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Removal Effectiveness of Co-mingling Off-site Flows with FDOT Right-of-way Stormwater

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DISCLAIMER

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the state of Florida Department of Transportation. Furthermore, the authors are not responsible for the actual effectiveness of these control options or for drainage problems that might occur due to their improper use. This report does not promote the specific use of any of these particular systems.

METRIC CONVERSIONS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	Liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	Kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
TEMPERATURE (exact degrees)				
ºF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	ºC

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
AREA				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	Liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
MASS				
g	grams	0.035	ounces	oz
Kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
TEMPERATURE (exact degrees)				
ºC	Celsius	1.8C+32	Fahrenheit	ºF

TECHNICAL REPORT DOCUMENTATION

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The Florida Department of Transportation (FDOT) manages runoff with best management practices (BMPs) in their right-of-way (onsite) to meet regulatory requirements for removal of nitrogen and phosphorus. In some situations, runoff water from outside the right-of-way (offsite) may be present. FDOT has an option to treat offsite runoff in an onsite facility or to bypass the onsite facility. The decision to bypass frequently is based on the cost of bypass vs. the cost of treating in an onsite BMP plus the mass removal obtained by mixing the onsite with offsite waters (comingling). Before this report was completed, there were no evaluation methods. Within this report is the development of the methodologies for estimating the removal effectiveness of comingling as well as the incorporation of the methods into the BMPTRAINS model for evaluating the mass removal and cost of the options.

To determine capture volumes when comingling, simulations for runoff volume were completed for five rainfall locations within the state of Florida. Seventy-five (75) runoff simulations for each of the five sites use a combination of values for three probable causative parameters, namely runoff volume, delay of offsite runoff to reach an onsite BMP, and treatment size of the onsite BMP. It was shown that the three causative factors have a direct impact on the removal effectiveness. The three causative factors were incorporated in the BMPTRAINS calculation routines.

Example problems illustrate the use of the BMPTRAINS model considering onsite as well as of offsite runoff. To aid in the decision to bypass or not to bypass an onsite BMP, cost analysis was added to the BMPTRAINS model. One of the example problems demonstrates the calculation of cost. The BMPTRAINS model was also improved with the addition of a routine to incorporated mixed soil and cover conditions within a catchment. The program is acceptable for use by all the water management districts and the Department of Environmental Protection within the state of Florida.

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Students, staff, and faculty from the Stormwater Management Academy located at the University of Central Florida competed the research. The staff and students of the Academy provided valuable assistance in the collection and analyses of runoff water capture simulations, data analysis, and BMPTRAINS programming. There were four students and two faculty members conducting the research. Two of the students are listed as authors for this publication. Both students have graduated with doctorates and are employed doing stormwater management work.

In addition, a statewide committee composed of members from the water management districts, Department of Environmental Protection, Department of Transportation, with professional consultants, provided input on the acceptance of comingling, cost, multi-land use and soil conditions, and other enhancements to the computer-aided effectiveness program, namely BMPTRAINS. We are very thankful for all input on the model development.

EXECUTIVE SUMMARY

The Florida Department of Transportation (FDOT) manages runoff with best management practices (BMPs) in their right-of-way (onsite) to meet regulatory requirements for removal of nitrogen and phosphorus. In some situations, runoff water from outside the right-of-way (offsite) may be present. FDOT has an option to treat offsite runoff in an onsite facility or to bypass the onsite facility. The decision to bypass frequently is based on the cost of bypass vs. the cost of treating in the onsite BMP plus the mass removed after mixing the offsite with onsite waters (comingling) vs. the mass removal without comingling.

Prior to the completion of this report, there were no evaluation methods for comingling acceptable to the reviewing agencies and consultants in the state of Florida. The reviewing agencies and consultants who use the information for comingling evaluation now accept the results of this research. Within this report is the development of the methodologies for estimating the removal effectiveness of comingling as well as the incorporation of the methods into the BMPTRAINS model for evaluating the removal effectiveness and cost of the options. Not only FDOT but also Cities and Counties that have the option of treating offsite water in an onsite BMP can use the results of this research.

To evaluate the addition of offsite runoff to an existing or yet to be designed onsite BMP, BMPTRAINS was modified to add calculations for comingling offsite runoff as it affects the removal effectiveness of onsite BMPs, calculations for capital and present worth costs, and an improved routine for estimating runoff from a catchment with multiple soil and land uses. Example problems are used to demonstrate BMPTRAINS that include comingling.

Simulations for runoff capture volume using five rainfall locations within the state of Florida were completed to demonstrate the sensitivity of annual removal effectiveness using BMPs. Seventy-five (75) runoff simulations for each of the five sites used a combination of values for three causative parameters, namely ratio of offsite to onsite

runoff volume, delay of offsite runoff to reach an onsite BMP, and treatment size of the onsite BMP. The locations reflected the five meteorological zones used for stormwater treatment in the state. The onsite BMPs were retention and wet detention types. The simulations calculated the average annual capture volume. The mass of each pollutant and removal effectiveness was determined by multiplying the concentration of nitrogen and phosphorus associated with both the offsite and onsite land uses times the runoff volume and the fraction of annual capture volume. The results of the simulations are in equation form and indicate that three causative factors are important for calculating average annual capture volume. Annual capture and thus mass removal are calculated for any physical catchment condition, and rainfall volume in the meteorological zones using the BMPTRAINS model. The BMPTRAINS model is an accepted by the regulatory and consulting professionals as a methodology for analyzing average annual stormwater treatment effectiveness of BMPS. In addition, any land use condition, which affects runoff, can be evaluated as well as changes to existing BMP sizes. All can be input to the model.

To assist in understanding the use of the BMPTRAINS model, example problems illustrate the use of model considering onsite as well as of offsite runoff. There are 17 example problems to aid in the general use of the model. Seventeen examples were used because it is important to understand many BMP treatment options and the capabilities of the model to be proficient in assessing typical offsite as well as onsite conditions. Of the seventeen example problems, there are five, namely example problems 2, 5, 8, 12, and 14 that are completed to help understand the solution procedures when using comingling. In addition, the removal effectiveness figures in Chapter 2 for retention and wet detention address specific results for comingling or bypass. These figures were produced with BMPTRAINS and help demonstrate the use and value of comingling evaluation.

To aid in the decision to bypass or not to bypass an onsite BMP, cost is analyzed with the BMPTRAINS model. Example problems 17 demonstrates the calculation of cost for alternative BMP treatment trains. Additionally, the BMPTRAINS model is improved with the addition of a routine to incorporate mixed soil and cover conditions within a catchment.. The program is acceptable for use by all the water management districts and the Department of Environmental Protection within the state of Florida. The use of the BMPTRAINS program is recommended to evaluate comingling opportunities.

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ACRONYMS AND ABBREVIATIONS

B&G™	Bold & Gold™
BAM	Biosorption activated media
BMP	Best management practice
BMPTRAINS	Excel-based computer program for annual effectiveness estimates
C	Annual runoff coefficient
CN	Curve number
DCIA	Directly connected impervious area
DE	Decrease in capture efficiency
E	Efficiency
EIA	Equivalent impervious area
F.A.C.	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FDOT	Florida Department of Transportation
FS	Factor of safety
LID	Low impact development
N	Nitrogen
Non-DCIA	Non-directly connected impervious area
NOAA	National Oceanic and Atmospheric Administration
OP	Ortho-Phosphorus
P	Phosphorus
Ratio	Ratio of offsite runoff to onsite runoff
REV curve	Rate-efficiency-volume curve
R	Correlation coefficient
RO	Surface runoff [L]
SRP	Soluble reactive phosphorus
T.Depth	Treatment depth [inches]
TKN	Total Kjeldahl Nitrogen
TMDL	Total maximum daily load
TN	Total Nitrogen

TP	Total Phosphorus
TSS	Total Suspended Solids
U.S. EPA	United States Environmental Protection Agency
UCF	University of Central Florida

CHAPTER 1 INTRODUCTION, OBJECTIVES, AND LIMITATIONS

1.1 BACKGROUND

The Florida Department of Transportation (FDOT) has constructed best management practices (BMPs) for runoff water within their right-of-way to meet regulatory requirements for removing a target annual mass of nitrogen and phosphorus. In some cases, there are runoff waters from offsite that may bypass the onsite BMP. The option exists to treat this offsite runoff water in the existing facility. For purposes of this report, the treating of an offsite stormwater with an onsite stormwater BMP is called comingling. The comingling of offsite treated runoff water within an onsite BMP may add to the total mass of nitrogen and phosphorus removed compared to not treating the offsite runoff water. However, there may be watershed conditions for which comingling will not improve the total mass removed from both the offsite and onsite watersheds.

New designs or alterations of existing facilities may take advantage of routing offsite runoff into an onsite BMP to remove more pollutants from both the onsite and offsite relative to treating only the onsite runoff. The decision to comingle the waters or to bypass the onsite BMP is based on cost and removal effectiveness with and without the comingling.

1.2 OBJECTIVES

The purpose of this work was to develop modifications to the BMPTRAINS model for assessing the removal effectiveness of existing or newly designed fixed size BMPs when adding additional runoff water not from the right-of-way. Additional runoff water may be added to an onsite BMPs and is called offsite water. The model was expanded to allow the calculation of a flow weighted average EMC based on complex land use, directly connected impervious areas, and soil conditions. The existing BMPTRAINS computer model can reasonably duplicate the effectiveness but does not have the capability of adding additional offsite runoff to existing BMPs. Thus, a modification of the existing BMPTRAINS model to account for offsite runoff into an onsite BMP was completed. In addition, a cost analysis routine was added to BMPTRAINS that allows a present value and construction cost evaluation for any treatment train combination to include comingling strategies.

1.3 LIMITATIONS

The BMPs considered are those currently acceptable to the regulatory review professionals in the state of Florida. While directly using the terminology for retention and wet detention BMPs, the capture volumes can be extended to any other retention design, such as depression storage, tree wells, and exfiltration as well as wet detention designs for the reuse of runoff water.

The results are applicable to Florida rainfall conditions. In addition, the average annual conditions are used and should not be confused with a design single event based rainfall.

CHAPTER 2 COMINGLING AS AN OPTION IN STORMWATER MANAGEMENT

2.1 WHAT IS COMINGLING

For purposes of this report, the treating of an offsite stormwater within an onsite stormwater BMP is called comingling. The question facing transportation stormwater professionals is whether to comingle or to bypass an onsite BMP when there is offsite runoff. This is a question facing all professionals when evaluating an onsite existing BMP and challenged with the option of treating stormwater offsite and bypassing an existing BMP or treating offsite stormwater in an existing onsite BMP. A model schematic in BMPTRAINS of this evaluation is shown in Figure1.

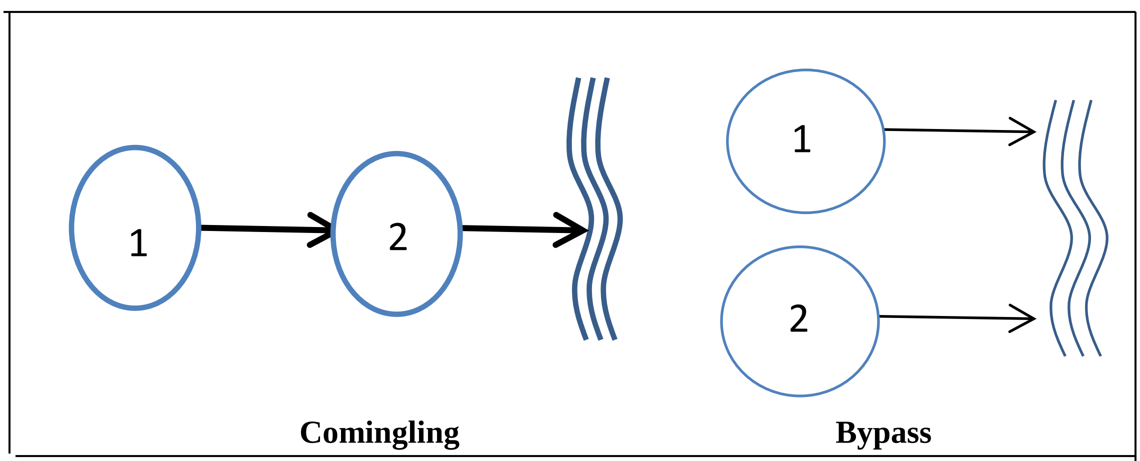


Figure 1 – Schematic of Comingling and Bypass Nodes

2.2 EFFECTIVENESS OF RETENTION BEST MANAGEMENT PRACTICES

Stormwater retention system effectiveness is a function of the watershed runoff and rainfall (volumes and inter-event dry times) conditions as well as the retention depth. As an example, average annual removal as a function of retention volume is shown in Figure 2 for specific watershed and rainfall conditions. This relationship is the same general form and the specific shape is dependent on the watershed and rainfall conditions.

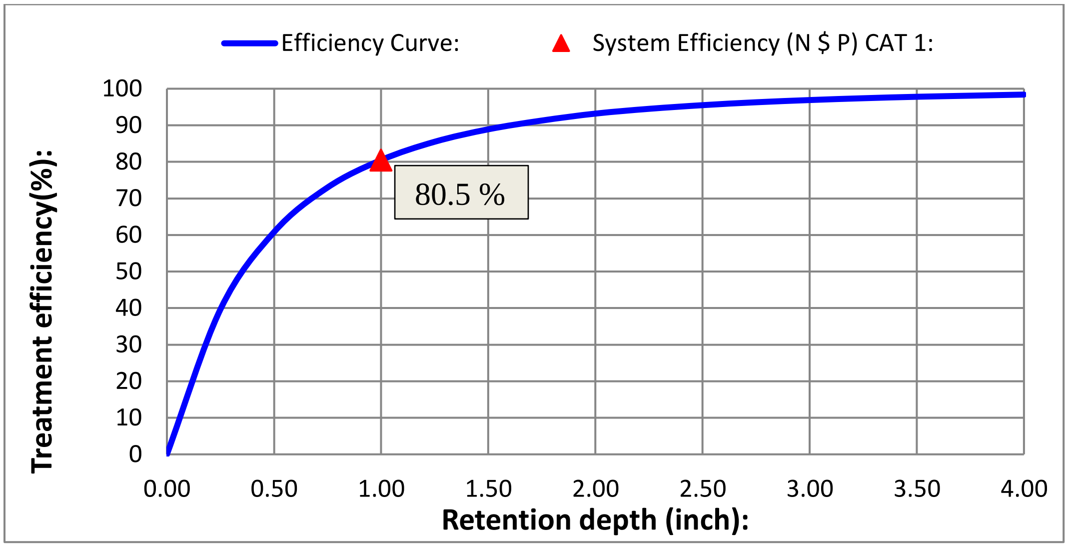


Figure 2 – Retention Basin Capture Effectiveness (from BMPTRAINS)

The volume of retention (cubic feet) divided by the watershed area (square feet) times the conversion of 12 inches/foot is the retention depth (inches). The data used to generate the retention effectiveness curve of Figure 2 is a highway catchment area of 2 acres and with a volume of retention of 1 inch. The retention storage in cubic feet is 2 Ac x 43,560 SF/Ac / 12 inches/foot x 1 inch = 7,260 CF. The BMPTRAINS program is used to calculate the effectiveness and adjusts for the catchment and rainfall conditions. The meteorological zone is 2 with 50 inches annual rain. Fifty (50) % Directly Connected Impervious Area (DCIA) and a soil condition curve number of 80 (non-DCIA) are used. The loading removed is 12.74 and 1.68 pounds per year for TN and TP respectively (BMPTRAINS Summary Worksheet).

If the catchment area were to double (offsite area is double the onsite area) with the same % DCIA and CN for the non-DCIA area, and the existing facility remained at the same retention volume of 7,260 CF, thus the retention depth is ½ inch (7,260 x 12 / 4 / 43,560). The removal decreases to 60.8% as shown in Figure 3. However, the TN and TP removed was 19.25 and 2.53 pounds per year respectively. From the shape of the curves in Figures 2 and 3, the change in effectiveness is not linear and thus the removal is expected to not decrease by half when the treatment depth is decreased by half. When the runoff from the offsite 2 acres is added to the onsite basin, the existing BMP would remove an additional 6.15 pounds per year of nitrogen (19.25-12.74) and an addition 0.85 pounds per year of phosphorus (2.53- 1.68) with comingling. The cost to achieve comingling or to bypass the existing BMP is also needed. Both the cost and the effectiveness can be calculated using the BMPTRAINS program. Thus, details on the use of the program follow in the next Chapters. There is no delay in the offsite runoff.

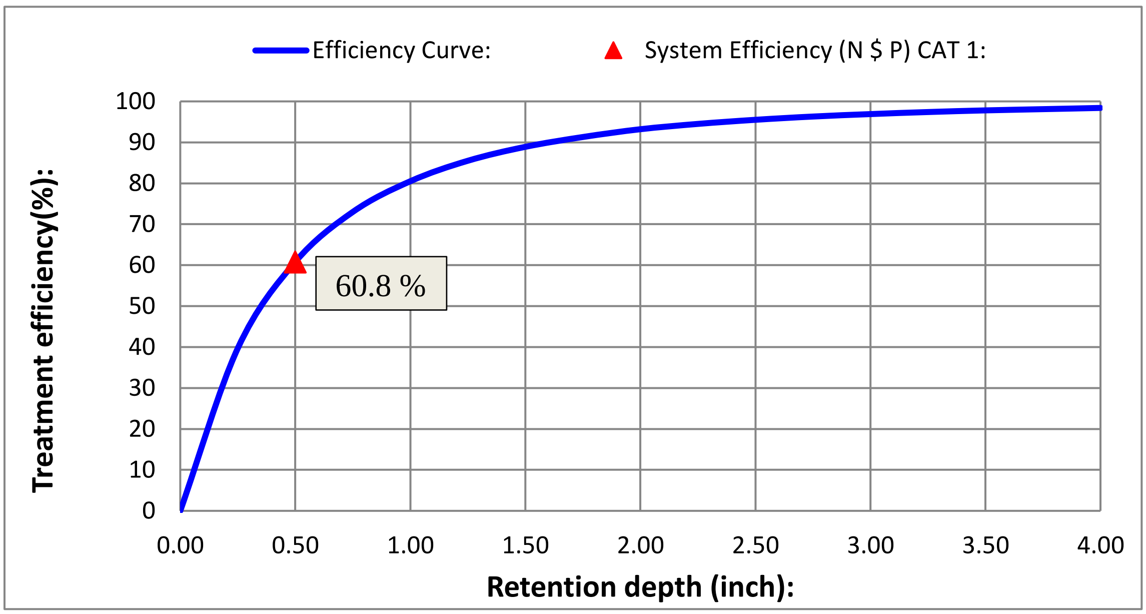


Figure 3 – Increased Offsite Runoff to an Existing Onsite Retention Basin with No Delay

2.3 DELAY OF OFFSITE RUNOFF TO AN ONSITE RETENTION BMP

For a delay in offsite flow in reaching an onsite existing retention basin, there is an additional removal expected because of the recovery of treatment volume during the delay time. The runoff from offsite to the onsite BMP is delayed because of travel time from the offsite watershed or because of a BMP reducing the time. Thus, this delay has to be considered in assessing the removal effectiveness of an existing fixed size of a BMP. The delay in arrival time of the offsite water will give a recovery time for some of the capacity of an onsite retention basin. Water level with delay is shown in Figure 4. At the start of runoff, the common assumption is that the onsite basin starts to fill up and in the example of Figure 4 is full at the end of 4 hours. Offsite water does not start to enter the onsite retention basin until hour 10.

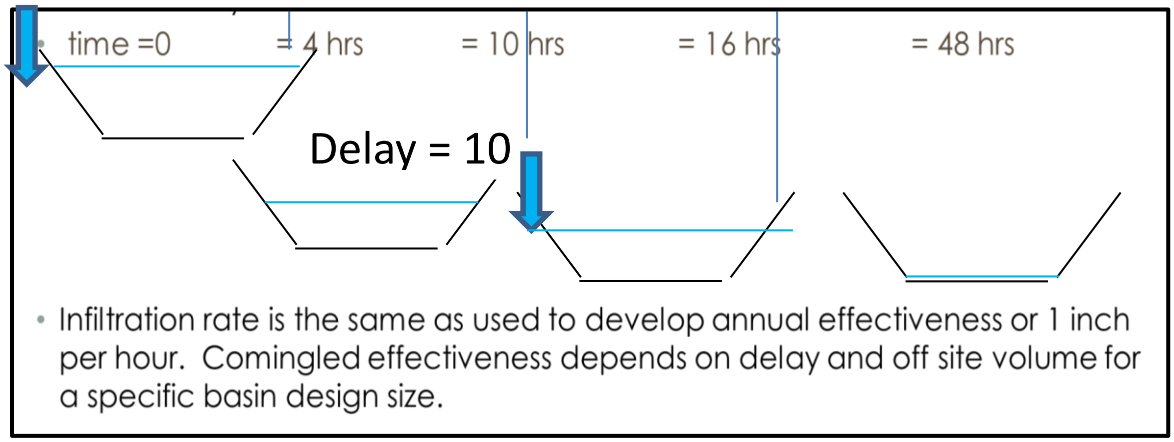


Figure 4 – Delay of Offsite Water to an Onsite Retention Basin and Water Level over Time

The delay time is calculated based on a 1 inch per hour rainfall event. The one inch per hour is recommended because it is close to the median rainfall intensity for storms producing runoff in Florida. Actual data on runoff time estimates would be more accurate.

2.4 SIMULATION OF A RETENTION BASIN TO DETERMINE EFFECTIVENESS

Average annual capture effectiveness was determined using a simulation of rainfall and runoff for fixed retention basins. The mass balance equations were the same as those used to determine annual volume capture of retention basins without offsite flows and as reported by Harper (2007).Thus, comparisons with offsite additional volume and delay are comparable.

The simulations incorporated watershed and rainfall conditions that affect capture effectiveness when offsite runoff is added to an existing or fixed size retention basin. An observable factor is an increase in runoff water to a basin relative to the onsite runoff water. The larger the offsite runoff for a fixed treatment depth the less capture effectiveness.

Rainfall and runoff volume with inter-event times vary throughout the state and that also has an impact on the existing design volume. Thus, simulations were done for each of the five meteorological regions of the state. The results were structured so that the capture effectiveness can be applied to any watershed conditions, using runoff volume in inches over the catchment.

For the simulations, average annual capture effectiveness of an existing BMP with offsite runoff vary with four causative factors listed with their range of simulation values as:

1. delay time in hours, (Delay), (0-15 hours)
2. ratio of the volume of average annual offsite runoff to volume of average annual onsite runoff, (Ratio), (0-2)
3. rainfall volume and inter-event dry periods, (Region), and
4. treatment depth of the existing onsite BMP in inches (T.Depth) (0.1 – 4.0 inches).

Initially, effectiveness using each causative factor was determined by simulating the effectiveness response curve using many values for each of the factors. As an example for delay time, incremental times of 1 hour were chosen, thus 15 different times were simulated holding the other factors of the simulation constant. The simulation uses one hour precipitation data varying one factor and holding the other factors constant. The response curve showed that it be essentially the same equation when five delays were used, namely 0, 1, 3, 6, and 12 hours. The same procedure was used for the ratio of offsite to onsite runoff giving ratio values of 0.5, 1.0 and 2.0. Similarly, the design treatment depths were set at 0.21, 0.42, 0.79, 1.05 and 1.57 inches.

For each of the five state meteorological regions that represent the rainfall volume and inter-event times, the decrease in average annual capture effectiveness is estimated based on a simulation of rainfall. The volume of treatment, ratio of offsite to onsite annual runoff, and delay time are evaluated for each region. Seventy-five (75) simulations were done for one rainfall site in each meteorological region. One rainfall site per region was chosen because of the extensive number of simulations needed. The sites with their regions are Tallahassee in Region 1, Orlando in Region 2, Key West in Region 3, Tampa in Region 4, and Miami in Region 5. The average annual rainfall at these measuring stations are close to the average for their regions, which is justification for their selection. A total number of simulations of 375 was completed for the five meteorological regions.

The causative factors (Ratio, Delay and T.Depth) were related to the change in effectiveness in each Region using a multiple linear regression form. The results are shown in Table 1. As an example of a calculation for change in effectiveness using Tallahassee, a treatment depth of 1 inch is used for an existing retention basin, a ratio of offsite to onsite flow of 0.5, and a delay of 6 hours. The decrease in effectiveness capture (DE) calculation is:

DE= -2.042 + 11.117 x (0.5) - 0.264 x (6) + 11.196 x (1) = 13.13% decrease in capture.

However, the volume of water captured has increased by 50%. Assume the existing basin captured 70% of the onsite annual runoff volume of 100 Ac-feet year (calculated for catchment configurations using the BMPTRAINS model). The existing basin captures 70 Ac-feet. Added to the existing basin is 50% (Ratio of 0.5) additional annual runoff, thus making the runoff loading equal to 150 Ac-feet. After the offsite is added, the effectiveness is 56.87% (70-13.13) and the capture is .5687 x 150 = 85.30 Ac-feet, or larger than 70 Ac-feet.

If the ratio of offsite to onsite were 2.0, the capture decreases by 30%, and the capture efficiency after offsite runoff is 40% (70-30). The capture is 40 x 150 or 60 Ac-feet, which is less than the existing onsite capture of 70 Ac-feet. This calculation illustrates that if the Ratio exceeds two, the capture volume decreases below that of the onsite basin with no offsite runoff. The BMPTRAINS model adds the concentration values to calculate to nutrient mass loading whereas in this example, only capture volume is used. BMPTRAINS program calculates the runoff volumes for the meteorological region, and the catchment characteristics and then adjusts the effectiveness for the delay using the coefficients for delay in Table 1.

Table 1 – Comparison of Effectiveness Changes for Five Meteorological Regions with Causative Factors

Site	Best Fit Equation	R^2	Region
Tallahassee	DE = -2.042+11.117*Ratio-0.264*Delay+11.196*T.Depth	0.810	1
Orlando	DE = -5.449+11.082*Ratio-0.337*Delay+14.594*T.Depth	0.801	2
Key West	DE = 1.92+11.978*Ratio-0.35*Delay+5.156*T.Depth	0.829	3
Tampa	DE = -2.120+9.65*Ratio-0.269*Delay+10.572*T.Depth	0.880	4
Miami	DE = -0.562+10.956*Ratio-0.229*Delay+8.870*T.Depth	0.832	5

The value of the equations is in the "goodness of fit" as measured by the correlation coefficient (R). Also graphically, the significance of the equation is shown in Figures 5-9 for each meteorological region. The 95% confidence limits and standardized values for each causative factor are shown. Delay has the lowest variability as thus a good predictor. The 45^{o} line indicates the accurate the prediction equation (Pred(DE)) to the simulated value (DE)).

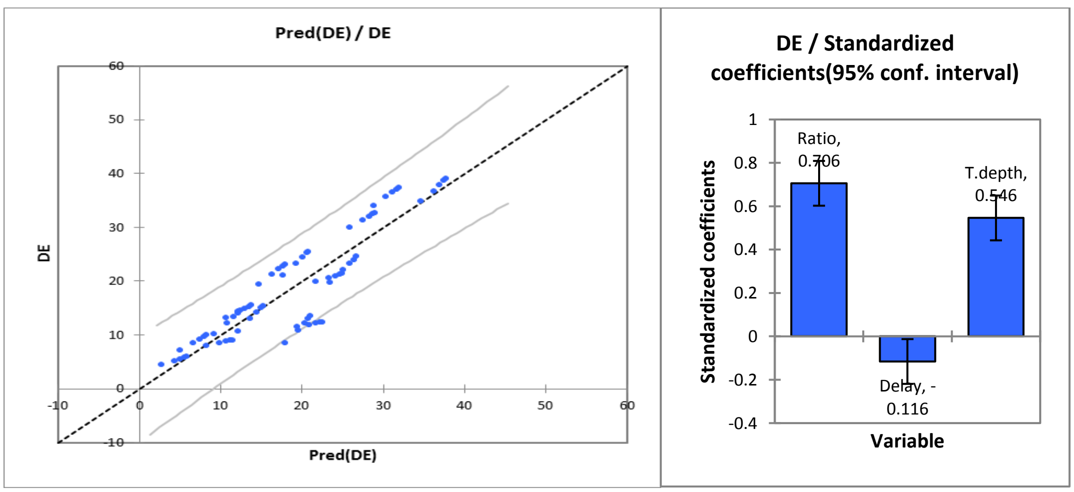


Figure 5 – Region 1 Goodness of Fit between Predictive Equation and Simulation

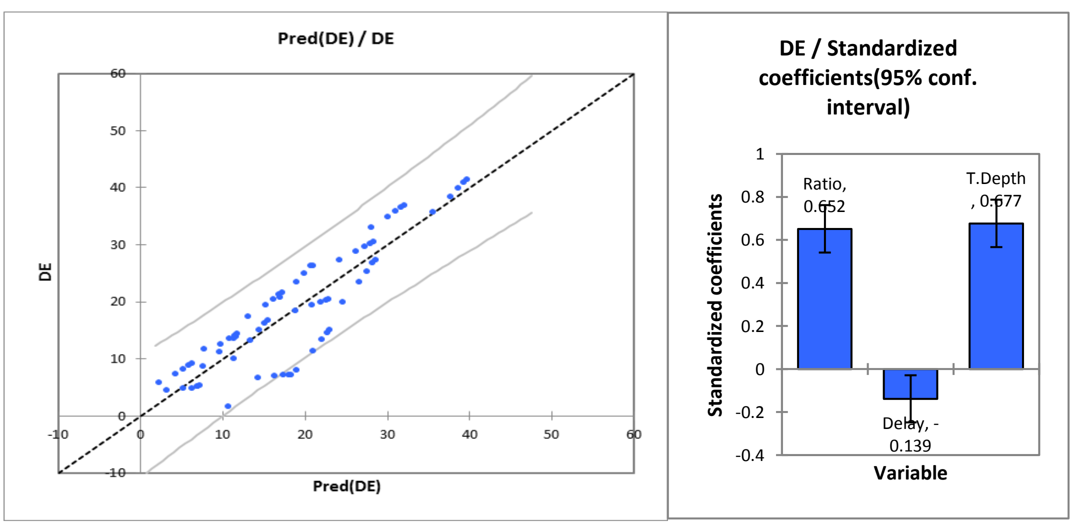


Figure 6 – Region 2 Goodness of Fit between Predictive Equation and Simulation

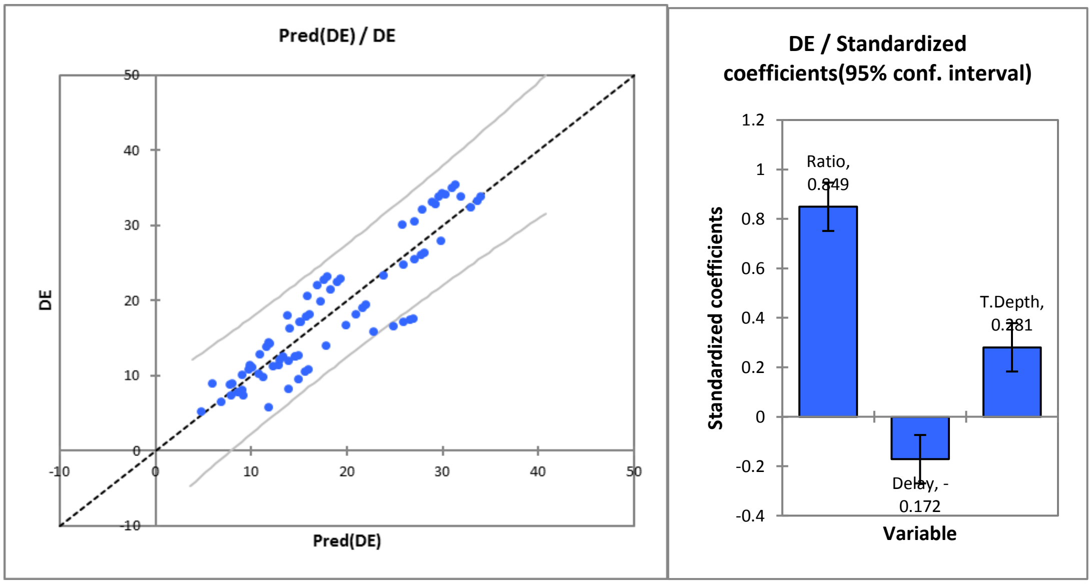


Figure 7 – Region 3 Goodness of Fit between Predictive Equation and Simulation

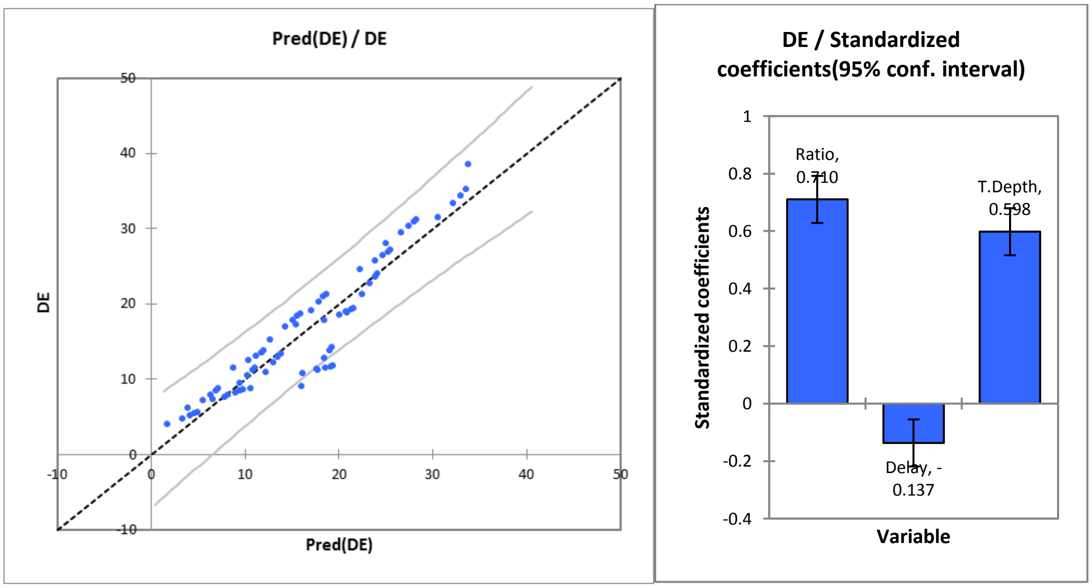


Figure 8 – Region 4 Goodness of Fit between Predictive Equation and Simulation

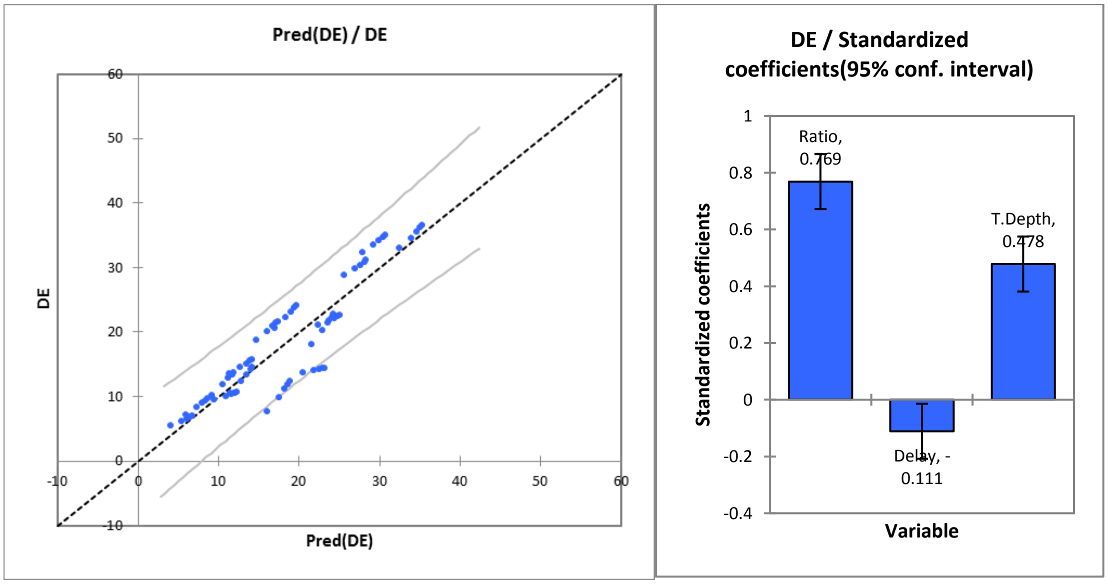


Figure 9 – Region 5 Goodness of Fit between Predictive Equation and Simulation

2.5 EFFECTIVENESS OF WET DETENTION BEST MANAGEMENT PRACTICES

Stormwater wet detention system effectiveness is a function of the watershed runoff and rainfall conditions as well as the average annual residence time. As an example, average annual removal as a function of residence time is shown in Figure 10 for specific watershed and rainfall conditions in meteorological zone 2 with 50 inches of annual rainfall. This relationship is the same general form and the specific shape is dependent on the watershed and rainfall conditions. A delay of hours has negligible effect since residence time is usually greater than 20 days.

The volume of the permanent pool (cubic feet) divided by the average annual runoff volume (cubic feet/year) times the conversion of 365 days per year is the average annual residence time (days). The data used to generate the wet detention effectiveness curve of Figure 10 is a residential catchment area of 2 acres, 50% directly connected impervious area (DCIA), a curve number for the non-DCIA of 84, and with an average annual residence time of 30 days. The average annual runoff is 4.0 Ac-feet /year (from BMPTRAINS). The annual removal of nitrogen and phosphorus is 6.82 and 1.89 pounds per year respectively.

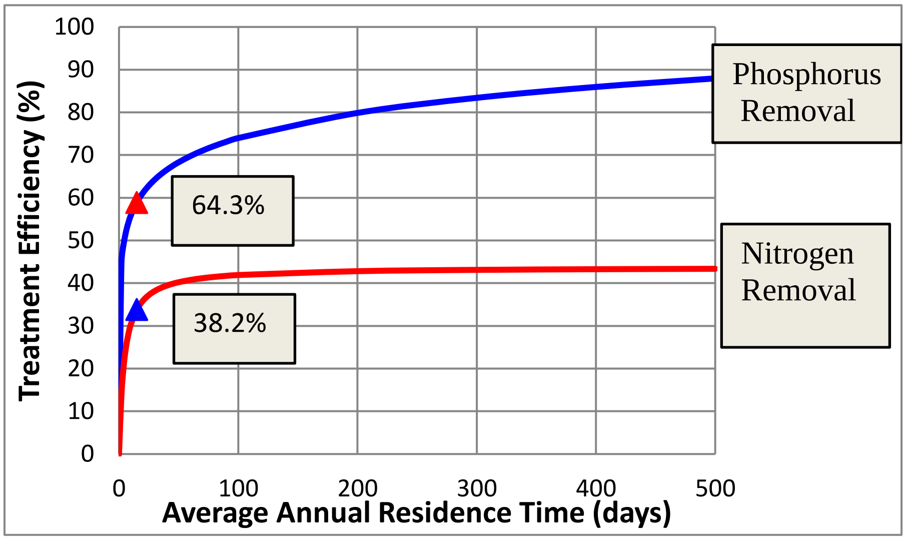


Figure 10 – Wet Detention Pond Effectiveness Onsite Treatment (from BMPTRAINS)

The wet detention effectiveness curve of Figure 11 is a highway catchment area of 4 acres (2 additional offsite acres, no delay), 50% directly connected impervious area (DCIA), a curve number for the non-DCIA of 84, and with an average annual residence time of 15 days. The average annual runoff is 8.0 Ac-feet /year (from BMPTRAINS). The annual removal of nitrogen and phosphorus is 12.10 and 3.46 pounds per year respectively. Thus, the increased pounds per year removed for nitrogen and phosphorus is 5.28 (12.1-6.82) and 1.57 (3.46-1.89).

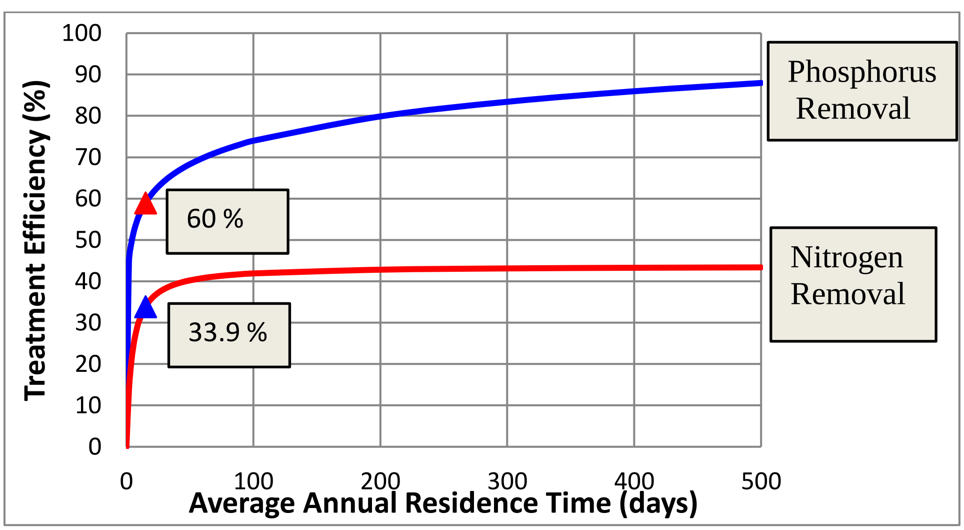


Figure 11 – Wet Detention Pond Effectiveness with offsite flows (from BMPTRAINS)

CHAPTER 3 BEST MANAGEMENT PRACTICES EVALUATION AND DESIGN COMPUTER PROGRAM (BMPTRAINS)

3.1 INTRODUCTION

BMPTRAINS is a program for the analysis and design of stormwater best management practices. The model is used to evaluate **B**est **M**anagement **P**ractice **T**reatment options for **R**emoval on an **A**nnual basis by those **I**nterested in **N**utrients in **S**tormwater. Thus the name, BMPTRAINS and the implied function that BMPs in a train (series) can be evaluated. In addition, BMPs in parallel can be evaluated. The model is based on many field derived sampling programs and simulations conducted primarily within the state of Florida. It is in response to a need to address concerns for the over-enrichment of Florida's lakes, rivers, ground waters, springs and estuaries by nutrients (FDEP, 2010).

To understand the evaluation of comingling or bypass of facilities, required is an understanding of the model capabilities.

3.2 MODEL CAPABILILITIES

BMPTRAINS is an EXCEL based program with visual basic interfaces. It must use EXCEL releases after the year 2007 because of its size. It has over 100 worksheets. In Figure 12, displayed are model introductory information to include printing instructions and credit for development, along with buttons for supplemental training information. The user must remember on this page to enable all macros if the warning appears on this first worksheet. It is a screen capture of the latest (April 12, 2017) version of the program. The program is updated a few times a year to accommodate new research and field sampling results as well as input from the practicing and reviewing professionals. Thus, the screen captures may not always appear within this report as they are in the program.

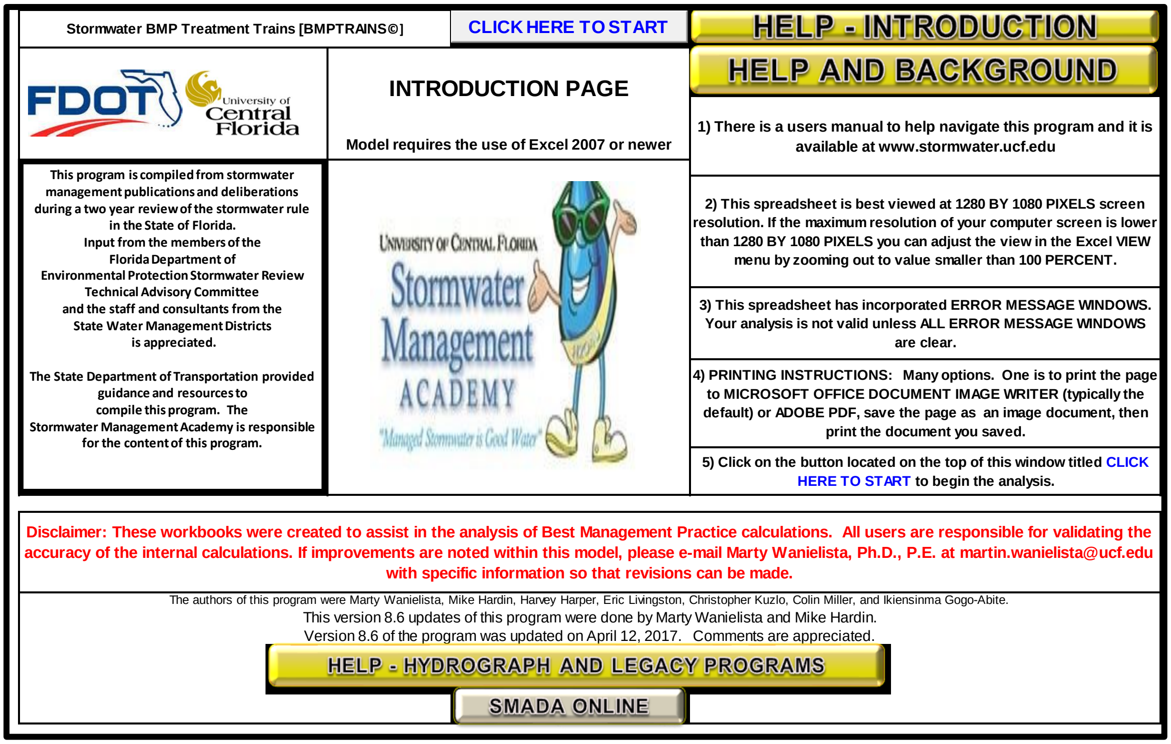


Figure 12 – Introduction worksheet

The calculations in the BMPTRAINS model are based on average annual removal for nitrogen and phosphorus using one or a combination of BMPs. Some of the methodologies for calculation of the nitrogen and phosphorus removal efficiency used in this model are derived from "Evaluation of Current Stormwater Design Criteria within the state of Florida" report published by the state of Florida Department of Environmental Protection, in June 2007 (Harper and Baker, 2007). Others are added as methodologies are approved by the reviewing agencies.

The required removal efficiency that the BMP(s) must achieve is specified in the model. The annual nitrogen and phosphorus loadings are calculated based on average annual runoff volume and Event Mean Concentrations (EMC) for the pre- and post-development conditions. The annual runoff volumes in the BMPTRAINS model are computed based on the project meteorological zone location, watershed area, mean annual rainfall depth, non-DCIA Curve Number, and DCIA percentage input. These parameters are specified in the General Site Information (Figure 13) and Watershed Characteristics worksheets (Figure 14).

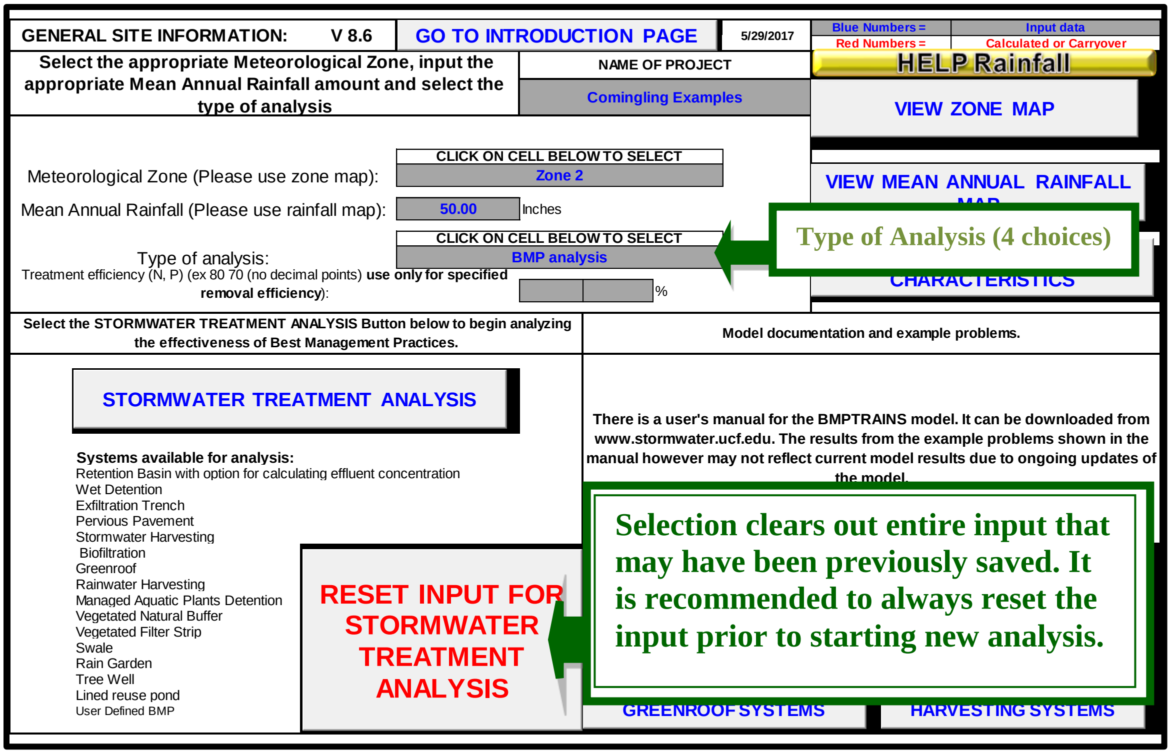


Figure 13 – General Site Information worksheet

The BMPTRAINS model also has the capability of analyzing for user specified removal efficiency. This option is selected using the “Specified Removal Efficiency” selection from the “Type of Analysis” dropdown menu (see Figure 13) on the General Site Information worksheet. In this case, the BMPs are analyzed to see if the specified reduction target is met rather than the removal efficiency found from the difference between the pre-and post- development nutrient loadings. As such, the pre-development condition characteristics are not used in this type of analysis. However, the user can specify this information as the pre-development loading values can be useful in certain analysis (i.e. compensatory treatment analysis). In addition, the user can select the option of 10% lower loadings than pre-development condition that is useful in a redevelopment of lands where it is necessary to show more removal than the pre-condition.

Finally, the BMPTRAINS model is capable of analyzing individual or multiple BMPs to evaluate effectiveness without a target removal. For this type of analysis, the pre development watershed characteristics are not used and do not need to be entered into the model. This type of analysis is useful for evaluating the efficiency of individual or some combinations of BMPs.

Watershed Characteristics

The existing and proposed watershed characteristics are input in the Watershed Characteristics worksheet (Figure 14). The model provides the capability of subdividing the total watershed into four (4) separate catchment areas. This option can be utilized if there is a possibility for a BMP for different catchment areas and are called Low Impact Development (LID) options. However, for one area, three (3) BMPs can be used in series provided there is no additional catchment area runoff between the BMPs. Where there exists multiple soil or ground cover conditions, the GIS option can be used for a catchment. In the Watershed Characteristics worksheet, the user indicates information specific to the watershed area such as non-DCIA Curve Number and DCIA percentage. This is also, where the user indicates EMCs by selecting the land use most appropriately representing the existing and proposed conditions. However, if the built-in selection does not contain a representative land use, or if more appropriate site-specific information is available, the model can accept a user specified EMCs. Land use Characteristics and EMC values are listed in Appendix A.

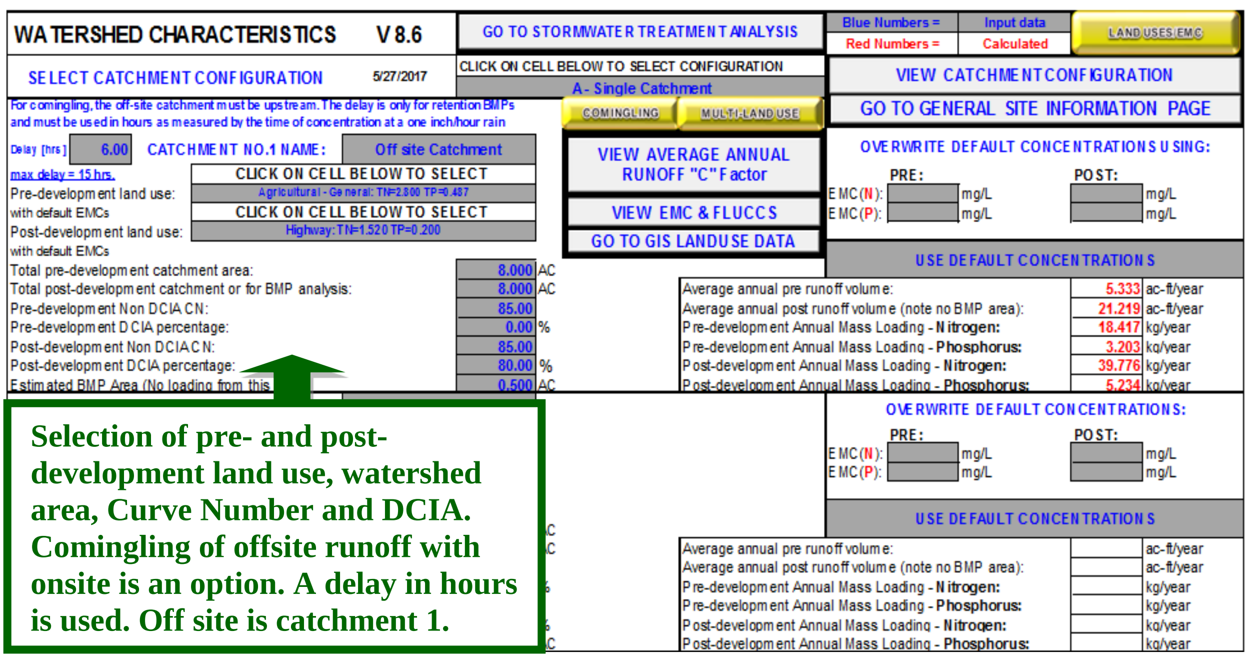


Figure 14 – Watershed Characteristics worksheet

The model also allows for the specification of a configuration of the catchments within a watershed. For example, if there are three catchments in a watershed and two of the catchments are in series and one is in parallel, the model will allow for this selection. Since this model allows for up to four catchments per watershed, each possible combination is presented as a selection. The user is prompted to input the number of catchments at which time all possible configurations will be presented from which the user can choose. It should be noted that if multiple BMPs are used in a watershed they are assumed to be in series, or one after another. If detention and retention BMPs are used within a single catchment, the detention BMP is assumed downstream of the retention BMP. If there is a retention basin downstream of detention, then two catchments are used. Multiple BMPs in parallel are to be treated as different catchments.

3.3 Stormwater Treatment Methods

The Stormwater Treatment Analysis worksheet (see Figure 15) is viewed after the watershed and general site information are added. If BMP analysis option is used, there is no printed target effectiveness as this is the value to be calculated. The catchment configuration must be selected in the watershed characteristics worksheet to proceed to the stormwater treatment analysis worksheet and two catchments in series is selected to analysis the comingling option as displayed in Figure 15.

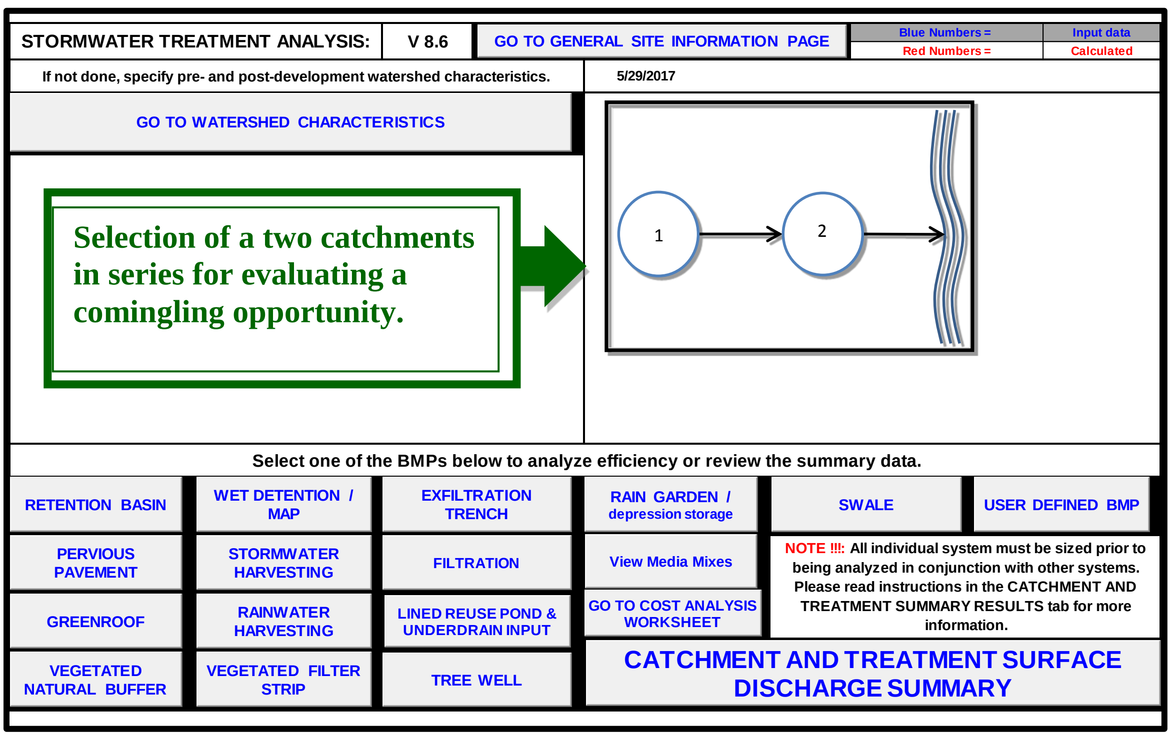


Figure 15 – Stormwater Treatment Analysis worksheet

After viewing the required treatment efficiencies and catchment configuration, the user may proceed to the second part (STEP 2) of the analysis in the Stormwater Treatment Analysis worksheet (Figure 15). The second part of the analysis includes the selection and adequate sizing of the BMP (or combination of BMPs) to meet the required treatment efficiencies. The BMP selections include retention basin, wet detention, exfiltration trench, pervious pavement, stormwater and rainwater harvesting, filtration including biofiltration, greenroof, floating islands with wet detention, vegetated natural buffer, vegetated filter strip, tree well, rain garden, swale, and a user defined BMP. All the BMPs in the BMPTRAINS model are presented because some the offsite annual flow can be affected by the choice of the BMP method. A summary results button is also showed and used once the BMP methods data are selected.

Retention Basin

A retention basin is one of the more popular BMPs used for stormwater treatment. A retention system is a recessed area within the landscape that is designed to store and retain a defined volume of runoff, allowing it to percolate through permeable soils. The volume of basin (cubic feet) divided by the catchment area (square feet) times 12 inches per foot is the runoff volume (expressed as inches). The BMPTRAINS model then adjusts the effectiveness for runoff conditions. A runoff depth less than 4 inches must be used because the removal effectiveness estimates do not exceed 4 inches. Greater than 4 inches retention produces a marginal increase in effectiveness and at 4 inches, the effectiveness is usually greater than 98%.

The effectiveness of the retention system in terms of yearly capture is assessed with the retention efficiency tables published by Harper and Baker (2007). These tables contain a performance efficiency of dry retention as a function of DCIA and NON-DCIA Curve Number. The retention efficiency tables are also applied to other retention systems, namely exfiltration trench, pervious pavement, filtration including biofiltration, swale, vegetated natural buffer, vegetated filter strip, rain garden, depression storage, and tree well.

In the BMPTRAINS model, any retention system can be analyzed in the Retention Basin worksheet (Figure 16). The user can size the system to provide the entire retention volume required to meet the treatment efficiency goal, or the user has an option of specifying a fraction of the required retention volume (under sizing treatment), or additional retention volume (over sizing treatment). The volume of treatment is varied for situations where retention is a part of a treatment train or if compensatory treatment is required due to site constraints.

As in many of the BMP options found in the BMPTRAINS model and in other models, some calculations are assumed to be outside of or before a system is evaluated in the model. As an example, the land when the retention system is placed has to be available to meet the area requirements and the invert elevation specifications. Thus, the model evaluates effectiveness for partial treatment because of area or other physical constraints.

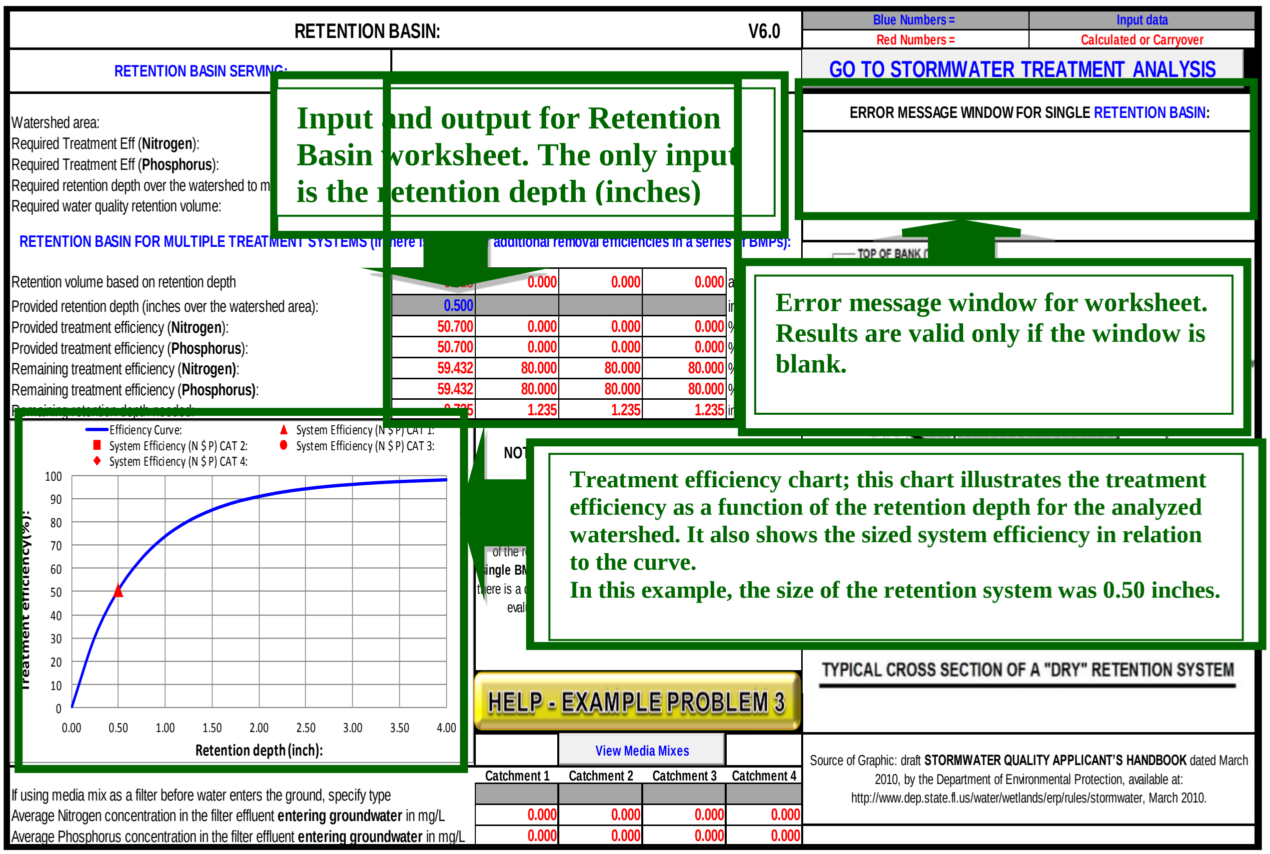


Figure 16 – Retention Basin worksheet

Another useful feature of the Retention Basin worksheet, or any other retention based BMP worksheet, is the retention efficiency chart. The retention efficiency chart illustrates the treatment efficiency of the retention-based system as a function of the retention depth. The properties of the retention efficiency curve are dependent on the post-development watershed characteristics such as non-DCIA Curve Number and DCIA percentage and the rainfall patterns in a rainfall zone. The efficiency of the retention basin sized by the user is shown on the chart as a mark (example would be a red triangle for catchment one). Another purpose of this chart is to illustrate to the user that there is a point of diminishing return as the retention depth is increased. This may enable the user to pursue other treatment options such as treatment trains, cost comparisons and compensatory treatment.

The calculation of effluent or groundwater TN and TP concentrations under a retention basin is available in the Retention Basin worksheet. If no pollution control media mixes are used, the groundwater concentration is assumed equal to the basin concentration. If a pollution control media mix is used, then the groundwater concentration beneath the mix is calculated. There are at least six pollution control media choices commonly acceptable in Florida. User input data are possible. Media effectiveness data are shown in the media mix worksheet. The fraction of nitrogen and phosphorus removed by the ground is set at 30%. The media removes a fraction of the remaining 70%. In addition, an open basin does not capture all of the runoff water for infiltration. Thus, the capture fraction of the yearly volume is multiplied by the removal.

Exfiltration Trench

Another commonly used form of retention BMP is an exfiltration trench. An exfiltration trench is a subsurface retention system consisting of a conduit such as a perforated pipe surrounded by aggregate which temporarily stores and infiltrates the runoff water (Wanielista and Yousef, 1993). This pipe can also be used with a pollution control media mix (see Table 2 for a listing of currently acceptable mixes. The pore space in the rock surrounding the pipe is used to calculate the storage of water as well as the open space within the pipe.

There are many useful pollution control mixes. The choice of the mix depends on the availability, local preferences, effectiveness, and cost. Table 2 shown commonly (June, 2017) used media mixes. For comingling facilities in exfiltration, those marked by ○→● can be used.

Table 2 - Examples of Pollution Control Media Mixes

DESCRIPTION OF MEDIA		PROJECTED TREATMENT PERFORMANCE *			TYPICAL OPERATING LIMITING FILTRATION RATE (in/hr)
Media and Typical Location in BMP Treatment Train	**MATERIAL**	**TSS REMOVAL EFFICIENCY**	**TN REMOVAL EFFICIENCY**	**TP REMOVAL** EFFICIENCY**	
B&G ECT (ref A) A first BMP, ex. Up-Flow Filter in Baffle box and a constructed wetland[#] (USER DEFINED BMP)	Expanded Clay[2] Tire Chips[1]	70%	55%	65%	96 in/hr
B&G OTE (ref A,B) Up-flow Filter at Wet Pond or Dry Basin Outflow (FILTRATION)	Organics[8] Tire Chips[1] Expanded Clay[4]	60%	45%	45%	96 in/hr
B&G ECT3 (ref C) After Wet Detention using Up-flow Filter	Expanded Clay[4] Tire Chip[1]	60%	45%	45%	96 in/hr
SAT (ref D) A first BMP, as a Down-flow Filter (FILTRATION)	Sand[3]	85%	30%	45%	2 in/hr
B&G CTS (ref E,F) Down-Flow Filters **12"** depth*** at wet pond or dry basin pervious pave, tree well, rain garden, swale, and strips	Clay[6] Tire Crumb[5] Sand[7] & Topsoil[9]	90%	60%	90%	1.0 in/hr
B&G CTS (ref E,F) Down-Flow Filters **24"** depth*** at wet pond or dry basin pervious pave, tree well, rain garden, swale, and strips	Clay[6] Tire Crumb[5] Sand[7] & Topsoil[9]	95%	75%	95%	1.0 in/hr

NOTES [#]No generally accepted BMP at this time. Also can be used as a donwstream BMP but the removal must be lowered.
*All Effectiveness Estimates to nearest 5%: **Phosphorus removal has limited life expectancy. ***24" depth has TN and TP removals of 75 & 95%
acronyms B&G - BOLD & GOLD; SAT - Sand Austin Tx; ECT- Expanded Clay and Tire; ECT3 Expanded Clay and Tire in Treatment Train
[1] Tire Chip 3/8" and no measurable metal content (approximate dry density = 730 lbs/CY)
[2] Expanded Clay 5/8 and 3/8 blend (approximate dry density = 950 lbs/CY)
[3] Sand ASTM C-33 with no more than 3% passing # 200 sieve (approximate dry density = 2200 lbs/CY)
[4] Expanded Clay 3/8 in blend (approximate density = 950 lbs/CY)
[5] Tire Crumb 1-5 mm and no measurable metal content (approximate density = 730 lbs/CY)
[6] Medium Plasticity typically light colored Clay (approximate density = 2500 lbs/CY)
[7] Sand with less than 5% passing #200 sieve (approximate density = 2200 lbs/CY)
[8] Organics: Either compost (approximate density of 700 lbs/CY) Class 1A Compost or wood chips (sawdust) without pesticides
[9] Local top soil is used over CTS media in dry basins, gardens, swales and strips, is free of roots & debris but is not used in other BMPs.

A - Demonstration Bio Media for Ultra-urban Stormwater Treatment, Wanielista, et.al. FDOT Project BDK78 977-19, 2014
B - Nutrient Reduction in a Stormwater Pond Discharge in Florida, Ryan, et al, Water Air Soil Pollution, 2010
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

Just as with the retention basin, the nutrient removal performance of the exfiltration system is estimated from retention efficiency charts (Harper and Baker, 2007). The user also has an option of sizing the system to the required removal efficiency or design to another size. The Exfiltration Trench worksheet (Figure 17). Also contains a retention efficiency chart with the designed system displayed on the curve. An additional feature included with the worksheet is a simple exfiltration trench volume calculator which allows the user to calculate a retention volume provided by the system based on the specified dimensions.

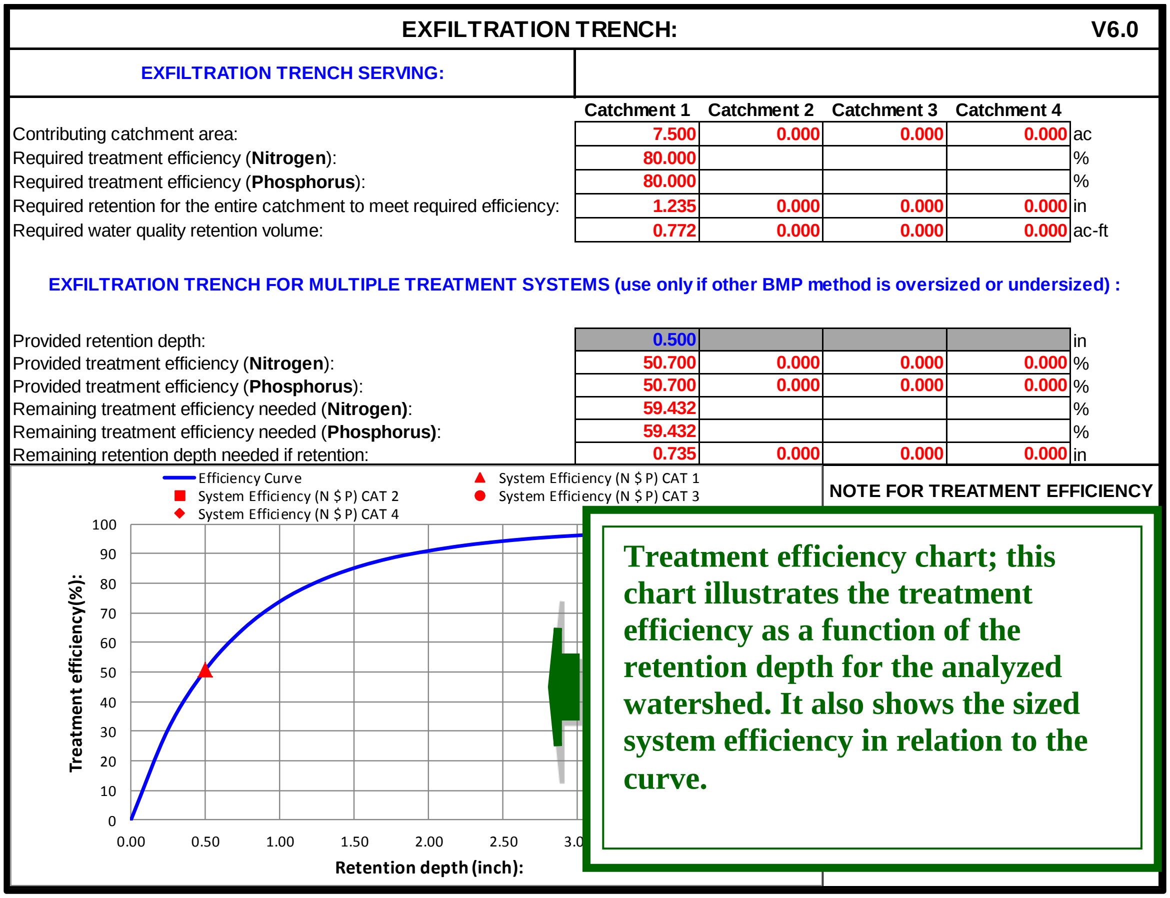


Figure 17 – Exfiltration Trench worksheet

Pervious Pavement

Pervious pavement is another form of a retention system that is available for analysis in the BMPTRAINS model. Pervious pavement systems include the sub-base and 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 (Draft statewide Stormwater Treatment Rule Development, FDEP 2010).

Similarly, to the other retention systems, the nutrient load reduction of the pervious pavement system is calculated based on the retention efficiency tables. However, unlike the retention basin or exfiltration trench, the pervious pavement system retention volume is not automatically sized for the user. Instead, the user must indicate appropriate parameters of the pervious pavement system based on which the treatment efficiency is calculated. The user is alerted by a message whether or not the system is adequate to meet the required treatment efficiency. If the system is not adequate, the pervious pavement system can be used in series with other BMP(s).

The input parameters include the dimension of the individual layers, operational void space of the individual layers and area of the pavement system. The Pervious Pavement worksheet (Figure 18) has a selection of pervious pavement sections and sub-base materials with their appropriate operational void space values built in. These values were obtained from the "Porosity and Curve Numbers for Pervious Pavement Systems" technical memorandum published by the University of Central Florida (UCF) Stormwater Management Academy (SMA). The user may also use other products that are not available in the model's selection. In order to do so, the user must provide operational void space information of the products used in the analysis.

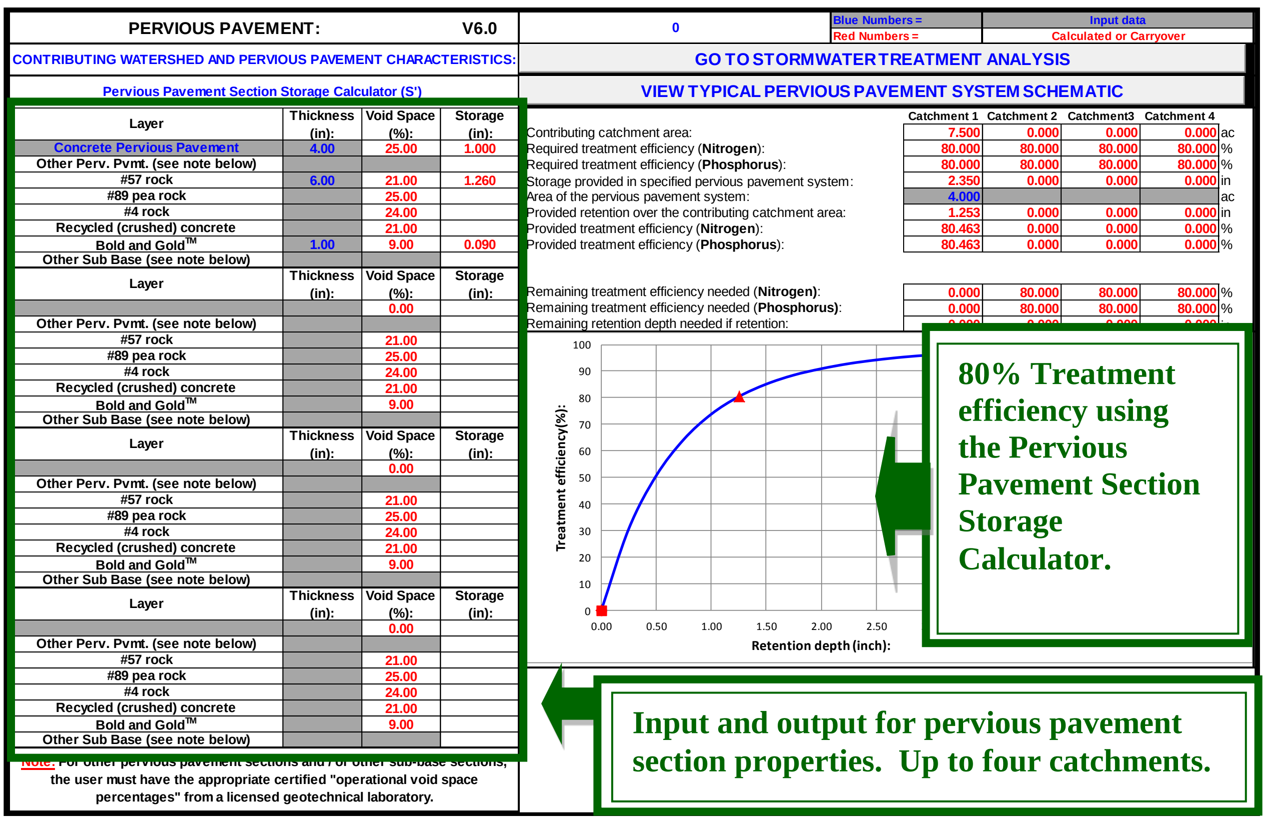


Figure 18 – Pervious Pavement worksheet

Wet Detention

Wet detention is defined by a permanent wet pool. The pond is designed to release a portion of the collected stormwater runoff through an outlet structure (Draft Statewide Stormwater Treatment Rule Development, FDEP 2010). Wet detention ponds are a popular BMP option in areas where groundwater conditions do not allow for infiltration-based systems.

Wet detention systems are available for analysis in the BMPTRAINS model. The effectiveness assessment of wet detention systems in the model is based on the residence time efficiency equations published by in 2007. In this study, a linear regression analysis was conducted to evaluate relationships between removal of nitrogen and phosphorus as a function of residence time within wet ponds (Harper and Baker, 2007).

In the BMPTRAINS model, the user can analyze wet detention system by indicating the average annual residence time that the system will provide. By indicating the residence time, the model will compute the required minimum permanent pool volume that the wet detention system will have to provide. The size of the minimum permanent pool volume is dictated by the average annual residence time as well as the volume of annual runoff to the pond.

In the BMPTRAINS model, wet detention ponds can be analyzed in the Wet Detention/MAP (Figure 19), worksheet and with the option of having a littoral zone or a floating wetland. In addition to the residence time, the user has an option of specifying an efficiency credit associated with the littoral zone. The littoral zone is that portion of a wet detention pond that is designed to contain rooted aquatic plants (Draft Statewide Stormwater Treatment Rule Development, FDEP 2010). With the Floating Wetlands option in the Wet Detention worksheet the user may take credit for the use of Managed Aquatic Plant Systems (MAPS) in the design. MAPS are aquatic plant-based BMPs, which remove nutrients through a variety of processes related to nutrient uptake, transformation, and microbial activities. It is recommended to assign a 10% removal of the remaining concentration when using floating wetland mats.

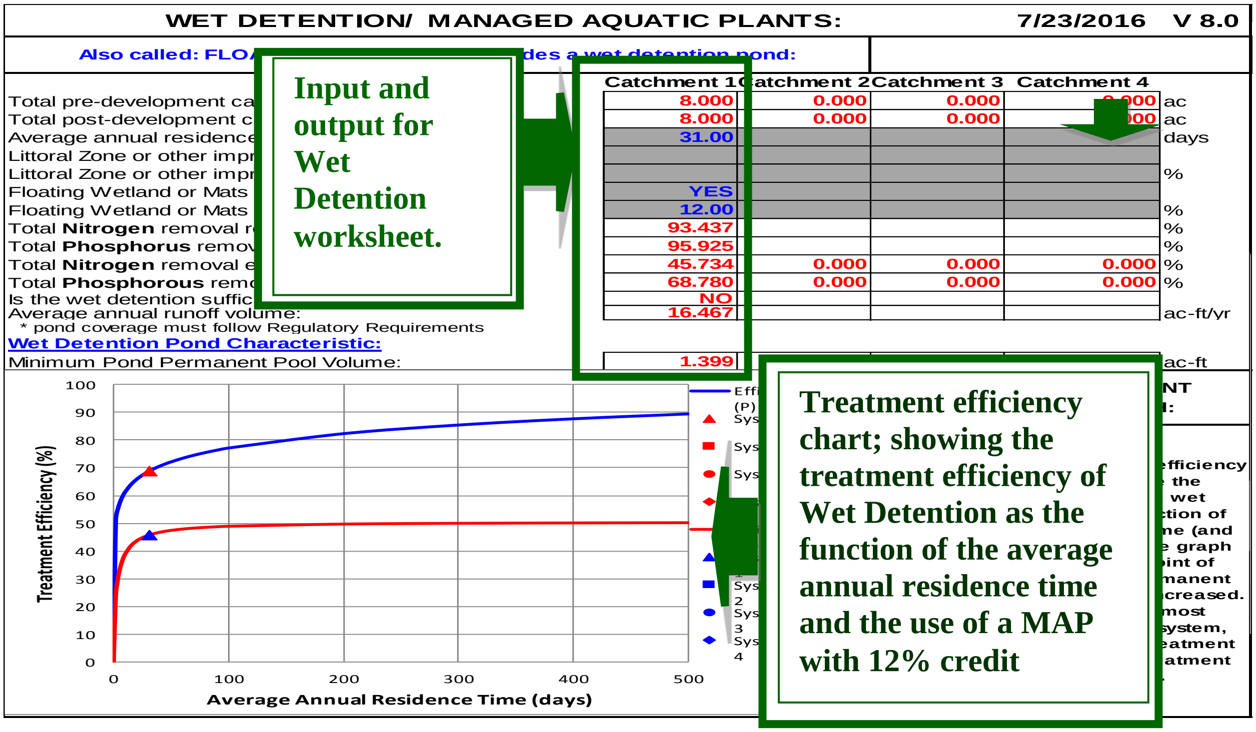


Figure 19 – Wet Detention worksheet

Just as with the retention BMP worksheets, the Wet Detention and Floating Island with Wet Detention worksheets contain treatment efficiency charts. These charts illustrate the treatment efficiency of the wet detention systems as a function of the average annual residence time. The efficiency curves for nitrogen and phosphorus removal are adjusted based on the littoral zone and MAPS credit entries. Typical credits for both littoral and floating wetlands is 10% (removal) of the remaining concentration.

It should be noted that the initial treatment efficiency achieved is due to settling of particles and therefore will not be achieved if the wet detention system receives water from another BMP, i.e. is downstream of another BMP that removes some of the particulate matter. For cases where this is true, the achieved treatment efficiency is reduced by 30% for nitrogen and 55% for phosphorus. The purpose of the removal efficiency chart as a function of permanent pool (residence time) is to illustrate to the user that there is a point of diminishing return as the residence time (and permanent pool volume) is substantially increased. This may enable the user to pursue other treatment options such as additional treatment train BMPs or compensatory treatment.

Stormwater and Rainwater Harvesting

Stormwater harvesting collects runoff from ground level, while rainwater harvesting is used for roof runoff. They are considered cost-effective methods for pollution control, because the water in many cases can be sold to offset the cost of maintenance and operation. Stormwater harvesting uses treated stormwater before it is discharged to surface waters, thus reducing the stormwater volume and mass of pollutants discharged (Wanielista et al., 1991). Stormwater harvesting is an option to improve mass removal from a wet detention pond. Floating islands (wetlands) is another option.

