawdown time.

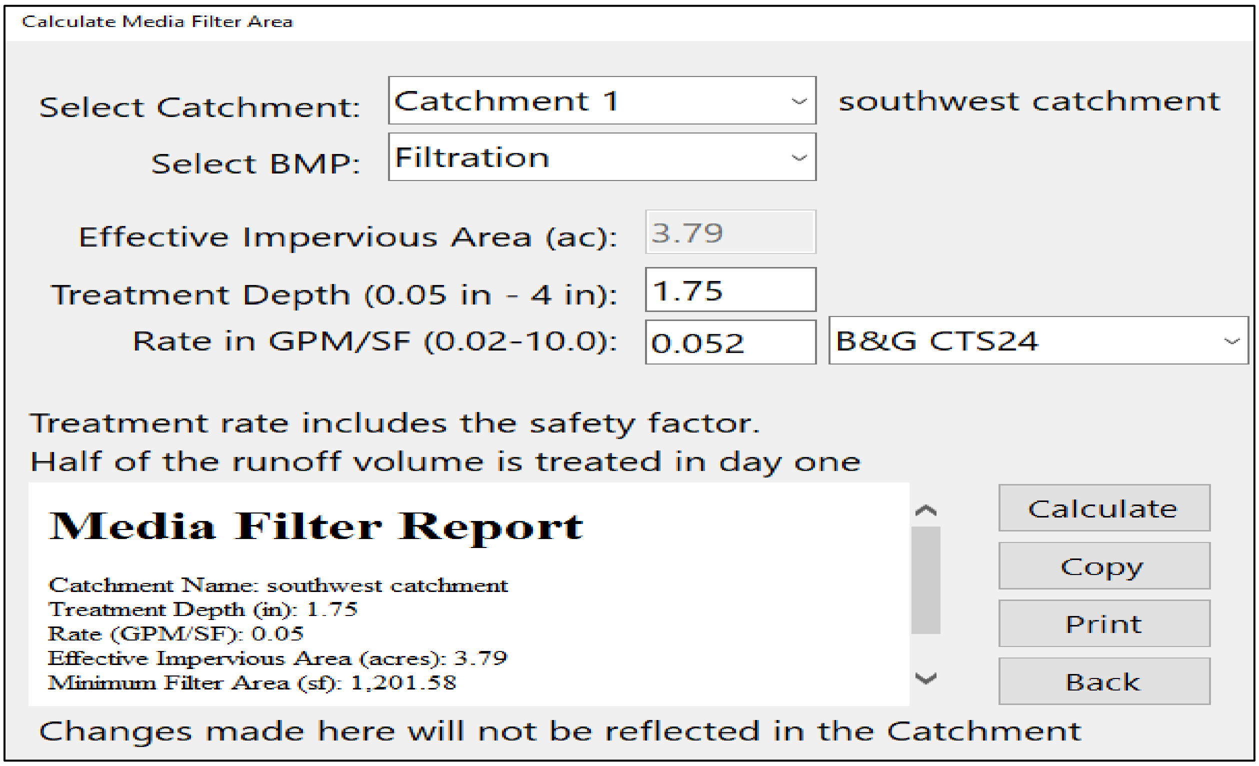


Figure 22f. Media Minimum Filter Area Calculator.

6. The calculation of service life is based on filter media capacity to remove Ortho-phosphorus (OP) from the stormwater and the amount of OP retained per year. The formula is: service life (years) equals the filter removal capacity (mg OP) divided by OP removed per year (mg OP/yr.) by the media. The filter removal capacity is the Filter Volume Provided and with typical units in cubic feet (CF) x moist Weight (pounds/CF) of media x 454 g/pound x media capacity for removal (mg OP/ gram of media). The OP removed is the fraction of OP in TP x mass removed (kg/yr.) x 1,000,000 mg/kg. Nitrogen removal is by biological means and service life is considered to be long term. This calculation is for media in a stand-alone BMP or there is no other water to be treated from other sources.

When using CTS media, the overall removal rate is 0.2 mg OP/g. The filter volume provided is 2400 CF (1200 SF x 2 feet depth). Media in-place weight (frequently called saturated weight) is 95 pounds/cubic foot, and the fraction of OP in TP is assumed to be 1. It is noted that not all TP will be in the OP form but for a conservative (low) estimate of service life, it is assumed to be 1.0. The input and service life are shown in Figure 22g. If the media were user defined, the removal rate and saturated media weight would be input. Note: if you made any changes to the treatment volumes (permanent pool or filtration treatment depth), then go to the **Configure Catchments** to insure you have the changes recorded in the calculation under "multiple BMP".

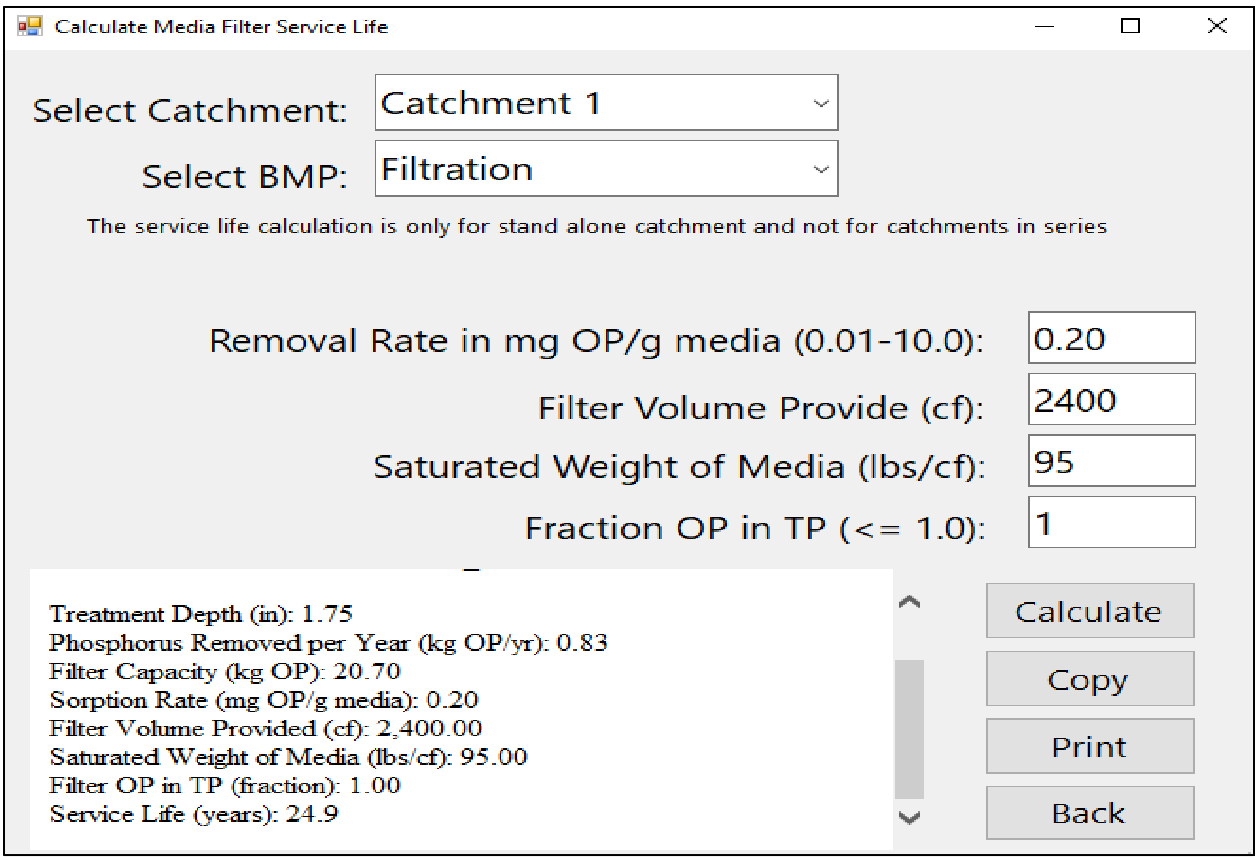


Figure 22g. Service Life Calculator.

7. Always in completing an analysis, proceed to the **Select Treatment Options Worksheet** and select the "BMP in Series" button to enter the order of the BMPs in the **Multiple BMP Worksheet** (Figure 22h). This is a reminder to do so when reloading the .bmpt file.

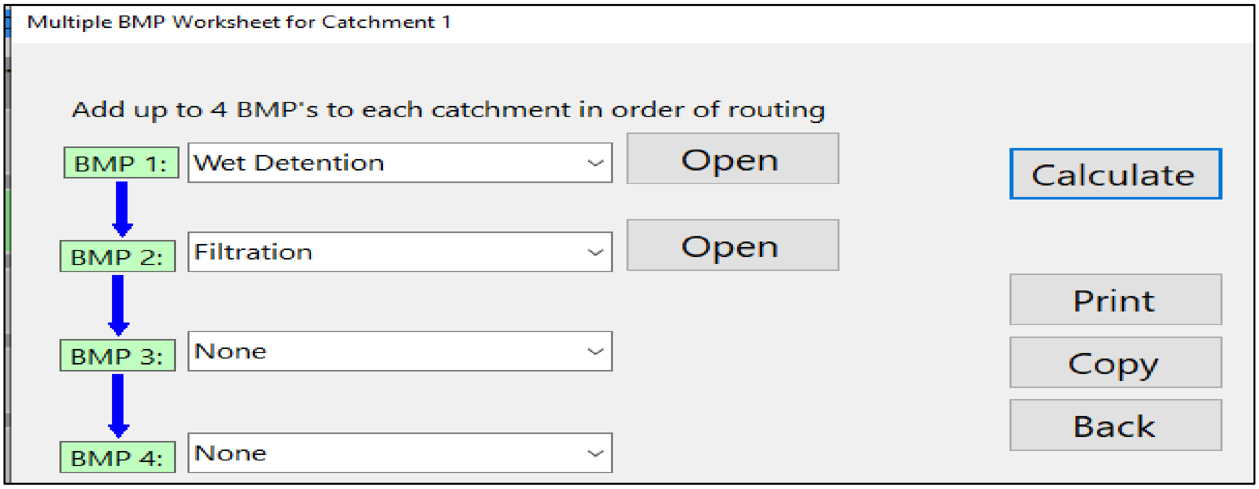


Figure 22h. Multiple BMP Worksheet for BMPs in Series.

8. Proceed to the **General Site Information Worksheet** and select the "**Configure Catchment Button**." Enter on the **Select Catchment Configuration Worksheet** the BMP used with the "Edit" button. Multiple BMPs are used (wet detention plus side bank filter) in this case as well as the specification of routing to the outlet (0). The selection is shown in Figure 22i. This button must be used any time there are changes to the BMP design criteria, such as in this case wet pond permanent pool and filter treatment rate.

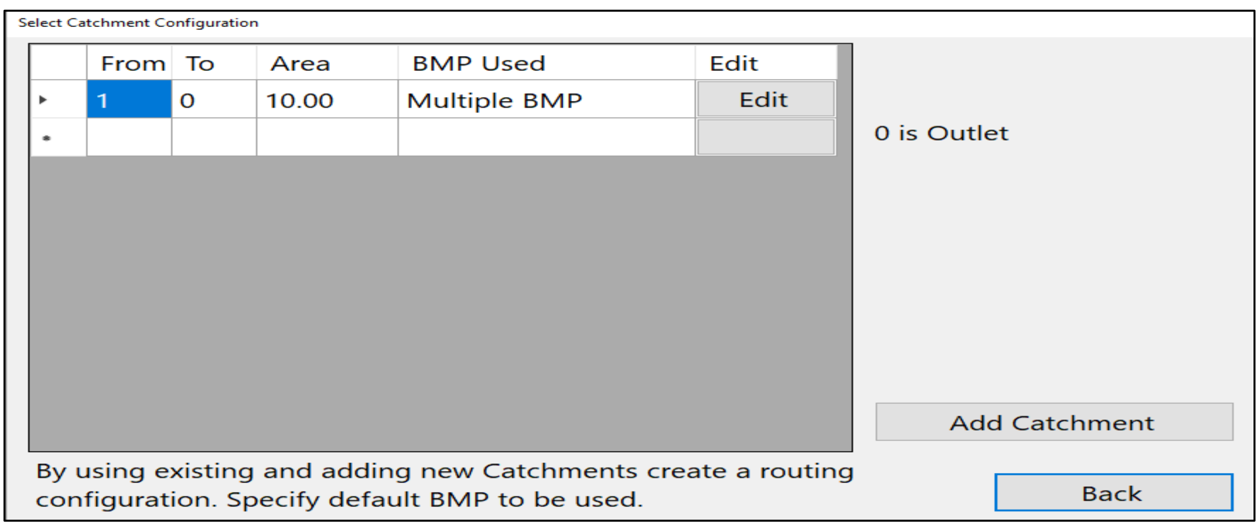


Figure 22i. Select BMPs Used - Multiple BMPs.

9. The summary results of the calculations can now be viewed on the **Summary Treatment Report.** Note that the net improvement target annual removal effectiveness has been achieved with the combination of a wet pond and side bank filter. The evaluation of this

combination results in a removal of 83% TN and 98%TP (see Figure 22j). This example demonstrates the use of **BMP Trains 2020** for the evaluation of annual effectiveness using more than one BMP in a catchment. It also shows the calculation of a side drain filter area for a wet pond and with specific catchment characteristics, filter treatment depth and filter media with an associated filtration rate.

Project: Ex 12 detention with bank filter

Analysis Type: Net Improvement
BMP Types:
Catchment 1 - (southwest catchment) Multiple BMP
Based on % removal values to the nearest percent
Total nitrogen target removal met? **Yes**
Total phosphorus target removal met? **Yes**

Routing Summary
Catchment 1 Routed to Outlet

Summary Report

Nitrogen

Surface Water Discharge

Total N pre load	4.79 kg/yr	
Total N post load	27.37 kg/yr	
Target N load reduction	83 %	
Target N discharge load	4.79 kg/yr	
Percent N load reduction	83 %	
Provided N discharge load	4.63 kg/yr	10.21 lb/yr
Provided N load removed	22.74 kg/yr	50.15 lb/yr

Phosphorus

Surface Water Discharge

Total P pre load	.391 kg/yr	
Total P post load	4.324 kg/yr	
Target P load reduction	91 %	
Target P discharge load	.391 kg/yr	
Percent P load reduction	98 %	
Provided P discharge load	.1 kg/yr	.22 lb/yr
Provided P load removed	4.225 kg/yr	9.315 lb/yr

Figure 22j. Summary Results for Example Problem 12 using BMPs in Series.

Example problem # 13 – Impervious Area with Overland Flow to a Pervious Area

This is an example applicable to a parking lot or a highway section. The unique feature is the impervious surface is separated from the BMP by a pervious surface. As a general guide, when the impervious surface flows onto a pervious surface with sandy soils and has a width of flow equal to or greater than half the width of the contributing impervious area, separation or disconnecting the impervious area is recommended for evaluation when calculating annual loading. As an example for evaluating a disconnection, net improvement analysis for a retention BMP is used. The professional needs to know the average annual removal so that the post development condition is not discharging to a surface water body more Nitrogen and Phosphorus than in the pre-condition.

The impervious surface is 12 feet wide, the pervious area including a retention area is 18 feet wide to the edge of the property line (edge of catchment). Thus the width of the section is 30 feet. The percent impervious is 40 ((12/30)*100). The curve number for the pervious surface is 50. The curve number for the impervious surface is 95 to replicate the simulations for annual effectiveness or runoff occurs when rainfall exceeds 0.1 inches. If there were a transport pipe or channel from the impervious surface to the BMP, the impervious area should be considered as a Directly Connected Impervious Area (DCIA) . The area is located in Southwestern Polk County Florida and in meteorological zone 2 with an average annual rainfall of 51 inches. Site information data are shown in Figure 23a.

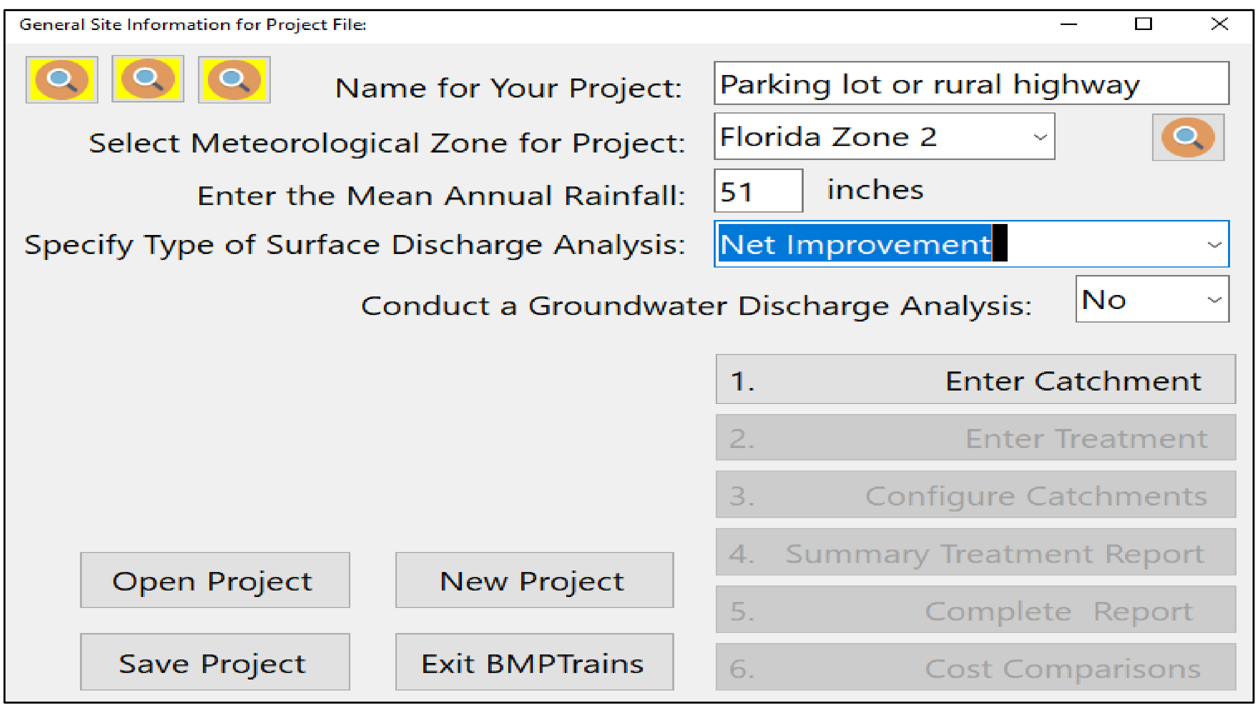


Figure 23a. General Site Information Worksheet.

1. Select the *Enter Catchment* button to proceed to the **Watershed Characteristics Worksheet** (Figure 23b). Enter the catchment configuration land use, catchment area, and pre-condition non-DCIA Curve Number. The non-DCIA Curve Number for the post condition will be a composite curve number (CCN), thus enter the calculation routine to calculate the CCN. . The CN values for the impervious area is 95 (runoff occurs if rainfall exceeds 0.1 inch). The CCN calculator is shown in Figure 23c. After the data for the catchment are entered, click on the *Calculate* button to view the annual C value, annual runoff (acre-feet/yr), and the Nitrogen and Phosphorus loadings (kg/yr).

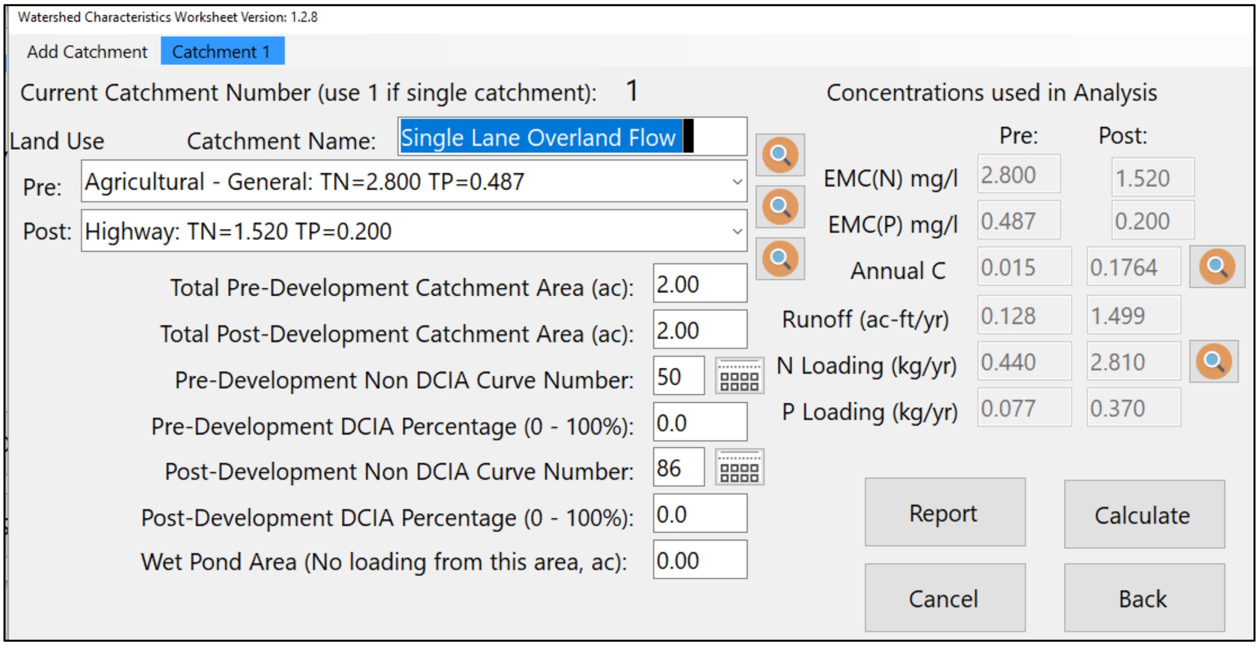


Figure 23b. Watershed Characteristics.

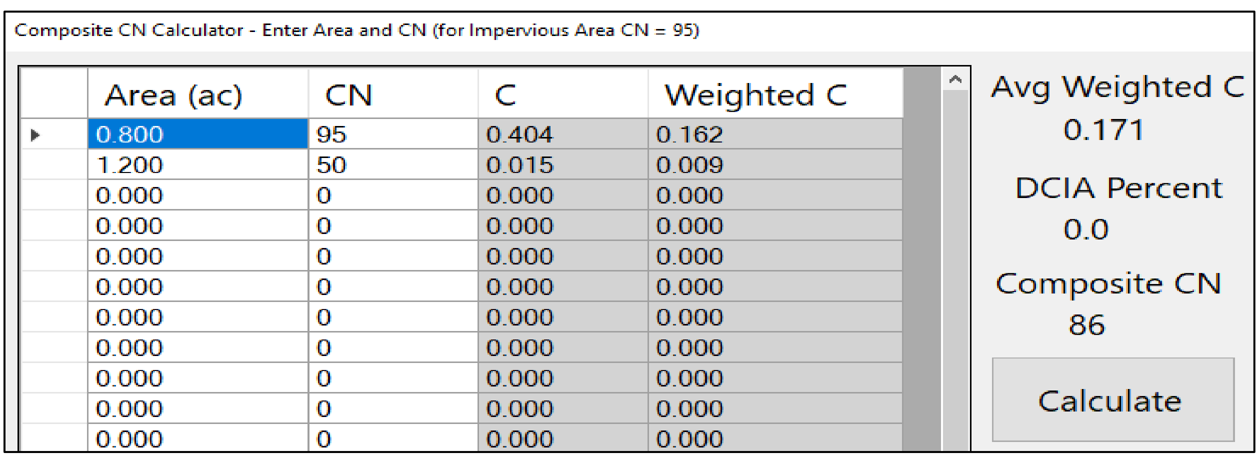


Figure 23c. Composite CN Calculator with Impervious Area CN of 95.

2. Click on the *Back* button to return to the **General Site Information Worksheet**. And proceed to add the treatment. The site pervious area safely can support a retention area that is no wider than 10 feet nor deeper than one foot. The retention volume necessary to match post and pre annual discharge is 0.24 acre-feet (1.44 inches over the catchment) and is shown with other data in Figure 23d. This can be among other design options a shallow retention basin triangular in shape with a maximum water depth of one foot and a width of only 7.2 feet. Recall there is 18 feet of pervious area adjacent to the impervious area.

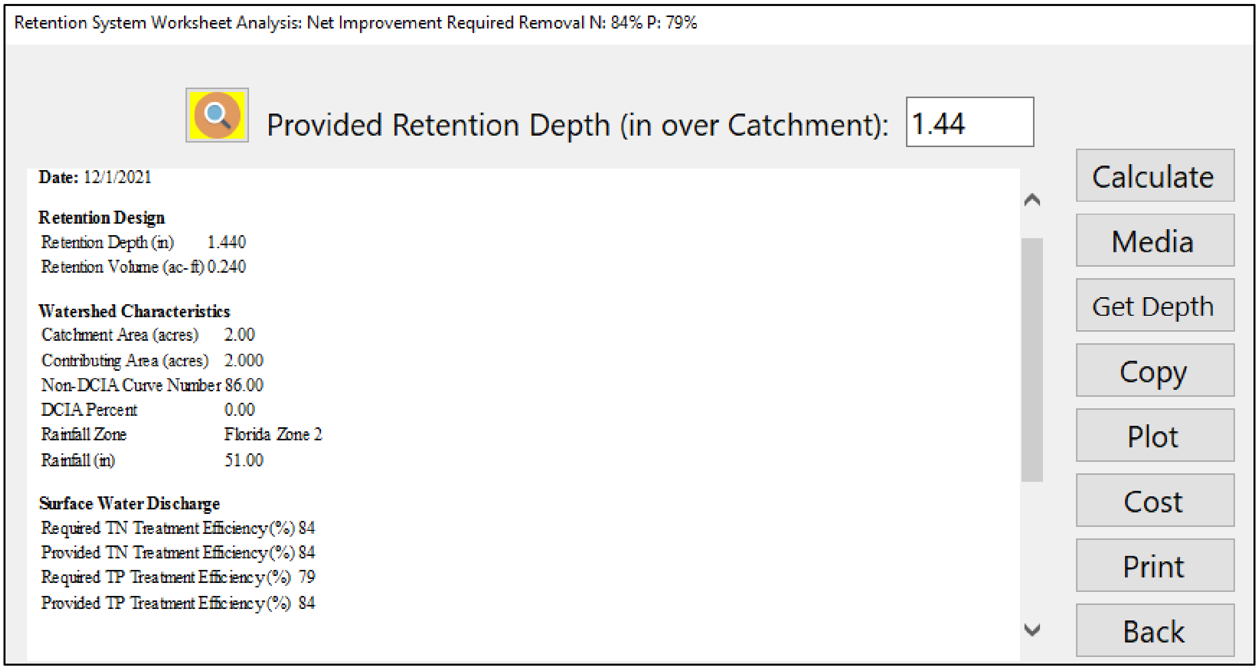


Figure 23d. Retention Volume and Depth for Net Improvement.

3. Proceed to *3. Configure the Catchment* on the **General Site Information Worksheet** and add the retention basin, then proceed to review the *4. Summary Treatment Report* and obtain if needed a *5. Complete Report*.

Note: The simulations for annual load adjusted the pervious CN value for the added runoff volume from the impervious surface (Harper, 2007). It is known that overland flow rates and volume are also affected by the slope of land. The simulations for annual loadings assumed that the rainfall excess is not affected by the slope. This is most likely not a limiting assumption because in most of Florida the relative flat lands are such that infiltration from impervious surfaces as overland flow occurs within about 10 feet provided the soils can maintain infiltration. This overland flow is observed, simulated and by measurement (Hood, 2013). Hood measurements showed no runoff over a 10 foot shoulder for up to 3 inches of rainfall on a 14 foot impervious area.

Example problem # 14 – Holding Basin

A holding basin is in a BMP where the seasonal high water table and soils may permit some natural infiltration and a side bank filter can be used for surface discharge. A fraction of the water in the basin infiltrates into the ground, while another fraction of water filters through engineered media to discharge. The certified filter media typically includes sorption media and a discharge pipe or channel. The design treatment volume is based on the recovery time. The sorption media is used to obtain average annual removal credit. These facilities are sometimes referred to as dry detention or wet retention ponds and can include filters.

A goal for the evaluator when using **BMP Trains 2020** is to determine the credit for removal using a filter sorption media with and without natural infiltration. For infiltration and media filtration, an analysis for BMPs in series is used. The site and watershed conditions are for example problem # 4, a highway in southeast Florida.

1. Enter the site and watershed data of example problem #4. The discharge analysis is BMP for evaluation of the removal of the post condition design. The G**eneral Site Information Worksheet** is shown in Figure 24a. Enter the catchment data also.

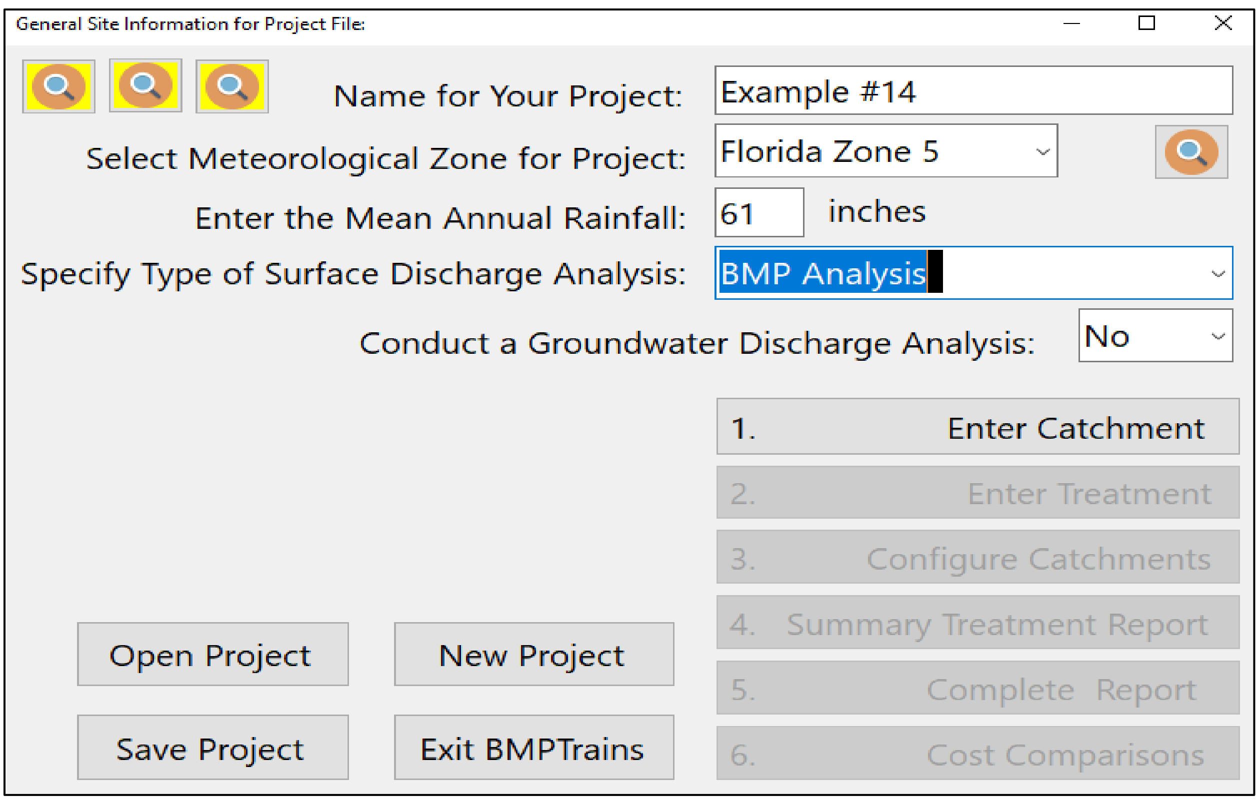


Figure 24a. General Site Information Worksheet with BMP Analysis for Surface Discharge.