In the BMPTRAINS model, water harvesting can be analyzed in the Stormwater Harvesting and Rainwater Harvesting worksheets. The pollution removal of the water harvesting systems is assessed with the Rate-Efficiency-Volume (REV) curves. The REV curves were developed by long-term mass balance simulations of harvesting ponds. Curves reflecting several efficiencies track the appropriate combinations of reuse rates and reuse storage volumes (Wanielista et al., 1991).

The user may use Stormwater (Figure 20) and Rainwater Harvesting worksheets to size the system for the desired harvest efficiency or harvest rate. The Stormwater Harvesting worksheet is more appropriate for watersheds that consist of pervious and impervious areas. As such, the user must indicate the representative Runoff Coefficient of the analyzed watershed. The Rainwater Harvesting worksheet is appropriate for watersheds that consist entirely of impervious areas (roof, pavement, etc.). This worksheet has built in selections of different types of impervious areas based on which the appropriate Runoff Coefficient is utilized in the calculations. The Runoff Coefficient values for the impervious surface selections were obtained from the study conducted by Wanielista et al. (2011) entitled "Evaluating Runoff and Abstraction from Impervious Surfaces as Components Affecting Recharge". Additional required inputs include indication of the watershed area contributing to the harvesting system and area available for irrigation.

The user has two calculation options available. In the first option, analysis is performed to solve for the harvest rate. This option involves indication of the available harvest volume and the desired harvest efficiency. The second option allows solving for harvest efficiency. With this selection, the user must indicate the provided harvest volume and harvest rate.

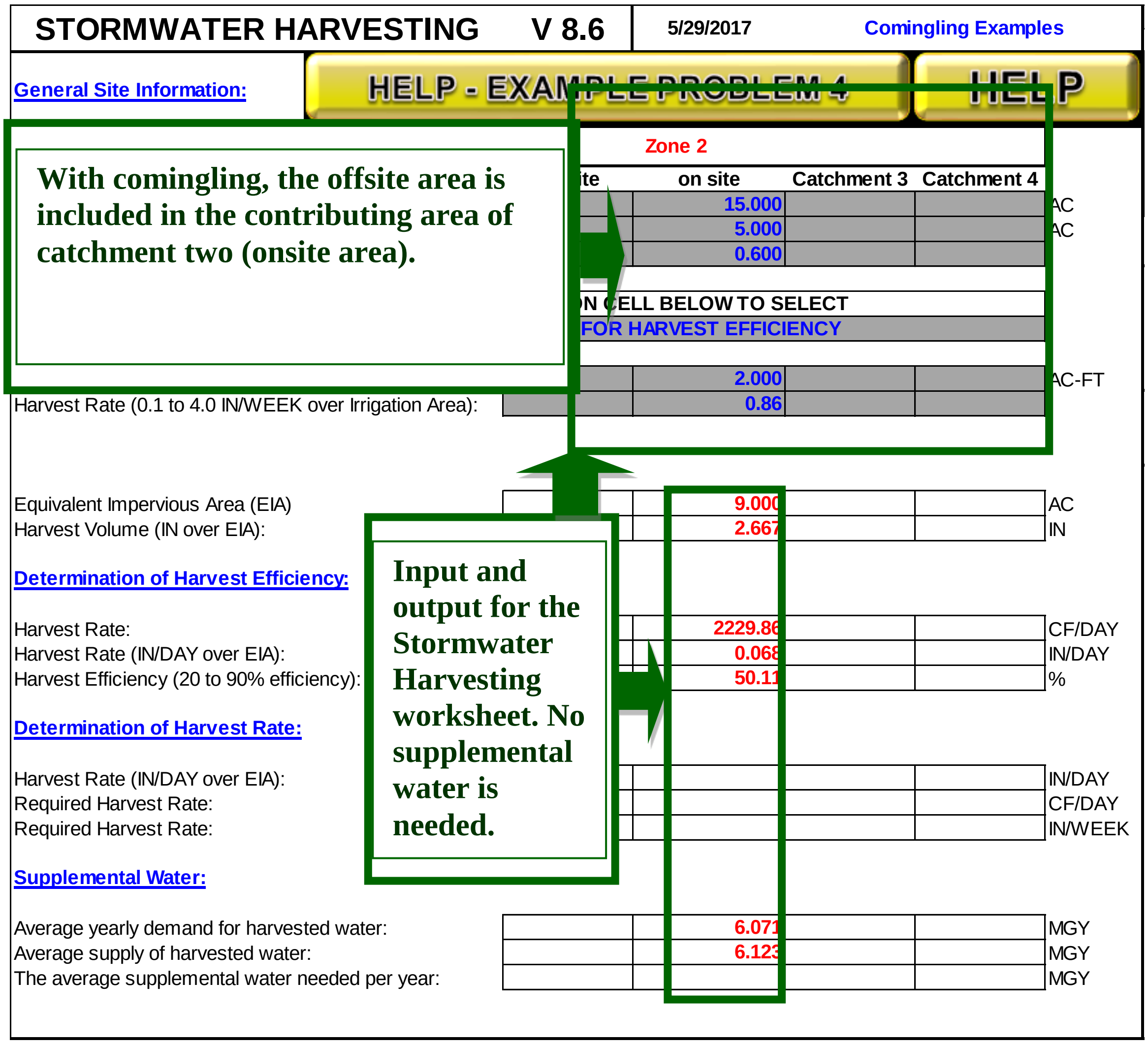


Figure 20 – Stormwater Harvesting worksheet

Floating Islands (Wetlands)

Floating islands are a combination of plants floating in a wet detention pond. The island plants, roots and associated organisms reduce nitrogen and phosphorus concentrations (Wanielista, et al., 2012) and thus the mass of nitrogen and phosphorus are reduced in the discharge. The wet detention pond has to be designed according to the specifications listed above. Usually a credit of 10% removal of the remaining concentration is given for mass reduction when the floating wetland is designed to occupy about 10% of the surface area and the plants are maintained. Credit up to 12% may be granted in rare situations. Maintenance is at least once per year and usually consists of replacing plants and removing unwanted plants. The usual design calls for a floating mat with plants distributed around the pond in the direction of primary water movement (Chang, et al., 2012). There is a separate entry on the worksheet for input data related to design of the floating wetland as well as input data for a littoral zone. The littoral zone area and slopes of the pond banks have to be consistent with regulatory requirement.

Filtration

Filtration is done to enhance the removal of nitrogen and phosphorus after retention or after wet detention. The removal is enhanced with the use of Biosorption Activated Media (BAM) used at the bottom of a retention basin or in an up-flow filter after wet detention. It is an option in basins where soil conditions do not allow for a successful drainage or an infiltration rate. Filtration systems can be used to both control the water table elevation over the entire area of the treatment basin, and provide for the drawdown of the treatment volume. Filtration is also used for onsite retention BMPs such as tree wells, exfiltration pipes and rain gardens.

Filtration systems in the BMPTRAINS model are sized with the help of the retention efficiency tables. However, the retention efficiency tables are only utilized to assess the hydraulic annual average capture efficiency of the filter. The hydraulic capture efficiency is directed through a filter and is calculated based on the retention depth stored in the basin or pond below a weir crest. The calculated hydraulic capture efficiency is then adjusted based on the type of pollution control media mix used in the design. This adjustment quantifies the nutrient removal efficiency of the filter.

The input parameters for the Filtration worksheet (Figure 21) include the maximum hydraulic capture (retention depth) and the selection of media used for pollution control. The specification of retention depth is used to calculate the hydraulic capture efficiency and the selection of the media yields annual phosphorus and nitrogen removal efficiencies of the filter. In this case, an up-flow filter is used after a wet detention pond as noted in Figure 21.

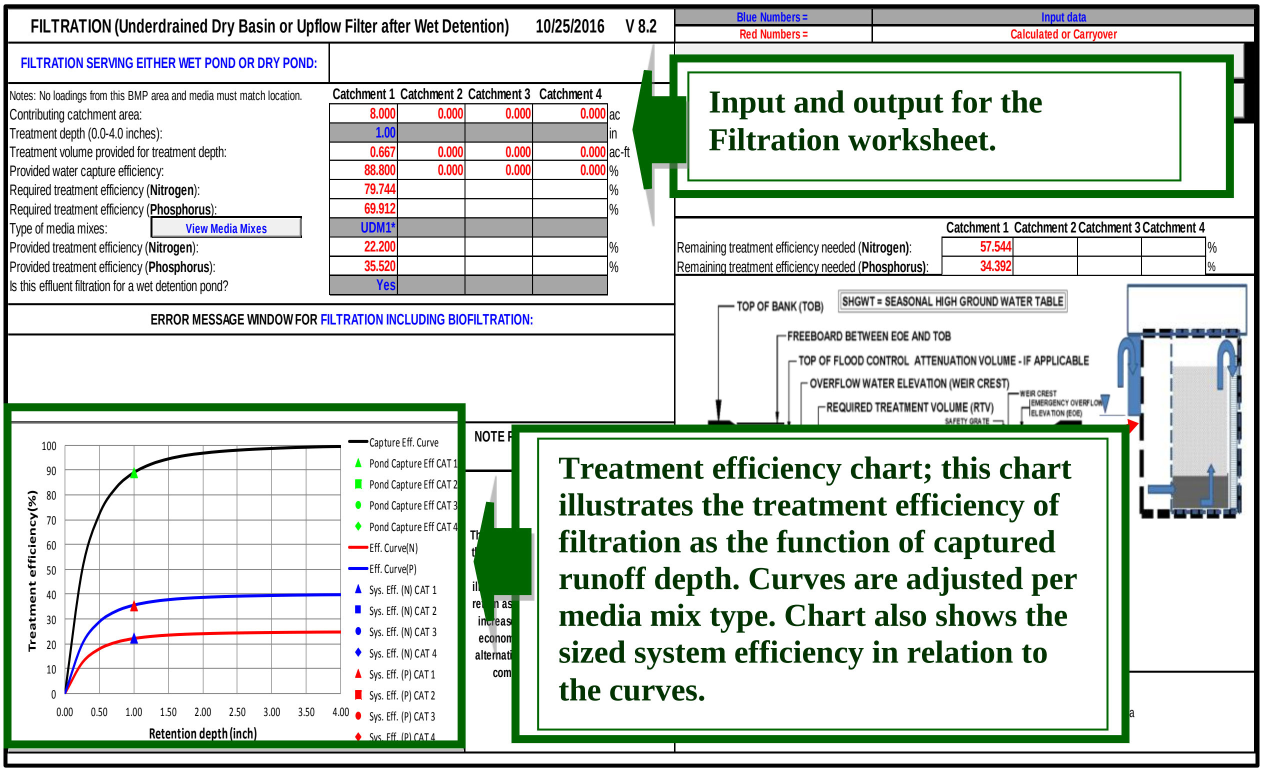


Figure 21 – Filtration worksheet

The Filtration worksheet contains a treatment efficiency chart of the system (Figure 21). Similar to the other BMP worksheets, this chart illustrates the treatment efficiency of the filtration including biofiltration systems as a function of the retention depth. The chart contains curves for hydraulic capture efficiency, nitrogen removal efficiency and phosphorus removal efficiency. The efficiency curves are adjusted based on the media selection. The performance efficiency of the sized system is also shown on each curve.

The worksheet also contains a window displaying additional required treatment efficiencies if the system is not adequate. These values can be used as guidance in sizing of the preceding treatment system. The worksheet also contains an error message window alerting the user about issues with the analysis.

Greenroof

A Greenroof while not a part of a highway is a LID BMP option that can be utilized for the offsite areas where there is a lack of space for typical retention/detention ponds. Every option should be evaluated and thus included in this discussion. A greenroof/cistern stormwater treatment system is a vegetated roof followed by storage in a cistern for the filtrate that is reused. A greenroof/cistern system functions similar to a retention BMP in that captured rainwater is available for evapotranspiration and effectiveness is directly related to the annual volume of roof runoff that is captured (Hardin, 2006).Users can analyze the runoff volume and pollution reduction benefits of the greenroof systems in the Greenroof worksheet (Figure 22). The effectiveness of the greenroof/cistern system in the model is assessed with the greenroof harvesting efficiency charts. The effectiveness design graphs showed that a specifically designed greenroof stormwater treatment system with a cistern is an effective way to reduce both the volume of and mass of pollutants in stormwater runoff (Hardin, 2006). The design graphs have been developed for several locations in the state of Florida.

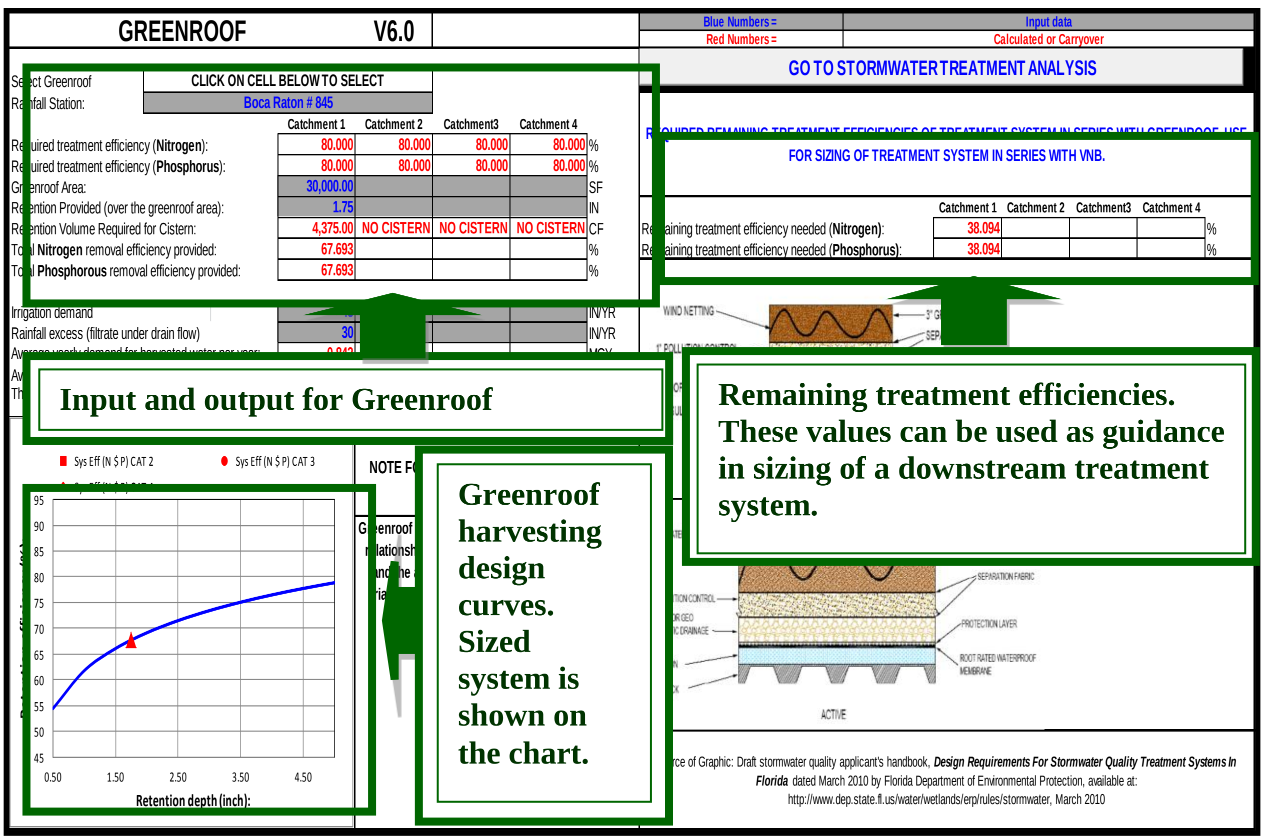


Figure 22 – Greenroof worksheet

To analyze a greenroof/cistern stormwater treatment system in the BMPTRAINS model, the user must select the closest rainfall station to the project site. In addition, the user must indicate the area of the greenroof and retention depth over the greenroof area provided by the associated cistern. If the design does not include a cistern, the area and retention depth inputs do not need to be specified. The result of the calculations is the runoff volume reduction efficiency of the system and required cistern volume (if retention depth is indicated).

Additional features of the Greenroof worksheet include typical greenroof cross-sections and the greenroof/cistern volume reduction efficiency chart. The analyzed greenroof system efficiency is displayed on the chart. The worksheet also contains a window with remaining treatment efficiency values for undersized greenroof systems.

Vegetated Natural Buffer and Vegetated Filter Strip

Vegetated natural buffers (VNBs) are defined as areas with vegetation suitable for nutrient uptake and soil stabilization that are set aside between developed areas and a receiving water or wetland for stormwater treatment purposes (Draft Statewide Stormwater Treatment Rule Development, FDEP 2010).

VNBs as stormwater BMPs can be valuable in areas where construction of ponds, swales, exfiltration trenches or other systems can be difficult or impossible due to site constraints. VNBs could also be a valuable part of a BMP treatment train for road projects and other development.

In the BMPTRAINS model, VNBs can be analyzed in the Vegetated Natural Buffer (Figure 23) and Vegetated Filter Strips (VFS) worksheets. VNBs and VFSs can be analyzed as retention or detention systems. The difference between VNBs and VFSs is that the VNB design contains natural soil while VFSs contain augmented soil (pollution control media).

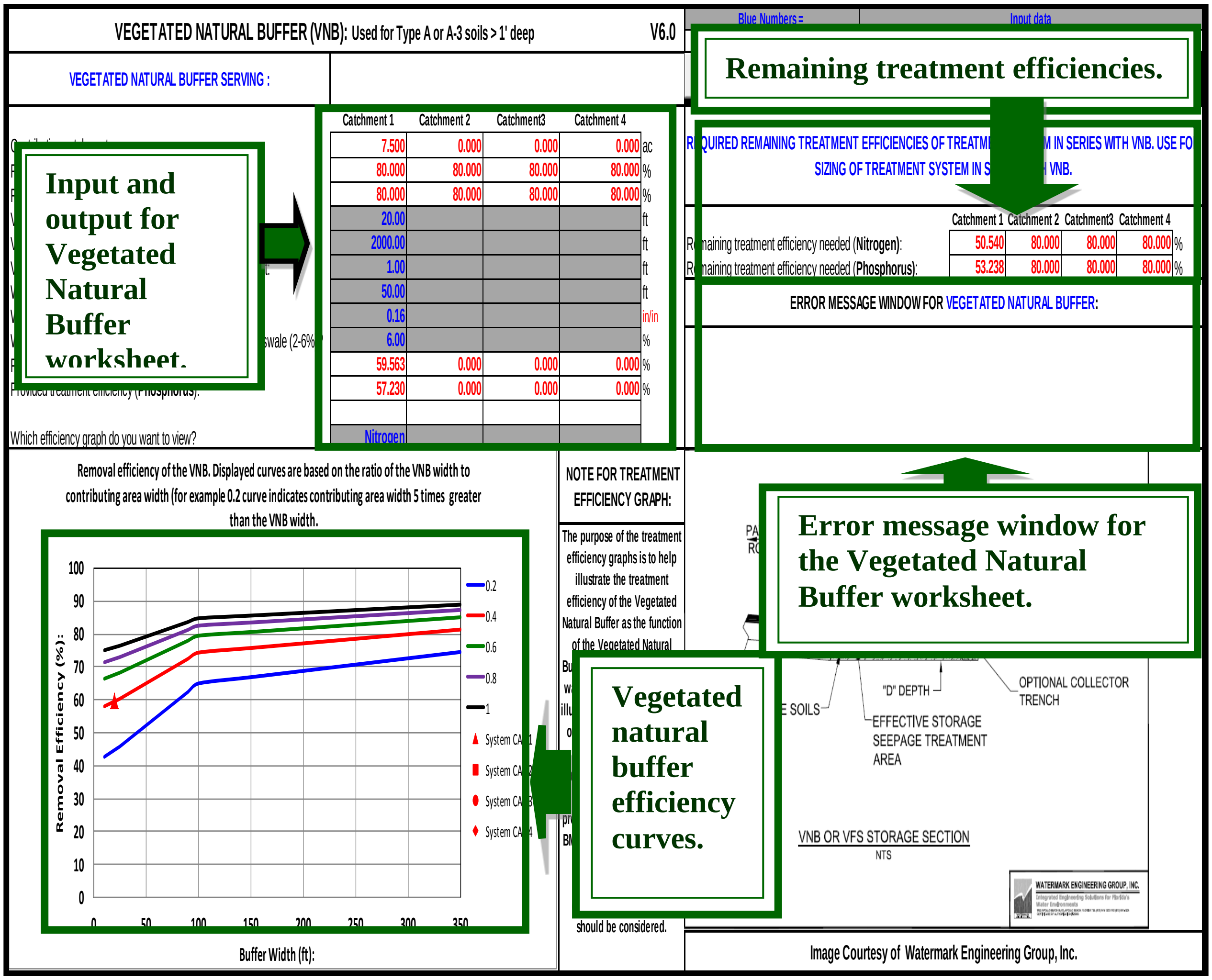


Figure 23 – Vegetated Natural Buffer worksheet

VNBs and VFSs are analyzed using different methodologies in the BMPTRAINS model for the nutrient load removal efficiency. Therefore, it is important for the user to recognize which option most accurately reflects the designed system. In the retention option, the nutrient load reduction performance is evaluated based on the retention efficiency tables. This is appropriate for a system in which runoff percolates in to the groundwater table. In the detention option, the efficiency of the VNB or VFS is analyzed based on the seepage flow removal efficiency. This option is appropriate for VNB or VFS systems where runoff is drained by underdrain collector systems (or other equivalent system). In addition, in all cases efficiency is adjusted for the overland flow effects.

The input parameters for the VNB and VFS BMP worksheets include the buffer (filter strip) width, length, and storage depth, storage capacity of the soil/media within the system and width of the area feeding the system. The user must also indicate whether the analyzed BMP is a retention or detention system. In addition, the VFS worksheet requires a type of media mix if the detention system option is selected.

The VNB and VFS worksheets are also equipped with treatment efficiency chart. This chart contains curves, which show the treatment efficiency of the VNB (VFS) as the function of system width. In addition, since the width of the contributing area affects the performance of the system, each chart contains five separate curves, which are plotted based on the different width ratios of the system to the contributing area. The chart displays system efficiency based on the specified input.

Swale

Swales transport and infiltrate stormwater while encouraging accumulation within an area during storm events. The water is held for a few hours or days with infiltration into the soil. Swales are online retention systems and their treatment effectiveness is directly related to the amount of the annual stormwater volume that is infiltrated (Draft Statewide Stormwater Treatment Rule Development, FDEP 2010).

The BMPTRAINS model contains a worksheet (Figure 24) which can analyze the runoff volume reduction efficiency of swales. The calculation of runoff volume reduction efficiency, and associated nutrient load, is based on the annual runoff volume of stormwater that is retained in the swale and not discharged downstream. Unlike with other retention-based worksheets, the annual runoff volume of stormwater that is not discharged downstream includes the runoff volume infiltrated due to flow in the swale and runoff volume retained due to a ditch or swale block. The calculated infiltration in swale is based on the equations presented by Wanielista and Yousef (1993) in the “Stormwater Management” publication. The combined retained and infiltrated runoff depth is used to calculate the efficiency of the swale with the application of retention efficiency tables (Harper and Baker, 2007).

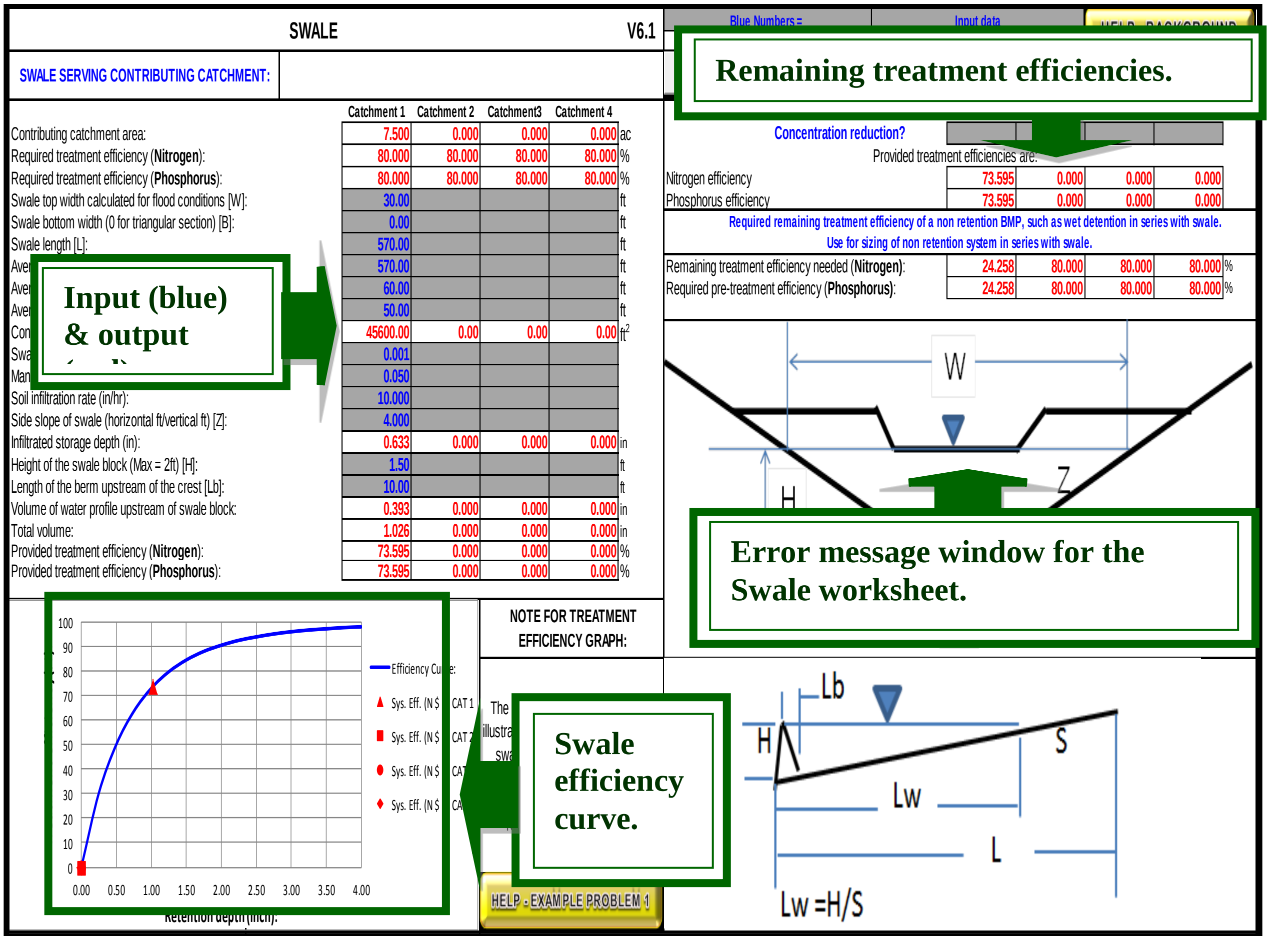


Figure 24 – Swale worksheet

The required input information in the Swale worksheet includes the width of the swale, width of the watershed contributing to the swale, length of the swale, length of the watershed contributing to the swale, swale dimensions and soil properties. The combined area of the swale and area contributing to the swale must be equivalent to the post-development watershed area from the Watershed Characteristics tab. The worksheet output includes infiltration depth, retention depth, and associated runoff reduction efficiency.

The additional features of the Swale worksheet include swale diagram and runoff volume reduction efficiency chart. Just like in other BMP worksheets, the efficiency of the sized swale is shown on the chart. In addition, the worksheet contains an error message window communicating possible errors with the analysis to the user. The worksheet also contains a window with calculated remaining treatment efficiency values for swales, which are not sufficient to provide entire required treatment.

Rain Garden

Rain gardens provide a combination of landscape esthetics and water quality treatment functionality. A rain garden can be a retention or infiltration area. In addition, if under-drained, a rain garden can function as a detention area. They are usually found in depression areas and are usually have natural plants. Typically, it is a small garden, which is designed to withstand the extremes of moisture and concentrations of nutrients, particularly Nitrogen and Phosphorus, which are found in stormwater runoff (Low Impact Development Center, 2011).

In the BMPTRAINS model, rain gardens can be analyzed as retention or detention systems. Retention rain gardens are systems where the entire retention depth is infiltrated into the groundwater table. In the model, these types of systems are analyzed just like other types of retention systems. The nutrient reduction efficiency of the system depends on the provided retention depth, which determines the annual capture volume.

The detention rain garden systems effectiveness is dependent on the capture effectiveness and the media used to remove the pollutants. First, the hydraulic capture efficiency of the rain garden is calculated based on the retention depth stored. The calculated hydraulic capture efficiency is then adjusted based on the type of media mix used in the design. This adjustment quantifies the nutrient removal efficiency of the detention rain garden system.

The input parameters for the Rain Garden worksheet (Figure 25) include the retention depth provided by the system and selection of whether the analyzed garden is a retention or detention system. The indicated retention depth is used to calculate the hydraulic capture efficiency. If the detention option is selected, in addition to the retention depth, the user must select the media used. Based on the media mix selection, the model will calculate the annual phosphorus and nitrogen removal efficiencies of the system.

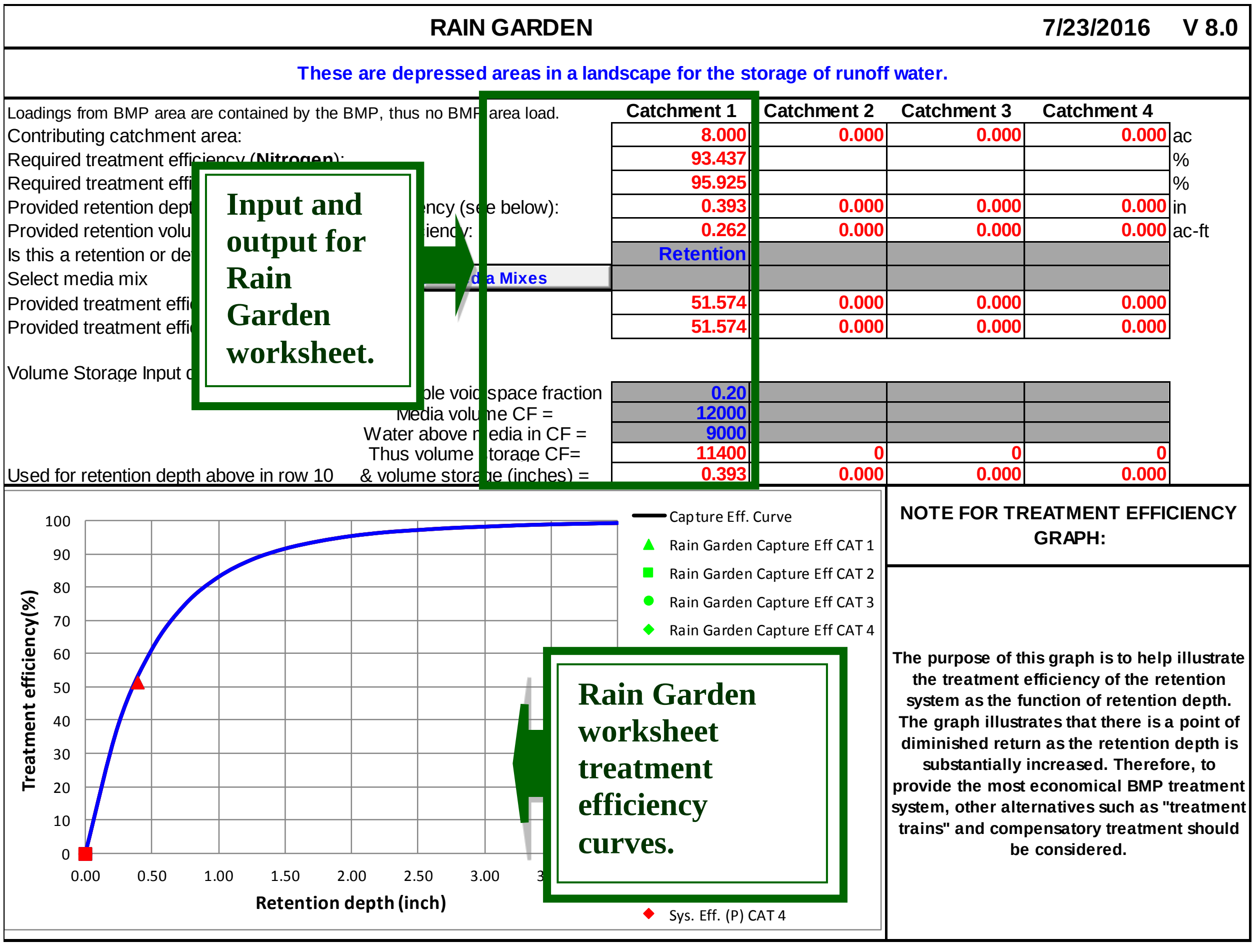


Figure 25 – Rain Garden (a.k.a. Depression Storage) worksheet

In addition to the calculated nutrient removal efficiencies, the Rain Garden worksheet includes a treatment efficiency chart with an error message window and calculated remaining treatment efficiencies.

Tree Well

Tree Wells provide a combination of landscape esthetics and water quality treatment functionality. Tree wells are depression areas with media mixes that support vegetation. The typical vegetation used is a tree. During a rain event, runoff water is directed to and across the top of the tree well area and resulting in storage of runoff water in a depth below the tree well area. The soil is a media mix that supports vegetation growth and provides storage of the runoff water (determined based on the media's porosity). The storage volume is, in general, relatively small for each tree well, but when many tree wells are used for one catchment, the storage can be significant. In many cases, the addition of trees adds to the beauty of the landscape as well as provide for runoff storage. In dense urban areas, a grate is frequently used to eliminate trip hazards (equal the elevation of the surface path ways) or a "filler" mix of rock/mulch/or rubber chips may be used.

In the BMPTRAINS model, tree wells can be analyzed as retention or detention systems. Retention tree wells are systems where the entire retention depth is infiltrated into the groundwater table. In the model, these types of systems are analyzed just like other types of retention systems. The nutrient reduction efficiency of the system depends on the provided retention depth.

The detention tree well systems is analyzed in the model similar to the analysis performed for a rain garden. First, the hydraulic capture efficiency of the tree well is calculated based on the retention depth stored. The detained water discharge elevation is usually above an elevation where backwater will not affect the rate of discharge. If the rate of discharge is affected by the downstream surface water (like floodwater in a sewer adjacent to a tree well), then the storage within the tree well will have to be reduced. The calculated hydraulic capture efficiency is then adjusted based on the type of media mix used in the design. This adjustment quantifies the nutrient removal efficiency of the detention tree well system.

The input parameters required to estimate the storage for tree wells is the volume of the media mix, the volume of the "filler" mix with sustainable porosity and the clear volume above the mixes (Figure 26). The porosity of the media mix is usually around 0.16 to 0.25. For most designs, there is a volume of clear storage above the media and "filler" mix and an elevation equal to a paved surface (or other discharge device) elevation when no more water will enter into the tree well. When this clear storage is filled, runoff water will be diverted to a downstream area. That downstream area is frequently referred to as a flood control structure. The indicated retention depth is used to calculate the hydraulic capture efficiency. If the detention option is selected, in addition to the retention depth, the user must select the adsorption media used for a media mix. Based on the media mix selection, the model will calculate the annual phosphorus and nitrogen removal efficiencies of the system.

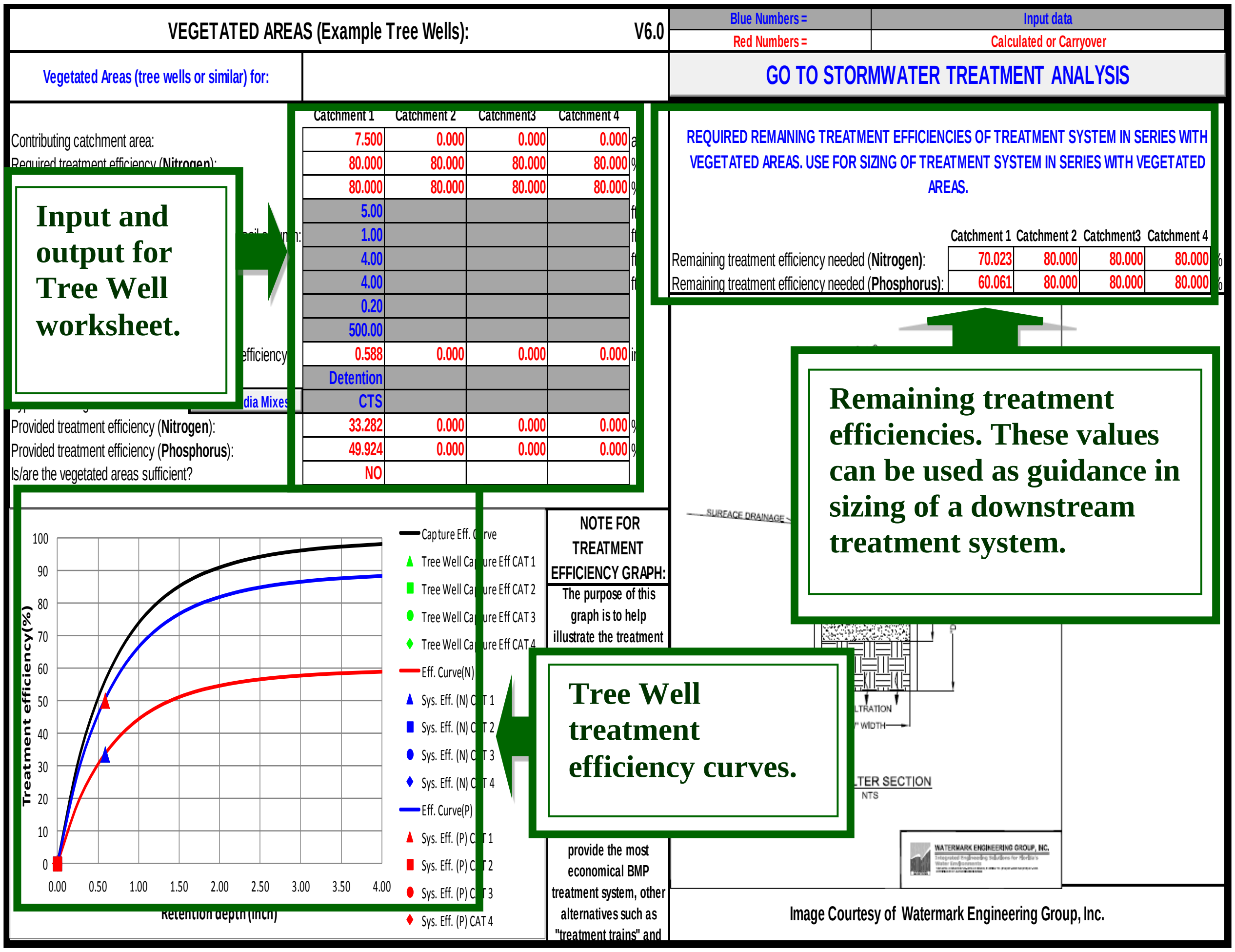


Figure 26 – Tree Well worksheet

Lined Reuse Pond with Underdrain Input

Lined reuse pond with underdrain input is a reuse BMP for the special condition of an irrigated area with an underdrain that drains to a lined pond. The intention is for the grass or other vegetation as well as microbes in the soil matrix to remove pollutants and get rid of water via evapotranspiration. During a rain event, runoff water is directed to the lined pond where it is stored to meet future irrigation needs; excess water is discharged as overflow. The irrigated area can be any number of vegetated areas that have underdrains such as sports fields. This BMP is particularly useful for vegetated areas that are fertilized as nutrient rich runoff waters are collected are reused for irrigation. This has the additional benefit of potentially reducing fertilization demands, which can result in a cost savings.

In the BMPTRAINS model, the lined reuse pond with underdrain input BMP is analyzed as a reuse system. Lined reuse ponds with underdrain inputs are systems where runoff water is stored for irrigation with excess water being discharged as overflow. In the model, these types of systems are analyzed just like the green roof BMP. The nutrient reduction efficiency of the system depends on the size of the lined reuse pond and the size of the irrigation area it serves.

The input parameters required to estimate the efficiency for lined reuse ponds with underdrain inputs is the drainage and irrigation area, the retention provided, the irrigation demand, and the rainfall excess (Figure 27).

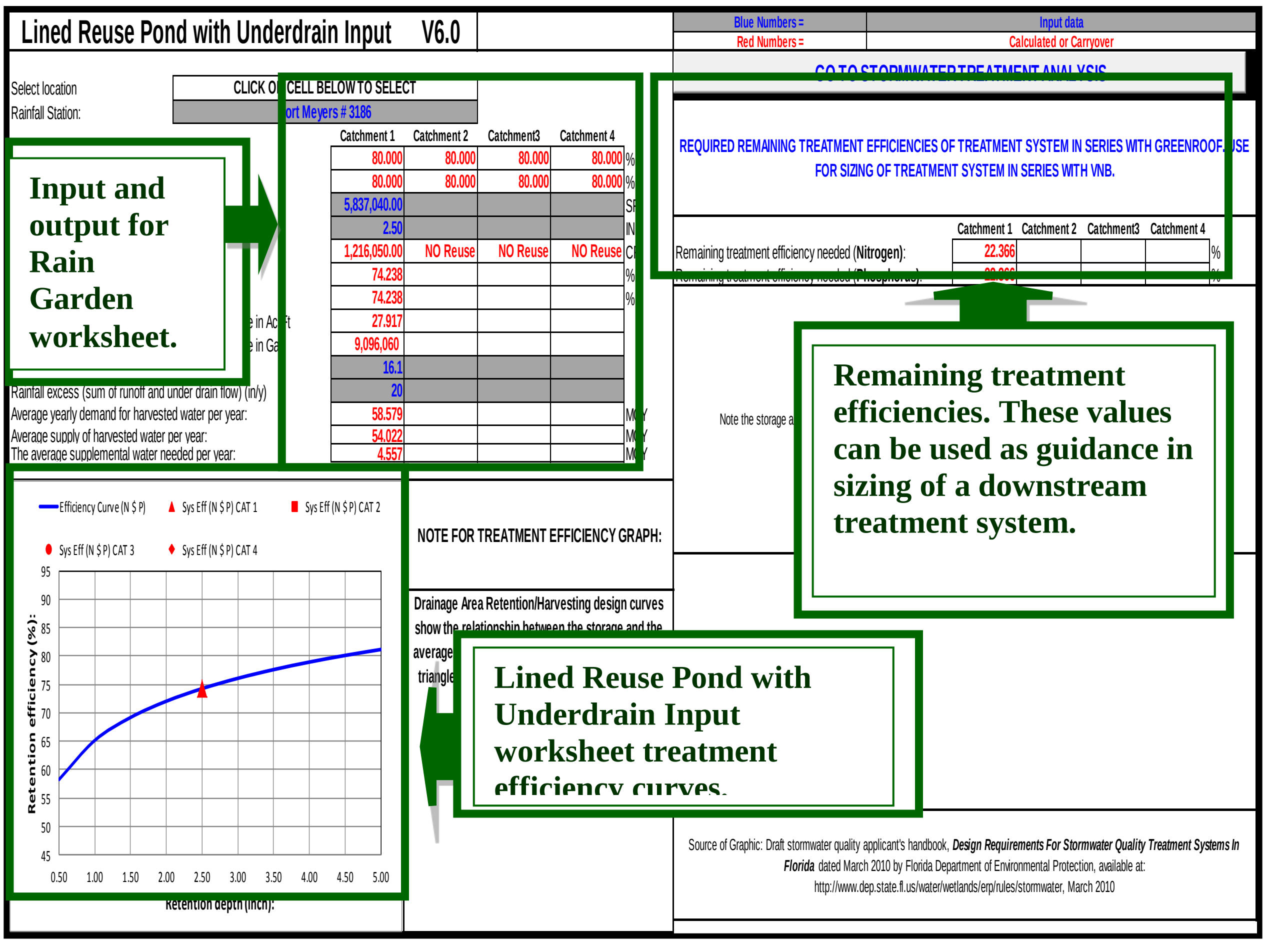


Figure 27 – Lined Reuse Pond with Underdrain Input worksheet

User Defined BMPs

There are additional BMPs that are only partly documented in terms of average yearly effectiveness and/or standards for operation and maintenance are not complete or well defined. At the time of this publication, it is recognized that for application in certain watersheds, such BMPs are not in general permitted for use. Nevertheless, the model input allows for inclusion of these. Examples are chemical treatment using polymers, alum or other salts; pre-treatment using baffle box designs, street sweeping, and specialty designs using propriety equipment. It could be possible that some agencies granting permits will encourage the use these nontraditional BMPs and for that reason, this option within the BMPTRAINS model allows for inclusion. Some input parameters and the output expected are shown below in Figure 28, Figure 29, and Figure 30.

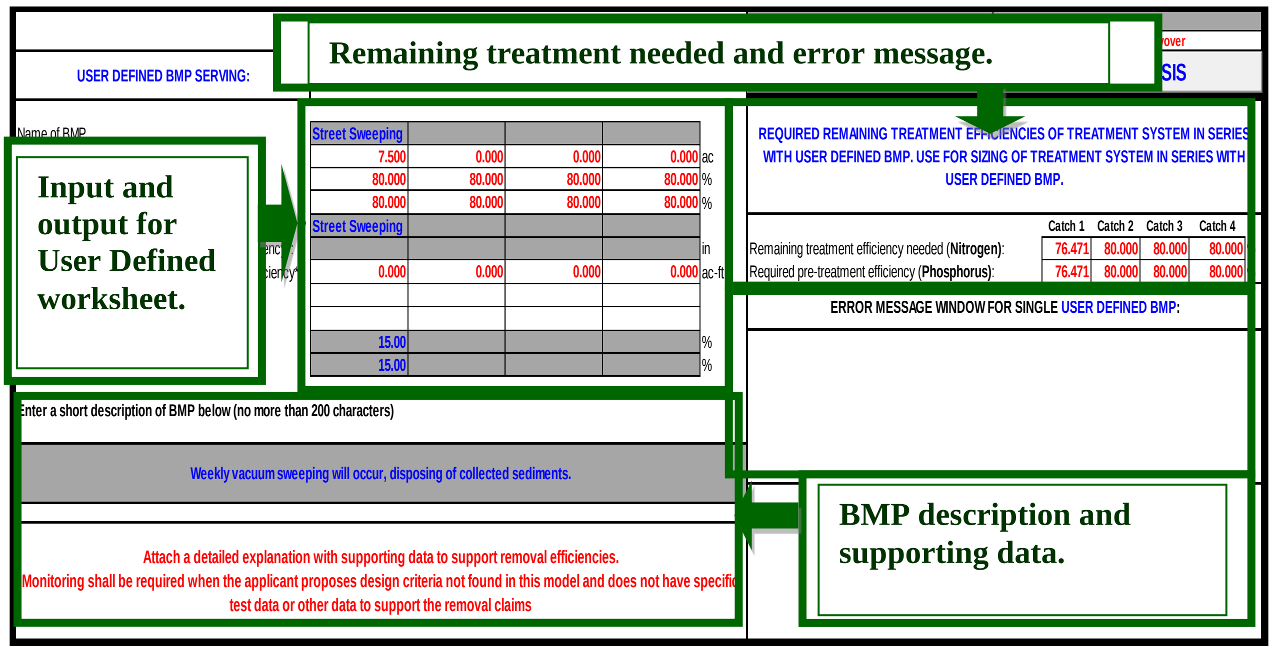


Figure 28 – User-defined BMP worksheet for Street Sweeping

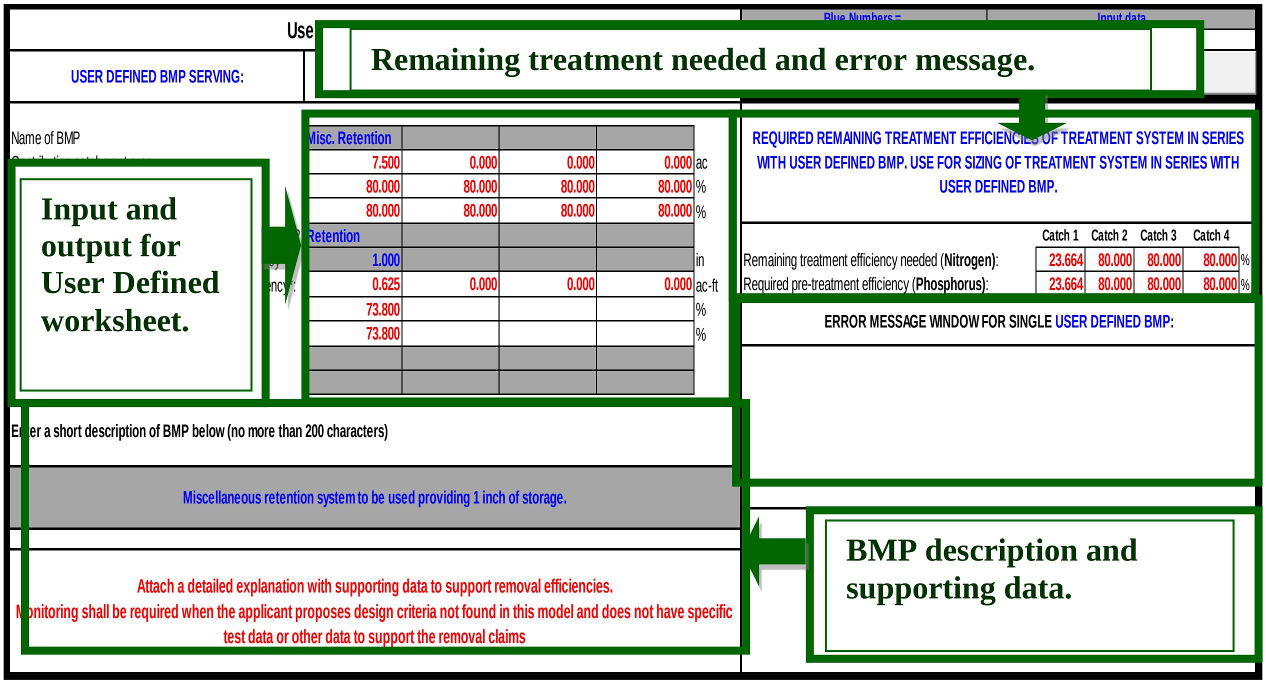


Figure 29 – User-Defined BMP for Misc. Retention

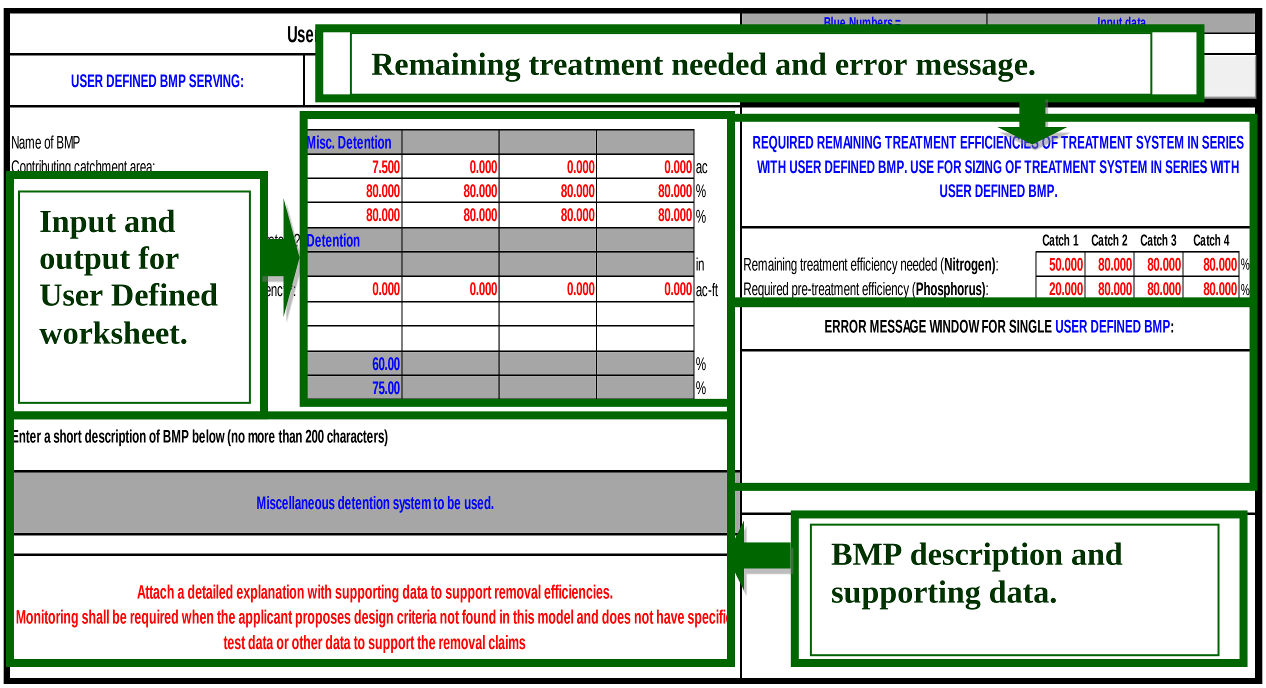


Figure 30 – User-defined BMP for Misc. Detention

Catchment and Treatment Summary Results

The user can view a summary of the results by selecting the *Catchment and Treatment Summary Results* button on the **Stormwater Treatment Analysis** worksheet (Figure 15). The **Catchment and Treatment Summary Results** worksheet (Figure 31) shows the BMPs used in each catchment, the selected catchment configuration, the N and P mass loadings for the pre and post development conditions, the target N and P efficiencies, the target N and P mass loading, the provided N and P efficiencies, and the achieved N and P mass loads. All of the information presented on this worksheet is carried over from other worksheets within the model. This worksheet allows the user to see the effect of the overall treatment specified by the user.

CATCHMENTS AND TREATMENT SURFACE DISCHARGE SUMMARY V 8.6

CALCULATION METHODS:

1. The effectiveness of each BMP in a single catchment is converted to an equivalent capture volume.
2. Certain BMP treatment train combinations have not been evaluated and in practice they are at this time not used, an example is a greenroof following a tree well.
3. Wet detention is last when used in a single catchment with other BMPs, except when followed by filtration

PROJECT TITLE	Comingling Examples	Optional Identification		
	off site	on site	Catchment 3	Catchment 4
BMP Name	Wet Detention/ MAPs	Stormwater Harvesting		
BMP Name				
BMP Name				

Surface Water Discharge Summary Performance of Entire Watershed

Catchment Configuration	B - 2 Catchment-Series	Treatment Objectives or Target for	5/29/2017
			BMPTRAINS MODEL
Nitrogen Pre Load (kg/yr)	0.00		
Phosphorus Pre Load (kg/yr)	0.00		
Nitrogen Post Load (kg/yr)	30.93		
Phosphorus Post Load (kg/yr)	4.07		
Target Load Reduction (N) %	50	TN MET	
Target Load Reduction (P) %	50		
Target Discharge Load, N (kg/yr)	15.47		
Target Discharge Load, P (kg/yr)	2.03	TP MET	
Provided Overall Efficiency, N (%):	56		
Provided Overall Efficiency, P (%):	64		
Discharged Load, N (kg/yr & lb/yr):	13.50	29.74	
Discharged Load, P (kg/yr & lb/yr):	1.48	3.27	
Load Removed, N (kg/yr & lb/yr):	17.43	38.39	
Load Removed, P (kg/yr & lb/yr):	2.59	5.70	

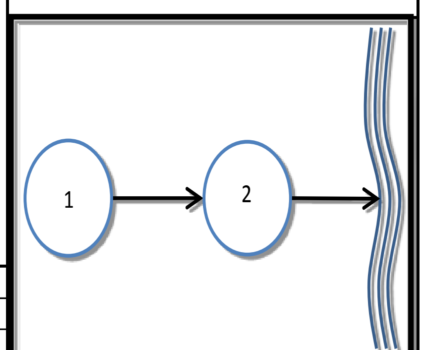


Figure 31 – Multiple Catchments and Treatment Systems Analysis worksheet

CHAPTER 4 EXAMPLE PROBLEMS

4.1 INTRODUCTION

The example problems are presented to offer the user a systematic data entry procedure using actual screen captures. In the evolution of the releases, some worksheets have not changed and thus, the release shown on the screen capture may be an earlier one than currently used. It is important to understand the application of the model as applied to one watershed before proceeding to the more detailed applications with two or more catchments. A minimum of two catchments must be used for the comingling evaluations. Usually for cost comparisons, one catchment with multiple BMPs or more than one catchment is evaluated.

Upon opening the BMPTRAINS model, some users may encounter the security warning in the upper left corner of the Microsoft Excel window (Figure 32). This message indicates that some content of the model has been disabled. This is a typical warning message for users whose Excel security settings are disabling all macros within the spreadsheet. In order to navigate through the model, as well as to perform certain calculations, the user must enable all macros upon opening of the document. This process will have to be repeated every time the model is opened until the user's security settings are changed permanently.

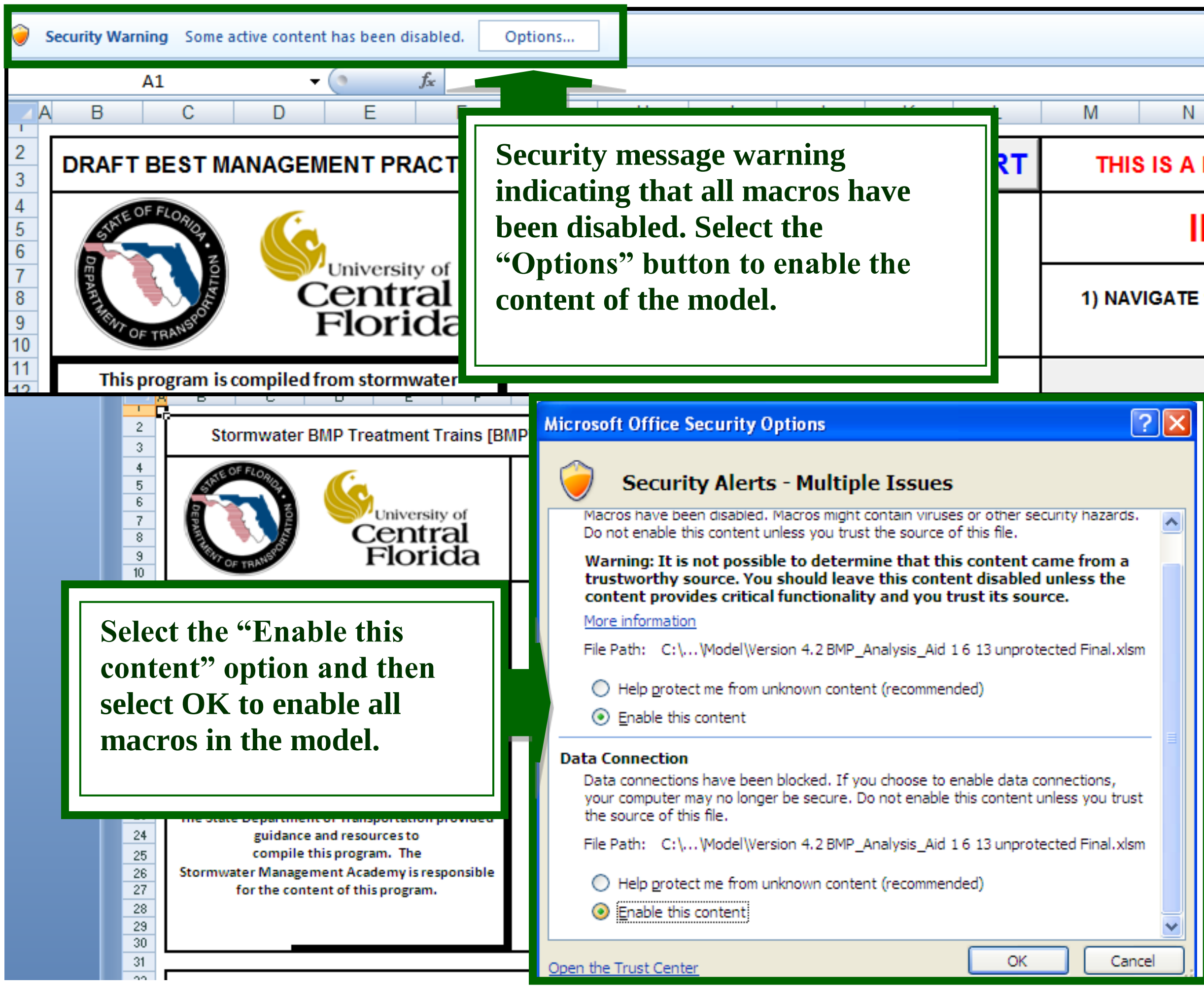


Figure 32 – Introduction Security and Macros worksheet

The model is ready for use when all macro content is enabled. However, prior to the use of the model, the user is strongly encouraged to familiarize themselves with some basic model features, capabilities and limitations.

Key instructions for navigation, viewing and printing the model results are displayed in the Introduction Page worksheet under the help buttons (Figure 33).

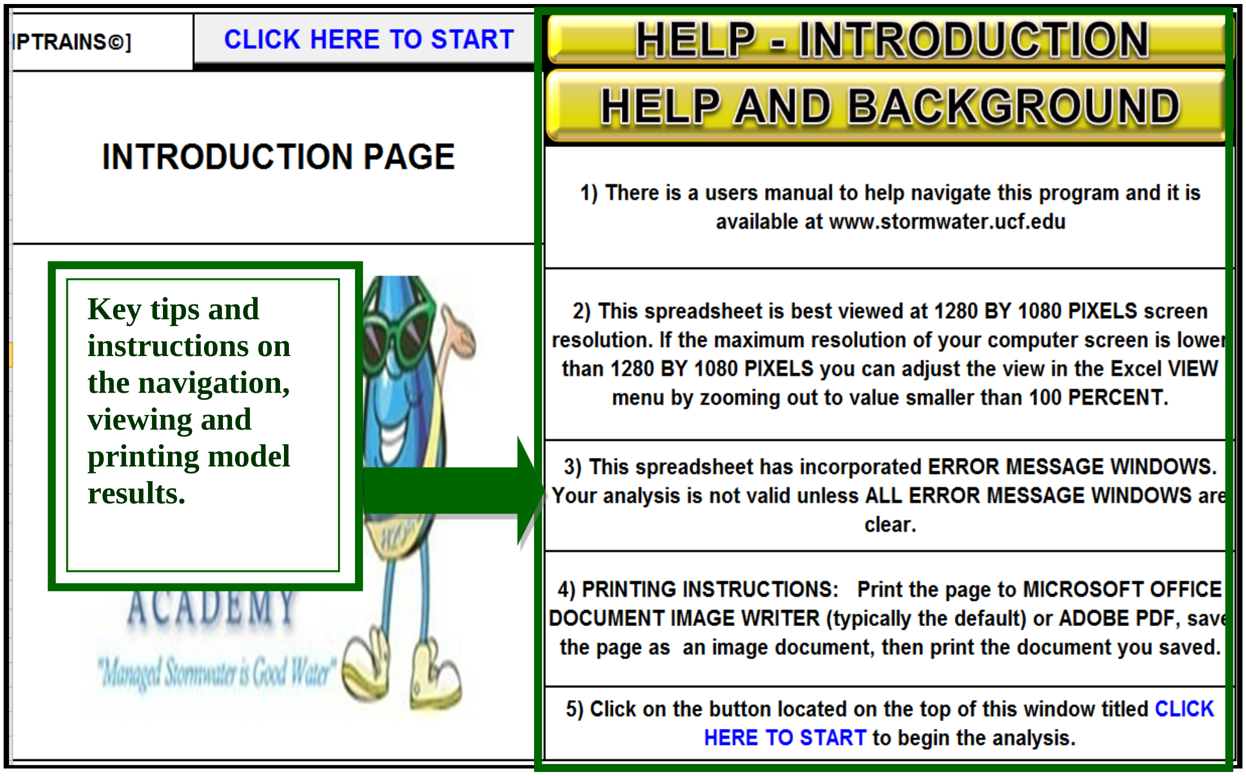


Figure 33 – Introduction User Information worksheet

It should be noted that the navigation between different worksheets is only available via the use of gray macro buttons. The user should become comfortable using these buttons as this is the only way one can navigate through the model since the individual worksheet tabs are not displayed. However, this should not be difficult since the buttons are clearly labeled with the worksheet destinations.

Another important message displayed in the Introduction Page worksheet is related to the printing of the input and output. All worksheets, which require an input of information or provide calculated results, are formatted to print only the necessary information. However, due to differences in printer resolutions, the user may still need to adjust the print settings for optimum printing results. Another way to get around the printing issue is to use Microsoft Office Image Writer, Microsoft XPS Office Document Writer, Adobe PDF, or another default software to print the information to document (Figure 34).

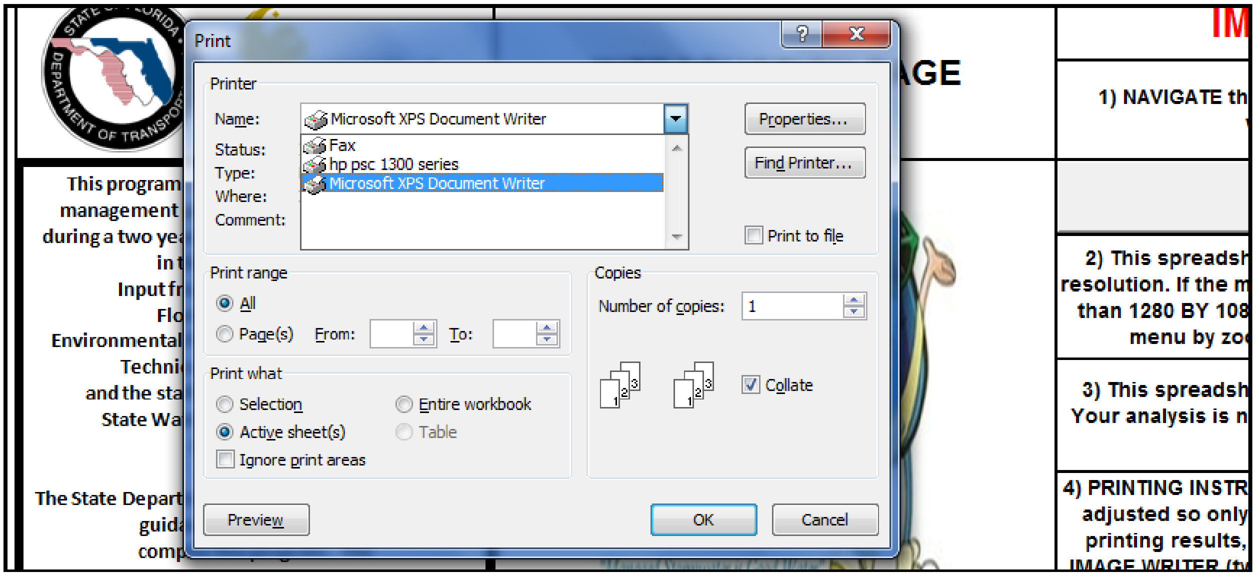


Figure 34 – Introduction for Printer worksheet

Once the user becomes familiar with all of the important information on the Introduction Page, please proceed to the General Site Information page (Figure 35) by selecting the *Click Here to Start* button. This is the first worksheet which requires the user to specify information if they desire to begin the BMP nutrient removal efficiency analysis. Therefore, it is important to recognize which cells represent the information input and which cells represent the calculated output. All input cells are characterized by a grey background and blue font. All output cells are characterized by a white background and red font. This arrangement is shown in the upper right corner of each worksheet that requires input (Figure 35).

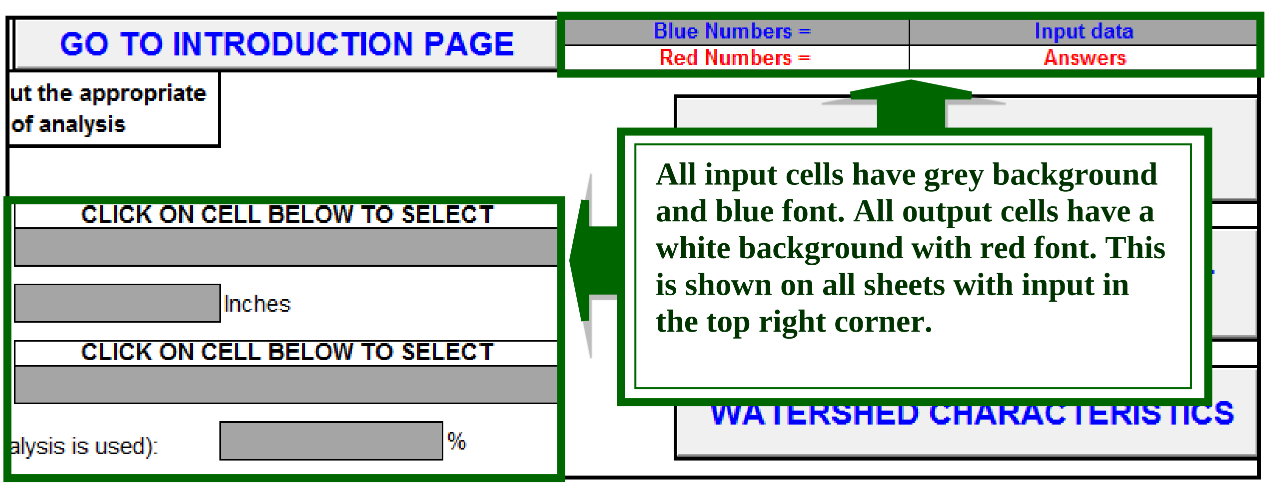


Figure 35 – General Site Information worksheet

Another feature permits the user to enter the name of the project on the general site information sheet. This name will carry on to a print out on the multiple watersheds and treatment analysis sheet. There is also an opportunity on the multiple watershed and treatment systems sheet to enter a description for an optional treatment system analyzed. The input area on the general site information sheet to enter the project name is shown in Figure 36.

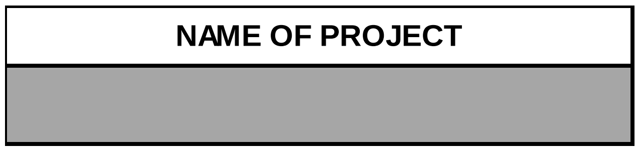


Figure 36 – Name of Project

The General Site Information worksheet also contains two buttons (view zone map and view mean annual rainfall map) that direct the user to maps to aid the user with appropriate input selections in this worksheet (Figure 37).

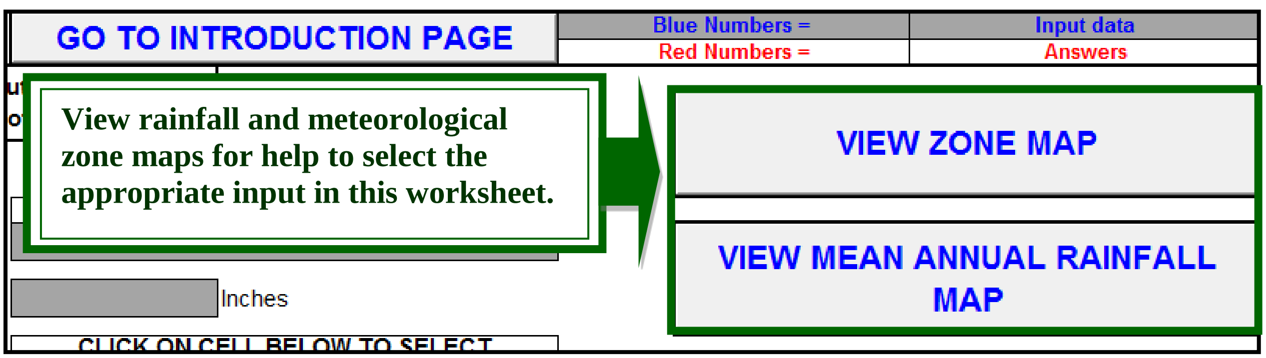


Figure 37 – General Site Information worksheet

The first map is the meteorological zone map (Figure 38). This map can help the user to select the appropriate meteorological zone applicable to the location of the project site. Appropriate selection of the meteorological zone is necessary to ensure that the model is using the correct coefficients in the calculations.

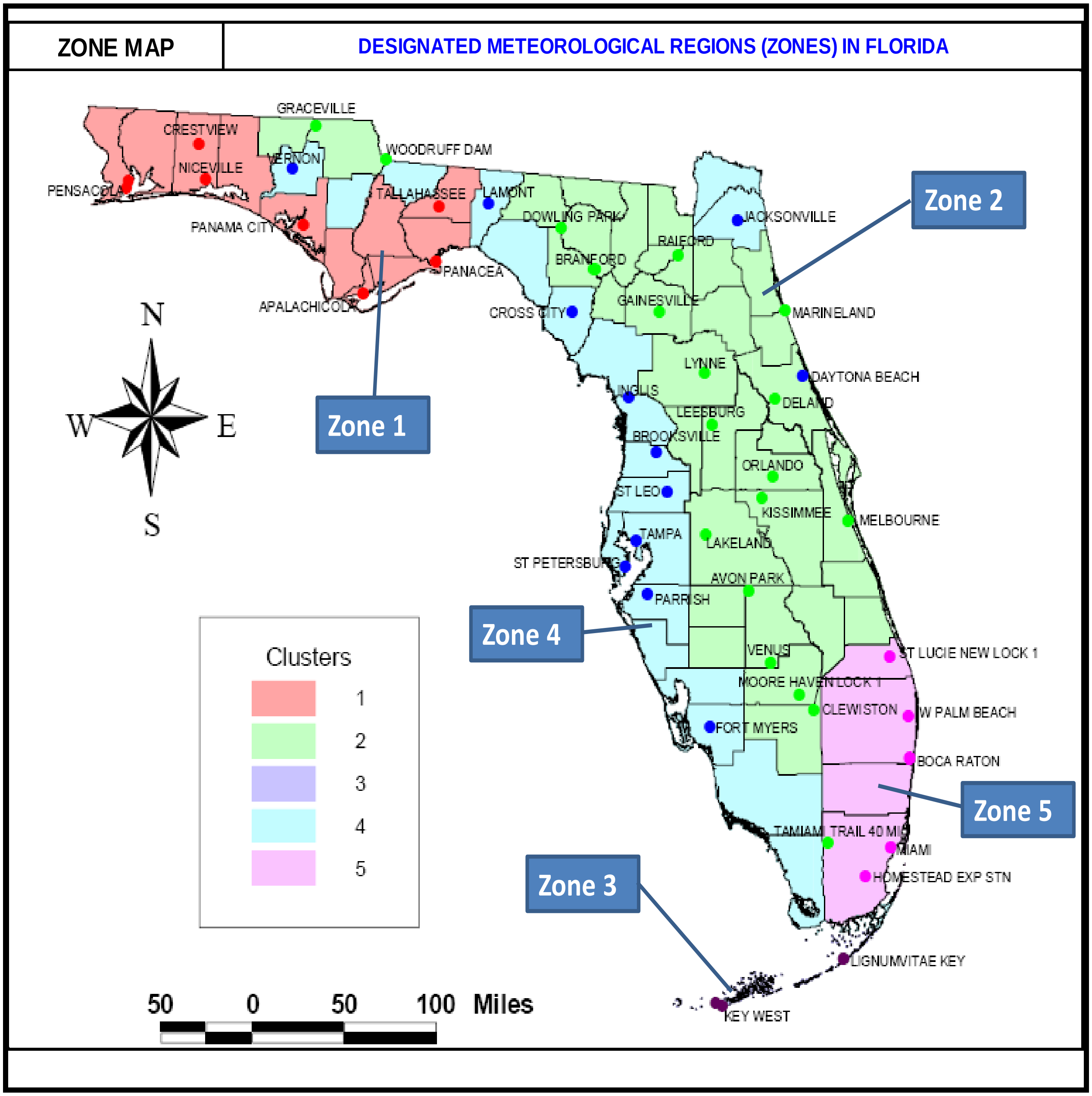


Figure 38 – Meteorological Zone Map Description

The second map is the mean annual rainfall map (Figure 39). This map allows the user to find the annual rainfall amount applicable to the project site location. Appropriate selection of the mean annual rainfall amount is necessary to ensure that calculated annual runoff volumes most accurately represent the existing and proposed conditions.

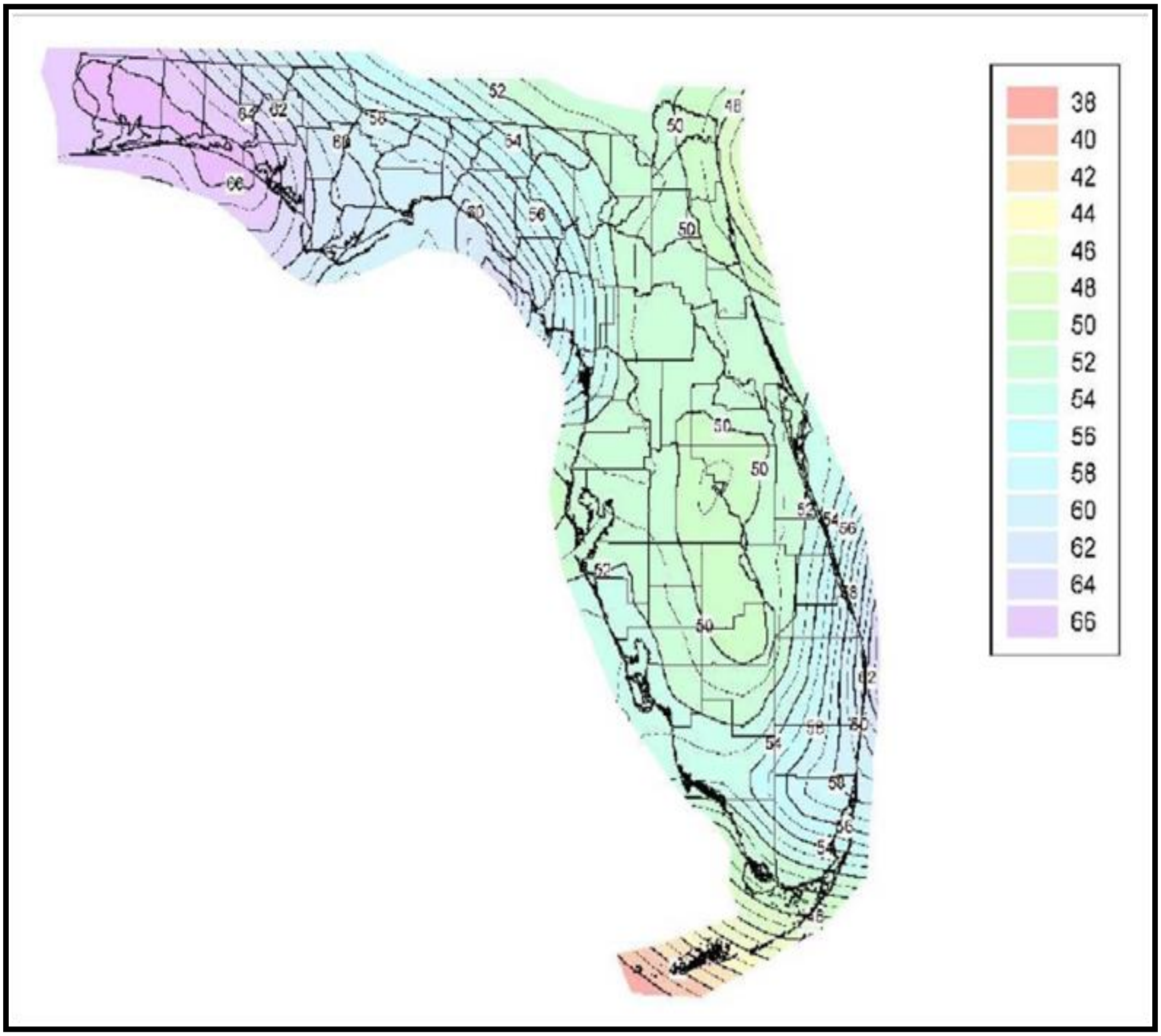


Figure 39 – Mean Annual Rainfall Map worksheet

4.2 EXAMPLE PROBLEMS

Example problem # 1 – Swale: Specified Removal Efficiency of 80%

A 0.1-acre retention swale is serving a 1.1-acre highway project. The site is located in Liberty County, Southwest of Tallahassee, FL area on Hydrologic Soil Group D. The existing land use condition is assumed 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 50% DCIA. Does the swale provide treatment sufficient to reduce the annual nutrient loading by 80.0%? The swale dimensions are shown in Figure 43. Assume that additional concentration reduction is achieved because of the very low longitudinal slope.

1. From the introduction page click on the *Click Here to Start* button to proceed to the **General Site Information** worksheet.
    a. Select the *Reset Input for Stormwater Treatment Analysis* button to erase any existing data.
    b. Enter the project name and select the meteorological zone in the **General Site Information** worksheet (Figure 40).
    c. Indicate the mean annual rainfall amount in the **General Site Information** worksheet.
    d. Select the *Specified Removal Efficiency* option from the type of analysis drop down menu in the **General Site Information** worksheet.
    e. Specify the desired removal efficiency.

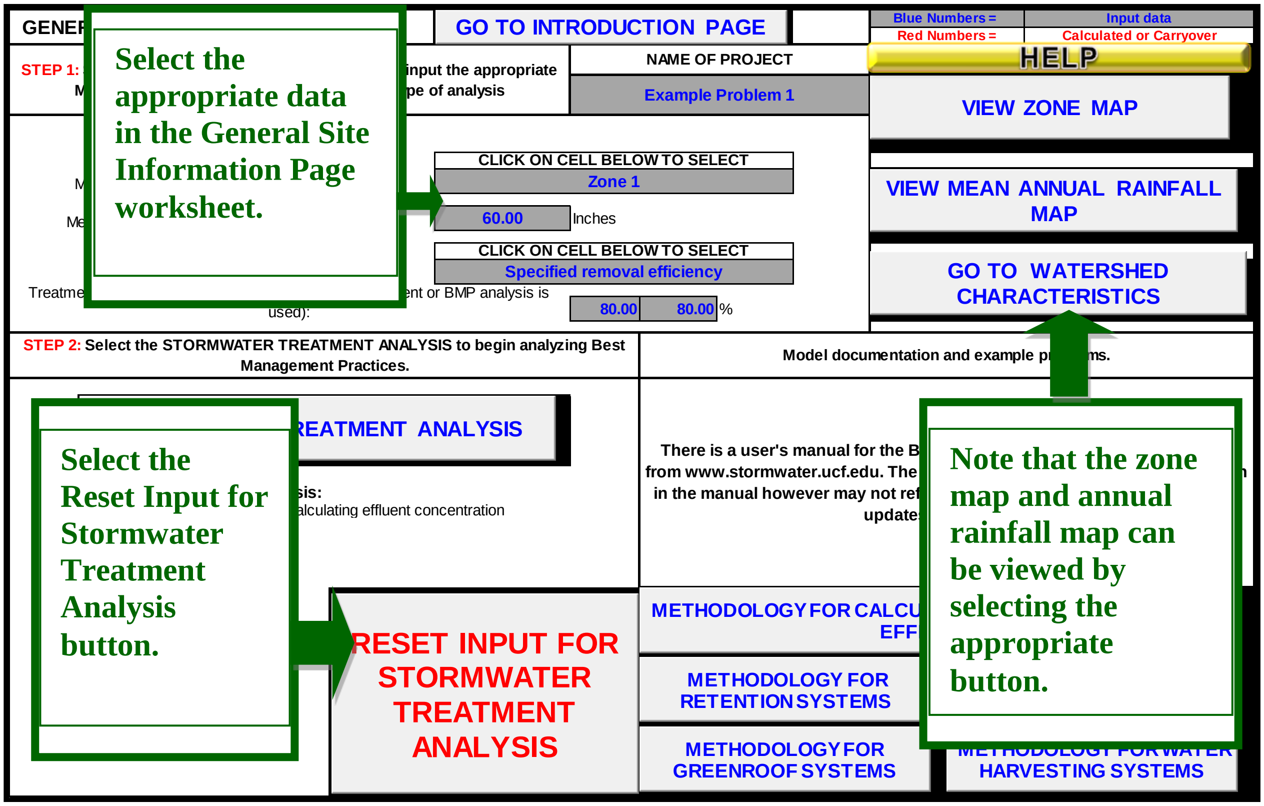


Figure 40 – General Site Information worksheet

2. Select the *Go To Watershed Characteristics* button to proceed to the **Watershed Characteristics** worksheet (Figure 41).

   a. Select a catchment configuration from the drop down menu; for diagrams of the different catchment configurations available, click the *View Catchment Configuration* button to proceed to the **Catchment Configuration** worksheet. Go back to the **Watershed Characteristics** worksheet by selecting the *Go to Watershed Characteristics* button (Figure 41). **Note: The catchment configuration must be selected to proceed.**

1.