2. Go to **the Select Treatment Options Worksheet:** the total design treatment depth is 0.39 inch or 0.179 ac-ft (5.5 ac x 0.39 in/12). The filter trench media is 5’ wide and 96’ long or 480 SF. It drains at 0.052 GPM/SF. The volume of water removed by a drain with sorption media is 4792 CF (0.11 Ac-ft). Expressed as inches over the catchment, the treatment depth is 0.24 inch (12 x 0.11/5.5). The treatment rate is input to the **Filtration System Worksheet** (Figure 24b) as accessed from the “*Surface Discharge Filer*” button. The water recovered by the drain is discharged to another surface water body. Removal credit is from the use of a sorption media. The credit for the use of the media depends on the capture volume (25% in this example) and the removal of TN and TP associated with the specific media. Credit using a B&G CTS 24 inch deep sorption media is calculated using the **Filtration System Worksheet** (Figure 24b) and the removal is 19% TN and 24% TP. Note again that this is for a “stand-alone” BMP in the same catchment with other BMPs.

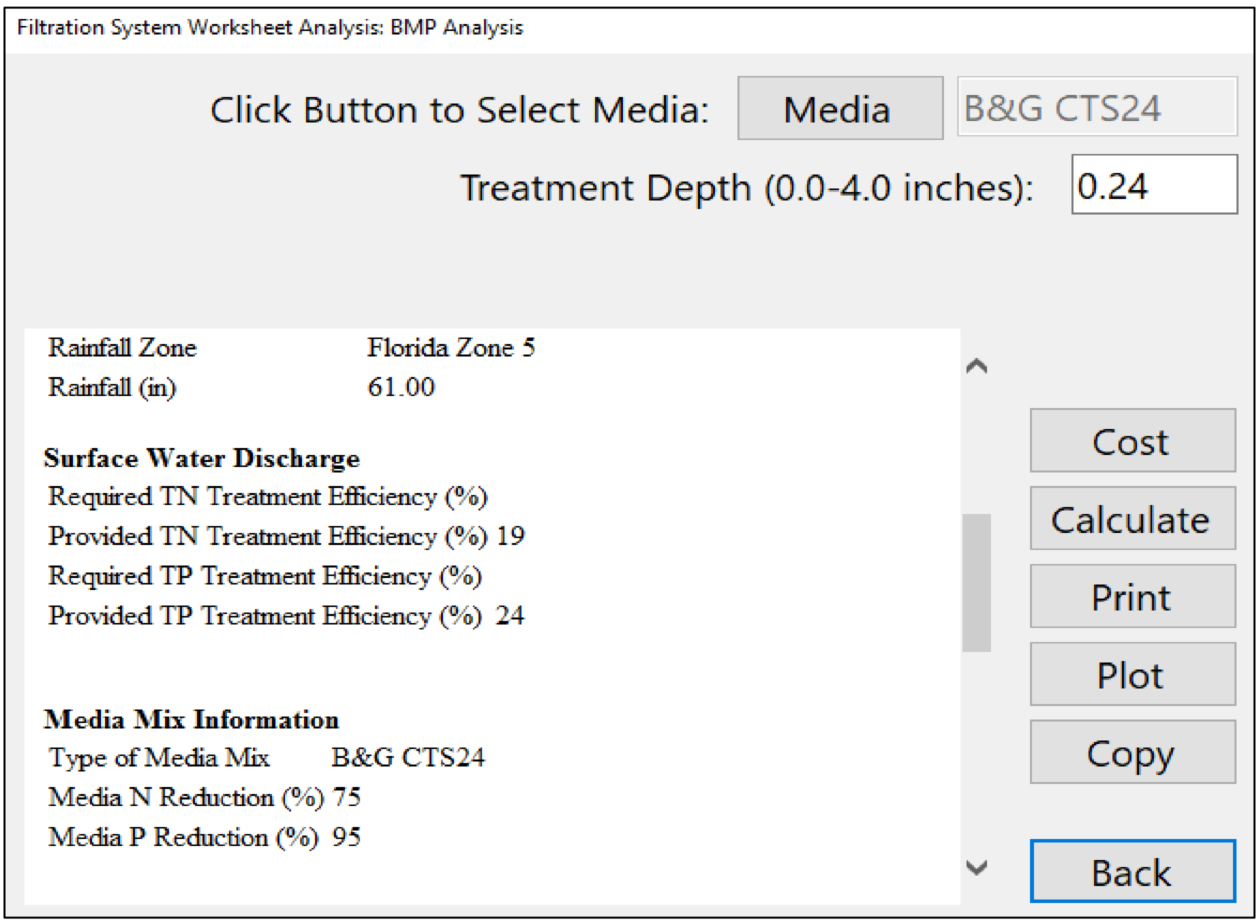


Figure 24b. Surface Water Discharge Filtration.

For this stormwater management facility, the BMP is a surface filtration media. However, the operation of the facility with filter to facilitate recovery also includes retention as a result of infiltration. The infiltration is 0.15 inch (0.39-0.24). This infiltration is a design calculation and done together with the filter discharge volume and within a recovery time.

3. Add the credit for infiltration (retention) using the **Retention Basin Worksheet** as shown in Figure 24c.

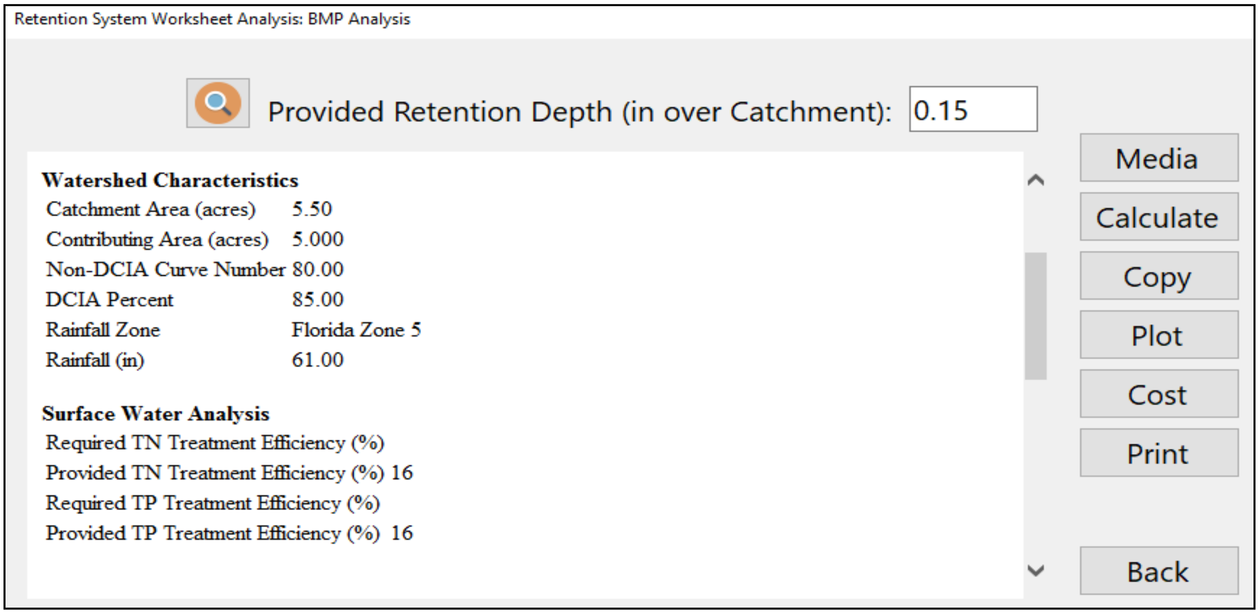
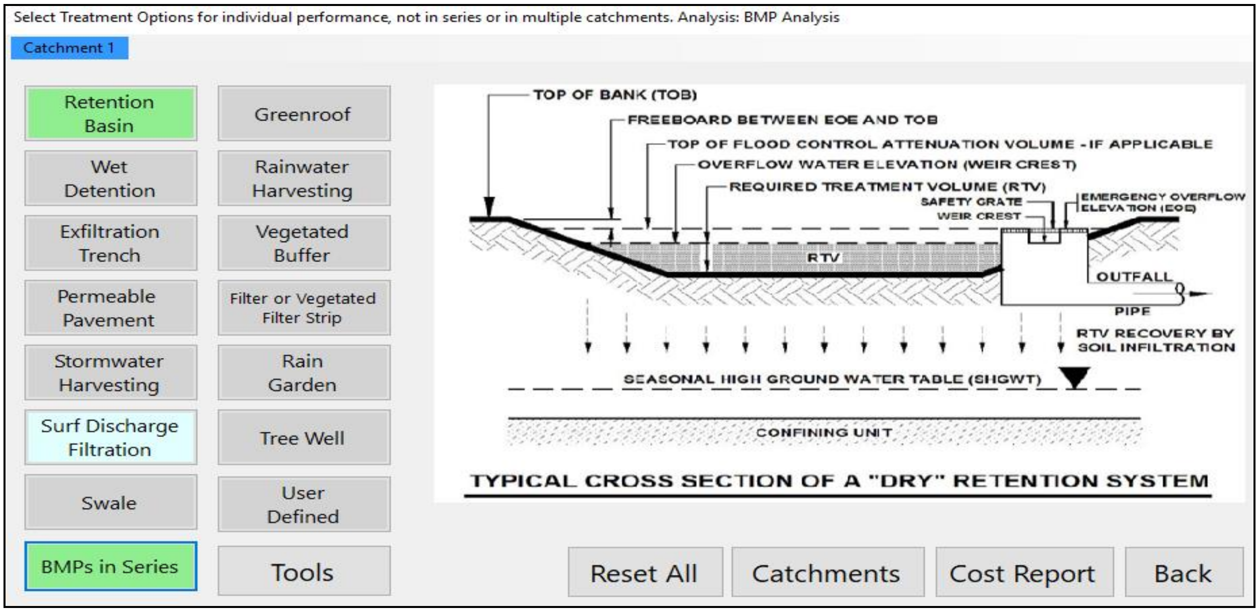


Figure 24c. Retention Capacity and Capture Effectiveness.

4. To evaluate retention and sorption media filtration together, use the *BMPs in Series* button and proceed to enter the information as shown in the two screen captures of Figure 24d. Since surface discharge is the add-on to infiltration by retention, or filtration cannot exist without retention, retention is the first BMP in the series. Note, it there are other catchments routing into these BMPs, the runoff water from these others must be included in the sizing of the retention and filter BMPs.

   Notes: 1. There is no credit given for detention as these holding basins typically drain through the filter or into the surrounding ground area, leaving little to no standing water. 2. If there is a ponded area with water storage or a detention facility, the water which passes through the filter can be assessed for removal in series with a wet detention facility assuming the wet detention facility is designed according to acceptable design and operation criteria (see example problem 12). 3. Without the filter, natural infiltration has been calculated in most situations to remove a low volume of water and thus the treatment depth is usually very low (less than 0.25 inches). 4. Water which is filtered and moves into the ground can be assessed using the “rain garden BMP” (see example problems 7 and 15).



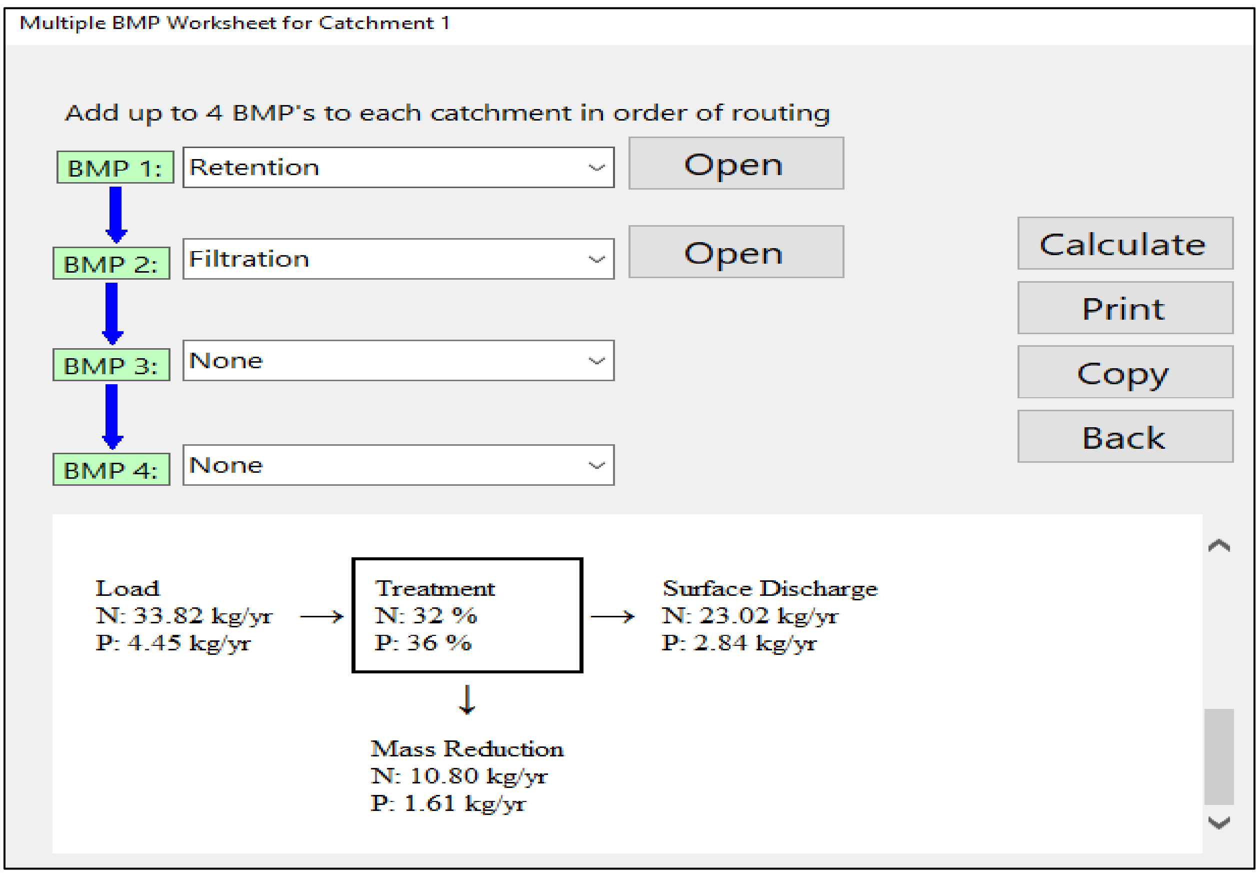


Figure 24d. Series Evaluation for Retention and Filtration.

5. Proceed to the **Configure Catchment** Button and select "Multiple BMP" and route to the Outlet (Figure 24e). Always use this button after a series application.

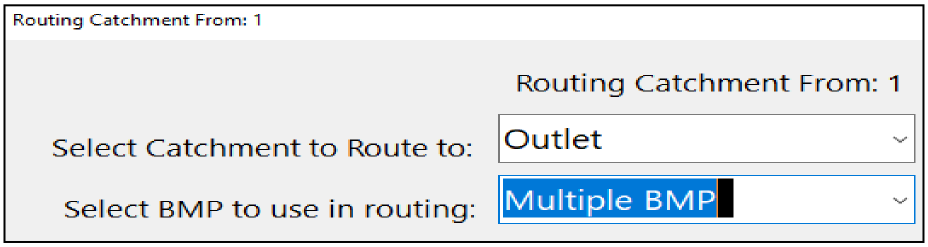


Figure 24e. Routing of Flow Through Multiple BMPs.

The results of using both a sorption filter and infiltration is shown in Figure 24f. Overall removal is 32% TN and 36% TP. This example uses both infiltration and sorption media treatment. When using one stand-alone BMPs, each removal is shown in Figures 24b (filtration) and 24c (retention).

Project: Example #14 Holding Basin

Analysis Type: BMP Analysis
BMP Types:
Catchment 1 - (highway) Multiple BMP
Based on % removal values to the nearest percent

Routing Summary
Catchment 1 Routed to Outlet

Summary Report

Nitrogen

Surface Water Discharge

Total N post load	33.82 kg/yr	
Percent N load reduction	32 %	
Provided N discharge load	23.02 kg/yr	50.75 lb/yr
Provided N load removed	10.8 kg/yr	23.82 lb/yr

Phosphorus

Surface Water Discharge

Total P post load	4.45 kg/yr	
Percent P load reduction	36 %	
Provided P discharge load	2.838 kg/yr	6.26 lb/yr
Provided P load removed	1.612 kg/yr	3.555 lb/yr

Figure 24f. BMP Analysis for Surface Water Discharge Using Infiltration and Filtration.

Example problem # 15 – Existing BMP in the Pre-condition Land Use

There is an existing BMP in the pre-condition catchment and its use will continue in the post-condition either as a stand-alone BMP or expanded. To account for an existing BMP with a new land use, the annual removal in the post-condition compared to the pre-condition with BMP is used for net improvement. Thus post discharge annual mass equals or is lower than pre discharge mass including the mass removed with the existing BMP. The analysis is performed by running the model in the pre-condition with BMP and then to reduce errors, the input and output for the pre-condition with BMP is transferred digitally to the new post condition **BMP Trains 2020** run.

The mass discharged with the existing BMP is calculated considering a BMP analysis (thus the post condition discharge considers the land use, rainfall volume and the existing BMP). The land use and BMP in the pre-condition yields a mass discharge. This is the mass discharge that must be meet in the post-condition with this BMP expanded or with other BMPs used.

The land use and meteorological conditions of example problem 7 are used to demonstrate how **BMP Trains 2020** is used to match net improvement with an existing BMP. The discharge from the pre-condition is saved as the "target" load to meet rather than the precondition without BMP discharge. These saved discharge mass loads are then used in a new program run to be matched with a post condition and an expanded or additional BMPs.

1. Enter the site and watershed data of example problem #7. The discharge analysis is **BMP Analysis** for evaluation of the removal of the pre-condition design with BMP. The G**eneral Site Information Worksheet** is shown in Figure 25a.

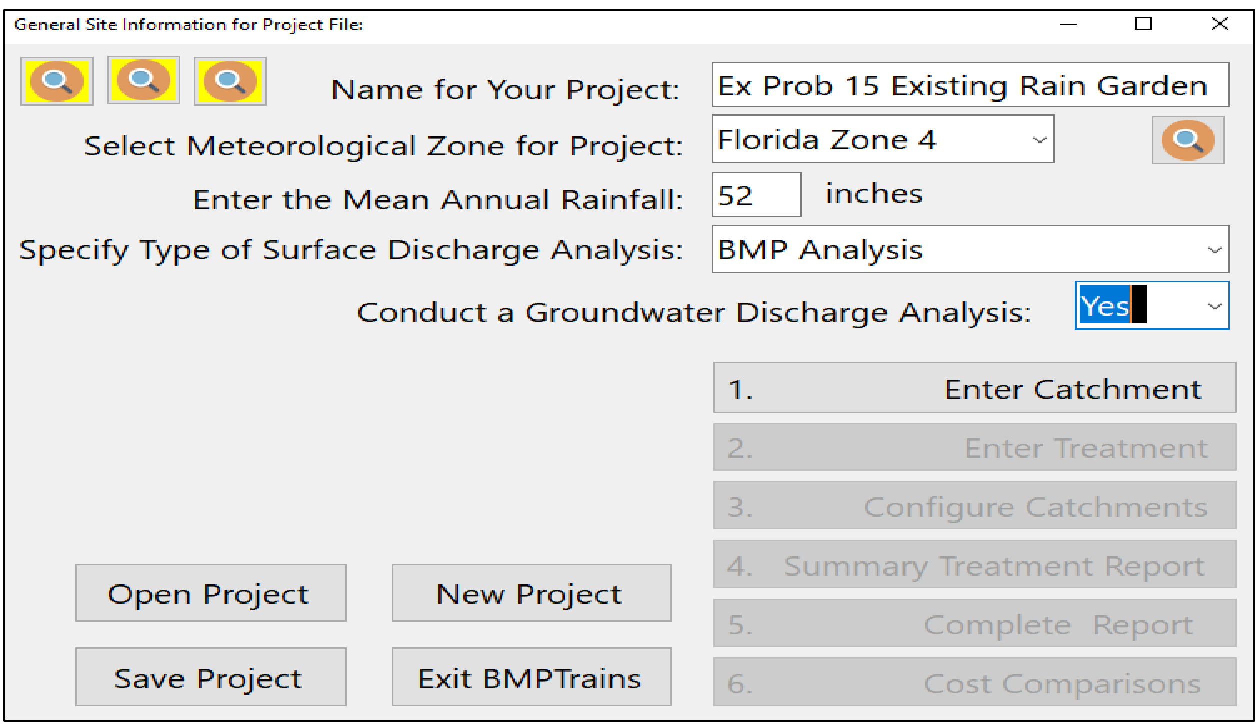


Figure 25a. General Site Information Worksheet for BMP analysis with an Existing BMP.

2. Click on the *Enter Catchment* button and enter the data as shown in Figure 25b. Note that this is a BMP analysis so the pre-condition data are not necessary however shown in this screen capture to illustrate the increase in the DCIA and to recognize the use of an existing BMP in the treatment analysis worksheets.

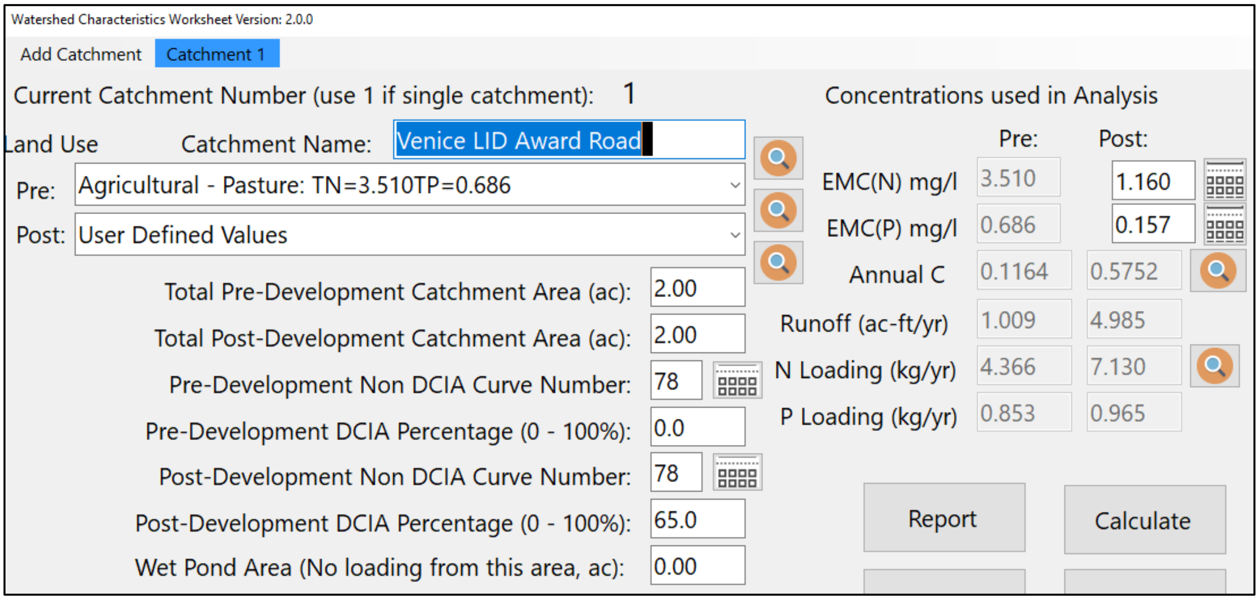


Figure 25b. Watershed Characteristics with Existing BMP considered as the Post Condition Input

3. Enter the existing treatment data on the appropriate **BMP Worksheet**. In this case, the BMP is a rain garden and it has an existing storage volume of 1040 cubic feet (CF) before it over-flows to the flood control system. The data input are shown in Figure 25c.

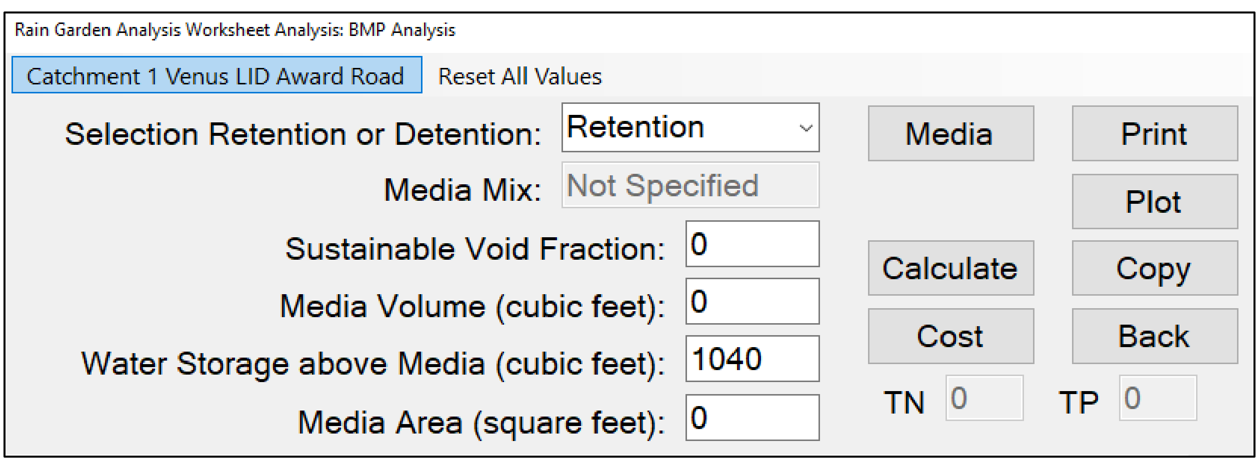


Figure 25c. Rain Garden Treatment Input Data for the Existing BMP in the Pre-Condition.

4. Select the BMP and configure the flow as shown in the **Select Catchment Configuration Worksheet** (Figure 25d). The **Summary Treatment Worksheet** is

shown in Figure 25e. Note the surface discharge in the pre-condition is 5.8 kg/yr and 0.785 kg/yr for TN and TP respectively.

Select Catchment Configuration

	From	To	Area	BMP Used	Edit
▸	1	0	2.00	Rain Garden	Edit
*					

0 is Outlet

Figure 25d. Select Configuration Worksheet

Project: Example Prob 15 Exisiting Rain Garden

Analysis Type: BMP Analysis
BMP Types:
Catchment 1 - (Venus LID Award Road) Rain Garden retention with media

Routing Summary
Catchment 1 Routed to Outlet

Summary Report

Nitrogen

Surface Water Discharge

Total N post load	7.13 kg/yr	
Percent N load reduction	19 %	
Provided N discharge load	5.8 kg/yr	12.79 lb/yr
Provided N load removed	1.33 kg/yr	2.94 lb/yr

Groundwater Discharge

Average Annual Recharge	.303 MG/yr	
Provided N recharge load	1.331 kg/yr	2.94 lb/yr
Provided N Concentration	1.159 mg/l	

Phosphorus

Surface Water Discharge

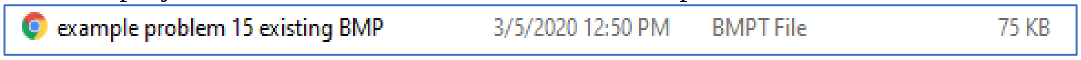
Total P post load	.965 kg/yr	
Percent P load reduction	19 %	
Provided P discharge load	.785 kg/yr	1.73 lb/yr
Provided P load removed	.18 kg/yr	.397 lb/yr

Groundwater Discharge

Average Annual Recharge	.303 MG/yr	
Provided P recharge load	.1802 kg/yr	.3972 lb/yr
Provided P Concentration	.1569 mg/l	

Figure 25e. Summary Results for Pre-condition with BMP

5. Save the project file, in this case the name of the .bmpt file is:



6. The target discharge TN and TP in the post-condition must equal the pre-condition with BMP discharge of 5.8 kg/yr and 0.785 kg/yr for TN and TP respectively. The pre-condition with BMP has the results associated with a saved project ".bmpt" which is read into an analysis using the *Open Pre BMP* button shown in Figure 25f. Note: **Before opening,** set the type of surface discharge analysis to **BMP Analysis**. By opening the saved file to copy the discharge and other data, the chances of incorrect data by "hand" copy or re-entering inconsistent data in a new **BMP Trains 2020** run are minimized.

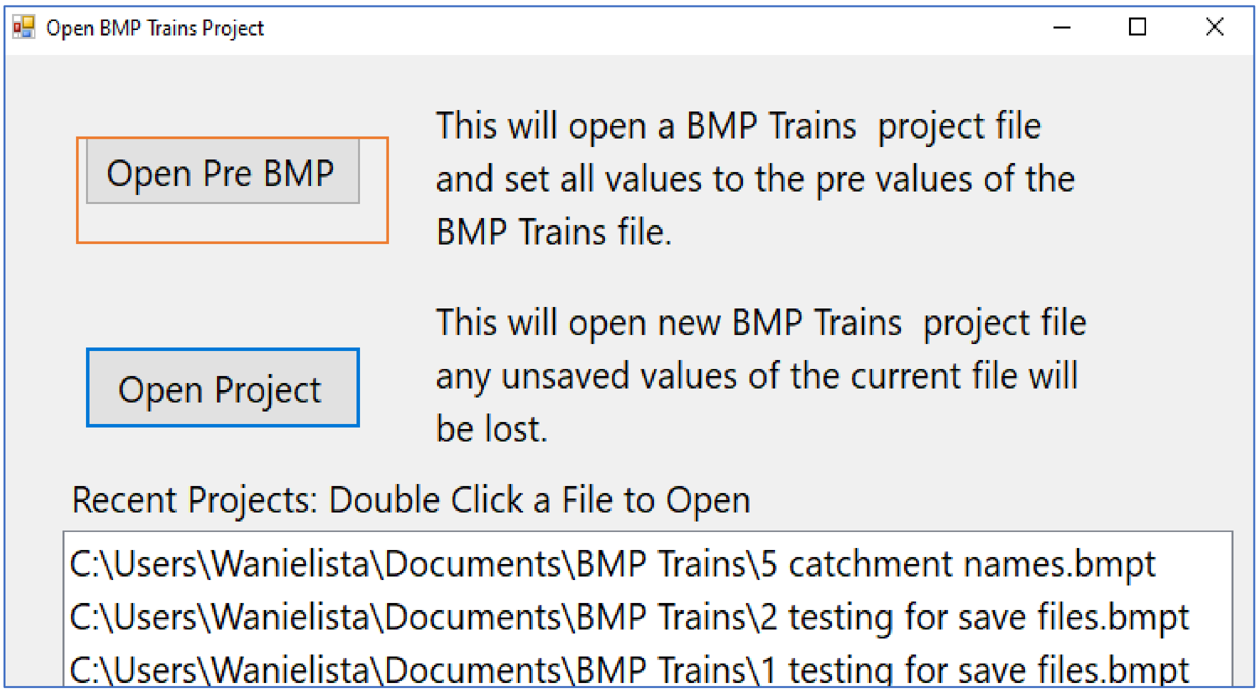


Figure 25f. To Enter data for a Pre-Condition with BMP, Use Open Pre BMP Button

7. The data saved and entered for the general site information worksheet are shown in Figure 25g, except the name of the project has to be entered as it is now post=pre with existing BMP (shown in the name of the project in Figure 25g). The existing annual discharge loading with the existing BMP are shown. It is required to estimate the groundwater discharge yearly volume (recharge) and average annual concentrations, thus the need to conduct a groundwater analysis as noted in Figure 25g.

   The objective for the post-development BMPs is for the post development discharge annual load to match or be lower than the existing pre-development with a BMP which is 5.8 kg/yr and 0.785 kg/yr for N and P respectively.

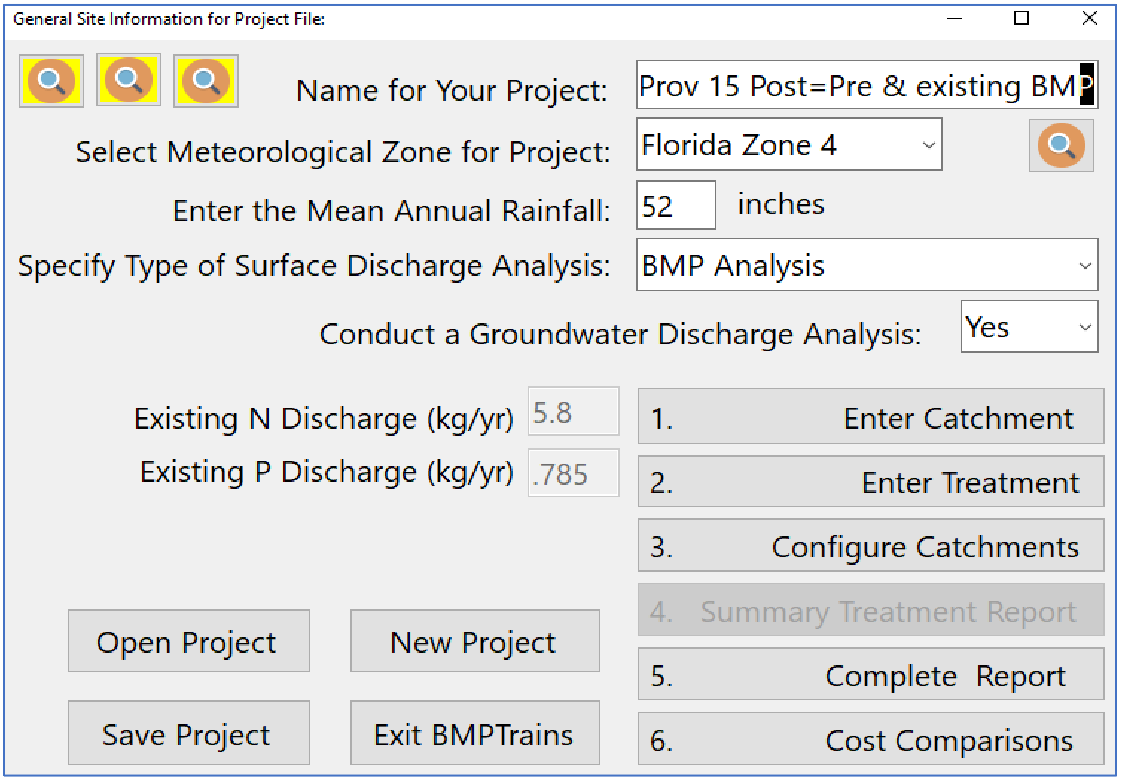


Figure 25g. Saved Existing Site Information and Existing Discharge for Post=Pre Analysis

8. The watershed characteristics data are the same as used for the existing conditions BMP analysis (see Figure 25h).

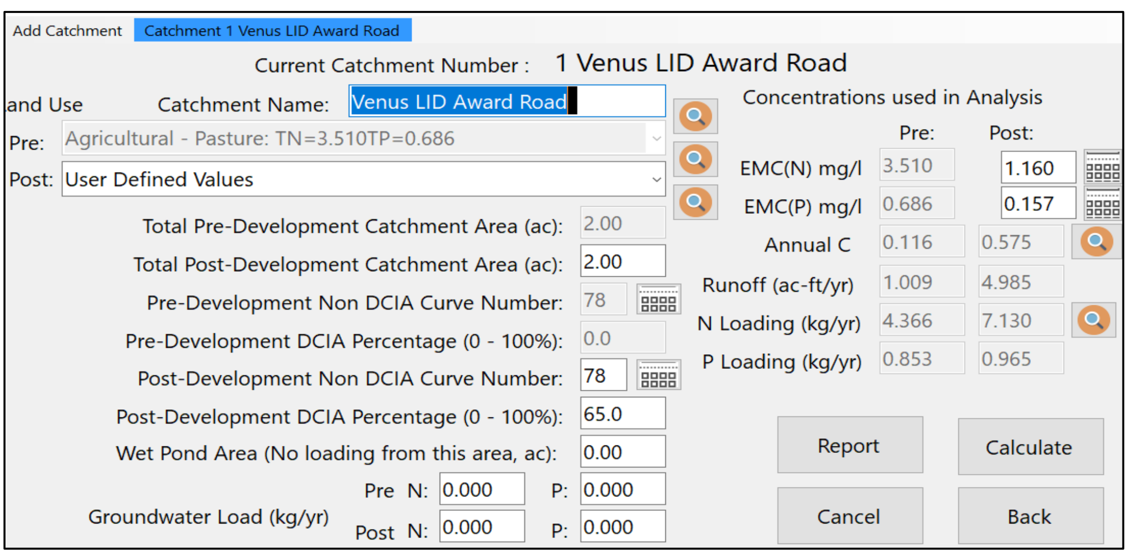


Figure 25h. The Post-Condition Rain Garden with Sorption Media

9. The rain garden has an added storage volume because a sorption media is now used. In addition, the media removes nutrients and thus groundwater loadings are reduced. The media type and volume of media with loading mass diagrams are shown in Figure 25i. Note the surface discharge for N and P is 5.47 kg/yr and 0.74 kg/yr respectively, which is lower than the pre- condition with BMP of 5.8 kg/yr and 0.785 kg/yr.

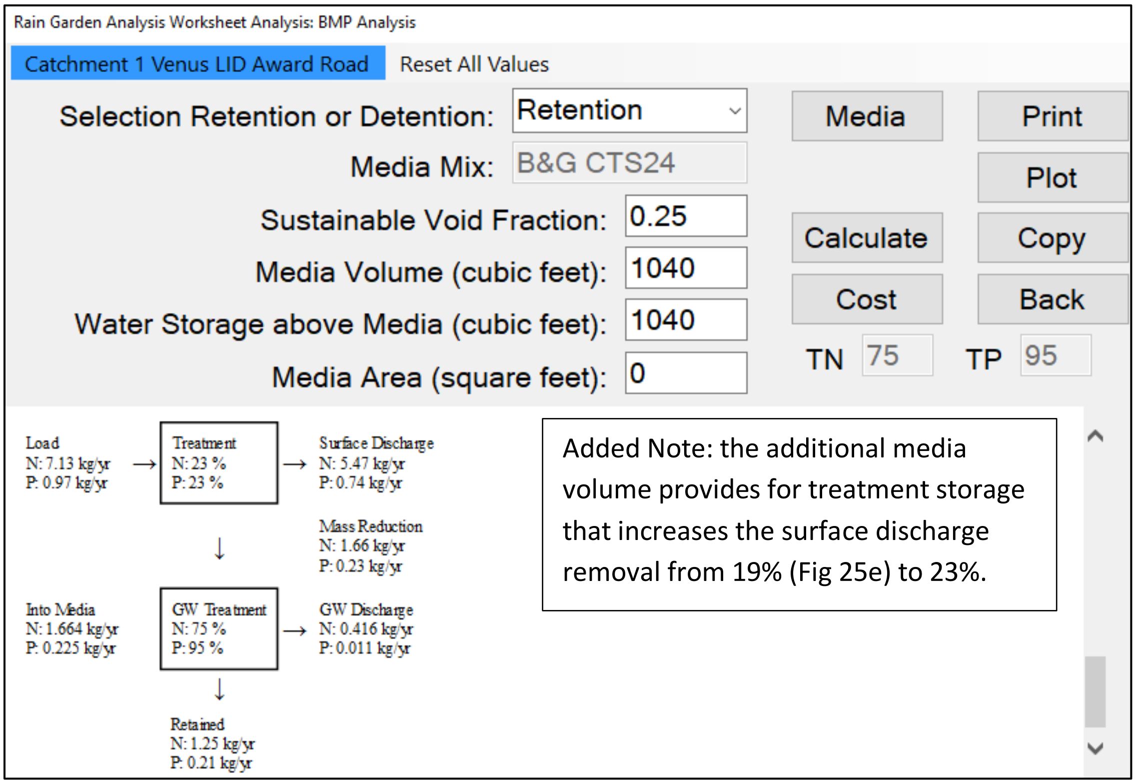


Figure 25i. The Post-Condition Rain Garden with Sorption Media

The configuration has to be entered as with any BMP Trains analysis with the selection of the rain garden **button 3**: (site characteristics worksheet). Then proceed to **button 4** (Summary Treatment Report). The summary treatment report includes both the surface and ground water N and P discharge loads as shown in Figure 25j. The objective is to have a post-condition discharge load less than or equal to the pre-condition discharge that includes a BMP as well as groundwater protection. The results are shown in Figure 25j, and post TN discharge (5.47 kg/yr) is less than pre with the existing rain garden (5.8 kg/yr). The post TP discharge (0.74 kg/yr) is less than pre with the existing rain garden (0.785 kg/yr). The addition of media results in groundwater protection. Shown is the average annual recharge (GW Discharge) in million gallons per year (MG/yr), load (kg/yr), and concentration (mg/L). The equation for average annual concentration (mg/L) is annual mass load into the ground (kg/yr) / annual recharge (MG/yr) / 3.7854 L/G x 1,000,000 mg/kg / 1,000,000 G/MG.

Summary Treatment Report Version: 5.2.0

Project: ex 15 post = pre with BMP

Analysis Type: BMP Analysis
BMP Types:
Catchment 1 - (Venus LID Award Road) Rain Garden retention with media
Based on % removal values to the nearest percent

Routing Summary
Catchment 1 Routed to Outlet

Summary Report
Nitrogen

Surface Water Discharge

Total N post load	7.13 kg/yr	
Percent N load reduction	23 %	
Provided N discharge load	5.47 kg/yr	12.05 lb/yr
Provided N load removed	1.66 kg/yr	3.67 lb/yr

Groundwater Discharge

Average Annual Recharge	.379 MG/yr	
Provided N recharge load	.416 kg/yr	.92 lb/yr
Provided N Concentration	.29 mg/l	

Phosphorus

Surface Water Discharge

Total P post load	.965 kg/yr	
Percent P load reduction	23 %	
Provided P discharge load	.74 kg/yr	1.63 lb/yr
Provided P load removed	.225 kg/yr	.497 lb/yr

Groundwater Discharge

Average Annual Recharge	.379 MG/yr	
Provided P recharge load	.0113 kg/yr	.0248 lb/yr
Provided P Concentration	.0078 mg/l	

Figure 25j. Summary Report for Pre-condition with a BMP and Post with Additional Treatment.

When adding to the existing BMP for the post condition land use, the target values are 5.8 kg/yr and 0.785 kg/yr for TN and TP, respectively. In this case, there is a post=pre analysis and the pre-condition loading is with an existing BMP. The loading with the pre-condition BMP must be achieved in the post condition or result in a net improvement condition. In this case, groundwater protection is also provided.

Example problem # 16 –Wet Pond Upstream of a Swale using Two Catchments

This example shows the use of a constructed swale after a wet detention pond. The wet pond is also used for peak discharge control. Two catchments are used because the downstream catchment swale area does not contribute runoff water to the upstream catchment. Note the downstream catchment has to have a larger area (>0.01 acre) than the BMP area in order to use this evaluation method. This area is built up with sand. Also, this is an example of a mix of detention and retention when calculating effectiveness (See Appendix C, section 15).

The example is based on information from two permits. The water to the swale from the wet detention results in a higher water table and thus a lower treatment rate (soil infiltration rate = 1.0 inch per hour in this example). With a 2X factor of safety, the rate is 0.5 inch per hour. This is a situation that can result from soil condition changes where the swale is located. This location of retention downstream of a wet pond was also used in another permit when the wet pond was used as an aesthetic feature and thus used a pond liner. The swale must be designed according to applicable District criteria/local government codes and the physical dimensions and design infiltration data as input to the BMP Trains 2020 model. It will have a “stand-alone” evaluation,.

The total watershed area is 12 acres and is developed as a single-family residential area. The swale catchment area is 0.4 acres. The input data and results are shown in Figures 26a – 26g.

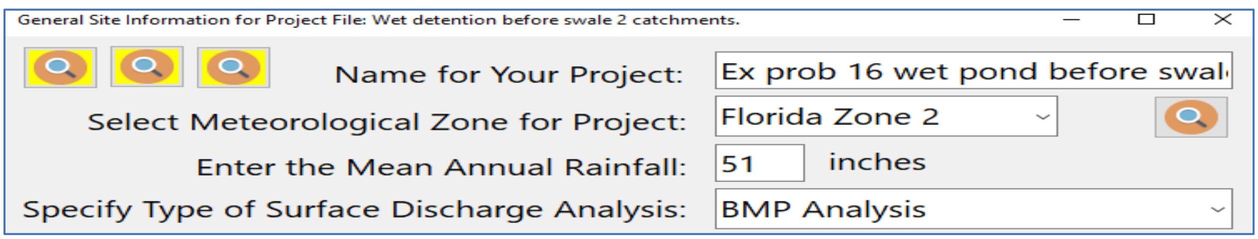


Figure 26a General Site Information

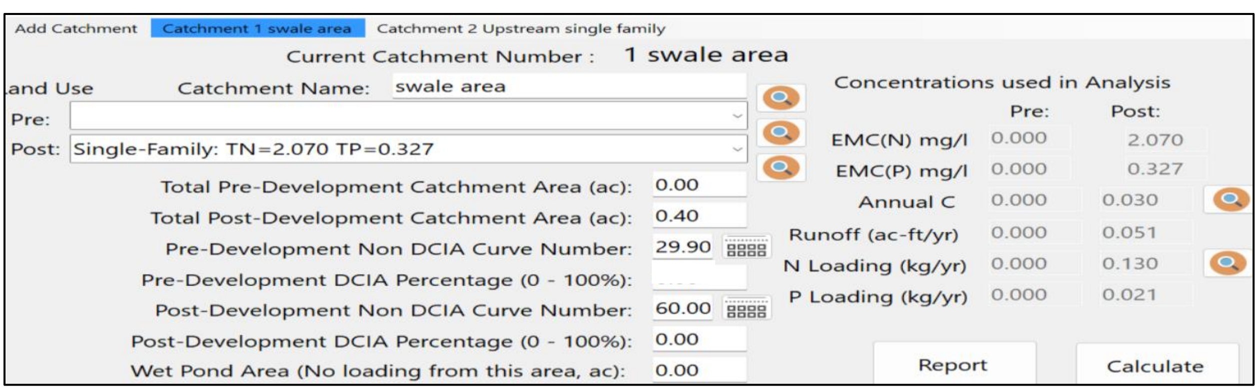


Figure 26b Downstream BMP Area that Does Not Contribute Runoff to the Upstream Catchment

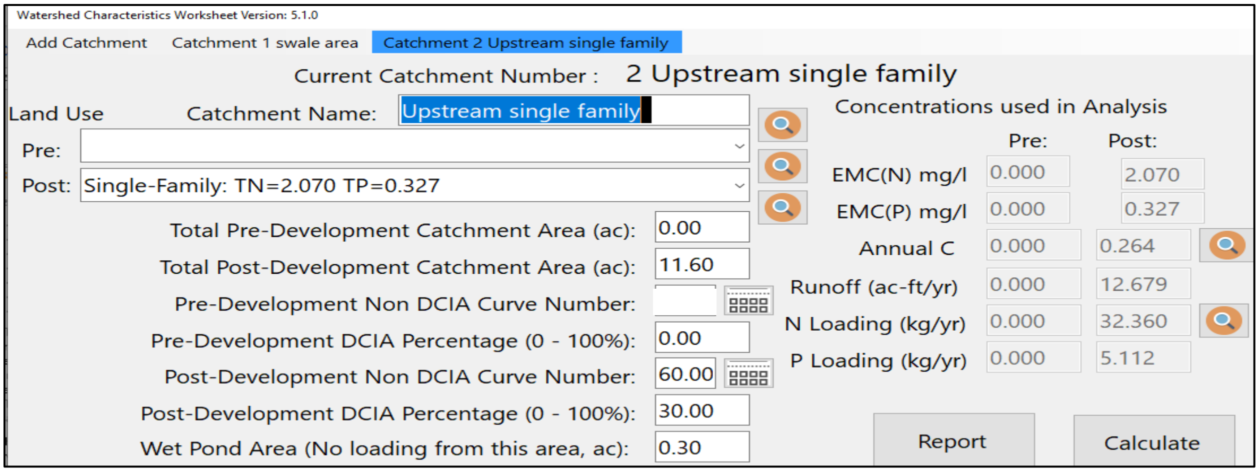


Figure 26c Upstream Catchment Area with Discharge to a Downstream Catchment.

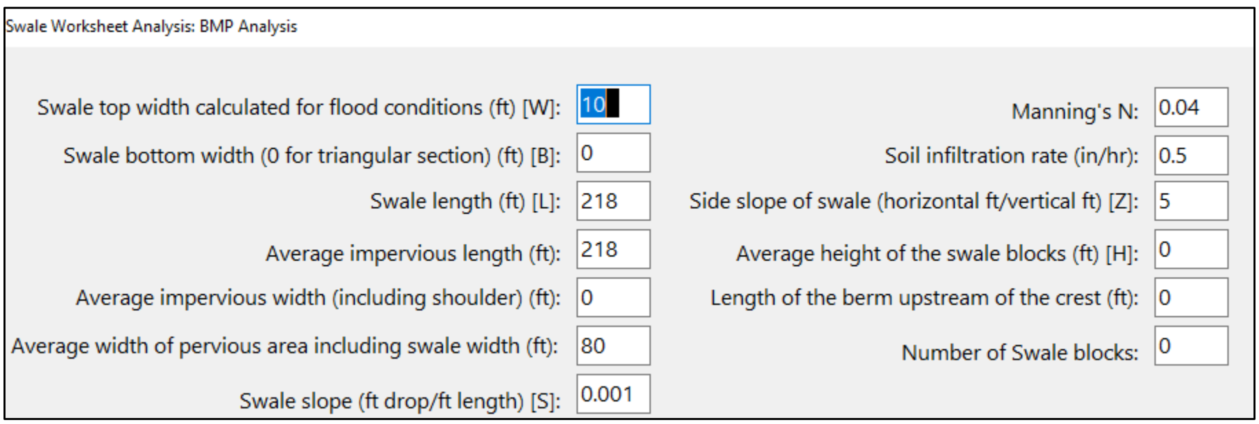
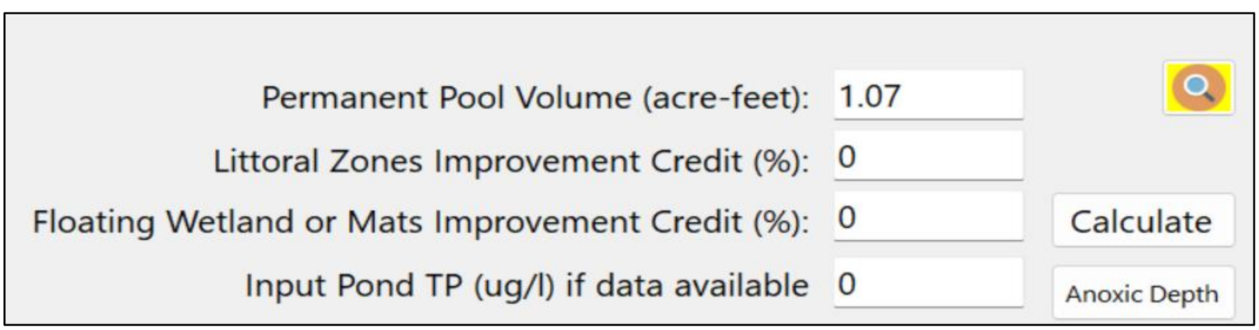


Figure 26d Swale Design Data Resulting in 24% Capture for that Catchment (stand-alone).



Resulting in a 31-day average annual residence time for 38% TN and 64% TP removal if stand-alone.

Figure 26e Wet Pond Design Data Resulting in an Annual Residence Time of 31 days (stand-alone).

Select Catchment Configuration

From	To	Area	BMP Used	Edit
1	0	0.40	Swale	Edit
2	1	11.60	Wet Detention	Edit

Volume From Catchment	0.05
Volume From Upstream	12.68
Total Volume In	12.73
Volume Into GW (or Media)	3.09
Volume Out (to next node)	9.64

Figure 26f Configuration of Catchments with BMP and Flow Balance Report (ac-ft).

This example illustrates the use of a swale downstream of a wet pond. Note that a swale both transports and infiltrates water. There are 2 catchments and the use of one BMP per catchment. It is emphasized that the swale must be designed according to District, State, and local government codes. The swale infiltrates a portion of the runoff water from both catchments. The total runoff from both catchment areas must be used. Also, the option of using a downstream retention area after a wet pond is possible if the infiltration rate at design flow conditions can be reasonably estimated. It is lower than the rate when there is no additional flow from another catchment. The swale annual removal effectiveness equations as used in the BMP Trains 2020 model were developed for runoff from adjacent areas as well as input from runoff from upstream catchments. The infiltration rates were estimated under these conditions and were much less than the double ring infiltration rates with no water in the swales (Wanielista and Yousef, 1993, pages 244-251). Also, refer to appendix C, section 4, Swales for further definition, design and operating conditions for swales.

The swale area contributing runoff is larger than the surface area of the swale at design peak flow. As an example, for this site the average catchment width is 80 feet while the surface width of the swale for the 25-year rain-event is about 20 feet wide and the swale is 218 feet long. Discharge from the pond orifice is directed to the swale. If using retention and to show the equivalency of annual removal, use the retention treatment option in place of the swale area. The same retention treatment depth is used for the swale and the retention basin yielding the same average annual effectiveness as a stand-alone swale area.

The summary results for this two-catchment example with retention following detention is shown in Figure 26g. Using a swale after a wet pond in this case, the overall TN average annual removal efficiency is 53% or 15% more than using only a wet pond. Again, it should be noted that the swale infiltrates and transports the runoff water from the two catchments. It is normal to provide back-up information on the methodology for estimating the infiltration (treatment) rate.

Project: Ex prob 16 2 catchment wet pond before swale

Analysis Type: BMP Analysis
BMP Types:
Catchment 1 - (swale area) Swale
Catchment 2 - (Upstream single family) Wet Detention
Based on % removal values to the nearest percent

Routing Summary
Catchment 1 Routed to Outlet
Catchment 2 Routed to Catchment 1

Summary Report

Nitrogen

Surface Water Discharge

Total N post load	32.49 kg/yr	
Percent N load reduction	53 %	
Provided N discharge load	15.2 kg/yr	33.52 lb/yr
Provided N load removed	17.29 kg/yr	38.12 lb/yr

Phosphorus

Surface Water Discharge

Total P post load	5.132 kg/yr	
Percent P load reduction	73 %	
Provided P discharge load	1.387 kg/yr	3.06 lb/yr
Provided P load removed	3.745 kg/yr	8.258 lb/yr

Figure 26g Summary for Two Catchments using Wet Pond and Swale Downstream.

Example problem # 17 –Dual Treatment

A dual-use BMP is a BMP that treats runoff water and when not treating runoff water it is used to treat water from another source. Example BMPs in use in 2022 for dual treatment are filters, dry retention BMP with or without a filter or a wet pond with a filter. The dual use BMP in use in 2022 treats groundwater high in nitrates, excess reclaimed water, water not fully treated upstream, or base flow water high in nutrients in a surface stream, river, ditch or lake.

Runoff Conditions: Runoff treated in retention or wet pond usually is completed within 72 hours for the design storm. It frequently takes less time because most of the runoff events will be less in time than the design event. There are about 80 rain events per year producing runoff in the State. The average runoff time in retention is about 4.5 hours and in wet ponds is about 11 hours. From continuous simulations, the time for treating runoff in one year is less than 10%. Thus, there is about 90% of the time the BMP can be used for other treatment and maintenance. The following is an example problem of dual use of a filter at the end of a treatment train.

A City with an existing 426-acre land development discharges to a lake. The City wished to remove more nutrients to help meet a Basin Management Action Plan (BMAP). The City owns land at the discharge point and it can accommodate a 3000 SF filter with ICS media. During the dry period, the filter can operate 174 days per year during the non-runoff condition. Thus, the filter can remove more nutrients during non-runoff as well as during runoff conditions. The objectives are to determine how much more nutrients are removed from dual use and what is the service life of the media in this case. The 17 catchment configurations is shown with the configuration nodal diagram and input worksheet of BMP Trains in Figures 27a.

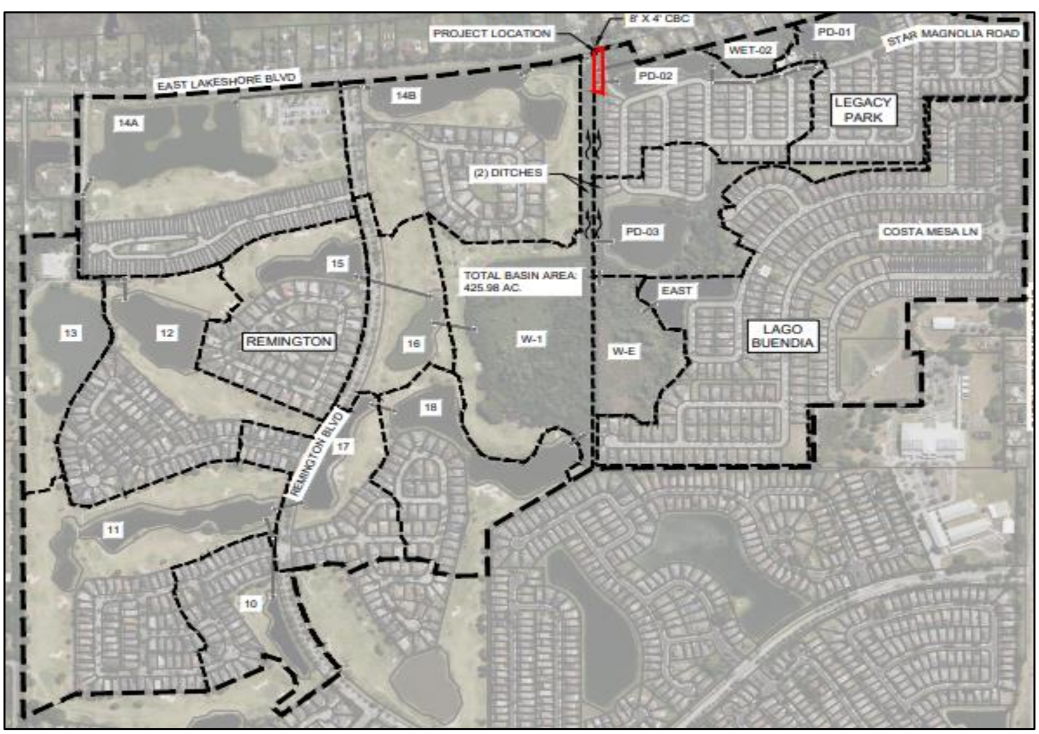


Figure 27a 426 Acre Watershed with Catchments.

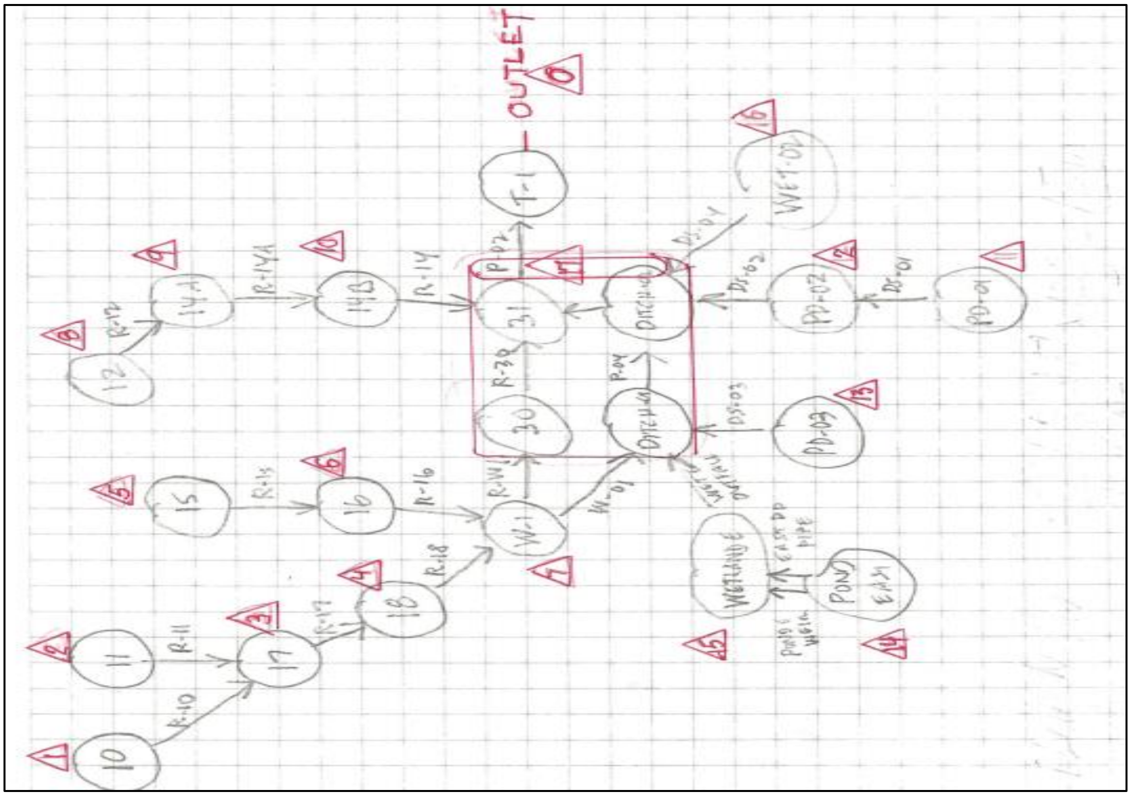


Figure 27a. Hand Details of a Catchment and Treatment Diagram

From	To	Area	BMP Used
1	3	15.60	Wet Detention
2	3	39.60	Wet Detention
3	4	16.40	Wet Detention
4	7	22.10	Wet Detention
5	6	23.30	Wet Detention
6	7	15.40	Wet Detention
7	17	25.50	None
8	9	29.30	Wet Detention
9	10	41.20	Wet Detention
10	17	37.60	Wet Detention
11	12	27.32	Wet Detention
12	17	20.55	Wet Detention
13	17	17.50	Wet Detention
14	15	80.92	Wet Detention
15	17	11.19	None
16	17	2.50	None
17	0	0.01	Filtration

Figure 27a Flow Diagram on the Select Configure Catchments Worksheet.

For the volume treated by the filter in 3 days, from which half needs to be discharge in one day, the volume treated = (10 inches/hour x 24 hrs x 1/12in/ft x 3000 SF) x 2 another equal volume = 120,000 CF. the Treatment Depth (inch) = 120,000 CF/426 ac /43,560 SF/ac = 0.08 inch over the total watershed. This Treatment volume is used as input for catchment 17 as shown in Figure 27b.

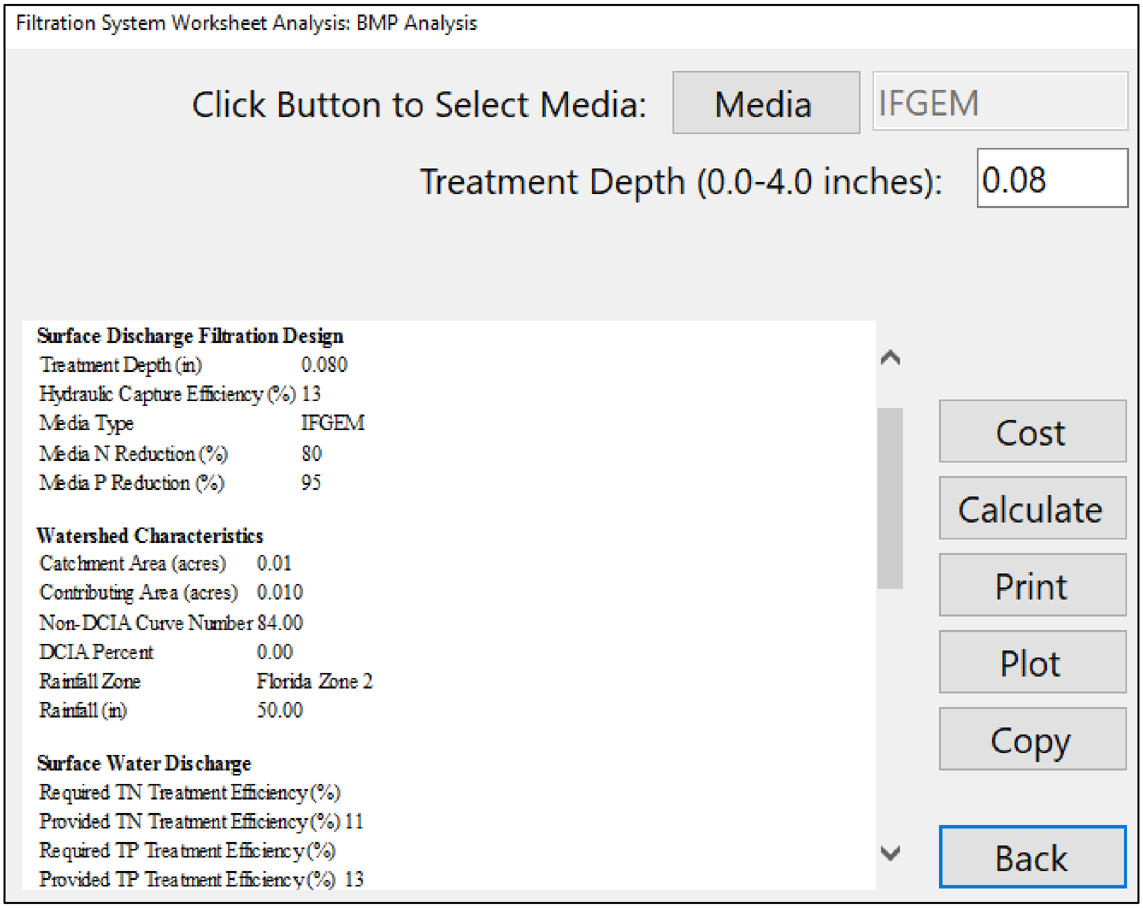
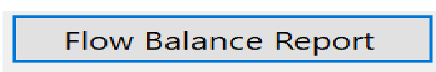
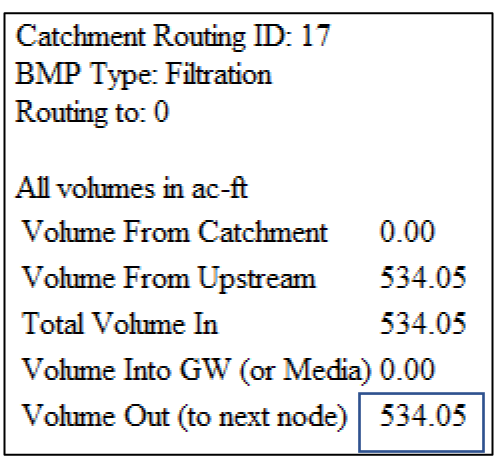


Figure 27b. Input and Removal Effectivness for ICS media during Runoff Conditions.