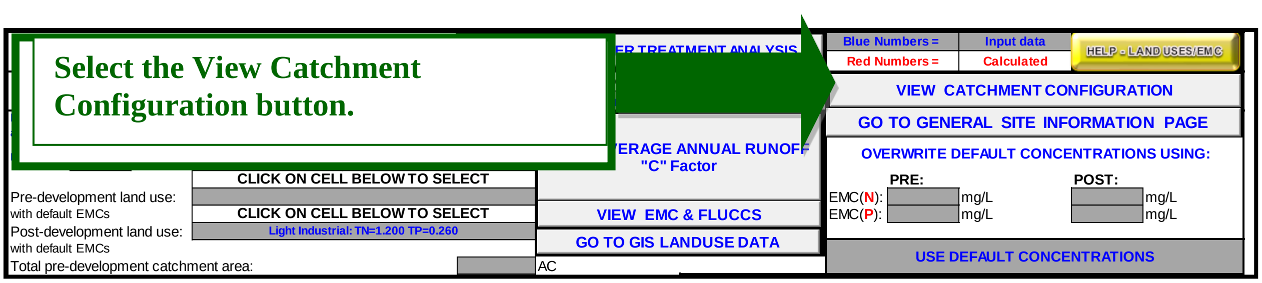


Figure 41 – Watershed Characteristics - Catchment Configuration selection

3. From the **Watershed Characteristics** worksheet:

   a. Select the single catchment option from the drop down menu.

   b. Indicate the pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage.

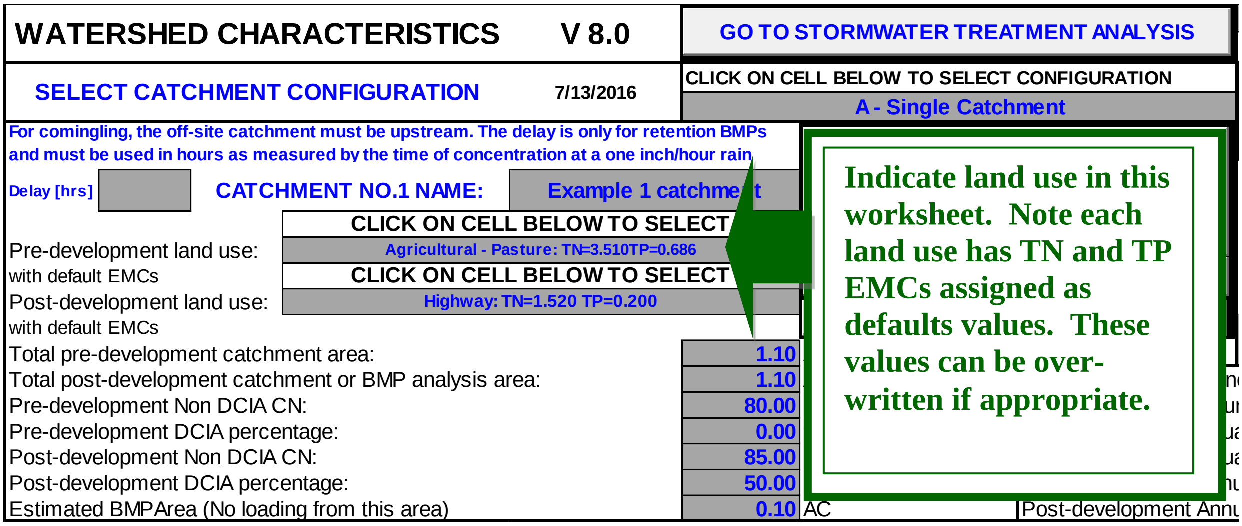


Figure 42 – Watershed Characteristics worksheet

4. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.

   a. Select the *Swale* button to proceed to the **Swale** worksheet (Figure 43).

5. Specify the required input in the **Swale** worksheet as shown in Figure 43.

6. The example problem specifies additional concentration reduction, so select yes in the cell P6.

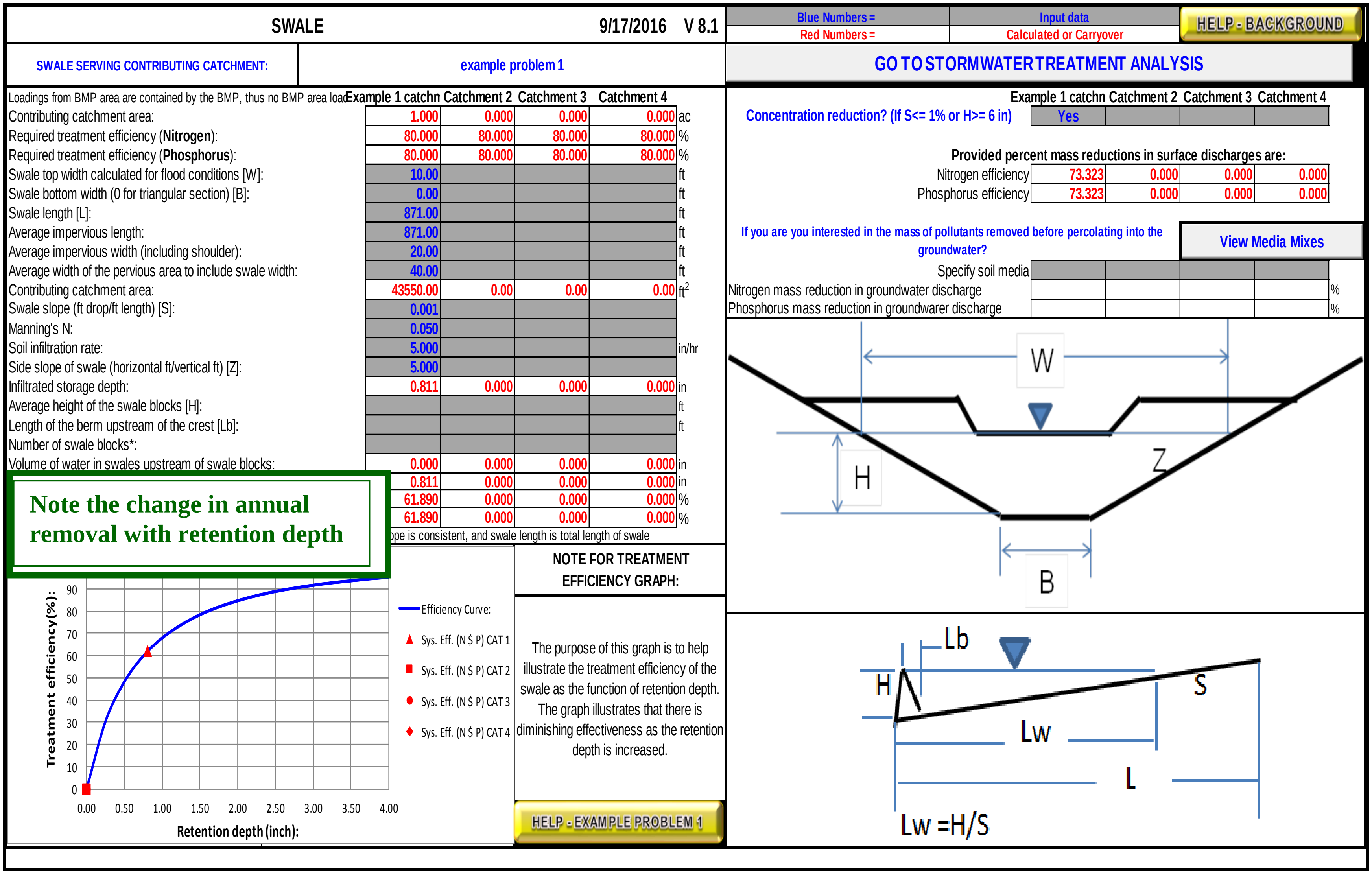


Figure 43 – Swale worksheet

7. Select the *Go to Stormwater Treatment Analysis Button* to go to the **Stormwater Treatment Analysis** worksheet and proceed to the **Catchment and Treatment Summary Results** worksheet by clicking the *Catchment and Treatment Summary Results* button (see Figure 44 for details).

CATCHMENTS AND TREATMENT SURFACE DISCHARE SUMMARY **V 8.1**

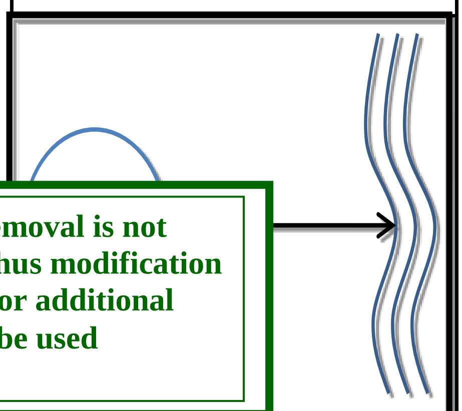
CALCULATION METHODS:

1. The effectiveness of each BMP in a single catchment is converted to an equivalent capture volume.
2. Certain BMP treatment train combinations have not been evaluated and in practice they are at this time not used, an example is a greenroof following a tree well.
3. Wet detention is last when used in a single catchment with other BMPs, except when followed by filtration

PROJECT TITLE	example problem 1	Optional Identification		
	Example 1 catchmen	Catchment 2	Catchment 3	Catchment 4
BMP Name	Swale			
BMP Name				
BMP Name				

Surface Water Discharge Summary Performance of Entire Watershed

Catchment Configuration	A - Single Catchment	Treatment Objectives or Target	9/17/2016
Nitrogen Pre Load (kg/yr)	3.86		BMPTRAINS MODEL
Phosphorus Pre Load (kg/yr)	0.75		
Nitrogen Post Load (kg/yr)	5.01		
Phosphorus Post Load (kg/yr)	0.66		
Target Load Reduction (N) %	80		
Target Load Reduction (P) %	80	NOT MET	
Target Discharge Load, N (kg/yr)	1.00		
Target Discharge Load, P (kg/yr)	0.13		
Provided Overall Efficiency, N (%):	73		
Provided Overall Efficiency, P (%):	73		
Discharged Load, N (kg/yr & lb/yr):	1.34		
Discharged Load, P (kg/yr & lb/yr):	0.18		
Load Removed, N (kg/yr & lb/yr):	3.68		
Load Removed, P (kg/yr & lb/yr):	0.48	1.07	



Note 80% removal is not achieved. Thus modification to the swale or additional BMPs must be used

Figure 44 – Catchment and Treatment Summary Results

8. To increase the removal efficiency, try modifying the swale, for example change the shape from triangular to trapezoidal.

Example problem # 2 – Retention Basin: Target 80% Removal and Comingling

This example problem includes the step-by-step procedure to input information for sizing a retention basin with the results used for Figure 2 in Chapter 2. It is the application of BMPTRAINS for retention and the first step in analyzing the option of comingling or bypass of an offsite runoff. The description of the example is a retention basin serving a 2.0-acre highway with the option to bypass or treat an equivalent offsite area. These 2 acres with 50% impervious roadway owned by another transportation entry has the option to bypass or be treated with the existing onsite basin. Thus the rainfall excess would be the same from each roadway. The site is located in Orlando, 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 the area.

The onsite retention basin must provide treatment to produce an 80% removal. This is the regulatory requirement for the area. The usual starting point is to assume a treatment 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). There is no more treatment volume onsite for a deeper basin because of water table depth. Also no more area can be used within the right-of-way. The BMPTRAINS program is used to analysis the one inch of treatment depth. The analysis option selected is the BMP analysis. We wish to determine if the 1-inch size of retention results in 80% removal. We could have also pick 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 *Click Here to Start* button to proceed to the **General Site Information** worksheet.
   a. IF using an open program, select the *Reset Input for Stormwater Treatment Analysis* button to erase any existing data.
   b. Enter the project name and select the meteorological zone in the **General Site Information** worksheet (Figure 45).
   c. Input the mean annual rainfall amount in the **General Site Information** worksheet.
   d. Select the *BMP* option from the type of analysis drop down menu in the **General Site Information** worksheet.

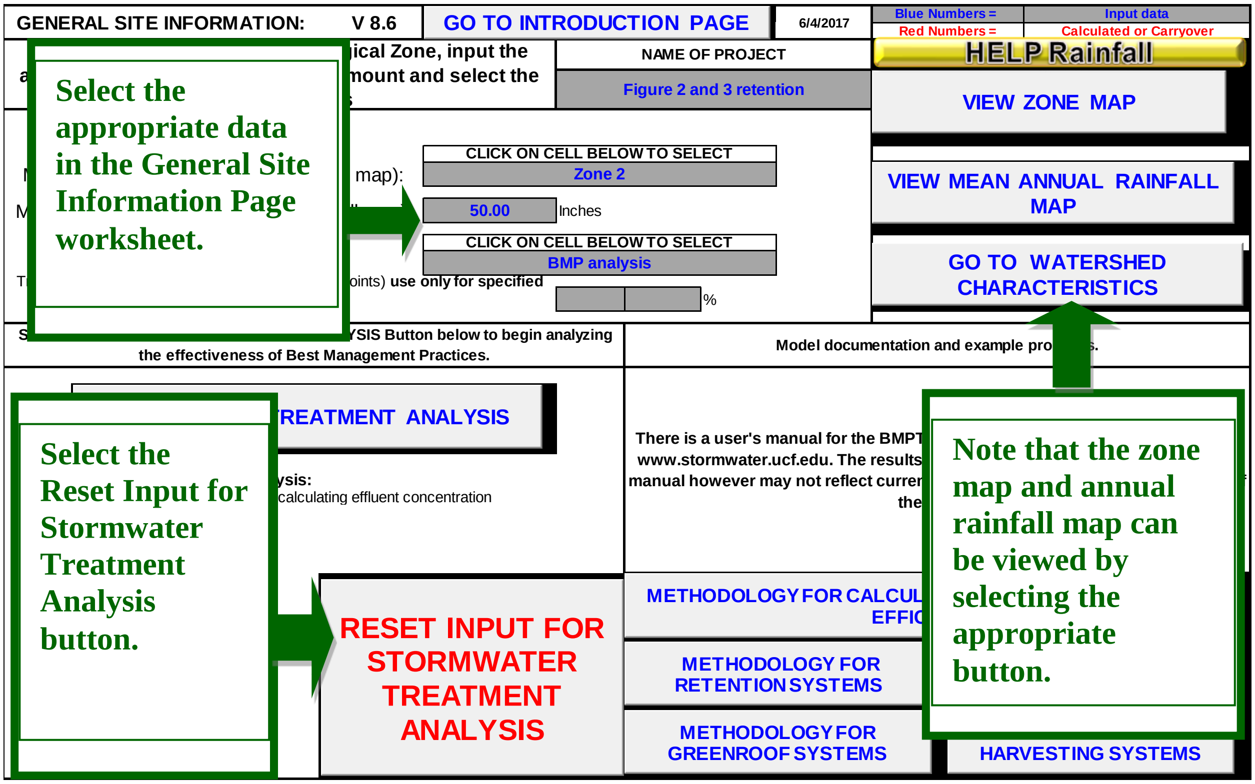


Figure 45 – General Site Information worksheet

2. Click on the *Go To Watershed Characteristics* button to proceed to the **Watershed Characteristics** worksheet (Figure 46).
    a. Select single catchment from the drop down menu and indicate the pre- and post-development conditions.

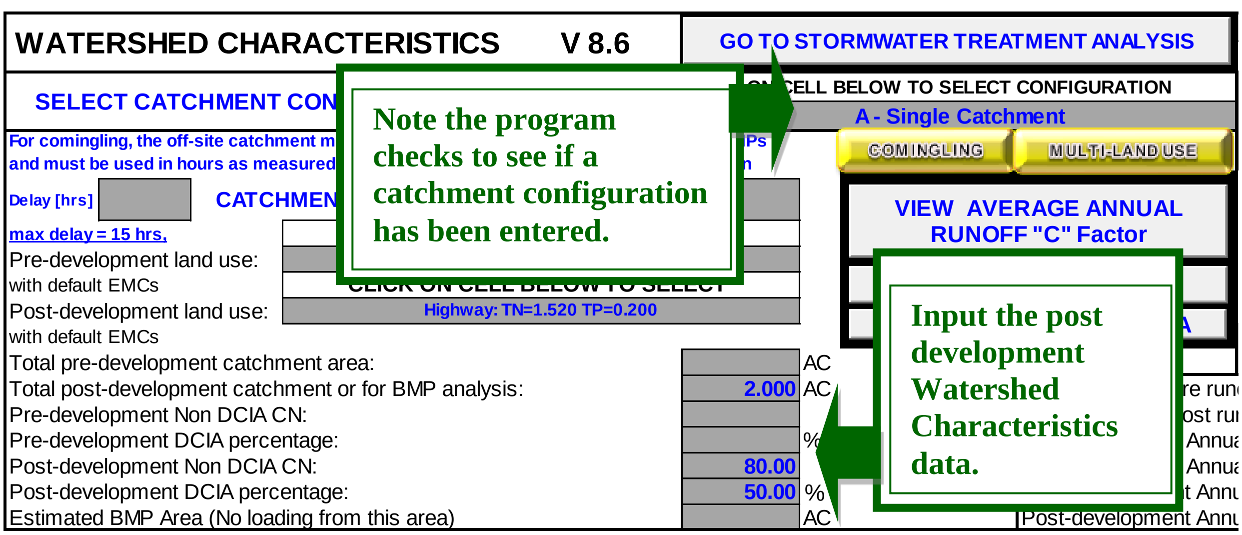


Figure 46 – Watershed Characteristics worksheet

3. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
4. Select the *Retention Basin* button to proceed to the **Retention Basin** worksheet (Figure 47).
    a. The Retention Basin worksheet shows the retention depth required to meet the required efficiency or the user can enter a different depth in the cell "Provided Retention Depth"

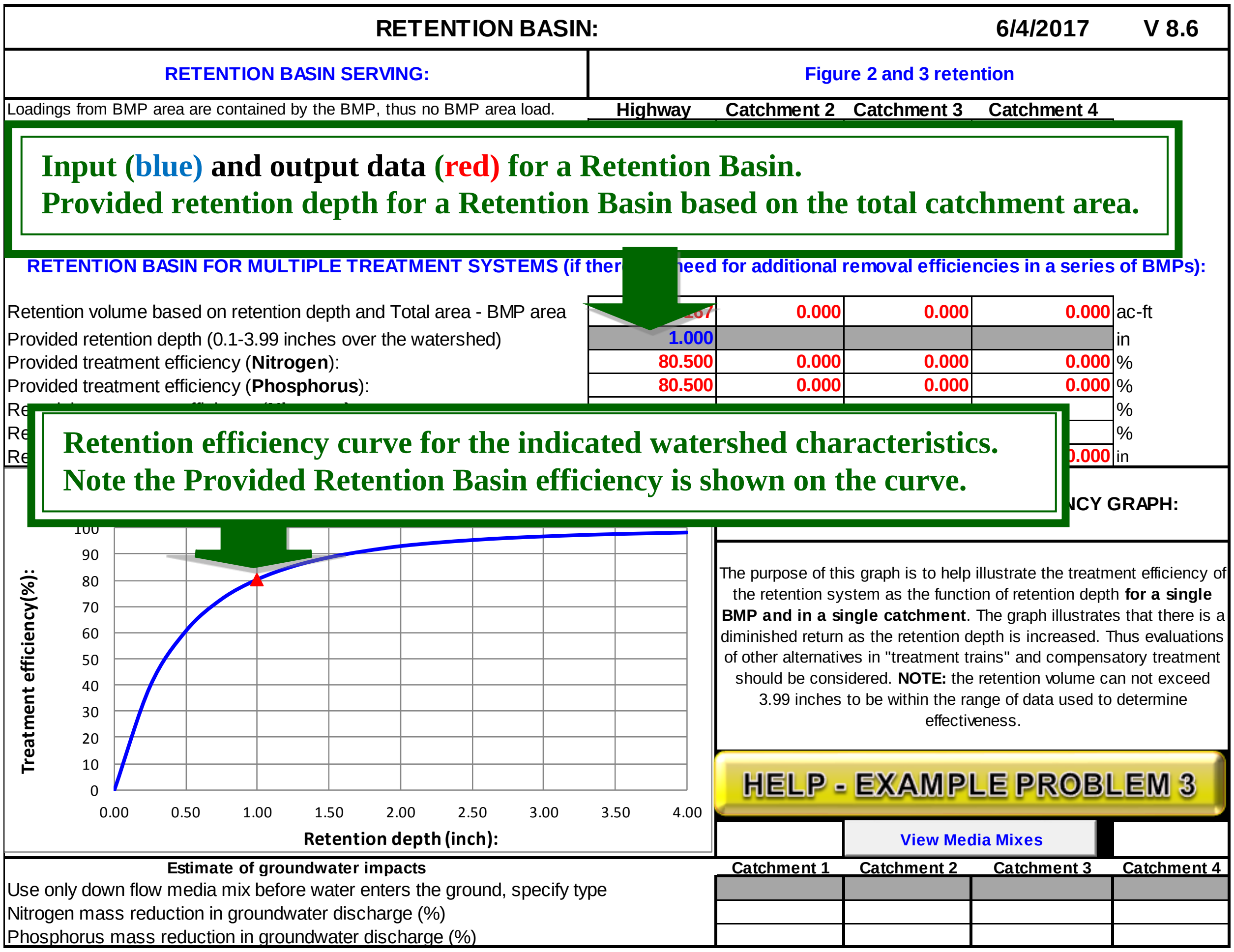
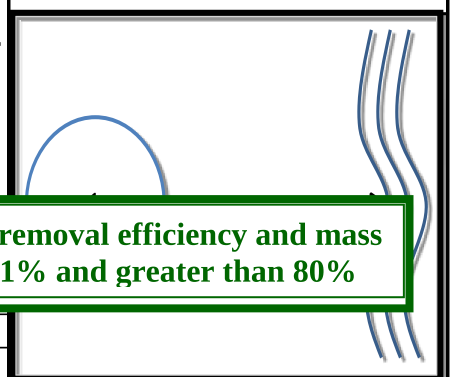


Figure 47 – Retention Basin worksheet

5. The user can now view a summary of the treatment achieved for the specified site conditions and BMP used by selecting the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet, and then selecting the *Catchment and Treatment Summary Results* button to go to the **Catchment and Treatment Summary Results** worksheet (Figure 48). The BMP analysis calculates the effectiveness of the design.

CATCHMENTS AND TREATMENT SURFACE DISCHARGE SUMMARY				V 8.6
CALCULATION METHODS:				
1. The effectiveness of each BMP in a single catchment is converted to an equivalent capture volume.				
2. Certain BMP treatment train combinations have not been evaluated and in practice they are at this time not used, an example is a greenroof following a tree well.				
3. Wet detention is last when used in a single catchment with other BMPs, except when followed by filtration				
PROJECT TITLE	Figure 2 and 3 retention	Optional Identification		
	Highway	Catchment 2	Catchment 3	Catchment 4
BMP Name	Retention Basin			
BMP Name				
BMP Name				
Surface Water Discharge Summary Performance of Entire Watershed				
Catchment Configuration	A - Single Catchment	Treatment Objectives or Target for	6/4/2017	
Nitrogen Pre Load (kg/yr)	0.00		BMPTRAINS MODEL	
Phosphorus Pre Load (kg/yr)	0.00			
Nitrogen Post Load (kg/yr)	7.19			
Phosphorus Post Load (kg/yr)	0.95			
Target Load Reduction (N) %				
Target Load Reduction (P) %				
Target Discharge Load, N (kg/yr)				
Target Discharge Load, P (kg/yr)				
Provided Overall Efficiency, N (%):	81			
Provided Overall Efficiency, P (%):	81			
Discharged Load, N (kg/yr & lb/yr):	1.40			
Discharged Load, P (kg/yr & lb/yr):	0.18	0.41		
Load Removed, N (kg/yr & lb/yr):	5.78	12.74		
Load Removed, P (kg/yr & lb/yr):	0.76	1.68		



The overall removal efficiency and mass removal is 81% and greater than 80%

Figure 48 – Catchment and Treatment Summary Results

Discussion: The target average annual effectiveness of 80% has been achieved with the 1-inch retention design. The next step is to determine how much removal is achieved if the offsite runoff volume is added to the onsite basin. The onsite basin was design to capture runoff from 2 acres but when the offsite area is added, the total area is doubled with the same average annual runoff of the onsite area. Thus the treatment level of the existing basin is reduced to ½ inch. The effectiveness of a ½ inch retention basin design is shown in Figure 3.

Example problem # 3 – Retention Basin: Specified Removal Efficiency of 75%

A 1-acre retention basin is serving an 11.0-acre residential subdivision. The site is located in 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 a 75% reduction of the post-development annual nutrient loads. One-acre has been set as the area for a retention basin. This one-acre generates no runoff.

1. From the introduction page click on the *Click Here to Start* button to proceed to the **General Site Information** worksheet.

   a. Select the *Reset Input for Stormwater Treatment Analysis* button to erase any existing data.
   b. Enter the project name and select the meteorological zone in the **General Site Information** worksheet (Figure 49).
   c. Indicate the mean annual rainfall amount in the **General Site Information** worksheet
   d. Select the *Specified Removal Efficiency* option from the type of analysis drop down menu in the **General Site Information** worksheet.
   e. Specify the desired removal efficiency.

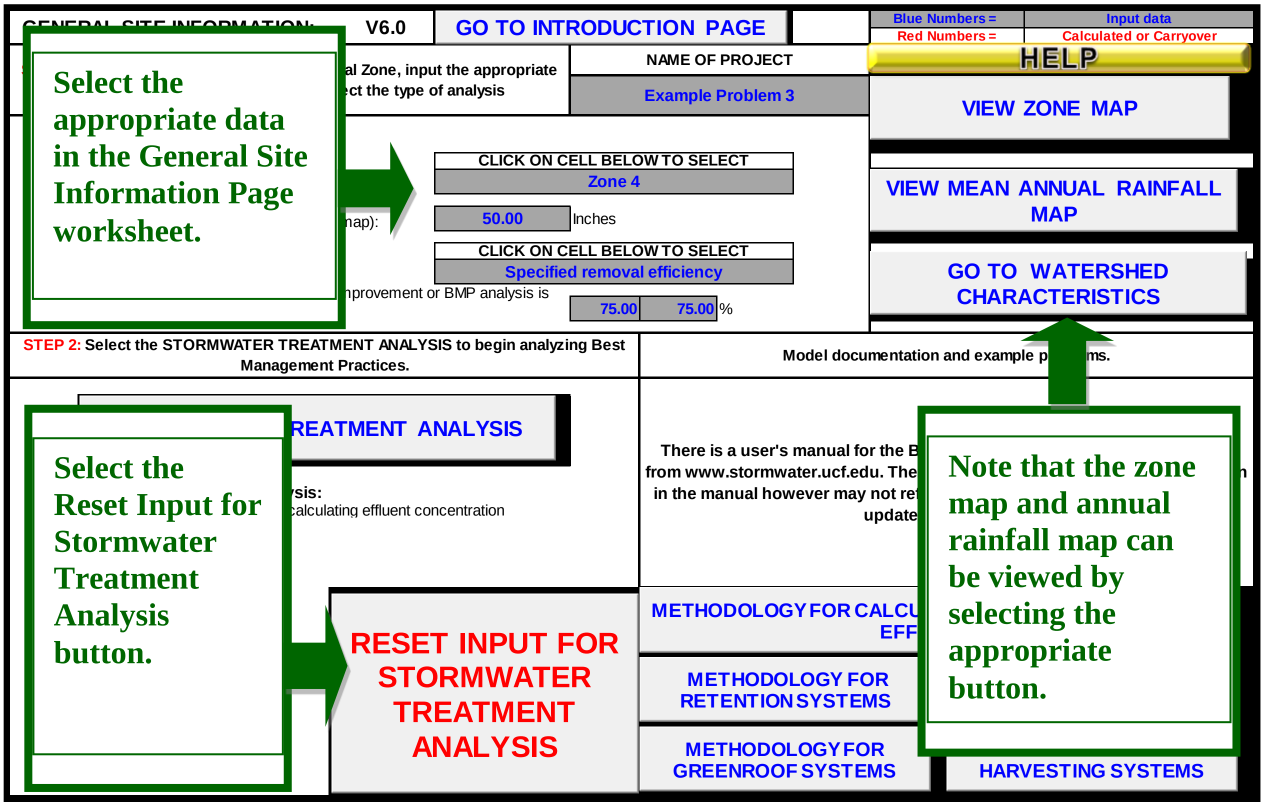


Figure 49 – General Site Information worksheet.

2. Select the *Watershed Characteristics* button to proceed to the **Watershed Characteristics** worksheet (Figure 50).
   a. Indicate the catchment configuration, pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage.
3. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.

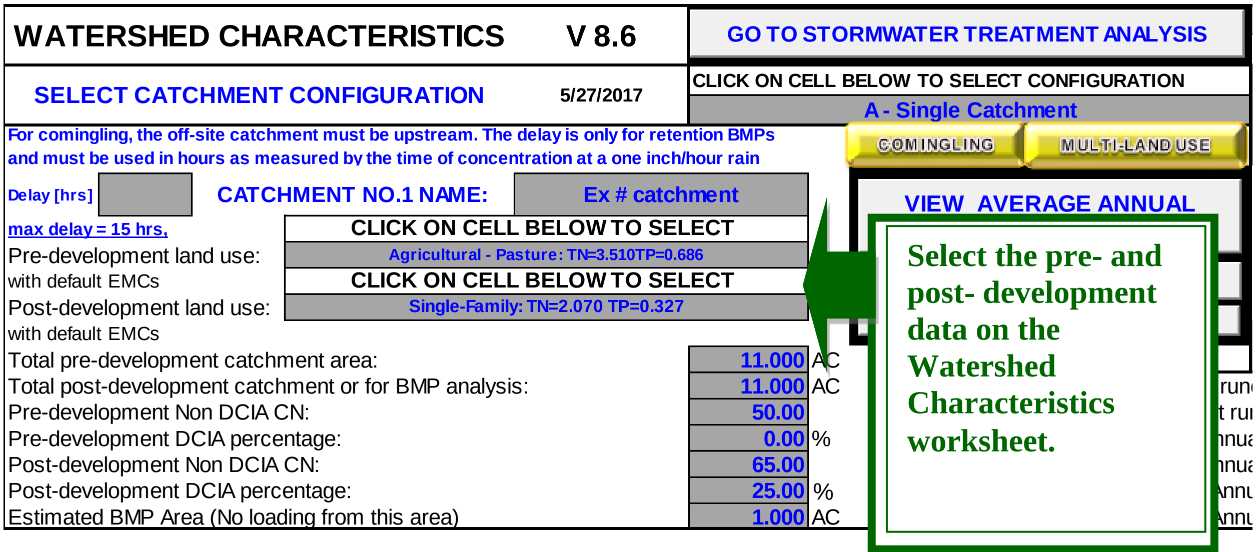


Figure 50 – Watershed Characteristics worksheet

4. Select the *Retention Basin* button to proceed to the **Retention Basin** worksheet (Figure 51)
   a. The Retention Basin worksheet shows the retention depth required to meet the required efficiency or the user can enter in a different depth in the cell labeled "Provided Retention Depth"

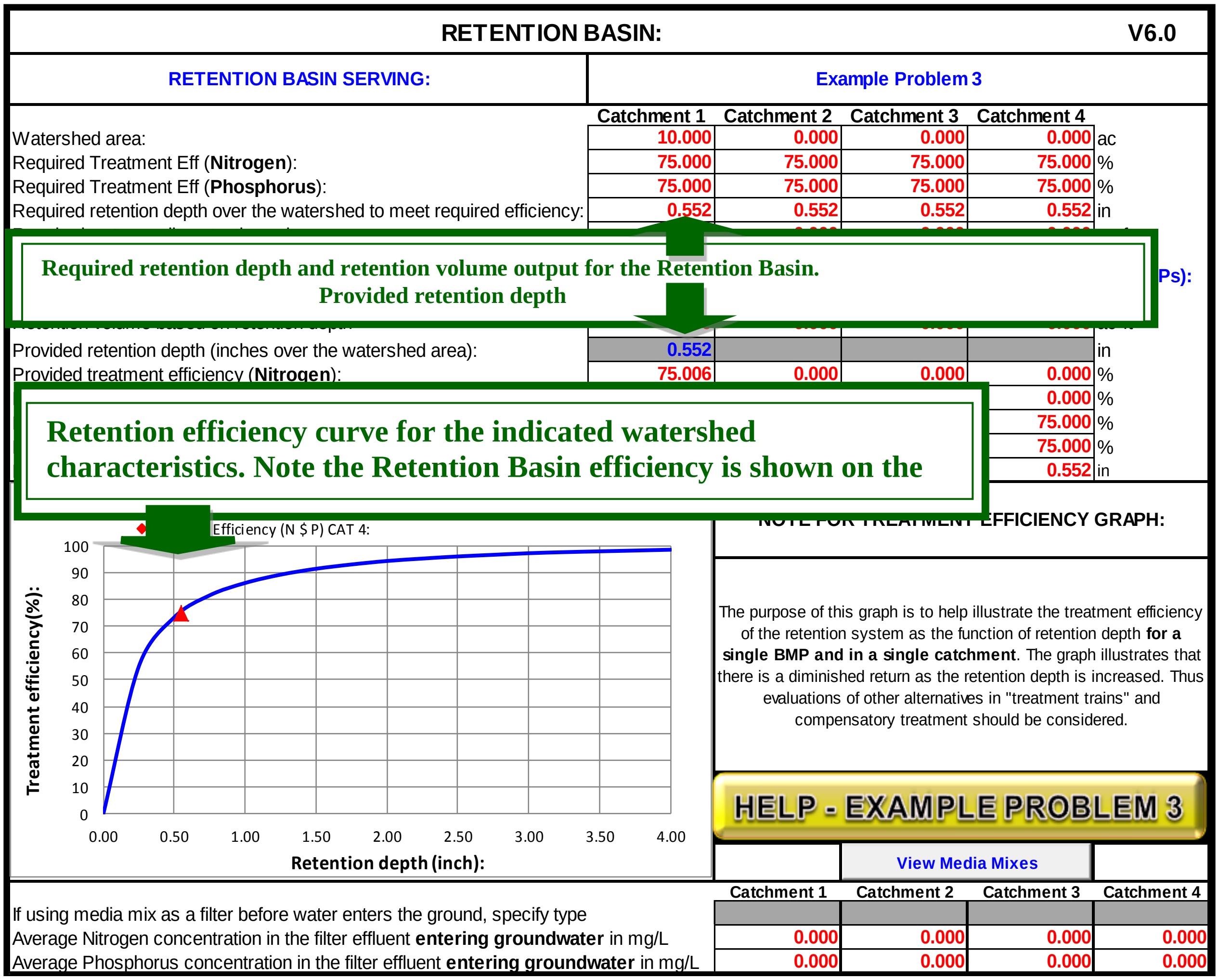


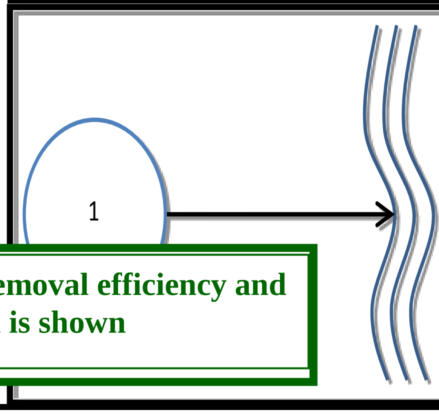
Figure 51 – Retention Basin worksheet

5. The user can now view a summary of the treatment achieved for the specified site conditions and BMP used by selecting the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet, and then selecting the *Catchment and Treatment Summary Results* button to go to the **Catchment and Treatment Summary Results** worksheet (Figure 52).

CATCHMENTS AND TREATMENT SUMMARY RESULTS				V6.0
CALCULATION METHODS:				
1. The effectiveness of each BMP in a single catchment is converted to an equivalent capture volume.				
2. Certain BMP treatment train combinations have not been evaluated and in practice they are at this time not used, an example is a greenroof following a tree well.				
3. If multiple BMPs are used in a single catchment and one of them is detention, then it is assumed to be last in series.				
PROJECT TITLE	Example Problem 3	Optional Identification		
	Catchment 1:	Catchment 2:	Catchment 3:	Catchment 4:
BMP1	Retention Basin			
BMP2				
BMP3				

Summary Performance

Catchment Configuration	A - Single Catchment		1/24/2014
Catchment Nitrogen Pre Load	4.32		BMPTRAINS MODEL
Catchment Phosphorus Pre Load	0.77		
Catchment Nitrogen Post Load	26.17		
Catchment Phosphorus Post Load	4.13		
Target Load Reduction (N) %	75		
Target Load Reduction (P) %	75		
Target Discharge Load, N (kg/yr)	6.54		
Target Discharge Load, P (kg/yr)	1.03		
Provided Overall Efficiency, N (%):	75		
Provided Overall Efficiency, P (%):	75		
Discharged Load, N (kg/yr & lb/yr):	6.54		
Discharged Load, P (kg/yr & lb/yr):	1.03		
Load Removed, N (kg/yr & lb/yr):	19.63		
Load Removed, P (kg/yr & lb/yr):	3.10	6.83	



The overall removal efficiency and mass removal is shown

Figure 52 – Summary Input & Output worksheet

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 assumed to be a highway with a non-DCIA Curve Number of 80 and 85% DCIA. This will be a net improvement problem using a wet detention pond which will utilize a littoral zone (assumed 10% removal efficiency credit) in the design. An average annual residence time of 50 days was calculated for the pond.

After net improvement is evaluated, if needed add a stormwater harvesting operation to help obtain an 80% removal of both nitrogen and phosphorus.

1. From the introduction page click on the *Click Here to Start* button to proceed to the **General Site Information** worksheet.

a. Select the *Reset Input for Stormwater Treatment Analysis* button to erase any existing data.

b. Enter the project name and select the meteorological zone in the **General Site Information** worksheet (Figure 53).

c. Indicate the mean annual rainfall amount in the **General Site Information** worksheet

d. Select the *Net Improvement* option from the type of analysis drop down menu in the **General Site Information** worksheet.

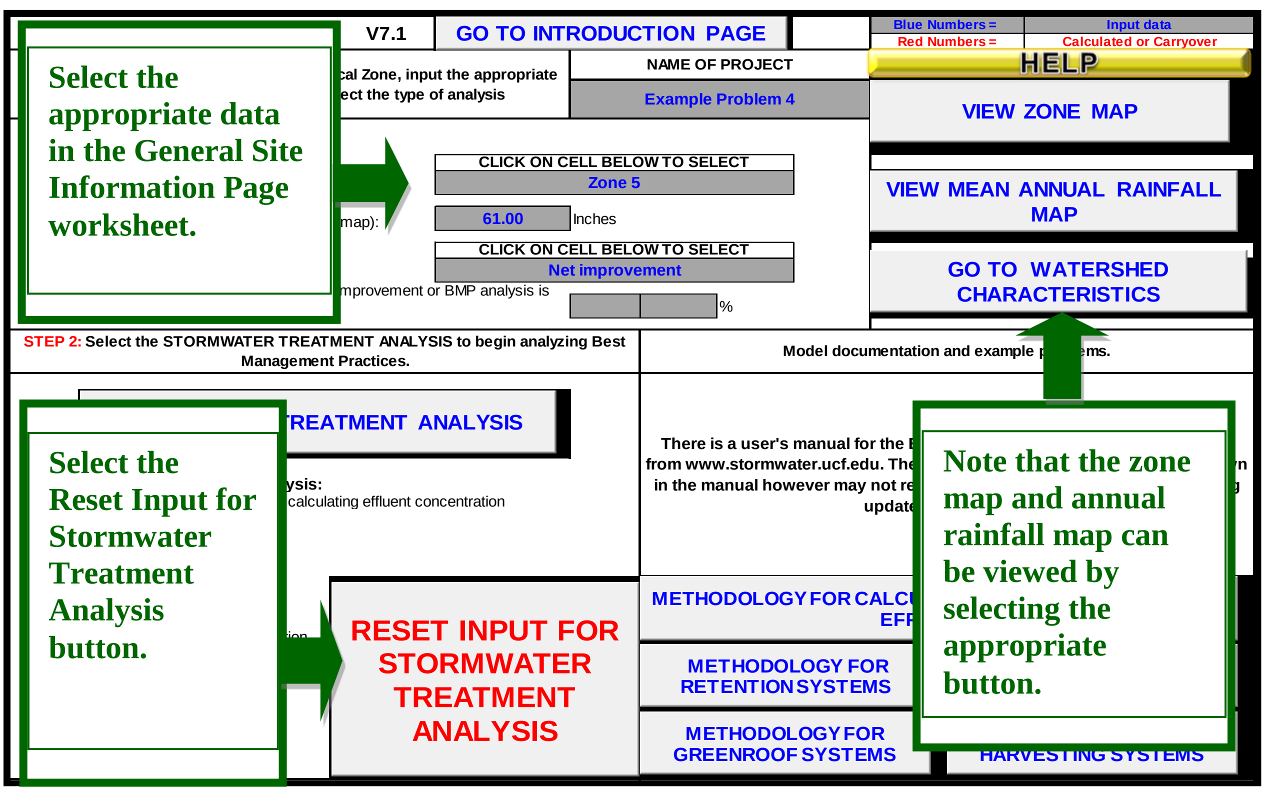


Figure 53 – General Site Information worksheet

2. Select the *Watershed Characteristics* button to proceed to the **Watershed Characteristics** worksheet (Figure 54).
   a. Indicate the catchment configuration, pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage.

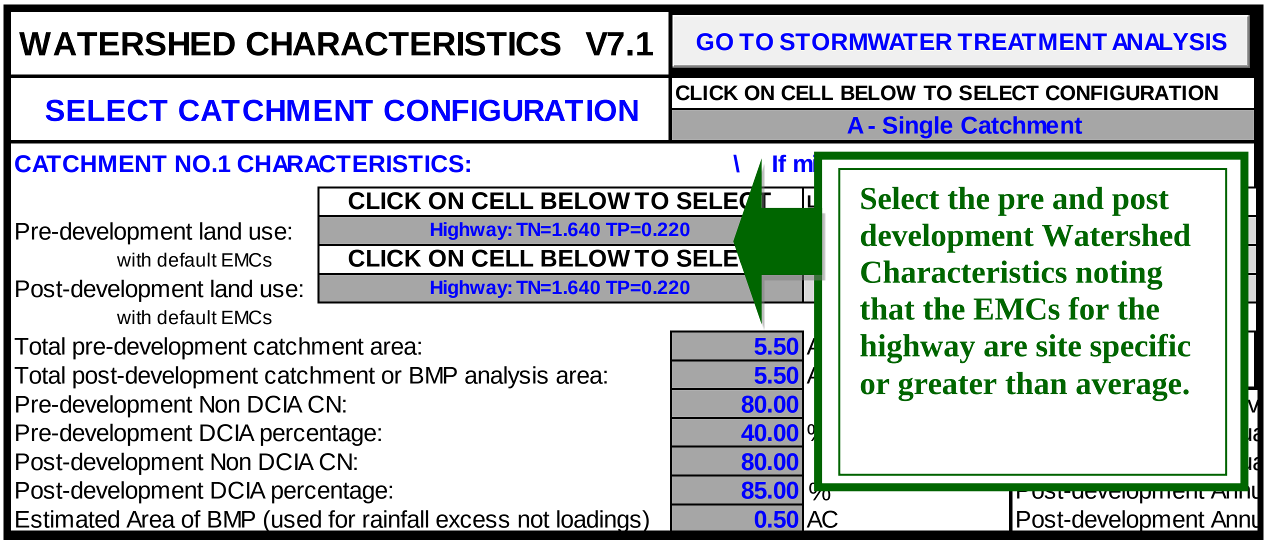


Figure 54 – Watershed Characteristics worksheet

3. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
4. Select the *Wet Detention* button to proceed to the **Wet Detention** worksheet (Figure 55).
   a. Specify the average annual residence time. Also specify whether the littoral zone is used in the design and indicate the efficiency credit associated with it.

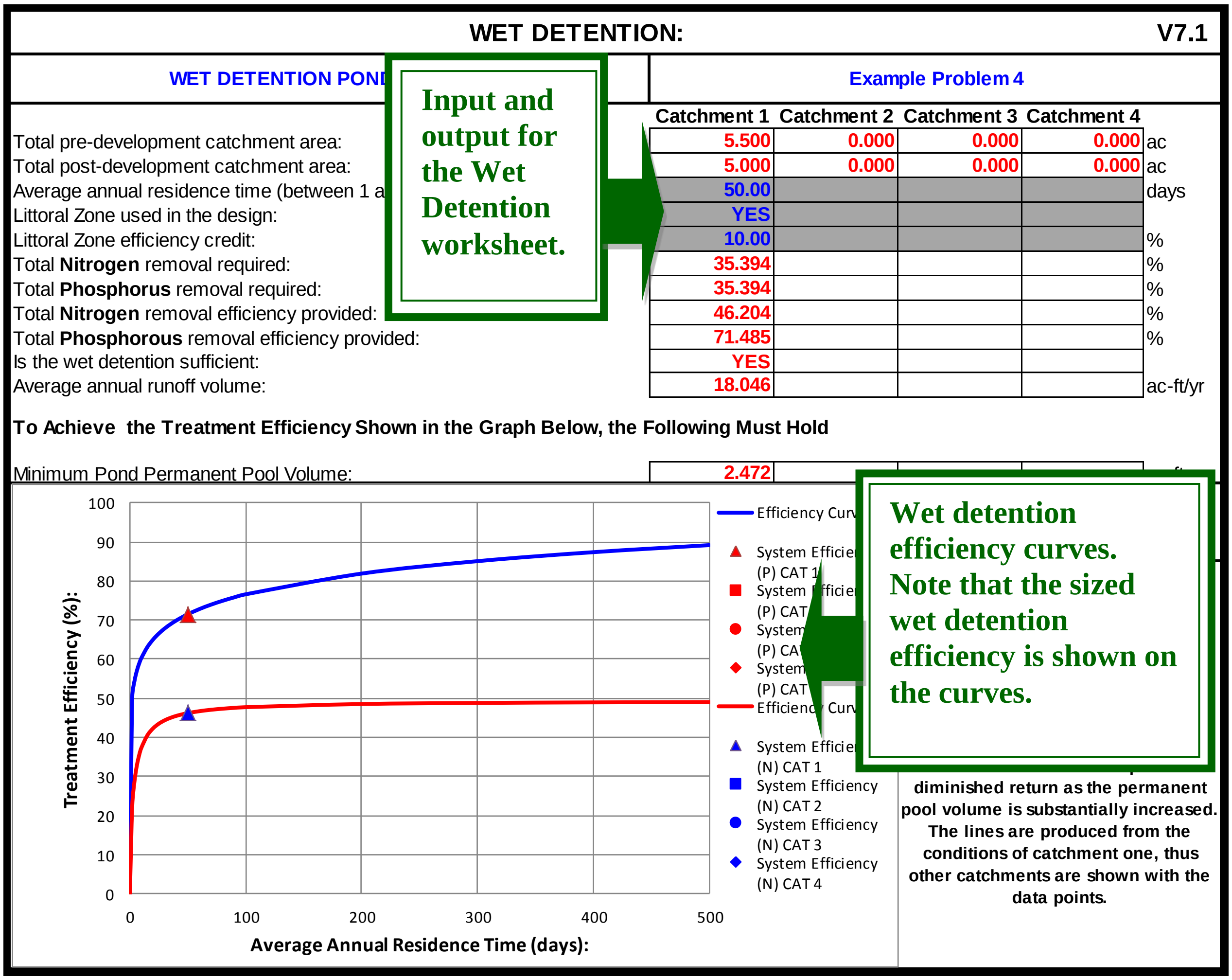


Figure 55 – Wet Detention worksheet

5. The user can now view a summary of the treatment achieved for the specified site conditions and BMP used by selecting the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet, and then selecting the *Catchment and Treatment Summary Results* button to go to the **Catchment and Treatment Summary Results** worksheet (Figure 56).

CATCHMENTS AND TREATMENT SUMMARY RESULTS V7.1

CALCULATION METHODS:

1. The effectiveness of each BMP in a single catchment is converted to an equivalent capture volume.
2. Certain BMP treatment train combinations have not been evaluated and in practice they are at this time not used, an example is a greenroof following a tree well.
3. If multiple BMPs are used in a single catchment and one of them is detention, then it is assumed to be last in series.

PROJECT TITLE	Example Problem 4	Optional Identification		
	Catchment 1:	Catchment 2:	Catchment 3:	Catchment 4:
BMP Name	Wet Detention			
BMP Name				
BMP Name				

Summary Performance of Entire Watershed

Catchment Configuration	A - Single Catchment		4/14/2014
Nitrogen Pre Load (kg/yr)	23.58		BMPTRAINS MODEL
Phosphorus Pre Load (kg/yr)	3.16		
Nitrogen Post Load (kg/yr)	36.50		
Phosphorus Post Load (kg/yr)	4.90		
Target Load Reduction (N) %	35		
Target Load Reduction (P) %	35		
Target Discharge Load, N (kg/yr)	23.58		
Target Discharge Load, P (kg/yr)	3.16		
Provided Overall Efficiency, N (%):	46		
Provided Overall Efficiency, P (%):	71		
Discharged Load, N (kg/yr & lb/yr):	19.63		
Discharged Load, P (kg/yr & lb/yr):	1.40	3.08	
Load Removed, N (kg/yr & lb/yr):	16.86	37.14	
Load Removed, P (kg/yr & lb/yr):	3.50	7.71	

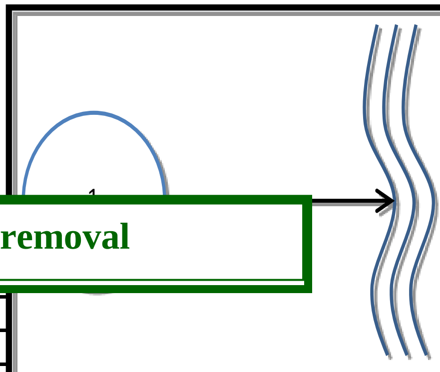


Figure 56 – Summary Input & Output worksheet

Discussion: To achieve an 80% efficiency, the wet detention pond can be operated as a stormwater reuse pond. This is possible because there is a need for irrigation water adjacent to the highway. The irrigation water will follow the guidelines of the Water Management Districts and use on the average 0.86 inches per week of water over an eight and a half (8.5) acre area. Using the stormwater harvesting BMP option, the capture effectiveness can be calculated. The only change in the meteorological and catchment input data shown in Figure 53 and Figure 54 is that the BMP effectiveness is the type of analysis and not net improvement. If there is any increase in effectiveness by using stormwater harvesting, the increase can be used to satisfy compensatory treatment needs on the other parts of the highway.

The water quality or reuse volume in the wet detention pond is 0.733 ac-ft. Using a weighted runoff coefficient of 0.80, the available harvest volume over the EIA is 2 inches [(12 in/foot)(0.733 ac-ft)/(5.5 ac)(0.80)]. Selecting the stormwater harvesting BMP, the data are entered with the option of solving for the harvesting efficiency as shown in Figure 57. The annual capture efficiency is 80.14% of the yearly runoff into the reuse pond. To provide for a continuous source of irrigation water, other supplemental water is needed (4.481 MG/y). The pond reduces the need for irrigation water from other sources by supplying 5.841 MG/y of the total 10.321 MG/y [(0.86 in/week)(8.5 ac)(1 foot/12 inches)(52 weeks/year)(0.3258)]. Also in Figure 57 the REV curve for the watershed conditions of this problem in Zone 5 shows how changes in the water quality volume (a.k.a. runoff volume) on the (X axis) and reuse rate (Y axis) can affect the average annual capture effectiveness for the reuse pond.

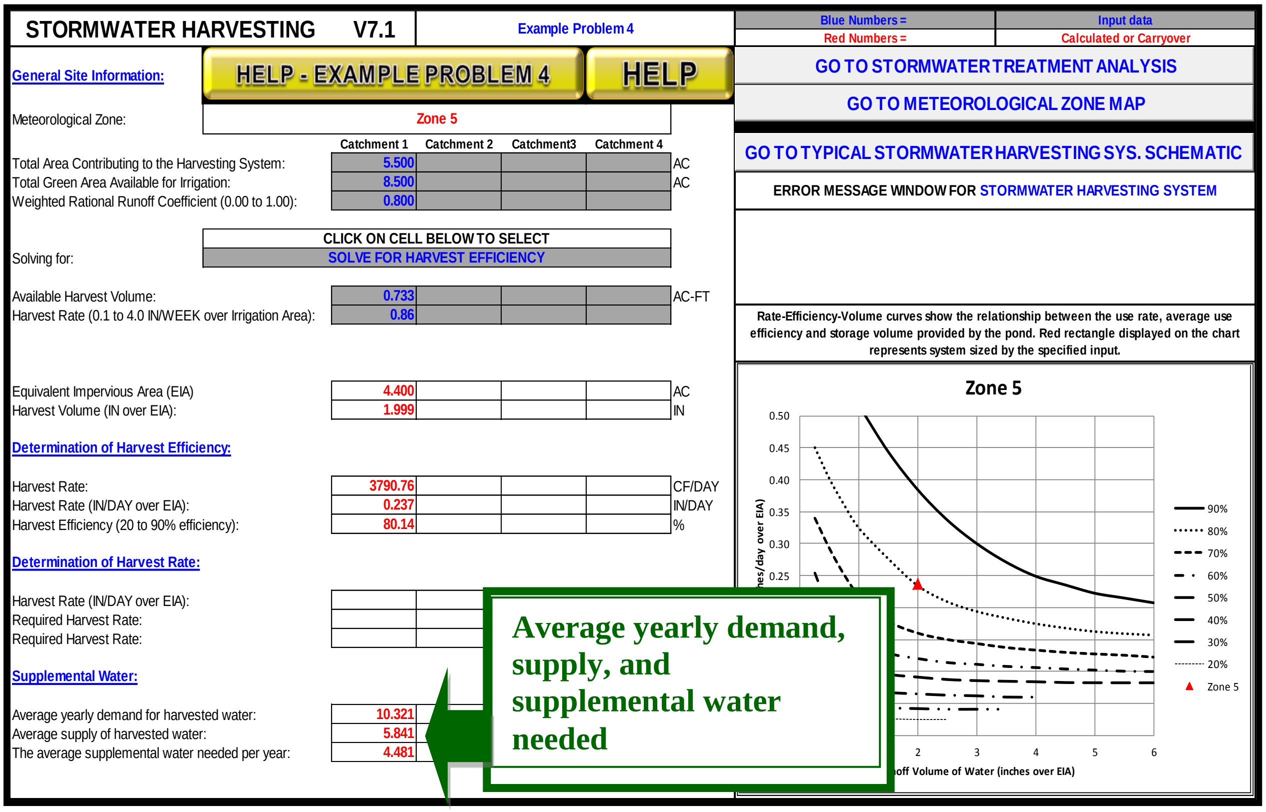


Figure 57 – Reuse or Harvesting Pond Calculation worksheet

Discussion: To calculate the pollutant removal effectiveness, the detention pond mass removal effectiveness is added as if the reuse and wet pond were in series (actually, they are one in the same). The average residence time in the pond is at 50 days, which is higher than usual. With reuse, the residence time will increase as water is removed for irrigation rather than being discharged from the wet detention pond. Note however that the efficiency does not increase significantly beyond 50 days of residence time, and thus the residence time is not changed when adding the wet pond efficiency to the capture efficiency of the reuse pond. What has to be changed is the configuration from a single BMP to two in series. There are now 2 BMPS (namely reuse and wet detention) in series. Figure 58 shows in the summary worksheet the performance statistics given the input data.

CATCHMENTS AND TREATMENT SUMMARY RESULTS				V7.1
CALCULATION METHODS:				
1. The effectiveness of each BMP in a single catchment is converted to an equivalent capture volume.				
2. Certain BMP treatment train combinations have not been evaluated and in practice they are at this time not used, an example is a greenroof following a tree well.				
3. If multiple BMPs are used in a single catchment and one of them is detention, then it is assumed to be last in series.				
PROJECT TITLE	Example Problem 4	Optional Identification		
	Catchment 1:	Catchment 2:	Catchment 3:	Catchment 4:
BMP Name	Wet Detention			
BMP Name	Stormwater Harvesting			
BMP Name				

Summary Performance of Entire Watershed

Catchment Configuration	A - Single Catchment		4/14/2014
Nitrogen Pre Load (kg/yr)	23.58		BMPTRAINS MODEL
Phosphorus Pre Load (kg/yr)	3.16		
Nitrogen Post Load (kg/yr)	36.50		
Phosphorus Post Load (kg/yr)	4.90		
Target Load Reduction (N) %	35		
Target Load Reduction (P) %	35		
Target Discharge Load, N (kg/yr)	23.58		
Target Discharge Load, P (kg/yr)	3.16		
Provided Overall Efficiency, N (%):	89		
Provided Overall Efficiency, P (%):	94		
Discharged Load, N (kg/yr & lb/yr):	3.90		
Discharged Load, P (kg/yr & lb/yr):	0.28		
Load Removed, N (kg/yr & lb/yr):	32.60		
Load Removed, P (kg/yr & lb/yr):	4.62	10.17	

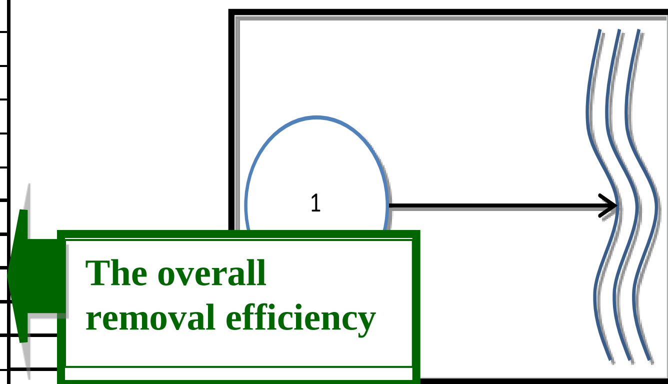


Figure 58 – Summary Input and Output worksheet for Two BMPs in Series

Discussion: the overall average nitrogen annual efficiency in series using stormwater reuse with a wet detention pond increased from 46 to 89%. The average annual phosphorus efficiency increased from 71 to 94%. By example, the calculations show that a reuse pond designed consistently with wet detention pond pollution control criteria can usually meet an 80% efficiency target or provide compensatory value, or net improvement type of analysis.

Example problem # 5 – Wet Detention after and in Series with Retention System (Retention Basin, Exfiltration Trench, Swales, Retention Tree Wells, Pervious Pavement, etc.)

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 Hydrologic Soil Group D. The existing land use condition is assumed to be Wet Flatwoods with a non-DCIA Curve Number of 80 and 0% DCIA. The post-development land use condition is assumed to be highway where the non-DCIA Curve Number is 80 and DCIA is 60%. The target removal efficiency for both nitrogen and phosphorus is 80%. A wet detention pond is used for flood control with a 100-day annual average residence time. The wet detention pond also will utilize a littoral zone (assumed 10% removal efficiency credit) in the design.

1. From the introduction page click on the *Click Here to Start* button to proceed to the **General Site Information** worksheet.
   a. Select the *Reset Input for Stormwater Treatment Analysis* button to erase any existing data.
   b. Enter the project name and select the meteorological zone in the **General Site Information** worksheet (Figure 59).
   c. Indicate the mean annual rainfall amount in the **General Site Information** worksheet
   d. Select the *Specified Removal Efficiency* option from the type of analysis drop down menu in the **General Site Information** worksheet.
   e. Specify the desired removal efficiency.

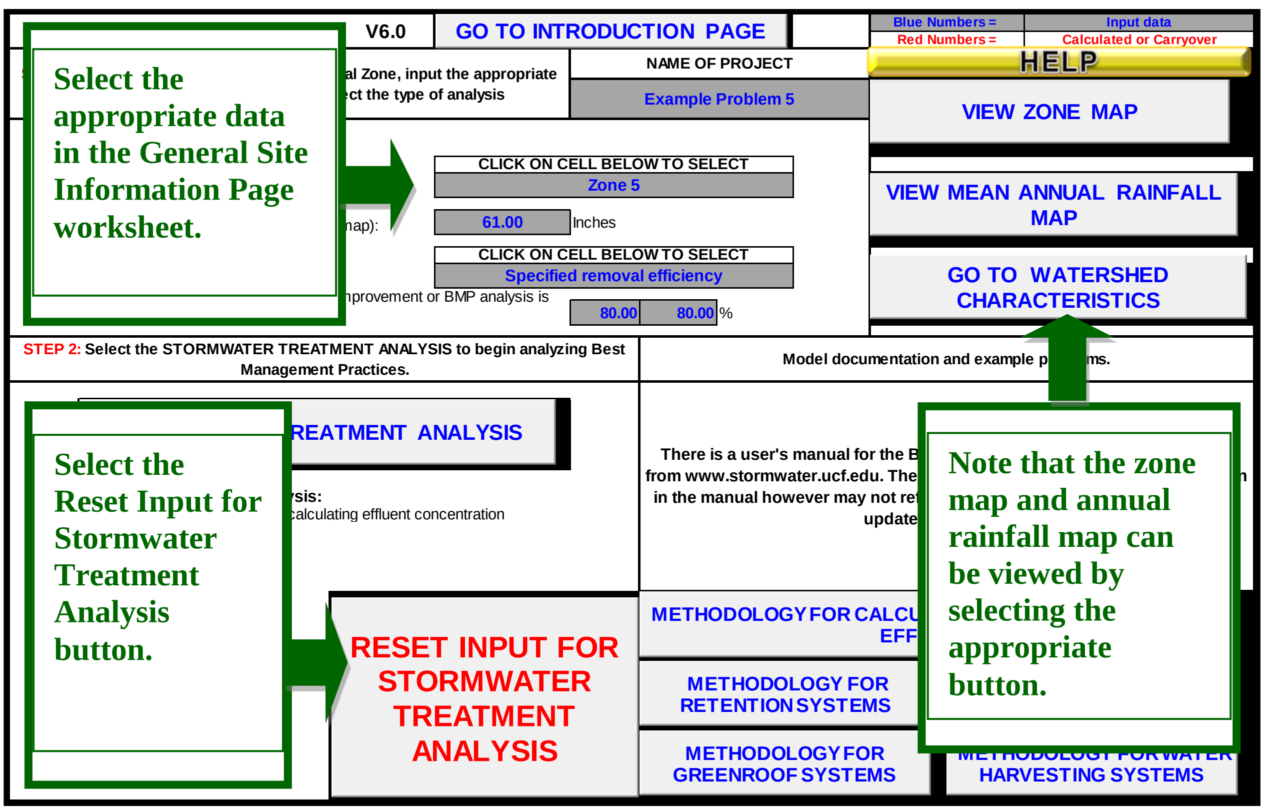


Figure 59 – General Site Information worksheet

2. Select the *Watershed Characteristics* button to proceed to the **Watershed Characteristics** worksheet (Figure 60).
   a. Indicate the catchment configuration, pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage.

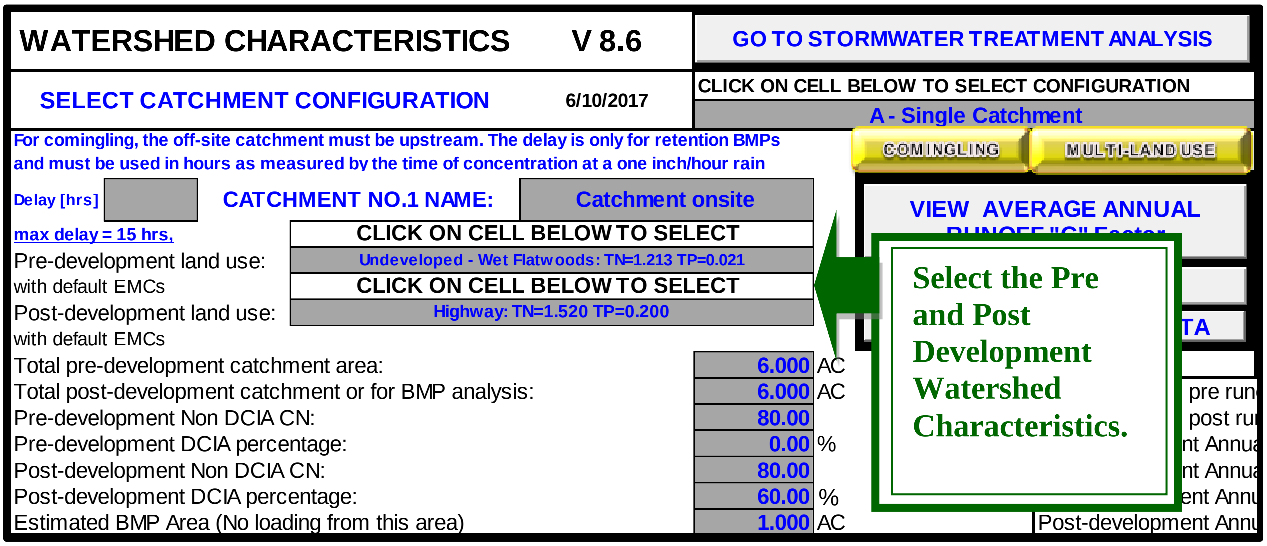


Figure 60 – Watershed Characteristics worksheet

3. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
4. Select the *Wet Detention* button to proceed to the **Wet Detention** worksheet (Figure 61).
   a. Specify the average annual residence time. Also specify whether the littoral zone is used in the design and indicate the efficiency credit associated with it.
   b. Make note of the remaining treatment efficiency needed as this value will be needed to determine the required retention storage (Figure 61). In this case 61.74% for Nitrogen and 14.56% for Phosphorus. Since Nitrogen requires more additional treatment, this value will set the retention storage.

   The water characteristics worksheet shown in Figure 60 has been enhanced over time with an input variable for comingling of offsite runoff. In some situations, runoff water from a remote offsite can flow to an existing onsite BMP, (so-called comingling) or the offsite runoff can bypass the onsite BMP. Remote is defined as an offsite flow that does not reach the onsite BMP for some time after the rainfall event has started. This is known as a delay and must be entered in units of hours. The delay is calculated knowing the distance from the discharge of the offsite watershed to the influent to the onsite BMP. The delay is calculated based on a rainfall intensity of one inch per hour. As an alternative way of estimating delay, use field derived data and average the delays. The delay for this example problem is six (6) hours

This input for delay has been added to all watershed characteristics worksheets starting with version 8.0 series. To enter the delay data for comingling, the selected configuration in this case must be chosen so that the offsite catchment is up-stream of the onsite catchment. Thus, the configuration chosen is type B, or two catchments in series. The offsite catchment data are entered as catchment No.1. Catchment No. 2 is the downstream onsite watershed with BMP where the comingling can occur. This delay is used for retention effectiveness calculations. IT is not used for wet detention calculations. Wet detention average yearly residence time is in the order of at least 21 days and frequently much larger. A delay of up to 15 hours has a marginal change in the average annual effectiveness. The delay is used to calculate the recovered volume of water in the onsite BMP before the offsite water reaches the onsite BMP. The delay cannot exceed 15 hours.

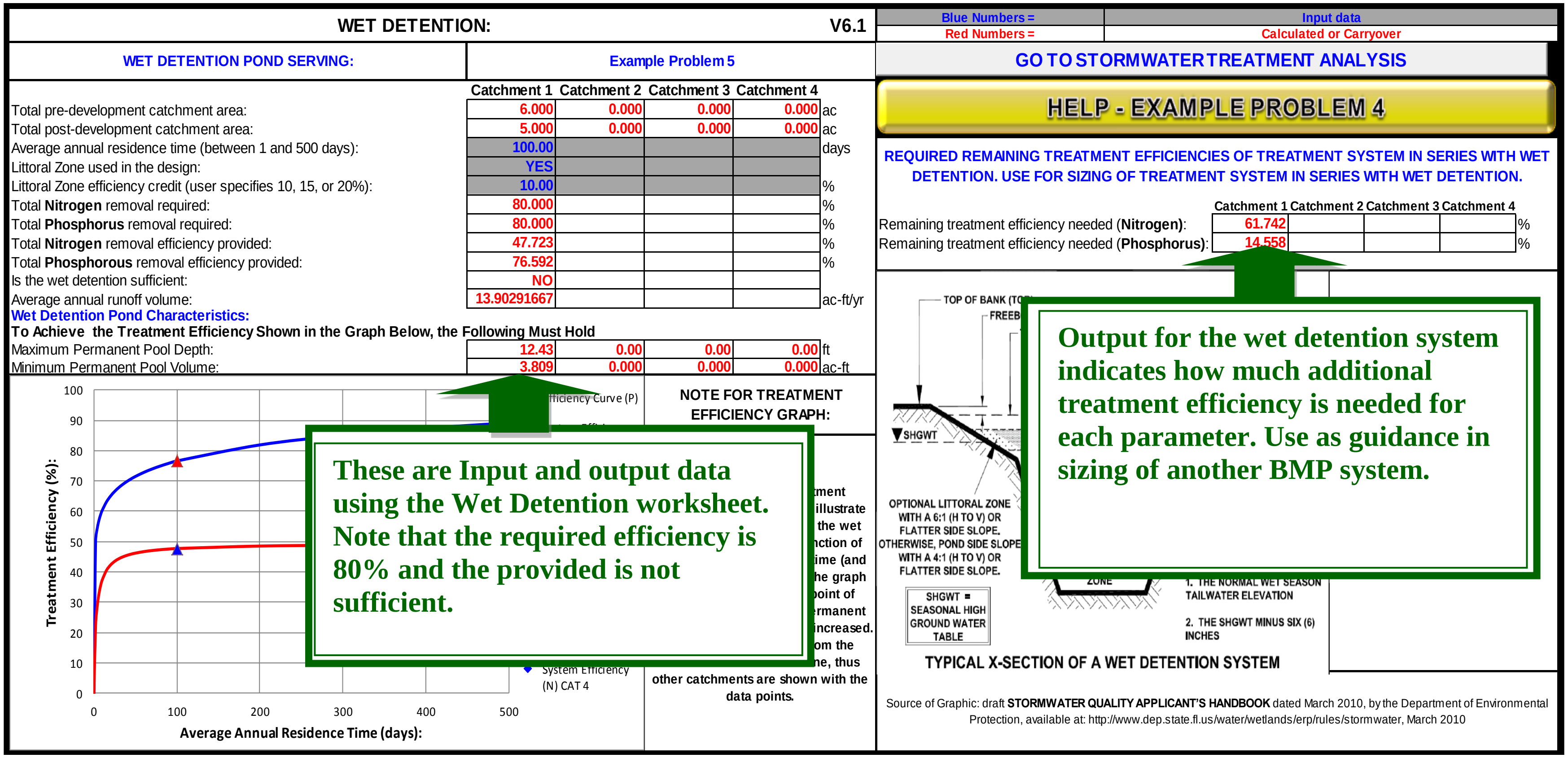


Figure 61 – Wet Detention worksheet

5. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.

6. Select the *Retention Basin* button to proceed to the **Retention Basin** worksheet (Figure 62).
    a. Indicate the retention depth to be provided upstream of the wet detention system in the second part of the Retention Basin worksheet. This is iterative process and the retention depth needs to be adjusted until the provided treatment efficiency of the retention basin matches the remaining treatment efficiency value from the wet detention pond.

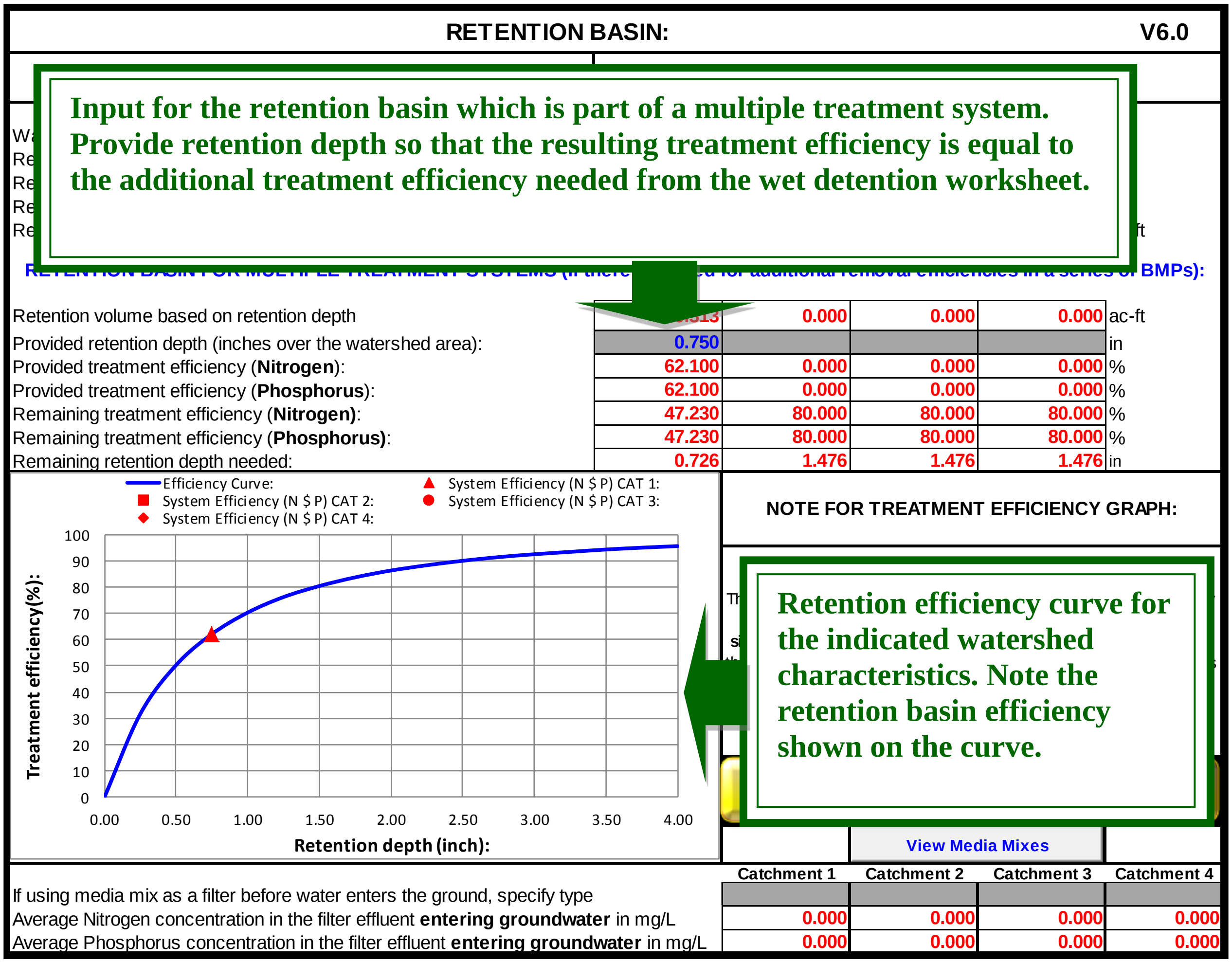


Figure 62 – Retention Basin worksheet

7. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
8. Select the *Catchment and Treatment Summary Results* button to proceed to the **Catchment and Treatment Summary Results** worksheet (Figure 63).

CATCHMENTS AND TREATMENT SUMMARY RESULTS	V7.3

CALCULATION METHODS:

1. The effectiveness of each BMP in a single catchment is converted to an equivalent capture volume.
2. Certain BMP treatment train combinations have not been evaluated and in practice they are at this time not used, an example is a greenroof following a tree well.
3. If multiple BMPs are used in a single catchment and one of them is detention, then it is assumed to be last in series.

PROJECT TITLE	Example Problem 5	Optional Identification	

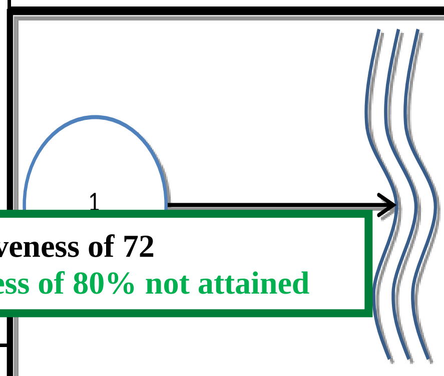
	Catchment 1:	Catchment 2:	Catchment 3:	Catchment 4:
BMP Name	Retention Basin			
BMP Name	Wet Detention			
BMP Name				

Summary Performance of Entire Watershed

Catchment Configuration	A - Single Catchment	
Nitrogen Pre Load (kg/yr)	6.94	
Phosphorus Pre Load (kg/yr)	0.09	
Nitrogen Post Load (kg/yr)	28.12	
Phosphorus Post Load (kg/yr)	3.77	
Target Load Reduction (N) %	80	
Target Load Reduction (P) %	80	
Target Discharge Load, N (kg/yr)	5.62	
Target Discharge Load, P (kg/yr)	0.75	
Provided Overall Efficiency, N (%):	72	
Provided Overall Efficiency, P (%):	88	
Discharged Load, N (kg/yr & lb/yr):	7.92	
Discharged Load, P (kg/yr & lb/yr):	0.46	1.02
Load Removed, N (kg/yr & lb/yr):	20.20	44.50
Load Removed, P (kg/yr & lb/yr):	3.31	7.29

6/23/2014

BMPTRAINS MODEL



Provided N effectiveness of 72

Note: N effectiveness of 80% not attained

Figure 63 – Catchment and Treatment Summary Results worksheet

Discussion: Achieved effectiveness did not meet treatment goal. This is due to the fact that most of the treatment provided by wet detention is from settling. Since this model treats all detention systems as downstream from retention systems, settling has already occurred by the time the water reaches the detention system. Therefore, for this case, the achieved treatment by the detention BMP is less for nitrogen and phosphorus when detention is used with retention.

Example problem # 6 – Retention Systems in Series - Pre vs. Post-Development Loading

A half-acre exfiltration trench in series with a half-acre retention basin is serving a 6.0-acre low-intensity commercial site. In addition, the plan calls for 10 tree wells along the road. The tree wells are to be 3 feet deep with a 6-inch depth above soil column. The length and width of the tree wells are to be 4 feet for each. A 0.2 sustainable water storage capacity of the soil is assumed. The tree wells are retention systems. All 6-acres drain to the three BMPS that are in series with each other (note if there were a catchment area between each BMP, a more accurate estimated of effectiveness is possible with multiple catchments, instead of one catchment). The site is located in Orlando, FL on Hydrologic Soil Group C. The existing land use condition is assumed undeveloped-dry prairie with a non-DCIA Curve Number of 79 and 0.0% DCIA. The post-development land use condition is a low intensity commercial area with a non-DCIA Curve Number of 85 and 65% DCIA. The combination of treatment systems is to provide treatment sufficient to match the post-development annual nutrient loads with the pre-development annual nutrient loads.

1. From the introduction page click on the *Click Here to Start* button to proceed to the **General Site Information** worksheet.
    a. Select the *Reset Input for Stormwater Treatment Analysis* button to erase any existing data.
    b. Enter the project name and select the meteorological zone in the **General Site Information** worksheet (Figure 64).
    c. Indicate the mean annual rainfall amount in the **General Site Information** worksheet
    d. Select the *Net Improvement* option from the type of analysis drop down menu in the **General Site Information** worksheet.

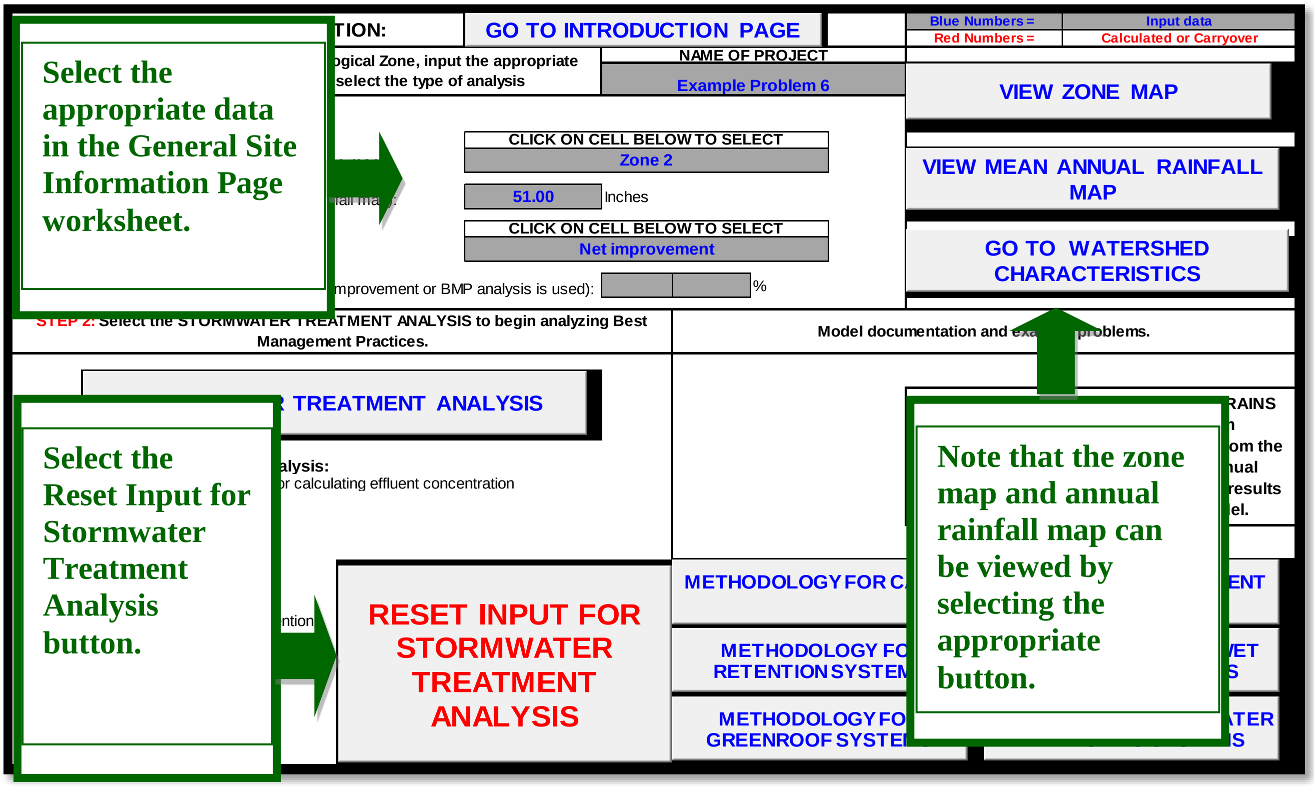


Figure 64 – General Site Information worksheet

2. Select the *Watershed Characteristics* button to proceed to the **Watershed Characteristics** worksheet (Figure 65).

   a. Indicate the catchment configuration, pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage.