From the Select Catchment Configuration Worksheet, select the flow balance and flow rounting reports.




Catchment Routing ID: 17
BMP Type: Filtration
Routing to: 0

All volumes in ac-ft

Volume From Catchment	0.00
Volume From Upstream	534.05
Total Volume In	534.05
Volume Into GW (or Media)	0.00
Volume Out (to next node)	534.05

Figure 27c. Average Annual Flow Data from the total Watershed.

Full Routing Report

Catchment Pre Loading (kg/yr)	0.00
Catchment Post Loading (kg/yr)	0.00
Upstream Mass Loading (kg/yr)	32.50
Total Mass Loading [Catchment + Upstream] (kg/yr)	32.50
Target Load Reduction (%)	
Target Discharge Load (kg/yr)	32.50
Provided Removal Efficiency (%)	13
Total Discharged Load [Total * Efficiency] (kg/yr)	28.43
Discharged Load (lb/yr)	62.67
Removed Load [Total - Discharged] (kg/yr)	4.07
Removed Load [Total - Discharged] (lb/yr)	8.98

Load Diagram for Filtration (As Used In Routing)

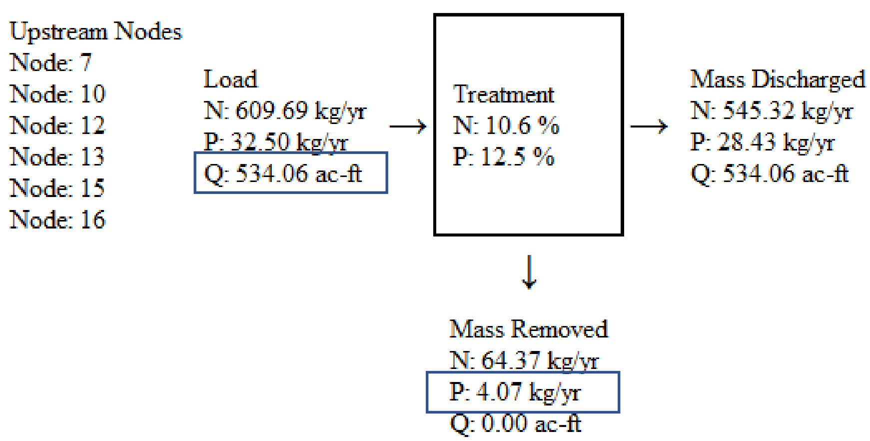


Figure 27d. Losding Data from the Filter at Discharge

During runoff, the volume of water discharged is 534.06 Acre-Feet and the TP removed by the filter media is 4.07 kg/yr.

Note the service life calculator in the “tools” menu cannot be used because it is useful for stand-alone BMPs. We have catchments with BMPs in parallel and in series. We will calculate service life considering both runoff and non-runoff removal for a fixed size of filter. From the summary sheet, the kg/yr of TN and TP removed for all the catchments during runoff conditions are 786.48 kg TN per year and 174.955 kg TP per year.

Summary Sheet Runoff Condition

Nitrogen

Surface Water Discharge

Total N post load	1331.8 kg/yr	
Percent N load reduction	59 %	
Provided N discharge load	545.32 kg/yr	1202.43 lb/yr
Provided N load removed	786.48 kg/yr	1734.18 lb/yr

Phosphorus

Surface Water Discharge

Total P post load	203.384 kg/yr	
Percent P load reduction	86 %	
Provided P discharge load	28.429 kg/yr	62.69 lb/yr
Provided P load removed	174.955 kg/yr	385.776 lb/yr

Figure 27e. Summary of Runoff Loads, Discharges and Removal of Nutrients.

Non-Runoff Conditions: The filter will function in a dual use capacity treating water in the discharge ditch during non-runoff. The removal using the filter during non-runoff is for the partly treated water from wet ponds. If groundwater flow is considered, the ditch water will either have a lower or higher concentration.. We assume no groundwater, thus the concentration of runoff water not treated is calculated by BMP Trains. This results in the calculation of an EMC for the ditch water. We will assume that there are no other inputs and the water not treated by the wet ponds will be the non-runoff water concentration. The calculation for ditch EMCs is to use the overall discharge mass during the runoff condition and the yearly flow after treatment. From the summary report (Figure 27e), the mass of TP discharged is 28.429 kg/yr and the runoff load after development is 534.05 ac-ft/yr. Another calculation for the non-runoff EMC is to use the Mass of Nutrients and the total flow, which for TP is 0.043 mg/L (28.429 x 10^6 / (534.06 x 1,233475 x 10^6)). TN is 0.828 mg/L.

To calculate the nutrient removal and the media service life, the filter at catchment 17 is used for runoff and non-runoff treatment. The non-runoff water volume is equal to runoff volume determined by the treatment BMP train model and is 534.06 acre-feet. The total area is 426 acres and to calculate the 534.06 acre-feet runoff available to one catchment, the DCIA has to be 36.985 (determined by trial and error). The DCIA (rounded to 36.99) is shown in Figure 27f.

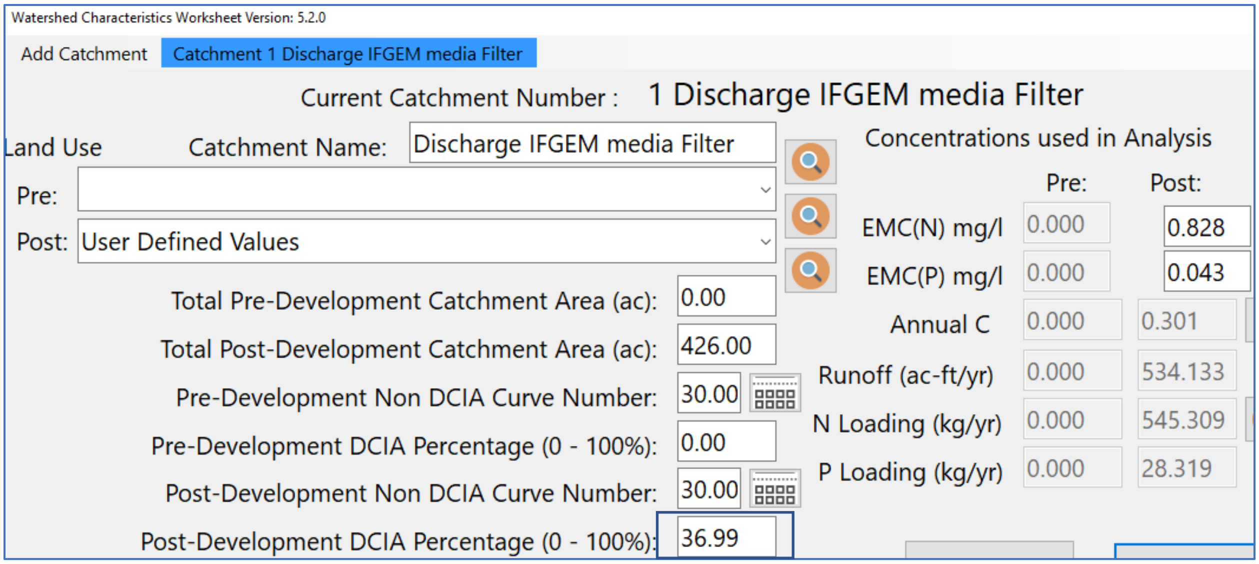


Figure 27f. Catchment Input to Represent Non-Runoff Conditions.

To calculate the annual % of the discharge volume treated by the filter during non-runoff times, the filter operation time is set at an equivalent 175.5 days per year. This allows for treatment of the runoff water, vacation time, and maintenance of the filter. Each day the filter will treat 60,000 CF (10 inches/hour x 24 hours x 3000 SF x 1/12 in/ft). For 175.5 days, total treatment is 10,530,000 CF. There is 534.05 ac-ft (Figure 27d) or 23,263,218 CF per year. The filter media is treats 0.45 (10,530,000/23,263,218) or 45% of the average yearly discharge (Figure 27g).

The annual treatment depth is calculated knowing 45% annual volume capture and by trial error (selection of depth of 0.205 inch is selected with12.09 kg/yr TP removed, Figure 27h.

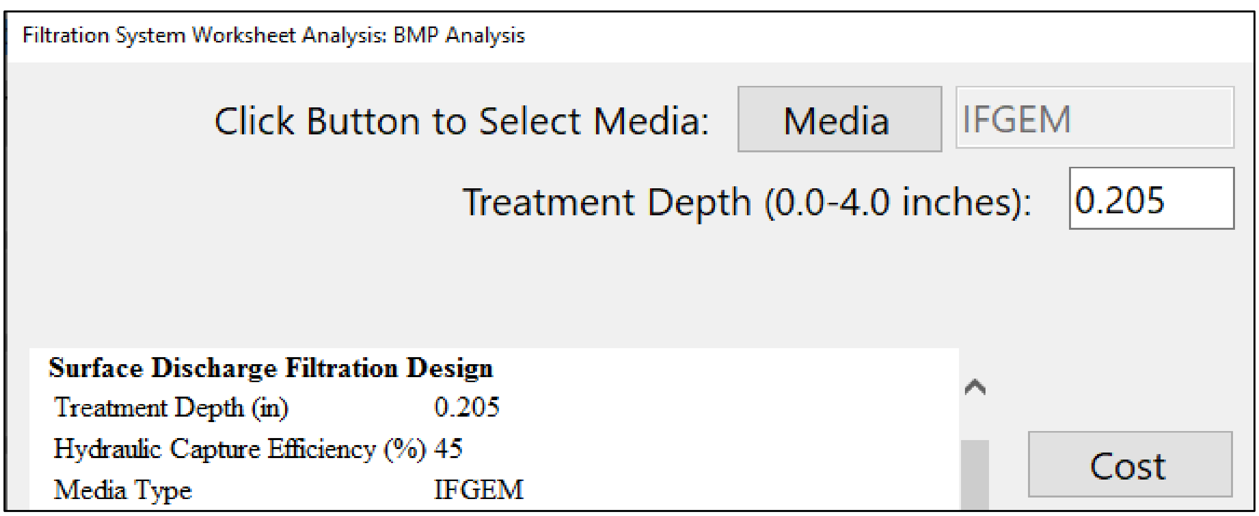


Figure 27g. Annual Capture and Treatment Depth During Non-Runoff.

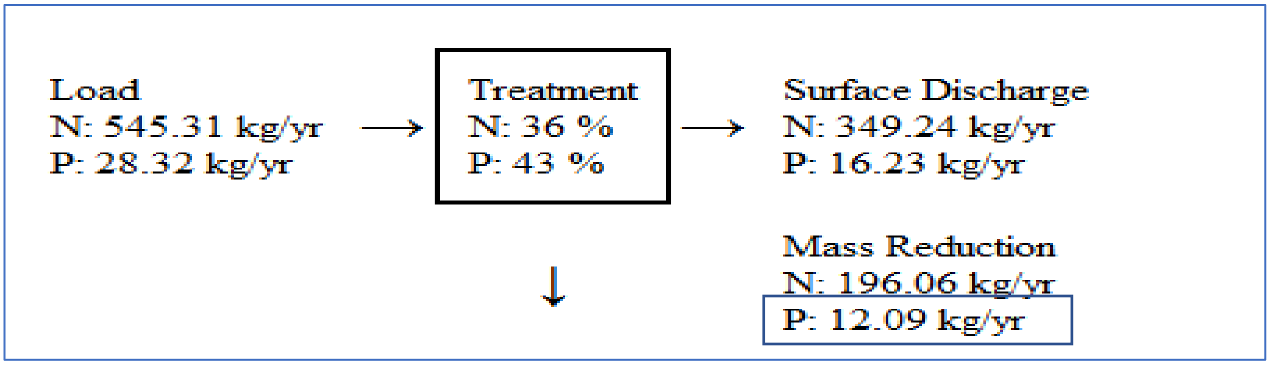


Figure 27h. Annual Treatment (Mass Reduction) During Non-Runoff.

Service life is calculated knowing the OP media capacity and the amount of OP removed by the filter in a year. The OP removal capacity is the Filter Volume Provided and with typical units in cubic feet (CF) x in-place moist weight (105 pounds/CF) of media x 454 g/pound x OP removal rate of the media (mg OP/ gram of media). The OP removed is the fraction of OP in TP x mass removed (kg/yr.) x 1,000,000 mg/kg. The fraction of OP in TP is assumed at 1.0 (most conservative) and likely because of particulate settling in the ponds and in the transport ditches. The amount removed is the sum during runoff conditions as well as during non-runoff conditions at the discharge (the BMP at catchment 17).

$$\text{Service life (years)} = 10.6 \text{ years} = \frac{0.6 \text{ mg/g x } 6000 \text{ CF x } 105 \text{ lbs/CF x } 454 \text{ dg/lb}}{(4.07 + 12.09) \text{ kg/yr x } 10^6 \text{ mg/kg}}$$

The total amount of nutrients removed is the sum of the overall system removal during runoff (Figure 27e) and non-runoff conditions at catchment 17 (Figure 27g). The data and the average percent removals are shown in Figure 27i. Treatment during non-runoff conditions increases the average annual removal of TN and TP from 59 to 74% and 86 to 92% respectively.

		Average Yearly Mass Removal (kg/yr)		
Parameter	Input kg/yr	Runoff Removal	Non-Runoff Removal	% Removal
TN	1331.8	786.48	196.06	74
TP	203.38	174.96	12.09	92

Figure 27i. Mass Removal using a Filter for Runoff and Non-Runoff Flows (Dual Treatment).

Concluding Statements Regarding the Example Problems

The example problems use data for EMCs and design sizes used in actual permits. Data were obtained from consultants doing work in the five meteorological regions of the State and from permits submitted to FDEP and all WMDs . However, the examples do not reflect all site conditions that may be encountered by a design and review team. The examples were used primarily to illustrate the navigation and capabilities of the **BMP Trains 2020** model using realistic data. All details of each site specific location were not presented in order to focus on the capabilities of the model. Nevertheless it is important for designers and reviewers to determine the site specific input data. It is generally understood that the time for permit reviews is minimized when there is an adequate understanding of the site-specific conditions.

The design of BMPs must follow the design conditions as shown in the appendices to obtain annual removal effectiveness. An example of a design condition is depth to the seasonal high-water table of at least 2 feet or that volume of water infiltrated in 72 hours to obtain the removal effectiveness in the model. In the appendices, information is presented for EMC and cost input data, as well as design conditions accepted by the profession in January, 2023.

EMCs are listed in Appendix A with descriptions of land use for the EMC data. These EMC data reflect the conditions of the overall land uses. As an example, high intensity commercial land use reflects the condition of traffic entry and exit on a frequent time interval and the runoff from the roof tops of the buildings, parkin, and surrounding pervious areas. As another example, the runoff from single family reflects the runoff from pervious as well as impervious surfaces. Also note that the example problems may use EMC values from previous years and changes may have been made since their initial use.

The cost data of appendix B reflects local working conditions as well as supply and demand for materials. The data in the appendix are used as a guide. Nevertheless, some have found the data useful for preliminary analysis of cost effectiveness. No cost data were used for permits.

For each BMP shown in Appendix C, design conditions are stipulated and the removal effectiveness calculated. BMP types and design sizes are usually chosen before an assessment of annual effectiveness is done by the **BMP Trains 2020** model. Examples of BMP design sizes are retention depth, permanent pool volume, filter volume and others. Examples of catchment related design parameter are directly connected impervious area (DCIA), depression storage and the water quality (EMC) of the water being treated. The model is used for assessment but is also used for professional discovery that leads to changes in design sizes.

Deviation from design conditions must be done with full understanding of how the deviations will affect annual removal effectiveness. When the deviation is judged to have an effect on removal that is different than used in the model, the BMP input to the model is done using the **user defined** treatment option and only after a mutual understanding of the removal by the reviewers and those proposing the removal effectiveness. The model is used to evaluate the annual removal effectiveness given rainfall, catchment and BMP designs. BMPs must be designed before analyses for annual removal and is based on user defined input data.

Appendix A. EMCs and Land Use

The 2022 Event Mean Concentration (EMC) values are listed below and are based on the arithmetic mean for the data collected. Changes are expected so the user should maintain the latest version of the program. EMCs are identified by land use, thus a description for each land use is in this Appendix. Each land use included the contribution of all surfaces, such as roof tops, roadways and landscape. The Indian River Lagoon watershed field investigations were added. In addition, a "general nature" land use designation was added to allow those situations where the natural undeveloped land use could not be characterized into one of the existing categories.

The EMCs used within BMP Trains are determined after watershed land use review and agreement among applicant and review agency. There is an option within BMP Trains for a user defined or weighted average EMC if it is not found in the above table. The data used for the EMCs and references follow.

Pasture Land Characterization Data

Location	Reference	Reported EMC (mg/l)			
		TN	**TP**	**BOD**	**TSS**
Indian River Lagoon watershed	Graves, et al, (2004)	1.09	0.222		
St. Cloud	CH2M-Hill (1977)	5.57	0.880	7.0	180.0
St. Johns River Basin	Fall (1987)	2.48	0.270	3.2	8.6
Ash Slough	Hendrickson (1987)	2.37	0.697		
Lettuce Creek	ERD (2004)	3.62	0.898		12.7
Mean Value		**3.03**	**0.593**	**5.1**	**67.1**
Median Value		**2.48**	**0.697**	**5.1**	**12.7**
Log-Normal Mean:		**2.64**	**0.506**	**4.7**	**27.0**

Citrus Land Runoff Characterization Data					
Location	Reference	Reported EMC (mg/l)			
		TN	TP	BOD	TSS
Indian River Lagoon watershed	Graves, et al, (2004)	1.23	0.16		
St. Johns River Basin (Citrus/Row)	Fall (1987)	3.26	0.240	3.0	28.0
St. Johns Water Control District (Citrus/Pasture)	Fall, et al. (1987)	1.33	0.090	2.1	4.6
Armstrong Slough (Citrus/Pastrure)	Hendrickson (1987)	1.57	0.090		
Upper St. Johns River Basin	Fall (1990)	2.72	0.160		23.3
Gator Slough (Hendry/Collier Co.)	Sawaka and Black (1993)	3.32	0.170		
Upper St. Johns River Basin	Fall (1995)	2.31	0.450		20.1
Charlotte/DeSoto Counties (4 sites)	Bahk and Kehoe (1997)	1.15	0.080		1.7
Mean Value		**2.11**	**0.180**	**2.6**	**15.5**
Median Value		**1.94**	**0.160**	**2.6**	**20.1**
Log-Normal Mean:		**1.94**	**0.153**	**2.5**	**10.1**

Row Crop Runoff Characterization Data					
Location	Reference	Reported EMC (mg/l)			
		TN	TP	BOD	TSS
Indian River Lagoon watershed	Graves, et al, (2004)	1.31	0.45		
Willowbrook Farms	Hendrickson (1987)	2.68	0.562		
Upper St. Johns River Basin	Fall (1987)	3.26	0.240		
Upper St. Johns River Basin	Fall (1990)	4.73	0.430		37.4
Upper St. Johns River Basin	Fall (1995)	3.36	1.070		32.4
Manatee Co. (5 sites)	Bahk et al. (1997)	1.45	0.500		7.0
Cockroach Bay (Ruskin)	Bahk (1997)	1.57	0.510		
Upper St. Johns River Basin	Hendrickson (unpub.)	2.26	0.163		4.9
Cockroach Bay (Ruskin)	Rushton (2002)	1.85	1.265		17.4
Mean Value		**2.50**	**0.577**		**19.8**
Median Value		**2.26**	**0.500**		**17.4**
Log-Normal Mean:		**2.29**	**0.484**		**14.9**

General Agricultural Runoff EMCs are the average of the three or TN=2.55 mg/L and TP=0.450mg/L

Source: based on the EMC data from Harper (2007) and other references as shown.

High Intensity Commercial Runoff Characterization Data					
Location	Reference	Reported EMC (mg/l)			
		TN	TP	BOD	TSS
Broward County	Mattraw,et.al.,(1981)	1.10	0.100	5.4	45.0
Orlando-Downtown	Wanielista, (1982)	2.81	0.310	17.2	94.3
Dade Co.	Waller (1984)	3.53	0.820		
Broward County	Howie,et.al.(1986)	2.15	0.150		
Mean Value		**2.40**	**0.345**	**11.3**	**69.7**
Median Value		**2.48**	**0.230**	**11.3**	**69.7**
Log-Normal Mean:		**2.20**	**0.248**	**9.6**	**65.1**

Source: based on the EMC data from Harper (2007) and other references as shown.

Highway Land Use Runoff Characterization Data					
Location	Reference	Reported EMC (mg/l)			
		TN	TP	BOD	TSS
Broward Co. (6 lane)	Mattraw,et.al.,(1981)	0.96	0.080	9.0	15.0
Miami I-95	McKenzie,et.al.(1983)	3.20	0.160		42.0
Maitland	German (1983)	1.30	0.240		27.0
Maitland I-4	Harper (1985)	1.40	0.170		
Maitland Blvd.	Yousef,et.al.(1986)	1.40	0.170		
I-4 EPCOT	Yousef,et.al.(1986)	3.16	0.420		
Winter Park I-4	Harper (1988)	1.60	0.230	6.9	34.0
Orlando I-4	Harper (1988)	2.15	0.550	4.2	66.5
Bayside Bridge	Stoker (1996)	1.10	0.100		20.0
Tallahassee (6 lane)	ERD (2000)	1.10	0.166	1.9	70.6
Orlando US 441	ERD (2007)	0.68	0.085	4.2	23.1
Flamingo Dr. Collier, County	Johnson Eng. (2009)	0.94	0.060		18.5
SR-80, Hendry County	Johnson Eng. (2009)	1.31	0.168		120
Richard Rd, Lee Co.	Johnson Eng. (2006)	1.60	0.282		76.0
US 41, Lee County	Johnson Eng. (2008)	0.82	0.120		39.0
Mean Value		**1.515**	**0.200**	**5.2**	**46.0**
Median Value		**1.310**	**0.168**	**4.2**	**36.5**
Log-Normal Mean:		**1.371**	**0.167**	**4.6**	**38.1**

Source: based on the EMC data from Harper (2007) and other references as shown.

Light Industrial Runoff Characterization Data

Location	Reference	Reported EMC (mg/l)			
		TN	TP	BOD	TSS
Orlando-Downtown	ECFRPC (1985)	1.42	0.310	9.1	102.0
Manatee Co.	CDM (1985)	1.18	0.150		
Tallahassee	COT & ERD (2002)	1.09	0.090	6.0	18.0
Winter Haven	ERD (2007)	1.10	0.488		
Mean Value		**1.20**	**0.260**	**7.6**	**60.0**
Median Value		**1.14**	**0.230**	**7.6**	**60.0**
Log-Normal Mean:		**1.19**	**0.213**	**7.4**	**42.8**

Source: based on the EMC data from Harper (2007) and other references as shown.

Multi-Family Residential Runoff Characterization Data

Location	Reference	Reported EMC (mg/l)			
		TN	TP	BOD	TSS
Orlando - Shoals Apts.	ECFRPC (1978)	1.91	0.510	7.8	143.0
Miami - Kings Apts.	Miller (1979)	2.57	0.450	14.5	36.8
Loch Lomond	Weinburg, et al. (1980)	1.91	0.730		
Orlando - Downtown	Wanielista, et al. (1982)	4.68	0.720	10.1	95.6
Tampa - Young Apts.	USEPA (1983)	1.61	0.330	16.0	53.0
Tallahassee - Royal Pavilion Apts.	Lopez,et.al. (1984)	1.22	0.380	8.0	61.0
Mean Value		**2.32**	**0.520**	**11.3**	**77.9**
Median Value		**1.91**	**0.480**	**10.1**	**61.0**
Log-Normal Mean:		**2.10**	**0.497**	**10.8**	**69.5**

Source: based on the EMC data from Harper (2007) and other references as shown.

Single Family Residential Runoff Characterization Data

Location	Reference	Reported EMC (mg/l)			
		TN	TP	BOD	TSS
Pompano Beach	Mattraw,et.al.,(1981)	2.00	0.310	7.9	26.0
Tampa-Charter St.	US EPA (1983)	2.31	0.400	13.0	33.0
Maitland (3 sites)	German (1983)	2.20	0.340	7.1	43.0
St. Pete-Bear Creek	Lopez,et.al. (1984)	1.50	0.200	4.7	
Tampa-Kirby St.	Lopez,et.al. (1984)	2.20	0.250	4.5	
Tampa-St. Louis St.	Lopez,et.al. (1984)	3.00	0.450	6.1	
Orlando-Duplex	Harper (1988)	4.62		9.5	63.2
Orlando-Essex Pointe	Harper (1988)	1.85	0.200	6.5	30.1
Palm Beach-Springhill	Greg,et.al. (1989)	1.18	0.307		3.5
Tampa-102nd Ave.	Holtkamp (1998)	2.62	0.510	13.4	36.8
Bradfordville	ERD (2000)	1.30	0.280	2.7	57.1
Fl. Keys-Key Colony	ERD (2002)	1.20	0.281	2.0	26.9
Tallahassee-Woodgate	COT & ERD (2002)	1.29	0.505	15.0	76.0
Sarasota Co.	ERD (2004)	1.17	0.506	4.4	10.1
Orlando-Krueger St.	ERD (2004)	3.99	0.182	17.1	41.8
Orlando-Paseo St.	ERD (2004)	1.02	0.102	4.0	12.0
Windemere	ERD (2007)	1.69	0.402		65.0
Mean Value		**2.07**	**0.327**	**7.9**	**37.5**
Median Value		**1.85**	**0.309**	**6.5**	**34.9**
Log-Normal Mean:		**1.87**	**0.301**	**6.6**	**29.3**

Source: based on the EMC data from Harper (2007) and other references as shown.

Low-Density Residential Runoff Characterization Data

By definition, it is single family residential in a rural area. The EMC is calculated as the average of the single family and undeveloped rural average data (TN= 1.22 mg/L and TP = 0.213 mg/L). Thus, the average TN and TP are 1.645 mg/L and 0.27 mg/L respectively.

Source: based on the EMC data from Harper (2007) and other references as shown.

Low Intensity Commercial Runoff Characterization Data					
Location	**Reference**	**Reported EMC (mg/l)**			
		TN	**TP**	**BOD**	**TSS**
Orlando Areawide	ECFRPC (1978)	0.89	0.160	3.6	146.0
Coral Ridge Mall	Miller (1979)	1.10	0.100	5.4	45.0
Norma Park-Tampa	US EPA (1983)	1.19	0.150	12.0	22.0
Internat. Market	Harper (1988)	1.53	0.190	11.6	111.0
DeBary	Harper & Herr (1993)	0.76	0.260	6.9	79.1
Bradfordville	ERD (2000)	2.14	0.160	9.0	38.3
Cross Creek-Tall.	COT & ERD (2002)	0.93	0.150	8.0	15.0
Sarasota Co.	ERD (2004)	0.88	0.310	4.3	39.9
Fla. Aquarium-Tampa	Teague,et.al.(2005)	0.76	0.215		42.4
Mean Value		**1.13**	**0.188**	**7.6**	**59.9**
Median Value		**0.93**	**0.160**	**7.5**	**42.4**
Log-Normal Mean:		**1.07**	**0.179**	**7.00**	**47.51**

Source: based on the EMC data from Harper (2007) and other references as shown.

Rangeland Runoff Characteristic Data

LOCATION	REFERENCE	MEAN emc VALUE (mg/l)						
		TN	TP	BOD	TSS	Cu	Pb	Zn
Orlando ECFRPC	CH2M Hill (1977)	1.52	0.10	1.7	18.5	--	--	--
Miami	Waller (1982)	0.90	0.02	--	4.8	--	--	--
Boggy Creek Study	ECFRPC (1988)	1.47	0.07	--	--	--	--	--
Sarasota/Charlotte Counties	ERD (2004)	0.703	0.031	1.0	1.9	--	--	--
Overall Mean Value		**1.15**	**0.055**	**1.4**	**8.4**	**--**	**--**	**--**

Source: Harper and Baker (2007) page 4-23.

Mining Runoff Characteristics Data

LOCATION	REFERENCE	Mean EMC value (mg/l)			
		TN	TP	BOD	TSS
Boggy Creek Study	ECFRPC (1988)	1.18	0.15	--	--
Overall Mean Value		**1.18**	**0.15**	**--**	**--**

Source: Harper and Baker (2007) page 4-24.

Runoff Characteristics of Natural Area		
Land Type	Total N (µg/l)	Total P (µg/l)
Dry Prairie (DP)	2,025	184
Marl Prairie (MP)	684	12
Mesic Flatwoods (MF)	1,087	43
Ruderal/ Upland Pine (RUP)	1,694	162
Scrubby Flatwoods (SF)	1,155	27
Upland Hardwood (UH)	1,042	346
Upland Mixed Forest (UMF)	606	1,166
Wet Flatwoods (WF)	1,213	21
Wet Prairie (WP)	1,095	15
Xeric Scrub (XS)	1,596	156
General Natural	1,220	213

Source: Harper and Baker (2009)

CATCHMENT DEFINED AND GENERAL LAND USE CATEGORIES FOR RUNOFF and EMC CHARACTERIZATION

A catchment is a land area from which runoff water can be discharged and at the point of discharge for which a BMP is possible. Land use categories are defined by all features of the catchment; thus as an example low-intensity commercial area includes parking, building, and vegetated cover crop. A catchment can be furthered divided into a roof area catchment if there is a possibility of a BMP for the roof, as well as a parking/green space. A watershed is an area that is composed of one or more catchments. Land use categories are*:

GENERAL CATEGORY	DESCRIPTION**
Low-Density Residential	Rural areas with lot sizes greater than 1 acre or less than one dwelling unit per acre; internal roadways associated with the homes are also included
Single-Family Residential	Typical detached home community with lot sizes generally less than 1 acre and dwelling densities greater than one dwelling unit per acre; duplexes constructed on one-third to one- half acre lots are also included in this category; internal roadways associated with the homes are also included
Multi-Family Residential	Residential land use consisting primarily of apartments, condominiums, and cluster-homes; internal roadways associated with the homes are also included
Low-Intensity Commercial	Areas which receive only a moderate amount of traffic volume where cars are parked during the day for extended periods of time; these areas include universities, schools, professional office sites, and small shopping centers; internal roadways associated with the development are also included
High-Intensity Commercial	Land use consisting of commercial areas with high levels of traffic volume and constant traffic moving in and out of the area; includes downtown areas, commercial sites, regional malls, and associated parking lots; internal roadways associated with the development are also included
Industrial	Land uses include manufacturing, shipping and transportation services, sewage treatment facilities, water supply plants, and solid waste disposal; internal roadways associated with the development are also included
Highway	Includes major road systems, such as interstate highways and major arteries and thoroughfares; roadway areas associated with residential, commercial, and industrial land use categories are already included in loading rates for these categories
Agriculture	Includes cattle, grazing, row crops, citrus, and related activities
Open/ Undeveloped	Includes open space, barren land, undeveloped land which may be occupied by native vegetation, rangeland, and power lines; this land does not include golf course areas which are heavily fertilized and managed; golf course areas have runoff characteristics most similar to single-family residential areas, but also may include some open space.
Mining/ Extractive	Includes a wide variety of mining activities for resources such as phosphate, sand, gravel, clay, shell, etc.
Wetlands	Include a wide range of diverse wetland types, such as hardwood wetlands, cypress stands, grassed wetlands, freshwater marsh, and mixed wetland associations.
Open Water/ Lakes	Land use consists of open water and lakes, rivers, reservoirs, and other open waterbodies

"From: Refining the Indian River Lagoon TMDL – Technical Memorandum Report: Assessment and Evaluation of Model Input Parameters" – Final Report; Environmental Research & Design, Inc.; July 2013.
** Watersheds may be a combination of categories. Thus, Event Mean Concentrations (EMCs) may be a weighted average (based on annual runoff) for a number of categories.