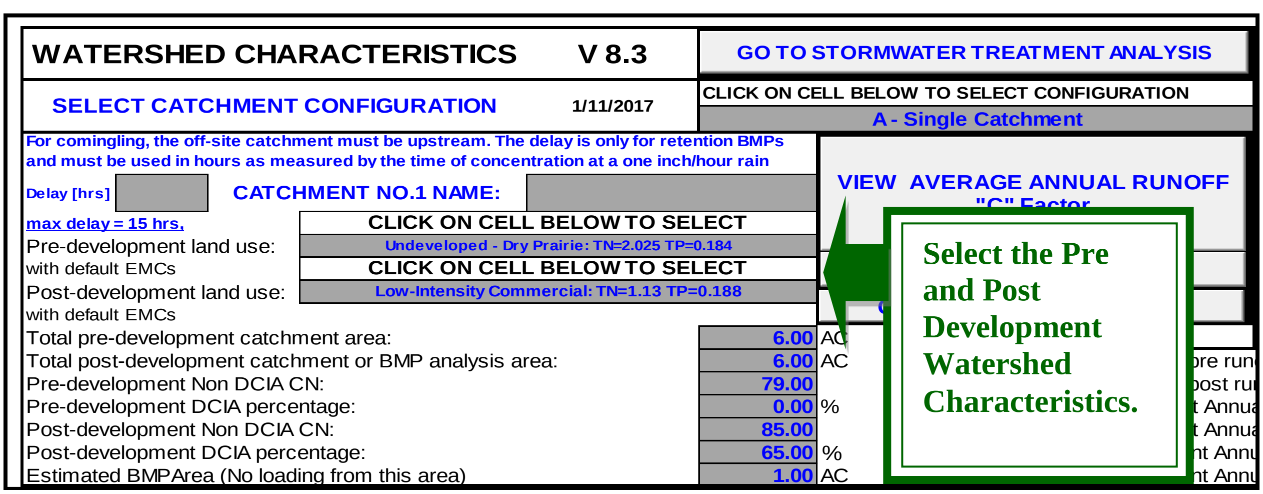


Figure 65 – Watershed Characteristics worksheet

3. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
4. Select the *Vegetated Area Example Tree Well* button to proceed to the **Vegetated Area Example Tree Well** worksheet (Figure 66).
   a. Fill out the input in the worksheet associated with the dimensions of the tree well and soil properties.
   b. Make note of the remaining treatment efficiency required for nitrogen and phosphorus (Figure 67 – Required remaining treatment from the Vegetated Areas (Example Tree Well) worksheet
   c. If in series, the remaining treatment efficiencies required are 60.83% TN and 78.61% TP.

Tree Well					1/11/2017 V 8.3
Tree wells that can include interceptor storage:	Example Problem 6				
Loadings from BMP area are contained, thus no BMP area load.	Catchment 1	Catc		Catchment 4	
Contributing catchment area:	5.000			0.000	ac
Required treatment efficiency (**Nitrogen**):	61.351				%
Required treatment efficiency (**Phosphorus**):	78.892				%
Vegetated Area (Tree Well) depth	3.00				ft
Tree Well Storage (intentional + canopy capture)	0.50				ft
Vegetated Area (Tree Well) length:	4.00				ft
Vegetated Area (Tree Well) width:	4.00				ft
Sustainable water storage capacity of the soil:	0.20				
Number of similar Areas within watershed:	10.00				
Retention depth for provided hydraulic capture efficiency:	0.010			0.000	in
Is this a retention or detention system?	Retention				
Type of soil augmentation: View Media Mixes#					
Provided treatment efficiency (**Nitrogen**):	1.307			0.000	%
Provided treatment efficiency (**Phosphorus**):	1.307			0.000	%
Is/are the vegetated areas sufficient?	NO				
# see media mixes for recommended TP and TN removal:					

Input and output for Tree Wells which will be a part of a multiple BMPs in series.

Figure 66 – Vegetated Areas (Example Tree Well) worksheet.

REQUIRED REMAINING TREATMENT EFFICIENCIES OF TREATMENT SYSTEM IN SERIES WITH VEGETATED AREAS. USE FOR SIZING OF TREATMENT SYSTEM IN SERIES WITH VEGETATED AREAS.

	Catchment 1	Catchment 2	Catchment 3	Catchment 4	
Remaining treatment efficiency needed (**Nitrogen**):	60.839				%
Remaining treatment efficiency needed (**Phosphorus**):	78.612				%

Figure 67 – Required remaining treatment from the Vegetated Areas (Example Tree Well) worksheet

5. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.

6. Select the *Exfiltration Trench* button to proceed to the **Exfiltration Trench** worksheet (Figure 68).
   a. Indicate the retention depth provided by the exfiltration trench in worksheet (Note: this is can be an iterative process if searching an exfiltration size to meet removal or is a fixed number based on a design.   In this case, it was a fixed design of ½-inch retention).

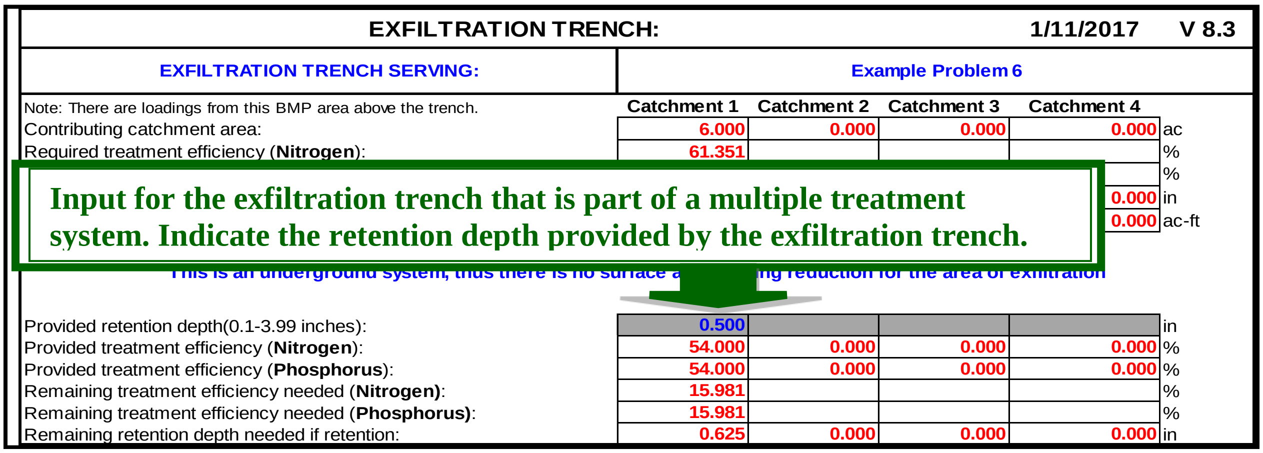


Figure 68 – Exfiltration Trench worksheet

7. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
8. Select the *Retention Basin* button to proceed to the **Retention Basin** worksheet (Figure 69).
   a. Indicate the treatment depth provided by the retention basin downstream of exfiltration trench. Note this can also be an iterative approach to match post to pre loadings.

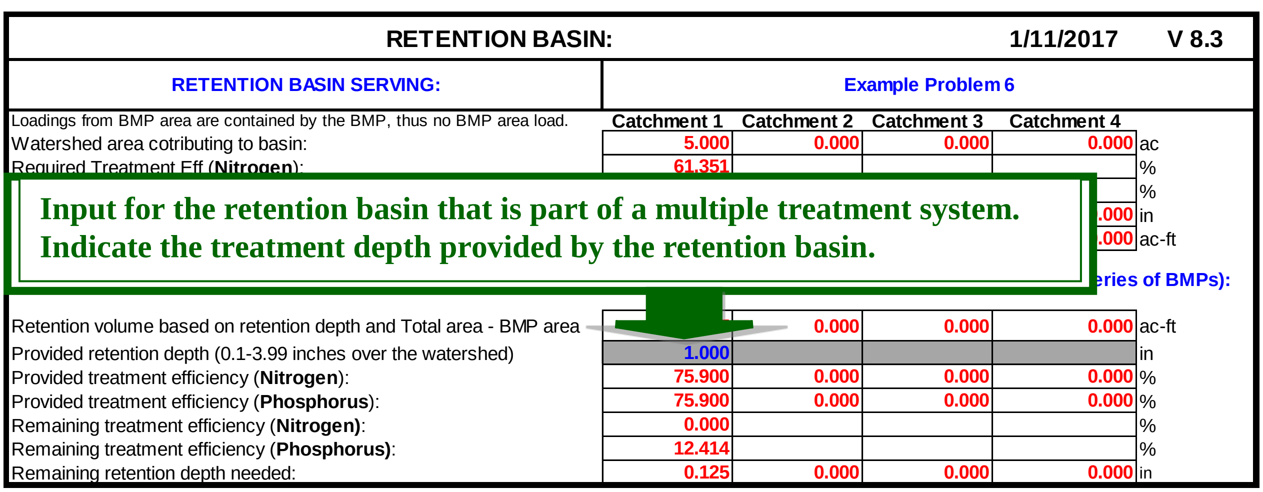


Figure 69 – Retention Basin worksheet

9. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
10. Select the *Catchment and Treatment Summary Results* button to proceed to the **Catchment and Treatment Summary Results** worksheet (Figure 70).

CATCHMENTS AND TREATMENT SURFACE DISCHARGE SUMMARY				V 8.3
CALCULATION METHODS: 1. The effectiveness of each BMP in a single catchment is converted to an equivalent capture volume. 2. Certain BMP treatment train combinations have not been evaluated and in practice they are at this time not used, an example is a greenroof following a tree well. 3. Wet detention is last when used in a single catchment with other BMPs, except when followed by filtration				
PROJECT TITLE	Example Problem 6	Optional Identification		
	Catchment 1	Catchment 2	Catchment 3	Catchment 4
BMP Name	Retention Basin			
BMP Name	Exfiltration Trench			
BMP Name	Tree Well			

Surface Water Discharge Summary Performance of Entire Watershed			
Catchment Configuration	A - Single Catchment	Treatment Objectives or Target for TN MET TP MET	1/11/2017 BMPTRAINS MODEL
Nitrogen Pre Load (kg/yr)	6.66		
Phosphorus Pre Load (kg/yr)	0.61		
Nitrogen Post Load (kg/yr)	17.24		
Phosphorus Post Load (kg/yr)	2.87		
Target Load Reduction (N) %	61		
Target Load Reduction (P) %	79		
Target Discharge Load, N (kg/yr)	6.72		
Target Discharge Load, P (kg/yr)	0.60		
Provided Overall Efficiency, N (%):	86		
Provided Overall Efficiency, P (%):	86		
Discharged Load, N (kg/yr & lb/yr):	2.37		
Discharged Load, P (kg/yr & lb/yr):	0.40		
Load Removed, N (kg/yr & lb/yr):	14.86		
Load Removed, P (kg/yr & lb/yr):	2.47	[illegible]	

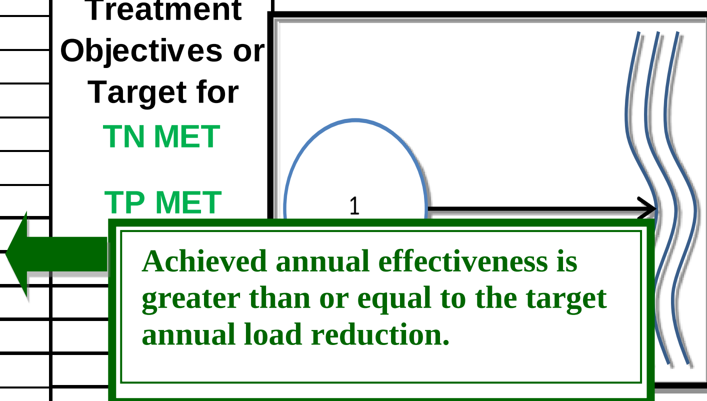


Figure 70 – Multiple Watersheds and Treatment Systems Analysis worksheet

If needed, the BMP sizes can be reduced on their worksheet pages until the overall provided efficiency matches the required target efficiency.

Discussion: For a single catchment for which cascading (in series) retention systems are used, the total treatment efficiency is calculated based on the sum of individual retention depths rather than the sum of the individual removal efficiencies (see Figure 71). This is for the situation of no area input between each of the retention systems.

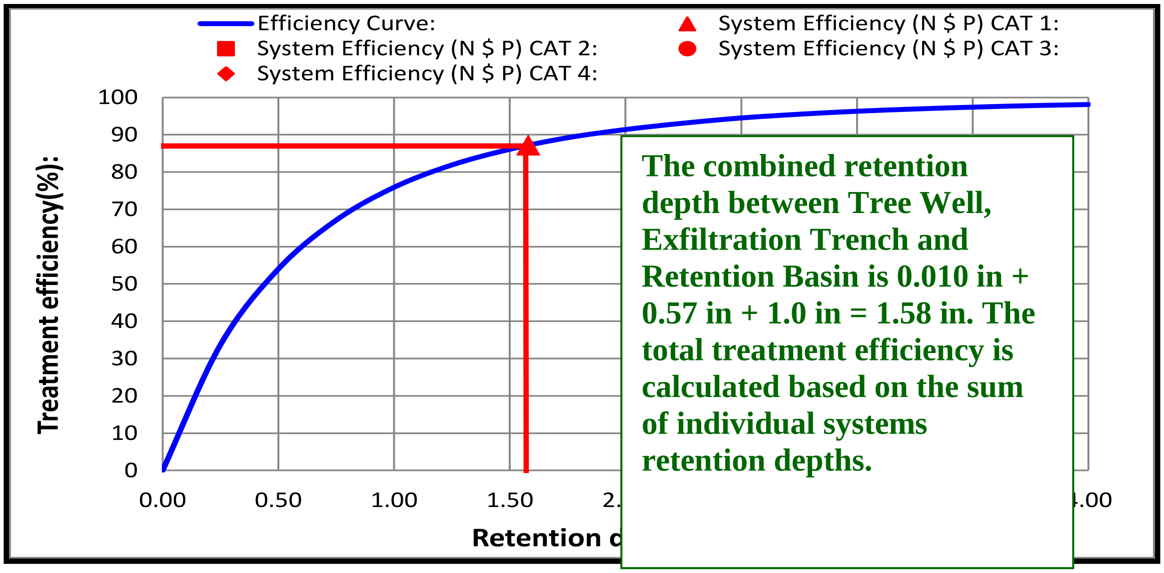


Figure 71 – Retention Basin worksheet illustrating retention in series

Example problem # 7 – Wet Detention Systems in Series - Pre vs. Post-Development Loading

Two half-acre wet detention ponds in series are serving a 6.0-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 portions of the highway will be treated in the post-development condition. The site is located in Boca Raton, FL on Hydrologic Soil Group D. The existing land use condition is assumed as a 3.0-acre highway with a non-DCIA Curve Number of 80 and 40% DCIA and 3.0-acre Wet Flatwoods with a non-DCIA Curve Number of 80 and 0% DCIA. The post-development land use condition is assumed as a highway with a non-DCIA Curve Number of 80 and 80% DCIA. Both wet detention ponds will utilize a littoral zone (assumed 10% removal efficiency credit) and floating wetland islands (assumed 20% removal efficiency credit) in the design. The combined average annual residence time provided between the two wet detention ponds in series is to be 90 days.

1. From the introduction page click on the *Click Here to Start* button to proceed to the **General Site Information** worksheet.
   a. Select the *Reset Input for Stormwater Treatment Analysis* button to erase any existing data.

b. Enter the project name and select the meteorological zone in the **General Site Information** worksheet (Figure 72).

c. Indicate the mean annual rainfall amount in the **General Site Information** worksheet.

d. Select the *Net Improvement* option from the type of analysis drop down menu in the **General Site Information** worksheet.

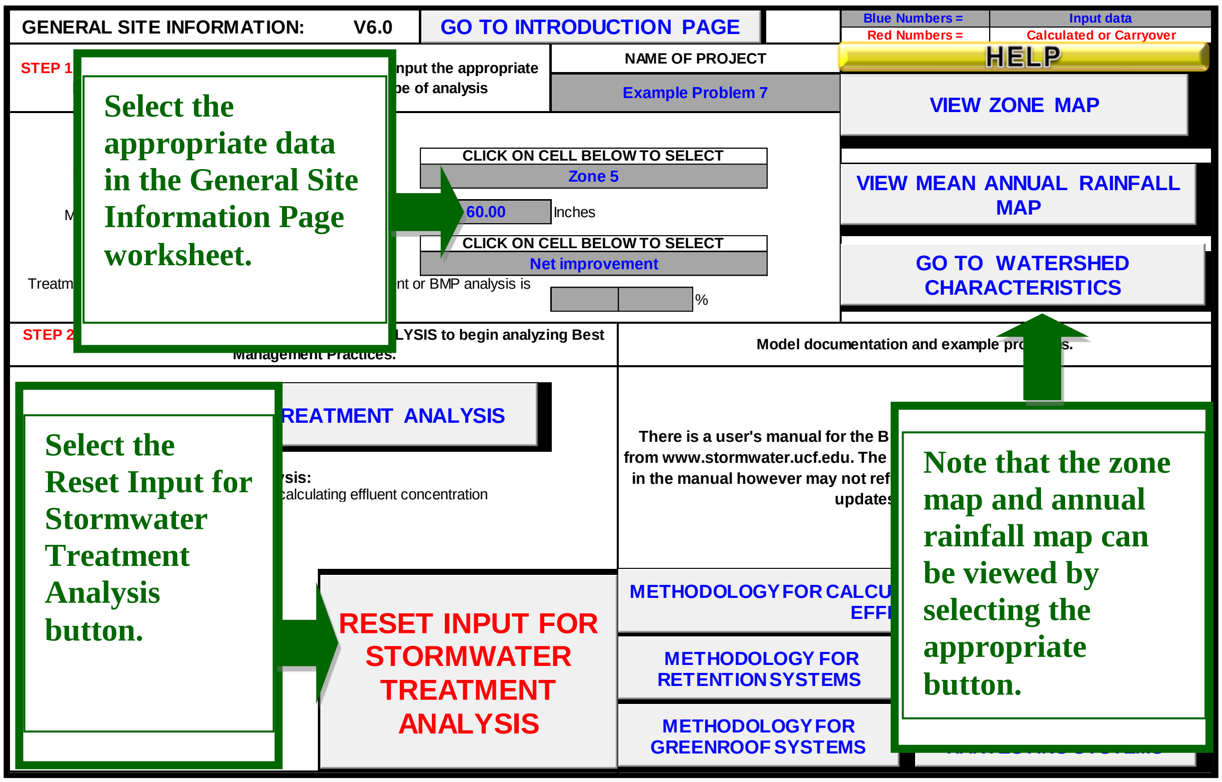


Figure 72 – General Site Information worksheet

2. Select the *Watershed Characteristics button* to proceed to the **Watershed Characteristics worksheet**

   a. Select the catchment configuration, two catchments in series for this problem.

   b. Enter the data for the first and second catchments in the *Watershed Characteristics* worksheet (Figure 73).

   c. Indicate the pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage.

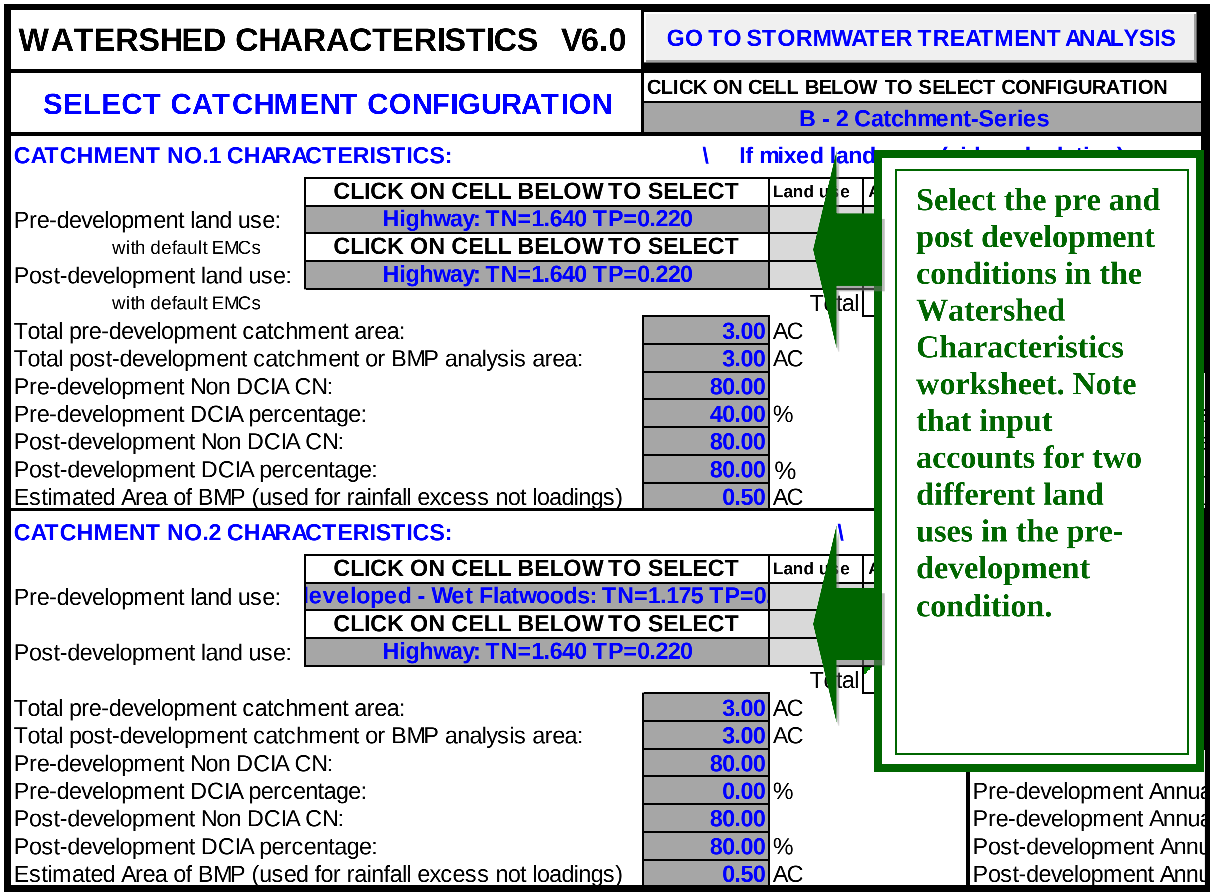
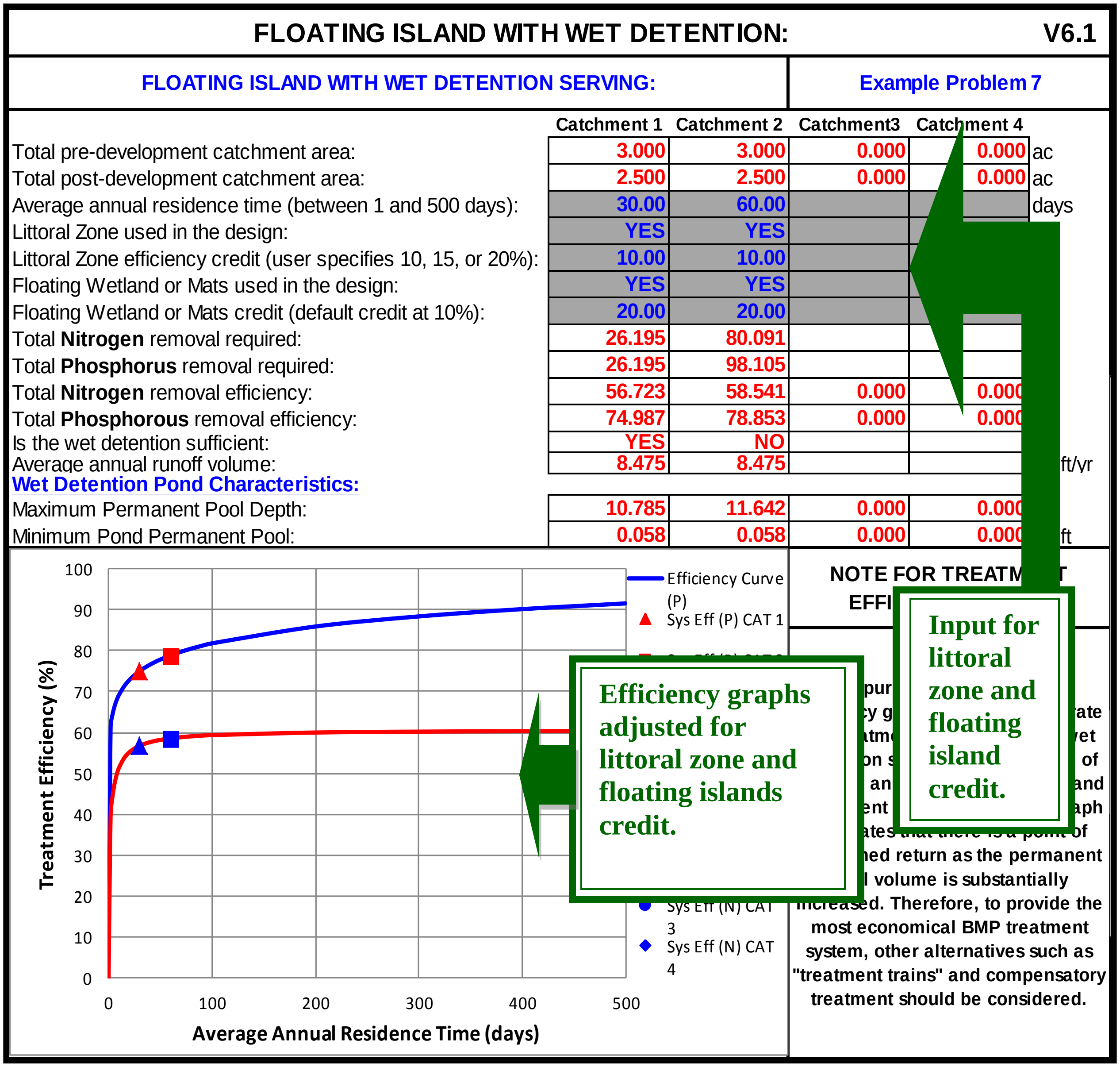


Figure 73 – Watershed Characteristics worksheet

3. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
4. Select the *Floating Islands with Wet Detention* button to proceed to the **Floating Islands with Wet Detention** worksheet (Figure 74).
   a. Specify average annual residence time provided between the two wet detention ponds in series. Note that the permanent pool volume provided between two wet detention ponds in series should be equivalent to the minimum pond permanent pool value provided by results.
   b. Specify that the littoral zone be used in the design and indicate the efficiency credit associated with it using the drop down menus (assumed 10% removal efficiency credit).
   c. Specify that the floating islands be used in the design and indicate the efficiency credit associated with it using the drop down menus (assumed 20% removal efficiency credit).



FLOATING ISLAND WITH WET DETENTION:					V6.1
FLOATING ISLAND WITH WET DETENTION SERVING:				Example Problem 7	
	Catchment 1	Catchment 2	Catchment3	Catchment 4	
Total pre-development catchment area:	3.000	3.000	0.000	0.000	ac
Total post-development catchment area:	2.500	2.500	0.000	0.000	ac
Average annual residence time (between 1 and 500 days):	30.00	60.00			days
Littoral Zone used in the design:	YES	YES			
Littoral Zone efficiency credit (user specifies 10, 15, or 20%):	10.00	10.00			
Floating Wetland or Mats used in the design:	YES	YES			
Floating Wetland or Mats credit (default credit at 10%):	20.00	20.00			
Total **Nitrogen** removal required:	26.195	80.091			
Total **Phosphorus** removal required:	26.195	98.105			
Total **Nitrogen** removal efficiency:	56.723	58.541	0.000	0.000	
Total **Phosphorous** removal efficiency:	74.987	78.853	0.000	0.000	
Is the wet detention sufficient:	YES	NO			
Average annual runoff volume:	8.475	8.475			ft/yr
Wet Detention Pond Characteristics:					
Maximum Permanent Pool Depth:	10.785	11.642	0.000	0.000	
Minimum Pond Permanent Pool:	0.058	0.058	0.000	0.000	ft

Figure 74 – Floating Island with Wet Detention worksheet

5. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
6. Select the *Catchment and Treatment Summary Results* button to proceed to the **Catchment and Treatment Summary Results** worksheet (Figure 75).

CATCHMENTS AND TREATMENT SUMMARY RESULTS				V6.0
CALCULATION METHODS:				
1. The effectiveness of each BMP in a single catchment is converted to an equivalent capture volume.				
2. Certain BMP treatment train combinations have not been evaluated and in practice they are at this time not used, an example is a greenroof following a tree well.				
3. If multiple BMPs are used in a single catchment and one of them is detention, then it is assumed to be last in series.				
PROJECT TITLE	Example Problem 7	Optional Identification		
	Catchment 1:	Catchment 2:	Catchment 3:	Catchment 4:
BMP1	Floating Island	Floating Island		
BMP2				
BMP3				

Summary Performance

Catchment Configuration	B - 2 Catchment-Series		1/27/2014
			BMPTRAINS MODEL
Catchment Nitrogen Pre Load	16.06		
Catchment Phosphorus Pre Load	1.74		
Catchment Nitrogen Post Load	34.28		
Catchment Phosphorus Post Load	4.60		
Target Load Reduction (N) %	53		
Target Load Reduction (P) %	62		
Target Discharge Load, N (kg/yr)	16.06		
Target Discharge Load, P (kg/yr)	1.74		
Provided Overall Efficiency, N (%):	58		
Provided Overall Efficiency, P (%):	77		
Discharged Load, N (kg/yr & lb/yr):	14.48		
Discharged Load, P (kg/yr & lb/yr):	1.06		
Load Removed, N (kg/yr & lb/yr):	19.80	43.62	
Load Removed, P (kg/yr & lb/yr):	3.54	7.80	

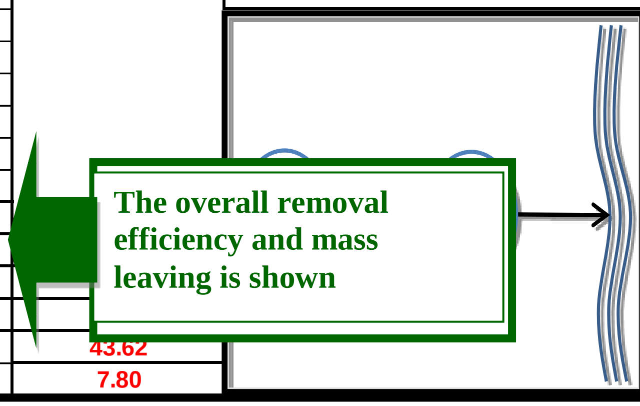


Figure 75 – Catchment and Treatment Summary Results for Example Problem 7

Example problem # 8 – Limited area for treatment and benefits of comingling treatment

This illustrates the option for treating runoff from an upstream catchment in a downstream BMP. The greater the lag time or the time of concentration to reach the downstream retention BMP, the greater the removal of pollutants from the two catchments. This is because there is capacity in the downstream BMP caused by the infiltration during the lag time.

A retention basin for a 2.5-acre addition to an existing highway is planned. The offsite and upstream is a 2-acre rural highway (30% DCIA) that does not have any treatment system. The runoff from the offsite area may be combined with the new roadway runoff. The pervious area has a Curve Number of 50 and 0% DCIA. The location is Lakeland, FL, with 50.5 inches of rain per year on average. The pre-development (pre-highway) land use condition is agricultural-citrus. The post-development land use condition is highway with a non-DCIA Curve Number of 50 and DCIA of 60%. The right-of-way area after the addition of the new highway watershed is large enough to accommodate a 2.255 inches' runoff volume. Also assume that the highway is in an area where net improvement is required. The problem solution is divided into parts for training purposes. The first part demonstrates an assessment of removal for the new highway when the flow from the old highway is bypassing the new highway stormwater treatment BMP.

Part 1. For the new or additional watershed area, compute the retention volume assuming no flow from the existing highway is routed to the new basin and the new highway watershed has to be treated in one retention basin:

1. From the introduction worksheet, click on the *Click Here to Start* button to proceed to the **General Site Information** worksheet.
    a. Select the *Reset Input for Stormwater Treatment Analysis* button to erase any existing data.
    b. Enter the project name and select the meteorological zone in the **General Site Information** worksheet (Figure 76).
    c. Indicate the mean annual rainfall amount in the **General Site Information** worksheet.
    d. Select the *Net Improvement* option from the type of analysis drop down menu in the **General Site Information** worksheet.

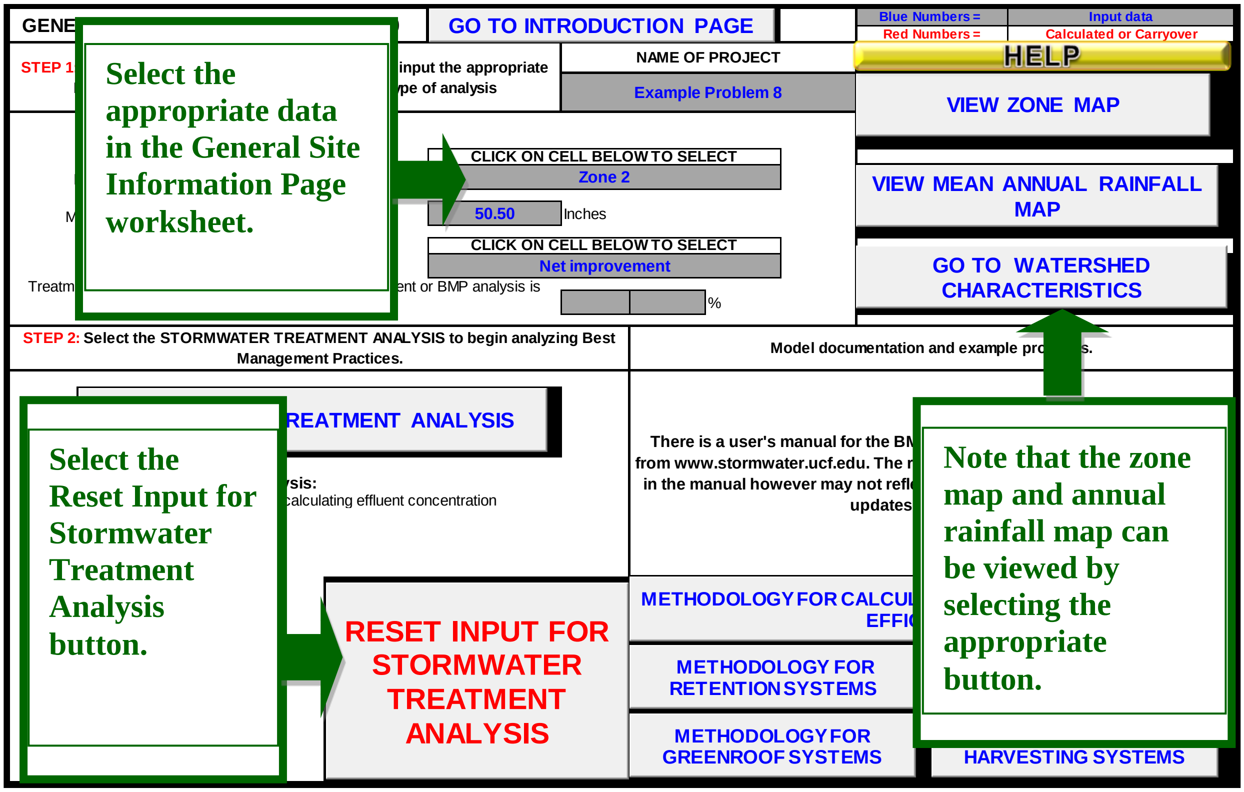


Figure 76 – General Site Information worksheet

2. Select the *Watershed Characteristics* button to proceed to the **Watershed Characteristics** worksheet (Figure 77).
   a. Indicate the catchment configuration, pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage.

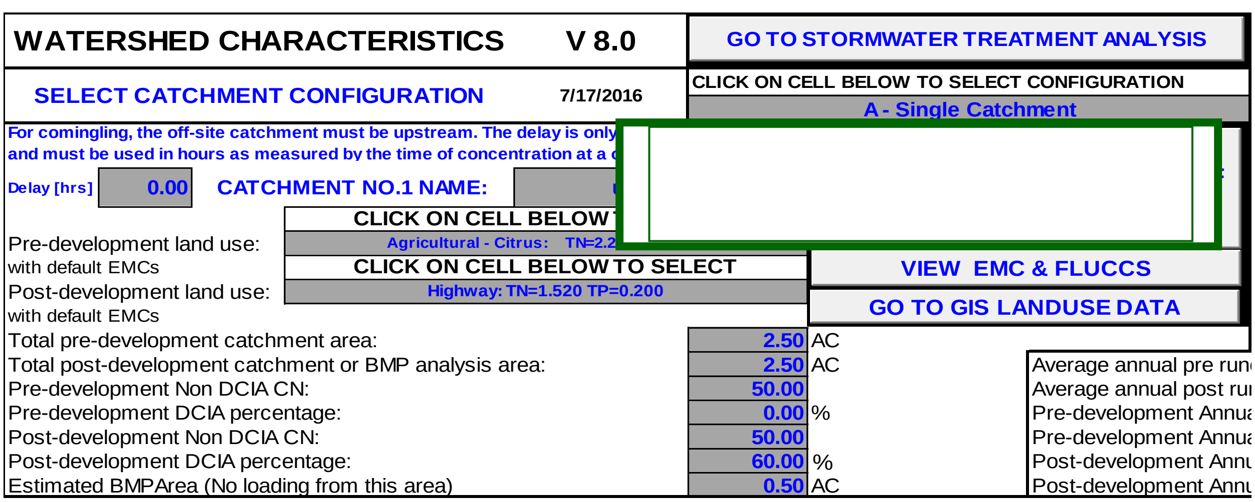


Figure 77 – Watershed Characteristics worksheet

3. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
4. Select the *Retention Basin* button to proceed to the **Retention Basin** worksheet (Figure 78). Notes:
   a. Required storage to achieve target (required) removal efficiency is 2.255 inches over the 2.5-acre watershed (assuming that 0.5 acres are used for water quality and water quantity control structures results in a 2-acre catchment).
   b. There is space to treat 2.255 inches of runoff but there is no treatment for the offsite rural roadway. The total pounds discharged for total nitrogen (TN) and total phosphorus (TP) after treatment from the new roadway are 0.27 and 0.04 kg/year respectively. Add to this the discharge loading from the existing highway for TN and TP at 4.007 and 0.527 kg/year and the total discharge from the existing and the new highway together are 4.277 (0.270+4.007) kg/year and 0.567 (0.040+0.527) kg/year respectively.
   c. At 2.255 inches, only a marginal increase in efficiency can be obtained with increased volume of retention basin. At first, the option to treat the runoff from the existing offsite watershed does not appear reasonable. However, note that the marginal decrease in effectiveness caused by adding the untreated existing offsite highway runoff may result in a greater overall loading reduction when the existing roadway runoff is co-mingled with the runoff from the new roadway.

The example problem can end at this evaluation point. However, consider the situation were the runoff from the existing highway can be routed (co-mingled) to the downstream basin and then treated in the volume provided for the downstream basin. Various assumptions have to be made that may not be eligible for permit and the user is cautioned to obtain all permit requirements and structure the solution to be consistent with them. Note also that there may be a delay in the offsite runoff reaching the onsite retention and the delay may provide for unused retention volume to capture the offsite runoff for additional removal (see part 2 of this example problem).

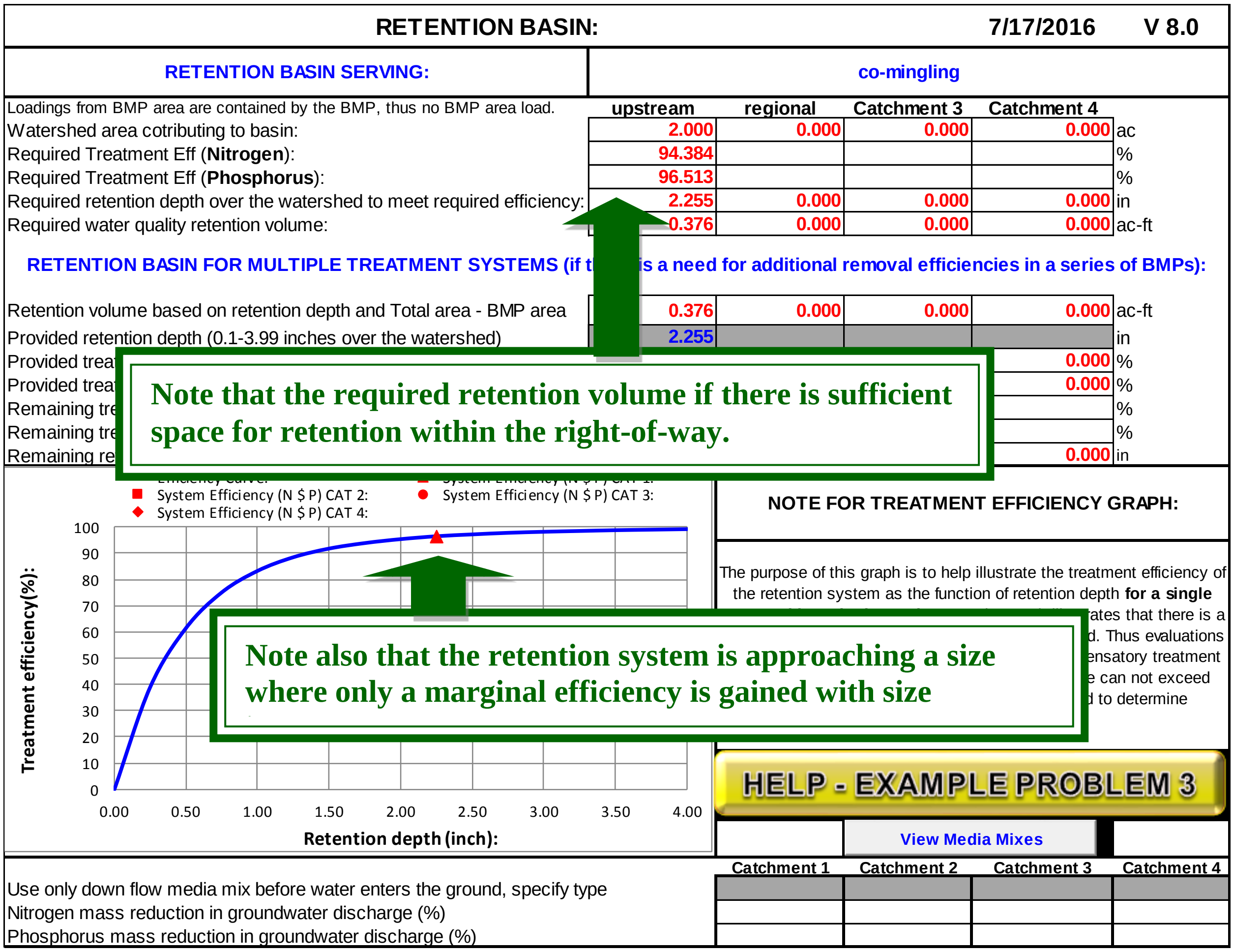


Figure 78 – Retention Basin worksheet for required treatment of additional catchment area

Part 2. Comingle the runoff from the existing highway with the runoff from the new highway and into the same size of retention basin that is planned for the new highway.

1. Select the *Watershed Characteristics* button to proceed to the **Watershed Characteristics** worksheet (Figure 79). There is a 2-hour delay for offsite runoff to onsite retention area.
   a. Input the catchment configuration as offsite and onsite land use, catchment areas, non-DCIA Curve Number and DCIA percentage of the new and existing highways. Note catchment 2 must have a BMP associated with it.

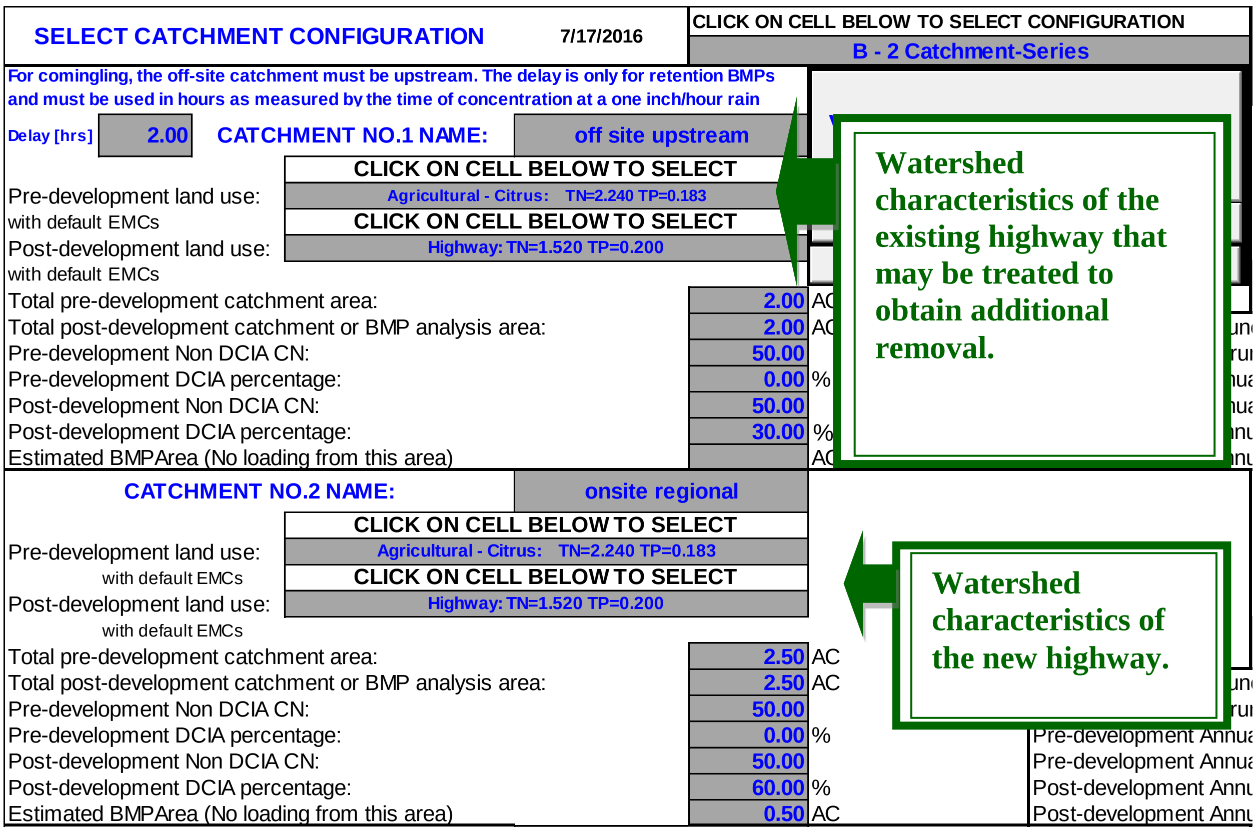


Figure 79 – Watershed Characteristics worksheet

2. Select the *Stormwater Treatment Analysis* button for **Stormwater Treatment Analysis**.
3. Select the *Retention Basin* button to proceed to the **Retention Basin** worksheet (Figure 80).
   a. Indicate for the Right-of-way basin a retention depth for the existing highway in catchment 2 of the **Retention Basin** worksheet. (Note: The user should select a retention depth value that will fit into the site area and geology.

b. The user does not have to specify a retention volume in catchment 1. It is assumed that the runoff water from the onsite catchment is co-mingled with that from the offsite catchment.

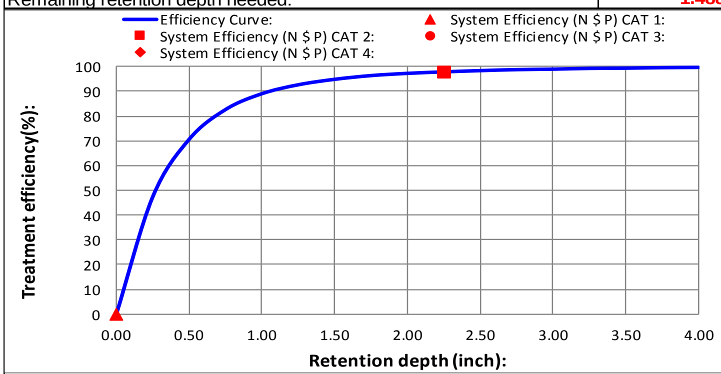
c. The existing retention basin volume is specified for the onsite highway basin, the output of the retention worksheet is shown in Figure 80.

RETENTION BASIN:			7/17/2016	V 8.0	
RETENTION BASIN SERVING:	co-mingling				
Loadings from BMP area are contained by the BMP, thus no BMP area load.	off site	onsite	Catchment 3	Catchment 4	
Watershed area			0.000	0.000	ac
Required Treatm					%
Required Treatm					%
Required retentio			0.000	0.000	in
Required water d			0.000	0.000	ac-ft

The retention system for the new highway remains at same volume required for its catchment.

RETENTION BASIN FOR MULTIPLE TREATMENT SYSTEMS (if there is a need for additio... removal efficiencies in a series of BMPs):

	off site	onsite	Catchment 3	Catchment 4	
Retention volume based on retention depth and Total area - BMP area	0.000		0.000	0.000	ac-ft
Provided retention depth (0.1-3.99 inches over the watershed)	0.000	2.255			in
Provided treatment efficiency (**Nitrogen**):	0.000	97.710	0.000	0.000	%
Provided treatment efficiency (**Phosphorus**):	0.000	97.710	0.000	0.000	%
Remaining treatment efficiency (**Nitrogen)**:	91.297	0.000			%
Remaining treatment efficiency (**Phosphorus)**:	94.596	0.000			%
Remaining retention depth needed:	1.488	0.000	0.000	0.000	in



NOTE FOR TREATMENT EFFICIENCY GRAPH:

The purpose of this graph is to help illustrate the treatment efficiency of the retention system as the function of retention depth **for a single BMP and in a single catchment**. The graph illustrates that there is a diminished return as the retention depth is increased. Thus evaluations of other alternatives in "treatment trains" and compensatory treatment should be considered. **NOTE:** the retention volume can not exceed 3.99 inches to be within the range of data used to determine effectiveness.

HELP - EXAMPLE PROBLEM 3

View Media Mixes

	Catchment 1	Catchment 2	Catchment 3	Catchment 4
Use only down flow media mix before water enters the ground, specify type				
Nitrogen mass reduction in groundwater discharge (%)				
Phosphorus mass reduction in groundwater discharge (%)				

Figure 80 – Retention Basin worksheet

4. The user checks to see the level of treatment and the mass removal when there is comingling. This is done from the **Catchment and Treatment Summary Results** worksheet. Note that there is **no treatment** for the existing offsite catchment.
5. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
6. Select the *Catchment and Treatment Summary Results* button to proceed to the **Catchment and Treatment Summary Results** worksheet (Figure 81).

7. The pollution load discharged for TN and TP when comingling is 0.32 kg/year and 0.04 kg/year respectively (Figure 81). Without comingling the total load discharged from the existing and the new highway together are 4.277 kg/year and 0.567 kg/year respectively (see calculations of part 1 of this example problem 8). Thus a decrease in the load with comingling in this case. The removal when using comingling is substantially higher primarily because of the very large volume of onsite retention.

CATCHMENTS AND TREATMENT SUMMARY RESULTS — **V 8.0**

CALCULATION METHODS:

1. The effectiveness of each BMP in a single catchment is converted to an equivalent capture volume.
2. Certain BMP treatment train combinations have not been evaluated and in practice they are at this time not used, an example is a greenroof following a tree well.
3. Wet detention is last when used in a single catchment with other BMPs, except when followed by filtration

PROJECT TITLE	co-mingling	Optional Identification	Example Problem 8	
	off site	onsite	Catchment 3	Catchment 4
BMP Name		Retention Basin		
BMP Name				
BMP Name				

ERROR, ONE OR MORE CATCHMENT HAS BEEN SPECIFIED WITHOUT A BMP

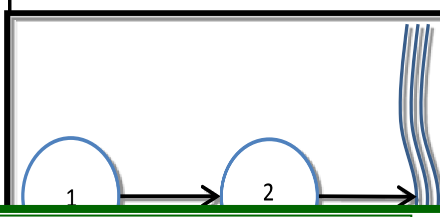
Summary Performance of Entire Watershed

Catchment Configuration	B - 2 Catchment-Series
Nitrogen Pre Load (kg/yr)	0.78
Phosphorus Pre Load (kg/yr)	0.06
Nitrogen Post Load (kg/yr)	11.77
Phosphorus Post Load (kg/yr)	1.55
Target Load Reduction (N) %	93
Target Load Reduction (P) %	96
Target Discharge Load, N (kg/yr)	0.82
Target Discharge Load, P (kg/yr)	0.06
Provided Overall Efficiency, N (%):	97
Provided Overall Efficiency, P (%):	97
Discharged Load, N (kg/yr & lb/yr):	0.32
Discharged Load, P (kg/yr & lb/yr):	0.04
Load Removed, N (kg/yr & lb/yr):	11.45
Load Removed, P (kg/yr & lb/yr):	1.51

Treatment Objectives or Target MET

7/17/2016

BMPTRAINS MODEL



Note: With comingling, overall removal has increased compared to no treatment of the existing roadway.

Figure 81 – Catchment and Treatment Summary Results worksheet

Discussion: This completes the example problem. One purpose was to demonstrate that comingling of offsite or adjacent catchment discharge may increase the load reduction from both sites without increasing the size of the treatment facility. It is recognized that there are many different permit and site conditions that can modify the calculations of this problem.

Example problem # 9 – Vegetated Natural Buffer in Series with Wet Detention

A half-acre wet detention pond and a vegetated natural buffer (12-foot-wide with a 1-foot storage depth along a 2355-foot-long new highway) are used for stormwater treatment of a highway. The slope across the width of the vegetated natural buffer is 6% with the width of the area feeding the buffer equal to 25 feet. The area to be treated is 3.15 acres. The site is located in West Palm Beach, FL on Hydrologic Soil Group D and has a storage capacity of 0.20 inch/inch depth. The existing land use condition is assumed as Wet Flatwoods with a non-DCIA Curve Number of 80 and 0% DCIA. The post-development land use condition is highway with a non-DCIA Curve Number of 80 and DCIA of 80%. The target removal efficiency for both Total Nitrogen and Total Phosphorus is 80%. The wet detention pond has 100 days' average annual residence time and a littoral zone (assumed 10% removal efficiency credit).

1. From the introduction worksheet, click on the *Click Here to Start* button to proceed to the **General Site Information** worksheet.
   a. Select the *Reset Input for Stormwater Treatment Analysis* button to erase any existing data.
   b. Enter the project name and select the meteorological zone in the **General Site Information** worksheet (Figure 82).
   c. Indicate the mean annual rainfall amount in the **General Site Information** worksheet.
   d. Select the *Specified Removal Efficiency* option from the type of analysis drop down menu in the **General Site Information** worksheet.
   e. Specify the desired removal efficiency.

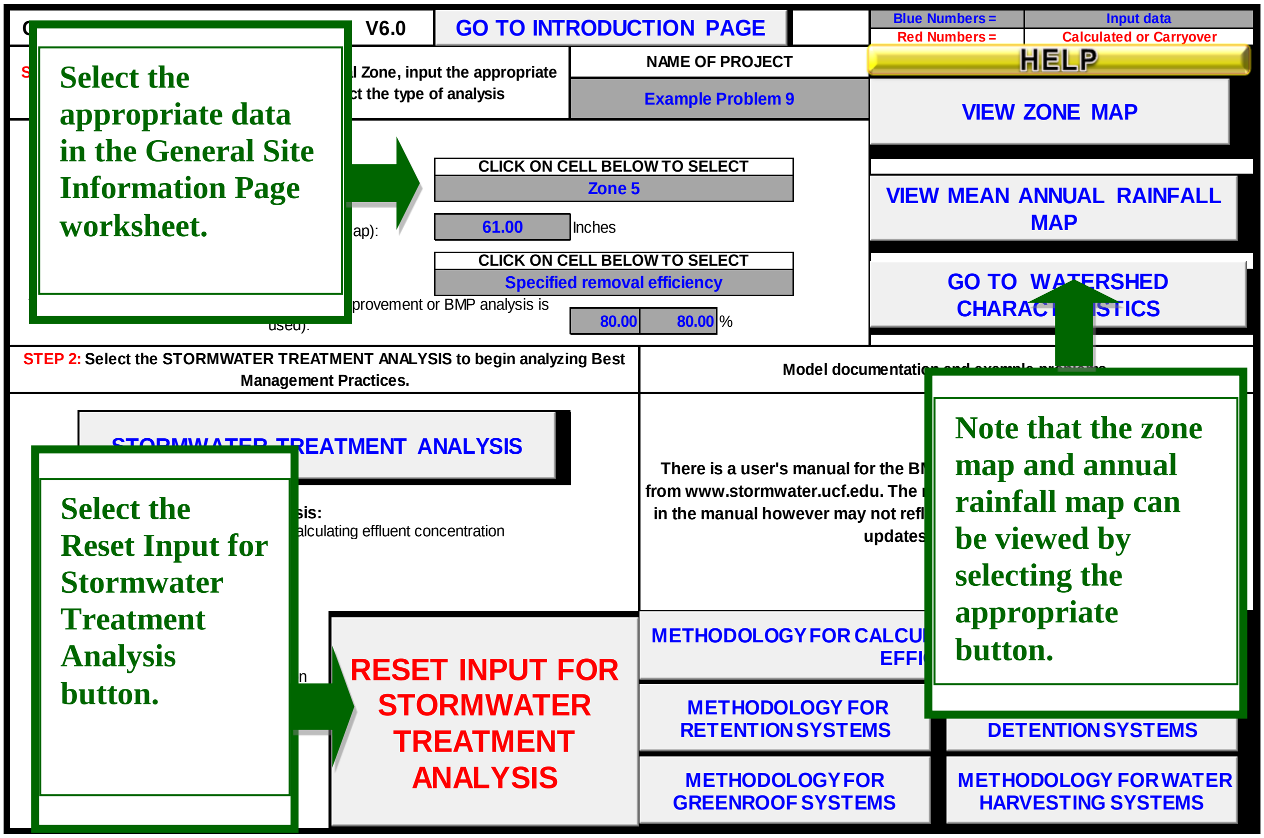


Figure 82 – General Site Information worksheet

2. Select the *Go To Watershed Characteristics* button to proceed to the **Watershed Characteristics** worksheet (Figure 83). Note the input EMC data can be changed or over-written.

   a. Indicate the catchment configuration, pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage.

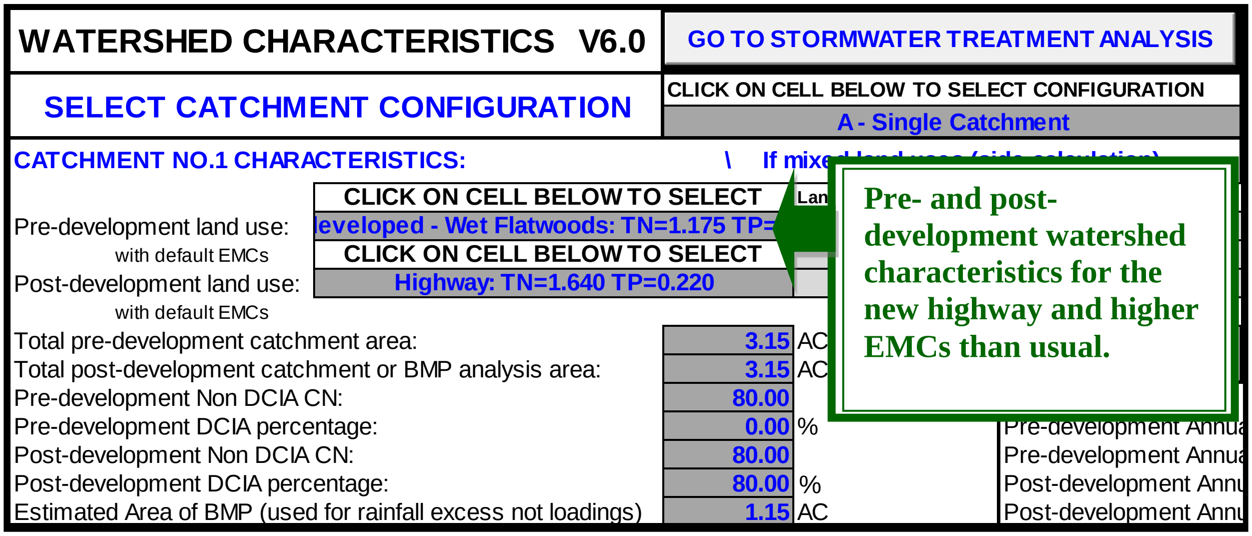


Figure 83 – Watershed Characteristics worksheet

3. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
4. Select the *Wet Detention* button to proceed to the **Wet Detention** worksheet (Figure 84).
   a. Specify the average annual residence time. Also, specify whether the littoral zone is used in the design and indicate the efficiency credit associated with it.

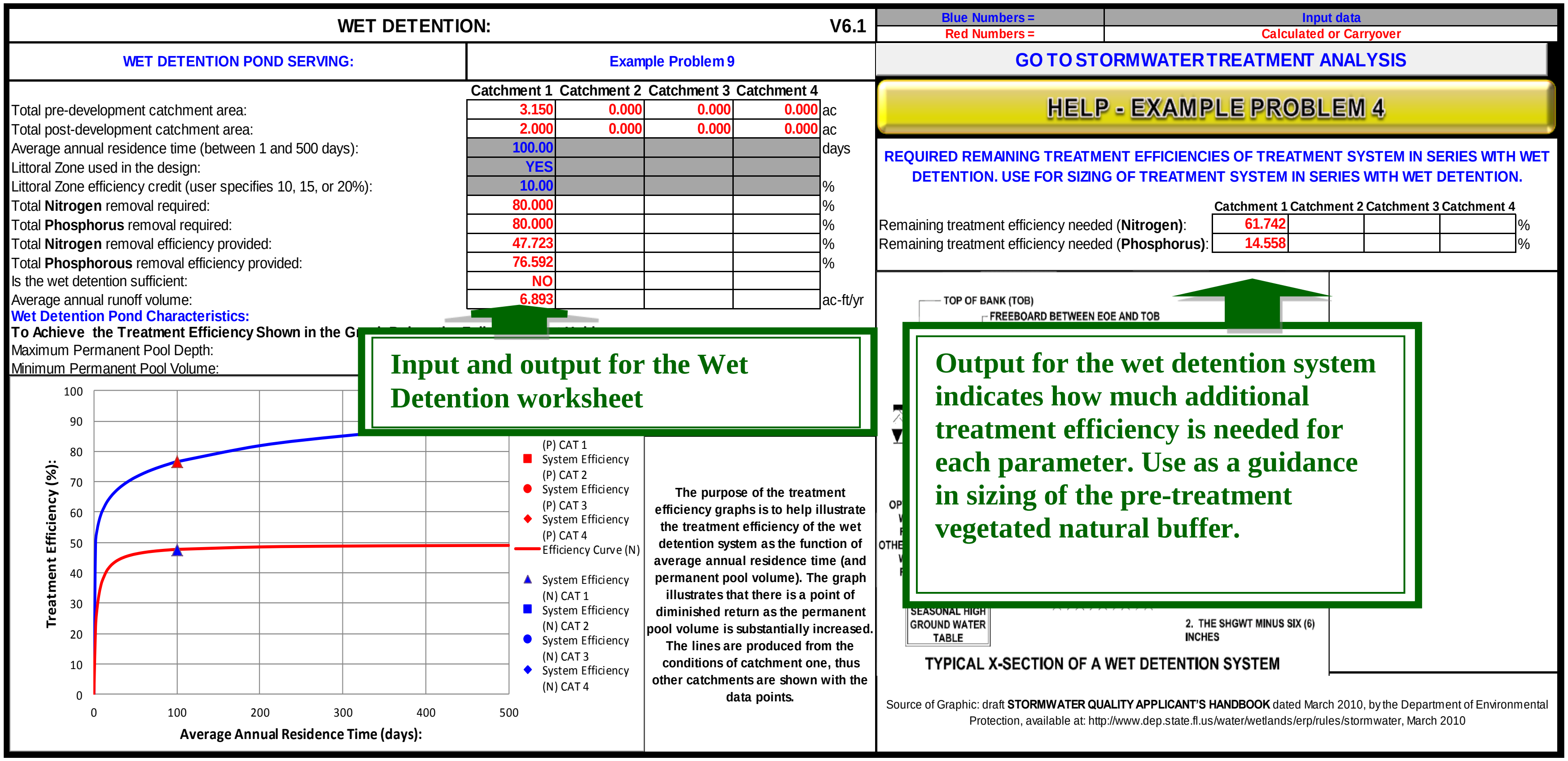
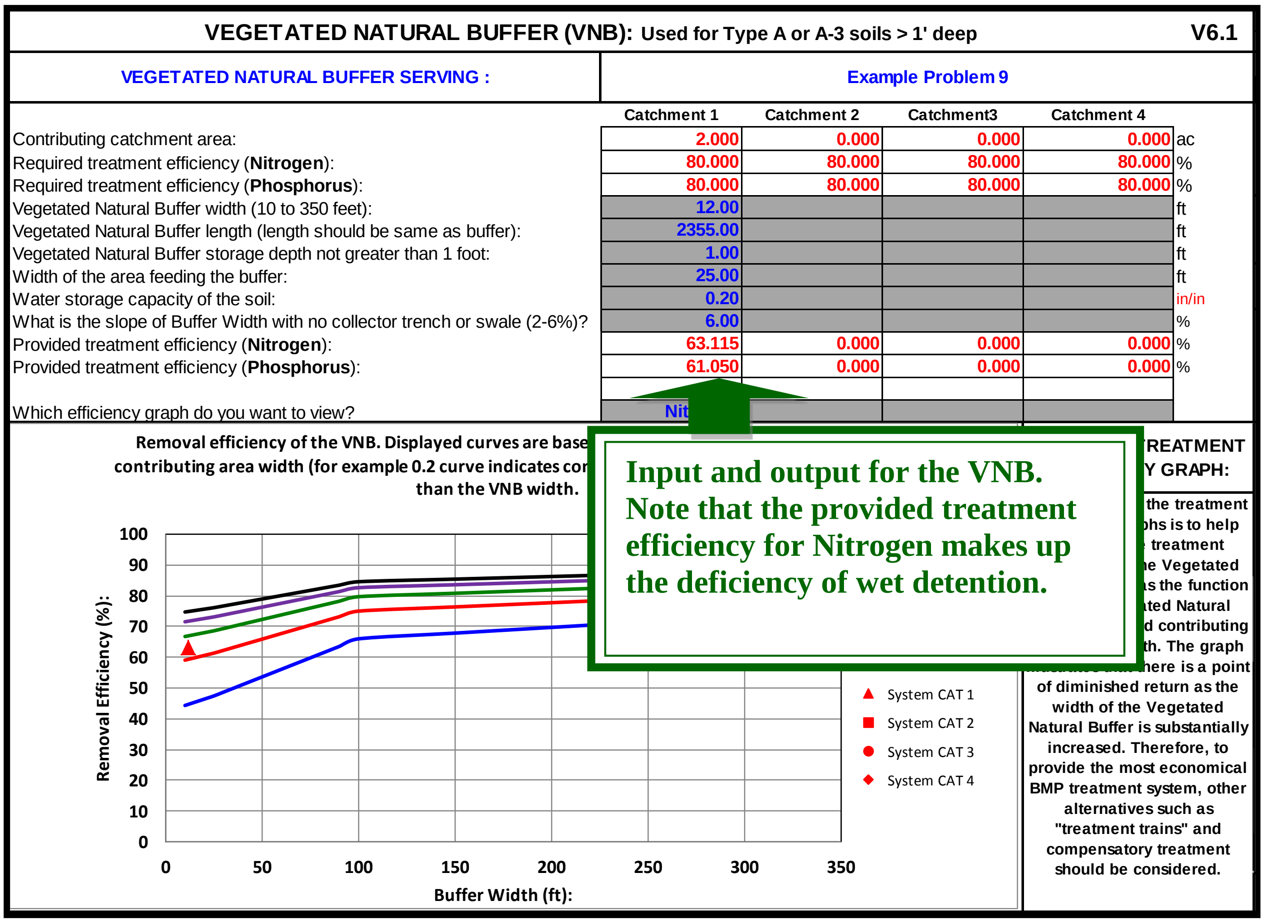


Figure 84 – Wet Detention worksheet

5. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
6. Select the *Vegetated Natural Buffer* button to proceed to the **Vegetated Natural Buffer** worksheet (Figure 85).
   a. Specify appropriate input for the vegetated natural buffer.



VEGETATED NATURAL BUFFER (VNB): Used for Type A or A-3 soils > 1' deep — V6.1

VEGETATED NATURAL BUFFER SERVING :	Example Problem 9				
	Catchment 1	Catchment 2	Catchment3	Catchment 4	
Contributing catchment area:	2.000	0.000	0.000	0.000	ac
Required treatment efficiency (**Nitrogen**):	80.000	80.000	80.000	80.000	%
Required treatment efficiency (**Phosphorus**):	80.000	80.000	80.000	80.000	%
Vegetated Natural Buffer width (10 to 350 feet):	12.00				ft
Vegetated Natural Buffer length (length should be same as buffer):	2355.00				ft
Vegetated Natural Buffer storage depth not greater than 1 foot:	1.00				ft
Width of the area feeding the buffer:	25.00				ft
Water storage capacity of the soil:	0.20				in/in
What is the slope of Buffer Width with no collector trench or swale (2-6%)?	6.00				%
Provided treatment efficiency (**Nitrogen**):	63.115	0.000	0.000	0.000	%
Provided treatment efficiency (**Phosphorus**):	61.050	0.000	0.000	0.000	%
Which efficiency graph do you want to view?	Nit				

Figure 85 – Vegetated Natural Buffer worksheet

7. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
8. Select the *Catchment and Treatment Summary Results* button to proceed to the **Catchment and Treatment Summary Results** worksheet (Figure 86).

a. Compare the **Target Load Reduction %** with the BMP **provided overall efficiency %**. If sum of the **target loads** is larger than the sum of **overall achieved %,** you must increase the size of the VNB or use other BMPs.

b. If the sum of the **Target Load Reduction** is less than the sum of **overall achieved %**, then the BMPs used do not have to be changed.

CATCHMENTS AND TREATMENT SUMMARY RESULTS V7.3

CALCULATION METHODS:

1. The effectiveness of each BMP in a single catchment is converted to an equivalent capture volume.
2. Certain BMP treatment train combinations have not been evaluated and in practice they are at this time not used, an example is a greenroof following a tree well.
3. If multiple BMPs are used in a single catchment and one of them is detention, then it is assumed to be last in series.

PROJECT TITLE	Example Problem 9	Optional Identification		
	Catchment 1:	Catchment 2:	Catchment 3:	Catchment 4:
BMP Name	Wet Detention			
BMP Name	VNB			
BMP Name				

Summary Performance of Entire Watershed

Catchment Configuration	A - Single Catchment	6/23/2014
Nitrogen Pre Load (kg/yr)	3.64	BMPTRAINS MODEL
Phosphorus Pre Load (kg/yr)	0.05	
Nitrogen Post Load (kg/yr)	13.94	
Phosphorus Post Load (kg/yr)	1.87	
Target Load Reduction (N) %	80	
Target Load Reduction (P) %	80	
Target Discharge Load, N (kg/yr)	2.79	
Target Discharge Load, P (kg/yr)	0.37	
Provided Overall Efficiency, N (%):	73	
Provided Overall Efficiency, P (%):	87	
Discharged Load, N (kg/yr & lb/yr):	3.82	
Discharged Load, P (kg/yr & lb/yr):	0.23	
Load Removed, N (kg/yr & lb/yr):	10.12	
Load Removed, P (kg/yr & lb/yr):	1.64	

Note: Provided overall efficiency not sufficient. Another iteration is required. The addition of another BMP may be the best option.

Changing BMPs or increasing sizes can produce an effectiveness > 80%

Figure 86 – Catchment and Treatment Summary Results worksheet

Example problem # 10 – Use of Rain Gardens or Transportation Depression Areas

Rain gardens are proposed to treat a 2.0-acre low-intensity commercial development. The project location is St. Petersburg, 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 is low-intensity commercial with a non-DCIA Curve Number of 78 and DCIA of 50%. Assume the media in the rain garden is to have dimensions of 80 ft by 30 ft with a depth of 1 foot, thereby making the volume of the media in the rain garden to be 2,400 cubic feet. Assume the water storage above the rain garden is 2,088 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 has as an option to use two media types, namely a compost, shredded paper, and sand (CPS) media and a Dade city clay, tire crumb, and sand (CTS) media. The CPS media has a sustainable void ratio of 0.20 and a depth of 24 inches. The CTS media has a sustainable void ratio of 0.20 and a depth of 12 inches. The high water table is below the media.

Part 1. Treating the Rain Garden as a retention system:

1. From the introduction worksheet, click on the *Click Here to Start* button to proceed to the **General Site Information** worksheet.
    a. Select the *Reset Input for Stormwater Treatment Analysis* button to erase any existing data.
    b. Enter the project name, and select the meteorological zone in the **General Site Information** worksheet (Figure 87).
    c. Indicate the mean annual rainfall amount in the **General Site Information** worksheet.
    d. Select the *Net Improvement* option from the type of analysis drop down menu in the **General Site Information** worksheet.

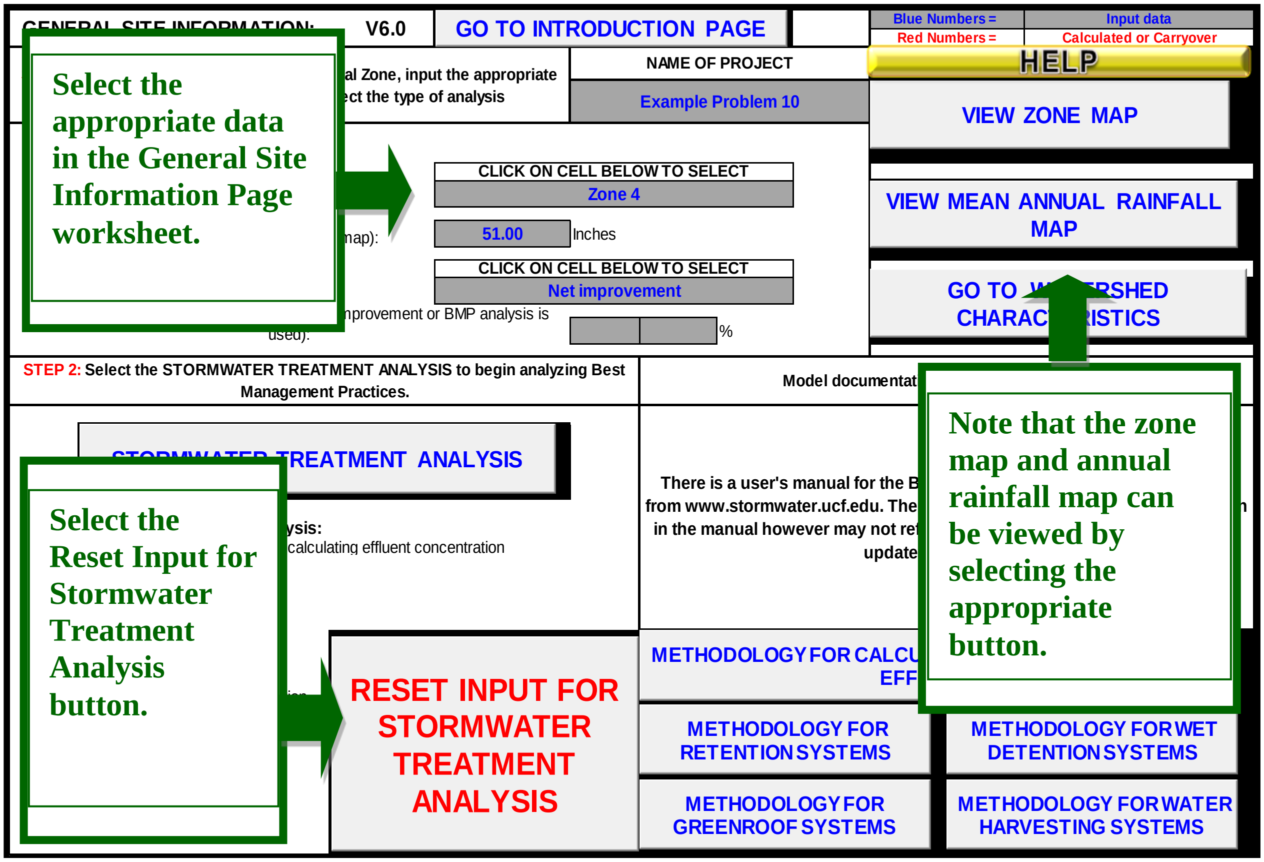


Figure 87 – General Site Information worksheet

2. Select the *Watershed Characteristics* button to proceed to the **Watershed Characteristics** worksheet (Figure 88).

   a. Indicate the catchment configuration, pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage.

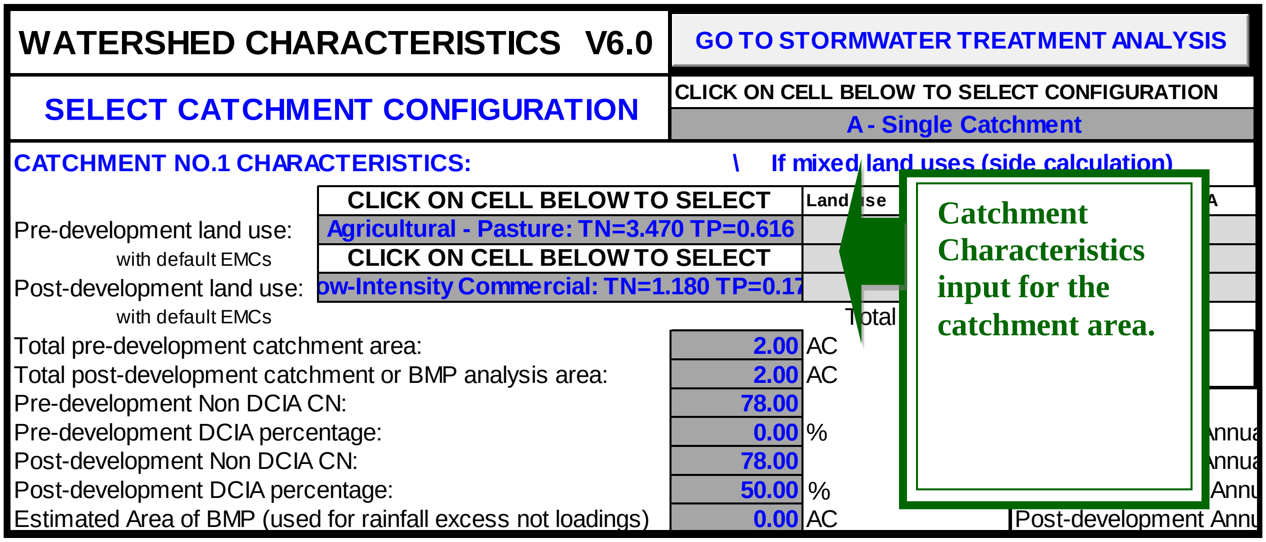


Figure 88 – Watershed Characteristics worksheet

3. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
4. Select the *Rain Garden* button to proceed to the **Rain Garden** worksheet (Figure 89).

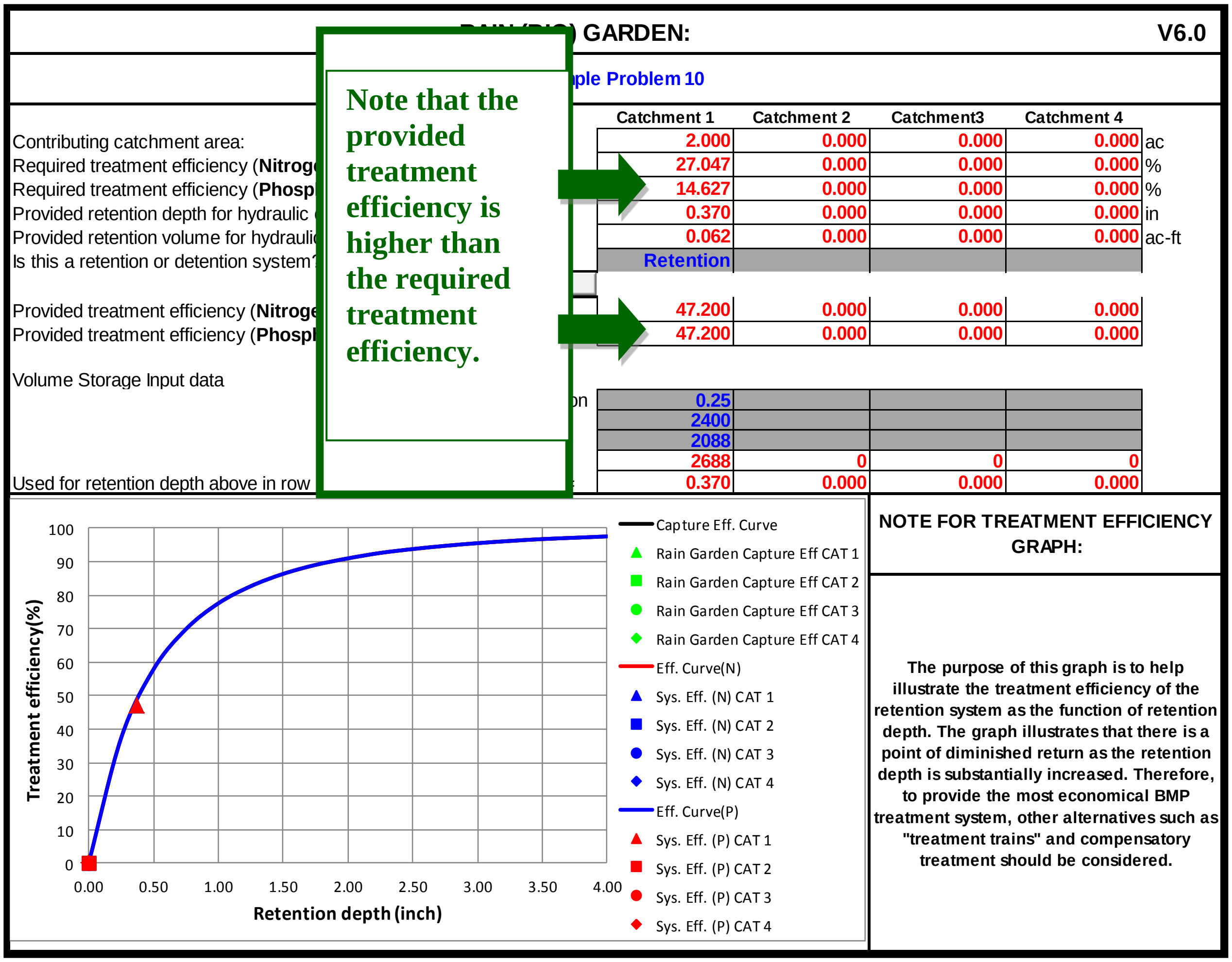


Figure 89 – Rain Garden worksheet

5. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
6. Select the *Catchment and Treatment Summary Results* button to proceed to the **Catchment and Treatment Summary Results** worksheet (Figure 90).