Florida Land Use Codes and Classification System (FLUCCS) descriptions are listed and related to the land use descriptions used within this Manual and Model. The user is encouraged to review the definitions of land use and FLUCCS.

Following is a summary of the FLUCCS code assignments to consolidated land use categories and EMCs. However, Site specific conditions must be used to specify the EMC.

FLUCCS CODE	LAND USE DESCRIPTION	GENERAL/ CONSOLIDATED LAND USE	EMC LAND USE I.D. NUMBER
2300	Feeding Operations	Agriculture	AG - GENERAL
2310	Cattle Feeding Operations	Agriculture	AG - GENERAL
2320	Poultry feeding operations	Agriculture	AG - GENERAL
2340	Other feeding operations	Agriculture	AG - GENERAL
2400	Nurseries and Vineyards	Agriculture	AG - GENERAL
2410	Tree nurseries	Agriculture	AG - GENERAL
2420	Sod farms	Agriculture	AG - GENERAL
2430	Ornamentals	Agriculture	AG - GENERAL
2431	Shade ferns	Agriculture	AG - GENERAL
2432	Hammock ferns	Agriculture	AG - GENERAL
2450	Floriculture	Agriculture	AG - GENERAL
2500	Specialty Farms	Agriculture	AG - GENERAL
2510	Horse Farms	Agriculture	AG - GENERAL
2520	Dairies	Agriculture	AG - GENERAL
2590	Other Specialty Farms	Agriculture	AG - GENERAL
2200	Tree Crops	Citrus	AG - CITRUS
2210	Citrus groves	Citrus	AG - CITRUS
2220	Fruit Orchards	Citrus	AG - CITRUS
1400	Commercial and Services	Commercial	HIGH INTENSITY COMMERCIAL
1410	Retail Sales and Services	Commercial	HIGH INTENSITY COMMERCIAL
1420	Wholesale Sales and Services <Excluding warehouses associated with industrial use>	Commercial	LOW INTENSITY COMMERCIAL

1430	Professional Services	Commercial	LOW INTENSITY COMMERCIAL
1440	Cultural and Entertainment	Commercial	LOW INTENSITY COMMERCIAL
1450	Tourist Services	Commercial	HIGH INTENSITY COMMERCIAL
1470	Mixed Commercial and Services	Commercial	LOW INTENSITY COMMERCIAL
1490	Commercial and Services Under Construction	Commercial	LOW INTENSITY COMMERCIAL
8130	Bus and truck terminals	Commercial	HIGH INTENSITY COMMERCIAL
8150	Port facilities	Commercial	HIGH INTENSITY COMMERCIAL
8160	Canals and Locks	Commercial	LOW INTENSITY COMMERCIAL
8180	Auto parking facilities - when not directly related to other land uses	Commercial	LOW INTENSITY COMMERCIAL
3100	Herbaceous Dry Prairie	Dry Prairie	DRY PRAIRIE*
3210	Palmetto Prairies	Dry Prairie	DRY PRAIRIE*
3211	Palmetto-Oak Shrubland	Dry Prairie	DRY PRAIRIE*
3212	Dry Prairie	Dry Prairie	DRY PRAIRIE*
3220	Coastal Strand	Dry Prairie	DRY PRAIRIE*
3300	Mixed Rangeland	Dry Prairie	DRY PRAIRIE*
1300	Residential, High-Density	High-Density Residential	MULTI FAMILY RES
1310	Fixed Single Family Units	High-Density Residential	SINGLE FAMILY RES
1330	Residential, High-Density; Multiple Dwelling Units, Low Rise <Two stories or less>	High-Density Residential	MULTI FAMILY RES
1340	Residential, High-Density; Multiple Dwelling Units, High Rise <Three stories or more>	High-Density Residential	MULTI FAMILY RES
1350	Residential, High-Density; Mixed Units <Fixed and mobile Homes>	High-Density Residential	MULTI FAMILY RES
1390	High-Density Under Construction	High-Density Residential	MULTI FAMILY RES
6181	Cabbage palm hammock	Hydric Hammock	HYDRIC HAMMOCK*
6182	Cabbage palm savannah	Hydric Hammock	HYDRIC HAMMOCK*
1460	Oil and Gas Storage(except industrial use or manufacturing)	Industrial	INDUSTRIAL
1500	Industrial Under Construction	Industrial	INDUSTRIAL

1510	Food Processing	Industrial	INDUSTRIAL
1520	Timber Processing	Industrial	INDUSTRIAL
1530	Mineral Processing	Industrial	INDUSTRIAL
1540	Oil and Gas Processing	Industrial	INDUSTRIAL
1550	Other Light Industrial	Industrial	INDUSTRIAL
1560	Other Heavy Industrial	Industrial	INDUSTRIAL
1561	Ship Building and Repair	Industrial	INDUSTRIAL
1562	Pre-stressed concrete plants	Industrial	INDUSTRIAL
1590	Industrial Under Construction	Industrial	INDUSTRIAL
2540	Aquaculture	Industrial	INDUSTRIAL
8200	Communications	Industrial	INDUSTRIAL
8220	Communication Facilities	Industrial	INDUSTRIAL
8300	Utilities	Industrial	INDUSTRIAL
8310	Electrical power facilities	Industrial	INDUSTRIAL
8330	Water supply plants	Industrial	INDUSTRIAL
8340	Sewage Treatment	Industrial	INDUSTRIAL
8350	Solid waste disposal	Industrial	INDUSTRIAL
8360	Other treatment ponds	Industrial	INDUSTRIAL
8390	Utilities under construction	Industrial	INDUSTRIAL

FLUCCS CODE	LAND USE DESCRIPTION	GENERAL/ CONSOLIDATED LAND USE	CONSOLIDATED LAND USE I.D. NUMBER
1700	Institutional (Educational, religious, health and military facilities)	Institutional	LOW INTENSITY COMMERCIAL
1710	Educational Facilities	Institutional	LOW INTENSITY COMMERCIAL
1720	Religious	Institutional	LOW INTENSITY COMMERCIAL
1730	Military	Institutional	LOW INTENSITY COMMERCIAL
1740	Medical and Health Care	Institutional	LOW INTENSITY COMMERCIAL
1750	Governmental	Institutional	LOW INTENSITY COMMERCIAL
1770	Other Institutional	Institutional	LOW INTENSITY COMMERCIAL
1780	Commercial Child Care	Institutional	LOW INTENSITY COMMERCIAL
1790	Institutional Under Construction	Institutional	LOW INTENSITY COMMERCIAL
8110	Airports	Institutional	LOW INTENSITY COMMERCIAL
1100	Residential, Low-Density-Less than two dwelling units/acre	Low-Density Residential	LOW DENSITY RES
1110	Fixed Single Family Units	Low-Density Residential	SINGLE FAMILY RES
1180	Residential, Rural < or = 0.5 dwelling units/acre	Low-Density Residential	LOW DENSITY RES
1190	Low-Density Under Construction	Low-Density Residential	LOW DENSITY RES
1200	Residential, Medium-Density (Two-five dwelling units per acre)	Medium-Density Residential	SFR OR MFR DEPENDING ON UNITS
1210	Fixed Single Family Units	Medium-Density Residential	SINGLE FAMILY RES
1290	Medium-Density Under Construction	Medium-Density Residential	SFR OR MFR DEPENDING ON UNITS

6250	Hydric pine flatwoods	Mesic Flatwoods	MESIC FLATWOODS*
1600	Extractive	Mining	MINING
1610	Strip Mines	Mining	MINING
1611	Clays	Mining	MINING
1620	Sand and Gravel Pits	Mining	MINING
1632	Limerock or dolomite quarries	Mining	MINING
1633	Phosphate quarries	Mining	MINING
1650	Reclaimed Land	Mining	MINING
1660	Holding Ponds	Mining	MINING
1320	Mobile Home Units	High-Density Residential	MULTI FAMILY RES
1810	Swimming Beach	Open	UNDEVELOPED
1900	Open Land	Open	UNDEVELOPED
1920	Inactive Land with street patterns but without structures	Open	UNDEVELOPED
2600	Other Open Lands - Rural	Open	UNDEVELOPED
2610	Fallow cropland	Open	UNDEVELOPED
7100	Beaches other than swimming beaches	Open	UNDEVELOPED
7200	Sand other than beaches	Open	UNDEVELOPED
7340	Exposed rocks	Open	UNDEVELOPED
7400	Disturbed land	Open	UNDEVELOPED
7410	Rural land in transition without positive indicators of intended activity	Open	UNDEVELOPED
7430	Spoil areas	Open	UNDEVELOPED
8120	Railroads	Open	UNDEVELOPED
8320	Electrical power transmission lines	Open	UNDEVELOPED
9999	(blank)	Open	UNDEVELOPED
2110	Improved Pasture	Pasture	PASTURE
2120	Unimproved Pastures	Pasture	PASTURE
2130	Woodland Pasture	Pasture	PASTURE
1480	Cemeteries	Recreational 1	AVERAGE OF SFR + UNDEVELOPED
1800	Recreational	Recreational 1	AVERAGE OF SFR + UNDEVELOPED

1820	Golf Course	Recreational 1	AVERAGE OF SFR + UNDEVELOPED
1840	Marinas and Fish Camps	Recreational 1	AVERAGE OF SFR + UNDEVELOPED
8115	Grass Airports	Recreational 1	AVERAGE OF SFR + UNDEVELOPED
1830	Race Tracks(horse, dog, car, motorcycle)	Recreational 2	AVERAGE OF MFR+UNDEVELOPPED
1850	Parks and Zoos	Recreational 2	AVERAGE OF MFR+UNDEVELOPPED
1860	Community Recreational Facilities	Recreational 2	AVERAGE OF MFR+UNDEVELOPPED
1870	Stadiums (not associated with high schools, colleges, or universities)	Recreational 2	AVERAGE OF MFR+UNDEVELOPPED
1890	Other Recreational(Riding stables, go-cart tracks, skeet ranges, etc.)	Recreational 2	AVERAGE OF MFR+UNDEVELOPPED
2140	Row Crops	Row Crops	ROW CROPS
2150	Field Crops	Row Crops	ROW CROPS
2160	Mixed Crops	Row Crops	ROW CROPS
2240	Abandoned tree crops	Ruderal	RUDERAL UPLAND PINE*
4220	Brazilian Pepper	Ruderal	RUDERAL UPLAND PINE*
4430	Forest regeneration	Ruderal	RUDERAL UPLAND PINE*
3200	Shrub and Brushland	Scrub	SCRUBBY FLATWOODS*
4130	Sand pine	Scrub	XERIC SCRUB*
8100	Transportation	Transportation	HIGHWAY
8140	Roads and Highways	Transportation	HIGHWAY
8191	Highways	Transportation	HIGHWAY

FLUCCS CODE	LAND USE DESCRIPTION	GENERAL/ CONSOLIDATED LAND USE	CONSOLIDATED LAND USE I.D. NUMBER
4111	Mesic longleaf pine flatwoods	Upland Flatwoods	MESIC FLATWOODS*
4112	Scrubby Pine flatwoods	Upland Flatwoods	MESIC FLATWOODS*
4200	Upland Hardwood Forest	Upland Flatwoods	MESIC FLATWOODS*
4340	Hardwood Conifer Mixed	Upland Flatwoods	MESIC FLATWOODS*
4120	Longleaf pine - xeric oak	Upland Mixed	UPLAND MIXED FOREST*
4140	Upland Mixed Forest	Upland Mixed	UPLAND MIXED FOREST*
4270	Maritime Hammock	Upland Mixed	UPLAND MIXED FOREST*
4271	Coastal Temperate Hammock	Upland Mixed	UPLAND MIXED FOREST*
4272	Prairie Hammock	Upland Mixed	UPLAND MIXED FOREST*
4275	Red Cedar- Cabbage Palm Hammock	Upland Mixed	UPLAND MIXED FOREST*
4300	Upland Hardwood Forests Continued	Upland Mixed	UPLAND MIXED FOREST*
4400	Tree Plantations	Upland Mixed	UPLAND MIXED FOREST*
5474	Spoil islands/coastal islands	Upland Mixed	UPLAND MIXED FOREST*
5100	Streams and waterways	Water	WATER
5120	Channelized waterways, canals	Water	WATER
5200	Lakes	Water	WATER
5201	Pond	Water	WATER
5250	Marshy Lakes	Water	WATER
5300	Reservoirs	Water	WATER

5330	Reservoirs larger >10 <100 acres	water	WATER
5400	Bays and estuaries	Water	WATER
5410	Embayment’s opening directly to the Gulf or Ocean	Water	WATER
5430	Enclosed saltwater ponds within a salt marsh	Water	WATER
5500	Major Springs	Water	WATER
5600	Slough Waters	water	WATER
5710	Atlantic Ocean	Water	WATER
7420	Borrow areas	Water	WATER
8370	Surface Water Collection Basin	Water	WATER
4110	Pine flatwoods	Wet Flatwoods	WET FLATWOODS*
4113	Hydric pine flatwoods	Wet Flatwoods	WET FLATWOODS*
4260	Tropical Hardwood Hammock	Wet Flatwoods	WET FLATWOODS*
4280	Cabbage palm	Wet Flatwoods	WET FLATWOODS*
6172	Mixed Shrubs	Wet Prairies	WET PRAIRIE*
6430	Wet prairies	Wet Prairies	WET PRAIRIE*
6110	Bay swamps	Wetland	WETLAND*
6120	Mangrove swamp	Wetland	WETLAND*
6150	Lowland Hardwood Forest/Swamp	Wetland	WETLAND*
6151	Willow Swamp	Wetland	WETLAND*
6152	Red Maple Swamp	Wetland	WETLAND*
6153	Shrub Swamp	Wetland	WETLAND*
6170	Mixed wetland hardwoods	Wetland	WETLAND*
6210	Cypress	Wetland	WETLAND*
6220	Pond pine	Wetland	WETLAND*
6300	Wetland Forested Mixed	Wetland	WETLAND*
6400	Freshwater marshes	Wetland	WETLAND*
6410	Freshwater marshes	Wetland	WETLAND*
6411	Sawgrass marsh	Wetland	WETLAND*
6412	Cattail marsh	Wetland	WETLAND*
6414	Graminoid marsh	Wetland	WETLAND*

6416	Flag marsh	Wetland	WETLAND*
6420	Saltwater marshes	Wetland	WETLAND*
6423	Low salt marsh	Wetland	WETLAND*
6424	High salt marsh	Wetland	WETLAND*
6440	Emergent aquatic vegetation	Wetland	WETLAND*
6460	Mixed scrub-shrub wetland	Wetland	WETLAND*
6500	Non-vegetated Wetland	Wetland	WETLAND*
6510	Tidal creek	Wetland	WETLAND*
6200	Wetland Coniferous Forest	Wetland	WETLAND*
4210	Xeric oak	Xeric Hammock	XERIC HAMMOCK*
4321	Xeric Oak Scrub	Xeric Hammock	XERIC HAMMOCK*
4322	Xeric Hammock	Xeric Hammock	XERIC HAMMOCK*
4370	Australian pine	Xeric Hammock	XERIC HAMMOCK*
4410	Coniferous pine	Xeric Hammock	XERIC HAMMOCK*

* Can always use the general undeveloped/rangeland/forest EMCs instead

Further descriptions on the next pages for the natural communities follow to aid in FLUCCS and Land use assignment

Natural Community Name	Synonyms	Description	Location	Soils	FLUCCS Code/Name
Dry Prairie	- palm savannah - palmetto prairie - pineland - treeless range	Flatland with sand substrate; mesic-xeric; subtropical or temperate nearly treeless plain with a dense ground cover of wiregrass, saw palmetto, and other grasses, herbs, and low shrubs. Other typical plants include broomsedge, carpet grass, runner oak, Indian grass, love grass, blazing star, rabbit tobacco, pine lily, marsh pink, milkwort, goldenrod, musky mint, pawpaw, dwarf wax myrtle, gallberry, stagger bush, fetterbush, and dwarf blueberry. Dry Prairie is closely associated with and often grades	Occurs on relatively flat, moderately to poorly drained terrain. Dry Prairie is very similar to Mesic Flatwoods in most respects, except that pines and palms are absent or at a density below one tree per acre. Dry Prairies are apparently endemic to Florida and largely confined to a few regions of the State.	Soils typically consist of 1 to 3 feet of acidic sands generally overlying an organic hardpan or clayey subsoil. The hardpan substantially reduces the movement of water below and above its surface, such that Dry Prairies may become flooded for short periods during rainy seasons. The normal water table is several inches to several feet below the surface	321/Palmetto Prairies 310/Herbaceous

		into Wet Prairie or Mesic.			
Natural Community Name	Synonyms	Description	Location	Soils	FLUCCS Code/Name
Hydric Hammock	- wetland hardwood hammock - wet hammock	A well-developed hardwood and cabbage palm forest with a variable understory often dominated by palms and ferns. Typical plants include cabbage palm, diamond-leaf oak, red cedar, red maple, swamp bay, sweetbay, water oak, southern magnolia, wax myrtle, saw palmetto, bluestem palmetto, needle palm, poison ivy, dahoon holly, myrsine, hackberry,	Hydric Hammock occurs on low, flat, wet sites where limestone may be near the surface. Hydric Hammock generally grades into Floodplain Swamp, Strand Swamp, Basin Swamp, Baygall, Wet Flatwoods, Coastal Berm, Maritime Hammock, Slope Forest, Upland Mixed Forest, or Upland Hardwood Forest. Hydric Hammock is	Soils are sands with considerable organic material that, although generally saturated, are inundated only for short periods following heavy rains	617/Mixed Wetland Hardwoods

		sweetgum, loblolly pine, Florida elm, swamp chestnut oak, American hornbeam, Hydric Hammock occurs as patches in a variety of lowland situations, often in association with springs or karst seepage, and in extensive forests covering lowlands just inland of coastal communities.	often difficult to differentiate from Bottomland Forest, Prairie Hammock, and Floodplain Forest.		
Natural Community Name	Synonyms	Description	Location	Soils	FLUCCS Code/Name
Marl Prairie	- Scrub cypress - marl flat - sedge flat - spikerush marsh - cypress savannah - coastal prairie	Sparsely vegetated flatland with marl over limestone substrate; seasonally inundated; Dominant plants include muhly grass, sawgrass, spikerush, bluestem, beakrush,	Marl Prairies are sparsely vegetated seasonal marshes on flatlands along the interface between deeper wetlands and coastal or upland communities where	Highly alkaline marl soils are from 2 inches to 3.5 feet thick and are fine gray or white muds. The most extensive types are freshwater Perrine marl, and Marine aragonite The	621/Cypress 641/Freshwater Marshes

	- coastal marsh - dwarf cypress savannah	shoregrass, and pond cypress. Although generally a system of sedges, grasses, and grass-like plants of varying heights and densities, widely scattered, stunted cypress or mangrove trees are often present.	limestone is near the surface. Marl Prairies are limited to south Florida and have several species endemic to the state. Several very large examples of this NC occur in the Everglades National Park and in Big Cypress National Preserve.	substrate may be concrete-like in the winter and spring dry seasons but soft and, slippery when wet. The soils are seasonally flooded but the hydro-period is highly variable. Marl Prairies are found mostly on coastal sites and may grade into Wet Prairies or Wet Flatwoods.	
Natural Community Name	Synonyms	Description	Location	Soils	FLUCCS Code/Name
Mesic Flatwoods	- pine/palmetto - meso-hydrophytic forest - pine flatwoods - pine savannahs - pine barrens	Mesic Flatwoods are characterized as an open canopy forest of widely spaced pine trees with little or no understory but a dense ground cover of herbs and shrubs. Flatland with sand substrate; mesic; subtropical or	Mesic Flatwoods occur on relatively flat, moderately to poorly drained terrain. Mesic Flatwoods are closely associated with and often grade into Wet Flatwoods, Dry Prairie, or Scrubby Flatwoods.	The soils typically consist of 1-3 feet of acidic sands generally overlying an organic hardpan or clayey subsoil. The hardpan substantially reduces the percolation of water below and above its surface. During the rainy seasons,	411/Pine Flatwoods 414/Pine - Mesic Oak 428/Cabbage Palm

		temperate; frequent fire; slash pine and/or longleaf pine with saw palmetto, gallberry and/or wiregrass or cutthroat grass Understory. Another important physical factor in Mesic Flatwoods is fire several species depend on fire for their continued existence. Mesic Flatwoods are the most widespread biological community in Florida, occupying an estimated 30 to 50% of the state's uplands.	The differences between these communities are generally related to minor topographic changes. Wet Flatwoods occupy the lower wetter areas, while Scrubby Flatwoods occupy the higher drier areas.	water frequently stands on the hardpan's surface and briefly inundates much of the flatwoods	
Natural Community Name	Synonyms	Description	Location	Soils	FLUCCS Code/Name
Ruderal/Upland Pine Forest	- longleaf pine – wiregrass	Upland Pine Forest is characterized as a rolling	Upland Pine Forest occurs on the rolling	The soils are composed of sand with variable,	414/Pine - Mesic Oak

	- longleaf pine upland forest - loblolly - shortleaf pine upland forest - clay hills - high pineland	forest of widely spaced pines with few understory shrubs and a dense ground cover of grasses and herbs. Pristine areas are dominated by longleaf pine and wiregrass. Other typical plants include southern red oak, runner oak, bluejack oak, blackjack oak, post oak, sassafras, black cherry, gallberry, persimmon, mockernut hickory, twinflower, huckleberry, dangleberry, goldenrod.	hills of extreme northern Florida. .	sometimes substantial, amounts of Miocene clays. The resultant prevalence of clays helps retain soil moisture. Thus, many plants which previously were restricted to valleys and other low areas may now inhabit the Upland Pine Forests	423/Oak - Pine - Hickory

Natural Community Name	Synonyms	Description	Location	Soils	FLUCCS Code/Name
Scrubby Flatwoods	- xeric flatwoods - dry flatwoods	Scrubby Flatwoods Are characterized as an open canopy forest of widely scattered pine trees with a sparse shrubby understory and numerous areas of barren white sand. The vegetation is a combination of Scrub and Mesic Flatwoods species; Scrubby Flatwoods often occupy broad transitions or ecotones between these communities. Typical plants include longleaf pine, slash pine, sand live oak, Chapman's oak, myrtle oak, scrub oak, saw palmetto, staggerbush, wiregrass,	Scrubby Flatwoods generally occur intermingled with Mesic Flatwoods along slightly elevated relictual sandbars and dunes. The elevated, deeper sandy soils of scrubby flatwoods engender a drier environment than the surrounding mesic flatwoods, the general sparsity of ground vegetation and the greater proportion of relatively incombustible scrub-oak leaf litter reduces the frequency of naturally occurring fires. Scrubby Flatwoods are	The white sandy soil is several feet deep and drains rapidly. However, the water table is unlikely to be very deep. Scrubby Flatwoods normally do not flood even under extremely wet conditions.	411/Pine Flatwoods 419/Other Pines

		dwarf blueberry, gopher apple, rusty lyonia, tarflower, golden-aster, lichens, silkbay, garberia, huckleberry, goldenrod, runner oak, pinweeds, and frostweed.	associated with and often grade into Mesic Flatwoods, Scrub, Dry Prairie or Sandhills.		
Natural Community Name	Synonyms	Description	Location	Soils	FLUCCS Code/Name
Upland Mixed Forest	- southern deciduous forest - southern mixed forest - mesic hammock -climax hardwoods -upland hardwoods - beech-magnolia climax - oak-magnolia climax - pine-oak-hickory association	Upland Hardwood Forests and Upland Mixed Forests are characterized as well-developed, closed canopy forests of upland hardwoods on rolling hills. These communities have quite similar physical environments and share many species, including southern magnolia, pignut hickory, sweetgum,	Location of this community is predominantly a result of minor climatic differences, Upland Hardwood Forests being most common in northern panhandle Florida, and Upland Mixed Forests being most common in northern and central peninsula Florida. Upland Hardwood	Soils are generally sandy-clays or clayey sands with substantial organic and often calcareous components. The topography and clayey soils increase surface water runoff, although this is counterbalanced by the moisture retention properties of clays and by the often thick layer of leaf mulch which	414/Pine - Mesic Oak 423/Oak - Pine – Hickory 425/Temperate Hardwood 434/Hardwood - Conifer Mixed 438/Mixed Hardwoods

	- southern mixed hardwoods - clay hills hammocks - Piedmont forest	Florida maple, devil's walking stick, redbud, flowering dogwood, Carolina holly, American holly, spruce pine, loblolly pine, live oak, and swamp chestnut oak. The primary difference between these communities is that Upland Mixed Forests generally lack shortleaf pine, American beech and other more northern species. The canopy is densely closed, except during winter in areas where deciduous trees predominate.	and Mixed Forests occur on rolling hills that often have limestone or phosphatic rock near the surface and occasionally as outcrops. associated with and grade into Upland Pine Forest, Slope Forest, or Xeric Hammock.	helps conserve soil moisture and create decidedly mesic conditions.	
Natural Community Name	Synonyms	Description	Location	Soils	FLUCCS Code/Name
Upland Hardwood Forest	- southern deciduous forest	Upland Hardwood Forests and Upland Mixed Forests are characterized	Location of this community is predominantly a	Soils are generally sandy-clays or clayey sands with substantial	431/Beech – Magnolia 434/Hardwood - Conifer Mixed

	- southern mixed forest - mesic hammock -climax hardwoods -upland hardwoods - beech-magnolia climax - oak-magnolia climax - pine-oak-hickory association - southern mixed hardwoods - clay hills hammocks - Piedmont forest	as well-developed, closed canopy forests of upland hardwoods on rolling hills. These communities have quite similar physical environments and share many species, including southern magnolia, pignut hickory, sweetgum, Florida maple, devil's walking stick, redbud, flowering dogwood, Carolina holly, American holly, spruce pine, loblolly pine, live oak, and swamp chestnut oak. The primary difference between these communities is that Upland Mixed Forests generally lack shortleaf pine,	result of minor climatic differences, Upland Hardwood Forests being most common in northern panhandle Florida, and Upland Mixed Forests being most common in northern and central Peninsula Florida. Upland Hardwood and Mixed Forests occur on rolling hills that often have limestone or phosphatic rock near the surface and occasionally as outcrops. associated with and grade into Upland Pine Forest, Slope Forest or Xeric Hammock.	organic and often calcareous components. The topography and clayey soils increase surface water runoff, although this is counterbalanced by the moisture retention properties of clays and by the often thick layer of leaf mulch which helps conserve soil moisture and create decidedly mesic conditions.	438/Mixed Hardwoods

		American beech and other more northern species. The canopy is densely closed, except during winter in areas where deciduous trees predominate.			
Natural Community Name	Synonyms	Description	Location	Soils	FLUCCS Code/Name
Wet Flatwoods	- hydric flatwoods - pine savannah - cabbage palm/ pine savannah - moist pine barrens - low flatwoods - pond pine flatwoods - pocosin,	Located in flatland with sand substrate; seasonally inundated; subtropical or temperate; frequent fire; Wet Flatwoods are characterized as relatively open-canopy forests of scattered pine trees or cabbage palms with either thick shrubby understory and very sparse ground cover, or a sparse understory and a dense ground cover of hydrophilic	Wet Flatwoods occur on relatively flat, poorly drained terrain. Exotic plants readily invade Wet Flatwoods in south Florida and must be controlled promptly. Flatwoods are closely associated with and often grade into Hydric Hammock, Mesic Flatwoods, Wet Prairie, or Basin Swamp.	The soils typically consist of 1 to 3 feet of acidic sands generally overlying an organic hardpan or clay layer. Cabbage palm flatwoods tend to occur on more circa-neutral sands (pH 6.0 - 7.5) underlain by marl or shell beds. The hardpan substantially reduces the percolation of water below and above its surface. During the rainy season, water frequently	411/Pine Flatwoods 419/Other Pines 428/Cabbage Palm 622/Pond Pine 624/Cypress - Pine - Cabbage Palm 630/Wetland Forested Mixed

		herbs and shrubs. Typical plants include pond pine, slash pine, sweetbay, spikerush, beakrush, sedges, dwarf wax myrtle, gallberry, saw palmetto, creeping beggar weed, deer tongue, gay feather, greenbrier, bluestem, and pitcher plants.		stands on the surface, inundating the Flatwoods for 1 or more months per year.	
Natural Community Name	Synonyms	Description	Location	Soils	FLUCCS Code/Name
Wet Prairie	- sand marsh - savanna, pitcher plant prairie -coastal savannah - coastal prairie	Wet Prairies occur on flatland with sand substrate; seasonally inundated; subtropical or temperate; annual or frequent fire; Wet Prairie is characterized as a treeless plain with a sparse to dense ground cover of grasses and herbs, including	Wet Prairie occurs on low, relatively flat, poorly drained terrain of the coastal plain. Wet Prairie is closely associated with and often grades into Wet Flatwoods, Depression Marsh, Seepage Slope, Mesic Flatwoods,	Soils typically consist of sands often with a substantial clay or organic component.	310/Herbaceous 641/Wet Prairies

		wiregrass, toothache grass, maiden cane, spikerush, and beakrush. Wet Prairie is seasonally inundated or saturated for 50 to 100 days each year and burns every 2 to 4 years. Wax myrtle quickly invades and will dominate Wet Prairies with longer fire intervals. In south Florida, melaleuca invasions can seriously impact Wet Prairies.	or Dry Prairie.		
Natural Community Name	Synonyms	Description	Location	Soils	FLUCCS Code/Name
Xeric Scrub .	- pine-oak-hickory woods - sand pine scrub - Florida scrub	Old dune area with deep fine sand substrate; xeric, temperate or subtropical vegetation;	Scrub occurs on sand ridges along former shorelines. Some of the sand ridges originated	upland with deep sand substrate; Some Scrub soils are composed of well-washed, deep sands that are	421/Xeric Oak 423/Oak - Pine – Hickory 425/Temperate Hardwood 427/Live Oak

	- sand scrub - rosemary scrub - oak scrub -Sand pine	rare fire (20-80 yrs); sand pine/scrub oaks/rosemary/ lichens, temperate or subtropical; Scrub occurs in many forms, but is often characterized as a closed to open canopy forest of sand pines with dense clumps or vast thickets of scrub oaks and other shrubs dominating the understory. The ground cover is generally very sparse, being dominated by ground lichens or, rarely, herbs. Open patches of barren sand are common. Ground vegetation is extremely sparse and leaf fall is minimal, thus reducing the chance of frequent ground fires.	as wind-deposited dunes, others as wave-washed sand bars. The rapidly draining soils create very xeric conditions for which the plants appear to have evolved several water conservation strategies. Scrub is associated with and often grades into Sandhill, Scrubby Flatwoods, Coastal Strand, and Xeric Hammock. Some Xeric Hammocks are advanced successional stages of Scrub, making intermediate stages difficult to classify.	brilliant white at the surface; some Scrubs occur on yellow sands. The loose sands drain rapidly.	432/Sand Live Oak

Appendix B Cost Considerations and Data

Due to the temporal and spatial variation in prices for the same construction practice and product, cost is a user input. User input is also necessary to limit updates to the model with cost information. Reliable sources of cost data can be found from local or site specific construction indexes and cost data, as well as in journal articles and government websites. Published cost data are presented in this section that can be used should the user not have access to site specific or other appropriate data. It should be noted that the cost data presented in this section can be used in the model, but it is recommended that local or user supplied (more recent, site specific, etc.) cost data be used.