CATCHMENTS AND TREATMENT SUMMARY RESULTS				V6.0
CALCULATION METHODS:				
1. The effectiveness of each BMP in a single catchment is converted to an equivalent capture volume.				
2. Certain BMP treatment train combinations have not been evaluated and in practice they are at this time not used, an example is a greenroof following a tree well.				
3. If multiple BMPs are used in a single catchment and one of them is detention, then it is assumed to be last in series.				
PROJECT TITLE	Example Problem 10	Optional Identification		
	Catchment 1:	Catchment 2:	Catchment 3:	Catchment 4:
BMP1	Rain Garden			
BMP2				
BMP3				

Summary Performance

Catchment Configuration	A - Single Catchment		1/27/2014
Catchment Nitrogen Pre Load	4.23		BMPTRAINS MODEL
Catchment Phosphorus Pre Load	0.75		
Catchment Nitrogen Post Load	5.80		
Catchment Phosphorus Post Load	0.88		
Target Load Reduction (N) %	27		
Target Load Reduction (P) %	15		
Target Discharge Load, N (kg/yr)	4.23		
Target Discharge Load, P (kg/yr)	0.75		
Provided Overall Efficiency, N (%):	47		
Provided Overall Efficiency, P (%):	47		
Discharged Load, N (kg/yr & lb/yr):	3.06		
Discharged Load, P (kg/yr & lb/yr):	0.46		
Load Removed, N (kg/yr & lb/yr):	2.74	6.03	
Load Removed, P (kg/yr & lb/yr):	0.42	0.92	

Again, Note that the provided treatment efficiency is higher than the required treatment efficiency.

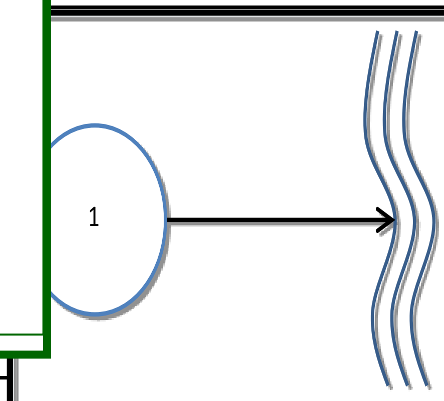


Figure 90 – Catchment and Treatment Summary Results

Note and discussion: The example problem can end at this evaluation point. However, consider the situation where the rain garden is a detention system rather than a retention system. Additionally, examine the use of two different pollution control media.

Part 2. Repeat assuming a detention system for two different media types. Data from the general site information worksheet and watershed characteristics worksheet will remain the same.

1. Select the *Rain Garden* button to proceed to the **Rain Garden** worksheet (Figure 91).
    a. Change to a detention problem from the drop down menu and select the compost, shredded paper, and sand (CPS) media mix (this is a user defined mix). This media mix is to be used at a depth of 24 inches, so the media volume needs to be changed to 4800 cubic feet. Additionally, this media has a sustainable void space fraction of 0.20. Figure 91 below illustrates these changes.

2.

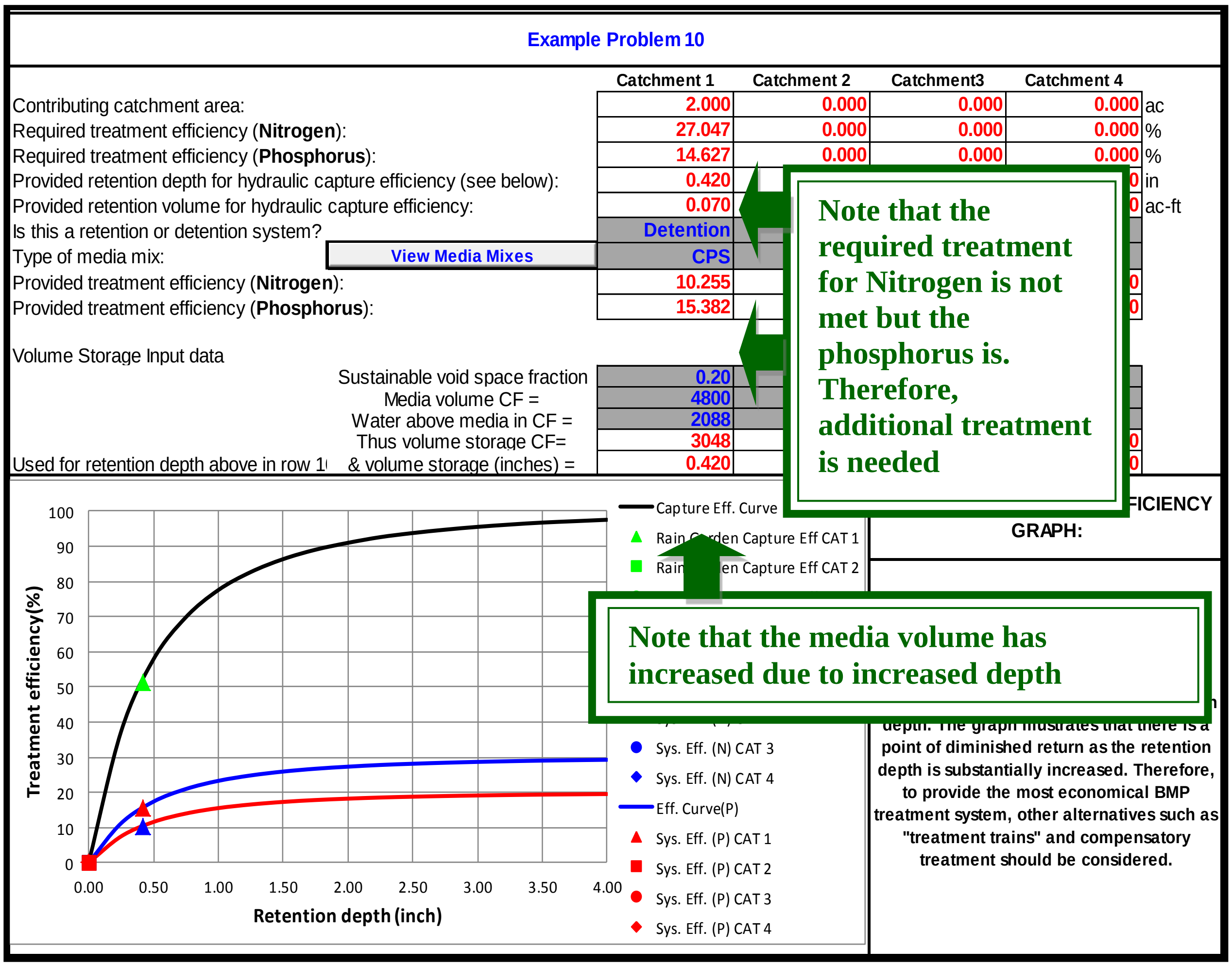


Figure 91 – Rain Garden

Note: The required treatment for phosphorus is met while the required treatment for nitrogen is not. Change the media type to Clay, Tire crumb, and Sand (CTS) at a depth of 12 inches and rework.

2. Since the location and site characteristics remain the same no changes need to be made to any of the other sheets except the **Rain Garden** worksheet.
   a. Select CTS from the media mix drop down list in the **Rain Garden** worksheet (Figure 92). Also, change the media volume to 2400 cubic feet to account for the decrease in media depth, from 24 inches to 12 inches.

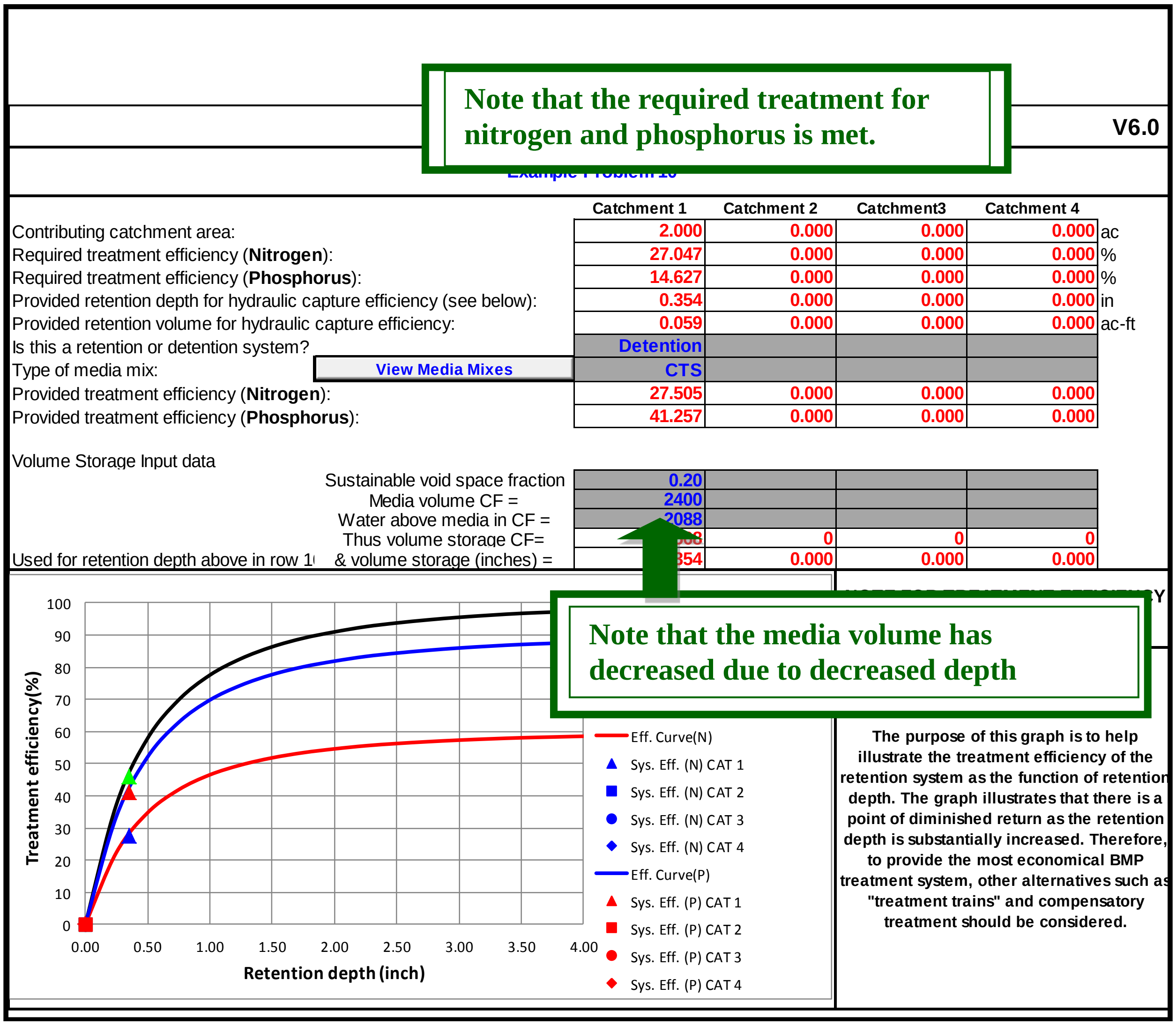


Figure 92 – Rain Garden Selecting a Media Mix

3. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
4. Select the *Catchment and Treatment Summary Results* button to proceed to the **Catchment and Treatment Summary Results** worksheet (Figure 93).

CATCHMENTS AND TREATMENT SUMMARY RESULTS					V6.0
CALCULATION METHODS:					
1. The effectiveness of each BMP in a single catchment is converted to an equivalent capture volume.					
2. Certain BMP treatment train combinations have not been evaluated and in practice they are at this time not used, an example is a greenroof following a tree well.					
3. If multiple BMPs are used in a single catchment and one of them is detention, then it is assumed to be last in series.					
PROJECT TITLE	Example Problem 10		Optional Identification		
		Catchment 1:	Catchment 2:	Catchment 3:	Catchment 4:
BMP1		Rain Garden			
BMP2					
BMP3					
Summary Performance					
Catchment Configuration	A - Single Catchment			1/27/2014	
Catchment Nitrogen Pre Load		4.23		BMPTRAINS MODEL	
Catchment Phosphorus Pre Load		0.75			
Catchment Nitrogen Post Load		5.80			
Catchment Phosphorus Post Load		0.88			
Target Load Reduction (N) %		27			
Target Load Reduction (P) %		15			
Target Discharge Load, N (kg/yr)		4.23			
Target Discharge Load, P (kg/yr)		0.75			
Provided Overall Efficiency, N (%):		28			
Provided Overall Efficiency, P (%):		48			
Discharged Load, N (kg/yr & lb/yr):		4.21			
Discharged Load, P (kg/yr & lb/yr):		0.46			
Load Removed, N (kg/yr & lb/yr):		1.60	3.52		
Load Removed, P (kg/yr & lb/yr):		0.42	0.93		

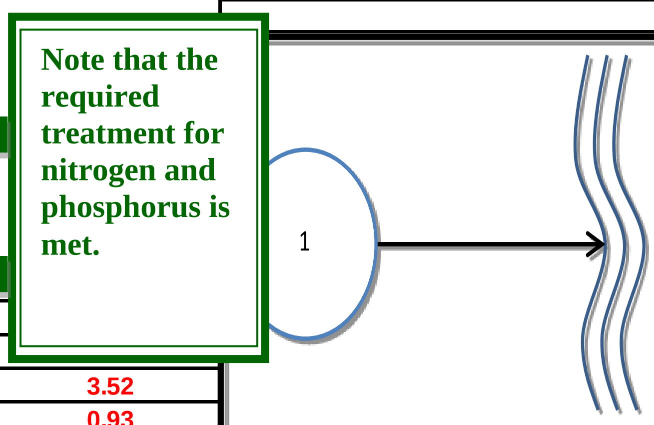


Figure 93 – Catchment and Treatment Summary Results

Discussion: The required treatment efficiency for nitrogen and phosphorus is met with this media mix. Notice how the treatment efficiency provided for retention is based on a volume captured while the detention system is based on a concentration reduction. This is due to the fact that for a retention system a fraction of the runoff water is not being surface discharged but is infiltrated, therefore the treatment efficiency is related to the hydraulic capture efficiency. For the detention systems, the water is treated with a pollution control media and then collected for discharge. This example showed that, for a detention system, media selection is important as the user defined CPS media was twice as deep and had lower treatment efficiency than the CTS media. The cost of removal however has not been considered. This example also showed that the retention system performed better than the detention system for both media types examined when considering surface discharges. This is due to the fact that 100% of the nitrogen and phosphorus in the infiltrated water will not be discharged downstream and this example is for surface water protection. If there was a groundwater protection target, then the analysis may not be the same. This completes the example problem.

Example problem # 11 – Three Catchments

A watershed with three catchments, each having an area of 5 acres, has to be treated to meet net improvement standards. The project location is East of Brooksville, Hernando County, FL. This problem is to be demonstrated in two parts, one assuming the catchments are in series and one assuming the catchments are in parallel.

The first catchment pre-development condition is agricultural-pasture with a Curve Number of 78 with 0% DCIA. The post-development conditions are highway with a non-DCIA Curve Number of 78 and DCIA of 60%. A swale is to be used which is 1.11 acres. It has a 10 ft top width, swale bottom width of 2 ft, swale and highway length of 4840 ft, highway width of 20 ft, average width of pervious area of 25 ft, swale slope of 0.001, Manning's n of 0.05, a soil infiltration rate of 5 in/hr, and a swale side slope of 5.

The second catchment pre-development condition is agricultural-pasture with a Curve Number of 78. The post-development conditions are high-intensity commercial with a non-DCIA Curve Number of 78 and DCIA of 80%. A 1-acre retention pond is used for treatment and due to site limitations, only 0.25 inch over the catchment area can be accommodated.

The third catchment pre-development condition is agricultural-pasture with a Curve Number of 78. The post-development conditions are low-density residential with a non-DCIA Curve Number of 78 and DCIA of 50%. A 1-acre wet-detention pond is to be used with an average annual residence time of 30 days and littoral zone is to be used with 10% credit.

Part 1. Treating the catchments in series:

1. From the introduction worksheet, click on the *Click Here to Start* button to proceed to the **General Site Information** worksheet.
   a. Select the *Reset Input for Stormwater Treatment Analysis* button to erase any existing data.

b. Enter the project name and select the meteorological zone in the **General Site Information** worksheet (Figure 94).

c. Indicate the mean annual rainfall amount in the **General Site Information** worksheet.

d. Select the *Net Improvement* option from the *Type of analysis* drop down menu in the **General Site Information** worksheet.

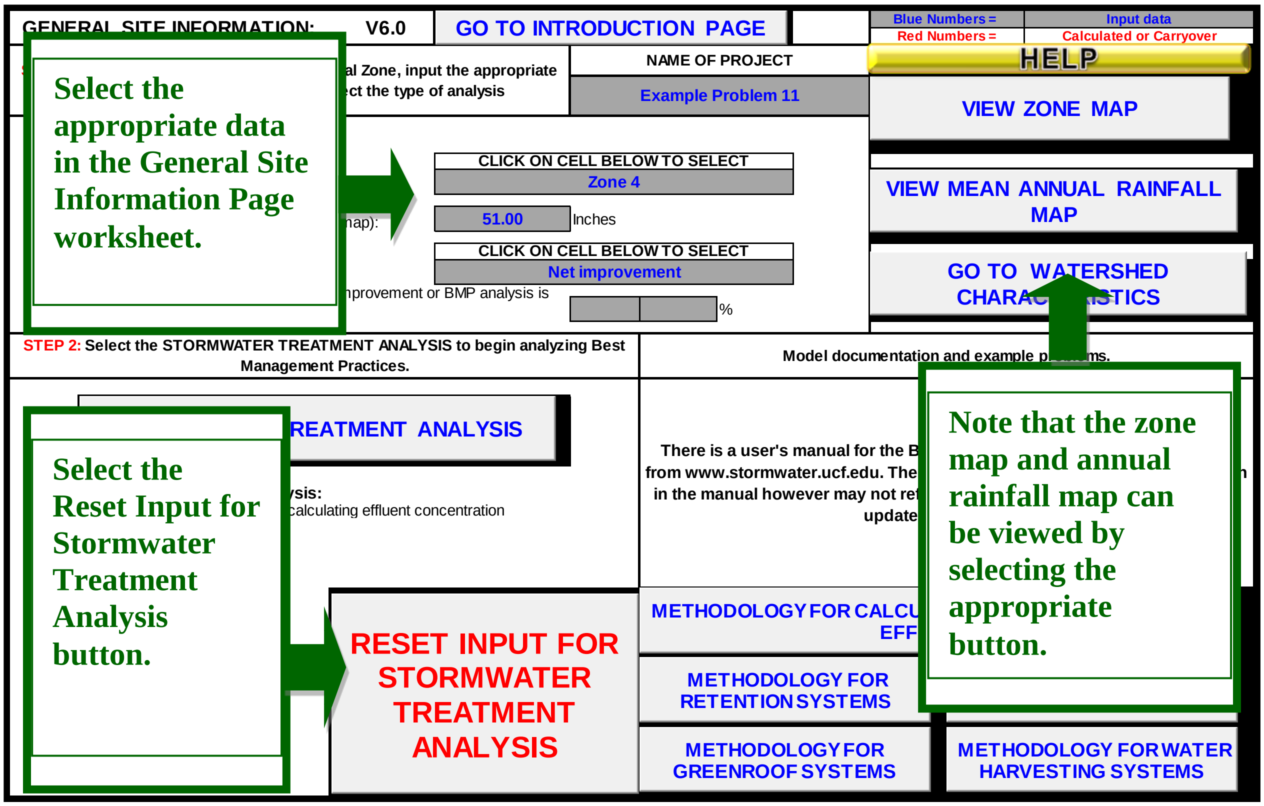


Figure 94 – General Site Information worksheet

2. Select the *Watershed Characteristics* button to proceed to the **Watershed Characteristics** worksheet.

   a. Indicate the catchment configuration (the different catchment configurations available can be viewed by selecting the *View Catchment Configurations* button). For this problem, D - 3 catchments in series (Figure 95).

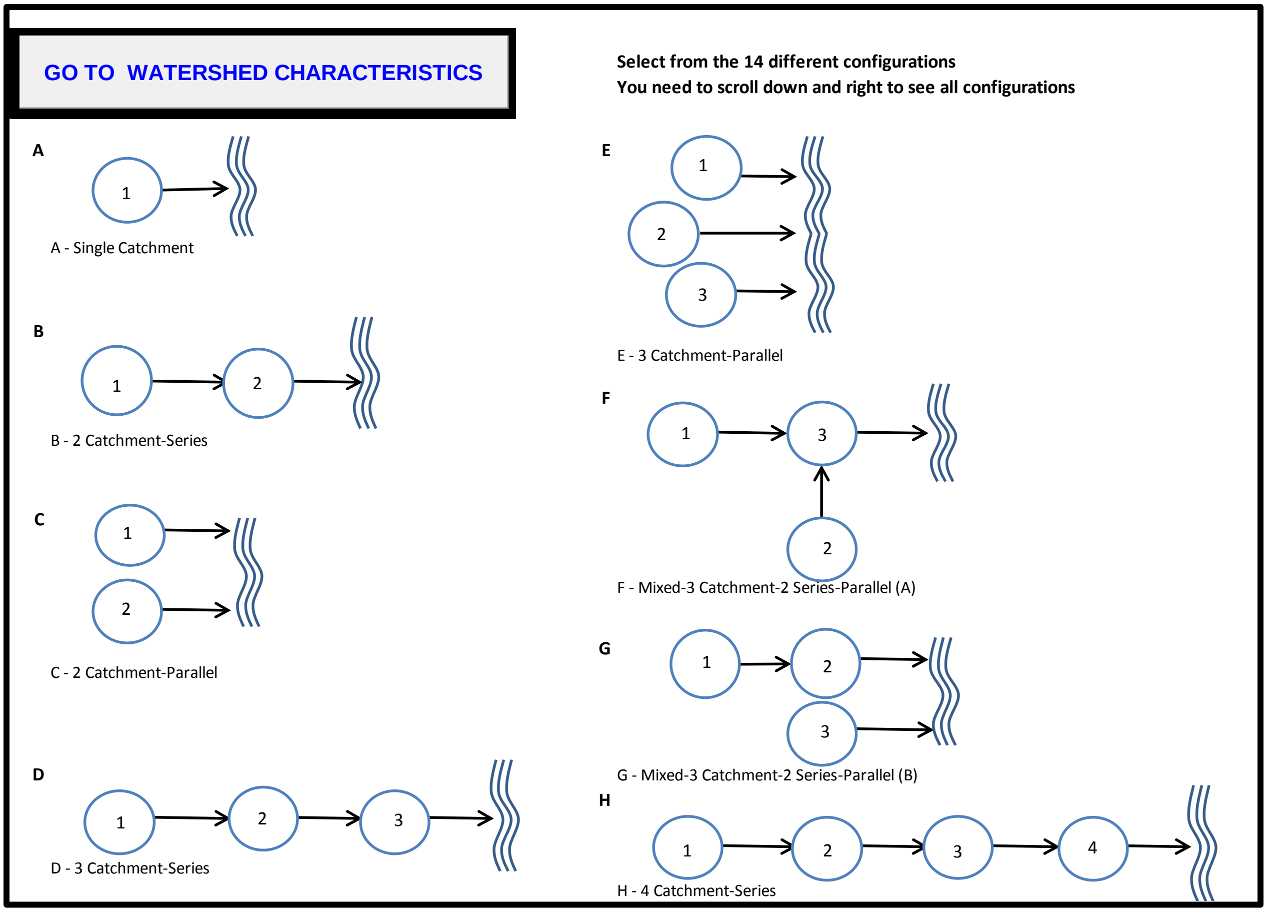


Figure 95 – Catchment Configuration Options worksheet

3. Go back to the **Watershed Characteristics** worksheet by selecting the *Go To Watershed Characteristics* button.
   a. Indicate the pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage (Figure 96).

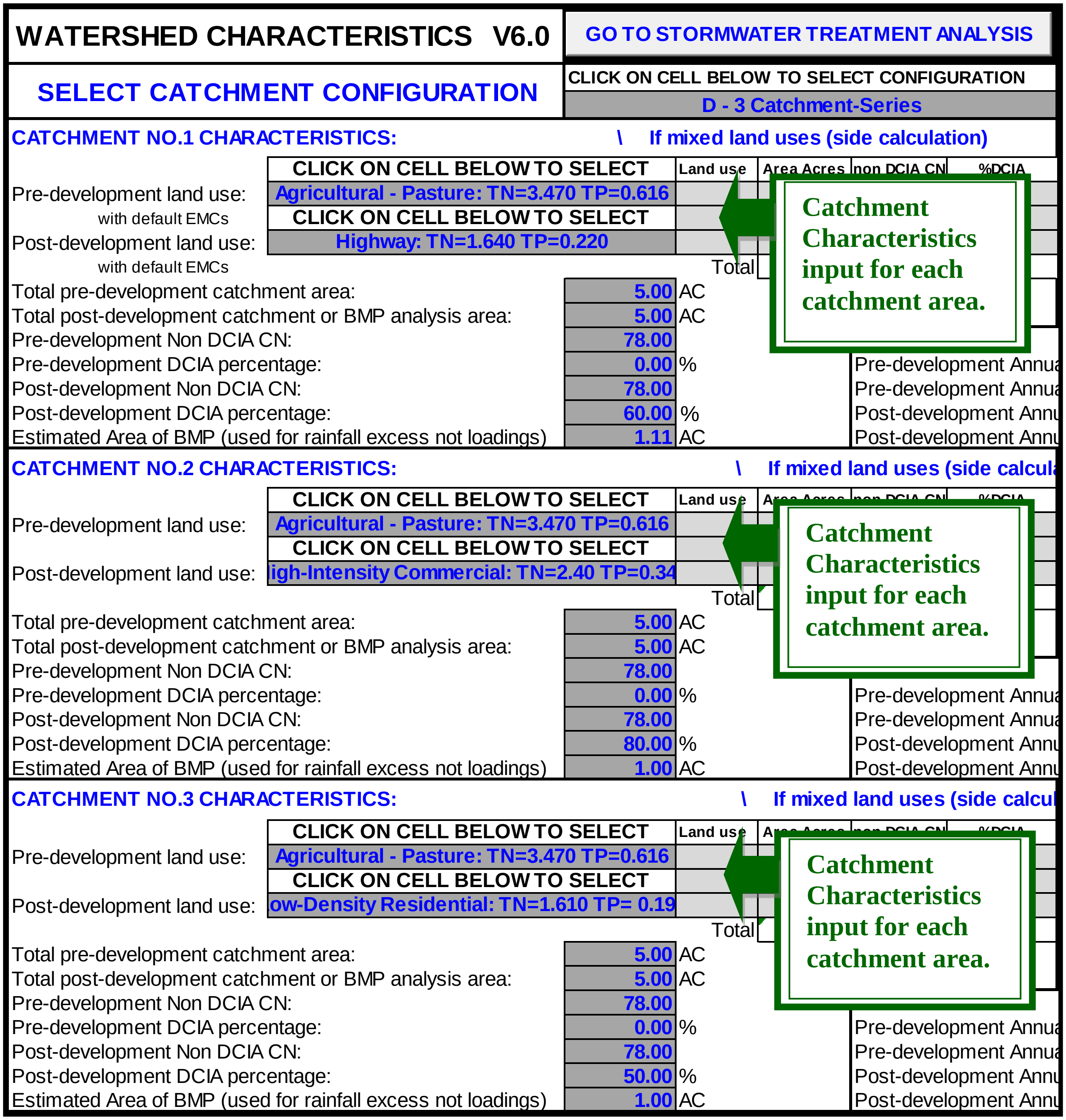


Figure 96 – Watershed Characteristics worksheet

4. Select the *Stormwater Treatment Analysis* button at the top of the worksheet to proceed to the **Stormwater Treatment Analysis** worksheet.
5. Select the *Swale* button to proceed to the **Swale** worksheet (Figure 97).
   a. Enter the required input based on the problem givens.

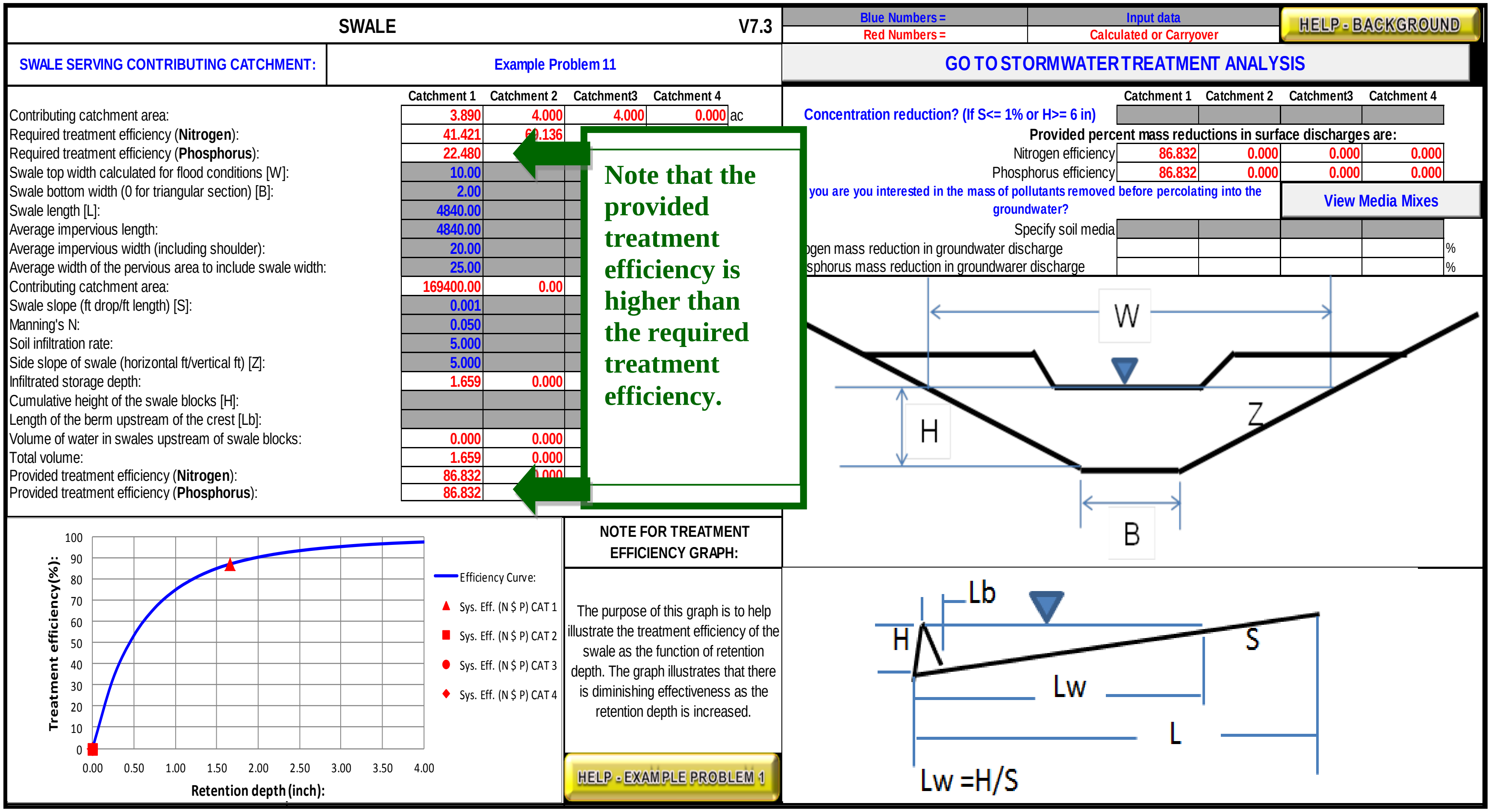


Figure 97 – Swale worksheet

6. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
7. Select the *Retention Basin* button to proceed to the **Retention Basin** worksheet.
   a. Specify a 0.25-inch retention depth (Figure 98).

RETENTION BASIN:					V6.0
RETENTION BASIN SERVING:	Example Problem 11				
	Catchment 1	Catchment 2	Catchment 3	Catchment 4	
Watershed area:	3.890	4.000	4.000	0.000	ac
Required Treatment Eff (**Nitrogen**):	41.421	69.136	33.164		%
Required Treatment Eff (**Phosphorus**):	22.480	61.885	0.000		%
Required retention depth over the watershed to meet required efficiency:	0.353	0.837	0.251	0.000	in
Required water quality retention volume:	0.115	0.279	0.084	0.000	ac-ft
RETENTION BASIN FOR MULTIPLE TREATMENT SYSTEMS (if there is a need for additional removal					
Retention volume based on retention depth	0.000	0.083			
Provided retention depth (inches over the watershed area):		0.250			
Provided treatment efficiency (**Nitrogen**):	0.000	33.064			
Provided treatment efficiency (**Phosphorus**):	0.000	33.064			
Remaining treatment efficiency (**Nitrogen)**:	41.421	53.890			
Remaining treatment efficiency (**Phosphorus)**:	22.480	43.057			
Remaining retention depth needed:	0.353	0.587	0.251	0.000	in

Note that the treatment required is not met.

Figure 98 – Retention Basin worksheet

8. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
9. Select the *Wet Detention* button to proceed to the **Wet Detention** worksheet.
   a. Specify a 30 day average annual residence time, a littoral zone (drop down menu), and a 10% efficiency credit (Figure 99).

WET DETENTION:					V7.1
WET DETENTION POND SERVING:	Example Problem 11				
	Catchment 1	Catchment 2	Catchment 3	Catchment 4	
Total pre-development catchment area:	5.000	5.000	5.000	0.000	ac
Total post-development catchment area:	3.890	4.000	4.000	0.000	ac
Average annual residence time (between 1 and 500 days):			30.00		days
Littoral Zone or other improvements used?			YES		
Littoral Zone or other improvement efficiency credit:			10.00		%
Total **Nitrogen** removal required:			33.164		%
Total **Phosphorus** removal required:			0.000		%
Total **Nitrogen** removal efficiency provided:			44.359		%
Total **Phosphorous** removal efficiency provided:			67.840		%
Is the wet detention sufficient:			YES		
Average annual runoff volume:	8.934	11.587	7.976		ac-ft/yr
To Achieve the Treatment Efficiency Shown in the Graph Below, the Following Must Hold					
Minimum Pond Permanent Pool Volume:			0.656		ac-ft

Figure 99 – Wet Detention worksheet

10. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
11. Select the *Catchment and Treatment Summary Results* button to proceed to the **Catchment and Treatment Summary Results** worksheet (Figure 100).

CATCHMENTS AND TREATMENT SUMMARY RESULTS — **V7.3**

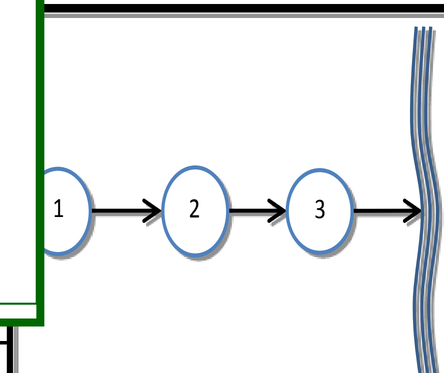
CALCULATION METHODS:

1. The effectiveness of each BMP in a single catchment is converted to an equivalent capture volume.
2. Certain BMP treatment train combinations have not been evaluated and in practice they are at this time not used, an example is a greenroof following a tree well.
3. If multiple BMPs are used in a single catchment and one of them is detention, then it is assumed to be last in series.

PROJECT TITLE	Example Problem 11	Optional Identification		
	Catchment 1:	Catchment 2:	Catchment 3:	Catchment 4:
BMP Name	Swale	Retention Basin	Wet Detention	
BMP Name				
BMP Name				

Summary Performance of Entire Watershed

Catchment Configuration	D - 3 Catchment-Series		7/8/2014
			BMPTRAINS MODEL
Nitrogen Pre Load (kg/yr)	31.76		
Phosphorus Pre Load (kg/yr)	5.64		
Nitrogen Post Load (kg/yr)	68.20		
Phosphorus Post Load (kg/yr)	9.23		
Target Load Reduction (N) %	53		
Target Load Reduction (P) %	39		
Target Discharge Load, N (kg/yr)	31.76		
Target Discharge Load, P (kg/yr)	5.64		
Provided Overall Efficiency, N (%):	70		
Provided Overall Efficiency, P (%):	81		
Discharged Load, N (kg/yr & lb/yr):	20.58		
Discharged Load, P (kg/yr & lb/yr):	1.78	3.92	
Load Removed, N (kg/yr & lb/yr):	47.62	104.89	
Load Removed, P (kg/yr & lb/yr):	7.46	16.42	



Note that the provided treatment efficiency is higher than the required treatment efficiency.

Figure 100 – Catchment and Treatment Summary Results

Part 2. Treating the catchments in Parallel:

1. Select the *Stormwater Treatment Analysis* button to return to the **Stormwater Treatment Analysis** worksheet.
2. All of the existing data can be used for this part of the problem except the catchment configuration needs to be changed.

3. Select the *Watershed Characteristics* button to proceed to the **Watershed Characteristics** worksheet.

   a. Indicate the catchment configuration. For this part, E - 3 catchments in parallel (Figure 101).

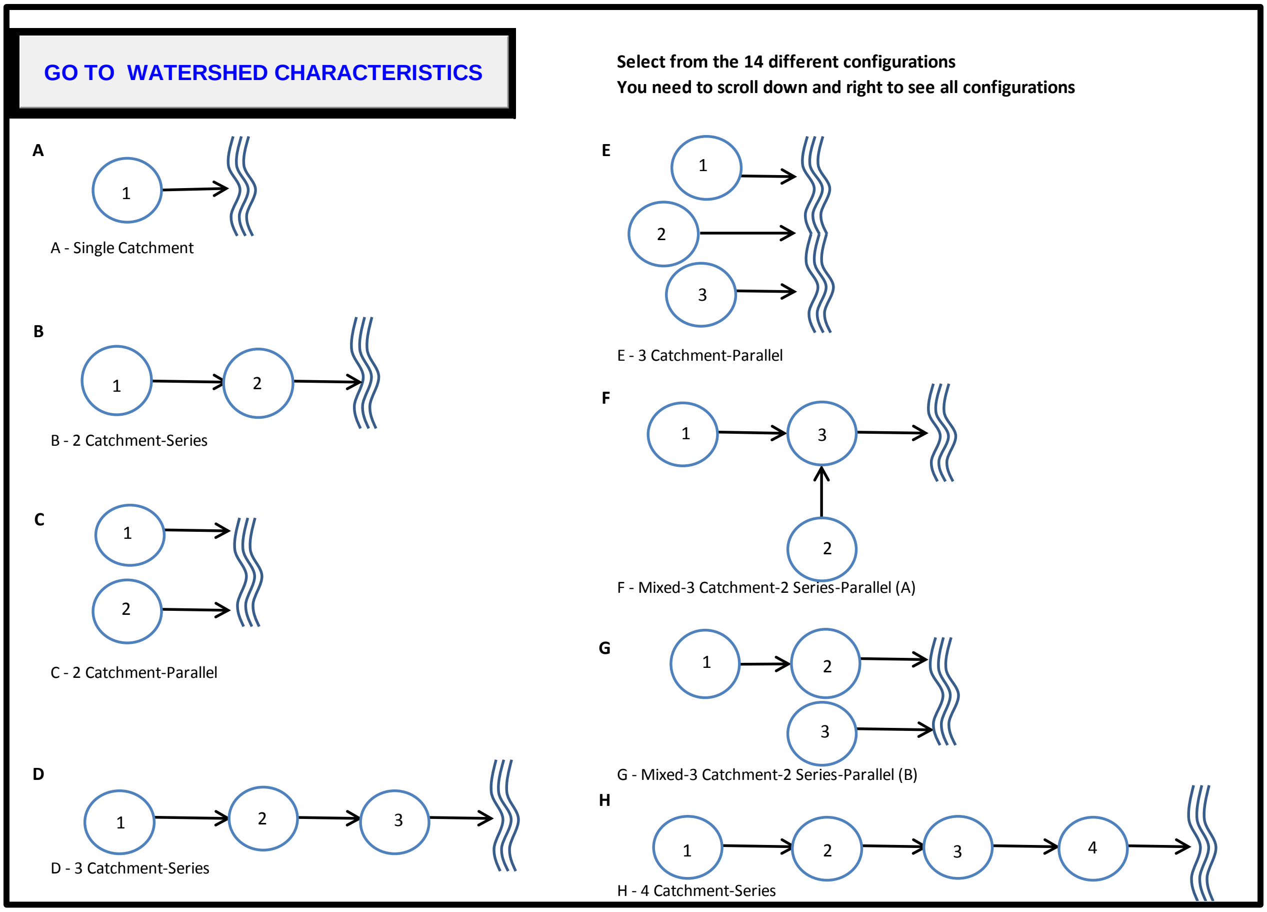


Figure 101 – Fifteen (15) Catchment Configuration Options worksheet.

   b. Leave the pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage from the previous part (Figure 102).

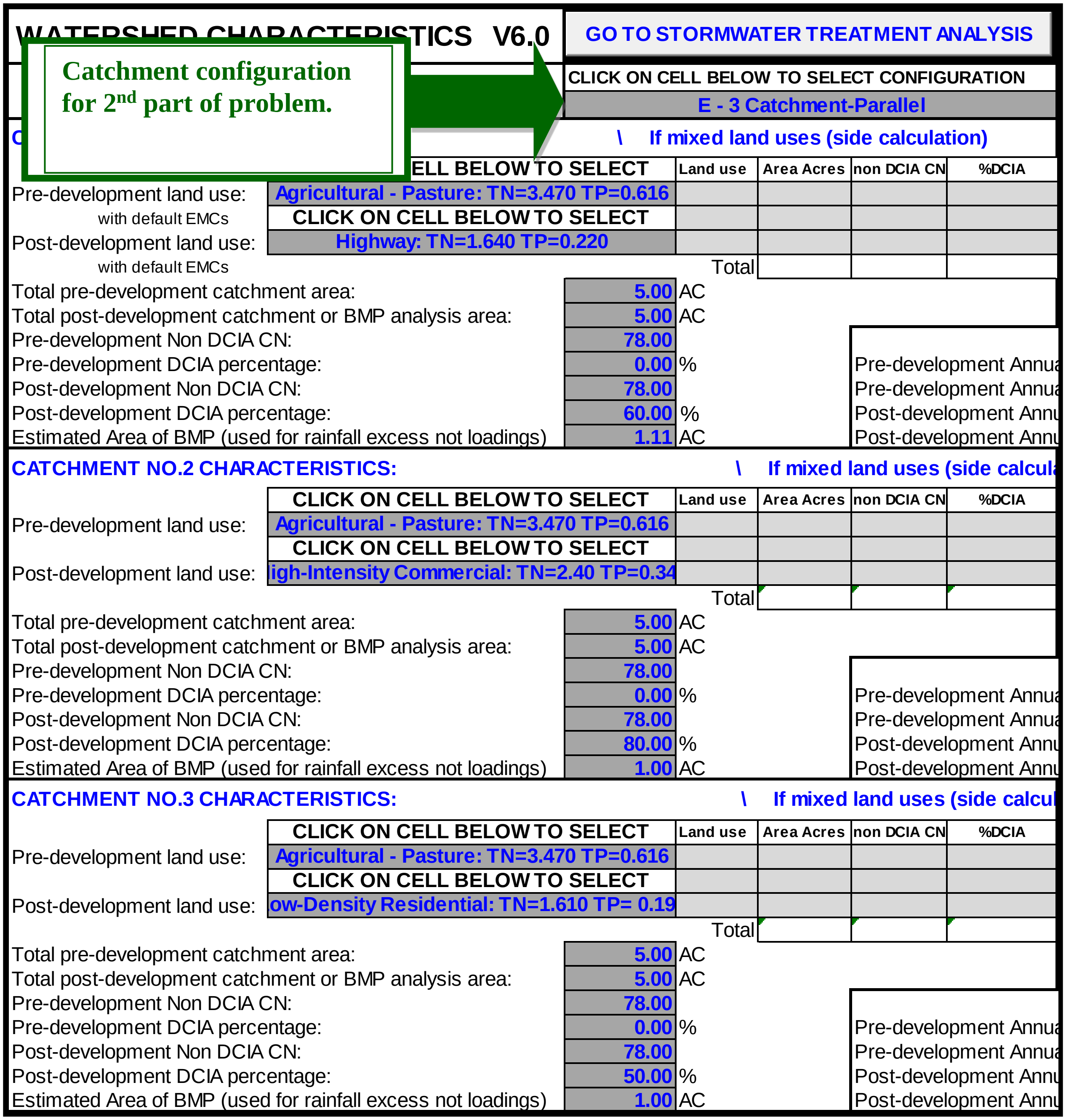
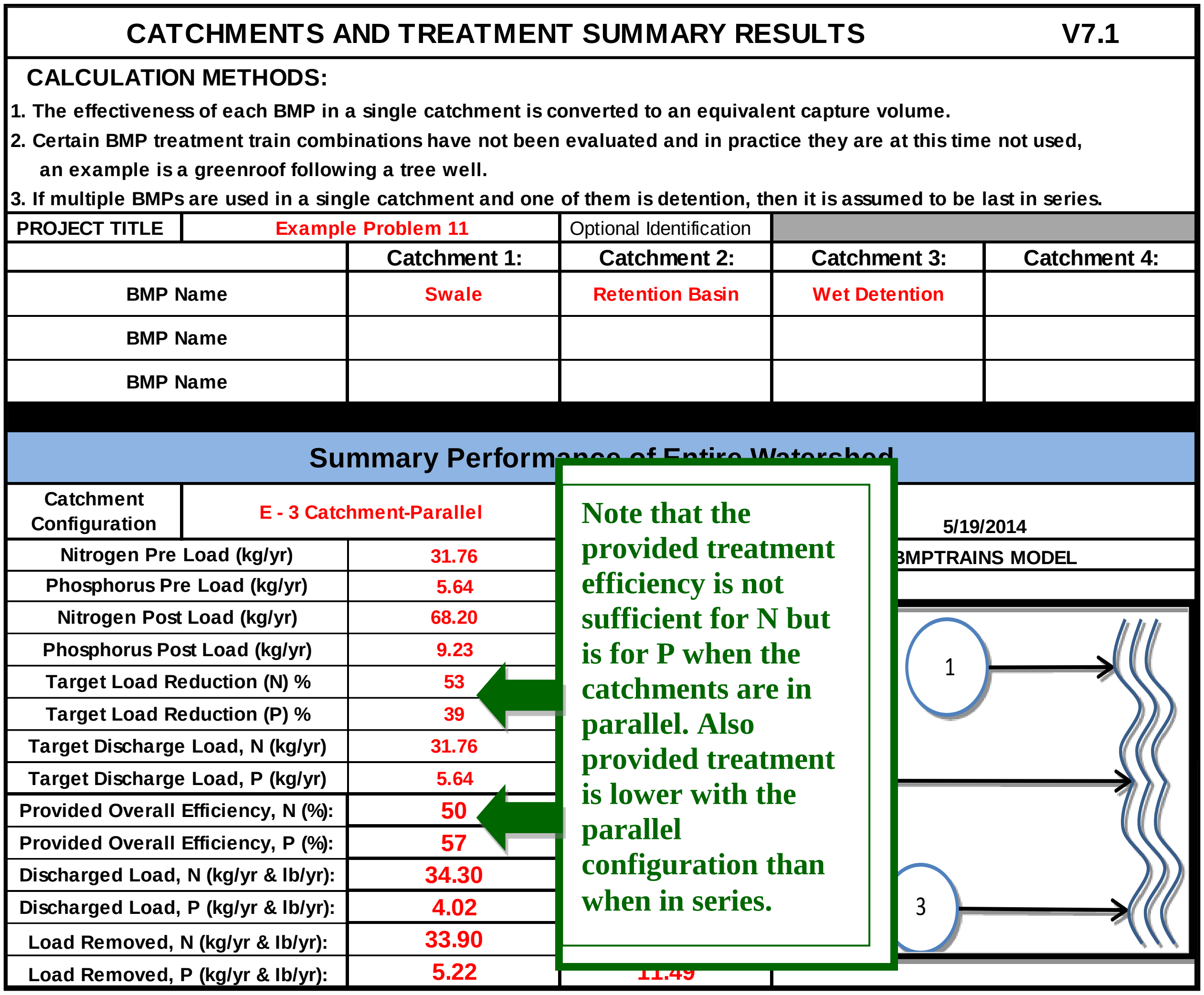


Figure 102 – Watershed Characteristics worksheet

4. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
5. Select the *Catchment and Treatment Summary Results* button to proceed to the **Catchment and Treatment Summary Results** worksheet (Figure 103).



CATCHMENTS AND TREATMENT SUMMARY RESULTS				V7.1
CALCULATION METHODS:				
1. The effectiveness of each BMP in a single catchment is converted to an equivalent capture volume.				
2. Certain BMP treatment train combinations have not been evaluated and in practice they are at this time not used, an example is a greenroof following a tree well.				
3. If multiple BMPs are used in a single catchment and one of them is detention, then it is assumed to be last in series.				
PROJECT TITLE	Example Problem 11	Optional Identification		
	Catchment 1:	Catchment 2:	Catchment 3:	Catchment 4:
BMP Name	Swale	Retention Basin	Wet Detention	
BMP Name				
BMP Name				

Summary Performance of Entire Watershed

Catchment Configuration	E - 3 Catchment-Parallel		5/19/2014
Nitrogen Pre Load (kg/yr)	31.76		BMPTRAINS MODEL
Phosphorus Pre Load (kg/yr)	5.64		
Nitrogen Post Load (kg/yr)	68.20		
Phosphorus Post Load (kg/yr)	9.23		
Target Load Reduction (N) %	53		
Target Load Reduction (P) %	39		
Target Discharge Load, N (kg/yr)	31.76		
Target Discharge Load, P (kg/yr)	5.64		
Provided Overall Efficiency, N (%):	50		
Provided Overall Efficiency, P (%):	57		
Discharged Load, N (kg/yr & lb/yr):	34.30		
Discharged Load, P (kg/yr & lb/yr):	4.02		
Load Removed, N (kg/yr & lb/yr):	33.90		
Load Removed, P (kg/yr & lb/yr):	5.22	11.49	

Figure 103 – Catchment and Treatment Summary Results

Discussion: This example shows how catchment configurations can be easily changed to examine different watershed configurations. This also shows the benefit of BMPs in series as opposed to parallel.

Example problem # 12 – Four Catchments

For this example problem, assume the conditions for Example problem #11 and add an additional 10-acre catchment. The problem is demonstrated twice, once in each of two configurations, namely (J and K). Configuration J is for three catchments in series and one in parallel, All discharge to the same surface water body. Configuration K allows for catchment 2 to discharge into catchment 3 and then catchment 3 flows into catchment 4 and then to the surface water body.

The project location is St. Petersburg, FL. There are options in design that reflect a possible comingling of offsite water into an onsite BMP rather than a direct discharge to the surface water body. The direct discharge is called a bypass.

The first catchment pre-development condition is agricultural-pasture with a Curve Number of 78. The post-development conditions are highway with a non-DCIA Curve Number of 78 and DCIA of 60%. A swale is to be used which is 1.11 acres. It has a 10 ft top width, swale bottom width of 2 ft, swale and highway length of 4840 ft, highway width of 20 ft, average width of pervious area of 25 ft, swale slope of 0.001, Manning's n of 0.05, a soil infiltration rate of 5 in/hr, and a swale side slope of 5.

The second catchment pre-development condition is agricultural-pasture with a Curve Number of 78. The post-development conditions are high-intensity commercial with a non-DCIA Curve Number of 78 and DCIA of 80%. A 1-acre retention pond is to be used for treatment and due to site limitations, only 0.25 inch over the catchment area can be accommodated.

The third catchment pre-development condition is agricultural-pasture with a Curve Number of 78. The post-development conditions are low-density residential with a non-DCIA Curve Number of 78 and DCIA of 50%. A 1-acre wet-detention pond is used with an average annual residence time of 30 days and littoral zone with 10% credit.

The fourth catchment pre-development condition is agricultural-pasture with a Curve Number of 78. The post-development conditions are light industrial with a non-DCIA Curve Number of 78 and DCIA of 60%. A 2-acre wet detention pond with an average annual residence time of 70 days is used. A littoral zone with 10% credit is also used.

Part 1. Treating the catchments in configuration J:

1. From the introduction worksheet, click on the *Click Here to Start* button to proceed to the **General Site Information** worksheet.
   a. Select the *Reset Input for Stormwater Treatment Analysis* button to erase any existing data.
   b. Enter the project name and select the meteorological zone in the **General Site Information** worksheet (Figure 104).
   c. Indicate the mean annual rainfall amount in the **General Site Information** worksheet.
   d. Select the *Net Improvement* option from the type of analysis drop down menu in the **General Site Information** worksheet.

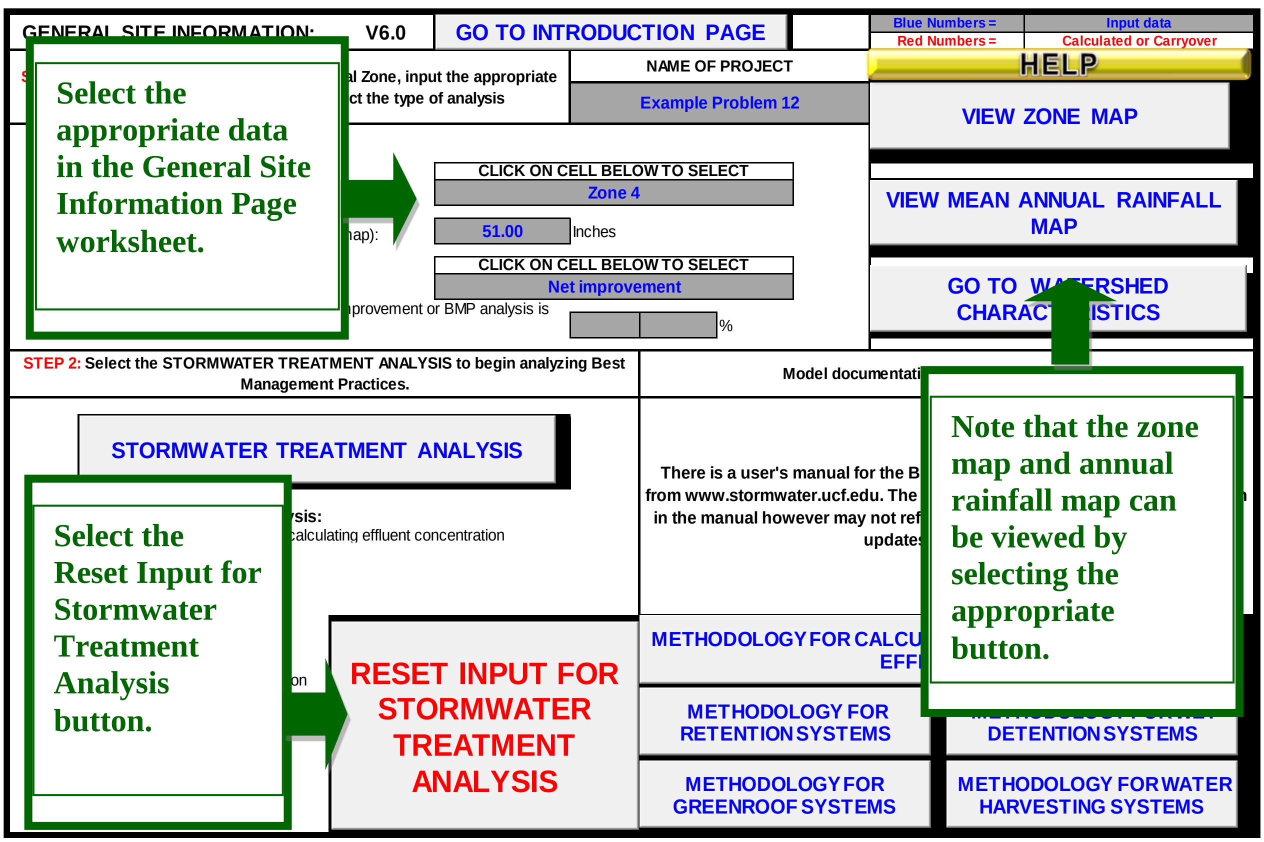


Figure 104 – General Site Information worksheet

2. Select the *Watershed Characteristics* button to proceed to the **Watershed Characteristics** worksheet.

a. Indicate the catchment configuration. For this problem, 4 catchments configured as shown in J (Figure 105).

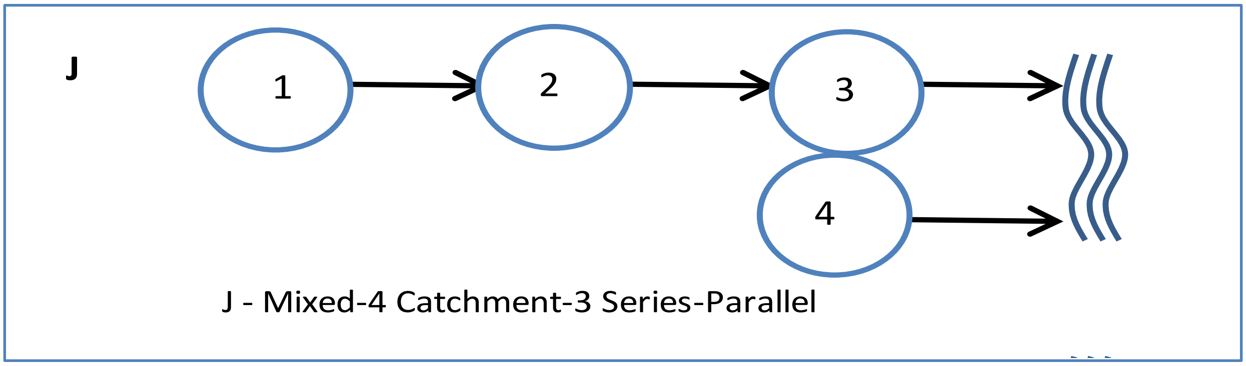


Figure 105 – Catchment Configuration for Part 1: Bypass or No Comingling.

b. Indicate the pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage (Figure 106).

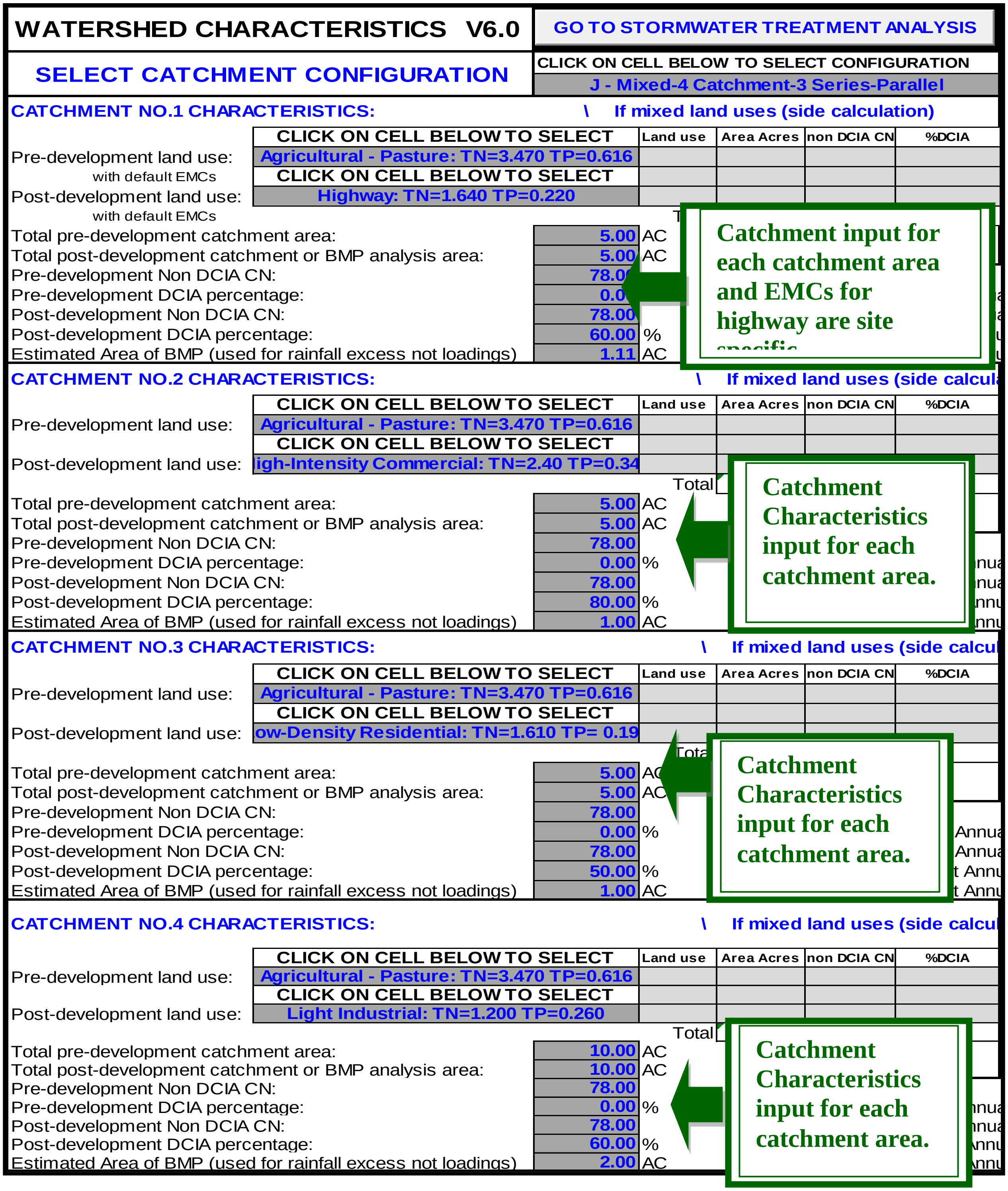


Figure 106 – Watershed Characteristics worksheet

3. Select the *Stormwater Treatment Analysis* button at the top of the worksheet.
4. Select the *Swale* button to proceed to the **Swale** worksheet (Figure 107).
   a. Enter the required input data from the problem givens.

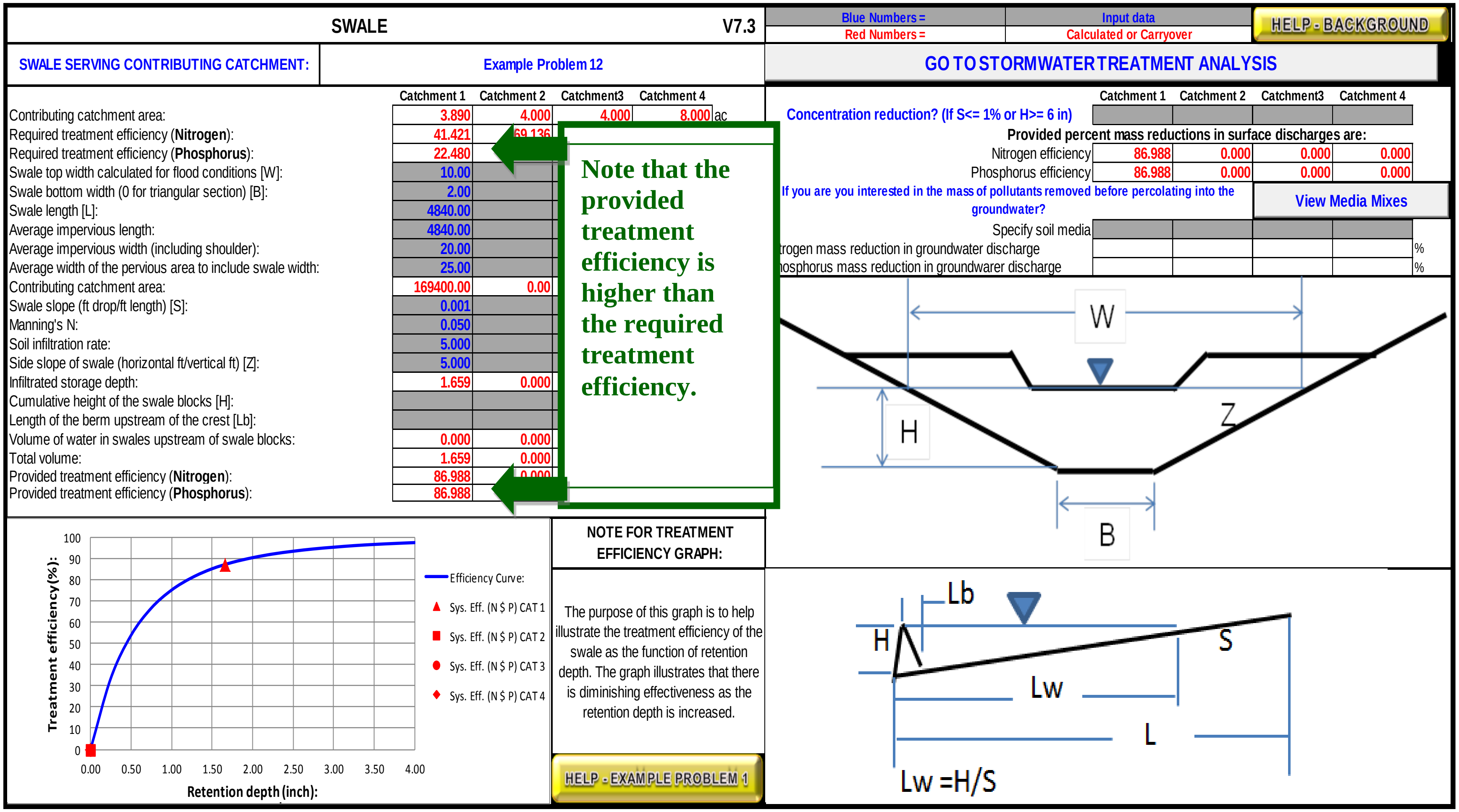


Figure 107 – Swale worksheet

5. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
6. Select the *Retention Basin* button to proceed to the **Retention Basin** worksheet.
   a. Specify a 0.25-inch retention depth (Figure 108).

RETENTION BASIN:					V6.0
RETENTION BASIN SERVING:	Example Problem 12				
	Catchment 1	Catchment 2	Catchment 3	Catchment 4	
Watershed area:	3.890	4.000	4.000	8.000	ac
Required Treatment Eff (**Nitrogen**):	41.421	69.136	33.164	22.143	%
Required Treatment Eff (**Phosphorus**):	22.480	61.885	0.000	36.210	%
Required retention depth over the watershed to meet required efficiency:	0.348	0.826	0.248	0.284	in
Required water quality retention volume:	0.113	0.275	0.083	0.189	ac-ft

RETENTION BASIN FOR MULTIPLE TREATMENT SYSTEMS (if there is a need for additional removal

	Catchment 1	Catchment 2	Catchment 3	Catchment 4	
Retention volume based on retention depth	0.000	0.083			
Provided retention depth (inches over the watershed area):		0.250			
Provided treatment efficiency (**Nitrogen**):	0.000	33.465			
Provided treatment efficiency (**Phosphorus**):	0.000	33.465			
Remaining treatment efficiency (**Nitrogen)**:	41.421	53.613			
Remaining treatment efficiency (**Phosphorus)**:	22.480	42.715			
Remaining retention depth needed:	0.348	0.576	0.248	0.284	in

Note that the treatment required is not met.

Figure 108 – Retention Basin worksheet

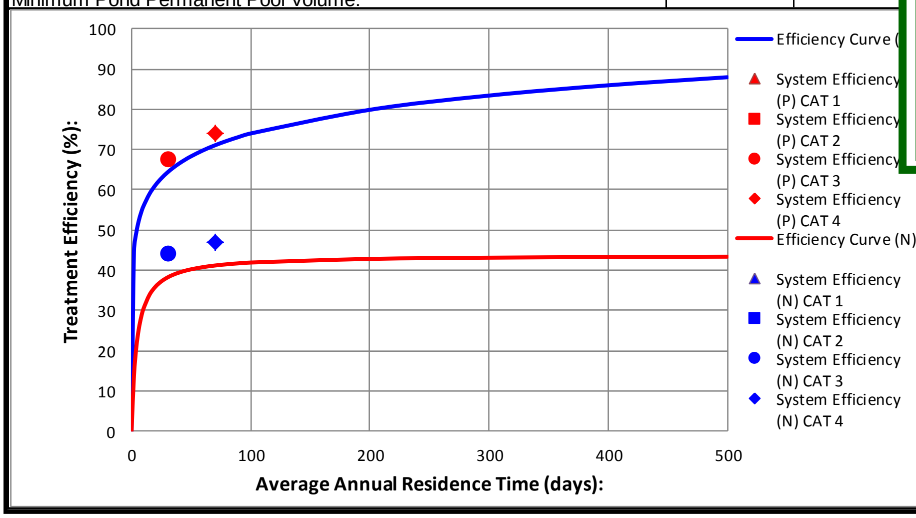
7. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
8. Select the *Wet Detention* button to proceed to the **Wet Detention** worksheet.
   a. Under catchment 3, specify a 30 day average annual residence time, a littoral zone (drop down menu), and a 10% efficiency credit (drop down menu) (Figure 109).
   b. Under catchment four specify a 70-day average annual residence time.

WET DETENTION:					V7.3
WET DETENTION POND SERVING:	Example Problem 12				
	Catchment 1	Catchment 2	Catchment 3	Catchment 4	
Total pre-development catchment area:	5.000	5.000	5.000	10.000	ac
Total post-development catchment area:	3.890	4.000	4.000	8.000	ac
Average annual residence time (between 1 and 500 days):			30.00	70.00	days
Littoral Zone or other improvements used?			YES	YES	
Littoral Zone or other improvement efficiency credit:			10.00	10.00	%
Total **Nitrogen** removal required:			33.164	22.143	%
Total **Phosphorus** removal required:			0.000	36.210	%
Total **Nitrogen** removal efficiency provided:			44.359	47.056	%
Total **Phosphorous** removal efficiency provided:			67.840	73.941	%
Is the wet detention sufficient:			YES	YES	
Average annual runoff volume:	8.934	11.587	7.976	18.374	ac-ft/yr

To Achieve the Treatment Efficiency Shown in the Graph Below, the Following Must Hold

Minimum Pond Permanent Pool Volume:

Note both catchment 3 and 4 data are entered here



efficiency graphs is to help illustrate the treatment efficiency of the wet detention system as the function of average annual residence time (and permanent pool volume). The graph illustrates that there is a point of diminished return as the permanent pool volume is substantially increased. The lines are produced from the conditions of catchment one, thus other catchments are shown with the data points.

Figure 109 – Wet Detention worksheet

9. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
10. Select the *Catchment and Treatment Summary Results* button to proceed to the **Catchment and Treatment Summary Results** worksheet (Figure 110).

CATCHMENTS AND TREATMENT SUMMARY RESULTS — V7.3

CALCULATION METHODS:

1. The effectiveness of each BMP in a single catchment is converted to an equivalent capture volume.
2. Certain BMP treatment train combinations have not been evaluated and in practice they are at this time not used, an example is a greenroof following a tree well.
3. If multiple BMPs are used in a single catchment and one of them is detention, then it is assumed to be last in series.

PROJECT TITLE	Example Problem 12	Optional Identification	

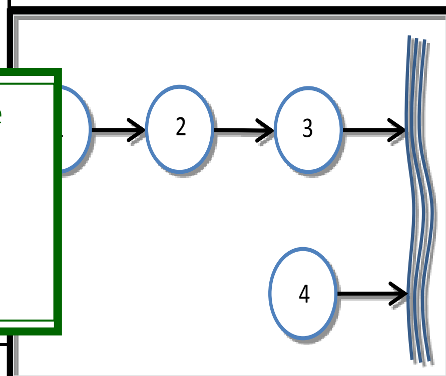
	Catchment 1:	Catchment 2:	Catchment 3:	Catchment 4:
BMP Name	Swale	Retention Basin	Wet Detention	Wet Detention
BMP Name				
BMP Name				

Summary Performance of Entire Watershed

Catchment Configuration	J - Mixed-4 Catchment-3 Series-Parallel	
Nitrogen Pre Load (kg/yr)	52.93	
Phosphorus Pre Load (kg/yr)	9.40	
Nitrogen Post Load (kg/yr)	95.39	
Phosphorus Post Load (kg/yr)	15.12	
Target Load Reduction (N) %	45	
Target Load Reduction (P) %	38	
Target Discharge Load, N (kg/yr)	52.93	
Target Discharge Load, P (kg/yr)	9.40	
Provided Overall Efficiency, N (%):	62	
Provided Overall Efficiency, P (%):	81	
Discharged Load, N (kg/yr & lb/yr):	35.80	
Discharged Load, P (kg/yr & lb/yr):	2.95	[illegible]
Load Removed, N (kg/yr & lb/yr):	59.60	131.26
Load Removed, P (kg/yr & lb/yr):	12.18	26.82

7/8/2014

BMPTRAINS MODEL



Note that the provided treatment efficiency is sufficient.

Figure 110 – Catchment and Treatment Summary Results

Part 2. Treating the catchments in configuration K:

1. All of the existing data can be used for this part of the problem except the catchment configuration needs to be changed.
2. Select the *Watershed Characteristics* button to proceed to the **Watershed Characteristics** worksheet.
   a. Indicate the catchment configuration. For this part, 4 catchments using configuration K (Figure 111).

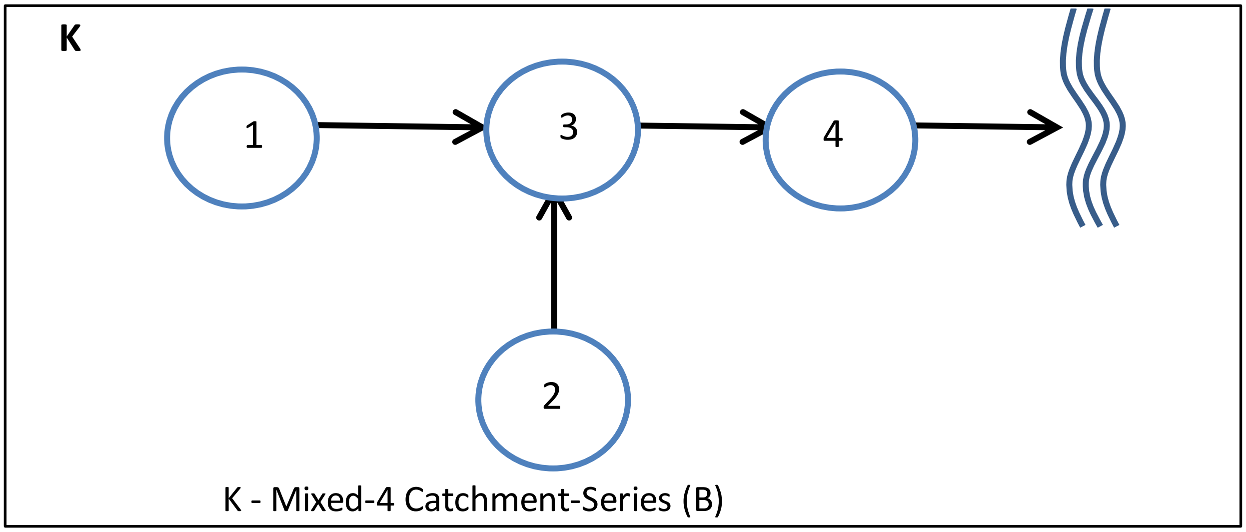


Figure 111 – Comingling Option: Catchment Configuration K

b. The pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage remains the same (Figure 112). Note there is no delay time in the offsite runoff (from node 2) reaching the onsite node 3.

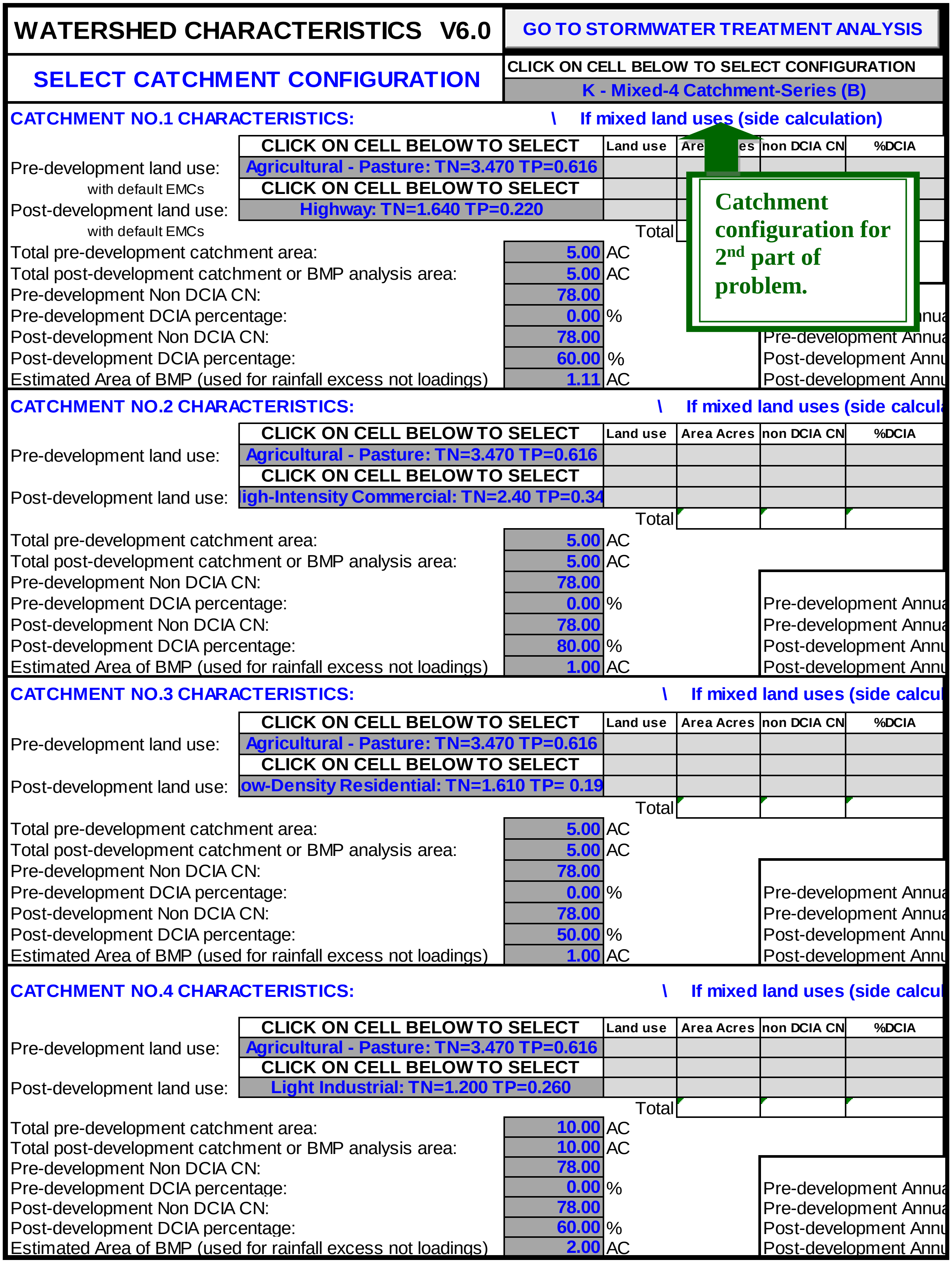


Figure 112 – Watershed Characteristics worksheet

3. Select the *Stormwater Treatment Analysis* button at the top of the worksheet to proceed to the **Stormwater Treatment Analysis** worksheet.

4. Select the *Catchment and Treatment Summary Results* button to proceed to the **Catchment and Treatment Summary Results** worksheet (Figure 113).

CATCHMENTS AND TREATMENT SUMMARY RESULTS					V7.3
CALCULATION METHODS:					
1. The effectiveness of each BMP in a single catchment is converted to an equivalent capture volume.					
2. Certain BMP treatment train combinations have not been evaluated and in practice they are at this time not used, an example is a greenroof following a tree well.					
3. If multiple BMPs are used in a single catchment and one of them is detention, then it is assumed to be last in series.					
PROJECT TITLE	Example Problem 12		Optional Identification		
		Catchment 1:	Catchment 2:	Catchment 3:	Catchment 4:
BMP Name		Swale	Retention Basin	Wet Detention	Wet Detention
BMP Name					
BMP Name					

Summary Performance of Entire Watershed			
Catchment Configuration	K - Mixed-4 Catchment-Series (B)		7/8/2014
Nitrogen Pre Load (kg/yr)	52.93		BMPTRAINS MODEL
Phosphorus Pre Load (kg/yr)	9.40		
Nitrogen Post Load (kg/yr)	95.39		
Phosphorus Post Load (kg/yr)	15.12		
Target Load Reduction (N) %	45		
Target Load Reduction (P) %	38		
Target Discharge Load, N (kg/yr)	52.93		
Target Discharge Load, P (kg/yr)	9.40		
Provided Overall Efficiency, N (%):	52		
Provided Overall Efficiency, P (%):	77		
Discharged Load, N (kg/yr & lb/yr):	46.11		
Discharged Load, P (kg/yr & lb/yr):	3.42		
Load Removed, N (kg/yr & lb/yr):	49.29	108.56	
Load Removed, P (kg/yr & lb/yr):	11.70	25.78	

Note that the provided treatment efficiency is sufficient.

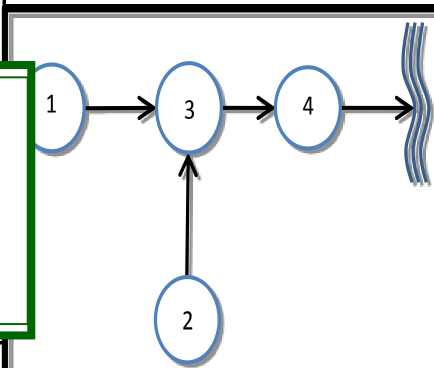


Figure 113 – Comingling Catchment and Treatment Summary Results

Discussion: This example shows how catchment configurations can be easily changed to examine different configurations. This also shows that different configurations can affect the overall result achieved.

Example problem # 13 – BMP Analysis

This example problem demonstrates how the model can be used to examine the effectiveness of a BMP without specifying a pre and post condition, or a specified removal. The application is for an existing BMP or it can also be used for new construction. The evaluation can be achieved by using one or more catchments. For BMPTRAINS model input, only post development area and CN number are specified. For this example problem, a single catchment is used and the BMP effectiveness is for a retention basin.

The project location is Orlando, FL. There is a small (20%) non-highway area in the catchment that contributes and is classified as an agricultural-pasture with a Curve Number of 78. The total project area is 6 acres. The highway DCIA is 80% of the catchment. The space for retention is limited, and it is desired to examine the effectiveness of a 0.25-acre retention pond.

This problem is a BMP analysis example.

Solution:

1. From the introduction page, click on the *Click Here to Start* button to proceed to the **General Site Information** worksheet.
    a. Select the *Reset Input for Stormwater Treatment Analysis* button to erase any existing data.
    b. Enter the project name, and select the meteorological zone in the **General Site Information** worksheet (Figure 114).
    c. Indicate the mean annual rainfall amount in the **General Site Information** worksheet.
    d. Select the *BMP Analysis* option from the type of analysis drop down menu in the **General Site Information** worksheet.

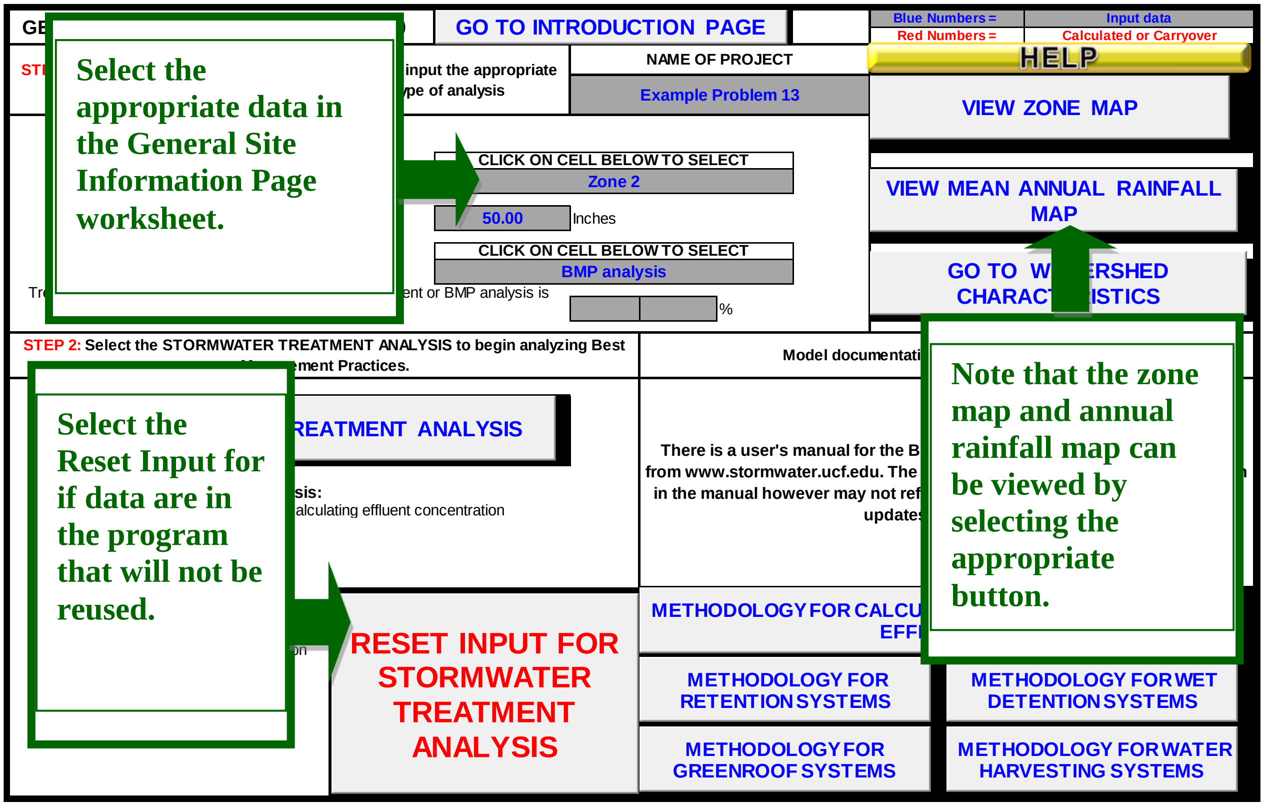


Figure 114 – General Site Information worksheet

2. Select the *Watershed Characteristics* button to proceed to the **Watershed Characteristics** worksheet.

   a. Indicate the catchment configuration. For this problem, a single catchment is used as shown in the BMPTRAINS MODEL as configuration A (Figure 115).

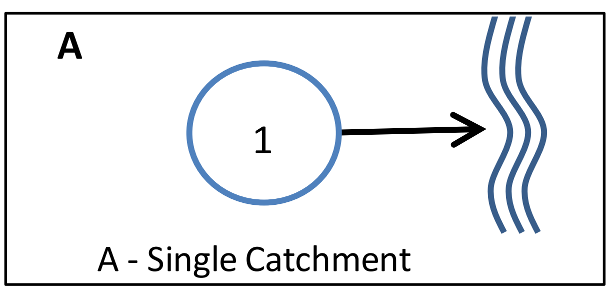


Figure 115 – Catchment Configuration for this problem

   b. Indicate the BMP land use data. Since we are only interested in BMP effectiveness, only the post-development catchment areas non-DCIA Curve Number and DCIA percentage are required but the post and pre land use conditions must also be entered (Figure 116).

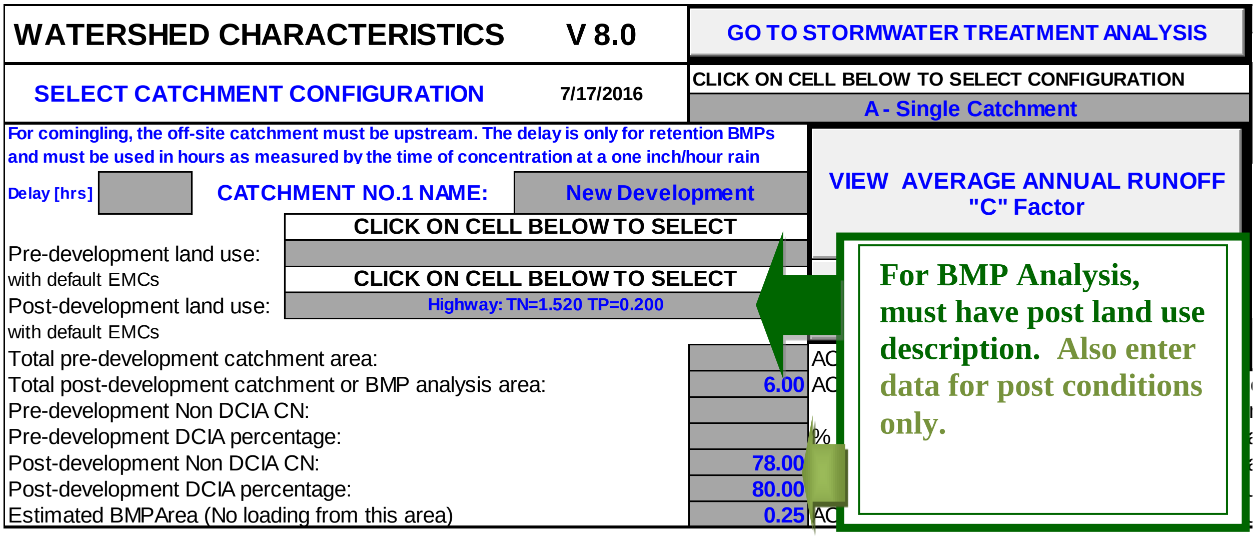


Figure 116 – Watershed Characteristics worksheet

3. Select the *Stormwater Treatment Analysis* button at the top of the worksheet to proceed to the **Stormwater Treatment Analysis** worksheet.
4. Select the *Retention Basin* button to proceed to the **Basin** worksheet.
   a. A retention area of 0.25 acres that is about an average of 10 feet deep exists and provides for 0.5-inch retention depth over the DCIA. Use retention depth of 0.5 inch (Figure 117).

RETENTION BASIN:					V6.0
RETENTION BASIN SERVING:	Example Problem 13				
	Catchment 1	Catchment 2	Catchment 3	Catchment 4	
Watershed area:	5.750	0.000	0.000	0.000	ac
Required Treatment Eff (**Nitrogen**):	TBD	TBD	TBD	TBD	%
Required Treatment Eff (**Phosphorus**):	TBD	TBD	TBD	TBD	%
Required retention depth over the watershed to meet required efficiency:	0.000	0.000	0.000	0.000	in
Required water quality retention volume:	0.000	0.000	0.000	0.000	ac-ft
RETENTION BASIN FOR MULTIPLE TREATMENT SYSTEMS (if there is a need for additional removal efficiencies in a series of BMPs):					
Retention volume based on retention depth	0.240	0.000	0.000	0.000	ac-ft
Provided retention depth (inches over the watershed area):	0.500				in
Provided treatment efficiency (**Nitrogen**):	50.860	0.000	0.000	0.000	%
Provided treatment efficiency (**Phosphorus**):	50.860	0.000	0.000	0.000	%
Remaining treatment efficiency (**Nitrogen)**:					%
Remaining treatment efficiency (**Phosphorus)**:					%
Remaining retention depth needed:	0.000	0.000	0.000	0.000	in

Figure 117 – Retention Basin worksheet.

5. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.

6. Select the *Catchment and Treatment Summary Results* button to proceed to the **Catchment and Treatment Summary Results** worksheet (Figure 118).

CATCHMENTS AND TREATMENT SUMMARY RESULTS				V 8.0
CALCULATION METHODS: 1. The effectiveness of each BMP in a single catchment is converted to an equivalent capture volume. 2. Certain BMP treatment train combinations have not been evaluated and in practice they are at this time not used, an example is a greenroof following a tree well. 3. Wet detention is last when used in a single catchment with other BMPs, except when followed by filtration				
PROJECT TITLE	BMP Analysis	Optional Identification	Example Problem 13	
	New Development	Catchment 2	Catchment 3	Catchment 4
BMP Name	Retention Basin			
BMP Name				
BMP Name				
Summary Performance of Entire Watershed				
Catchment Configuration	A - Single Catchment	Treatment Objectives or Target	7/17/2016	
Nitrogen Pre Load (kg/yr)	0.00		BMPTRAINS MODEL	
Phosphorus Pre Load (kg/yr)	0.00			
Nitrogen Post Load (kg/yr)	29.96			
Phosphorus Post Load (kg/yr)	3.94			
Target Load Reduction (N) %				
Target Load Reduction (P) %				
Target Discharge Load, N (kg/yr)				
Target Discharge Load, P (kg/yr)				
Provided Overall Efficiency, N (%):	51			
Provided Overall Efficiency, P (%):	51			
Discharged Load, N (kg/yr & lb/yr):	14.72	32.43		
Discharged Load, P (kg/yr & lb/yr):	1.94	4.27		
Load Removed, N (kg/yr & lb/yr):	15.24	33.57		
Load Removed, P (kg/yr & lb/yr):	2.01	4.42		

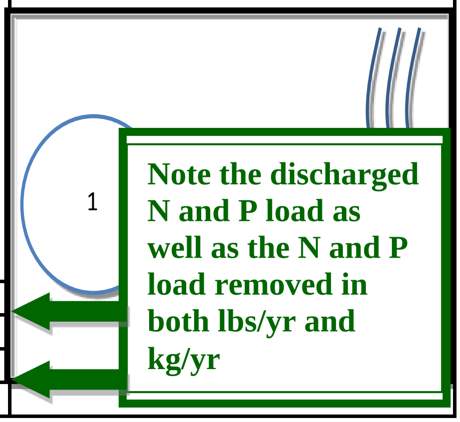


Figure 118 – Catchment and Treatment Summary Results.

Discussion: This example problem illustrates removal with a limited size of BMP, or retention basin in this example. The results show that a retention basin that treats 0.5 inches of the runoff from the watershed removes 14.72 kg/yr (32.43 lb/yr) of N and 1.94 kg/yr (4.27 lb/yr) of P discharging 15.24 kg/yr (33.57 lb/yr) of N and 2.01 kg/yr (4.42 lb/yr) of P. The efficiency for retention with the catchment land surface conditions and for the BMP size is 51%. If the retention basin can be deepened to a treatment volume of 1.00 inches of runoff a 74% efficiency can be expected. Note. The capture volume is calculated on the volume of the retention basin divided by the total catchment area.

Example problem # 14 – BMP Analysis for Offsite Drainage into an Onsite BMP

This example problem examines the possibility of offsite drainage into an onsite BMP (in this case, a FDOT right of way BMP) when there is no delay time from the offsite area to the treatment area. There are two treatment options; one is to comingle the offsite water through the onsite BMP, and thus two catchments in series with a BMP for the second catchment is used. For example, the onsite BMP is a retention basin and the area and treatment volume is limited. Thus, the treatment size of the onsite BMP will not change (0.5 inch over the onsite catchments as the treatment depth). Limitations to treatment volume occur when the depth of the BMP cannot be increased or the area for the BMP is constrained by right-of-way purchases or physical limitations.

The other option is to examine the benefit of bypassing the offsite discharge using a separate system without treatment. This configuration of catchments is identified as catchments in parallel.

The project location is Sanford, FL. The offsite catchment (number one in the BMPTRAINS model) pre-development and post-development condition is agricultural-pasture with a Curve Number of 78. The total area is 10 acres. No land use change is expected from pre to post development for the offsite catchment.

This is a design problem with limited area for treatment. However, the depth of the existing onsite basin can be up to 13 feet to accommodate offsite catchment flow. The onsite catchment pre-development condition is agricultural-pasture with a Curve Number of 78. The catchment area is 6 acres. The post-development conditions are highway with a non-DCIA Curve Number of 78 and DCIA of 80%. As in the previous example problem, a 0.25-acre retention basin is used for treatment that is 0.5 inch of treatment over the second catchment area.

Part 1. Treating the catchments in configuration B:

1. From the introduction page click on the *Click Here to Start* button to proceed to the **General Site Information** worksheet.
    a. Select the *Reset Input for Stormwater Treatment Analysis* button to erase any existing data.
    b. Enter the project name and select the meteorological zone in the **General Site Information** worksheet (Figure 119).

c. Indicate the mean annual rainfall amount in the **General Site Information** worksheet.

d. Select the *BMP Analysis* option from the type of analysis drop down menu in the **for the offsite runoff.**

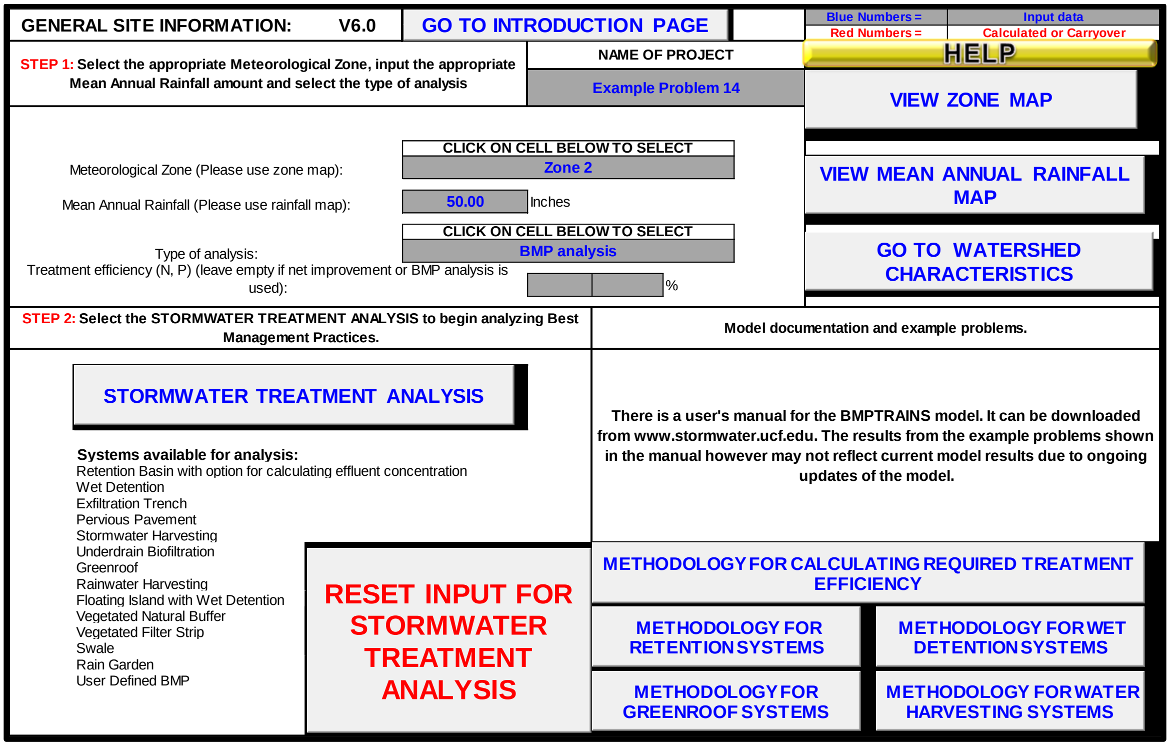


Figure 119 – General Site Information worksheet

2. Select the *Watershed Characteristics* button to proceed to the **Watershed Characteristics** worksheet.
   a. Indicate the catchment configuration. For this problem, two catchments configured as shown in BMPTRAINS option B (Figure 120).

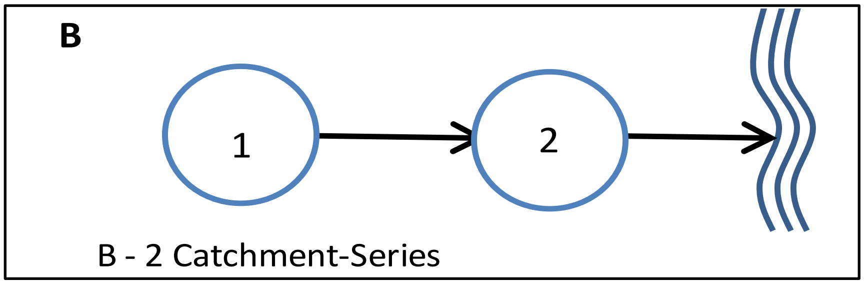
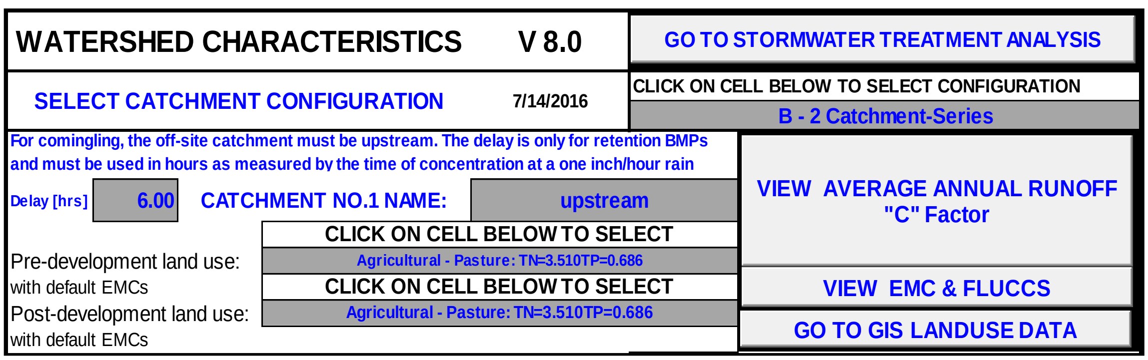


Figure 120 – Catchment Series Configuration for part 1 Comingling

b. Indicate the pre- and post-development land use. Since we are only interested in BMP effectiveness, only the post-development catchment areas, non-DCIA Curve Number and DCIA percentage are required (Figure 121 parts a and b).

If there is a delay time for the runoff water from the upstream catchment to reach the regional basin (#2 in the diagram), then the delay time is added on the watershed characteristics worksheet. The delay time of 6 hours is shown below and is calculated using time of concentration formulas and for an average rainfall intensity of 1 inch per hour. A partial screen capture is shown in Figure 121 (part a): Also, note that the delay time is only used when the treatment BMP is retention. There is no delay time needed when using a Wet Detention BMP. Also comingling is evaluated using two catchments, one upstream (offsite) and the other downstream (onsite or regional).



(Part a) of Figure 121 separated to emphasize the possible entry for a delay

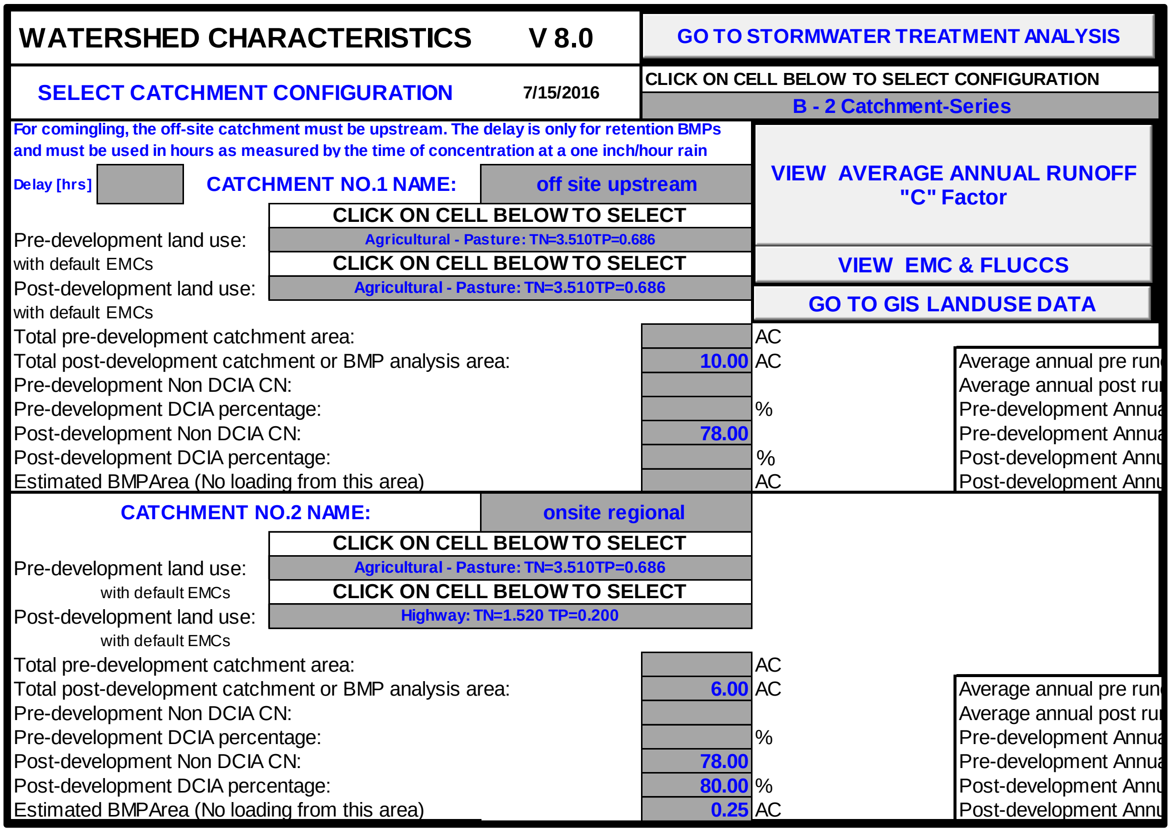


Figure 121 – Watershed Characteristics worksheet (part b)

3. Select the *Stormwater Treatment Analysis* button at the top of the worksheet to proceed to the **Stormwater Treatment Analysis** worksheet.
4. Select the *Retention Basin* button to proceed to the **Retention Basin** worksheet.
   a. Specify a 0.5-inch retention depth and note a deeper basin than used in the previous example problem to accommodate for the increased volume provided by the offsite flow. For the input data worksheet (see Figure 122).

RETENTION BASIN:					V6.0
RETENTION BASIN SERVING:	Example Problem 14				
	Catchment 1	Catchment 2	Catchment 3	Catchment 4	
Watershed area:	10.000	5.750	0.000	0.000	ac
Required Treatment Eff (**Nitrogen**):	TBD	TBD	TBD	TBD	%
Required Treatment Eff (**Phosphorus**):	TBD	TBD	TBD	TBD	%
Required retention depth over the watershed to meet required efficiency:	0.000	0.000	0.000	0.000	in
Required water quality retention volume:	0.000	0.000	0.000	0.000	ac-ft
RETENTION BASIN FOR MULTIPLE TREATMENT SYSTEMS (if there is a need for additional removal efficiencies in a series of BMPs):					
Retention volume based on retention depth	0.000	0.240	0.000	0.000	ac-ft
Provided retention depth (inches over the watershed area):		0.500			in
Provided treatment efficiency (**Nitrogen**):	0.000	68.197	0.000	0.000	%
Provided treatment efficiency (**Phosphorus**):	0.000	68.197	0.000	0.000	%
Remaining treatment efficiency (**Nitrogen)**:					%
Remaining treatment efficiency (**Phosphorus)**:					%
Remaining retention depth needed:	0.000	0.000	0.000	0.000	in

Figure 122 – Retention Basin worksheet

Comparing the removal effectiveness when offsite drainage is added to a fixed area of retention basin at the same average depth to a design with no offsite drainage shows a decrease to 68% (Figure 121) as compared without treating the offsite area or 74% (see comments under Figure 118).

5. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
6. Select the *Catchment and Treatment Summary Results* button to proceed to the **Catchment and Treatment Summary Results** worksheet (Figure 123).

CATCHMENTS AND TREATMENT SUMMARY RESULTS	V 8.0

CALCULATION METHODS:

1. The effectiveness of each BMP in a single catchment is converted to an equivalent capture volume.
2. Certain BMP treatment train combinations have not been evaluated and in practice they are at this time not used, an example is a greenroof following a tree well.
3. Wet detention is last when used in a single catchment with other BMPs, except when followed by filtration

PROJECT TITLE	co-mingling	Optional Identification		
	off site upstream	onsite regional	Catchment 3	Catchment 4
BMP Name		Retention Basin		
BMP Name				
BMP Name				

Summary Performance of Entire Watershed

Catchment Configuration	B - 2 Catchment-Series	Treatment Objectives or Target	7/15/2016
Nitrogen Pre Load (kg/yr)	0.00		BMPTRAINS MODEL
Phosphorus Pre Load (kg/yr)	0.00		
Nitrogen Post Load (kg/yr)	47.68		
Phosphorus Post Load (kg/yr)	7.40		
Target Load Reduction (N) %			
Target Load Reduction (P) %			
Target Discharge Load, N (kg/yr)			
Target Discharge Load, P (kg/yr)			
Provided Overall Efficiency, N (%):	64		
Provided Overall Efficiency, P (%):	64		
Discharged Load, N (kg/yr & lb/yr):	17.00	37.45	
Discharged Load, P (kg/yr & lb/yr):	2.64	5.82	
Load Removed, N (kg/yr & lb/yr):	30.67	67.56	
Load Removed, P (kg/yr & lb/yr):	4.76	10.49	

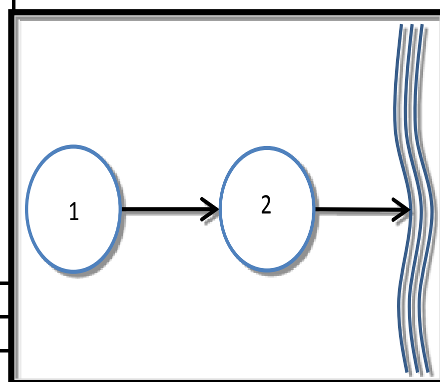


Figure 123 – Catchment and Treatment Summary Results

Discussion: The N discharged is 17.00 kg/yr (37.54 lb/yr) and the P discharged is 2.64 kg/yr (5.82 lb/yr). The N and P removal are both 64%. The maximum removal at the regional site was 68% removal. There was not a significant difference because the offsite (upstream) had no directly connected impervious area and thus low discharge. If there were a delay, then the comingling discharge would be closer to the non-delayed discharged. A delay allows more time for infiltration of the onsite runoff making more storage available for the offsite runoff**.**

Part 2. Treating the catchments as parallel flow streams as shown in the BMPTRAINS model configuration C (Figure 124): The offsite flow is bypassed.

1. All of the existing data can be used for this part of the problem except the catchment configuration needs to be changed.
2. Select the *Watershed Characteristics* button to proceed to the **Watershed Characteristics** worksheet.
3. Catchment Configuration input.
   a. Indicate the catchment configuration. For this part, 2 catchments using configuration C of the BMPTRAINS Model (Figure 124). We are examining the flow streams separately.

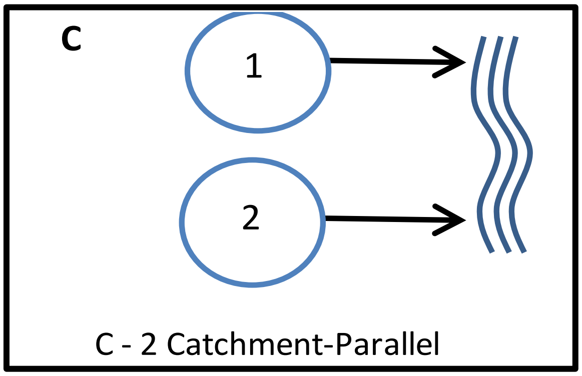


Figure 124 – Catchment Configuration C for Bypass of an Offsite Flow

b. The pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage remain the same (Figure 125)

c. Because the offsite flow is not treated and for ½” treatment, the retention basin can be 10 feet (not 13 feet) or less area (0.19 ac) is needed.

WATERSHED CHARACTERISTICS V6.0	**GO TO STORMWATER TREATMENT ANALYSIS**
SELECT CATCHMENT CONFIGURATION	**CLICK ON CELL BELOW TO SELECT CONFIGURATION**
	C - 2 Catchment-Parallel

CATCHMENT NO.1 CHARACTERISTICS: \ **If mixed land uses (side calculation)**

		Land use	Area Acres	non DCIA CN	%DCIA
	CLICK ON CELL BELOW TO SELECT				
Pre-development land use:	**Agricultural - Pasture: TN=3.470 TP=0.616**				
with default EMCs	**CLICK ON CELL BELOW TO SELECT**				
Post-development land use:	**Agricultural - Pasture: TN=3.470 TP=0.616**				
with default EMCs		Total			

Total pre-development catchment area:		AC	
Total post-development catchment or BMP analysis area:	**10.00**	AC	
Pre-development Non DCIA CN:			
Pre-development DCIA percentage:		%	Pre-development Annua
Post-development Non DCIA CN:	**78.00**		Pre-development Annua
Post-development DCIA percentage:	**0.00**	%	Post-development Annu
Estimated Area of BMP (used for rainfall excess not loadings)		AC	Post-development Annu

CATCHMENT NO.2 CHARACTERISTICS: \ **If mixed land uses (side calcula**

		Land use	Area Acres	non DCIA CN	%DCIA
	CLICK ON CELL BELOW TO SELECT				
Pre-development land use:	**Agricultural - Pasture: TN=3.470 TP=0.616**				
	CLICK ON CELL BELOW TO SELECT				
Post-development land use:	**Highway: TN=1.640 TP=0.220**				
		Total			

Total pre-development catchment area:		AC	
Total post-development catchment or BMP analysis area:	**6.00**	AC	
Pre-development Non DCIA CN:			
Pre-development DCIA percentage:		%	Pre-development Annua
Post-development Non DCIA CN:	**78.00**		Pre-development Annua
Post-development DCIA percentage:	**80.00**	%	Post-development Annu
Estimated Area of BMP (used for rainfall excess not loadings)	**0.25**	AC	Post-development Annu

Figure 125 – Watershed Characteristics worksheet

4. Select the *Stormwater Treatment Analysis* button at the top of the worksheet to proceed to the **Stormwater Treatment Analysis** worksheet.

5. Select the *Catchment and Treatment Summary Results* button to proceed to the **Catchment and Treatment Summary Results** worksheet (Figure Figure 126).

CATCHMENTS AND TREATMENT SUMMARY RESULTS				V 8.0
CALCULATION METHODS:				
1. The effectiveness of each BMP in a single catchment is converted to an equivalent capture volume.				
2. Certain BMP treatment train combinations have not been evaluated and in practice they are at this time not used, an example is a greenroof following a tree well.				
3. Wet detention is last when used in a single catchment with other BMPs, except when followed by filtration				
PROJECT TITLE	co-mingling	Optional Identification		
	off site upstream	onsite regional	Catchment 3	Catchment 4
BMP Name		Retention Basin		
BMP Name				
BMP Name				

Summary Performance of Entire Watershed

Catchment Configuration	C - 2 Catchment-Parallel		7/15/2016
Nitrogen Pre Load (kg/yr)	0.00		BMPTRAINS MODEL
Phosphorus Pre Load (kg/yr)	0.00		
Nitrogen Post Load (kg/yr)	47.68		
Phosphorus Post Load (kg/yr)	7.40		
Target Load Reduction (N) %			
Target Load Reduction (P) %			
Target Discharge Load, N (kg/yr)			
Target Discharge Load, P (kg/yr)			
Provided Overall Efficiency, N (%):	43		
Provided Overall Efficiency, P (%):	36		
Discharged Load, N (kg/yr & lb/yr):	27.24	60.00	
Discharged Load, P (kg/yr & lb/yr):	4.72	10.39	
Load Removed, N (kg/yr & lb/yr):	20.43	45.01	
Load Removed, P (kg/yr & lb/yr):	2.69	5.92	

Note: additional offsite loading not treated increased the discharge load and decreased the overall effectiveness.

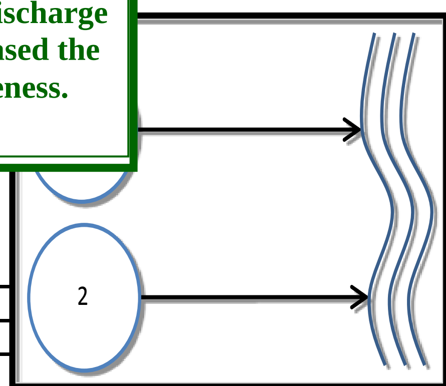


Figure 126 – Catchment and Treatment Summary Results

Discussion: When not treating the offsite drainage, the combined annual N discharged is 60.00 lb/yr and P discharged is 10.39 lb/yr compared to treating the offsite in the onsite fixed volume retention basin giving 37.45 lb/yr N and 5.82 lb/yr P (series treatment, Figure 123). The use of the onsite fixed volume of retention is favored because of the lower discharge load. However, this is not always the result and depends on the rainfall excess from the offsite as well as the size of the onsite treatment. For this set of conditions, and in terms of removal, it would be best to treat onsite the offsite runoff even if the onsite basin size were not increased.

Example problem # 15 – Different N and P Removal Efficiencies Specified

This example problem presents the instance of different required and specified removal efficiencies for N and P. For BMP removal effectiveness with different required amounts for N and P, any number of catchments (up to 4) in any configuration can be used.

For this example problem, one catchment is used. The project location is in the Tallahassee, Florida, area. The catchment pre-development condition is agricultural-general agricultural with a non-DCIA Curve Number of 60. The total area is 10 acres. The post-development conditions are light industrial with a non-DCIA Curve Number of 60 and DCIA of 70%. A 0.25-acre detention pond for treatment with an average annual residence time of 50 days is possible. In addition, a littoral zone with a 15% efficiency credit is assumed. This problem is treated as a specified removal efficiency problem. The objective is to remove 45% N and 70% P.

Solution:

1. From the introduction page click on the *Click Here to Start* button to proceed to the **General Site Information** worksheet.
   a. Select the *Reset Input for Stormwater Treatment Analysis* button to erase any existing data.
   b. Enter the project name and select the meteorological zone in the **General Site Information** worksheet (Figure 127).
   c. Indicate the mean annual rainfall amount in the **General Site Information** worksheet.
   d. Select the *Specified Removal Efficiency* option from the type of analysis drop down menu in the **General Site Information** worksheet and enter *45%* and *70%* for N and P, respectively.

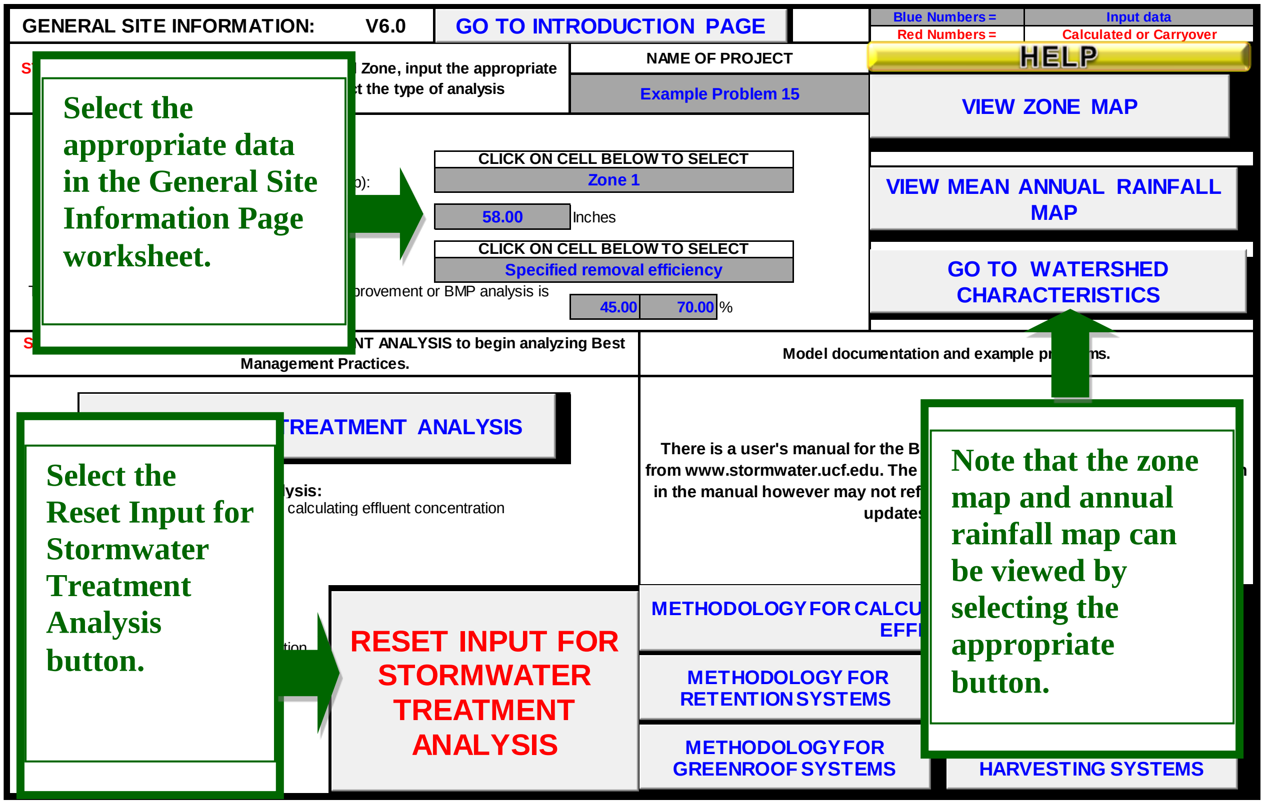


Figure 127 – General Site Information worksheet

2. Select the *Watershed Characteristics* button to proceed to the **Watershed Characteristics** worksheet.
   a. Indicate the catchment configuration. For this problem, 1 catchment configured as shown in A (Figure 128).

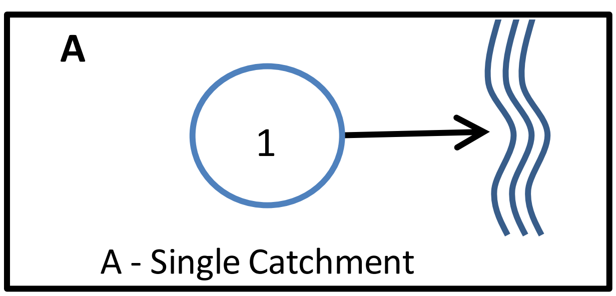


Figure 128 – Catchment Configuration for this problem.

   b. Indicate the pre- and post-development land use, catchment areas, non-DCIA Curve Number and DCIA percentage (Figure 129).

WATERSHED CHARACTERISTICS V6.0		GO TO STORMWATER TREATMENT ANALYSIS				
SELECT CATCHMENT CONFIGURATION		CLICK ON CELL BELOW TO SELECT CONFIGURATION A - Single Catchment				
CATCHMENT NO.1 CHARACTERISTICS:		\ If mixed land uses (side calculation)				
	CLICK ON CELL BELOW TO SELECT		Land use	Area Acres	non DCIA CN	%DCIA
Pre-development land use:	Agricultural - General: TN=2.790 TP=0.431					
with default EMCs	CLICK ON CELL BELOW TO SELECT					
Post-development land use:	Light Industrial: TN=1.200 TP=0.260					
with default EMCs			Total			
Total pre-development catchment area:		10.00	AC			
Total post-development catchment or BMP analysis area:		10.00	AC			
Pre-development Non DCIA CN:		60.00				
Pre-development DCIA percentage:		0.00	%		Pre-development Annua	
Post-development Non DCIA CN:		60.00			Pre-development Annua	
Post-development DCIA percentage:		70.00	%		Post-development Annu	
Estimated Area of BMP (used for rainfall excess not loadings)		0.25	AC		Post-development Annu	

Figure 129 – Watershed Characteristics worksheet

3. Select the *Stormwater Treatment Analysis* button at the top of the worksheet to proceed to the **Stormwater Treatment Analysis** worksheet.
4. Select the *Wet Detention* button to proceed to the **Wet Detention** worksheet.
   a. Under catchment 1 specify a 50 day average annual residence time, a littoral zone (drop down menu), and a 15% efficiency credit (drop down menu) (Figure 130).

WET DETENTION:				V6.1	
WET DETENTION POND SERVING:	Example Problem 15				
	Catchment 1	Catchment 2	Catchment 3	Catchment 4	
Total pre-development catchment area:	10.000	0.000	0.000	0.000	ac
Total post-development catchment area:	9.750	0.000	0.000	0.000	ac
Average annual residence time (between 1 and 500 days):	50.00				days
Littoral Zone used in the design:	YES				
Littoral Zone efficiency credit (user specifies 10, 15, or 20%):	15.00				%
Total **Nitrogen** removal required:	45.000				%
Total **Phosphorus** removal required:	70.000				%
Total **Nitrogen** removal efficiency provided:	49.192				%
Total **Phosphorous** removal efficiency provided:	73.070				%
Is the wet detention sufficient:	YES				
Average annual runoff volume:	28.74625				ac-ft/yr
Wet Detention Pond Characteristics:					
To Achieve the Treatment Efficiency Shown in the Graph Below, the Following Must Hold					
Maximum Permanent Pool Depth:	10.26			0.00	ft
Minimum Permanent Pool Volume:	3.938	0.000	0.000	0.000	ac-ft

Note the provided treatment is sufficient

Figure 130 – Wet Detention worksheet

5. Select the *Stormwater Treatment Analysis* button to proceed to the **Stormwater Treatment Analysis** worksheet.
6. Select the *Catchment and Treatment Summary Results* button to proceed to the **Catchment and Treatment Summary Results** worksheet (Figure 131).

CATCHMENTS AND TREATMENT SUMMARY RESULTS				V6.0
CALCULATION METHODS:				
1. The effectiveness of each BMP in a single catchment is converted to an equivalent capture volume.				
2. Certain BMP treatment train combinations have not been evaluated and in practice they are at this time not used, an example is a greenroof following a tree well.				
3. If multiple BMPs are used in a single catchment and one of them is detention, then it is assumed to be last in series.				
PROJECT TITLE	Example Problem 15	Optional Identification		
	Catchment 1:	Catchment 2:	Catchment 3:	Catchment 4:
BMP1	Wet Detention			
BMP2				
BMP3				
...mary Performance				
Catchment Configuration			1/28/2014	
Catchment Nitrogen Pr...	[illegible]		BMPTRAINS MODEL	
Catchment Phosphorus ...	[illegible]			
Catchment Nitrogen Po...	[illegible]			
Catchment Phosphorus Post Load	9.22			
Target Load Reduction (N) %	45			
Target Load Reduction (P) %	70			
Target Discharge Load, N (kg/yr)	23.40			
Target Discharge Load, P (kg/yr)	2.77			
Provided Overall Efficiency, N (%):	49			
Provided Overall Efficiency, P (%):	73			
Discharged Load, N (kg/yr & lb/yr):	21.61	47.61		
Discharged Load, P (kg/yr & lb/yr):	2.48	5.47		
Load Removed, N (kg/yr & lb/yr):	20.93	46.09		
Load Removed, P (kg/yr & lb/yr):	6.74	14.83		

Note the provided treatment efficiencies are sufficient.

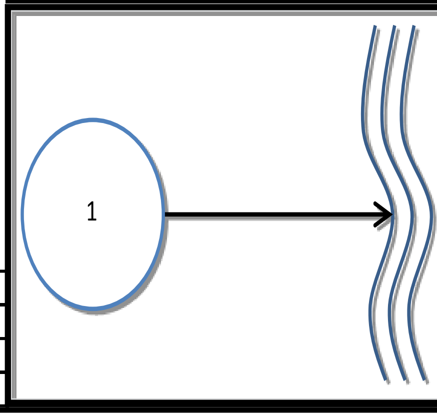


Figure 131 – Catchment and Treatment Summary Results

Discussion: This example shows how the user can select different target removal efficiencies for N and P. In this case, the target removal effectiveness values of 45 and 70 for N and P respectively were achieved. The target load reduction (effectiveness) is not achieved when there is no credit for littoral zones (40% for N and 68% for P). Also, the discharge loadings increase as the soil increases in clay content or in impervious cover (reflected in the non DCIA CN).

Example problem # 16 – More Than Four Catchments

There may be instances for a watershed where BMP treatment are possible at more than 4 catchments and it is desirable to present the evaluation of effectiveness for the total watershed (including all catchments with treatment) in one BMPTRAINS application (run). This would provide an occasion for breaking the watershed into separate model implementations and then combining the results into one final application of the BMPTRAINS model.

Consider as an example a site from North Central Florida that has the option for seven treatment sites at seven catchments. Figure 123 illustrates this condition.

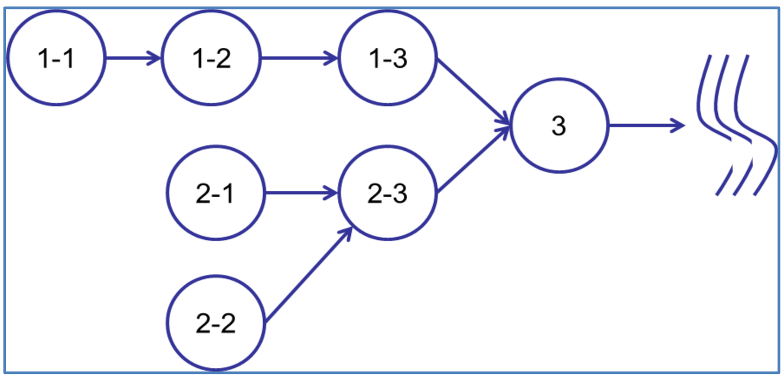
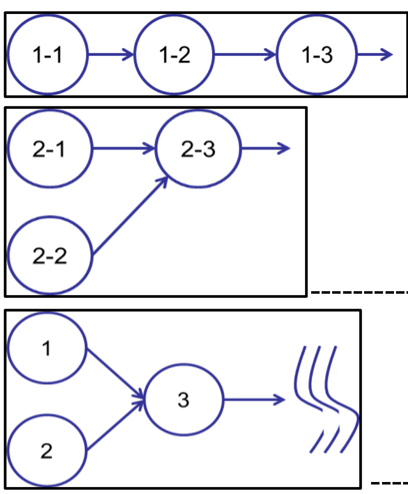


Figure 132 – More than Four Catchments with Possible BMPs at Each One

Solution:

Breaking the seven catchments into three separate model runs will allow an evaluation for BMPs for which there is no more than four catchments per model run.



----- COMPOSITE BMP Train 1. used as input to Train 3.

--------------- COMPOSITE BMP Train 2. used as input to Train 3.

--------- COMPOSITE BMP Train 3 with input from Trains 1 & 2.

Figure 133 – Composite Catchment Configurations

The pre-condition watershed land use is pasture and the post-condition land use is single family residential. The catchment conditions are listed in Table 3:

Table 3 – Catchment and Treatment Data for Example Problem 16

Catchment	Area [acres]	Pre-CN	Post-CN	Post %DCIA	Treatment
1-1	12	78	80	35	0.75 in retention
1-2	10	78	80	50	1 ac pond 21 day residence time
1-3	10	78	80	50	1 ac pond 21 day residence time
2-1	15	78	80	45	0.5 in retention
2-2	13	78	80	40	0.5 in retention
2-3	22	78	80	35	0.5 in retention
3	30	78	80	30	0.5 in retention

This example is labeled as the complex configuration. The general site information worksheet is the same for all three Composite watersheds and is shown as:

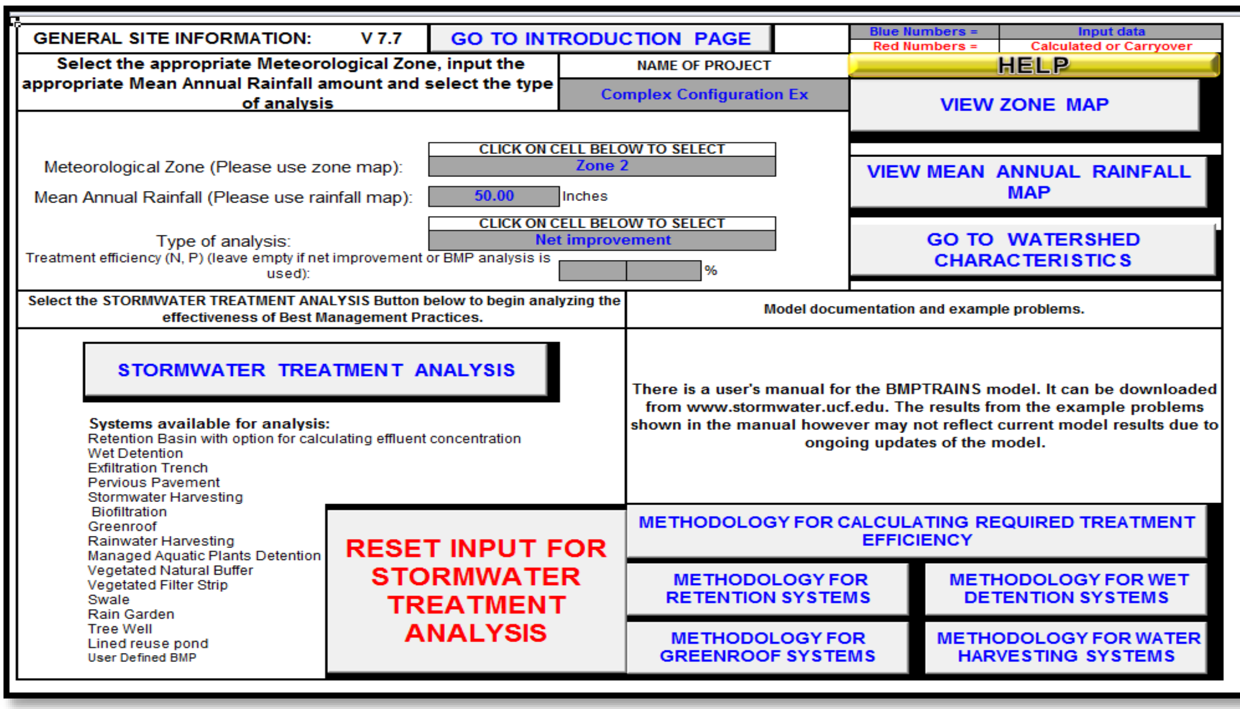
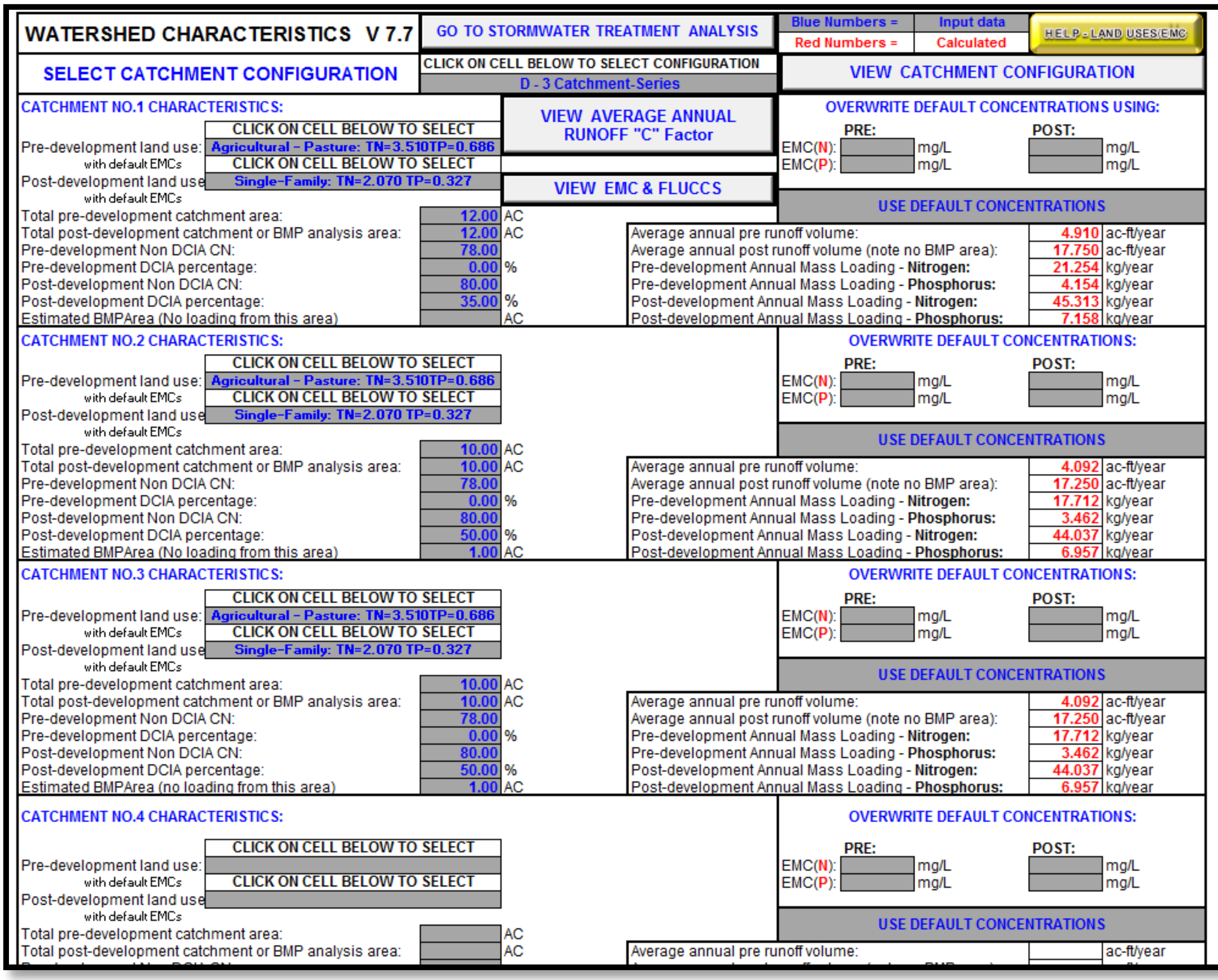


Figure 134 – General Site Information Input Data

The watershed treatment effectiveness is determined for the #1 and #2 composite watershed and then combing the output from these as user-defined input to number three composite catchment. For demonstration purposes, net improvement is assumed for each composite catchment however, the removal can be varied or adjusted to perform a cost analysis for different levels of treatment at each catchment.   For the first composite, the catchment data are:


WATERSHED CHARACTERISTICS V 7.7 | GO TO STORMWATER TREATMENT ANALYSIS | Blue Numbers = Input data | Red Numbers = Calculated | HELP - LAND USES/EMC
SELECT CATCHMENT CONFIGURATION | CLICK ON CELL BELOW TO SELECT CONFIGURATION | D - 3 Catchment-Series | VIEW CATCHMENT CONFIGURATION

CATCHMENT NO.1 CHARACTERISTICS: | VIEW AVERAGE ANNUAL RUNOFF "C" Factor | VIEW EMC & FLUCCS

Pre-development land use: with default EMCs	Agricultural - Pasture: TN=3.510TP=0.686	
Post-development land use with default EMCs	Single-Family: TN=2.070 TP=0.327	
Total pre-development catchment area:	12.00	AC
Total post-development catchment or BMP analysis area:	12.00	AC
Pre-development Non DCIA CN:	78.00	
Pre-development DCIA percentage:	0.00	%
Post-development Non DCIA CN:	80.00	
Post-development DCIA percentage:	35.00	%
Estimated BMPArea (No loading from this area)		AC

OVERWRITE DEFAULT CONCENTRATIONS USING: PRE: EMC(N): mg/L EMC(P): mg/L POST: mg/L mg/L
USE DEFAULT CONCENTRATIONS

Average annual pre runoff volume:	4.910	ac-ft/year
Average annual post runoff volume (note no BMP area):	17.750	ac-ft/year
Pre-development Annual Mass Loading - **Nitrogen:**	21.254	kg/year
Pre-development Annual Mass Loading - **Phosphorus:**	4.154	kg/year
Post-development Annual Mass Loading - **Nitrogen:**	45.313	kg/year
Post-development Annual Mass Loading - **Phosphorus:**	7.158	kg/year

CATCHMENT NO.2 CHARACTERISTICS:

Pre-development land use: with default EMCs	Agricultural - Pasture: TN=3.510TP=0.686	
Post-development land use with default EMCs	Single-Family: TN=2.070 TP=0.327	
Total pre-development catchment area:	10.00	AC
Total post-development catchment or BMP analysis area:	10.00	AC
Pre-development Non DCIA CN:	78.00	
Pre-development DCIA percentage:	0.00	%
Post-development Non DCIA CN:	80.00	
Post-development DCIA percentage:	50.00	%
Estimated BMPArea (No loading from this area)	1.00	AC

OVERWRITE DEFAULT CONCENTRATIONS: PRE: EMC(N): mg/L EMC(P): mg/L POST: mg/L mg/L
USE DEFAULT CONCENTRATIONS

Average annual pre runoff volume:	4.092	ac-ft/year
Average annual post runoff volume (note no BMP area):	17.250	ac-ft/year
Pre-development Annual Mass Loading - **Nitrogen:**	17.712	kg/year
Pre-development Annual Mass Loading - **Phosphorus:**	3.462	kg/year
Post-development Annual Mass Loading - **Nitrogen:**	44.037	kg/year
Post-development Annual Mass Loading - **Phosphorus:**	6.957	kg/year

CATCHMENT NO.3 CHARACTERISTICS:

Pre-development land use: with default EMCs	Agricultural - Pasture: TN=3.510TP=0.686	
Post-development land use with default EMCs	Single-Family: TN=2.070 TP=0.327	
Total pre-development catchment area:	10.00	AC
Total post-development catchment or BMP analysis area:	10.00	AC
Pre-development Non DCIA CN:	78.00	
Pre-development DCIA percentage:	0.00	%
Post-development Non DCIA CN:	80.00	
Post-development DCIA percentage:	50.00	%
Estimated BMPArea (no loading from this area)	1.00	AC

OVERWRITE DEFAULT CONCENTRATIONS: PRE: EMC(N): mg/L EMC(P): mg/L POST: mg/L mg/L
USE DEFAULT CONCENTRATIONS

Average annual pre runoff volume:	4.092	ac-ft/year
Average annual post runoff volume (note no BMP area):	17.250	ac-ft/year
Pre-development Annual Mass Loading - **Nitrogen:**	17.712	kg/year
Pre-development Annual Mass Loading - **Phosphorus:**	3.462	kg/year
Post-development Annual Mass Loading - **Nitrogen:**	44.037	kg/year
Post-development Annual Mass Loading - **Phosphorus:**	6.957	kg/year

CATCHMENT NO.4 CHARACTERISTICS:

Pre-development land use: with default EMCs	CLICK ON CELL BELOW TO SELECT	
Post-development land use with default EMCs	CLICK ON CELL BELOW TO SELECT	
Total pre-development catchment area:		AC
Total post-development catchment or BMP analysis area:		AC

OVERWRITE DEFAULT CONCENTRATIONS: PRE: EMC(N): mg/L EMC(P): mg/L POST: mg/L mg/L
USE DEFAULT CONCENTRATIONS
Average annual pre runoff volume: ac-ft/year

Figure 135 – Catchment Data for Composite BMP Train #1

The next Figures display the treatment effectiveness (Figure 136), the stormwater treatment retention worksheet (Figure 137) the wet detention worksheet (Figure 138) and the summary worksheet (Figure 139). The removal effectiveness from this composite 1 catchment becomes user input data for composite catchment # 3.

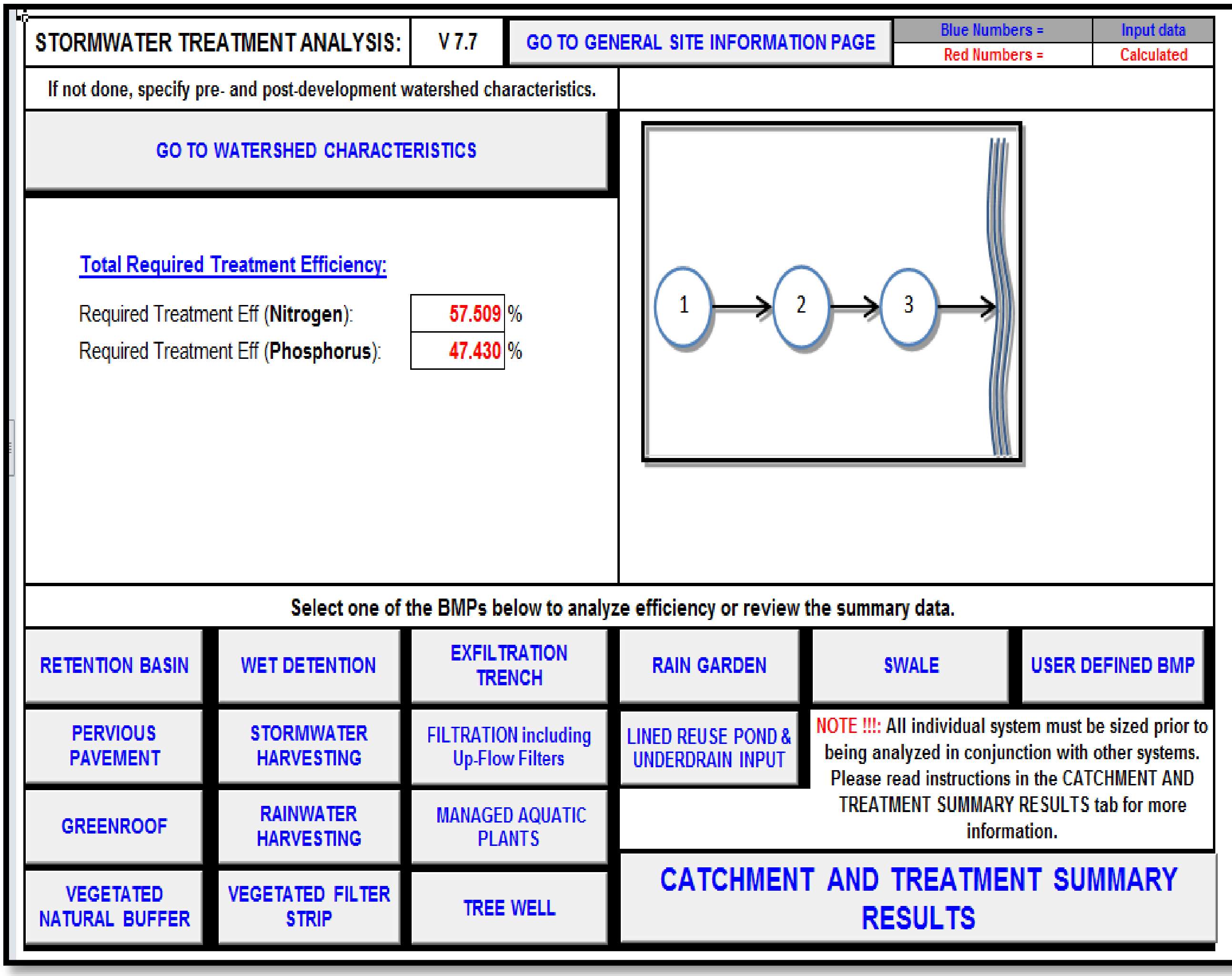


Figure 136 – Net Improvement for Composite Catchment #1

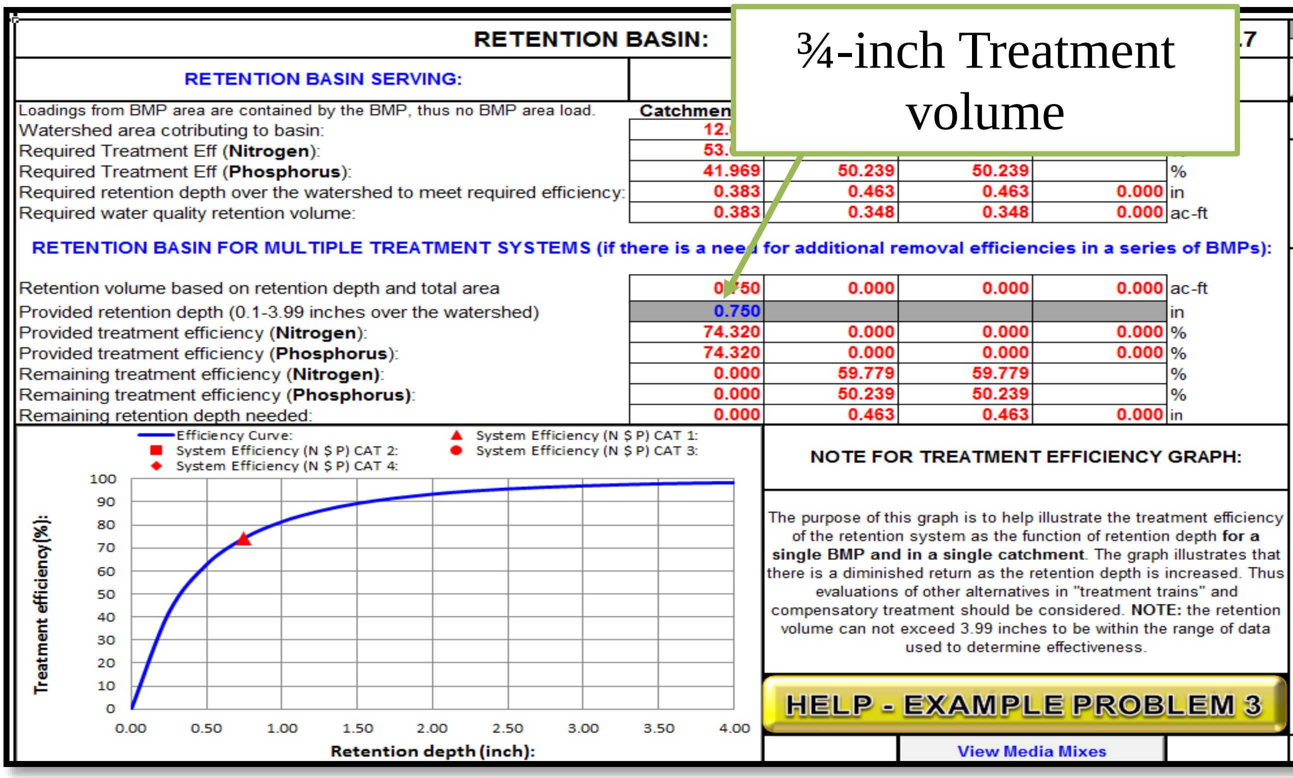


Figure 137 – BMP Catchment One of Composite catchment #1 Example Problem 16

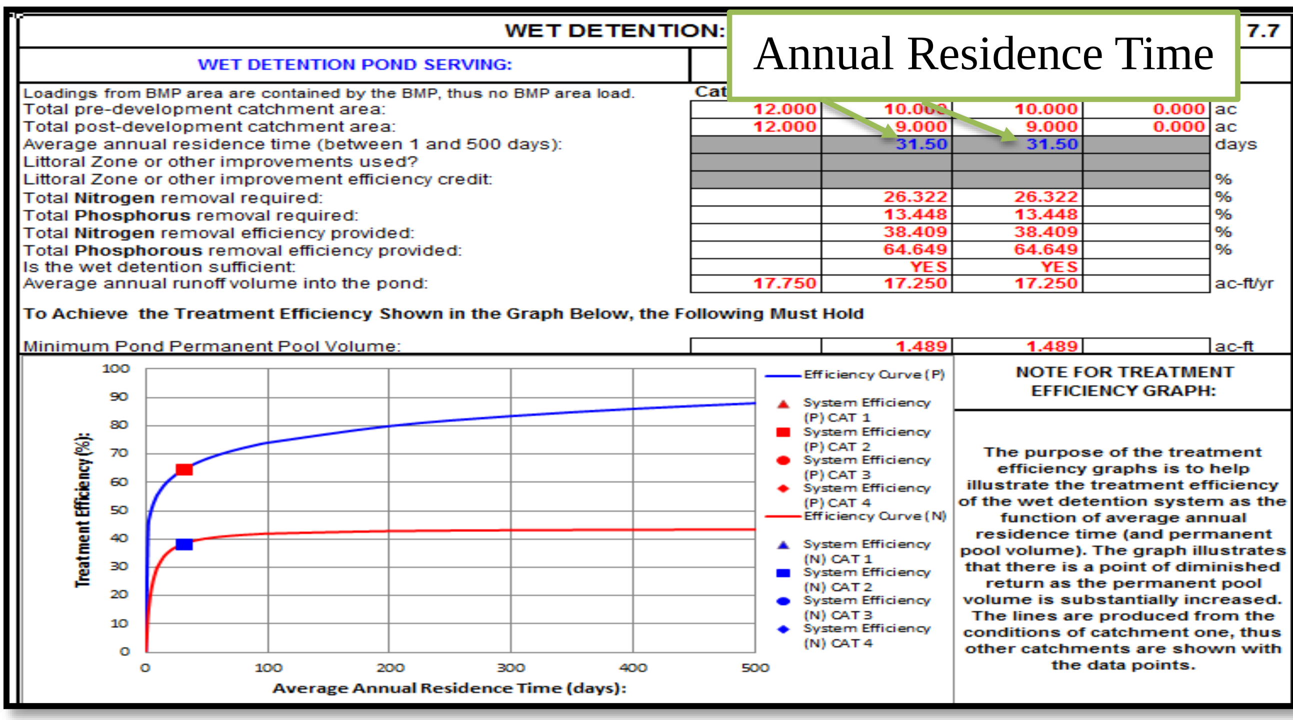


Figure 138 – Wet Detention BMPs for Composite Catchment #1

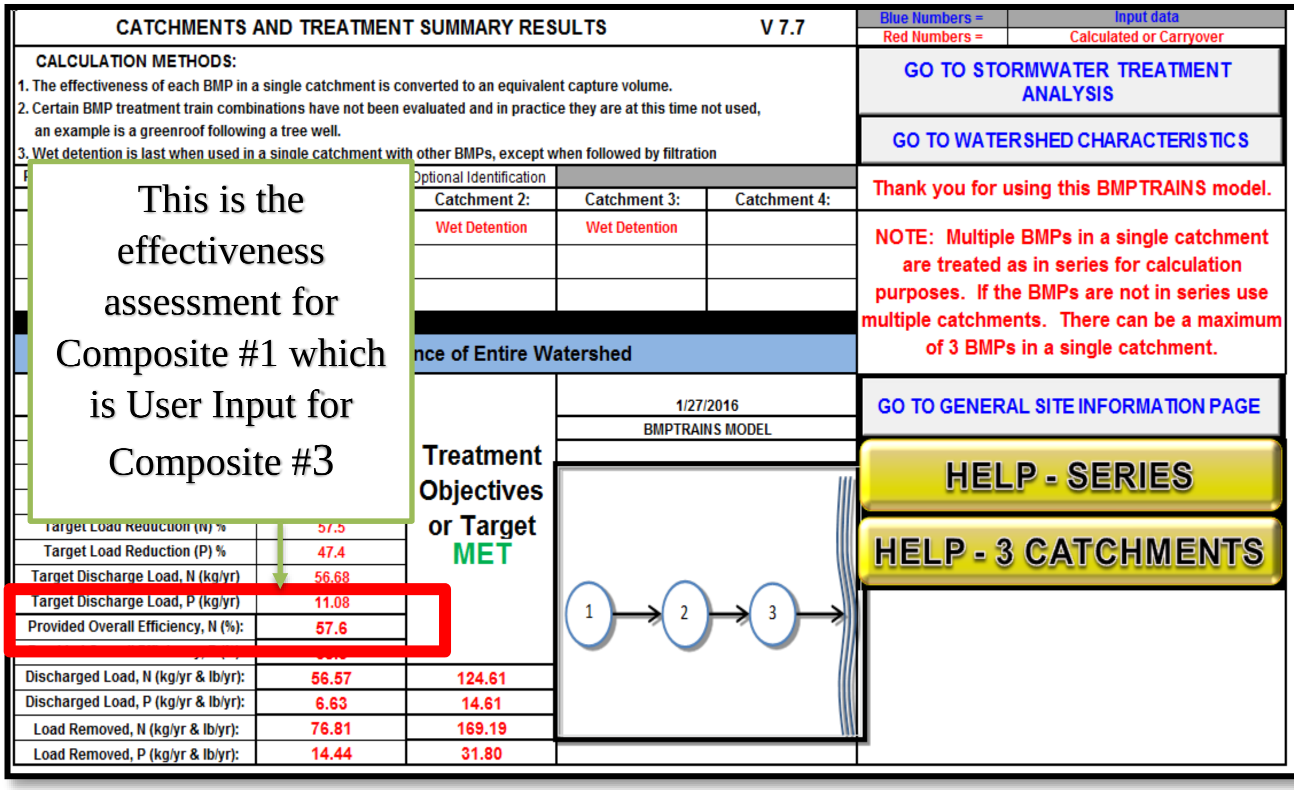


Figure 139 – Effectiveness for Composite Catchment #1

Next, the catchment input data for composite # 2 are entered (Figure 140) along with the half inch retention volumes for each of the catchments (Figure 141). Again, net improvement is assumed for each of the composite catchment. If there are constraints on land availability that lowers the size of the retention volumes, then the BMP option for effectiveness analysis may be used on the general site information worksheet (see Figure 134). The effectiveness summary worksheet is shown in Figure 142.

WATERSHED CHARACTERISTICS V 7.7	GO TO STORMWATER TREATMENT ANALYSIS	Blue Numbers =	Input data	HELP - LAND USES/EMC
		Red Numbers =	Calculated	
SELECT CATCHMENT CONFIGURATION	CLICK ON CELL BELOW TO SELECT CONFIGURATION F - Mixed-3 Catchment-2 Series-Parallel (A)	VIEW CATCHMENT CONFIGURATION		

VIEW AVERAGE ANNUAL RUNOFF "C" Factor

VIEW EMC & FLUCCS

CATCHMENT NO.1 CHARACTERISTICS:

	CLICK ON CELL BELOW TO SELECT
Pre-development land use: with default EMCs	Agricultural - Pasture: TN=3.510TP=0.686
	CLICK ON CELL BELOW TO SELECT
Post-development land use with default EMCs	Single-Family: TN=2.070 TP=0.327

Total pre-development catchment area:	15.00	AC
Total post-development catchment or BMP analysis area:	15.00	AC
Pre-development Non DCIA CN:	78.00	
Pre-development DCIA percentage:	0.00	%
Post-development Non DCIA CN:	80.00	
Post-development DCIA percentage:	45.00	%
Estimated BMPArea (No loading from this area)		AC

OVERWRITE DEFAULT CONCENTRATIONS USING:

	PRE:		POST:	
EMC(N):		mg/L		mg/L
EMC(P):		mg/L		mg/L

USE DEFAULT CONCENTRATIONS

Average annual pre runoff volume:	6.138	ac-ft/year
Average annual post runoff volume (note no BMP area):	26.563	ac-ft/year
Pre-development Annual Mass Loading - **Nitrogen:**	26.568	kg/year
Pre-development Annual Mass Loading - **Phosphorus:**	5.192	kg/year
Post-development Annual Mass Loading - **Nitrogen:**	67.810	kg/year
Post-development Annual Mass Loading - **Phosphorus:**	10.712	kg/year

CATCHMENT NO.2 CHARACTERISTICS:

	CLICK ON CELL BELOW TO SELECT
Pre-development land use: with default EMCs	Agricultural - Pasture: TN=3.510TP=0.686
	CLICK ON CELL BELOW TO SELECT
Post-development land use with default EMCs	Single-Family: TN=2.070 TP=0.327

Total pre-development catchment area:	13.00	AC
Total post-development catchment or BMP analysis area:	13.00	AC
Pre-development Non DCIA CN:	78.00	
Pre-development DCIA percentage:	0.00	%
Post-development Non DCIA CN:	80.00	
Post-development DCIA percentage:	40.00	%
Estimated BMPArea (No loading from this area)		AC

OVERWRITE DEFAULT CONCENTRATIONS:

	PRE:		POST:	
EMC(N):		mg/L		mg/L
EMC(P):		mg/L		mg/L

USE DEFAULT CONCENTRATIONS

Average annual pre runoff volume:	5.319	ac-ft/year
Average annual post runoff volume (note no BMP area):	21.125	ac-ft/year
Pre-development Annual Mass Loading - **Nitrogen:**	23.025	kg/year
Pre-development Annual Mass Loading - **Phosphorus:**	4.500	kg/year
Post-development Annual Mass Loading - **Nitrogen:**	53.929	kg/year
Post-development Annual Mass Loading - **Phosphorus:**	8.519	kg/year

CATCHMENT NO.3 CHARACTERISTICS:

	CLICK ON CELL BELOW TO SELECT
Pre-development land use: with default EMCs	Agricultural - Pasture: TN=3.510TP=0.686
	CLICK ON CELL BELOW TO SELECT
Post-development land use with default EMCs	Single-Family: TN=2.070 TP=0.327

Total pre-development catchment area:	22.00	AC
Total post-development catchment or BMP analysis area:	22.00	AC
Pre-development Non DCIA CN:	78.00	
Pre-development DCIA percentage:	0.00	%
Post-development Non DCIA CN:	80.00	
Post-development DCIA percentage:	35.00	%
Estimated BMPArea (no loading from this area)		AC

OVERWRITE DEFAULT CONCENTRATIONS:

	PRE:		POST:	
EMC(N):		mg/L		mg/L
EMC(P):		mg/L		mg/L

USE DEFAULT CONCENTRATIONS

Average annual pre runoff volume:	9.002	ac-ft/year
Average annual post runoff volume (note no BMP area):	32.542	ac-ft/year
Pre-development Annual Mass Loading - **Nitrogen:**	38.966	kg/year
Pre-development Annual Mass Loading - **Phosphorus:**	7.616	kg/year
Post-development Annual Mass Loading - **Nitrogen:**	83.074	kg/year
Post-development Annual Mass Loading - **Phosphorus:**	13.123	kg/year

CATCHMENT NO.4 CHARACTERISTICS:

	CLICK ON CELL BELOW TO SELECT
Pre-development land use: with default EMCs	
	CLICK ON CELL BELOW TO SELECT
Post-development land use with default EMCs	

Total pre-development catchment area:		AC
Total post-development catchment or BMP analysis area:		AC
Pre-development Non DCIA CN:		
Pre-development DCIA percentage:		%

OVERWRITE DEFAULT CONCENTRATIONS:

	PRE:		POST:	
EMC(N):		mg/L		mg/L
EMC(P):		mg/L		mg/L

USE DEFAULT CONCENTRATIONS

Average annual pre runoff volume:		ac-ft/year
Average annual post runoff volume (note no BMP area):		ac-ft/year
Pre-development Annual Mass Loading - **Nitrogen:**		kg/year

Figure 140 – Catchment Characteristics for Composite Catchment #2

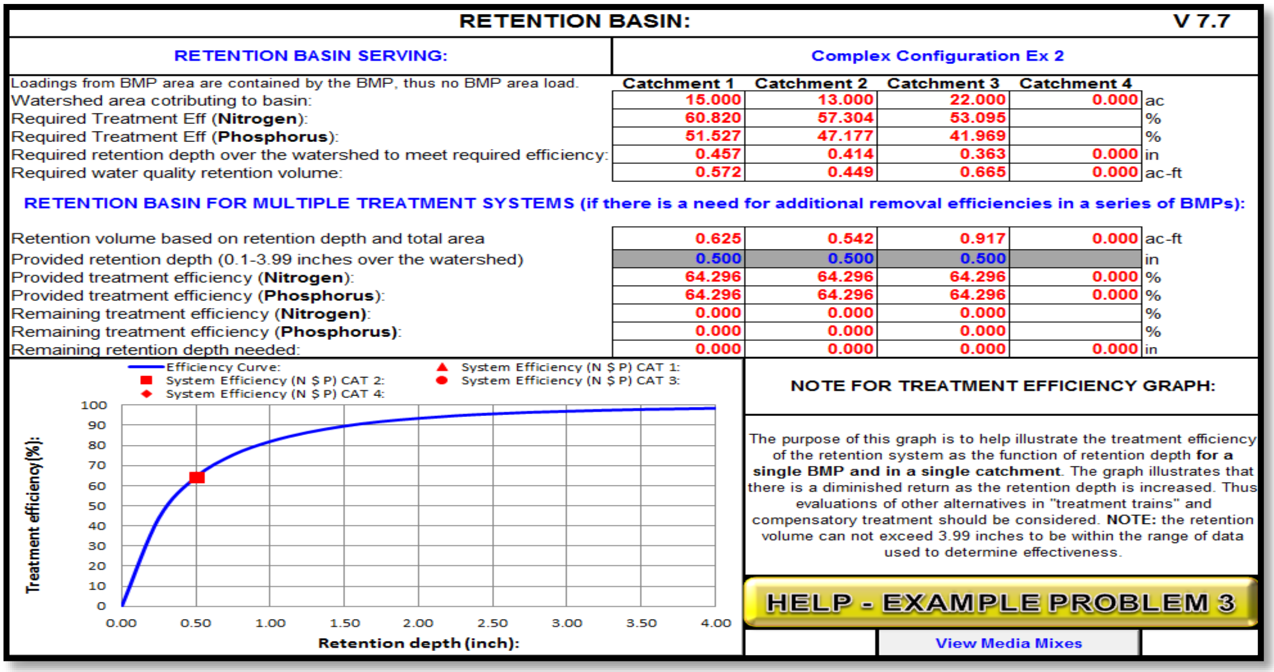


Figure 141 – Retention Worksheet for Composite Catchment #2 Example Problem 16

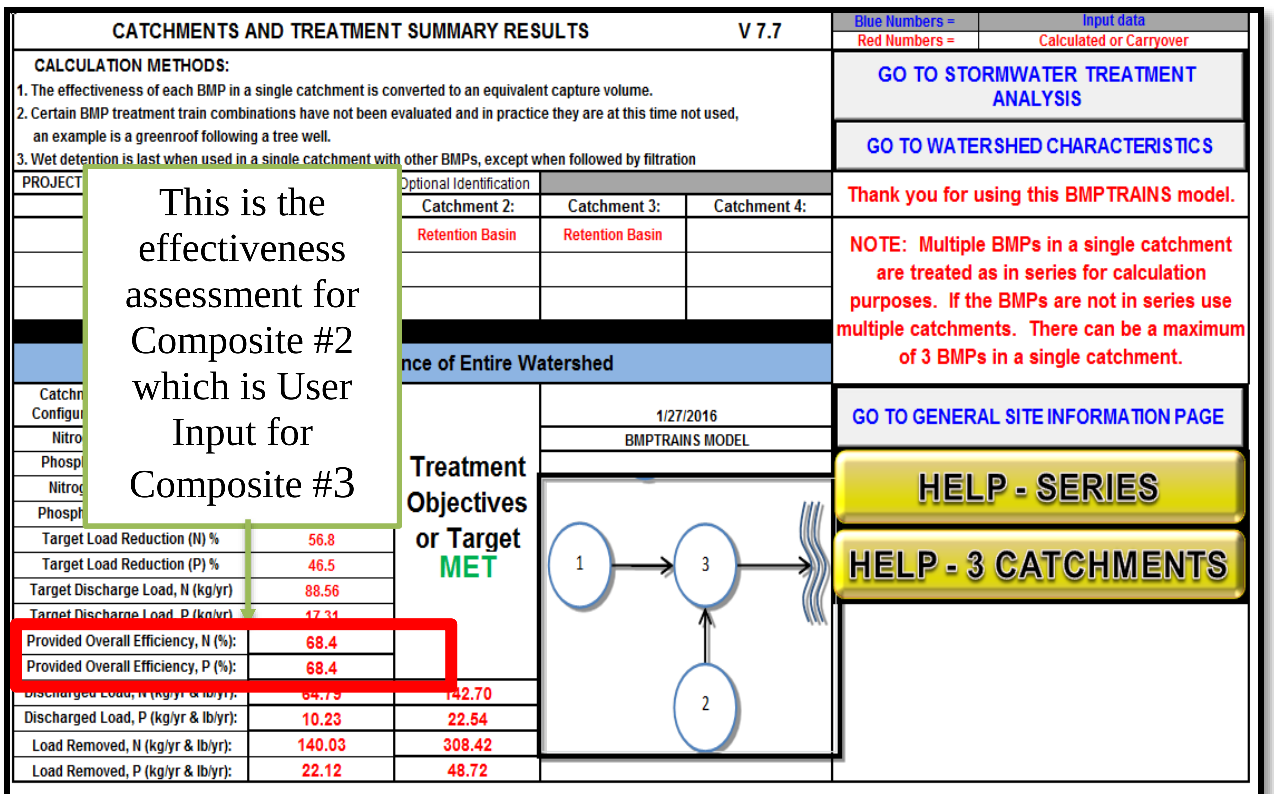


Figure 142 – Effectiveness for Composite Catchment #2

Catchment information for composite #3 are entered as shown in Figure 143. The user-defined inputs from composite catchments # 1 and #1 are entered as shown in Figure 144. The retention worksheet is shown in Figure 145 and it is noted that there is treatment at catchment 3. The final assessment is shown in Figure 146.