When using published cost data, it is important to keep in mind inflation if the data are several years old. It is recommended that the *consumer price index* (CPI) be used to adjust the price of an item to current or past dollars based on inflation. There are consumer price indexes for different segments of the economy. The *urban consumer price index (CPI–U)* is used to estimate the national inflation rate. The CPI–U is based on a typical market basket of goods and services utilized by a typical urban consumer (Park, 2002; U.S. Department of Labor Statistics, 2016). CPI-U annual average values for 2000-2016 are shown in Table B-1 and then compared to September data in 2017 and 2018. The CPI is used to calculate an average annual general inflation rate that is used to adjust the price to the desired year; the inflation calculator provided by the US Department of Labor Statistics can do the calculations with input data, see Figure B-2 (Park, 2002; US Department of Labor Statistics, 2016).

Table B-1 United States CPI-U (U.S. Department of Labor Statistics, 2016) with updates to September values in 2017 and 2018

Year	CPI-U (Average Annual)
2000	172.20
2001	177.10
2002	179.90
2003	184.00
2004	188.90
2005	195.30
2006	201.60
2007	207.30
2008	215.30
2009	214.54
2010	218.06
2011	224.94
2012	229.59
2013	232.96
2014	236.74
2015	237.02
2017*	246.82
2018*	252.44

* September values

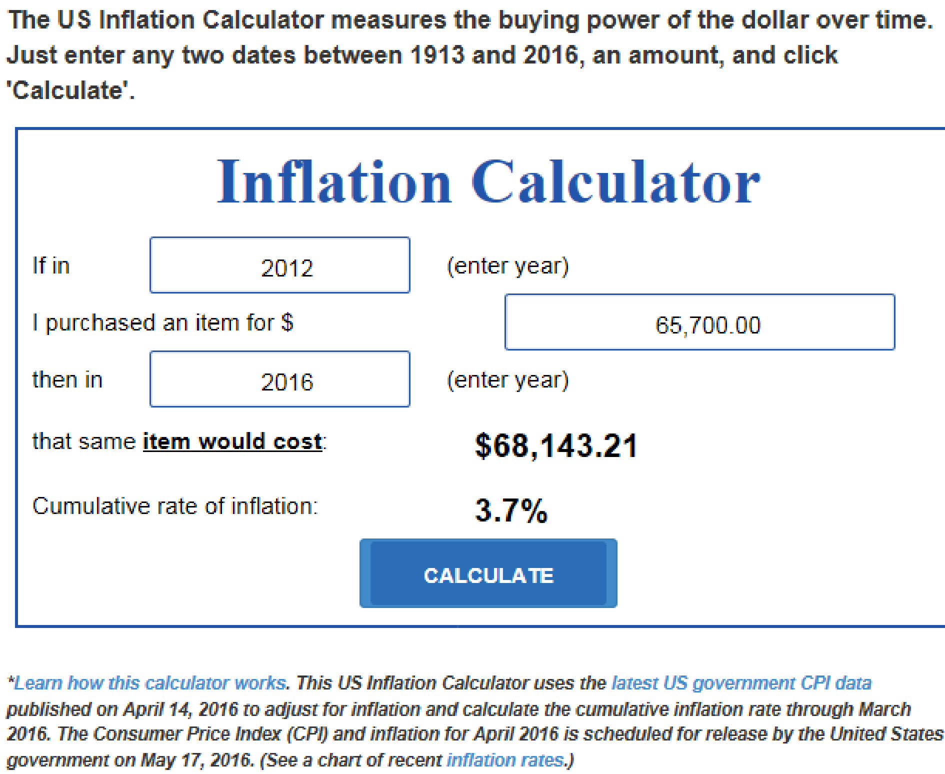


Figure B-2 US Department of Labor Statistics Inflation Calculator http://www.usinflationcalculator.com/ (US Department of Labor Statistics, 2016)

When determining the present value/worth of a proposed project, data can be adjusted to present worth, or any other year, by using an interest rate. The ability to bring all costs to a present worth is critical when comparing opportunity costs of different design options with varying annual operation and maintenance costs and lifespans. It is recommended to use the World Bank for information on interest rates. The World Bank provides yearly *real interest rates*, as well as other forms of interest rate, for various countries, including the United States (The World Bank), see Table B-2. Real interest rate, also known as inflation-free interest rate, is an estimate of the true earning power of money once the inflation effects have been removed. Real interest rate is used in *constant dollar analysis*. Constant dollar analysis is used when all cash flow elements needed are provided in constant dollars and you want to compute the equivalent present worth of the constant dollars. Constant dollar analysis is commonly used in the evaluation of long-term public projects since governments do not pay income taxes (Park, 2002). When obtaining costs from journal articles and reports it can be assumed, unless otherwise stated, that the costs presented are in terms of dollars in the year the article was written/submitted. If the year the article is written or submitted is not available, then assume that the cost data are in terms of the year prior to publication.

Table B-2 Real Interest Rates for the United States (The World Bank)

Year	2011	2012	2013	2014
Real Interest Rate (%)	1.2	1.4	1.7	1.8

The US EPA published the Preliminary Data Summary of Urban Storm Water Best Management Practices report in 1999 (Strassler, Pritts, & Strellec, 1999). This report contains performance and cost data, both capital, Table B-3, and operational for various BMPs, Table B-4. The cost data in Table B-3 do not include geotechnical testing, legal fees, land costs, and other unexpected costs. Cost ranges are provided for retention and detention basins to accommodate economies of scale in design and construction (Strassler, Pritts, & Strellec, 1999).

Table B-3 Typical Base Capital Construction Costs for BMPs (Strassler, Pritts, & Strellec, 1999)

BMP Type	Typical Cost* ($/cf)	Notes	Source
Retention and Detention Basins	0.50-1.00	Cost range reflects economies of scale in designing this BMP. The lowest unit cost represents approx. 150,000 cubic feet of storage, while the highest is approx. 15,000 cubic feet. Typically, dry detention basins are the least expensive design options among retention and detention practices.	Adapted from Brown and Schueler (1997b)
Constructed Wetland	0.60-1.25	Although little data are available to assess the cost of wetlands, it is assumed that they are approx. 25% more expensive (because of plant selection and sediment forebay requirements) than retention basins..	Adapted from Brown and Schueler (1997b)
Infiltration Trench	4.00	Represents typical costs for a 100-foot long trench.	Adapted from SWRPC (1991)
Infiltration Basin	1.30	Represents typical costs for a 0.25-acre infiltration basin.	Adapted from SWRPC (1991)
Sand Filter	3.00-6.00	The range in costs for sand filter construction is largely due to the different sand filter designs. Of the three most common options available, perimeter sand filters are moderate cost whereas surface sand filters and underground sand filters are the most expensive.	Adapted from Brown and Schueler (1997b)
Bioretention	5.30	Bioretention is relatively constant in cost, because it is usually designed as a constant fraction of the total drainage area.	Adapted from Brown and Schueler (1997b)
Grass Swale	0.50	Based on cost per square foot, and assuming 6 inches of storage in the filter.	Adapted from SWRPC (1991)
Filter Strip	0.00-1.30	Based on cost per square foot, and assuming 6 inches of storage in the filter strip. The lowest cost assumes that the buffer uses existing vegetation, and the highest cost assumes that sod was used to establish the filter strip.	Adapted from SWRPC (1991)

* Base year for all cost data: 1997

Table B-4 Annual Maintenance Costs of BMPs (Strassler, Pritts, & Strellec, 1999)

BMP	Annual Maintenance Cost (% of Construction Cost)	Source(s)
Retention Basins and Constructed Wetlands	3%-6%	Wiegand et al, 1986 Schueler, 1987 SWRPC, 1991
Detention Basins[1]	<1%	Livingston et al, 1997; Brown and Schueler, 1997b
Constructed Wetlands[1]	2%	Livingston et al, 1997; Brown and Schueler, 1997b
Infiltration Trench	5%-20%	Schueler, 1987 SWRPC, 1991
Infiltration Basin[1]	1%-3%	Livingston et al, 1997; SWRPC, 1991
	5%-10%	Wiegand et al, 1986; Schueler, 1987; SWRPC, 1991
Sand Filters[1]	11%-13%	Livingston et al, 1997; Brown and Schueler, 1997b
Swales	5%-7%	SWRPC, 1991
Bioretention	5%-7%	(Assumes the same as swales)
Filter strips	$320/acre (maintained)	SWRPC, 1991

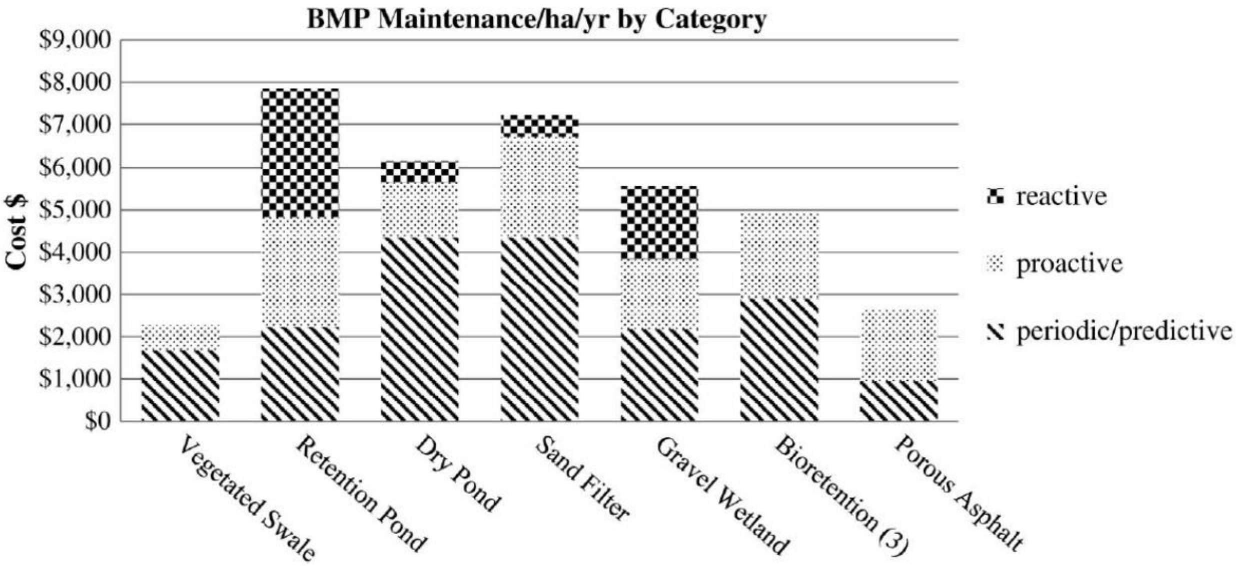
1. Livingston et al (1997) reported maintenance costs from the maintenance budgets of several cities, and percentages were derived from costs in other studies

The Transportation Research Board published a document titled the NCHRP REPORT 792; this report is an excellent source of data for capital cost, operating cost, life span (see Table B-5), and performance data on a cost basis for various BMPs (Taylor, et al., 2014). It is important to note that several of the tables in this report provide *Whole Life Cycle Costs*. Care must be taken when using *Whole Life Cycle Costs* with the BMP Trains model. Whole life cycle costs are calculated by bringing the operating costs and capital costs all to a single Present Value; this is exactly what the BMP Trains model Net Present Worth Analysis feature does. *Whole Life Cycle Costs* style data could be evaluated using the Capital Cost feature in the BMP Trains model. Care must be exercised when doing this as the assumptions must consistent between the BMP Trains Model and the source of the cost data.

Table B-5 BMP expected life span (Taylor, et al., 2014)

BMP Type	Life Span	Limiting Factor
Vegetated strips	8–60 years (depending on ecoregion)	Sediment accumulation
Vegetated swales	10–50 years (depending on ecoregion)	Sediment accumulation
Dry detention basin	80 years	Pipe material longevity
Bioretention	80 years	Pipe material longevity
Retention pond	80 years	Pipe material longevity
Sand filter	75 years	Concrete longevity
Permeable friction course	14 years	Sediment accumulation

Cost data can also be found in journals such as the ASCE Journal of Environmental Engineering. The article by Houle (Houle, Roseen, Ballestero, Puls, & Sherrard Jr., 2013), which discusses capital and maintenance costs on an area and gram of pollutant removed basis for swales, ponds, bioretention, pervious pavements, and others. A few examples of capital and maintenance costs figures and tables from the article are shown below in Figure B-3, Table B-6, & Table B-7.



- Reactive–complaint or emergency driven.
- Periodic and predictive–driven by inspections and standards embodied in an O&M plan; can be calendar-driven, known, or schedulable activities.
- Proactive–adaptive and applied increasingly more as familiarity with the system develops.

Figure B-3 Annualized maintenance costs per system per hectare of impervious cover treated per maintenance activity classification (Houle, Roseen, Ballestero, Puls, & Sherrard Jr., 2013) [Based on publication date, assume that all operating costs are on a 2012 basis unless otherwise stated.] Note in Florida a detention pond is the same as the category Retention Pond listed in Figure B-2.

Table B-6 Capital and Maintenance Cost Data, with Normalization per Hectare of Impervious Cover Treated (Houle, Roseen, Ballestero, Puls, & Sherrard Jr., 2013)

Parameter	Vegetated swale	Wet pond	Dry pond	Sand filter	Gravel wetland	Bioretention	Porous asphalt
Original capital cost ($)	29,700	33,400	33,400	30,900	55,600	53,300	53,900
Inflated 2012 capital cost ($)	36,200	40,700	40,700	37,700	67,800	63,200	65,700
Maintenance-capital cost comparison (year)[a]	15.9	5.2	6.6	5.2	12.2	12.8	24.6
Personnel (h/year)	23.5	69.2	59.3	70.4	53.6	51.1	14.8
Personnel ($/year)	2,030	7,560	5,880	6,940	5,280	4,670	939
Materials ($/year)	247	272	272	272	272	272	0
Subcontractor Cost ($/year)	0	0	0	0	0	0	1,730
Annual O&M Cost ($/year)	2,280	7,830	6,150	7,210	5,550	4,940	2,670
Annual maintenance/capital cost (%)	6	19	15	19	8	8	4

Note: Calculations based on original data with BGS units of $/acre and h/acre.
[a]Number of years at which amortized maintenance costs equal capital construction costs.

The article from which this cost information came from was published in 2013 & written in 2012. Assume all operating costs are on a 2012 basis unless otherwise stated. The capital cost in 2012 is stated in the table. Note that 1 hectare = 2.471 acres.

Table B-7 Summary of Removal Performance and Comparison per kg Removed of TSS and per g Removed of TP and TN as *Dissolved Inorganic Nitrogen (DIN)* (Houle, Roseen, Ballestero, Puls, & Sherrard Jr., 2013)

Parameter	Vegetated swale	Wet pond	Dry pond	Sand filter	Gravel wetland	Bioretention	Porous asphalt
Total suspended solids performance–annual load of 689 kg							
Removal efficiency (%)[a]	58	68	79	51	96	92	99
Annual mass removed (kg)	399	468	544	351	662	632	682
Capital cost performance ($/kg)	91	87	75	107	102	100	96
Operational cost ($/kg/year)	6	17	11	21	8	8	4
Total phosphorus performance–annual load of 2,950 g[b]							
Removal efficiency (%)[a]	0	0	0	33	58	27	60
Annual mass removed (g)	0	0	0	974	1,700	799	1,770
Capital cost performance ($/g)	NT	NT	NT	39	40	79	37
Operational cost ($/g/year)	NT	NT	NT	7	3	6	2
Dissolved inorganic nitrogen as total nitrogen performance–annual load of 26,600 g[b]							
Removal efficiency (%)[a]	0	33	25	0	75	29	0
Annual mass removed (g)	0	8,770	6,640	0	19,900	7,740	0
Capital cost performance ($/g)	NT	5	6	NT	3	8	NT
Operational cost ($/g/year)	NT	0.89	0.93	NT	0.28	0.64	NT

Note: NT = No treatment; values are incalculable as lack of SCMpollutant treatment results in infinite costs.
[a]Values from UNHSC et al. 2012.
[b]Denotes change in unit mass from kg to g.

The article from which this cost information came from was published in 2013 & written in 2012. Assume all capital and operating costs are on a 2012 basis unless otherwise stated.

The 2012 article by Taylor and Wong discusses the life cycle costs of several types of BMPs including swales, bioretention systems, ponds, filters, and street sweeping (Taylor & Wong, 2002). Table B-8 below compares the life cycle costs of two different types of street sweepers.

Table B-8 US Street Sweeping Cost Information (Taylor & Wong, 2002)

FEATURES	SWEEPER TYPE	
	MECHANICAL	VACUUM ASSISTED
Life (years)	5	8
Purchase price (US$)	75,000	150,000
Operation and maintenance costs ($US/kerb km)	30	15
Annualised sweeper costs ($US/kerb km/year)		
Weekly (sweeping frequency)	1,680	946
Bi-weekly	840	473
Monthly	388	218
Four times per year	129	73
Twice per year	65	36
Annual	32	18

The journal article by Weiss provides the capital costs for various BMPs on a basis of volume of water treated and operating cost based on a percent of capital cost for specific BMPs (Weiss, Gulliver, & Erickson, 2007).

Another example of a BMP cost data source is the Summary of Cost Data (2007) spreadsheet published by the International Stormwater Database (Wrigth Waters Engineers, Inc. and GeoSyntec Consultants, 2007). This Excel workbook published by the International Stormwater Database, prepared by Wright Waters Engineers, Inc. and Geosyntec Consultants, contains cost estimates and the year of the estimate for ponds, green roofs, grass swales, pervious pavement, infiltration basins & trenches, media filters, and other BMPs. The cost data is normalized to BMP size.

Additional cost data may be found in journal articles and government reports such as the reports by Curtis, 2002 (Curtis, 2002) and Geosyntec Consultants, 2015 (Geosyntec Consultants, 2015).

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Appendix C BMP Terminology and Descriptions

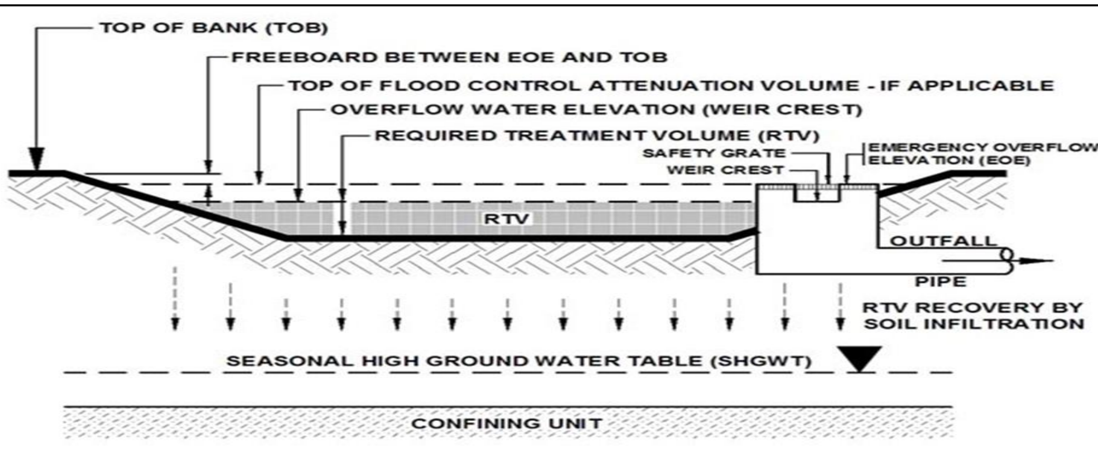
Descriptions of the stormwater BMPs that are within the BMP Trains Model are in this Appendix. This is to ensure that all users have a common understanding of BMP terminology and design used in Florida. At the end of this appendix there is information on average annual effectiveness calculations for BMPs in series and for corrections made to wet detention following retention.

1. **Retention Basin**

A "retention basin" is a recessed area within the landscape that is designed to store and retain a defined quantity of runoff, allowing it to percolate through permeable soils into the groundwater aquifer. They are constructed or natural depression areas, often integrated into a site's landscaping, where the bottom is typically flat, and turf, natural ground covers or other appropriate vegetative or other methods are used to promote infiltration and stabilize the basin bottom and slopes.

Retention basins provide numerous benefits, including reducing stormwater runoff volume, which reduces the average annual pollutant loading that may be discharged from the land. Additionally, many stormwater pollutants such as suspended solids, oxygen demanding materials, heavy metals, bacteria, some varieties of pesticides, and nutrients are removed as runoff percolates through the soil profile. The capture percentage on an annual basis is dependent on the rainfall zone and the size of the basin.

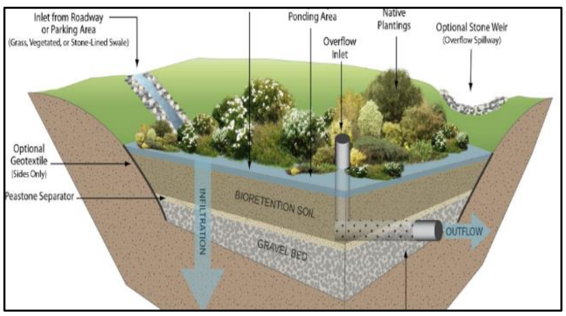
The annual treatment effectiveness of all retention BMPs is directly related to the percentage of the average annual stormwater volume that is captured and not surface discharged. Effectiveness was estimated for the volume of storage and simulations of runoff over at least 25 years. The capture depth (inches) is calculated as the volume of the basin divided by the watershed area with conversion factors (see Harper, et.al., 2007, 2016, and Wanielista and Yousef, 1993).



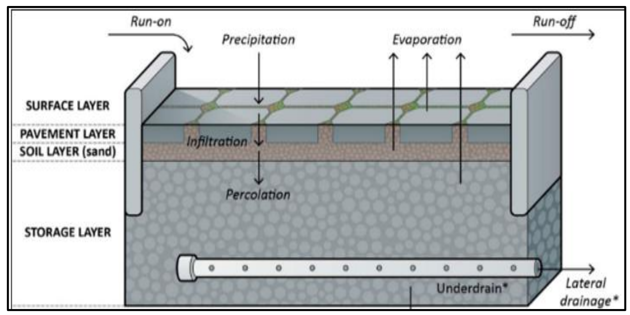
TYPICAL CROSS SECTION OF A "DRY" RETENTION SYSTEM
NOT TO SCALE

2. Rain Gardens

Rain gardens are retention or detention areas that can be integrated into a site's landscaping. They are usually in a shallow constructed depression that is planted with vegetation, typically deep-rooted Florida-Friendly or native plants. Frequently they have walk ways or parking areas. They are located in the landscape or within parking lot islands to receive runoff from hard surfaces such as a roof, a sidewalk, a driveway, or parking area. For design, the water holding of the soil or media holds water at a sustainable porosity and there is a water storage above the soil/media. Plant selection must be done so that the water storage above the rain garden ground level does not destroy the plants. When a cover crop is used, credit for removal of TN and TP is possible and must be documented. When sorption media is used a separate credit is assigned.



Retention option with vegetative cover crop

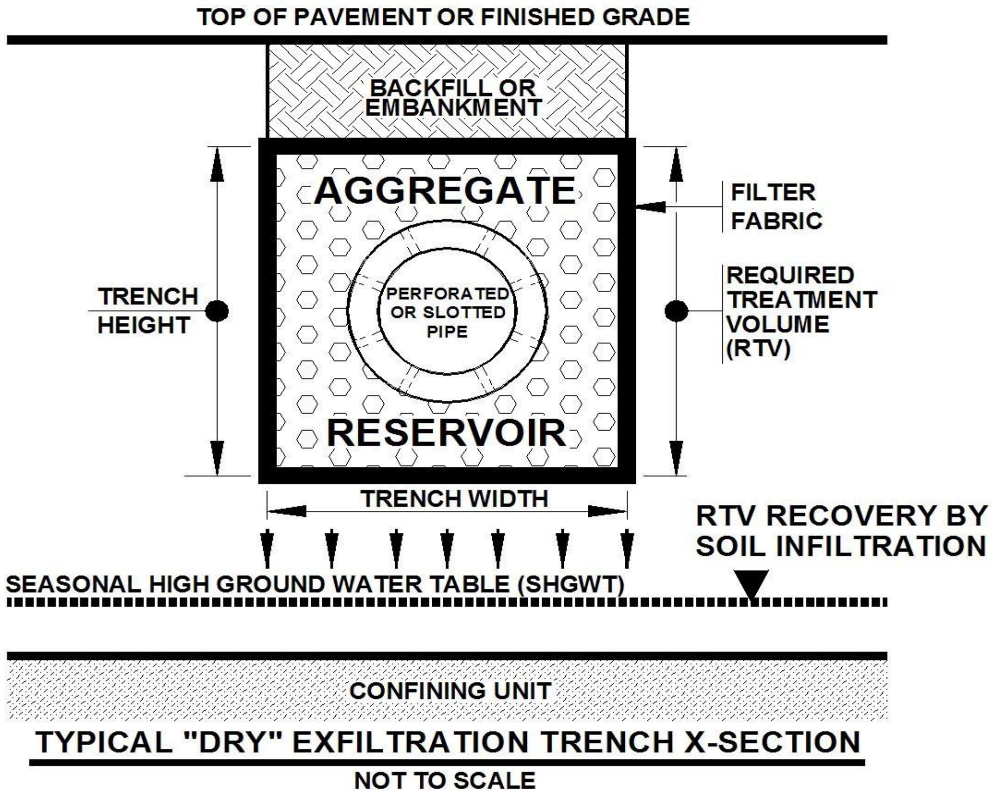


Detention option with paver cover crop

In some situations, where the SHGWT is high, a rain garden is classified as a detention system and an underdrain is used. Both of these Green Infrastructure (GI) BMPs are commonly used adjacent to buildings (planter boxes) and in parking lots (bioretention areas).

3. Exfiltration Trench

An exfiltration trench is a subsurface retention system consisting of a conduit which is perforated surrounded by natural or artificial aggregate that temporarily stores and infiltrates stormwater runoff. Stormwater passes through the perforated conduit and infiltrates through the trench sides and bottom into the groundwater aquifer. The perforated pipe increases the storage available in the trench and promotes infiltration by making delivery of the runoff more effective and evenly distributed over the length of the system. The "ex" is meant to distinguish between natural and constructed infiltration. A typical design section follows with "RTV" as the recovery treatment volume in 72 hours. When pollution control media are used, it must be traffic bearing. It is used in place of the aggregate around the pipe.



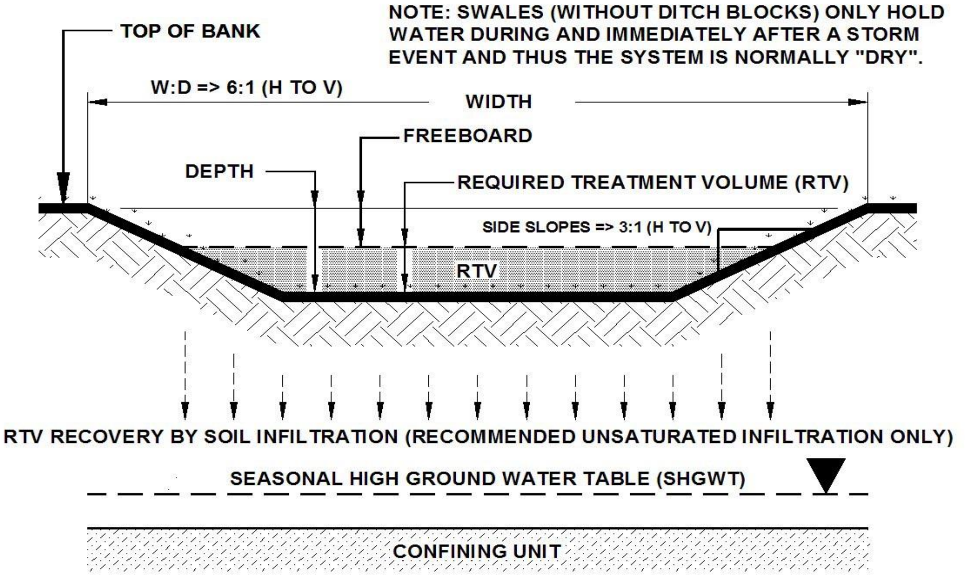
4. Swale

Swales have been used for roadside stormwater conveyance and infiltration for over 40 years and an annual removal can be quantified as retention BMPs for reducing stormwater annual pollutant mass load. As a retention system, the seasonal high water table must be at least 2 feet below the bottom of the swale to earn annual removal credit. Furthermore, concentration reduction is accounted for by the residence time in the swale (Wanielista and Yousef, 1993, pages 244-251). In general, a concentration reduction is noted when the longitudinal slope is less than 1% (1 foot drop in 100 feet). Additional design details that define a swale are found in Chapter 403.803(14), Florida Statutes, as follows:
"Swale" is defined as a manmade trench which:

- Has a top width to depth ratio of the cross-section equal to or greater than 6:1, or side slopes equal to or flatter than 3 feet horizontal to 1-foot vertical;
- Contains contiguous areas of standing or flowing water only following a rainfall event;
- Is planted with or has stabilized vegetation suitable for soil stabilization, stormwater treatment, and nutrient uptake; and
- Is designed to take consider the soil erosion, soil percolation, slope, slope length, and drainage area so as to prevent erosion and reduce pollutant concentration of any discharge."

Typically, swales are online retention systems and their treatment effectiveness is directly related to the amount of the annual stormwater volume that is infiltrated. Swales designed for stormwater treatment can be classified into three categories:

- Swales with swale blocks or raised driveway culverts
- Swales without swale blocks or raised driveway culverts)
- Swales incorporated into landscaping (an elongated rain garden)



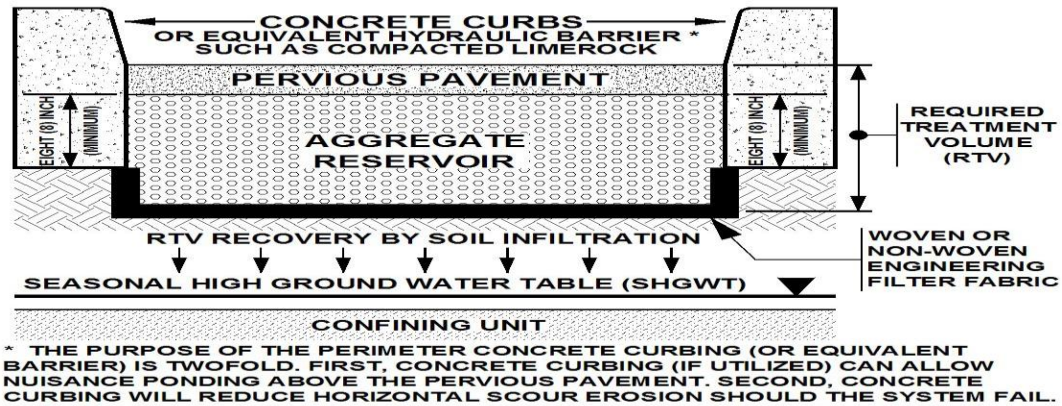
TYPICAL X-SECTION OF A VEGETATED CONVEYANCE SWALE WITHOUT SWALE BLOCKS

NOT TO SCALE

5. Pervious Pavement Systems

Pervious pavement systems include the subsoil, the reservoir, and the pervious pavement. They can include several types of materials or designed systems such as pervious concrete, pervious aggregate/binder products, pervious paver systems, and modular paver systems. At this time, pervious asphalt and pervious pavements using crushed and recycled glass are not used for credit until future improvements are made and verified with testing to address their structural capability, hydraulic performance and manufacturing process. Recent studies on the design, longevity, and infiltration characteristics of pervious pavement systems are available on the University of Central Florida's website http://stormwater.ucf.edu/. Included in these studies are data on the sustainable void spaces. If pervious pavement is used as detention, then the capture volume is calculated. Pollution control media that is traffic bearing can be used in the reservoir.