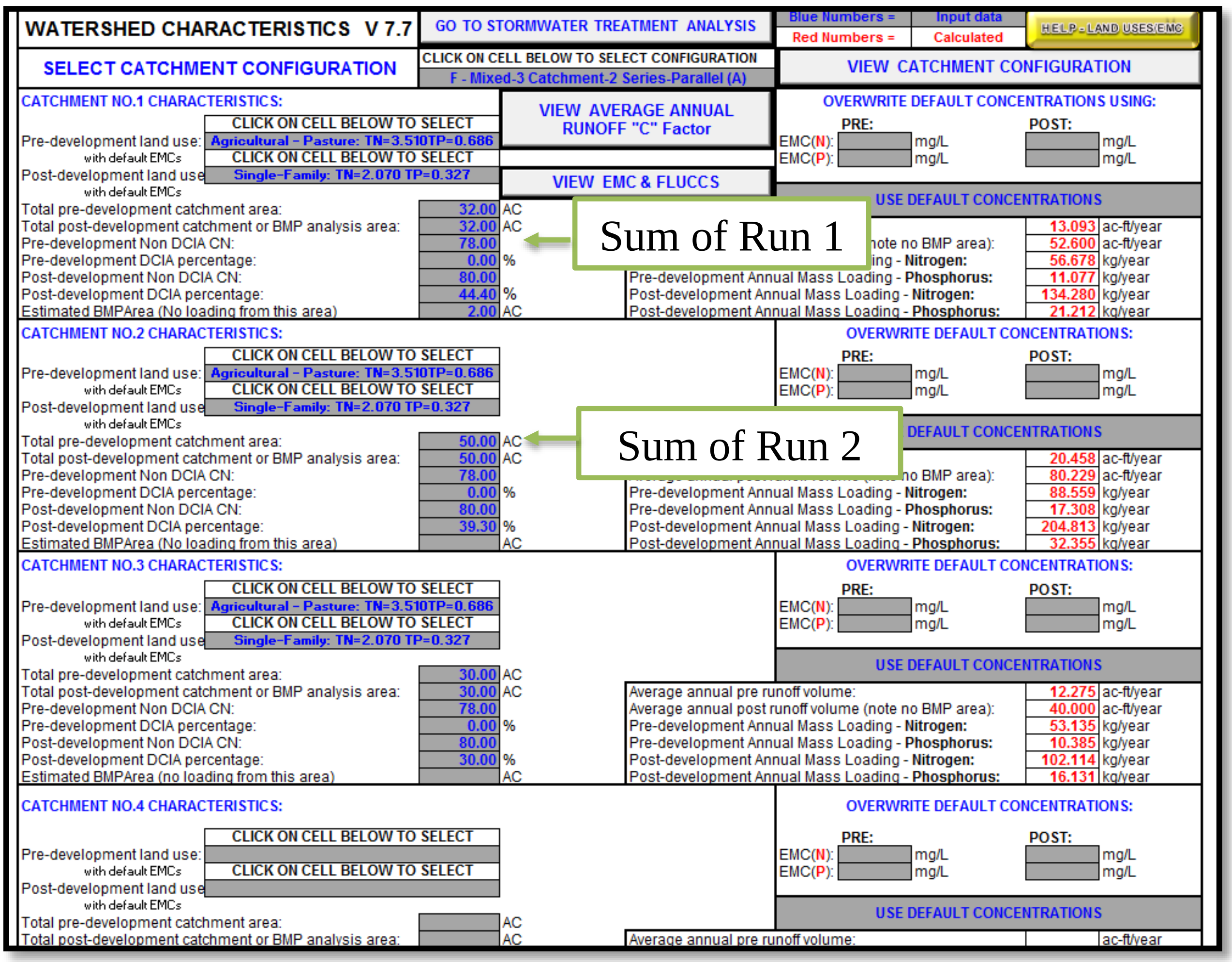
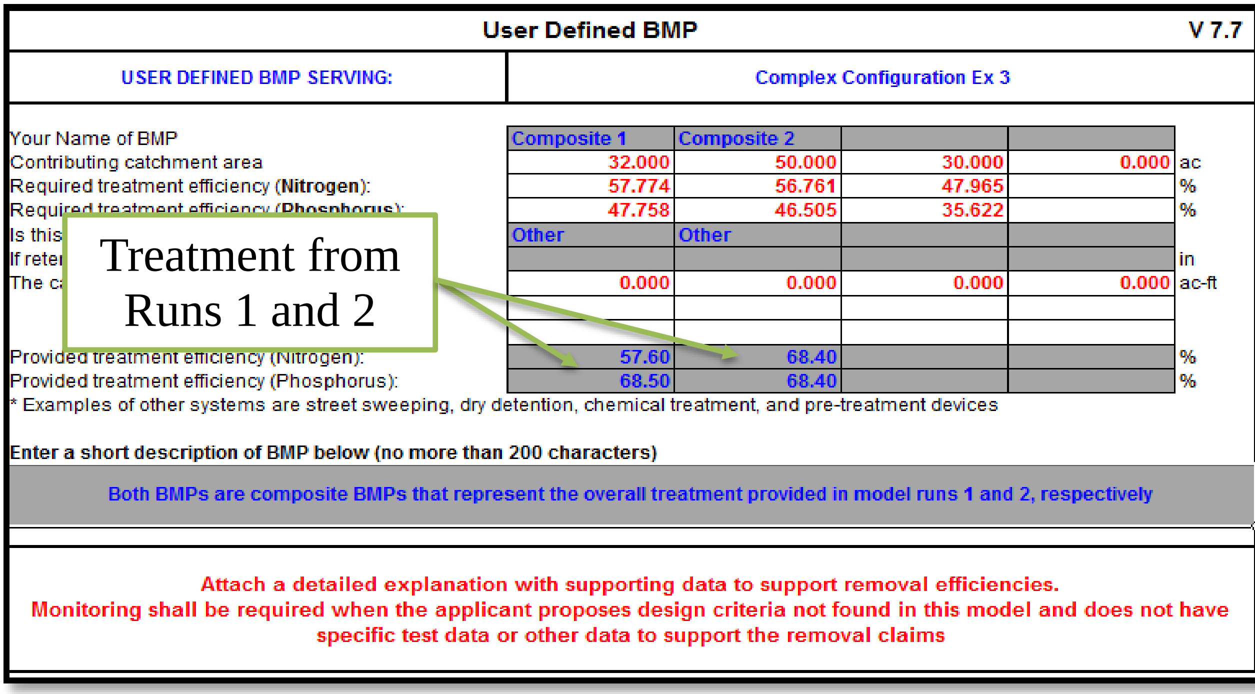


Figure 143 – Catchment Data for Composite Catchment #3



User Defined BMP					V 7.7
USER DEFINED BMP SERVING:	Complex Configuration Ex 3				
Your Name of BMP	Composite 1	Composite 2			
Contributing catchment area	32.000	50.000	30.000	0.000	ac
Required treatment efficiency (**Nitrogen**):	57.774	56.761	47.965		%
Required treatment efficiency (**Phosphorus**):	47.758	46.505	35.622		%
Is this	Other	Other			
If reten					in
The c	0.000	0.000	0.000	0.000	ac-ft
Provided treatment efficiency (Nitrogen):	57.60	68.40			%
Provided treatment efficiency (Phosphorus):	68.50	68.40			%

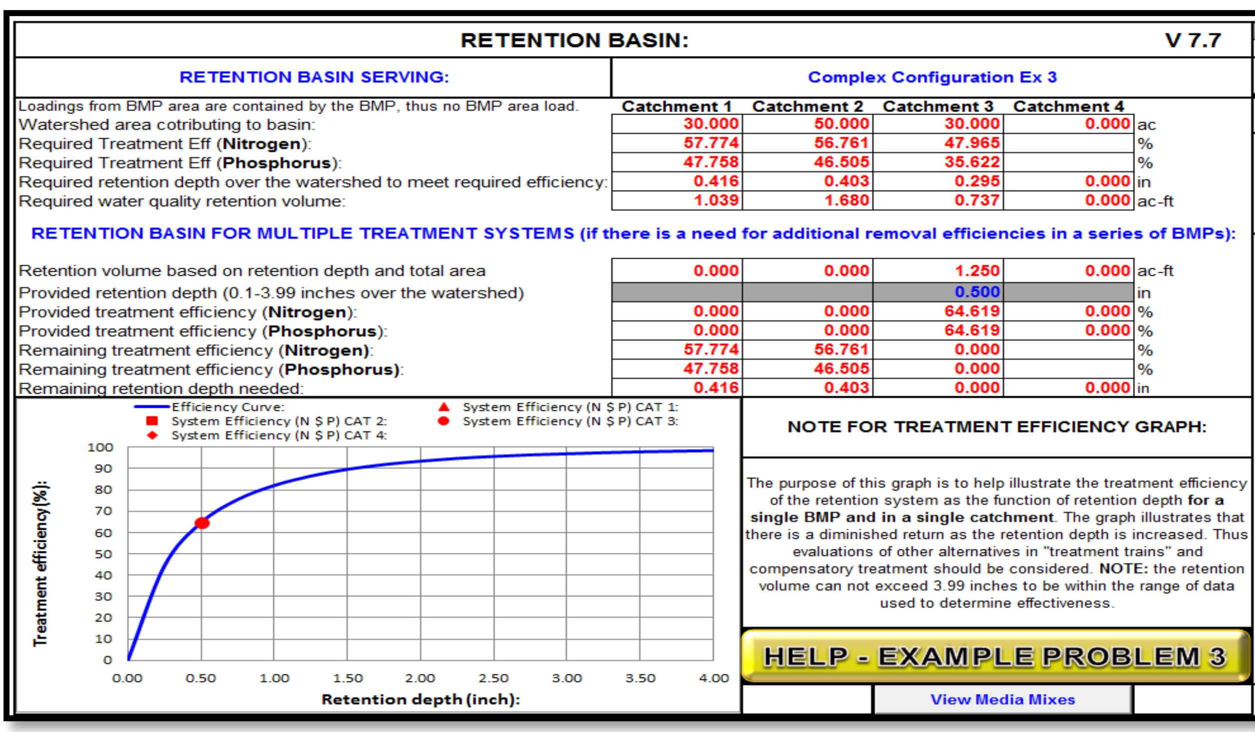
* Examples of other systems are street sweeping, dry detention, chemical treatment, and pre-treatment devices

Enter a short description of BMP below (no more than 200 characters)

Both BMPs are composite BMPs that represent the overall treatment provided in model runs 1 and 2, respectively

Attach a detailed explanation with supporting data to support removal efficiencies.
Monitoring shall be required when the applicant proposes design criteria not found in this model and does not have specific test data or other data to support the removal claims

Figure 144 – User-defined from Composites # 1 and #2 as input to Composite #3



RETENTION BASIN:					V 7.7
RETENTION BASIN SERVING:	Complex Configuration Ex 3				
Loadings from BMP area are contained by the BMP, thus no BMP area load.	Catchment 1	Catchment 2	Catchment 3	Catchment 4	
Watershed area cotributing to basin:	30.000	50.000	30.000	0.000	ac
Required Treatment Eff (**Nitrogen**):	57.774	56.761	47.965		%
Required Treatment Eff (**Phosphorus**):	47.758	46.505	35.622		%
Required retention depth over the watershed to meet required efficiency:	0.416	0.403	0.295	0.000	in
Required water quality retention volume:	1.039	1.680	0.737	0.000	ac-ft

RETENTION BASIN FOR MULTIPLE TREATMENT SYSTEMS (if there is a need for additional removal efficiencies in a series of BMPs):

Retention volume based on retention depth and total area	0.000	0.000	1.250	0.000	ac-ft
Provided retention depth (0.1-3.99 inches over the watershed)			0.500		in
Provided treatment efficiency (**Nitrogen**):	0.000	0.000	64.619	0.000	%
Provided treatment efficiency (**Phosphorus**):	0.000	0.000	64.619	0.000	%
Remaining treatment efficiency (**Nitrogen**):	57.774	56.761	0.000		%
Remaining treatment efficiency (**Phosphorus**):	47.758	46.505	0.000		%
Remaining retention depth needed:	0.416	0.403	0.000	0.000	in

NOTE FOR TREATMENT EFFICIENCY GRAPH:

The purpose of this graph is to help illustrate the treatment efficiency of the retention system as the function of retention depth **for a single BMP and in a single catchment**. The graph illustrates that there is a diminished return as the retention depth is increased. Thus evaluations of other alternatives in "treatment trains" and compensatory treatment should be considered. **NOTE:** the retention volume can not exceed 3.99 inches to be within the range of data used to determine effectiveness.

HELP - EXAMPLE PROBLEM 3

View Media Mixes

Figure 145 – Retention Worksheet for Composite Catchment #3

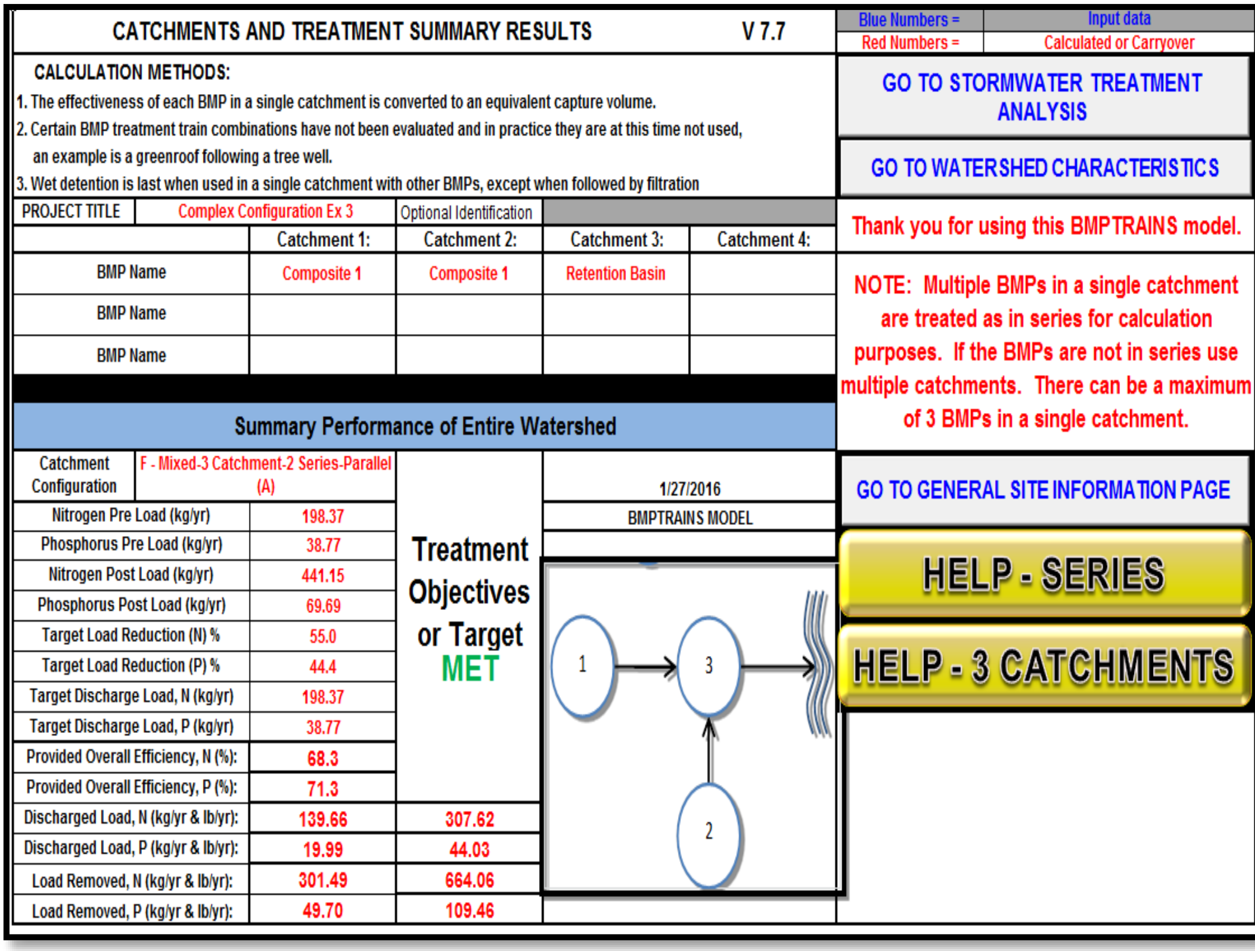


Figure 146 – Effectiveness Summary worksheet

Example problem # 17 – Cost Analysis

Consider a location in Jacksonville, Florida, within meteorological zone 4, with a mean average rainfall of 1270 mm (50 inches). The target removal efficiency of both TN and TP is 80%. The area of interest is a 2.0-acre single catchment. Pre-development conditions are agricultural-general land use with a non-DCIA Curve Number of 78 and no DCIA. The post-development land use condition is low-intensity commercial with a non-DCIA Curve Number of 78 and 90% DCIA. The post-development condition is assumed to consist of 40% building, 50% parking lot, and 10% green space. The green space is split, with ½ of it around the building and ½ left as natural or available for a retention basin. The two BMPs analyzed in this example are pervious concrete and a retention basin, both having an expected life of 20 years.

The pervious concrete section consisted of seven inches of #57 stone, compacted and then topped with a six-inch layer of pervious concrete. The soils is assumed to be sandy and free draining, allowing the system to fully recover in 72 hours from a 5-year design storm event. The retention basin is assumed to have a maximum depth of 12 inches. Recently, a significant land development near the catchment has been completed, resulting in an increase in land costs. Any additional land required to construct the retention basin is assumed to be purchased at a rate of $525,000 per acre, based on local land values from Zillow.com in 2016. The differential construction cost to build a pervious pavement BMP compared to a regular pavement is $200,561.29 per acre-ft. of treatment provided. The cost to maintain the installed pervious concrete is $2,017.28 per year, based on the cost of vacuum sweeping and other maintenance activities. If pervious concrete is not used as a BMP, there is no associated maintenance cost for vacuum sweeping and other activities. The cost to build the retention basin is based on a capital cost of $0.70 per cubic ft. of water treated in 1997 dollars, which is a total capital cost of $45,240.53 per acre-ft. of treatment in 2016 dollars. The maintenance cost for the retention basin is 3% of the capital cost per year (see Appendix B for cost data availability and references).

The time period analysis is 20 years at an interest rate of 1.8% which is assumed, based on the most recent values published by the World Bank (see appendix B) or for the local conditions and BMP construction. For the first scenario, only a pervious concrete parking lot is used, while for the sixth scenario only a retention basin is used. Scenarios two through five have different combinations of the two BMPs in series. BMP data are listed in Table 4.

Table 4 – Example Problem 17 BMP Data

BMP Characteristics			
Scenario	Pervious Concrete Area [ac]	Retention Basin Volume [ac-ft]	Additional Land Required [ac]
1	1	0	0
2	0.825	0.0417	0
3	0.65	0.0833	0
4	0.325	0.173	0.073
5	0.15	0.221	0.121
6	0	0.271	0.171

***Assume pervious concrete has an operational porosity of 25% (Hardin, 2014).

Solution:

1. For the first time, the example problems use cost analysis, thus a detailed navigation is done to facilitate an understanding. From the introduction page click on the *Click Here to Start* button to proceed to the **General Site Information** worksheet (see Figure 147).

   a. Select the *Reset Input for Stormwater Treatment Analysis* button to erase any existing data.

   b. Enter the project name and select the meteorological zone in the **General Site Information** worksheet.

   c. Indicate the mean annual rainfall amount in the **General Site Information** worksheet.

   d. Select the *Specified Removal Efficiency* option from the *Type of Analysis* drop down menu in the **General Site Information** worksheet.

   e. Specify the desired removal efficiency.

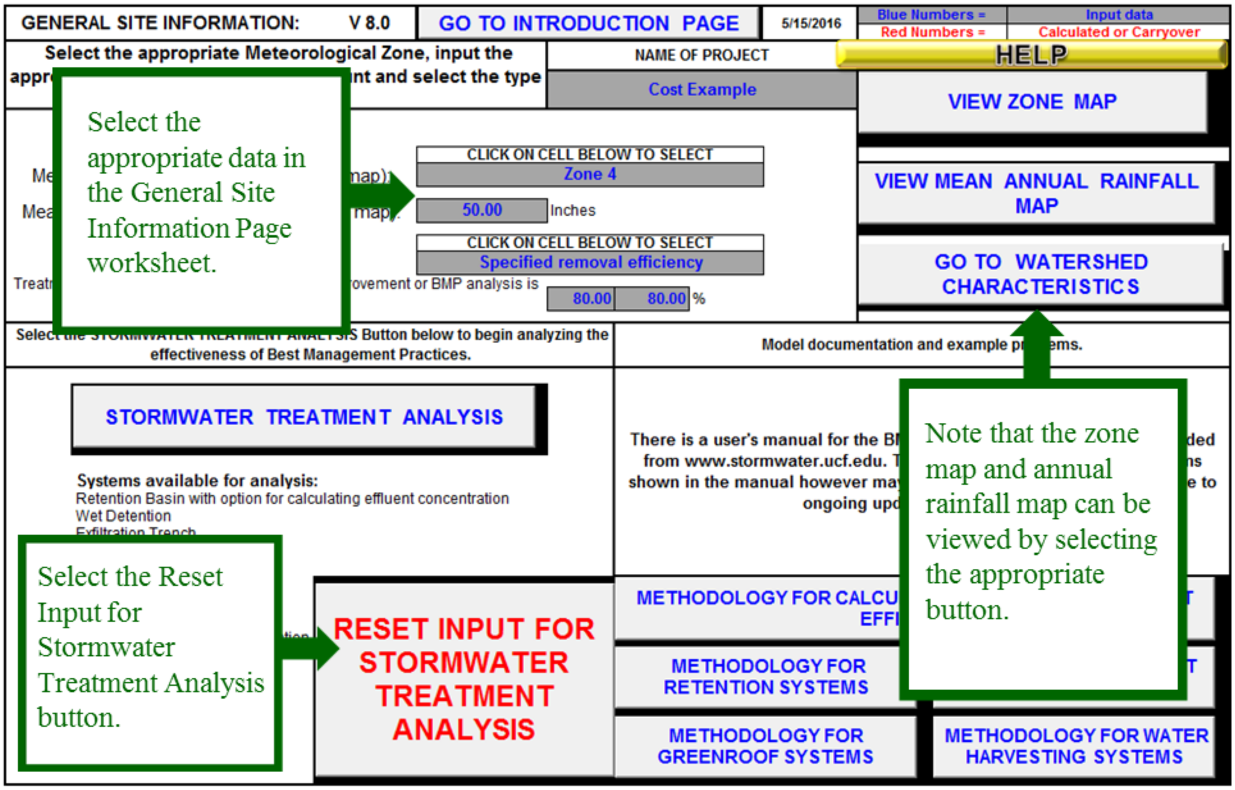


Figure 147 – General Site Information worksheet

2. Click **Watershed Characteristics**.

    a. In the *Click on Cell Below to Select Configuration* drop-down menu, select **A – Single Catchment** (see Figure 148).

    b. Name Catchment No. 1 as **Example A**

    c. Select **Agricultural – General** in the drop-down menu for Pre-development land use.

    d. Select **Low-Intensity Commercial** in the drop-down menu for Post-development land use.

    e. Enter the remaining catchment area, percent DCIA, and curve numbers using the given information in the problem statement.

    f. Input 0.0 acres for *Estimated BMPArea (No loading from this area).* A value is only input here if the BMP has permanent standing water, such as a wetland or wet detention/retention pond.

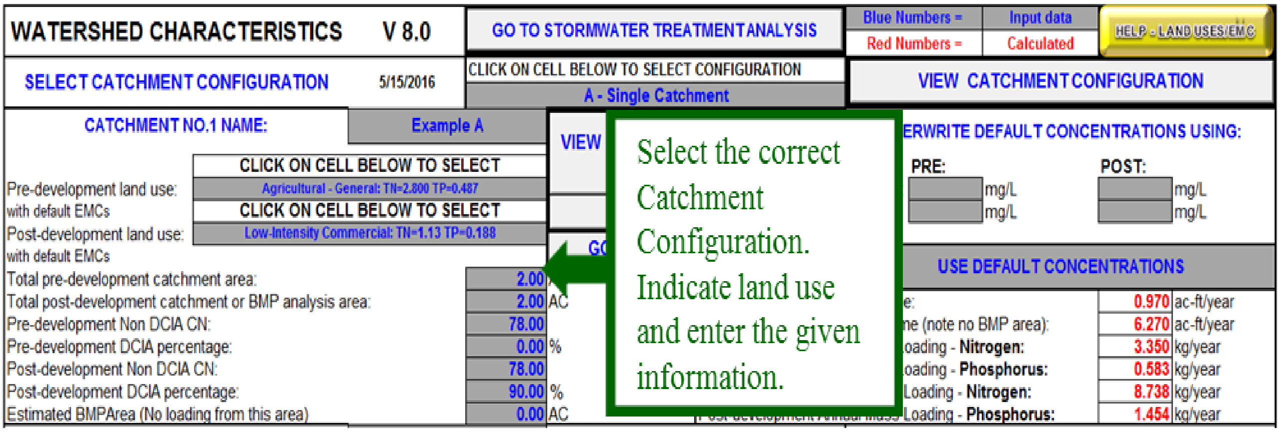


Figure 148 – Watershed Characteristics Worksheet

Treatment Train Scenario 1

The pervious concrete area, retention basin volume, and additional land required for BMP treatment train Scenario 1 are shown in Table 5:

Table 5 – BMP Characteristics Scenario 1 Example Problem 17

	BMP Characteristics		
Scenario	Pervious Concrete Area [ac]	Retention Basin Volume [ac-ft]	Additional Land Required [ac]
1	1	0	0

Note that pervious concrete is the only BMP. And on the watershed characteristics worksheet, the pervious pavement areas do contribute loadings. Nevertheless, enter the pervious pavement areas on the pervious pavement workshop and then the runoff mass loadings are subtracted after the volume of treatment has been reached.

3. Click **Go to Stormwater Treatment Analysis.**
   a. Select the **Pervious Pavement** tab (see Figure 149).
   b. Enter **Pervious Concrete** in the *Pvmt Name* cell (see Figure 150).
   c. Enter **6.0** in the *Pervious Concrete Thickness (in)* cell (see Figure 150).
   d. Enter **25.0** in the *Pervious Concrete Operational Porosity (%)* cell (see Figure 150).
   e. Enter **7.0** in the *#57 rock Thickness (in)* cell (see Figure 150).
   f. Enter **1.0** in the *Area of the pervious pavement* cell (see Figure 150).

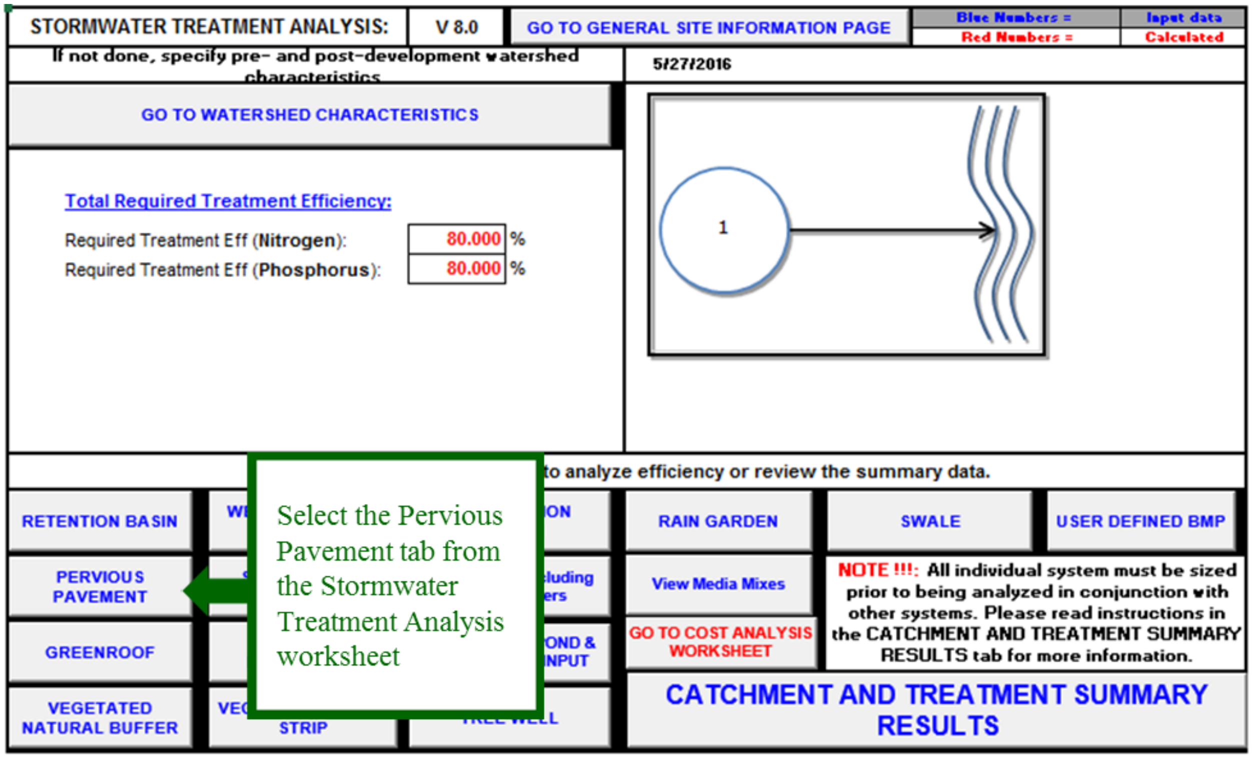


Figure 149 – Stormwater Treatment Analysis worksheet

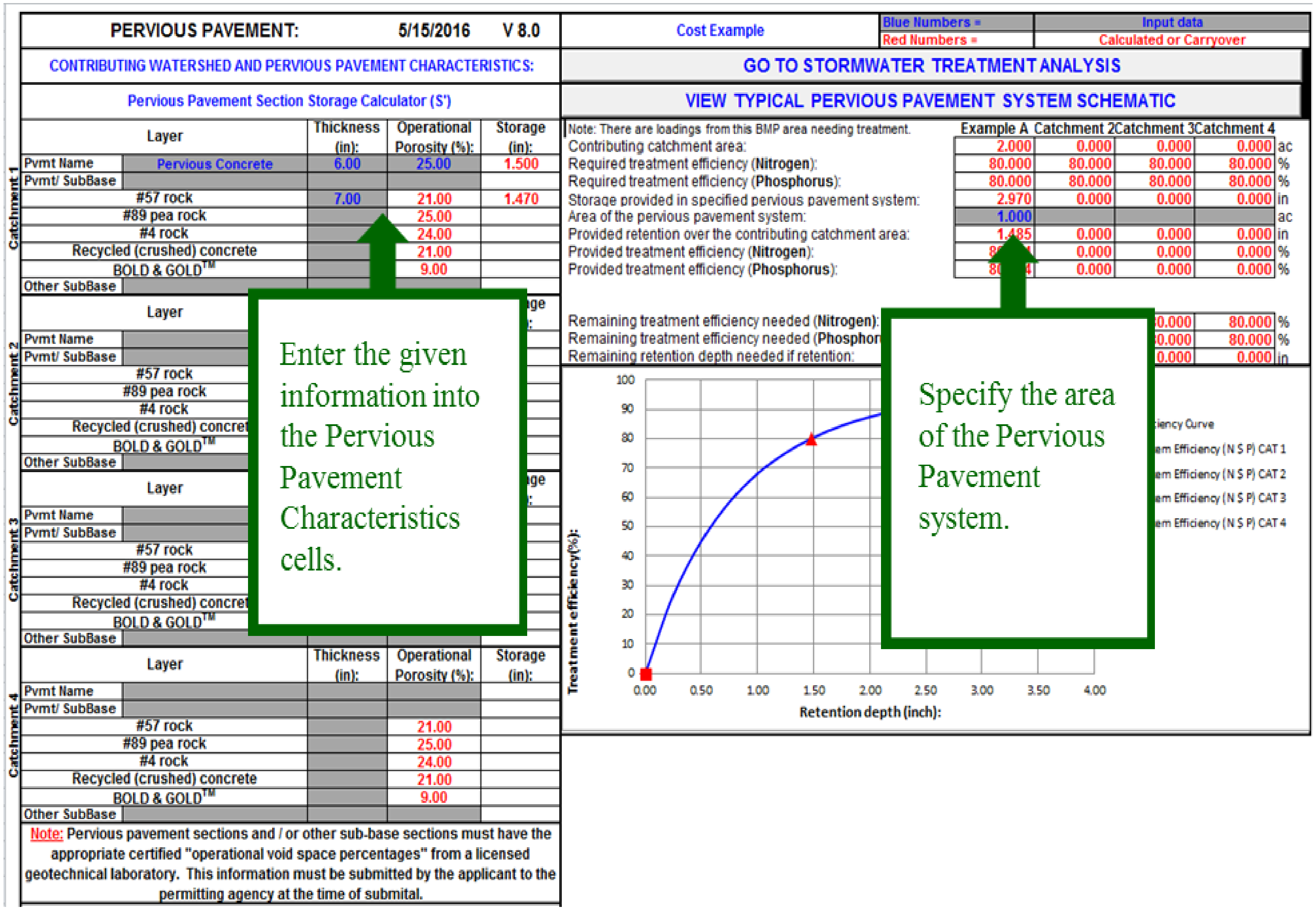


Figure 150 – Pervious Pavement BMP tab

4. Click **Go to Stormwater Treatment Analysis** to return to the **Stormwater Treatment Analysis worksheet.**

a. Click **Catchments and Treatment Summary Results** tab to see if the design meets criteria (see Figure 151).

b. If it does not pass, go back and adjust the BMP inputs until it passes.

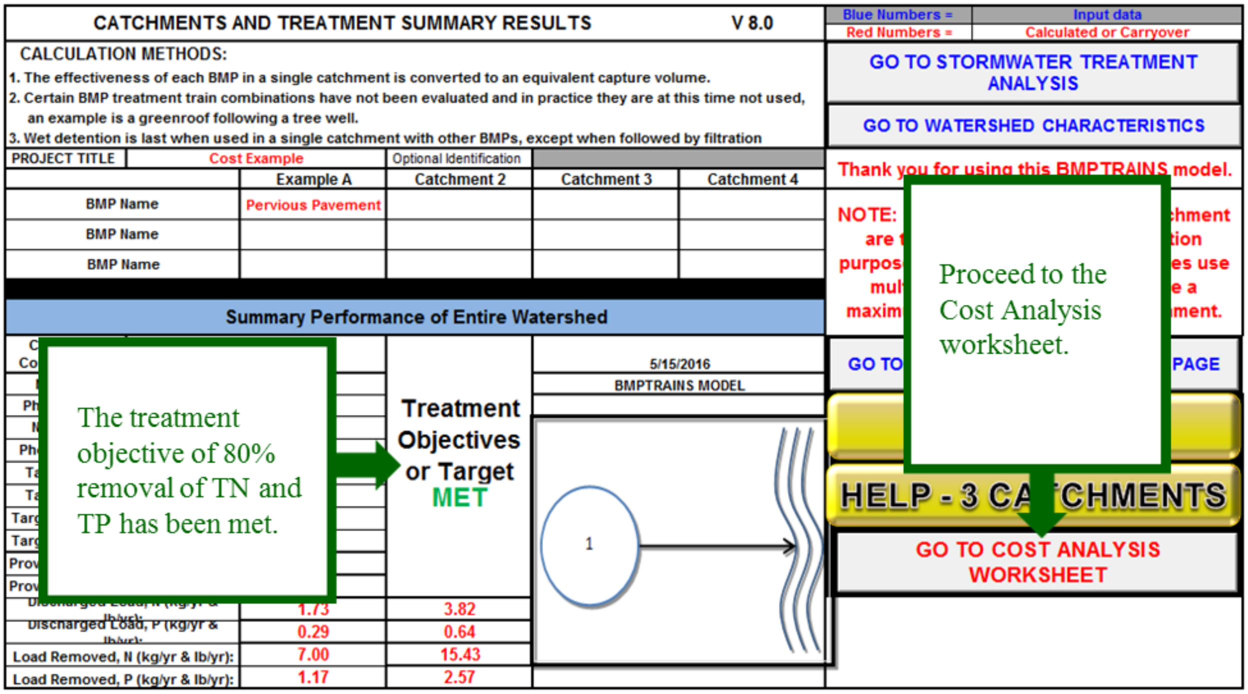


Figure 151 – Catchments and Treatment Summary Results

Treatment Train Scenario 1, Costs

5. Click **Go to Cost Analysis Worksheet**.

a. Capital and operating costs for pervious pavement. Use these values and adjust the cost per acre of impervious area treated. Table 6 shows numbers specific for this site.

Table 6 – Capital and Operating Cost for Site Specific Pervious Pavement

Capital cost per hectare of impervious area in 2012 dollars	Annual operating and maintenance cost per hectare of impervious area in 2012 dollars	Capital cost per acre of impervious area in 2012 dollars	Annual operating and maintenance cost per acre of impervious area in 2012 dollars
$65,700.00	$2,670.00	$26,588.43	$1,080.53

b. The literature is providing the cost data on a basis of cost per acre of impervious area, however the model needs the BMP Cost input on a basis of ($/acre-ft) for capital cost and

O & M cost on a basis of ($/year). For the basis of this conversion, consider the rainfall on the pavement and on the building to be treated. Recall that the site is 2 acres with 40% building and 50% parking lot, thus 90% shall be considered as the Effective Impervious Area, which is 1.8 acres. The cost for 1.8 acres is shown in Table 7.

Table 7 – Cost for 1.8 Acres of Contributing Catchment

Capital cost per acre of impervious area in 2012 dollars	Annual operating and maintenance cost per acre of impervious area in 2012 dollars	Acres contributing to the BMP	Capital cost in 2012 dollars	Annual operating and maintenance cost in 2012 dollars
$26,588.43	$1,080.53	1.8	$47,859.17	$1,944.96

c. Convert cost (Figure 8) to 2016 dollars using inflation calculator (see Appendix B).

Table 8 – Cost for Pervious Pavement in 2016 dollars

Capital cost per acre of impervious area in 2016 dollars	Annual operating and maintenance cost per acre of impervious area in 2016 dollars	Acres contributing to the BMP	Capital cost in 2016 dollars	Annual operating and maintenance cost in 2016 dollars
$27,577.18	$1,120.71	1.8	$49,638.92	$2,017.28

e. The model is in terms of $/acre-ft of water treated thus a volume calculation needs to be made. The area used for this calculation is the actual area of pervious pavement, 1 acre. The depth used is the "Storage provided in specified pervious pavement system" from the *Pervious Pavement worksheet* (2.970 inches).

6. **Storage volume** is 2.97 inches * 1 ft/12 inches * 1 acre = 0.2475 acre-feet

Convert capital cost to $/(Acre-ft) in 2016 dollars

$49,638.92 / 0.2475 acre-feet = $200,561.29 per acre-feet

Enter capital cost and operating cost data into model.

Fill in the remaining fields in the **Life Cycle Cost Comparison Worksheet** (see Figure 152)

a. For *What type of analysis would you like to perform* select **Net Present Worth**

b. The most recent interest rate value published by the World Bank is for the year 2014 so we will use this value, which is 1.8%.

c. Problem statement gave life span as 20 years; assume the project duration is the same since not otherwise stated.

d. Leave *BMP Fixed Cost* blank since the source cost data had the *Fixed Data* and *BMP Cost* combined into a single value.

e. Leave *Estimated Future Cost of Replacement* blank since the Project Duration and Expected Lifespan are the same.

f. Leave *Cost Land needed for BMP* blank because according to the data for scenario 1, no additional land is needed.

g. Enter the Scenario #

h. Click **Perform Cost Analysis**

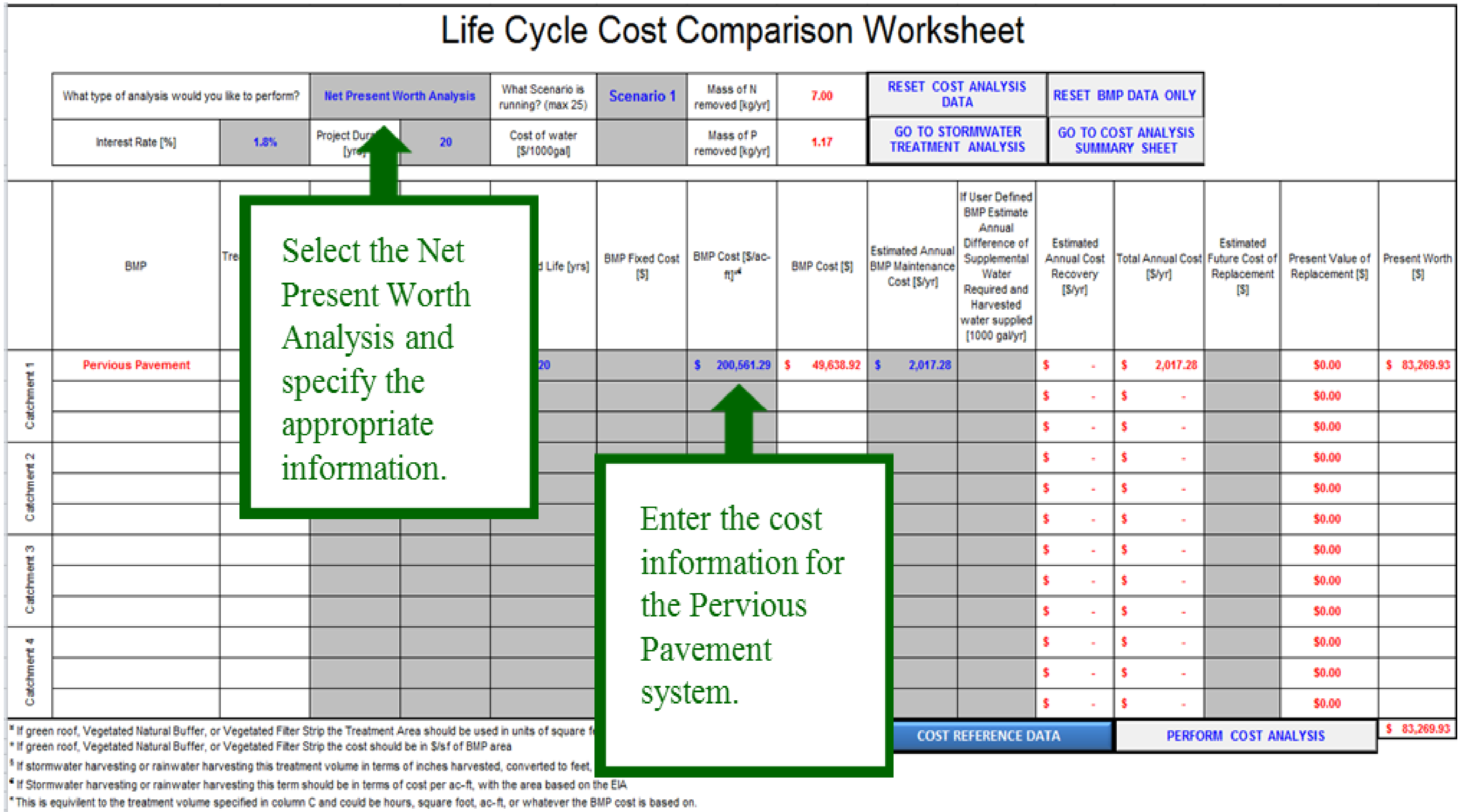
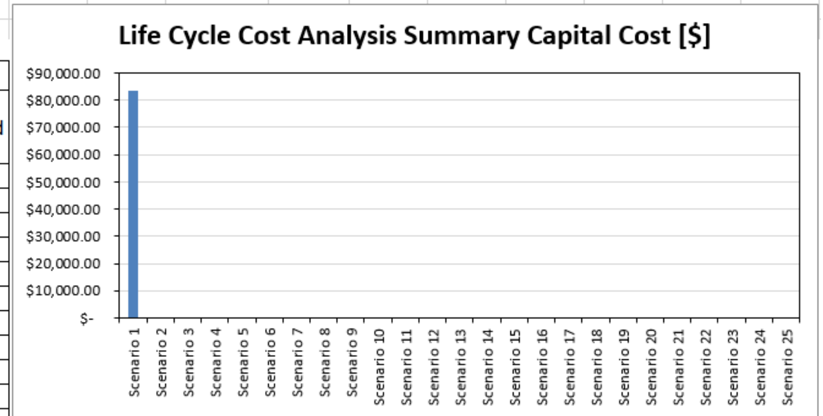


Figure 152 – Life Cycle Cost Comparison Worksheet

7. The resulting **Life Cycle Cost Analysis Summary Capital Cost** and **Life Cycle Cost of N and P Removed** figures and table will be created for Scenario 1 (see Figure 153).

GO TO COST ANALYSIS WORKSHEET

Life Cycle Cost Analysis Summary					
	Net Present Worth [$]	Cost of N Removed [$/kg-yr]	Cost of P Removed [$/kg-yr]	TN Removed [kg/yr]	TP Removed [kg/yr]
Scenario 1	$ 83,269.93	$ 11,887.91	$ 71,453.90	7.00	1.17
Scenario 2					
Scenario 3					
Scenario 4					
Scenario 5					
Scenario 6					
Scenario 7					
Scenario 8					
Scenario 9					
Scenario 10					
Scenario 11					
Scenario 12					
Scenario 13					
Scenario 14					
Scenario 15					
Scenario 16					
Scenario 17					
Scenario 18					
Scenario 19					
Scenario 20					
Scenario 21					
Scenario 22					
Scenario 23					
Scenario 24					
Scenario 25					



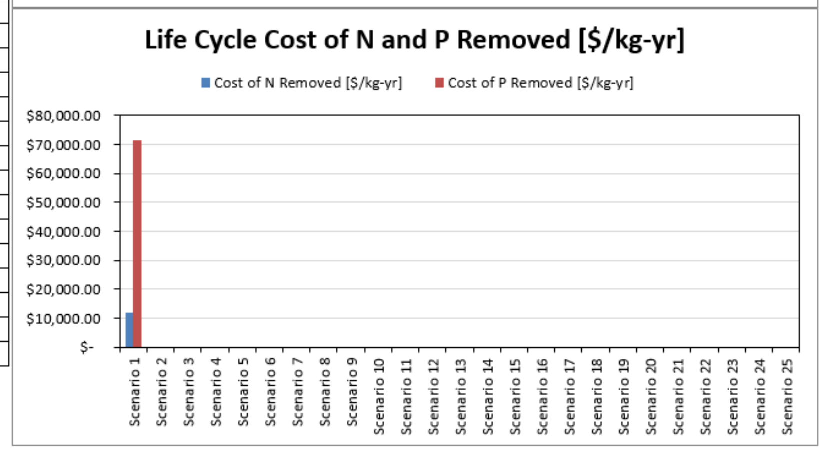


Figure 153 – Life Cycle Cost Analysis Summary

8. Return to the **Stormwater Treatment Analysis** worksheet.

Treatment Train Scenario 2

The pervious concrete area, retention basin volume, and additional land required for Scenario 2 are shown in Table 9.

Table 9 – Scenario 2 BMP Data

BMP Characteristics			
Scenario	Pervious Concrete Area [ac]	Retention Basin Volume [ac-ft]	Additional Land Required [ac]
2	0.825	0.0417	0

13. Select the BMP from the list and enter the information into the tab as you did in Step 3; however, this time you will also have to enter information for the retention basin.

   a. The information you previously entered for Pervious Pavement should still be in the cells and you will only need to change the value for *Area of the pervious pavement system.* If the values are not in the cells, re-enter them as you did in Step 3 (using the new area value) (see Figure 154).

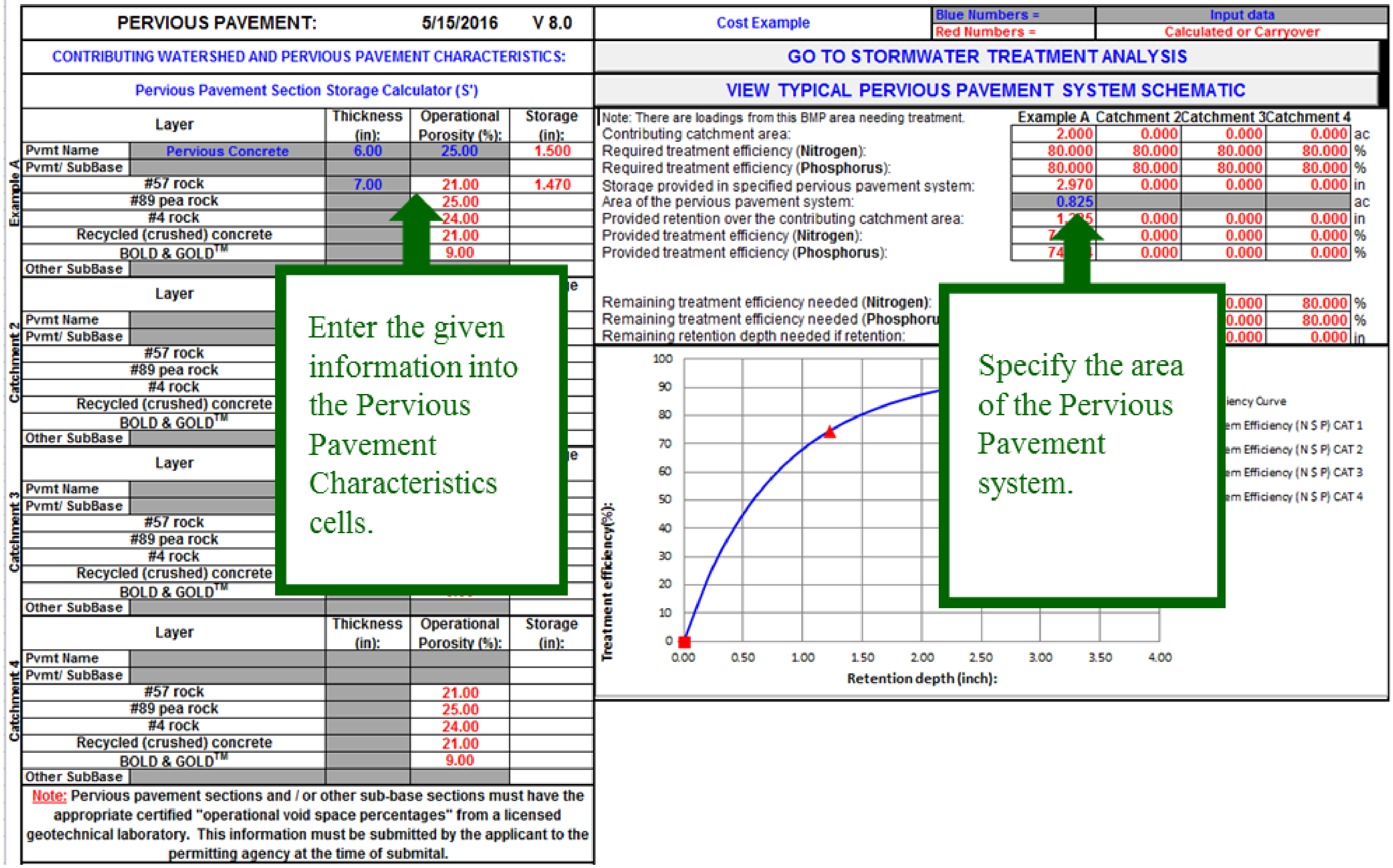


Figure 154 – Pervious Pavement BMP worksheet

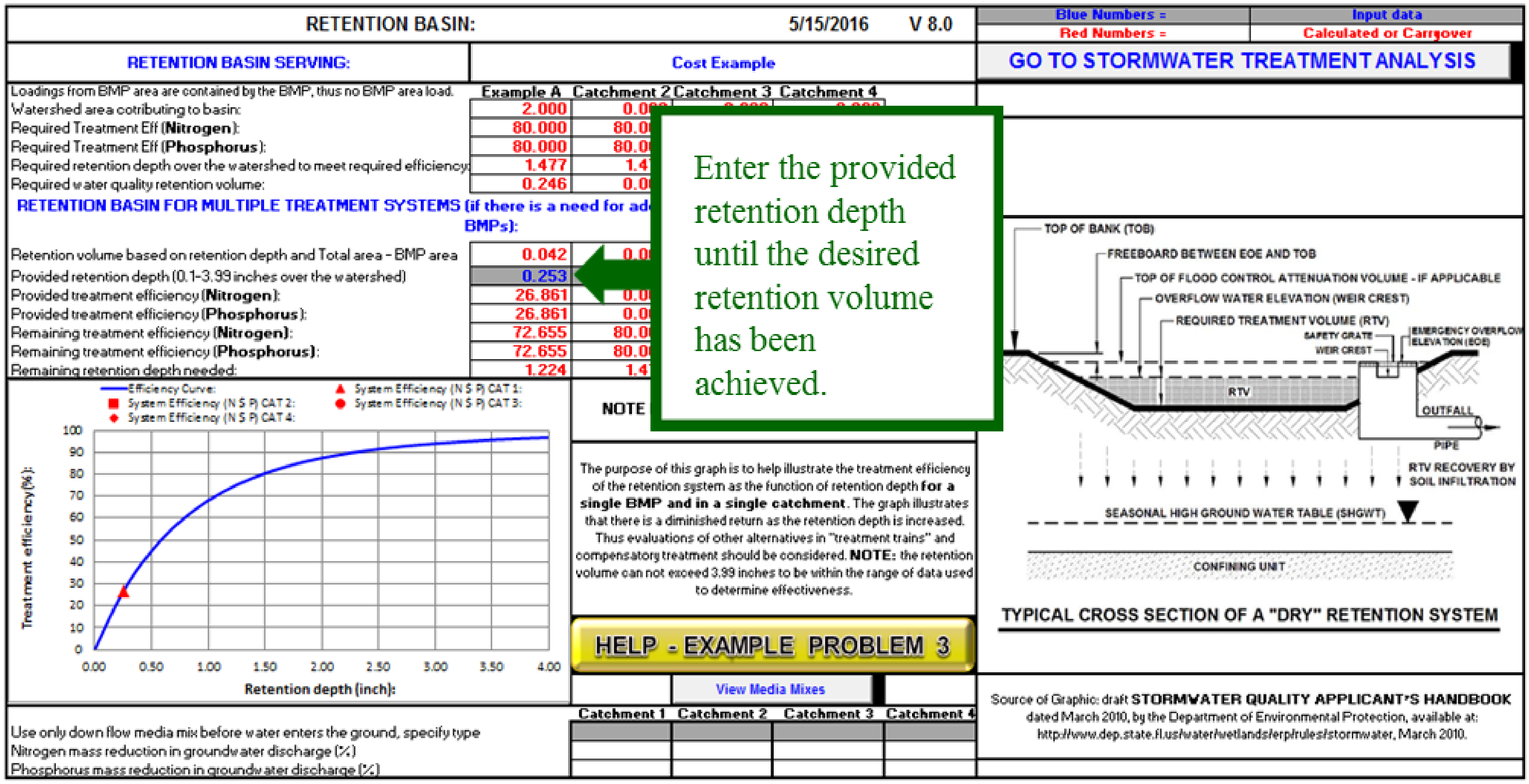


Figure 155 – Retention Basin BMP worksheet

*The problem stated that the provided retention volume for this scenario is 0.0417 acre-ft ≈ 0.042 acre-ft. Use an iterative guess and check approach by entering in a *Provided retention depth* and seeing if the *Retention volume based on retention depth and Total area –BMP area* becomes the desired value of 0.042 ac-ft. (see Figure 155).

9. Click **Catchments and Treatment Summary Results** to see if the design meets criteria. If it does not pass, then go back and adjust the BMP inputs until it passes (see Figure 156).

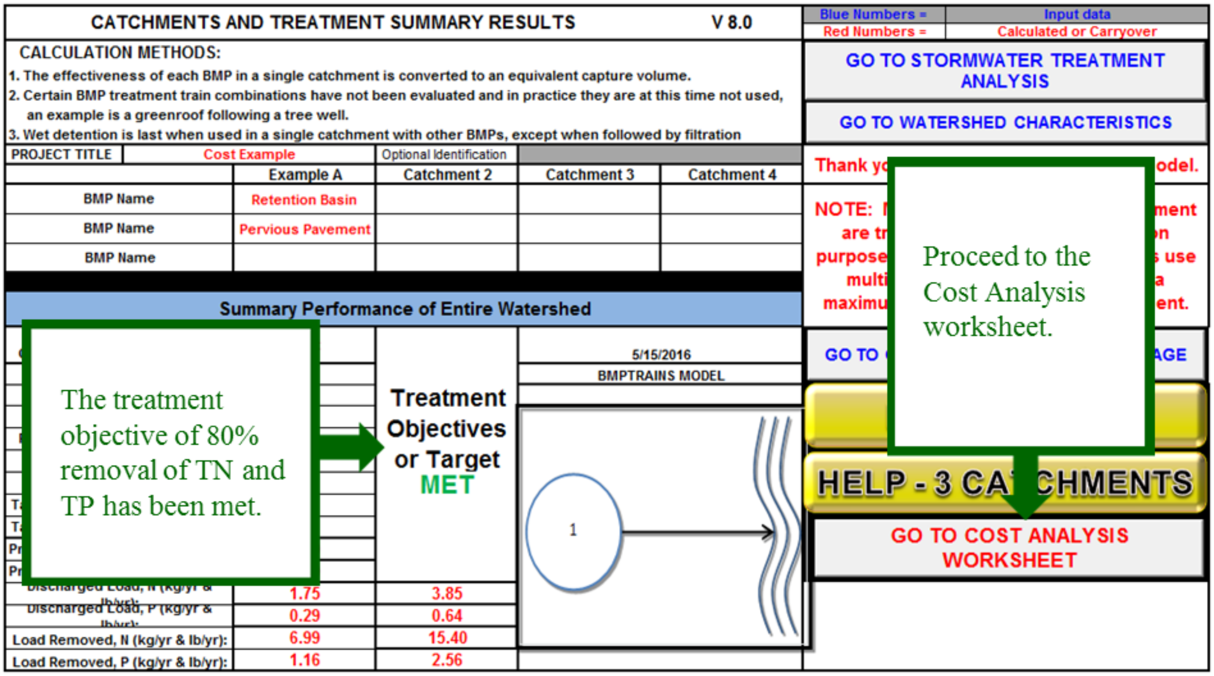


Figure 156 – Catchments and Treatment Summary Results

Scenario 2, Costs

Note For pervious pavement, use the *BMP Cost [$/acre-ft]* and *Estimated Annual BMP Maintenance Cost* determined in Scenario 1 for Scenario 2; both of these are based on the area of impervious area being treated and as stated in Scenario 1 the entire paved and building covered area is being considered impervious for the purpose of cost estimate.

10. Click **Go to Cost Analysis Worksheet (Figure 157).**

a. Example capital cost data on a volumetric basis (cubic feet) for retention basins and the operating cost can be calculated as a percentage of capital cost as shown below

- Capital cost of $0.7/cubic ft (1997 dollars)
- Operating cost of 3% of capital cost.
- 1 acre-foot = 43559.9 ft^3
- From Cost sheet: Treatment Volume = 0.0422
- Use the Inflation Calculator (see appendix B) to adjust to 2016 dollars.

b. Calculate the capital and operating costs (Figure 10).

Table 10 –Retention Basin Costs

Capital cost per cubic foot of treated water in 1997 dollars	Capital cost per acre-foot of treated water in 1997 dollars	Capital cost per acre-foot of treated water in 2016 dollars
$0.70	$30,491.93	$45,240.53

c. Enter capital cost and operating cost data into model. The best way to calculate and enter the operating cost is in the model cell for *Estimated Annual BMP Maintenance Cost*; create a formula to multiply the *BMP capital Cost* by 3%).

11. Fill in the remaining fields (see Figure 157).

a. For *What type of analysis would you like to perform* select **Net Present Worth?**

b. The most recent interest rate value published by the World Bank is for the year 2014 so we will use this value, which is 1.8%.

c. Problem statement gave life span as 20 years; assume the project duration is the same since not otherwise stated.

d. Leave *BMP Fixed Cost* blank since the source cost data had the *Fixed Data* and *BMP Cost* combined into a single value.

e. Leave *Estimated Future Cost of Replacement* blank since the Project Duration and Expected Lifespan are the same.

f. Leave *Cost Land needed for BMP* blank because according to the data for scenario 2, no additional land is needed.

g. Enter the Scenario #

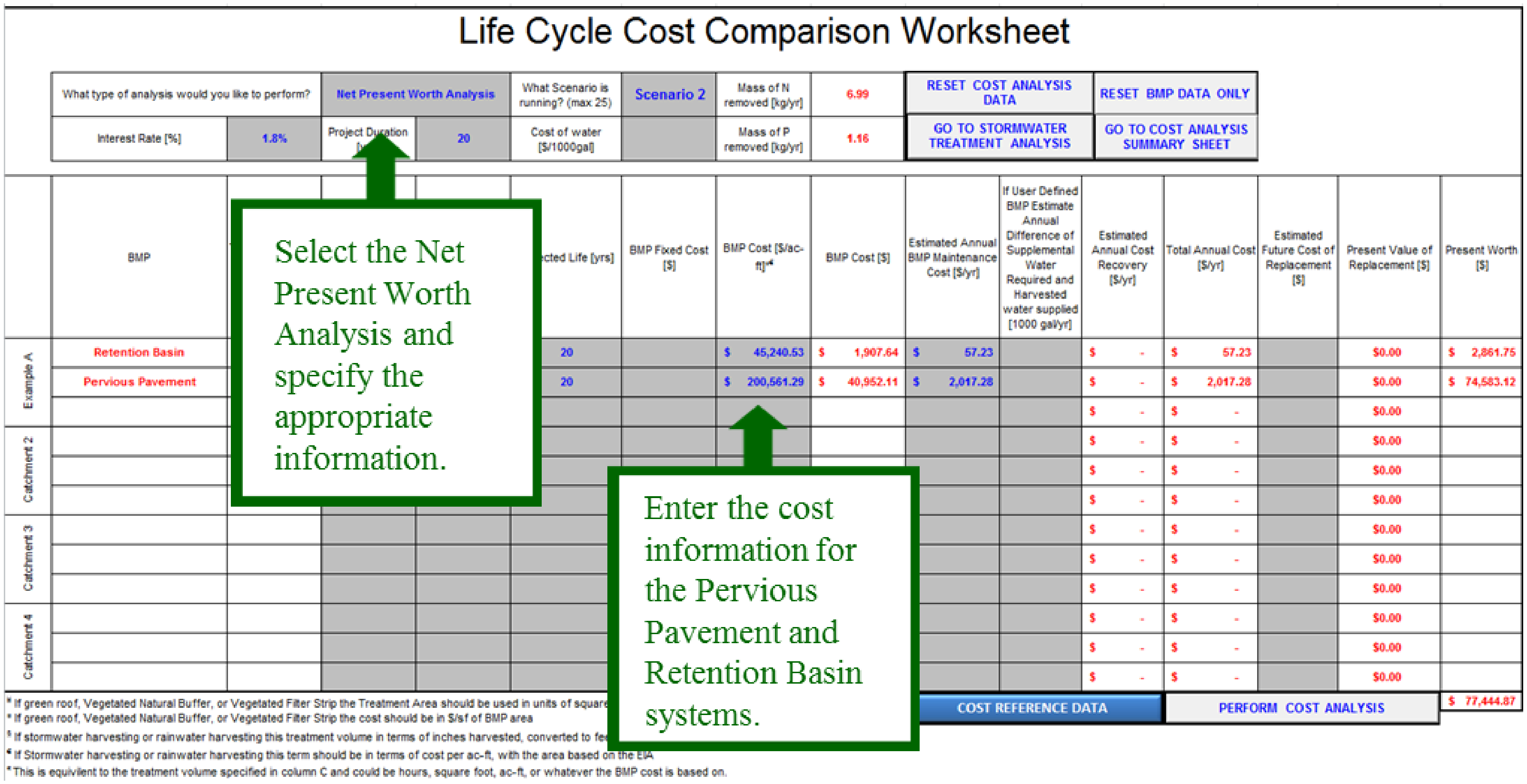
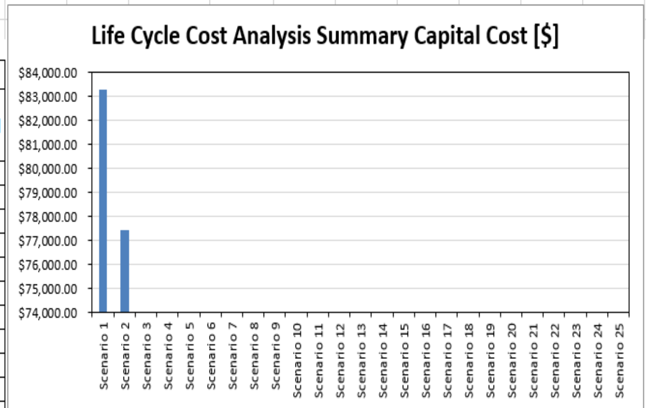


Figure 157 – Updated Life Cycle Cost Comparison Worksheet

GO TO COST ANALYSIS WORKSHEET

Life Cycle Cost Analysis Summary

	Net Present Worth [$]	Cost of N Removed [$/kg-yr]	Cost of P Removed [$/kg-yr]	TN Removed [kg/yr]	TP Removed [kg/yr]
Scenario 1	$ 83,269.93	$ 11,887.91	$ 71,453.90	7.00	1.17
Scenario 2	$ 77,444.86	$ 11,076.28	$ 66,575.54	6.99	1.16
Scenario 3					
Scenario 4					
Scenario 5					
Scenario 6					
Scenario 7					
Scenario 8					
Scenario 9					
Scenario 10					
Scenario 11					
Scenario 12					
Scenario 13					
Scenario 14					
Scenario 15					
Scenario 16					
Scenario 17					
Scenario 18					
Scenario 19					
Scenario 20					
Scenario 21					
Scenario 22					
Scenario 23					
Scenario 24					
Scenario 25					



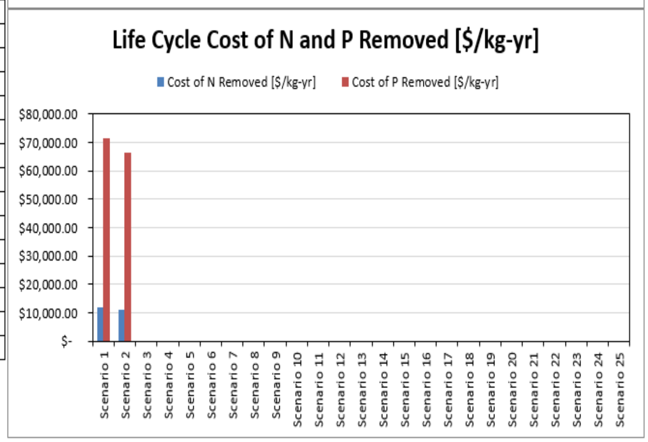


Figure 158 – Life Cycle Cost Analysis Summary

12. Return to the **Stormwater Treatment Analysis** worksheet

Treatment Train Scenario 3

The pervious concrete area, retention basin volume, and additional land required for Scenario 3 are given in Table 11.

Table 11 – Scenario 3 BMP Data

BMP Characteristics			
Scenario	Pervious Concrete Area [ac]	Retention Basin Volume [ac-ft]	Additional Land Required [ac]
3	0.65	0.0833	0

13. Select the BMP from the list and enter the information into the tab as you did in Step 3; however, this time you will also have to enter information for the retention basin.

a. The information you previously entered for Pervious Pavement should still be in the cells and you will only need to change the value for *Area of the pervious pavement system.* If the values are not in the cells, re-enter them as you did in Step 3 (using the new area value) (see Figure 159).

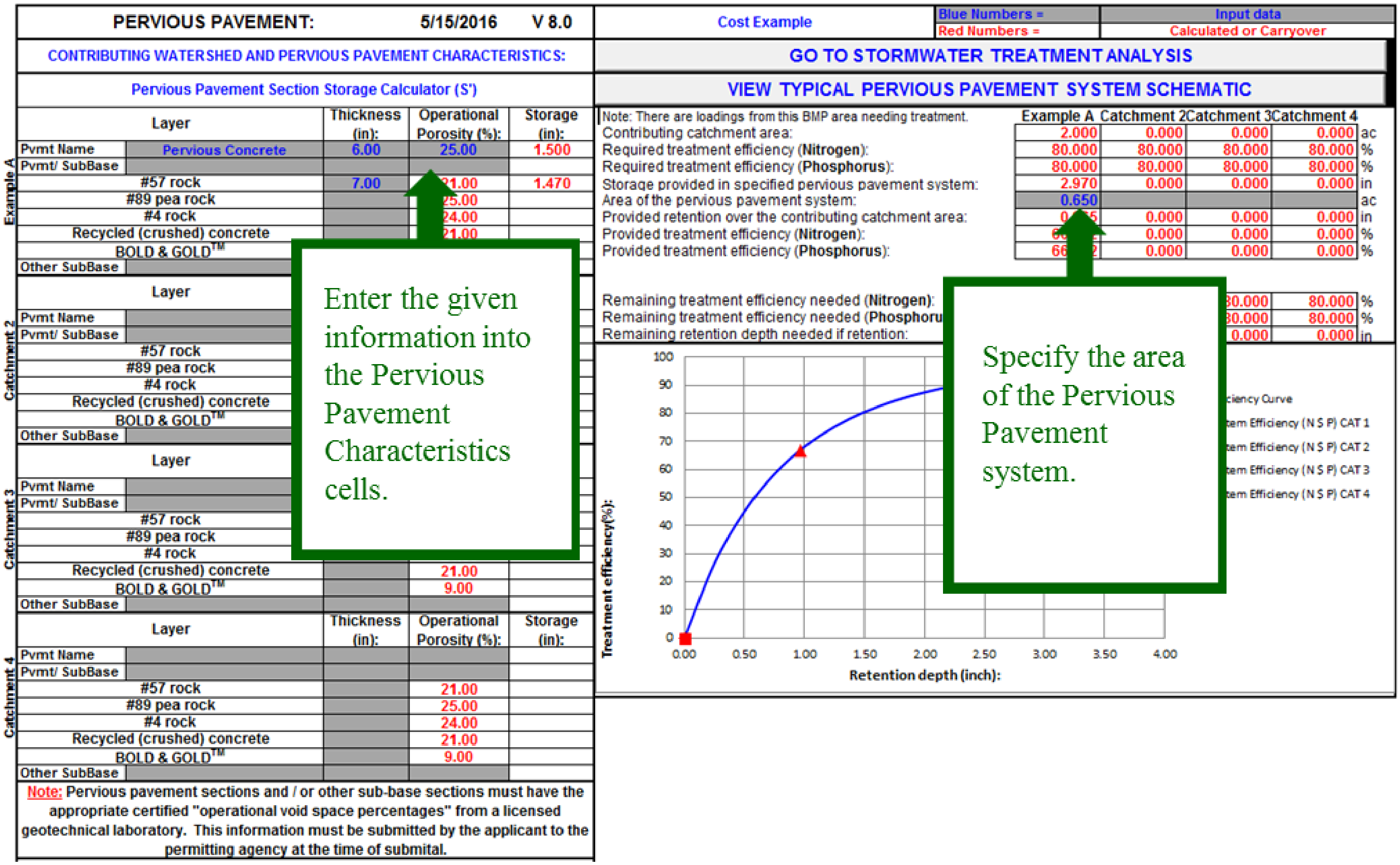


Figure 159 – Pervious Pavement BMP worksheet

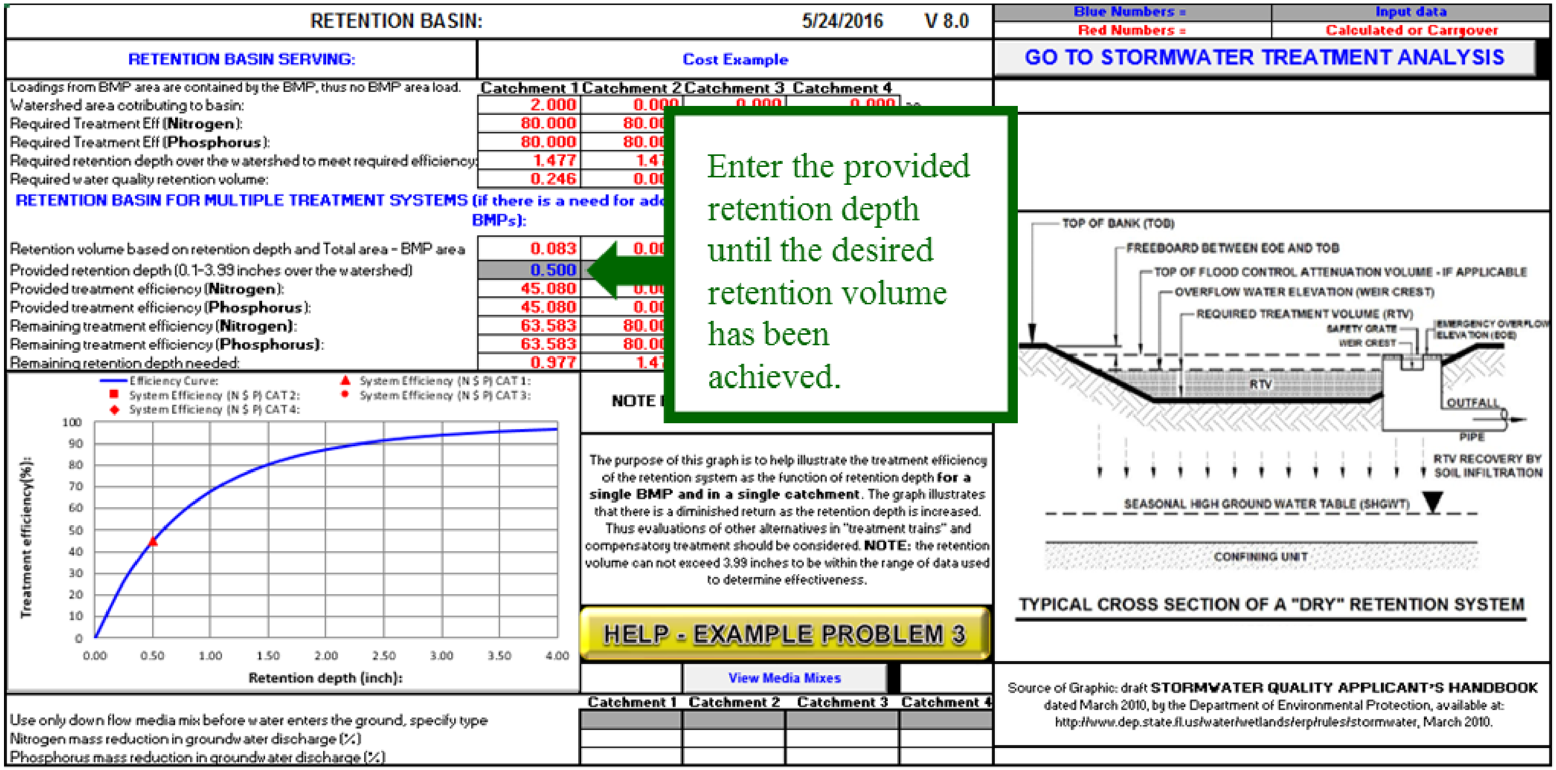


Figure 160 – Retention Basin BMP worksheet

*The problem stated that the provided retention volume for this scenario is 0.083 acre-ft. Use an iterative guess and check approach by entering in a *Provided retention depth* and seeing if the *Retention volume based on retention depth and Total area –BMP area* becomes the desired value (see Figure 160).

14. Click **Catchment and Treatment Summary Results**

a. As seen in the **Catchment and Treatment Summary Results**, the *Treatment Objectives or Target* was not met. We will have to go back and adjust the parameters for one or both of the BMPs.

b. Return to the **Stormwater Treatment Analysis** worksheet and click the *Retention Basin* Tab. Increase the *Provided retention depth* to 0.515 in. This results in a corresponding *Retention volume based on retention depth and total area – BMP area* of 0.086 ac-ft.

c. Return to the **Stormwater Treatment Analysis** worksheet and click **Catchment and Treatment Summary Results**. The Treatment Objectives have now been met (see Figure 161.

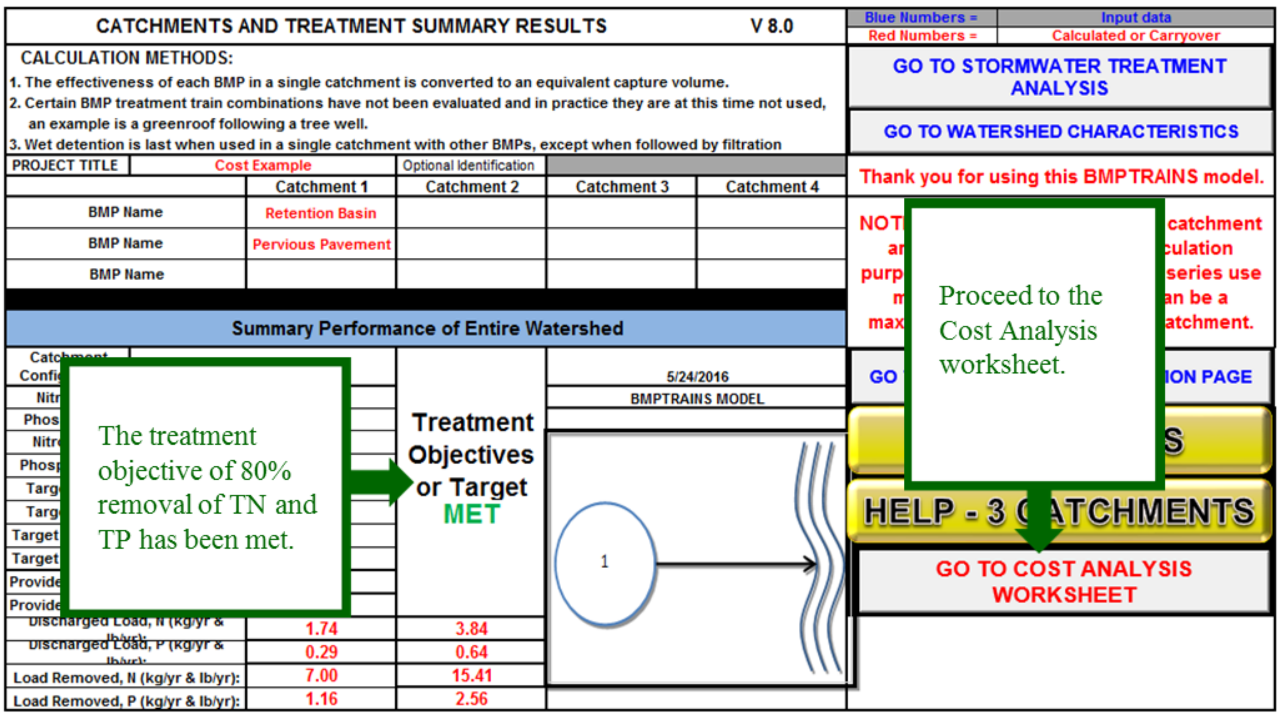


Figure 161 – Catchments and Treatment Summary Results

Scenario 3, Costs

15. Capital cost data on a volumetric basis (cubic feet) of water treated for retention basins, the operating cost is calculated as a percentage of capital cost and data are shown below.

a. For the retention basin use the same *BMP Cost per acre-ft* used in Scenario 2, no further data entry is need for capital cost. Additionally, just as in Scenario 2, multiply the formula for *Estimated Annual BMP Maintenance Cost* is still 3% of the capital *BMP Cost*.

b. For pervious pavement, use the *BMP Cost [$/acre-ft]* and *Estimated Annual BMP Maintenance Cost* determined in Scenario 1 for Scenario 3; both of these are based on the area of impervious area being treated and as stated in Scenario 1 the entire paved and building covered area is being considered impervious for the purpose of cost estimate.

16. Fill in the remaining fields (see Figure 162).

a. For *What type of analysis would you like to perform* select "Net Present Worth"

b. The most recent interest rate value published by the World Bank is for the year 2014 so we will use this value, which is 1.8%.

c. Problem statement gave life span as 20 years; assume the project duration is the same since not otherwise stated.

d. Leave *BMP Fixed Cost* blank since the source cost data had the *Fixed Data* and *BMP Cost* combined into a single value.

e. Leave *Estimated Future Cost of Replacement* blank since the Project Duration and Expected Lifespan are the same.

f. Leave *Cost Land needed for BMP* blank because according to the data for scenario 3, no additional land is needed.

g. Enter the Scenario #

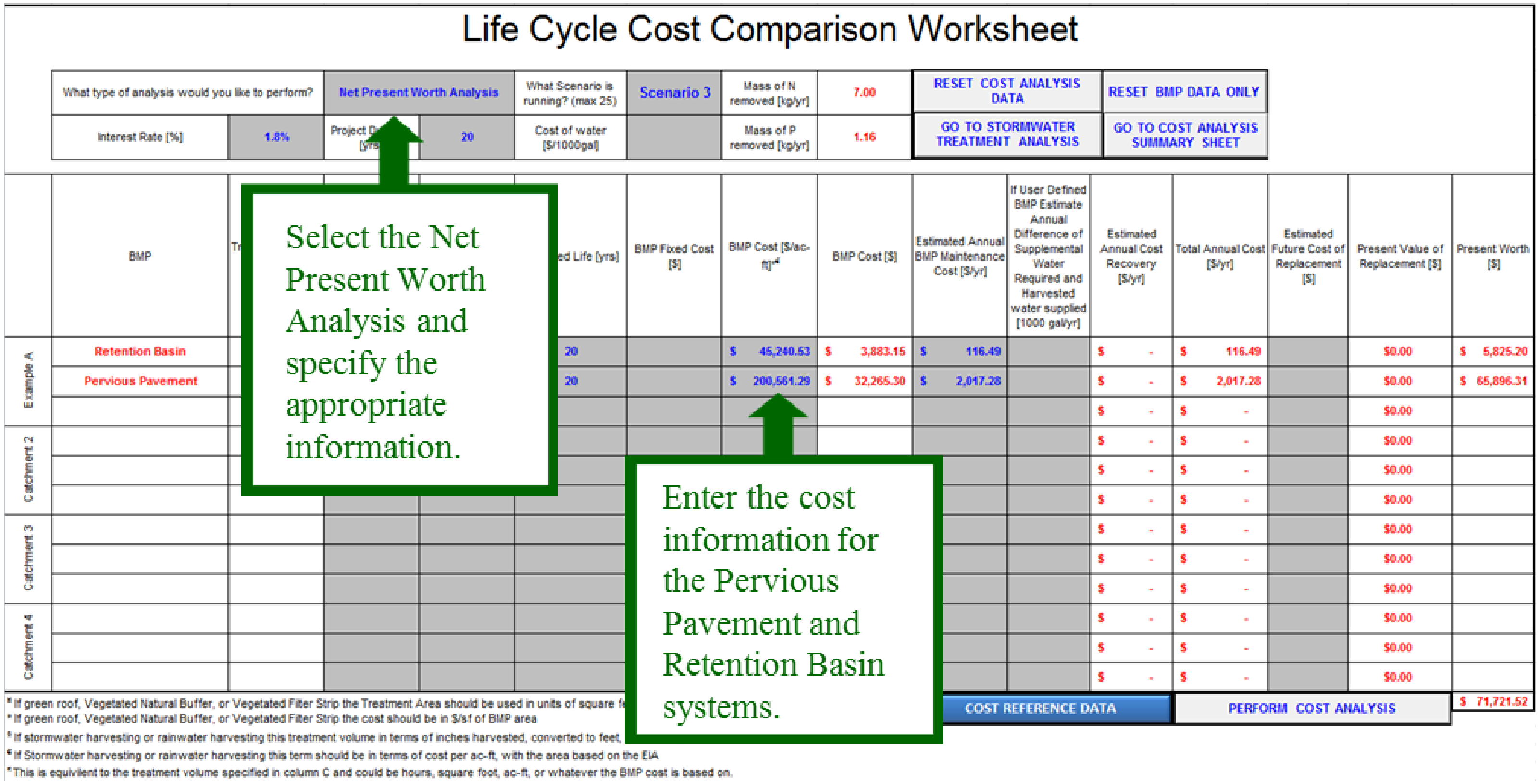


Figure 162 – Life Cycle Cost Comparison Worksheet

17. Perform the Cost Analysis (see Figure 163).

GO TO COST ANALYSIS WORKSHEET

Life Cycle Cost Analysis Summary					
	Net Present Worth [$]	Cost of N Removed [$/kg-yr]	Cost of P Removed [$/kg-yr]	TN Removed [kg/yr]	TP Removed [kg/yr]
Scenario 1	$ 83,269.93	$ 11,887.91	$ 71,453.90	7.00	1.17
Scenario 2	$ 77,444.86	$ 11,076.28	$ 66,575.54	6.99	1.16
Scenario 3	$ 71,721.59	$ 10,252.00	$ 61,621.09	7.00	1.16
Scenario 4					
Scenario 5					
Scenario 6					
Scenario 7					
Scenario 8					
Scenario 9					
Scenario 10					
Scenario 11					
Scenario 12					
Scenario 13					
Scenario 14					
Scenario 15					
Scenario 16					
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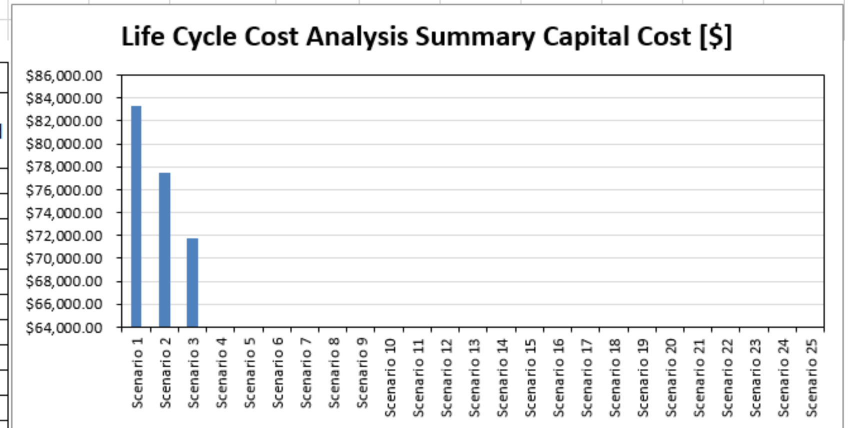
Scenario 18					
Scenario 19					
Scenario 20					
Scenario 21					
Scenario 22					
Scenario 23					
Scenario 24					
Scenario 25					



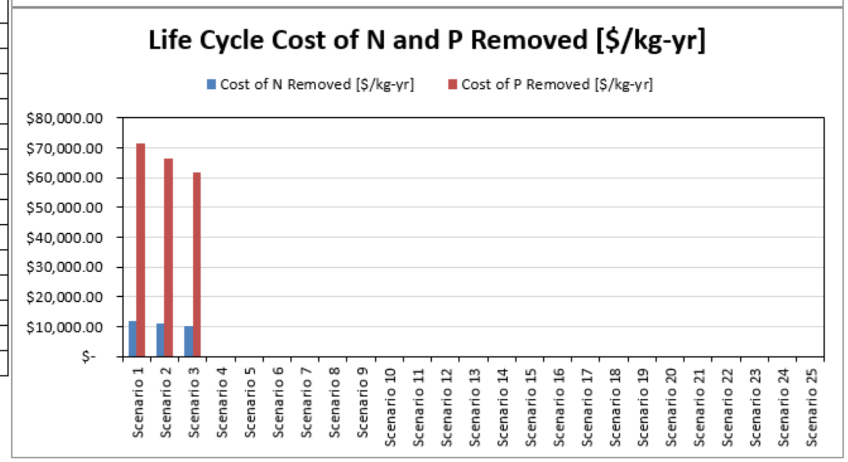


Figure 163 – Life Cycle Cost Analysis Summary

18. Return to the **Stormwater Treatment Analysis** worksheet.

Treatment Train Scenario 4

The pervious concrete area, retention basin volume, and additional land required for Scenario 4 are given in Table 12.

Table 12 – Scenario 4 BMP Data

BMP Characteristics			
Scenario	Pervious Concrete Area [ac]	Retention Basin Volume [ac-ft]	Additional Land Required [ac]
4	0.325	0.173	0.073

19. Select the BMP from the list and enter the information into the tab as you did previously; however, this time also enter information for the retention basin.

Note: when using pervious pavements, the runoff mass loadings are subtracted based on the size of the BMP and the area are not entered on the watershed characteristics page.

a. The information you previously entered for Pervious Pavement should still be in the cells and you will only need to change the value for *Area of the pervious pavement system.* If the values are not in the cells, re-enter them as you did in Step 3 (using the new area value) (see Figure 164).

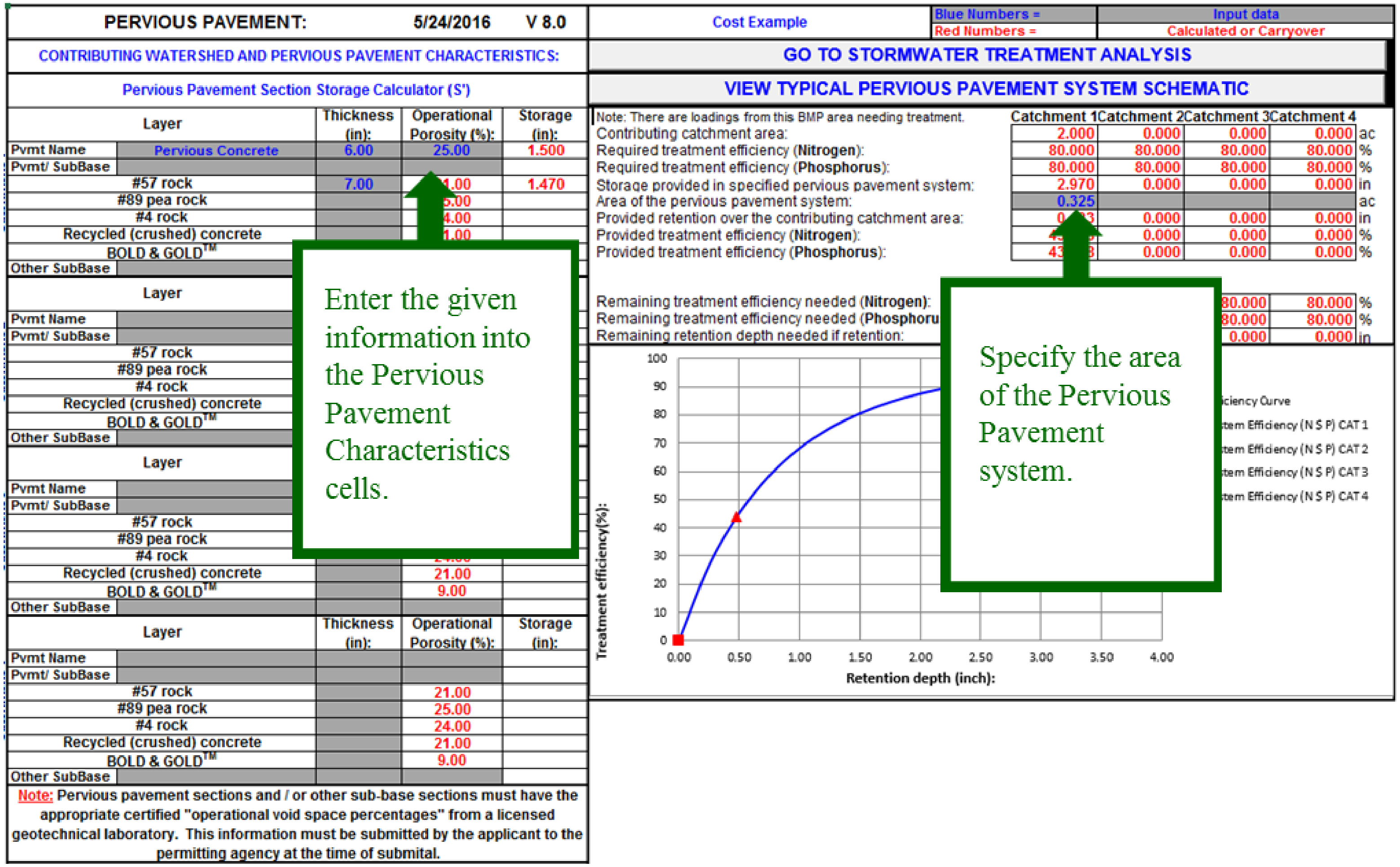


Figure 164 – Pervious Pavement BMP worksheet

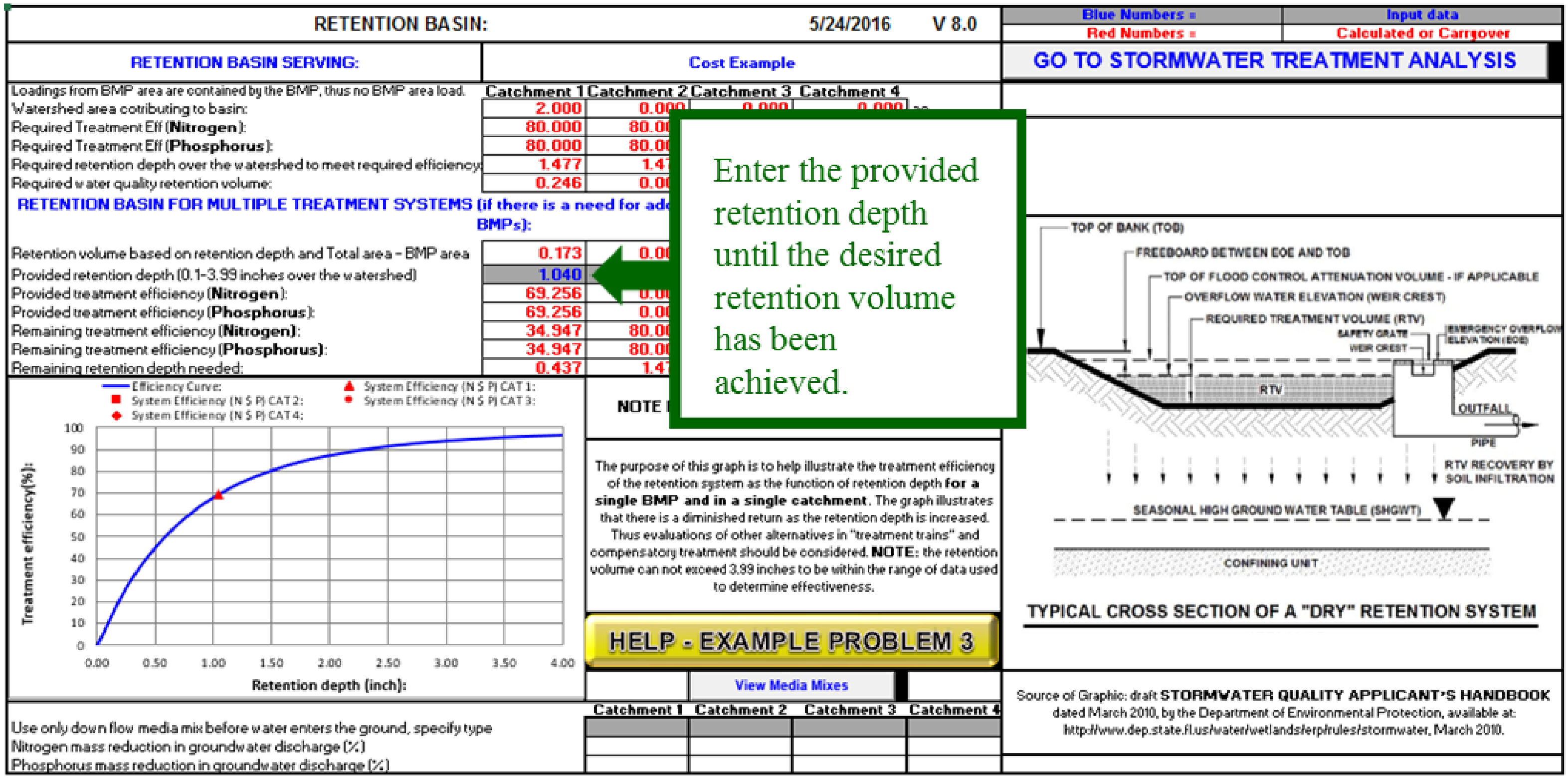


Figure 165 – Retention Basin BMP worksheet

The problem stated that the provided retention volume for this scenario is 0.173 acre-ft. Use an iterative guess and check approach by entering in a *Provided retention depth* and seeing if the *Retention volume based on retention depth and Total area –BMP area* becomes the desired value (see Figure 165).

20. Return to the **Stormwater Treatment Analysis** worksheet and click **Catchment and Treatment Summary Results** (see Figure 167).

a. If the treatment objectives are not met, adjust the BMP inputs until it passes.

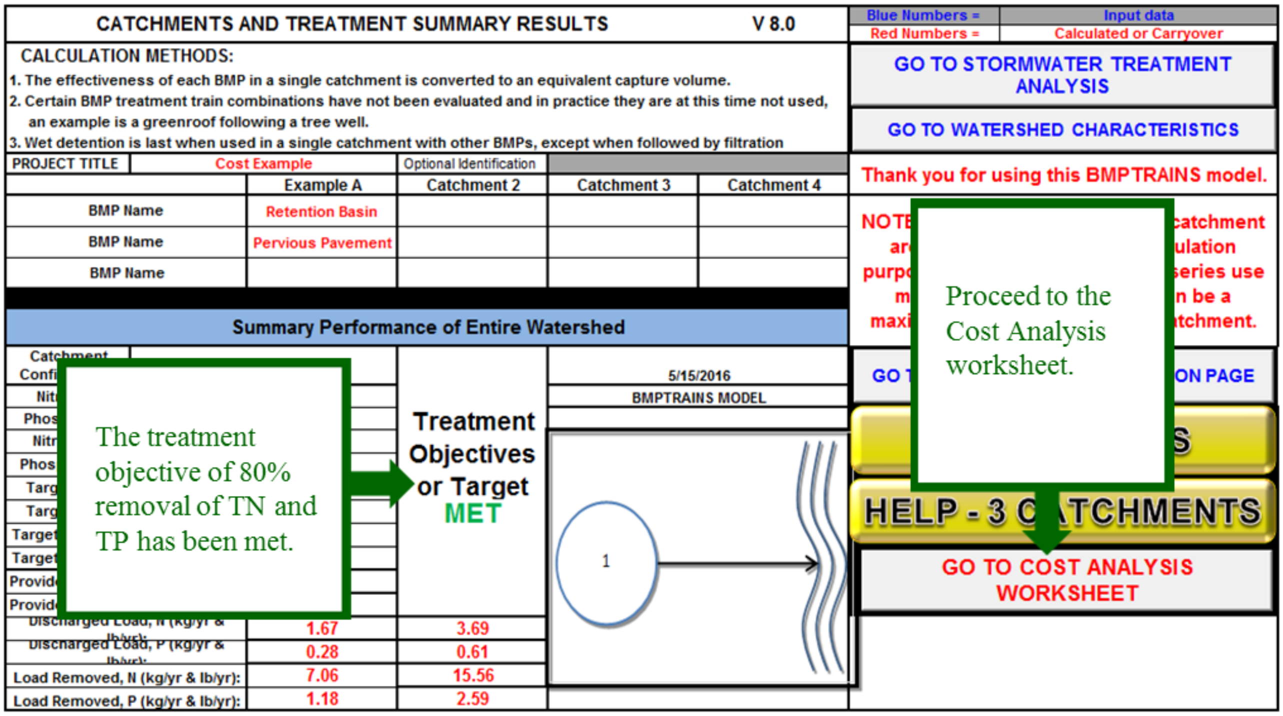


Figure 167 – Catchments and Treatment Summary Results

Scenario 4, Costs

21. This Scenario requires additional land.

a. Based on a web site for land cost (Zillow, May 2016), 1 acre of land costs about $525,000. For this scenario, the cost to purchase additional land would be $38,325.

b. For the retention basin use the same *BMP Cost per acre-ft* used in Scenario 2, no further data entry is need for capital cost. Additionally, just as in Scenario 2, multiply the formula for *Estimated Annual BMP Maintenance Cost* is still 3% of the capital *BMP Cost*.

c. For pervious pavement, use the *BMP Cost [$/acre-ft]* and *Estimated Annual BMP Maintenance Cost* determined in Scenario 1 for the current Scenario; both of these are based on the area of impervious area being treated and as stated in Scenario 1 the entire paved and building covered area is being considered impervious for the purpose of cost estimate.

22. Fill in the remaining fields.

a. For *What type of analysis would you like to perform* select “Net Present Worth”?

b. The most recent value published by the World Bank is for the year 2014 so we will use this value, which is 1.8%.

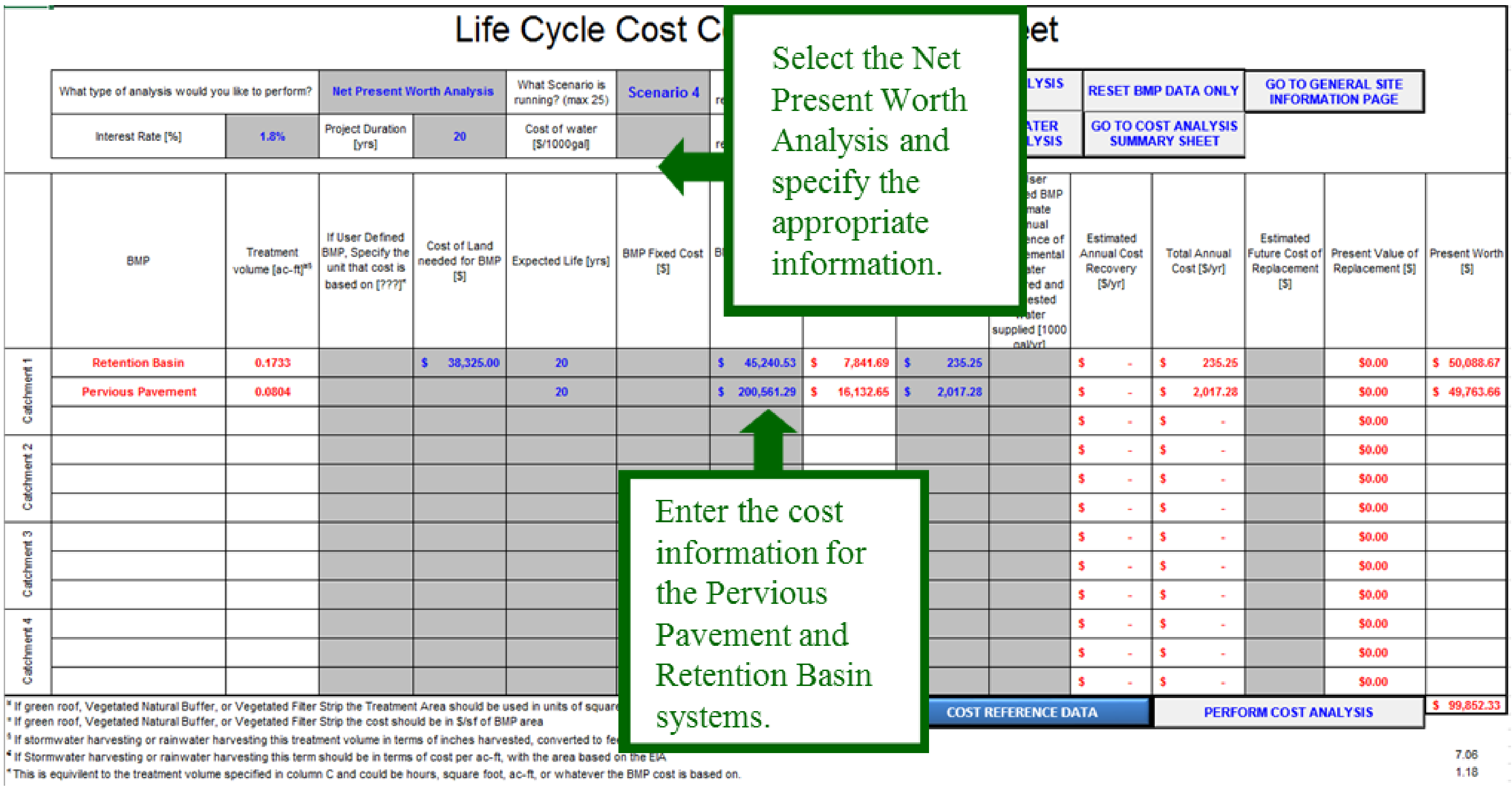
c. Problem statement gave life span as 20 years; assume the project duration is the same since not otherwise stated.

d. Leave *BMP Fixed Cost* blank since the source cost data had the *Fixed Data* and *BMP Cost* combined into a single value.

e. Leave *Estimated Future Cost of Replacement* blank since the Project Duration and Expected Lifespan are the same.

f. Leave *Cost Land needed for BMP* blank because according to the data for scenario 3, no additional land is needed.

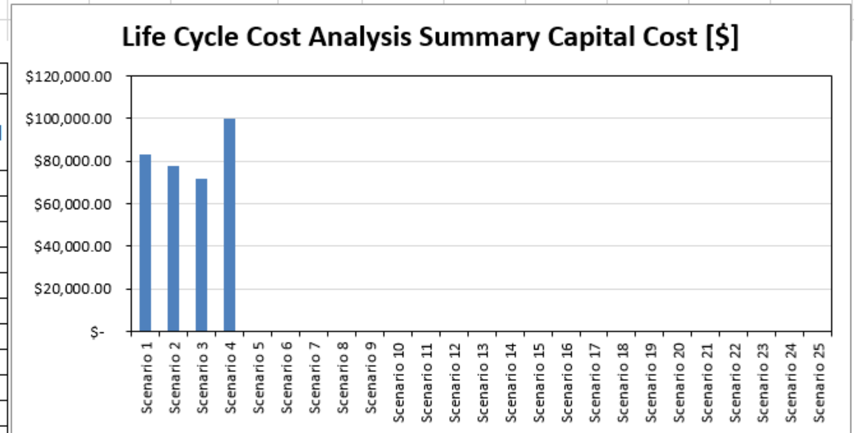
g. Enter the Scenario #



23. Perform Cost Analysis.

GO TO COST ANALYSIS WORKSHEET

Life Cycle Cost Analysis Summary					
	Net Present Worth [$]	Cost of N Removed [$/kg-yr]	Cost of P Removed [$/kg-yr]	TN Removed [kg/yr]	TP Removed [kg/yr]
Scenario 1	$ 83,269.93	$ 11,887.91	$ 71,453.90	7.00	1.17
Scenario 2	$ 77,444.86	$ 11,076.28	$ 66,575.54	6.99	1.16
Scenario 3	$ 71,721.59	$ 10,252.00	$ 61,621.09	7.00	1.16
Scenario 4	$ 99,852.33	$ 14,135.78	$ 84,965.07	7.06	1.18
Scenario 5					
Scenario 6					
Scenario 7					
Scenario 8					
Scenario 9					
Scenario 10					
Scenario 11					
Scenario 12					
Scenario 13					
Scenario 14					
Scenario 15					
Scenario 16					
Scenario 17					
Scenario 18					
Scenario 19					
Scenario 20					
Scenario 21					
Scenario 22					
Scenario 23					
Scenario 24					
Scenario 25					



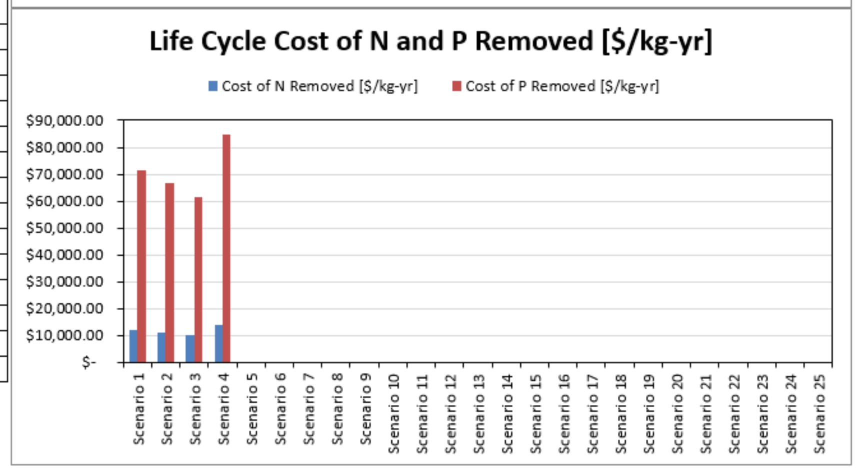


Figure 166 – Life Cycle Cost Analysis Summary

24. Return to **Stormwater Treatment Analysis** worksheet.

Treatment Train Scenario 5

The pervious concrete area, retention basin volume, and additional land required for Treatment Train Scenario 5 are given in Table 13.

Table 13 – Scenario 5 BMP Data

	BMP Characteristics		
Scenario	Pervious Concrete Area [ac]	Retention Basin Volume [ac-ft]	Additional Land Required [ac]
5	0.15	0.221	0.12

25. Select the BMP from the list and enter the information into the tab as you did in Step 3; however, this time you will also have to enter information for the retention basin.

a. The information you previously entered for Pervious Pavement should still be in the cells and you will only need to change the value for *Area of the pervious pavement system.* If the values are not in the cells, re-enter them as you did in Step 3 (using the new area value) (see Figure 167).

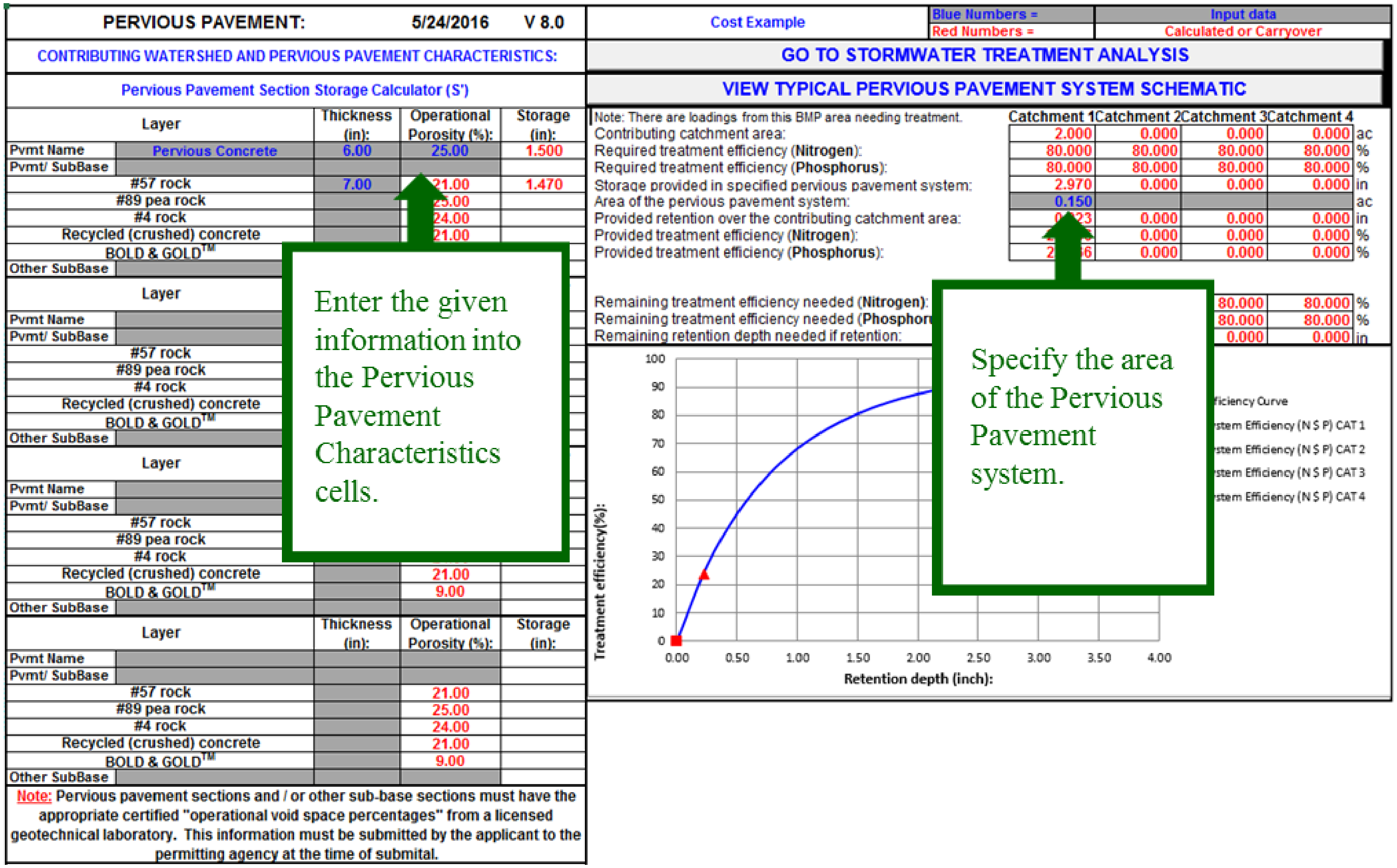


Figure 167 – Pervious Pavement BMP worksheet

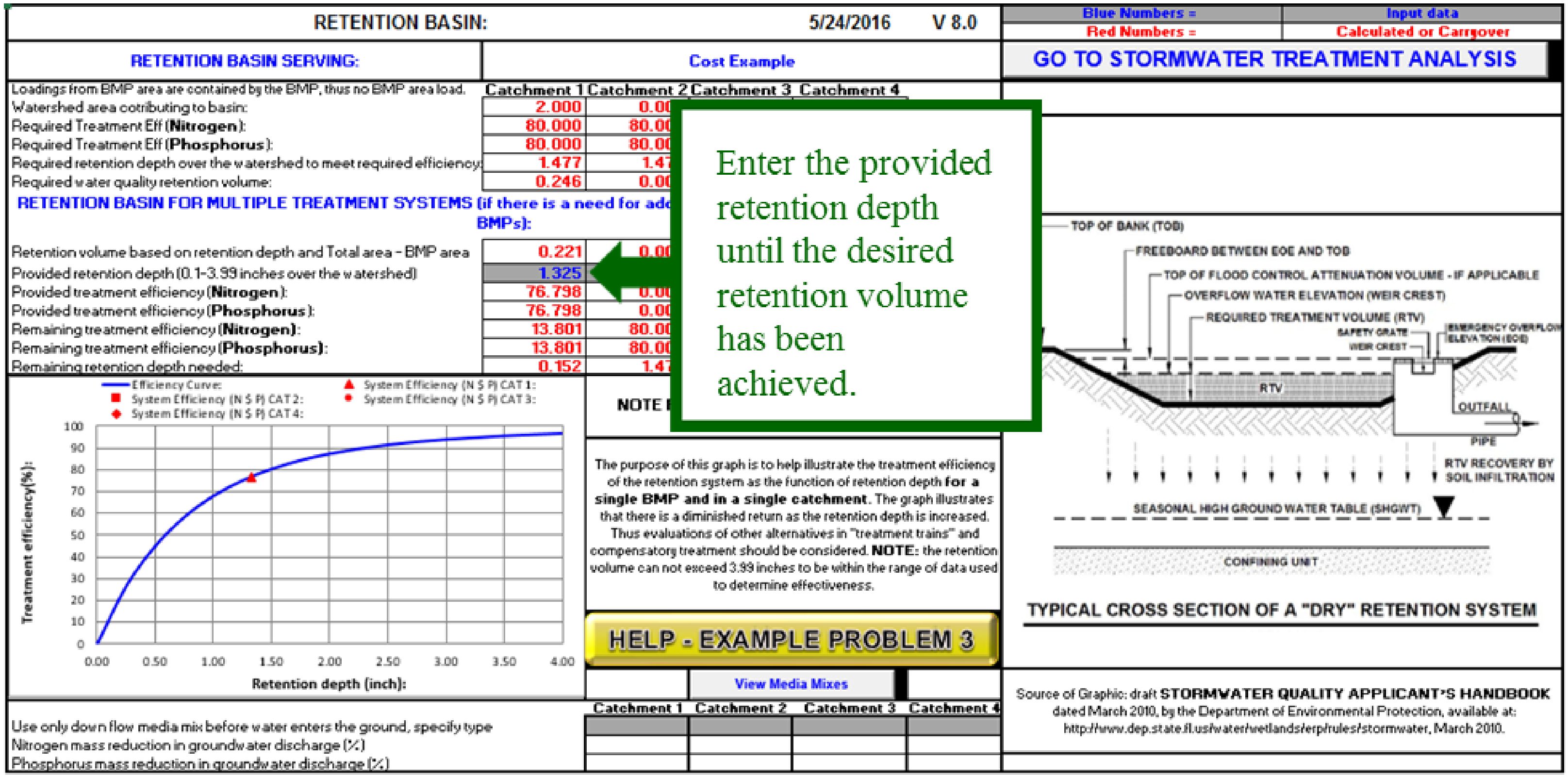


Figure 168 – Retention Basin BMP worksheet

*The problem stated that the provided retention volume for this scenario is 0.221 acre-ft. Use an iterative guess and check approach by entering in a *Provided retention depth* and seeing if the *Retention volume based on retention depth and Total area –BMP area* becomes the desired value (see Figure 168).

26. Return to the **Stormwater Treatment Analysis** worksheet and click **Catchment and Treatment Summary Results** (see Figure 169 –).

a. If the treatment objectives are not met, adjust the BMP inputs until it passes.

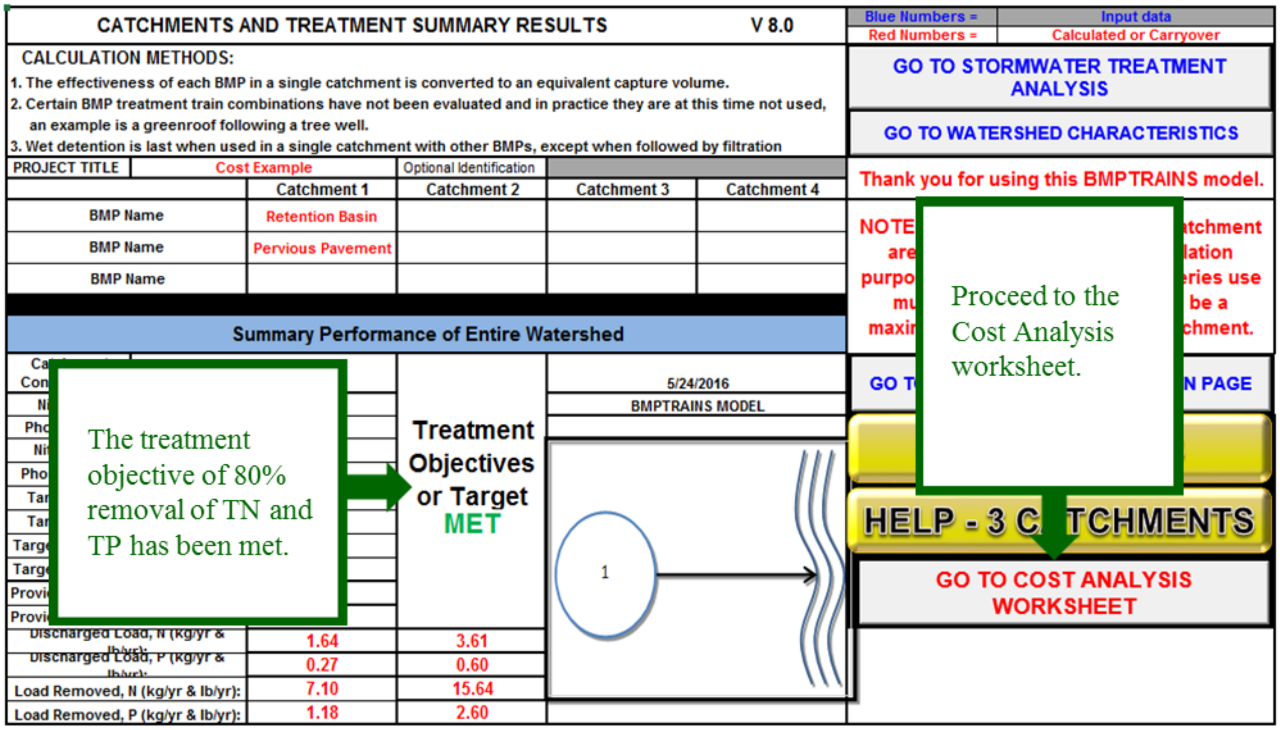


Figure 169 – Catchments and Treatment Summary Results

Scenario 5, Costs

27. This Scenario requires additional land.

a. Based on Zillow, May 2016, 1 acre of land costs about $525,000. For this scenario, the cost to purchase additional land would be $63,000.

b. For the retention basin use the same *BMP Cost per acre-ft* used in Scenario 2, no further data entry is need for capital cost. Additionally, just as in Scenario 2, multiply the formula for *Estimated Annual BMP Maintenance Cost* is still 3% of the capital *BMP Cost*.

c. For pervious pavement, use the *BMP Cost [$/acre-ft]* and *Estimated Annual BMP Maintenance Cost* determined in Scenario 1 for the current Scenario; both of these are based on the area of impervious area being treated and as stated in Scenario 1 the entire paved and building covered area is being considered impervious for the purpose of cost estimate.

28. Fill in the remaining fields.

a. For *What type of analysis would you like to perform* select “Net Present Worth”?

b. The most recent value published by the World Bank is for the year 2014 so we will use this value, which is 1.8%.

c. Problem statement gave life span as 20 years; assume the project duration is the same since not otherwise stated.

d. Leave *BMP Fixed Cost* blank since the source cost data had the *Fixed Data* and *BMP Cost* combined into a single value.

e. Leave *Estimated Future Cost of Replacement* blank since the Project Duration and Expected Lifespan are the same.

f. Leave *Cost Land needed for BMP* blank because according to the data for scenario 3, no additional land is needed.

g. Enter the Scenario #

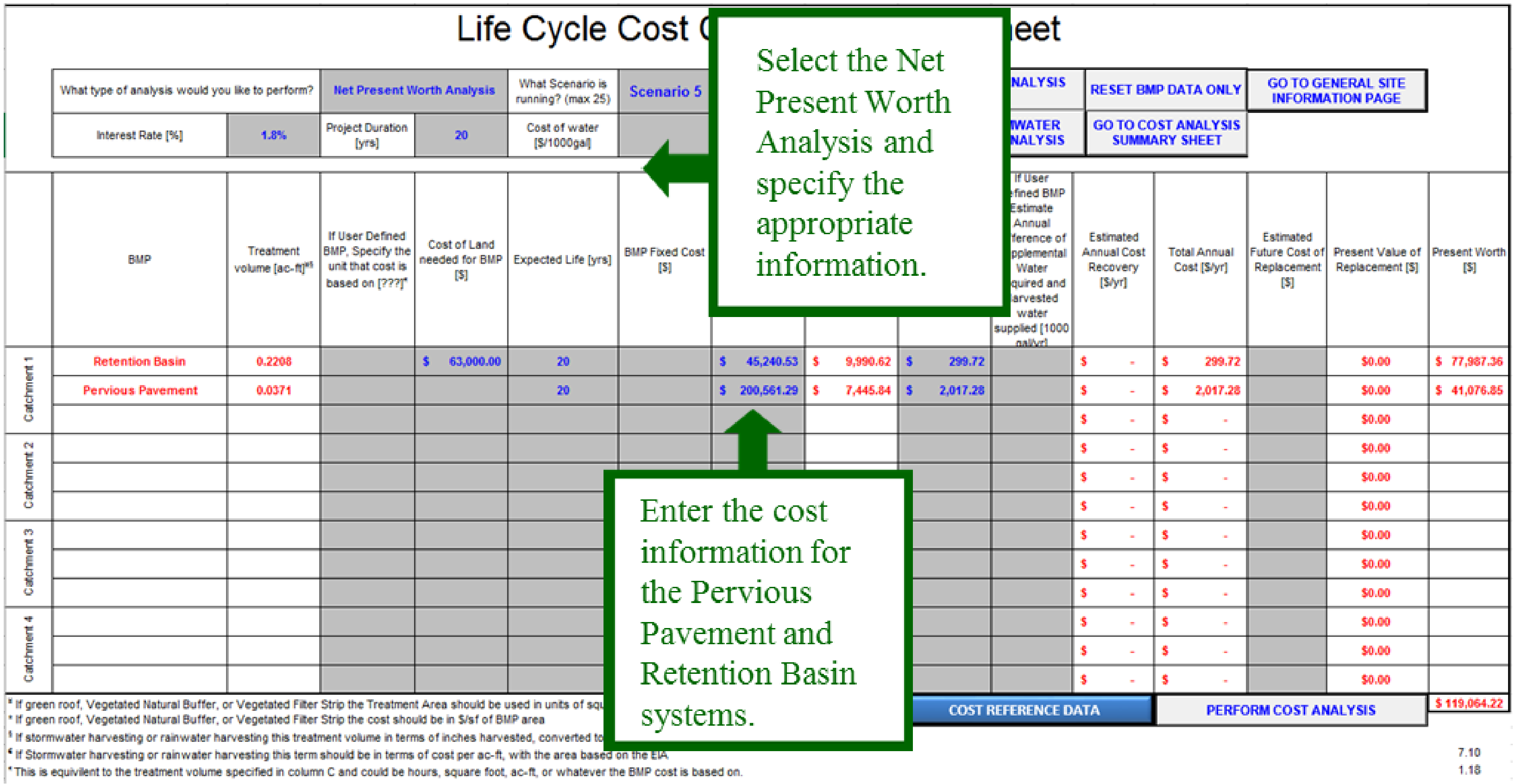


Figure 170 – Life Cycle Cost Comparison Worksheet Two Design Scenarios

29. Perform Cost Analysis.

GO TO COST ANALYSIS WORKSHEET

Life Cycle Cost Analysis Summary					
	Net Present Worth [$]	Cost of N Removed [$/kg-yr]	Cost of P Removed [$/kg-yr]	TN Removed [kg/yr]	TP Removed [kg/yr]
Scenario 1	$ 83,269.93	$ 11,887.91	$ 71,453.90	7.00	1.17
Scenario 2	$ 77,444.86	$ 11,076.28	$ 66,575.54	6.99	1.16
Scenario 3	$ 71,721.59	$ 10,252.00	$ 61,621.09	7.00	1.16
Scenario 4	$ 99,852.33	$ 14,135.78	$ 84,965.07	7.06	1.18
Scenario 5	$ 119,064.22	$ 16,772.15	$ 100,811.30	7.10	1.18
Scenario 6					
Scenario 7					
Scenario 8					
Scenario 9					
Scenario 10					
Scenario 11					
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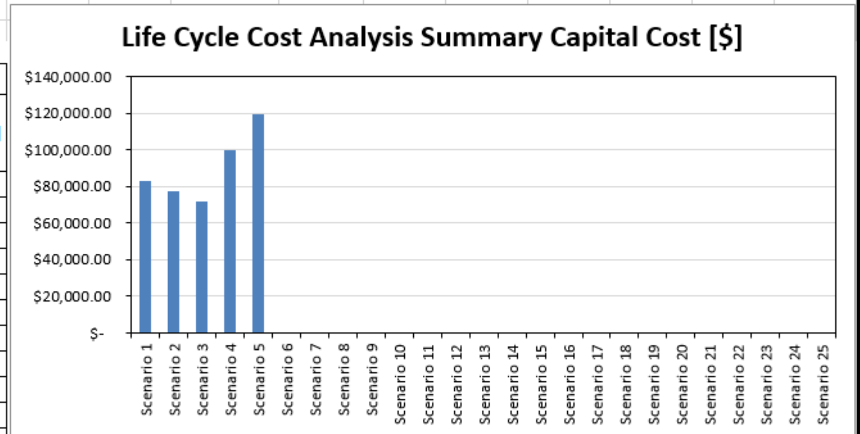
Scenario 23					
Scenario 24					
Scenario 25					



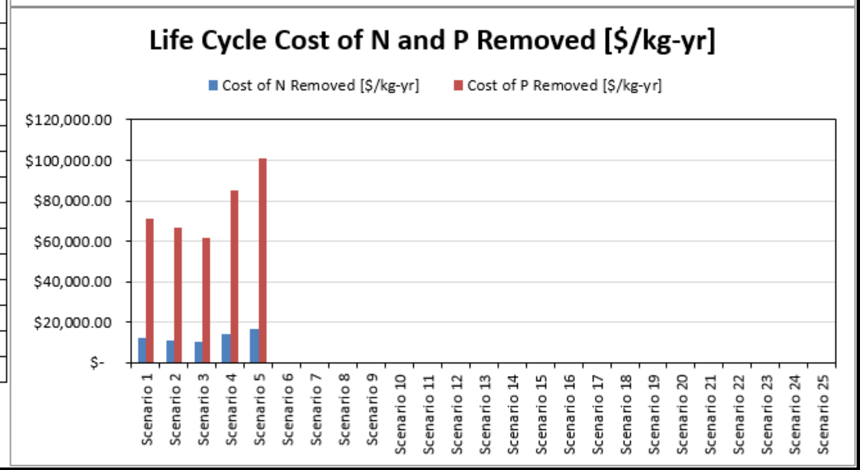


Figure 171 – Life Cycle Cost Analysis Summary Five Design Scenarios

30. Return to **Stormwater Treatment Analysis** worksheet.

Treatment Train Scenario 6

The pervious concrete area, retention basin volume, and additional land required for Scenario 6 are given in Table 14.

Table 14 – Scenario 6 Cost Analysis

BMP Characteristics			
Scenario	Pervious Concrete Area [ac]	Retention Basin Volume [ac-ft]	Additional Land Required [ac]
6	0	0.271	0.171

31. Select the BMP from the list and enter the information into the tab as you did in Step 3; however, this time you will also have to enter information for the retention basin.

a. The information you previously entered for Pervious Pavement should still be in the cells and you will need to change the value for *Area of the pervious pavement system* to **0.0** (see Figure 172 –).

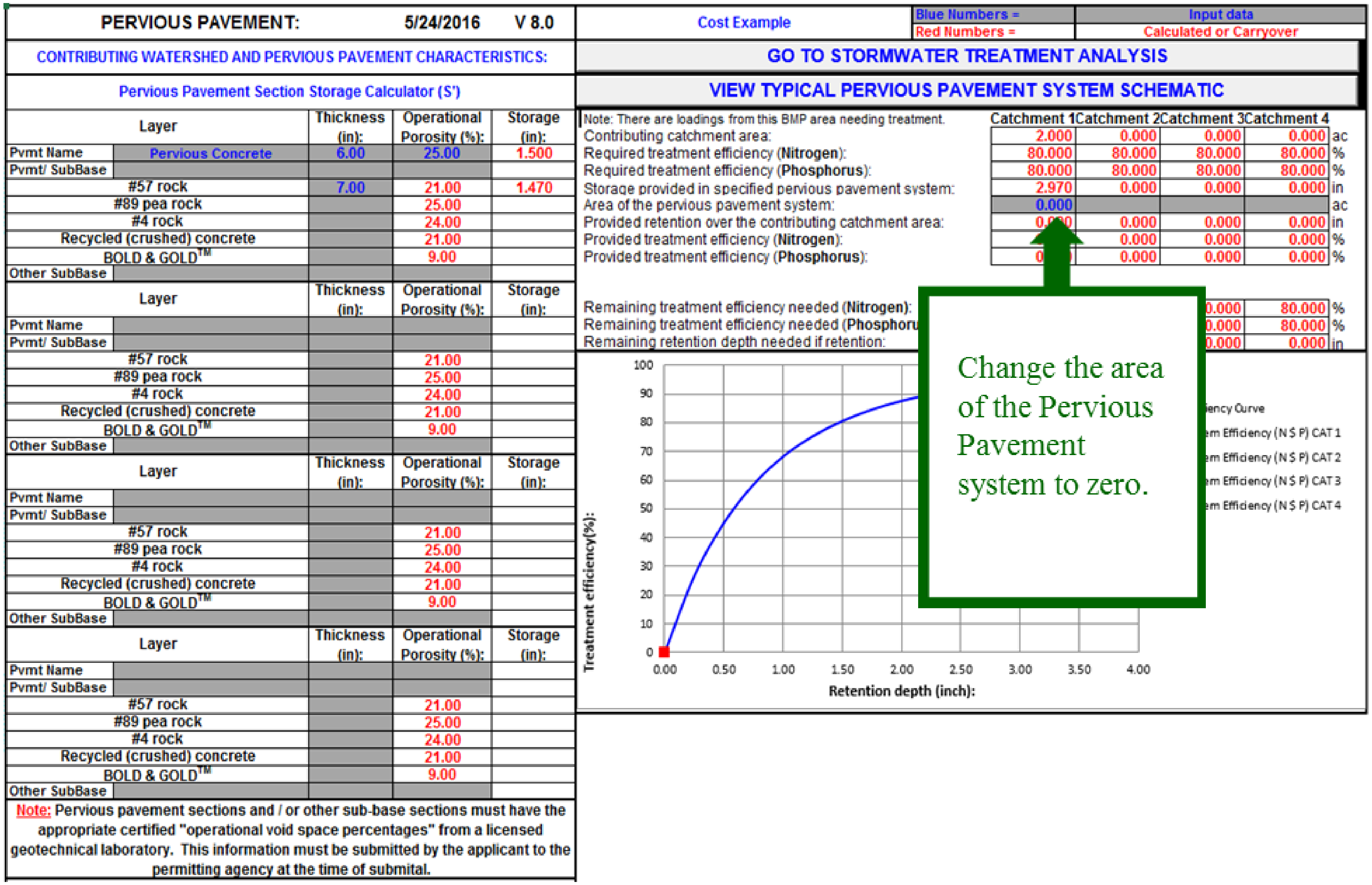


Figure 172 – Pervious Pavement BMP worksheet

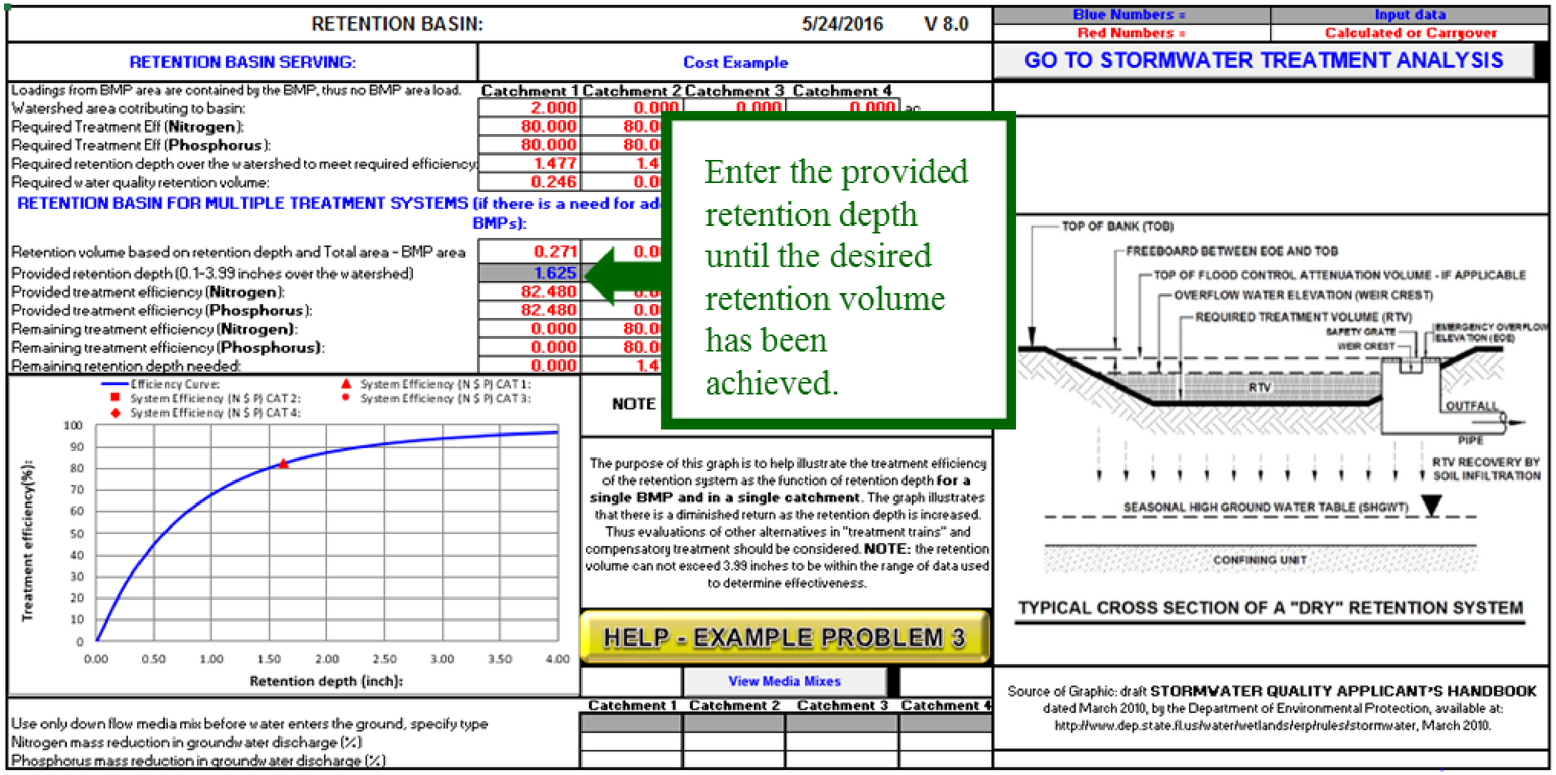


Figure 173 – Retention Basin BMP worksheet

The problem stated that the provided retention volume for this scenario is 0.271 acre-ft. Use an iterative guess and check approach by entering in a *Provided retention depth* and seeing if the *Retention volume based on retention depth and Total area – BMP area* becomes the desired value (see Figure 173 –).

32. Return to the **Stormwater Treatment Analysis** worksheet and click **Catchment and Treatment Summary Results** (see Figure 174).

a. If the treatment objectives are not met, adjust the BMP inputs until it passes.

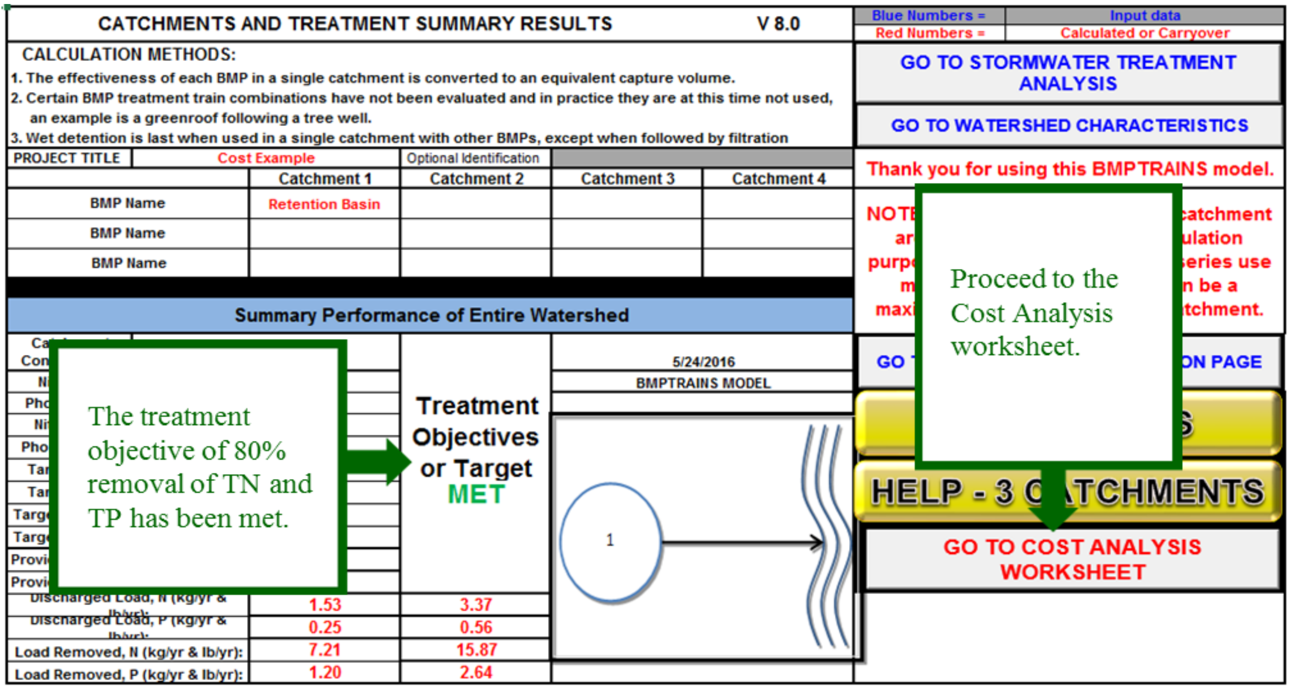


Figure 174 – Catchments and Treatment Summary Results

Scenario 6, Costs

33. This Scenario requires additional land.

a. Based on Zillow, May 2016, 1 acre of land costs about $525,000. For this scenario, the cost to purchase additional land would be $89,775.

b. For the retention basin use the same *BMP Cost per acre-ft* used in Scenario 2, no further data entry is need for capital cost. Additionally, just as in Scenario 2, multiply the formula for *Estimated Annual BMP Maintenance Cost* is 3% of the capital *BMP Cost*.

c. In Scenario 6 there is no pervious pavement present.

34. Fill in the remaining fields (see Figure 175).

a. For *What type of analysis would you like to perform* select “Net Present Worth”

b. The most recent value published by the World Bank is for the year 2014 so we will use this value, which is 1.8%.

c. Problem statement gave life span as 20 years; assume the project duration is the same since not otherwise stated.

d. Leave *BMP Fixed Cost* blank since the source cost data had the *Fixed Data* and *BMP Cost* combined into a single value.

e. Leave *Estimated Future Cost of Replacement* blank since the Project Duration and Expected Lifespan are the same.

f. Leave *Cost Land needed for BMP* blank because according to the data for scenario 3, no additional land is needed.

g. Enter the Scenario #

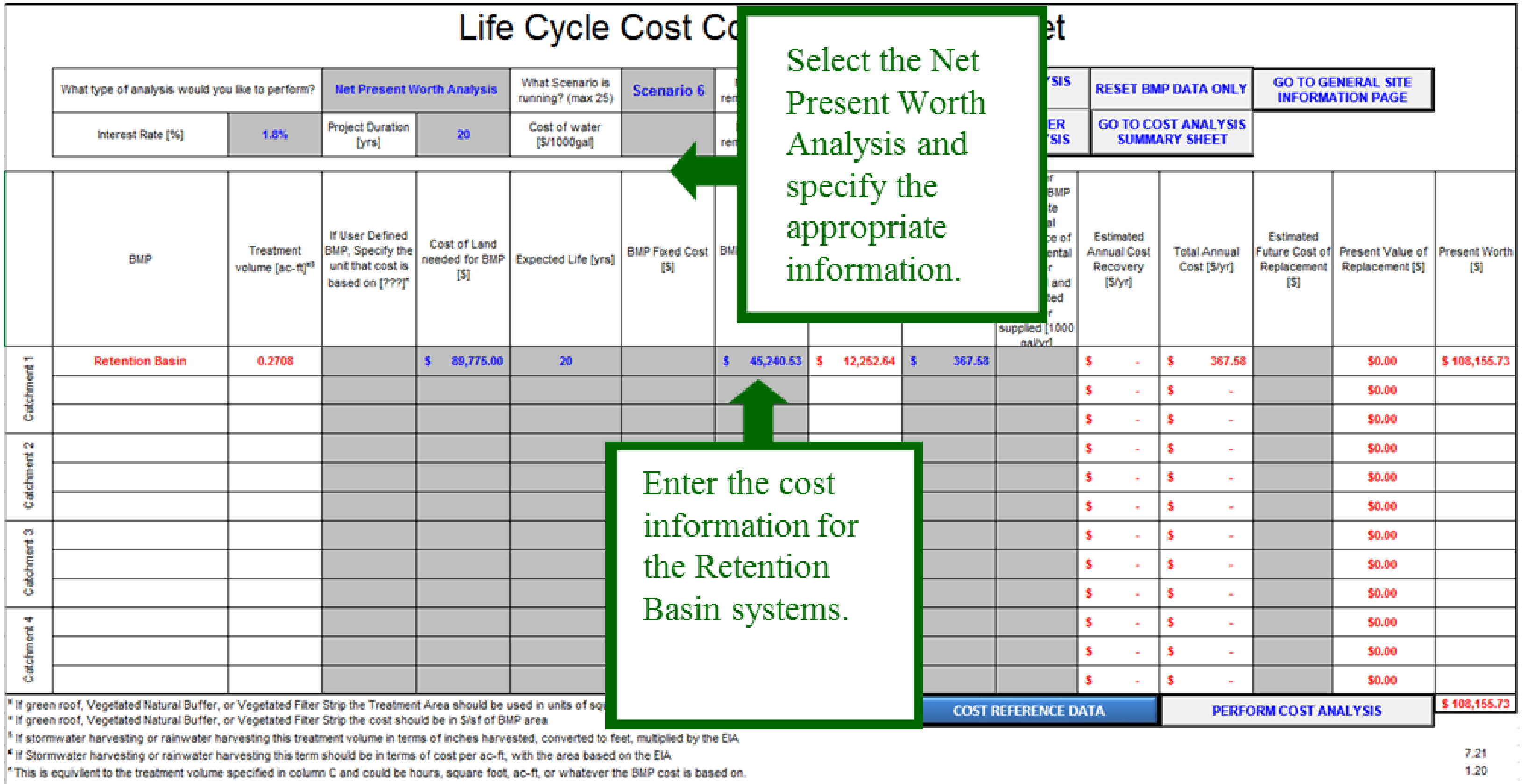
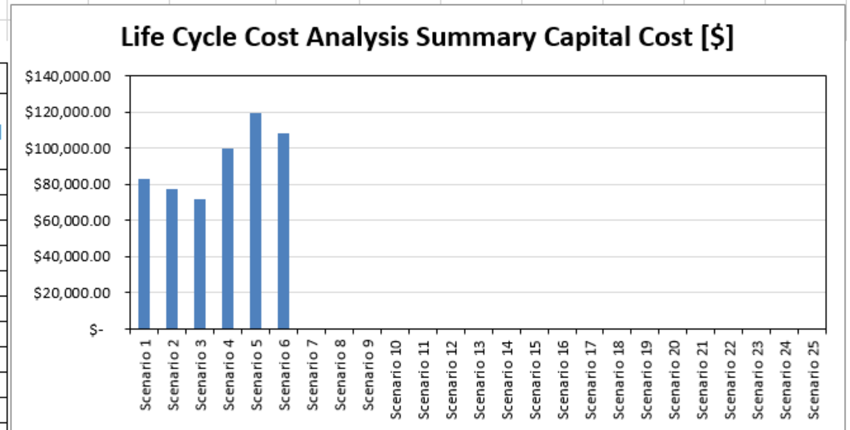


Figure 175 – Life Cycle Cost Comparison Worksheet

35. Perform Cost Analysis (see Figure 176).

GO TO COST ANALYSIS WORKSHEET

Life Cycle Cost Analysis Summary					
	Net Present Worth [$]	Cost of N Removed [$/kg-yr]	Cost of P Removed [$/kg-yr]	TN Removed [kg/yr]	TP Removed [kg/yr]
Scenario 1	$ 83,269.93	$ 11,887.91	$ 71,453.90	7.00	1.17
Scenario 2	$ 77,444.86	$ 11,076.28	$ 66,575.54	6.99	1.16
Scenario 3	$ 71,721.59	$ 10,252.00	$ 61,621.09	7.00	1.16
Scenario 4	$ 99,852.33	$ 14,135.78	$ 84,965.07	7.06	1.18
Scenario 5	$ 119,064.22	$ 16,772.15	$ 100,811.30	7.10	1.18
Scenario 6	$ 108,155.73	$ 15,007.20	$ 90,202.82	7.21	1.20
Scenario 7					
Scenario 8					
Scenario 9					
Scenario 10					
Scenario 11					
Scenario 12					
Scenario 13					
Scenario 14					
Scenario 15					
Scenario 16					
Scenario 17					
Scenario 18					
Scenario 19					
Scenario 20					
Scenario 21					
Scenario 22					
Scenario 23					
Scenario 24					
Scenario 25					



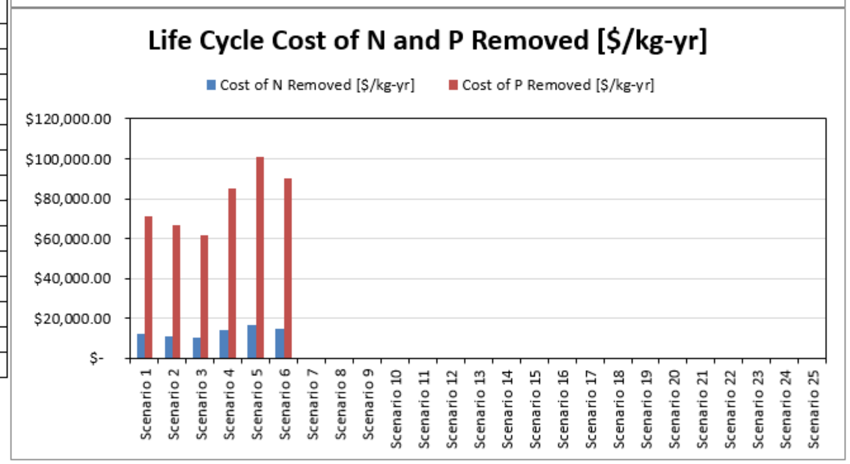


Figure 176 – Life Cycle Cost Analysis Summary

36. As seen in the Life Cycle Cost Analysis Summary, Scenario 3 is the most cost effective treatment method of the six scenarios. Scenario 3 utilizes 0.65 acres of pervious concrete and a retention basin with a volume of 0.0833 acre-feet. In Scenario 3, purchasing additional land is not required.

CHAPTER 5 SUMMARY AND RECOMMENDATIONS

5.1 INTRODUCTION

Comingling of offsite runoff waters into onsite retention or wet detention BMPs is an option for FDOT and others who operate onsite facilities. The decision to comingle offsite water is based on two factors considered in this report. One is the effectiveness of the onsite BMP with and without comingling and the other is cost. Because offsite runoff may come from a multitude of catchment conditions, the BMPTRAINS model was improved to use detailed land use and soil data to calculate average annual EMCs and offsite and onsite runoff.

Before this research, there were no acceptable methodologies to calculate the removal effectiveness of comingling for a fixed size of onsite BMP. The BMPTRAINS analysis and design program was improved to incorporate cost and effectiveness for comingling options. The program is acceptable for use by all the water management districts and the Department of Environmental Regulation within the state of Florida.

5.2 SUMMARY

To evaluate the addition of offsite runoff to an existing or yet to be designed onsite BMP, BMPTRAINS is modified to add calculations for offsite runoff as it affects the removal effectiveness of onsite BMPs, calculations for capital and present worth costs, and an improved routine for estimating runoff from a catchment with multiple soil and land uses.

Simulation for runoff capture volume using five rainfall locations within the state of Florida were completed. Seventy-five (75) runoff simulations for each of the five sites use a combination of values for three causative parameters, namely runoff volume, delay of offsite runoff to reach an onsite BMP, and treatment size of the onsite BMP. The rainfall locations reflect the five meteorological zones used for stormwater treatment in the state. The onsite BMPs were retention and wet detention types. The simulations calculate the capture volume. The mass of each pollutant and removal effectiveness is determined by multiplying the concentration of nitrogen and phosphorus by the runoff volume and the capture volume. The results of the simulations for capture volume are summarized in equation form and built into the BMPTRAINS model. The mass removal is calculated for any catchment configuration and rainfall condition using the BMPTRAINS model. The BMPTRAINS model is an accepted methodology for analyzing stormwater treatment effectiveness of BMPS.

Example problems illustrate the use of the BMPTRAINS model considering onsite as well as of offsite runoff. There are 17 example problems to aid in the use of the model. To aid in the decision to bypass or not to bypass an onsite BMP, cost analysis can be prepared with the BMPTRAINS model. One of the example problems demonstrates the calculation of cost for different alternative BMP treatment trains. The BMPTRAINS model is also enhanced with the addition of a routine to incorporated mixed soil and cover conditions within a catchment and an example problem is presented.

5.3 RECOMMENDATIONS

Designers and reviewers are encouraged to use the option of comingling offsite runoff stormwater within onsite BMPs. Cost and Effectiveness should be analyzed with the BMPTRAINS program.

When considering both onsite and offsite loadings, comingling can result in more removal and at an acceptable cost. Nevertheless, the BMPTRAINS program will also aid in determining when a comingling should not be done. Evaluation of retention and wet detention BMPs is possible.

Appendix A EMCs and Land Use

The 2016 Event Mean Concentration (EMC) values are listed in Table 15. They are based on the arithmetic mean for the data collected. They are identified by land use, thus a description for each land use is presented. In addition, Florida Land Use Codes and Classification System (FLUCCS) descriptions are listed and related to the land use descriptions used in the Model.

Table 15 – EMCs and Land Use

LAND USE CATEGORY	TN	TP
Agricultural - Citrus: TN=2.240 TP=0.183	2.24	0.183
Agricultural - General: TN=2.800 TP=0.487	2.8	0.487
Agricultural - Pasture: TN=3.510TP=0.686	3.51	0.686
Agricultural - Row Crops: TN=2.650 TP=0.593	2.65	0.593
Conventional Roofs: TN=1.050 TP=0.120	1.05	0.12
High-Intensity Commercial: TN=2.40 TP=0.345	2.4	0.345
Highway: TN=1.520 TP=0.200	1.52	0.2
Light Industrial: TN=1.200 TP=0.260	1.2	0.26
Low-Density Residential: TN=1.645 TP= 0.27	1.645	0.27
Low-Intensity Commercial: TN=1.13 TP=0.188	1.13	0.188
Mining / Extractive: TN=1.180 TP=0.150	1.18	0.15
Multi-Family: TN=2.320 TP=0.520	2.32	0.52
Single-Family: TN=2.070 TP=0.327	2.07	0.327
Undeveloped - Dry Prairie: TN=2.025 TP=0.184	2.025	0.184
Undeveloped - Marl Prairie: TN=0.684 TP=0.012	0.684	0.012
Undeveloped - Mesic Flatwoods: TN=1.09 TP=0.043	1.09	0.043
Undeveloped - Ruderal/Upland Pine: TN=1.694 TP=0.162	1.694	0.162
Undeveloped - Scrubby Flatwoods: TN=1.155 TP=0.027	1.155	0.027
Undeveloped - Upland Hardwood: TN=1.042 TP=0.346	1.042	0.346
Undeveloped - Upland Mix Forest: TN=0.606 TP=1.166	0.606	1.166
Undeveloped - Wet Flatwoods: TN=1.213 TP=0.021	1.213	0.021
Undeveloped - Wet Prairie: TN=1.095 TP=0.015	1.095	0.015
Undeveloped - Xeric Scrub: TN=1.596 TP=0.156	1.596	0.156
Apopka Open Space/Recreation/Fallow Crop: TN=1.100 TP=0.050	1.1	0.05
Apopka Forests/Abandoned Tree Crops: TN=1.250 TP=0.080	1.25	0.08
Rangeland/Parkland: TN=1.150 TP=0.055	1.15	0.055
Undeveloped natural communities: TN=1.22 TP=0.213	1.22	0.213
GIS Import Data		
User Defined		

The general land use categories and a brief description used in the BMPTRAINS model are shown in Table 16.

Table 16 – General Land Use and Description in BMPTRAINS*

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
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

*Excerpt from document titled "Refining the Indian River Lagoon TMDL, (July 2013) – Technical Memorandum Report: Assessment and Evaluation of Model Input Parameters" – Final Report; Prepared by Harvey Harper, Environmental Research & Design, Inc.; July 2013.

In Table 17, there is a listing of some FLUCCS codes. These are consistent with the FDOT FLUCCS definitions. A more extensive list is available in BMPTRAINS.

Table 17 – Level III FLUCCS Code Assignments to Consolidated Land Use Categories

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
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
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*
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

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 18 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 178.

Table 18 – United States CPI-U (U.S. Department of Labor Statistics, 2016)

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
2016	To be determined

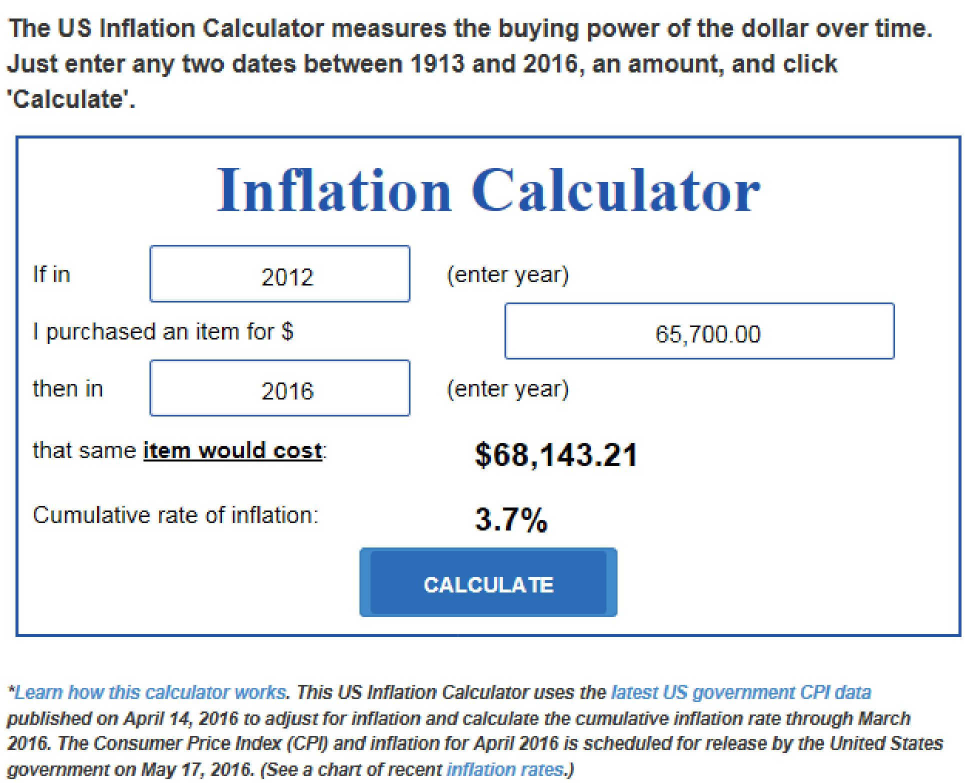


Figure 177 – US Department of Labor Statistics Inflation Calculator http://www.usinflationcalculator.com/ (US Department of Labor Statistics, 2016)

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 (World Bank, 2016) see Table 19. 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 19 – Real Interest Rates for the United States (World Bank 2016)

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 20, and operational for various BMPs, Table 21. The cost data in Table 20 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, et al., 1999).

Table 20 – Typical Capital Construction Costs for BMPs (Strassler, et al., 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 21 – Annual Maintenance Costs of BMPs (Strassler, et al., 1999)

BMP	Annual Maintenance Cost (% of Construction Cost)
Retention Basins and Constructed Wetlands	3%-6%
Detention Basins[1]	<1%
Constructed Wetlands[1]	2%
Infiltration Trench	5%-20%
Infiltration Basin[1]	1%-3%
	5%-10%
Sand Filters[1]	11%-13%
Swales	5%-7%
Bioretention	5%-7%
Filter strips	$320/acre (maintained)

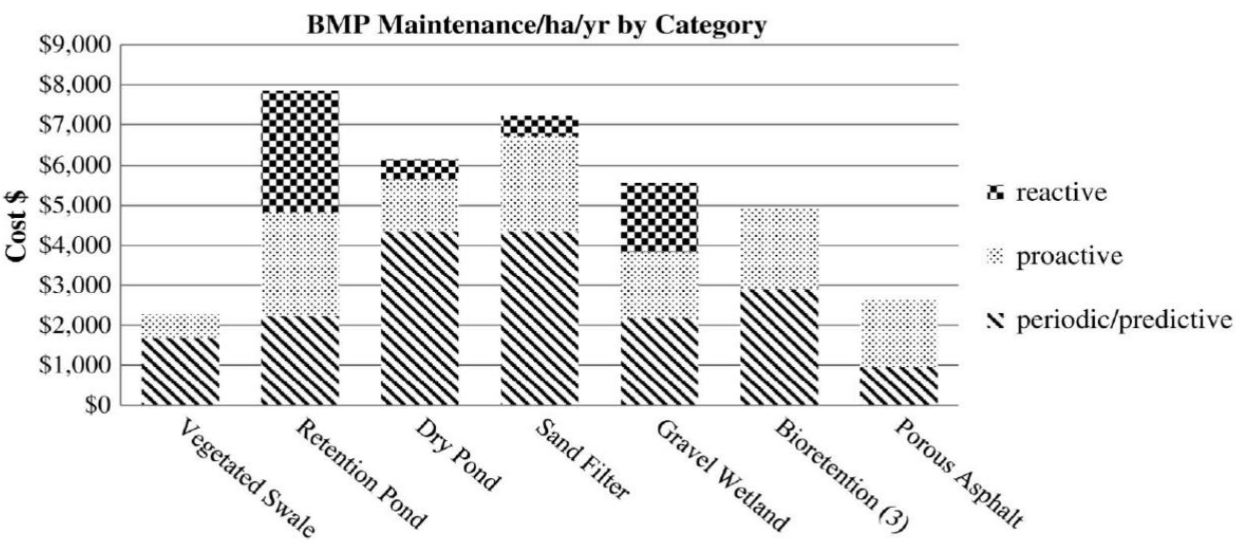
1. Local data in Florida are similar and does vary with location.

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 22), 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 BMPTRAINS 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 BMPTRAINS model Net Present Worth Analysis feature does. *Whole Life Cycle Costs* style data could be evaluated using the Capital Cost feature in the BMPTRAINS model. Care must be exercised when doing this as the assumptions must consistent between the BMPTRAINS Model and the source of the cost data.

Table 22 – 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. Information in the literature (Houle et al, (2013), discusses capital and maintenance costs on an area and gram of pollutant removed basis for swales, ponds, bioretention, pervious pavements, and others. Another article by Seters et al., (2013) is more general for all LID situations. A few examples of capital and maintenance costs figures and tables from the article are shown below in Figure 179,



- 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 178 – Annualized Maintenance Costs per Hectare of Impervious Cover 2012 Basis (Houle, et al., 2013)

Table 23 – Capital and Maintenance Cost Data, with Normalization per Hectare of Impervious Cover Treated (Houle, et al., 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 24 – 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, et al., 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 life cycle costs of several types of BMPs including swales, bioretention systems, ponds, filters, and street sweeping (Taylor and Wong, 2002) was completed that adds published cost data. Table 25 compares the life cycle costs of two different types of street sweepers. Also see a publication by the Water Environment Federation (Pomeroy, and Rowney, 2009).

Table 25 – US Street Sweeping Cost Information (Taylor and 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

Weiss provided cost information 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, et al., 2007).

Another example of a BMP cost data source is the Summary of Cost Data (2007) spreadsheet published by the International Stormwater Database (Wrigth Water Engineering and Geosyntec Engineering, 2007), This Excel workbook published by the International Stormwater Database, contains cost estimates and the year of the estimate for ponds, green roofs, grass swales, porous 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 those from individuals (Curtis, 2002) and Geosyntec Consultants, (2015).

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