However, pervious pavement systems are usually retention systems. They are usually part of a treatment train to reduce stormwater volume and pollutant load from parking lots, or similar types of areas. As with all infiltration BMPs, the treatment efficiency is based on the amount of the annual runoff volume infiltrated which depends on the available storage volume within the pavement system, the underlying soil permeability, and the ability of the system to readily recover this volume. The Volume of storage reduces over time due to the build-up of solids and thus a sustainable void space is used and included within the **BMP Trains 2020** model. Alternative effectiveness calculations for a required treatment volume recovered in 72 hours (slow infiltration) can be used with the **Retention Basin** treatment option,



TYPICAL PERVIOUS PAVEMENT CROSS SECTION
NOT TO SCALE

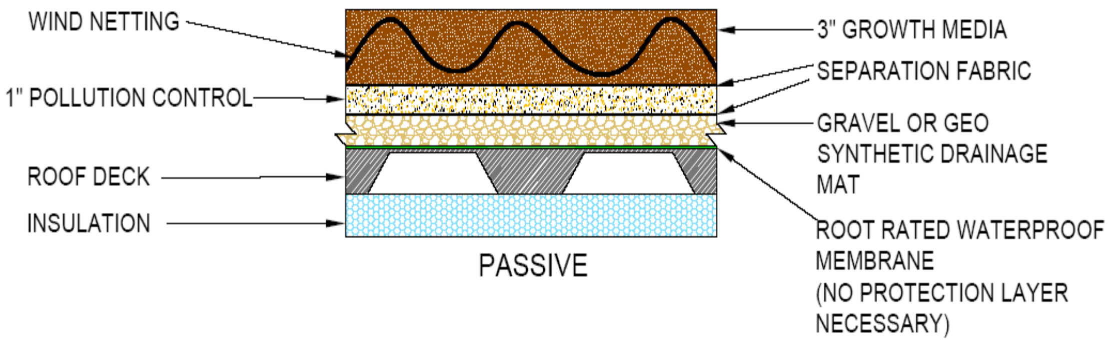
6. Green Roof and Cistern

A greenroof with cistern stormwater treatment system is a vegetated roof followed by storage in a cistern (or other similar device) for the filtrate that is harvested for irrigation. A greenroof and cistern system is a retention and harvested BMP. Effectiveness is the annual volume of roof runoff that is captured, retained, and used on site. The term harvesting is preferred to not confuse the process with wastewater harvesting.

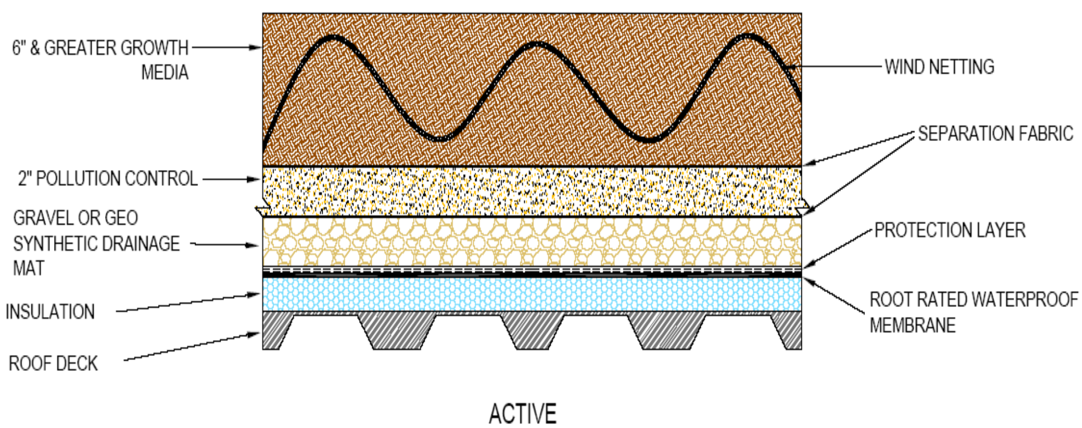
The filtrate from the greenroof is collected in a cistern or, if the greenroof is part of a BMP Treatment Train, the filtrate may be discharged to a downstream BMP such as a wet detention pond. A cistern is sized for a specific amount of filtrate and receives no other stormwater. Other pond storage must also provide capacity to detain a specified quantity of filtrate. The retained water is used to irrigate the roof since experience in Florida has shown that irrigation must be provided to maintain the plants. A back up source of water for irrigation is necessary during the dry season. Excess filtrate and excess runoff can be discharged to other stormwater treatment systems, infiltrated into the ground, or used for irrigation or other non-potable purposes. The greenroof and cistern system functions to attenuate, evaporate, and thus lower the volume of discharge and pollutant load coming from the roof surface. Greenroof systems have been shown to assist in stormwater management by attenuating hydrographs, neutralizing acid rain, reducing volume of discharge, and reducing the annual mass of pollutants discharged. They are most applicable to commercial or public buildings but have been successfully used on residences.

Green roofs are classified in two ways - both by who will have access to the finished roof (either passive or active) and by the depth of soil provided in the plant root zone (either extensive or intensive). Extensive green roofs tend to have passive use, while intensive green roofs support larger plants and tend to have active use. Passive green roofs usually only allow access by maintenance personnel. Active green roofs usually allow access to the public or building occupants in addition to maintenance personnel. In addition, extensive green roofs have a root zone less than 6 inches deep while intensive green roofs have a root zone equal to or greater than 6 inches deep.

Extensive Green Roof Section



Intensive Green Roof Section

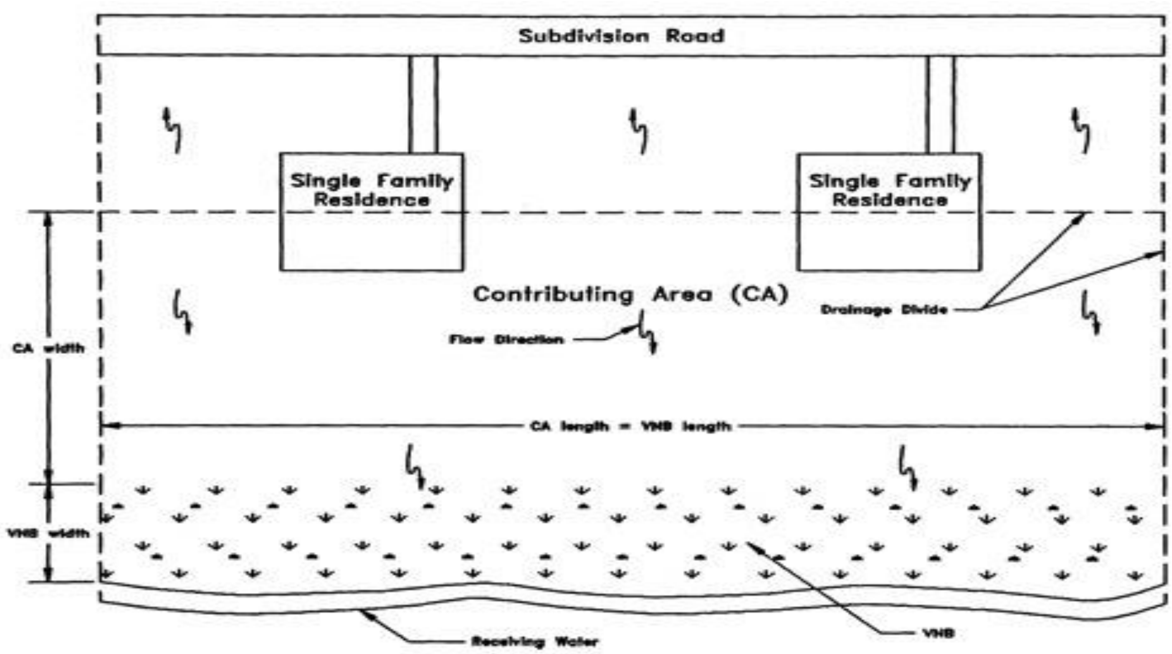


As an option to the use of wind netting, a parapet usually 30 inches or more in height is used to minimize wind damage during high wind conditions.

7. Vegetated Natural Buffer

Vegetated natural buffers (VNBs) are defined as areas with vegetation suitable for sediment removal along with nutrient uptake and soil stabilization that are set aside between developed areas and a receiving water or wetland for stormwater treatment purposes. They also can be used as the pre-filter for other BMPs. Under certain conditions, VNBs are an effective best management practice for the control of stormwater pollutants in overland flow by providing opportunities for filtration, deposition, infiltration, absorption, adsorption, decomposition, and volatilization.

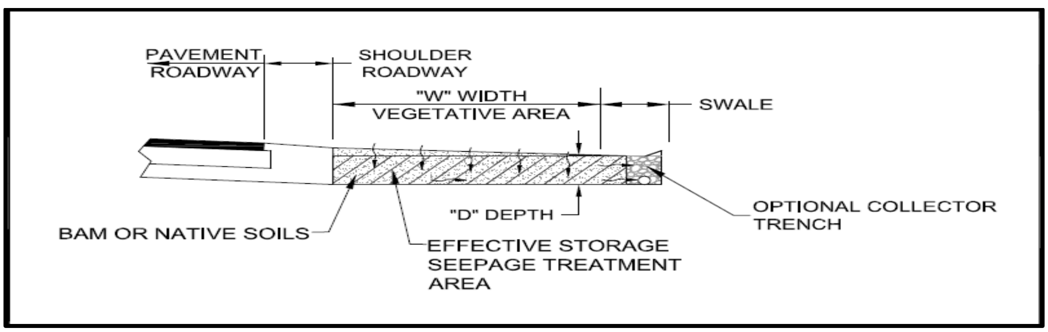
VNBs are most commonly used as an alternative to or in combination with swale/berm systems installed between backyards and the receiving water. Potential impacts to adjacent wetlands and upland natural areas are reduced because fill is not required to establish grades that direct stormwater flow from the back of the lot towards the front for collection in the primary stormwater management system. Additional impacts are potentially reduced since VNB strips can serve as wildlife corridors, reduce noise, and reduce the potential for siltation into receiving waters.



Vegetative natural buffers are not intended to be the primary stormwater management system for residential developments. They are most commonly used only to treat those rear-lot portions of the development that cannot be feasibly routed to the system serving the roads and fronts of lots. The use of a VNB in combination with a primary stormwater management system for other types of development shall only be allowed if the applicant demonstrates that there are no practical alternatives for those portions of the project.

8. Vegetated Filter Strips

Runoff water is directed over a vegetated filter strip that has select bio-sorption activated media (BAM) beneath it. Runoff water entering the VFS appears as discharge to a surface water nearby, usually a ditch or swale along a highway. The seasonal high-water table is no more than 3 feet below the ground at the point of surface discharge. Typically, 12 inches of media is used and the removal effectiveness is based on this depth (EPA, 2005). The minimum width in the direction of flow to obtain capture and pollution control is 10 feet. Usually for the first 10 feet, the water table intercepts the flow, or an impermeable membrane is used to redirect the flow horizontally. The capture effectiveness is a function of the vegetated filter strip width, the width of the impervious area catchment, the type of BAM, the slope of the VFS, and the rainfall zone in which the filter strip is located. The removal effectiveness is defined for a width and slope not to exceed 30 feet and 20% respectively. For a slope less than 2%, set the slope at 2% for the analysis. There are various BAM media that must be used to get credit for removal (Chang, 2019). A vegetated cover must be used as well as a minimum of 3 inches of top-soil. The top-soil must infiltrate at greater than the infiltration rate of the BAM. Typical values are 5-20 inches/hour. The storage volume of the BAM is dependent on the type of BAM used. If native soils are used, they must be homogeneously mixed and certified. Details on removal in Florida have been documented (see Shokri, 2021). A schematic of the strip is shown as:



9. Rainwater Harvesting System

The term "rainwater harvesting" as used here refers to water collected from roofs that is stored and used onsite. Rain is a source of relatively clean, soft water. As rain falls on non-roof surfaces such as concrete, pavement, and grass it contacts more contaminants than it would from a roof. Harvesting rainwater from roof runoff is a way to disconnect impervious surfaces and capture water before it has contacted many potential contaminants. Runoff as a fraction of rainfall was calculated for ten different roof surfaces and slopes allowing an estimate of runoff for future use (Wanielista, et.al., 2011). They calculated the abstraction of rain by various materials and slopes and these are built into **BMP Trains 2020**. The purpose of capturing and reusing stormwater is to replace the use of potable water. Usually harvested rainwater is used for outdoor irrigation. Harvested rainwater is also used for car washing, toilet flushing, clothes washing, cooling tower make-up, irrigation of indoor planters, hose bibs, and in rare cases as a potable water after treatment. Most of the indoor uses require approval of the local County Health Department and Planning Department.

There are four rainwater harvesting systems typically used within the State of Florida, namely, (1) Small residential systems that store rainwater in rain barrels for supplemental irrigation, (2) Large residential or commercial systems that store rainwater in a cistern for irrigation, vehicle washing, dust control, or other outdoor non-potable uses, (3) Large residential or commercial systems that store rainwater in a cistern as a source of indoor graywater uses such as toilet flushing, urinal flushing, Heating Ventilating and Air Conditioning (HVAC) make-up water, laundry wash water, and outdoor non-potable uses, and (4) Systems (including water purification) that store rainwater as a source of potable water. The annual capture effectiveness calculations within **BMP Trains** assumes the stored water is used every day. The stormwater harvesting BMP assumes the water is removed from the cistern twice per week.

10. Stormwater Harvesting System

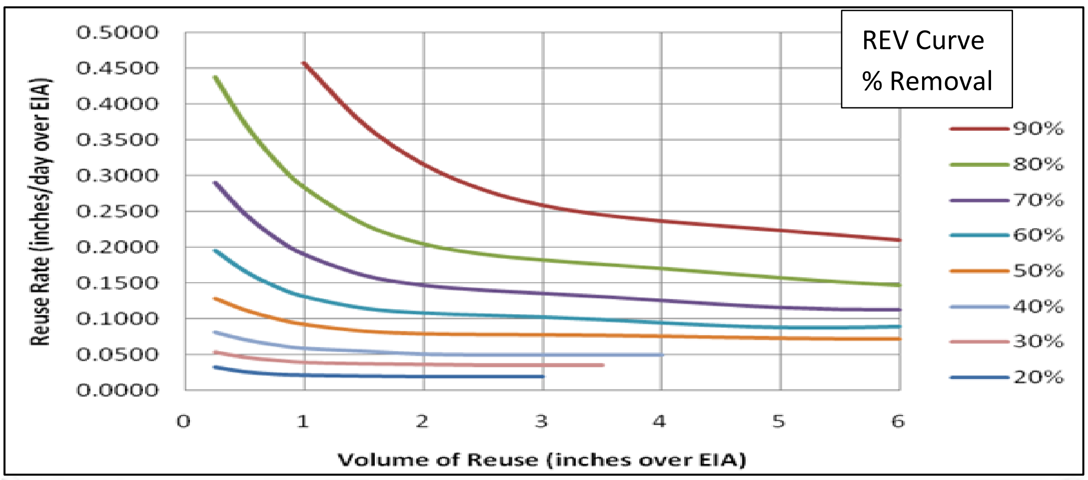
Stormwater harvesting systems use treated stormwater for beneficial purposes (usually to replace potable water) thus reducing the stormwater volume and mass of pollutants discharged from the storage areas, such as a wet detention pond. It is most often used in series with wet detention in the same catchment. The harvested stormwater can be used for numerous applications including irrigating lawns and landscape beds, irrigating green roofs, washing vehicles, industrial cooling and processing, and toilet flushing. To properly design a stormwater harvesting system that will result in a predictable average annual mass removal, water budgets are required. The development of a water budget for stormwater harvesting is done to quantify the capture of runoff or reduction in offsite discharge for a given period of time. Individual components of storage volume, rate of use, and discharge can be accounted for in the water budget. Calculation of these components requires knowledge of many variables, such as watershed soil and impervious characteristics, water use volumes and rates, desired percentage of stormwater runoff to be used, maximum volume of stormwater runoff storage, rainfall data, and evaporation data.

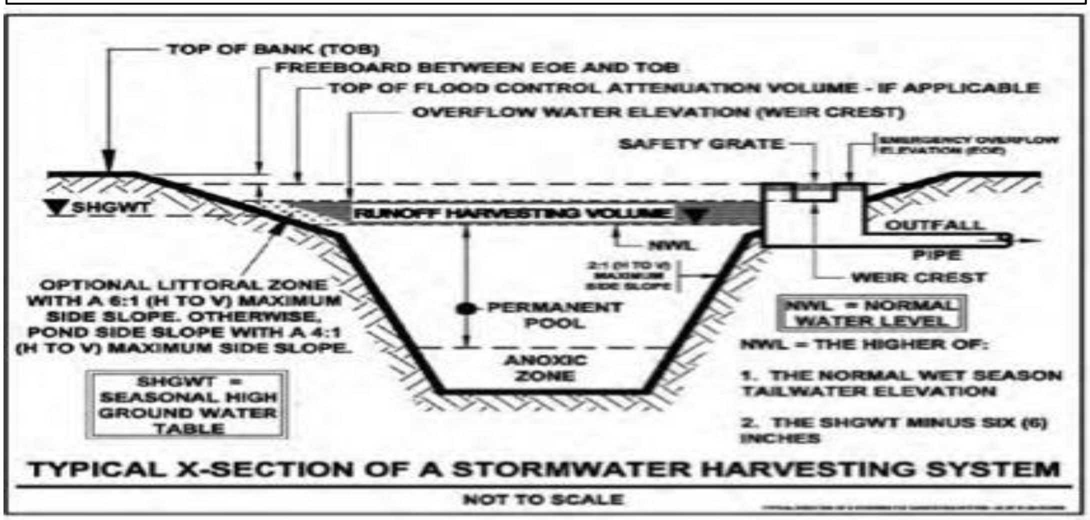
Simulations of runoff and use from stormwater harvesting ponds over long time periods were done to determine effectiveness curves known as Rate-Efficiency-Volume (REV) curves, shown below. The REV curves are used for stormwater-harvesting facilities to assess nutrient removal effectiveness. Important assumptions that must be understood when using the REV curves include:

- Net groundwater movement into or out of storage (pond) is assumed zero in a year.
- The use rate is the average in a year and presented on the REV curves as an average rate per day and over the equivalent impervious area (EIA).
- Beneficial use of water from the pond is twice per week with no water use the day after rainfall (based on water demands) and is equal to or greater than the daily water amount. A

sensitivity analysis for water use after rainfall was completed with less than one percent change in effectiveness.

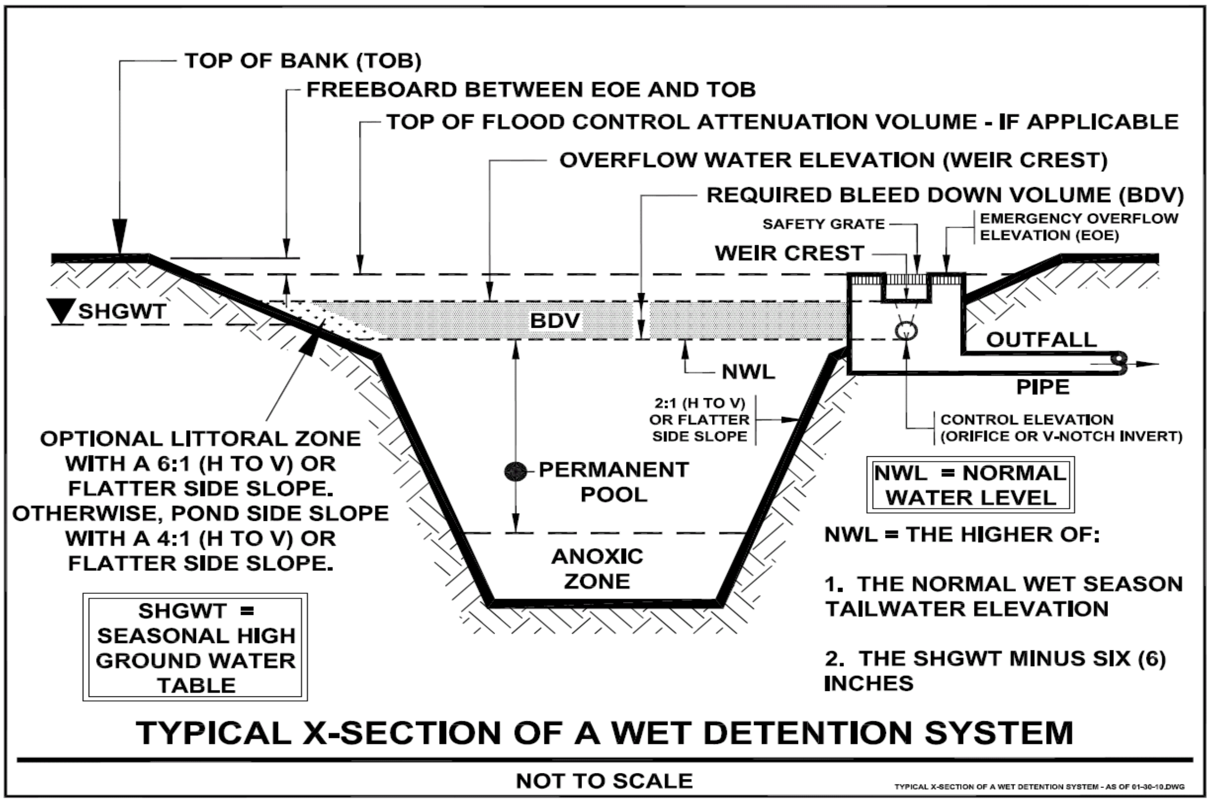
- Rainfall on a wet pond is equal to the evaporation from the wet pond in a year.
- The effectiveness results (REV curves) are long-term averages based on historical rainfall records. The average values for each year will be different.
- The drawdown of the permanent pool for beneficial use does not exceed 1 inch over the catchment. This is done to protect surrounding vegetation and for aesthetic reasons.





There are various storage devices or pond physical arrangements that are being used. If the storage is underground, there is no evaporation and no rainfall directly into the storage as well as no groundwater net exchange. The storage volume is the volume of water used. The assumptions for the REV curves are the same and thus provide a reasonable estimate of effectiveness based on runoff removal. Another popular option is to use pond storage for cooling water or wash water. Many cooling or wash water (car washing) applications require a separate holding vessel with a specific design volume. This is usually accommodated from the stormwater storage by pumping into a holding tank twice per week. When doing this, the colling water use is converted from an average gallons per week to the average rate in inches per day times the EIA using standard conversion factors. Again, the REV curves provide a reasonable estimate of annual removal. Note, average effectiveness must consider the effectiveness of the storage device plus the REV effectiveness in a series configuration.

11. Wet Detention Systems Wet detention ponds are permanently wet. They are designed to slowly release a portion of the collected stormwater runoff through an outlet structure and to remove runoff pollutants. They receive annual removal credit when installed using acceptable design and maintenance criteria. They are surface ponds open to the atmosphere. There is a catchment area associated with each as the normal permanent pool elevation is below the elevation of the surrounding land, even for vertical sides, the catchment area is greater than the permanent pool area. Wet ponds must be modeled in BMP Trains as a separate catchment.



Underground holding ponds are not considered as wet ponds. Wet ponds are often effective BMPs for sites with moderate to high water table conditions. Wet ponds are detention treatment systems that provide removal of both dissolved and suspended pollutants by taking advantage of physical, chemical, and biological processes within the pond for time periods usually greater than 14 days of residence time. There is an irreducible fraction of TP and TN that is not removed and thus the annual removal is less than what is input to the pond...

The ponds are relatively simple to design and operate, provide a predictable recovery of storage volumes within the pond, and are easily maintained by the maintenance entity.

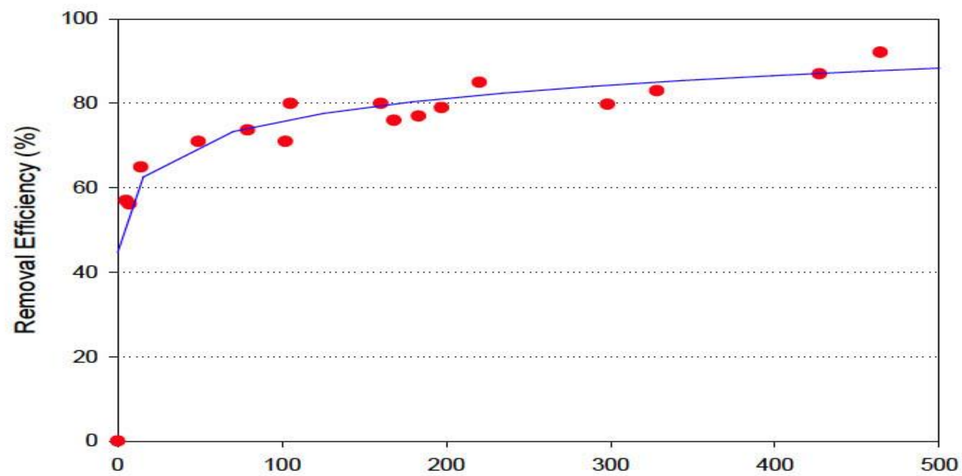
As shown in the Figures below, the treatment effectiveness of a wet pond is directly related to the annual residence time that the stormwater runoff occupies within the wet pond before discharge. The longer the residence time, the more time the various pollutant load reduction mechanisms within the wet pond system have to work. The formula for calculating annual residence time uses the permanent pool and runoff volume and is:

$$Rt = 365 \times V/Q$$

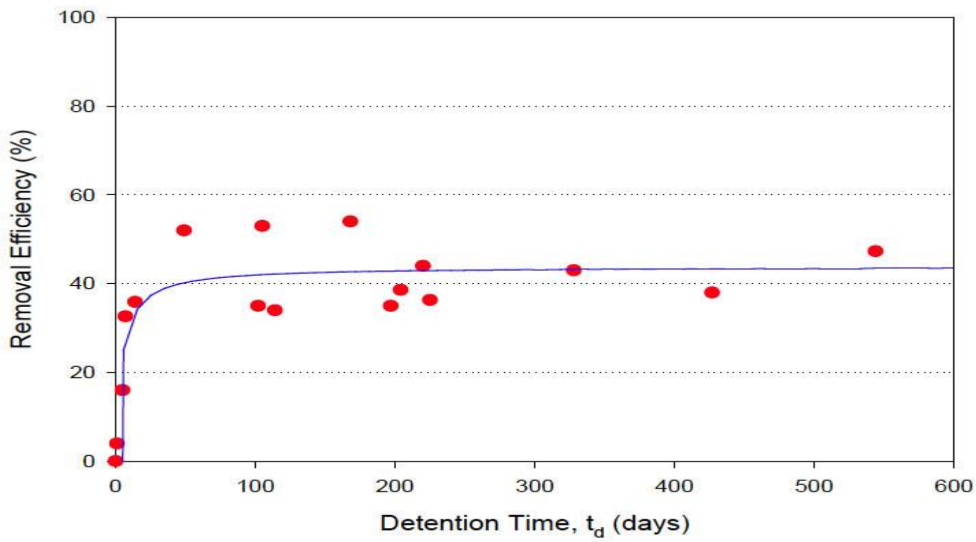
Where: Rt is average annual residence time in days

V is the volume of the wet detention pond permanent pool in ac-ft

Q is the average annual flow rate in ac-ft/year.



Removal Efficiency of Total Phosphorus in Wet Detention Ponds as a Function of Annual Residence Time



Removal Efficiency of Total Nitrogen in Wet Detention Ponds as a Function of Annual Residence Time

12. Managed Aquatic Plant Systems (MAPS)

Managed Aquatic Plant Systems (MAPS) are aquatic plant-based BMPs that remove nutrients through a variety of processes related to nutrient uptake, transformation, and microbial activities. Examples of MAPS include planted littoral zones and floating wetland mats. Harvesting of the biomass is an essential process of the BMP. Maintenance plans must be available.

Generally, wet detention systems by themselves can't achieve many required levels of nutrient removal from stormwater. In nearly all cases, a BMP treatment train will be required when using a wet detention system. Sometimes components of the BMP treatment train include source controls or pretreatment BMPs such as rain gardens or swales to reduce either the stormwater volume or nutrient concentrations in stormwater discharged to the wet detention system. However, in many areas, high water tables and slowly percolating soils do not make infiltration practices practical or effective. Managed Aquatic Plant Systems (MAPS) can be incorporated into a wet detention BMP treatment train to provide additional treatment and nutrient removal after the wet pond has provided reduction of pollutants through settling and other mechanisms that occur within the wet pond.

13. Filter Systems

Filters are used to improve water quality by removing pollution when discharging to surface or groundwater. Many types of media are used in conjunction with detention, either wet detention ponds or vault systems, to increase treatment train pollutant load removal effectiveness. They can be either up-flow or down-flow systems. When placed after a wet detention pond, there is a lower potential to plug with debris and particulates.

Up-flow filters are very suitable and applicable to ultra-urban development applications because of their capability to remove significant levels of sediments, particulate-bound pollutants (metals, Phosphorus and Nitrogen) and organics (oil and grease). They are amenable to ultra-urban constraints such as linear configurations and underground installations.

Down-flow filters are used in many sites and are typically used as side bank filters. They have the advantage of low construction cost and typically are placed within the pond bank or near the discharge structure.

Media removes sediment and both particulate and dissolved pollutants. Using a sorption media in the filter increases the removal of dissolved pollutants. The media are generally a mixture of materials. There are many different types of mixed media that when used together achieve specified pollutant removal effectiveness. Media mixtures that are effective for removing a wide range of pollutant types are sand/clay with other additions (Woelkers et al., 2006), and expanded clay with other media (Ryan et al., 2009, Hardin et al., 2012). Some mixes target specific pollutants, such as used by the Washington State DOT whose mix targets dissolved metals (WSDOT, 2008), and media mixes that target Phosphorus (Ma et al., 2009), nitrate (Kim et al., 2003), Phosphorus and Nitrogen (O'Reilly et al., 2012), organics (Milesi et al., 2006), and metals and dioxins (Pitt and Clark, 2010). Thus, a wide selection of media mixtures can be used for media filtration systems (Chang et al., 2010).

Most media can treat urban stormwater, wastewater, agricultural discharges, groundwater, landfill leachate, and sources of drinking water for nutrient removal via physicochemical and microbiological processes (Chang et al., 2010). The media may include, but are not limited to, compost, clay, zeolite, wheat straw, newspaper, sand, limestone, expanded clay, wood chips, wood fibers, mulch, pumice, bentonite, tire crumb, iron filings, expanded shale, oyster shell, coconut coir, and soy meal hull (Wanielista and Chang, 2008). A document, entitled Alternative Stormwater Sorption Media for the Control of Nutrients, was prepared for the SWFWMD and is:

http://stormwater.ucf.edu/wp-content/uploads/2014/09/AlternativeMedia2008.pdf

14. Biofiltration Systems with Biosorption Activated Media (BAM)

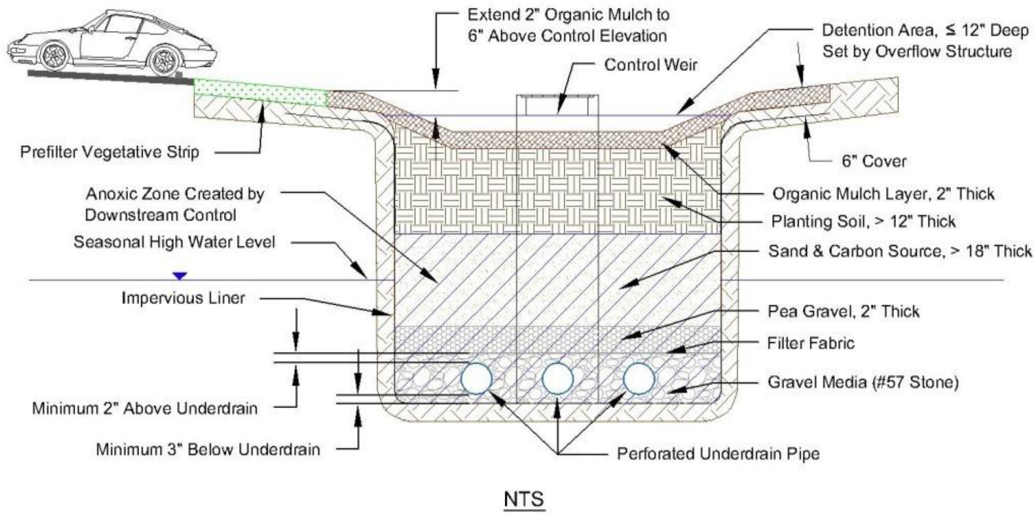
Biofilters or biofiltration systems are a suite of BMPs that use engineered media, such as Biosorption Activated Media (BAM), to enhance nutrient removal when native soils cannot provide adequate pollutant removal. Another use is where the soils do not have an adequate infiltration rate. They also are used in Sensitive Karst Areas to remove nitrates where the sandy soils (without clay) allow nitrate movement into the ground water. Commonly used BMPs are retention basins or wet detention ponds. Retention basins (Chang, et.al., 2019) and detention ponds may then use filters on the discharge from the ponds to further remove nutrients, usually the nitrate form of Nitrogen and Phosphorus. Small catchment areas can discharge into depression areas or rain gardens that have BAM. Typically, these are either offline retention BMPs or online stormwater detention BMPs that serve small drainage areas, usually up to two acres.

Biofiltration systems with BAM can incorporate natural soils, recycled materials, cellulose, or other materials. For the removal of Phosphorus, BAM has to have a Phosphorus sorption capacity. For nitrate removal, the BAM must retain moisture to promote an anoxic zone. Planted vegetation to facilitate treatment for removal of nutrients is common. The use of BAM will also reduce toxic compounds and organisms in the discharge waters.

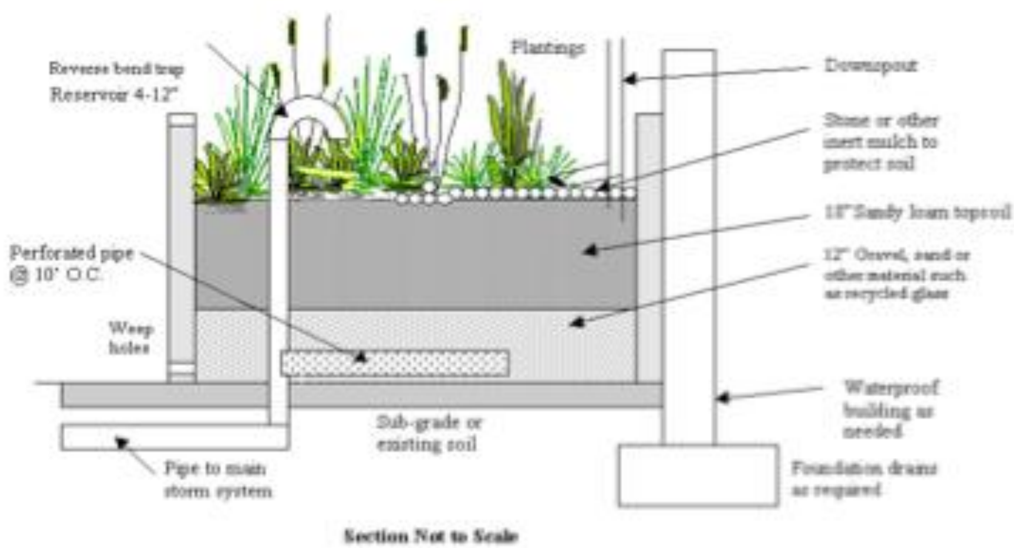
There are many opportunities for biofiltration systems (Wanielista, et.al., 2014) making them a superior choice for onsite treatment in urban development, especially in areas undergoing redevelopment. They can have an underdrain for surface water discharge but frequently are designed to function as retention systems. BMPs that can use BAM are listed as:

- Detention rain gardens
- Retention rain gardens
- Landscape planter boxes
- Tree wells or tree box filters
- Side-Bank Filters after wet detention
- Up-Flow Filters after wet detention
- Up-Flow Filters after baffle box chambers
- Regional Retention Basins
- Exfiltration pipes
- Vegetated Filter Strips

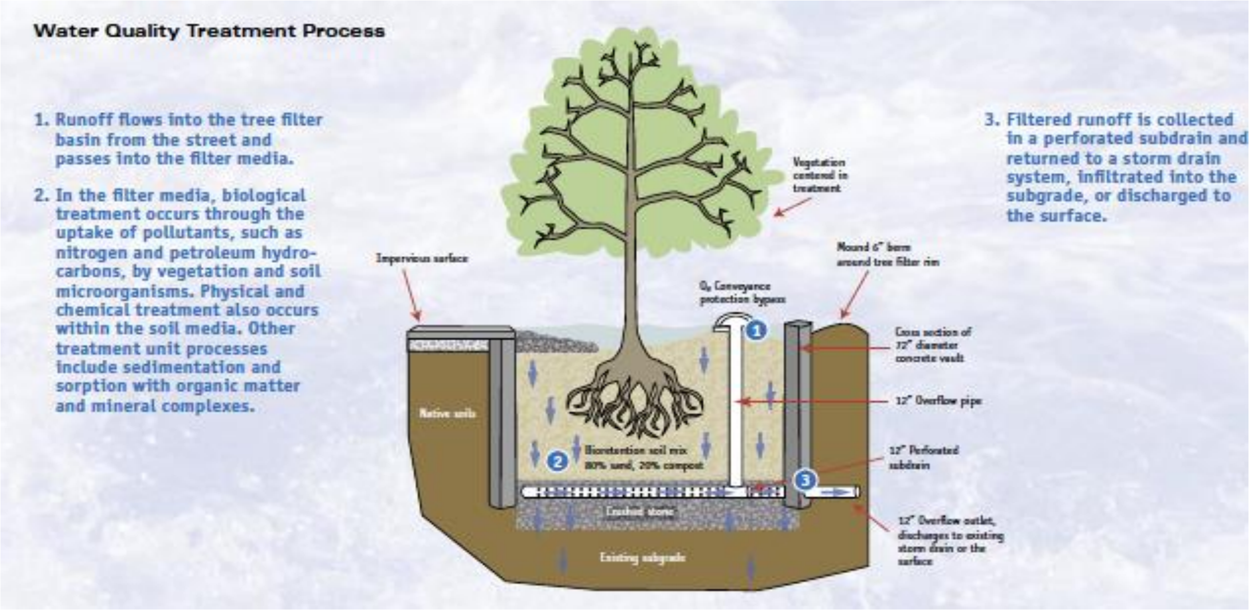
Before a BAM is used in any BMP within the State of Florida, acceptance must be granted by the review or regulatory agency. Those BAM currently used (January, 2023) within the State in BMPs are listed within the BMP Trains model. If not in the model as a specific entry, a user defined option is available. The user of the BMP Trains model is encouraged to contact the review and regulatory agency to validate assumptions on design parameters such as treatment rate as well as to document average annual removal effectiveness.



Example of a Cross section of Depression area or a Pavement Biofiltration System (Depths and Types of Media will Differ with Applications, see Regulatory Requirements)



Example of a Cross section of Landscape Planter Biofiltration System (Depths and Types of Media will Differ with Applications, see Regulatory Requirements)



Cross section of Tree Box Filter with Underdrain (Depths and Types of Media will Differ with Applications, see Regulatory Requirements)

Additional information and data on BAM used for pollution control:

As with any BMP, a filter only removes the pollutants that it was certified or measured to remove. An example is a filter that removes 80% of the particulate in TP and 25% of the dissolved TP when the input is runoff. If that same filter is used downstream of a detention facility which removes most of the particulate, the TP removal is reduced and frequently estimated for the dissolved fraction of TP, in this case 25%. In many cases, it is recommended to conduct field measurements to determine the removal effectiveness.

The removal of TN and TP within BMP Trains includes currently (January, 2023) used BAM mixes with specified authenticity and field sample performance. It is understood additional media mixes will be developed or are being used on a limited basis, thus there are options to add other BAMs, identified as User Defined Media (UDM). All media mixes should be certified for removal performance. Once permits are issued, the media type are included in BMP Trains as has been the practice for any BMP. If design changes or performance numbers are changes after the permit is issued, they can be made within the model at the recommendation of the user and acceptance by the review agency.

Usually, the media is mixed in a central facility. If not mixed in a central facility, then samples to verify the mix percentages during on-site mixing must be available. The target pollution removal now in use assumes design criteria that must be used. Thus, follow the examples and design and maintenance information within this manual.

Design information includes filtration (treatment) rates. These rates are determined by laboratory measures and validated from field operation under strict maintenance criteria. The rates used in the model have a safety factor of two, or the minimum field or lab rates are reduced by a factor of two to allow for operation difficulties.

Filter media used to remove a pollutant will have a design life expectancy, called service life. The service life for nutrient removal is based on the removal amount of OP and the media volume and treatment rate for OP. Service life is estimated for some of the media used within this manual.

It is also noted that BAM can be used for the removal of other pollutants such as some metals, solids, toxic compounds, bacteria including some pathogens and emerging contaminants. There are no suggested data on removal of other than Total Nitrogen and Total Phosphorus within this Manual. However, current (January, 2023) BAM properties and effectiveness are listed as:

Media[1]	Minimum	Treatment[2]	Treatment Efficiency[3]		Sustain	OP Removal[5]	Density[6]
	Depth (in)	Rate (GPM/SF)	TN (%)	TP(%)	Void %[4]	Rate (mg/g)	Lbs/CF
B&G ECT3 or ECT	24	1	45/25[7]	45/25[7]	30	0.2	43
ICS	24	0.104	80	95	30	0.6	105
User Defined	24						
B&G CTS12	12	0.052	60	90	30	0.2	95
B&G CTS24	24	0.052	75	95	30	0.2	95
Per Pave[8]	3-12	0.052	60	90	30	0.2	95
SAT[9]	24	0.02	20	45	30	0	100

1 January, 2023 commonly used. Others can be included as user defined.

2. Treatment Rate including a factor of safety equal to 2.

3. Average annual concentration reduction;
   mass reduction is the product of concentration and water passing through filter.

4. Percent of water in the media after loading with stormwater equal to 10 years of operation.

5. Measured dissolved fraction usually as Ortho-Phosphate (OP) in (mg OP/g of media).

6. Dry densities at operating density, will vary with source materials.

7. 45/25 (stand-alone BMP/downstream of another BMP) average annual efficiencies.

8. Limited to the bottom of a 3 to 12-inch-deep pervious pavement reservoir.

9. Limited to a stand-alone BMP or first in a series of BMPs, reflecting particulate removal.

Notes: 1. Average annual concentration reduction values are for a 50% mix of particulates.
2. Efficiencies are for stormwater runoff events with dry periods (no rainfall).
3. Continuous application of runoff may affect the concentration reduction.
4. Species mix for TN has DON less than 20% of the TN.

In Florida, the CTS12 media has been tested with VFS and in filters under pavements. Per Pave is composed of the same media mix as CTS but has been used at a 3-inch depth in the reservoir of the pervious pavement when no additional on-site runoff occurs. For runoff from additional land uses, example roofs, adjacent pervious and impervious areas, the 12 inches deep media is used in the reservoir of pervious pavements.

For design purposes, typical operating infiltration rates are derived from laboratory measures. The laboratory rates are usually divided by two to provide a factor of safety because of operating conditions not duplicated in the laboratory.

This summary of BAM properties with references are listed in **BMP Trains 2020**. The limiting infiltration rates listed include the design safety factor of 2. It is expected that additional media will be added to this list as well as their properties. The properties are also shown to illustrate the type of data needed in the approval process. All user defined media must have the approval of the review agencies before being used in BMP Trains. A partial list of references follow.

A - Demonstration Bio Media for Ultra-urban Stormwater Treatment, Wanielista, et.al. FDOT Project BDK78 977-19, 2014

B - Optimal Recipe Assessmenet of Iron-Filing Based..., Valencia, et.al., Environmental Engineering Science, 36, 10, 2019

C - Up-Flow Filtration for Wet Detention Ponds, Wanielista and Flint, Florida Stormwater Association, June 12, 2014.

D - City of Austin Environmental Criteria Manual, Section 1.6.5, Texas, 2012

E - Nitrogen Transport and Transformation in Retention Basins, Marion Co, Fl, Wanielista, et al, State DEP, 2011

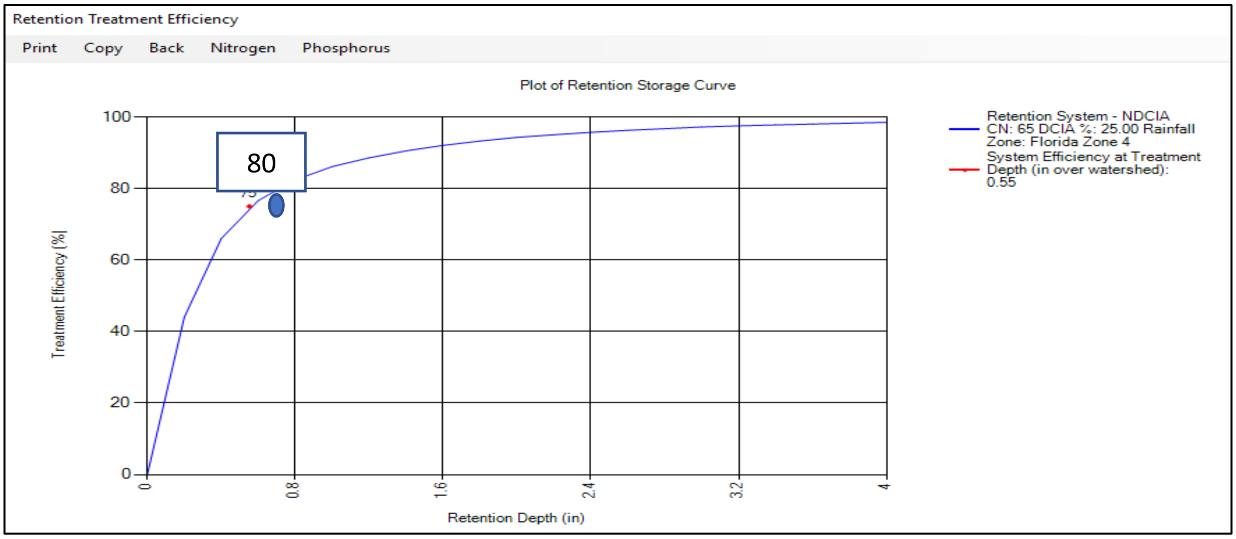
F - Improving Nitrogen Efficiencies in Dry Ponds, Williams and Wanielista, Florida Stormwater Association, June 18 2015

Caution: As with any BMP, the input water quality must be stormwater runoff within the EMC concentration values as well as the species distribution within, such as the amount of dissolved organic nitrogen (TON) must be less than about 10% of the total. For TON greater than 10%, consult the supplier of the BAM for removal effectiveness.

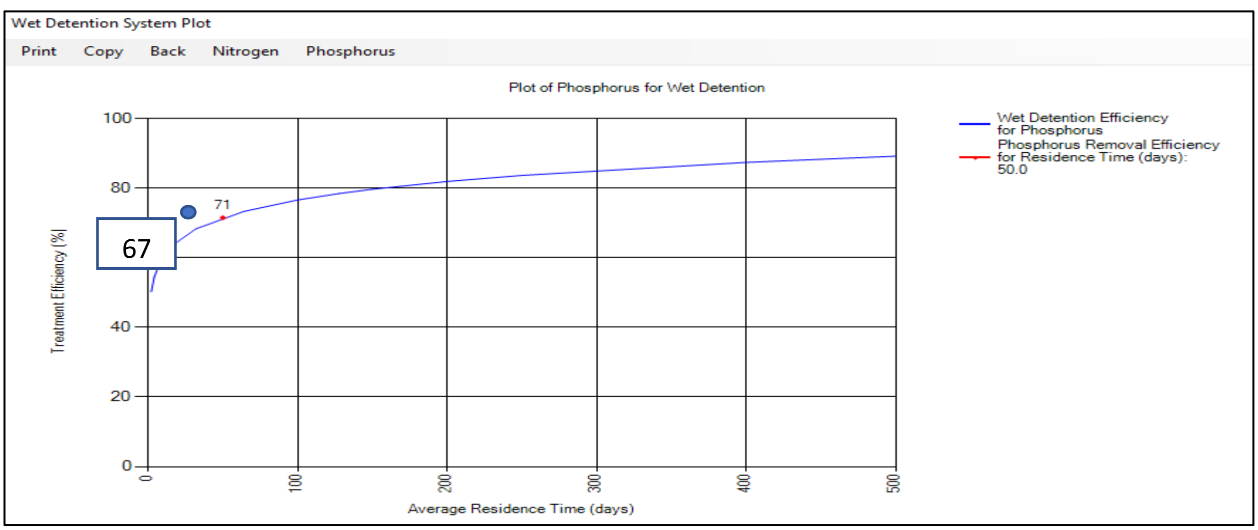
15. Annual Effectiveness for BMPs in Series

Retention in series: When the runoff from a catchment enters one BMP and the discharge enters into another BMP without additional catchment flow, the BMPs are said to be in series for the catchment. Examples for retention BMPs in series are a pervious pavement followed by a exfiltration and a rain garden followed by exfiltration. Without any additional runoff to the second BMP, the annual capture effectiveness is calculated from the total capture depth of the two retention systems. The annual capture effectiveness as a function of treatment volume is shown in the Figure below; for example problem 3 as 75% removal for a retention basin (use “plot” button) with a treatment depth of 0.552 inches over the catchment. The applicant wishes to get additional credit to be applied to another discharge in the same watershed. It was decided to use 0.5 acres of 4 inch thick pervious concrete parking with 8 inches of #57 rock and 2 inches of pea rock in the reservoir. The pervious pavement with reservoir by itself (stand-alone) produces a treatment volume of 0.151 inches over the catchment and a capture volume of 33%.

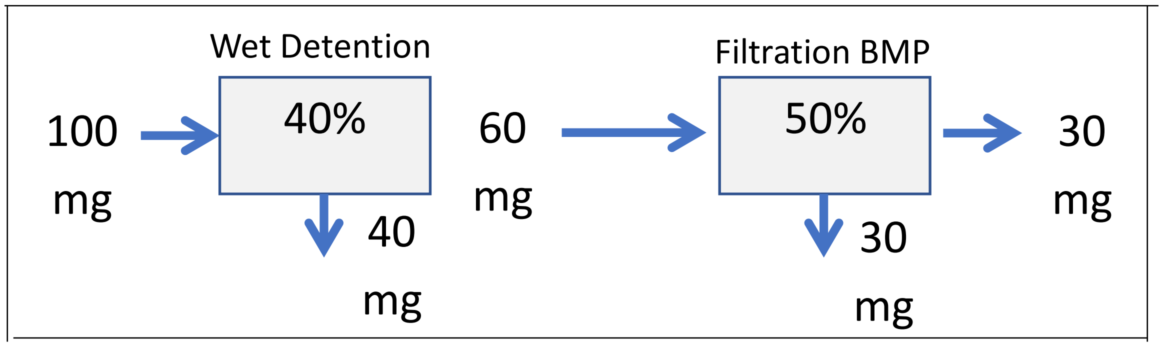
The annual capture is a function of the cumulative treatment depth of 0.703 inches (or 0.552 + 0.151) with a capture volume of 80%. It is not the sum of the capture volumes from each BMP which is 108% (75+33). Obviously, you cannot capture more than 100%, nor can you capture the same water volume twice. The same result of 80% removal is calculated from the **Select Treatment Options Worksheet** using the “BMPs in Series” button. Do not forget to use the **configure catchment** button to “select multiple BMP” as the catchment configuration.



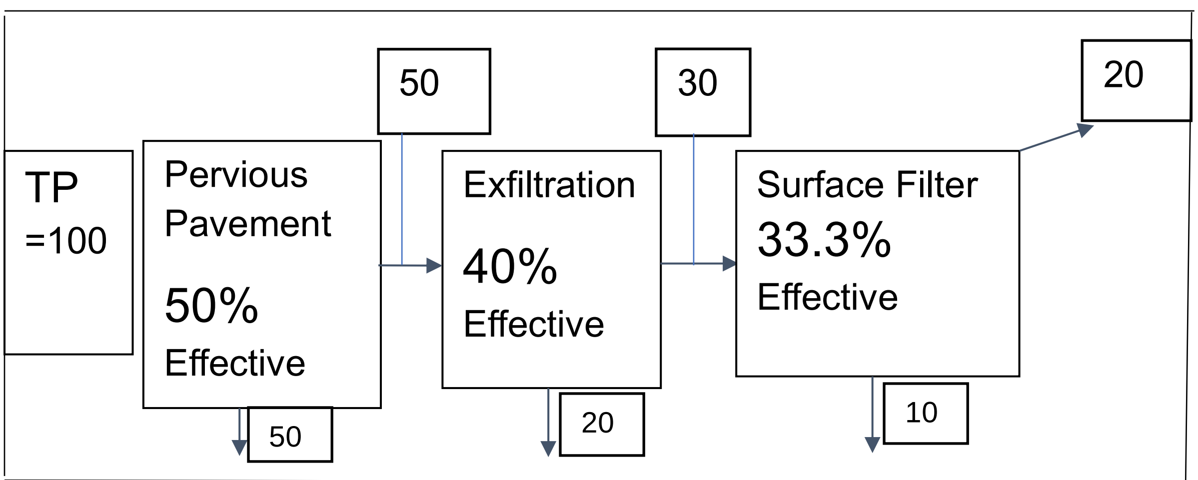
Wet detention in series: An example in series is the division of a wet pond into multiple cells such that there remains only one inlet. Removal as a function of average annual residence time is shown in the Figure below ("plot" button for example problem 4). If this wet detention pond were divided into two equal size ponds, the removal for one would be 67% TP (25 days average annual residence time) for one pond. When the total permanent pool is used, the removal at 50 days is 71%. Obviously, for two ponds of this example, the removal is not the sum of the two. The pollutant cannot be removed twice.



BMPs in Series for which the removal mechanisms are not the same or neither follows the same removal principles (examples: not both retention or detention): An example is a wet pond followed by a filter in the same catchment. The wet pond removes 40% of TN and the filter removes 50% of the remaining TN. The following diagram illustrates the calculations. For this example, there is an overall 70% removal of TN. The removal is not 90%.

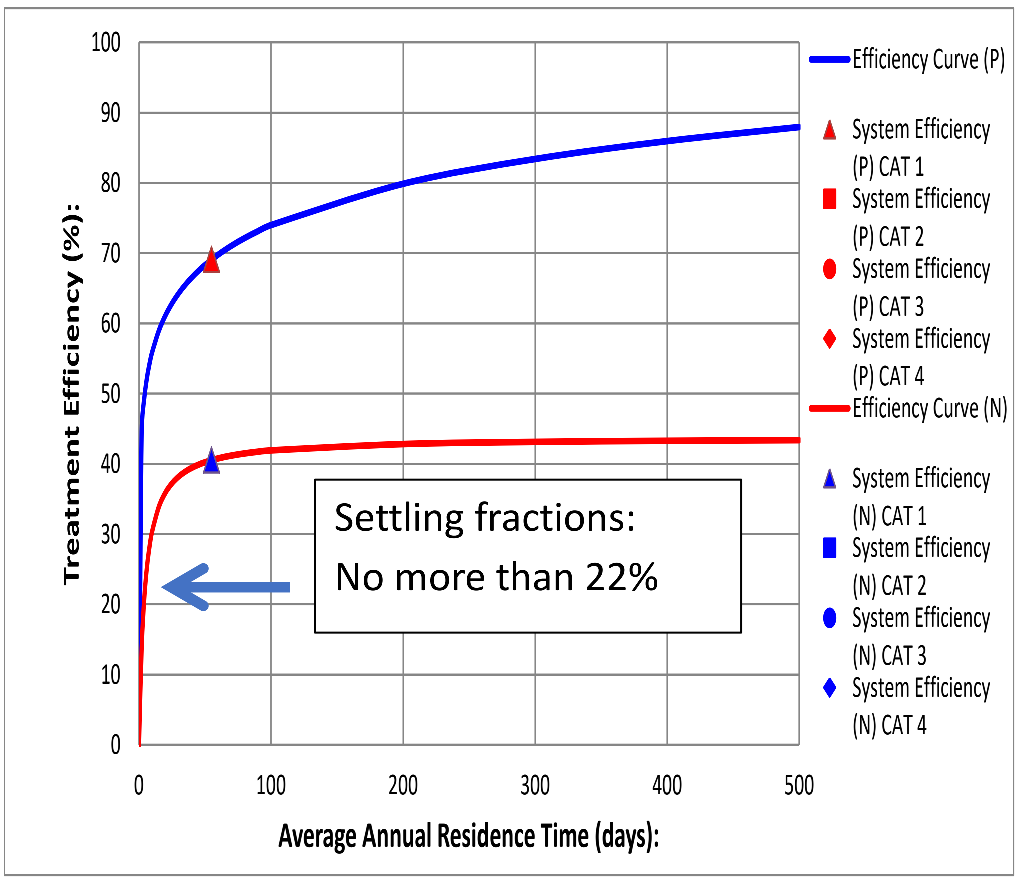


Another example is pervious pavement directly to exfiltration and filter. Note there is no additional input between the BMPs and thus not a need for additional catchments.



Removal % = 100 [1- {(1-0.5)(1-0.4)(1-.33)}] = 100[1-.20] = 80

Reduced Effectiveness of a wet detention pond due to removal of pollutants (normally particulates) in a BMP before wet detention: Removal mechanisms for TN and TP in a wet pond are classified as physical, chemical, and biological. The physical mechanism results from settling of particles which occur relatively fast compared to the chemical and biological removal. Some of the particles however can be removed by BMP retention systems before the wet pond. The maximum reduction in effectiveness is assumed to be no greater than 22%. However, when retention proceeds detention, the annual flow to detention decreases and thus the efficiency increases. Both the reduced removal effectiveness due to removal of pollutants by retention as well as the increased removal from added residency time is calculated in BMP Trains. The calculation procedure now based on limited field data follows. As new data become available, the calculation procedures may change.



The adjustment for a reduction in wet detention effectiveness resulting from retention volume before wet detention is based on simulations of various retention and detention sizes. The reduced removal percentage is calculated as follows:

- The stand-alone efficiency of wet detention is calculated
    - The increase in efficiency due to reduced annual volume is calculated based on the stand-alone efficiency as the adjusted efficiency due to reduced annual flow. An average efficiency uses the stand-alone efficiency and the reduced flow efficiency.
    - The decrease in efficiency due to lower pollutant levels is estimated as the retention effectiveness divided by 7, or a reduction based on the size of retention. Then the reduced detention efficiency from a lower pollution load = stand-alone detention efficiency – retention efficiency/7.
    - The overall retention plus detention efficiency is based on calculations for BMPs in Series for which the removal mechanisms are not the same or neither BMP follows the same removal principles.

The above estimates for reduction effectiveness due to pollution removal were done with simulations because it would be very time and resource consuming to conduct field tests for many combinations of retention and detention. Note with high retention volumes, the average annual removal for retention may be in the order of 80% or more. Thus, with only 20% of the average annual removal to be accomplished by detention following retention, the stand-alone detention removal is 68% and the reduced removal is 56%. The detention mass removal of the remaining 20% is only reduced by 2.6% [20% x(0.68-0.56)]. There are so many other combinations of retention and wet detention that produce other results.

The estimates for wet detention effectiveness with retention may change as knowledge of wet detention operations increase. Nevertheless, at the time of release of this manual the effectiveness values are assumed to be the best that can be done using the data available at the time as well as the assumptions within the BMP Trains 2020 model.

Also note the removal of nutrients by media filters with other than CTS media after a wet detention pond is 25%. An example would be ECT3 media which has a stand-alone removal percentage of 45%, but when used in combination with a wet detention pond, the removal percentage is 25% (Wanielista and Flint, 2014a).

16. An Estimate of the Anoxic Depth of a Wet Detention Pond.

The depth at which wet ponds function at the calculated removal effectiveness is considered to be that depth at which dissolved oxygen conditions are greater than 1 mg/L. That depth has been related to water quality conditions in the wet pond. Those water quality conditions are related to sunlight penetration and measured as: Chlorophyll-a (algal biomass), Secchi Disk depth (light penetration), and Total Phosphorus ("food" for algal growth). The equations used to estimate depth to the anoxic zone were developed by Harper (2007) and reported in numerous publications (FSA, 2016 annual meeting as an example). The pond average total phosphorus is from the runoff water and does not include any other sources. If other water sources (groundwater, pumped discharges, etc.) affect pond concentration, it is recommended an adjustment be made to the EMC. The equations used for Chlorophyll-a, Secchi Disk and anoxic depth or depth for DO>1 mg/L are listed as:

$$\ln(\text{chyl-a}) = 1.058 \ln(\text{TP}) - 0.934$$

where: chyl-a = chlorophyll-a concentration (mg/m3) and TP = Total P concentration (µg/l)

$$\text{SD} = [24.2386 + (0.3041 \times \text{Chyl-a})] / (6.0632 + \text{chyl-a})$$

Where: SD = Secchi disk depth (m) and chyl-a = chlorophyll-a (mg/m3)

$$\text{Anoxic Depth or Depth of DO} > 1 = 3.035 \times \text{Secchi} + 0.02164 \times (\text{chyl-a}) - 0.004979 \times \text{Total P}$$

where: anoxic depth (m), Secchi = Secchi disk depth (m), chyl-a = chlorophyll-a concentration (mg/m3) and TP = total phosphorus annual mean concentration in the pond (µg/l).

The above equations are valid for: 0.25 m < anoxic depth < 9.0 m, 0.09 m < Secchi disk depth < 3.49 m, 0.001 mg/l < TP < 0.498 mg/l, and 1 mg/m3 < chyl-a < 332 mg/ml.

The TP value used is calculated from the EMC and wet pond removal effectiveness and thus is based on the runoff water. Since the EMC and wet pond removal data are average yearly, the anoxic depth is a reflection of an average annual TP concentration. However, no consideration for changes over time. To convert the average annual anoxic depth to an average monthly, Harper (FSA, 2016) has recommended the mean annual depth be multiplied by 0.892. The BMP Trains program reports the mean annual anoxic depth in feet, thus multiplied by the conversion factor of meters to feet.

If TP field data or other site specific data indicate a different mean annual TP value, there is an input for entry of the TP data. When using this input, the overall stormwater effectiveness calculations are not changed.

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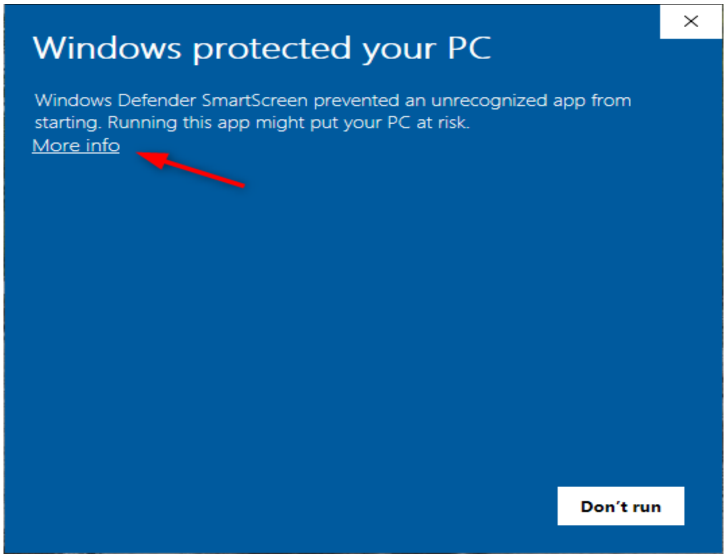
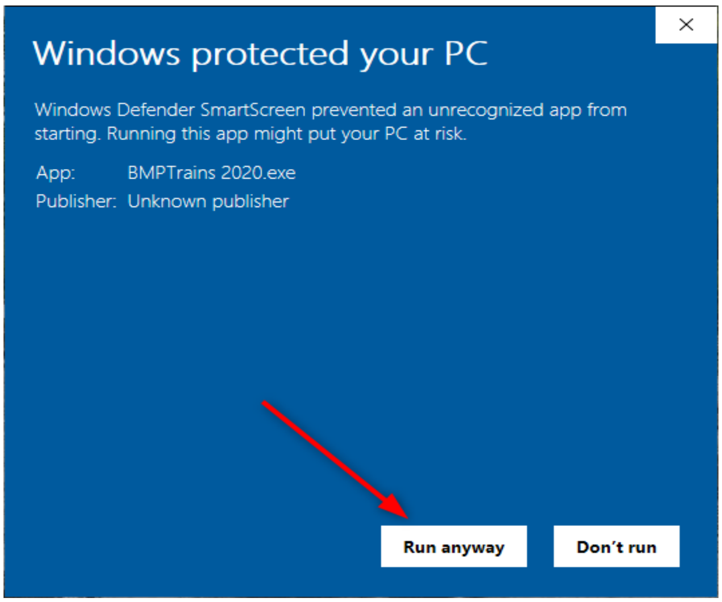
Loading the Program (January, 2023)

This version of **BMP Trains 2020** is configured for Microsoft Windows 10 operating system. If the operating system is earlier (example Window 7), add ".net4.6"or 4.7 to Windows 7. The first time the program is run, a colored blue warning window from Windows Defender will appear:



Click on "More info" in the top left corner. Then you will see the following screen:



Click on the "Run anyway" button and you will proceed to the program. You will **not** be presented with the warning "splash" screen every subsequent time that you run the program.