University of Central Florida BMPTRAINS Model Update

BMPTRAINS Cost TECHNICAL MEMORANDUM

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1. Introduction

The protection of surface water bodies is a priority in the United States and around the world. Stormwater discharges are identified by the USEPA as a significant source of pollution to surface water bodies (USEPA, 2009). The control of nutrients in stormwater runoff is a particular concern as it relates to the control of harmful algal blooms and dead zones in water bodies. Methods have been identified in the literature to reduce the volume of stormwater runoff generated in urban areas or reduce the pollutants in stormwater runoff before discharge (Chang, Islam, Marimon, & Wanielista, 2012; Hardin, 2006; Harper & Baker, 2007; Hood, Chopra, & Wanielista, 2013; O'Reilly, Wanielista, Chang, Xuan, & Harris, 2012; Sansalone, Kuang, & Ranieri, 2008; Wanielista, Yousef, Harper, & Dansereau, 1991). These methods are called low impact development (LID), which could be grouped into the wider classification of best management practices (BMP).

Many of these BMPs have been examined to describe their performance however, the use of this information is difficult as the information is scattered in many different sources and the studies have been done for specific regions or conditions. In an effort to address this, many state and local governments have been developing BMP manuals which attempt to gather the information on design and performance in a convenient to use manual (Burack, Walls, & Stewart, 2008; Michigan Department of Environmental Quality, 1999; Urban Drainage and Flood Control District, 2015; Seters, Graham, & Rocha, 2013; Powell, et al., 2005; Pomeroy, 2009). However, these manuals are not able to account for changes in expected efficiency due to spatial and temporal differences in site conditions nor do they provide adequate guidance on how to determine overall nutrient reduction achieved. Additionally, in many instances, the use of a single BMP is insufficient to achieve the goals of nutrient reduction and flood control in urban areas. It is for these reasons that a tool to analyze the use of several BMPs in different configurations is needed. This is called a treatment train approach.

The BMPTRAINS Model is a software modeling tool developed by the University of Central Florida Stormwater Management Academy (Client) to assess the performance of stormwater BMPs across the state of Florida. As such, the rainfall characteristics, typical event mean concentration (EMC) data for the common land uses across the state, and common BMPs are summarized and programmed into the model. The model is user friendly and the underlying methodology is accepted by all the water management districts in the State.

The work described herein is a result of the Client's desire to add features and update the model to accommodate more types of BMPs, analyze cost, and to provide for more user flexibility and functionality of the model. This memorandum focuses on the cost component of this project. Geosyntec Consultants Inc., (Geosyntec) added two worksheets to the BMPTRAINS Model which will allow for the evaluation of cost of BMPs. A description of the methodology utilized is provided in the Methods section below.

Due to the temporal and spatial variation in price for different construction practices and products, reference cost data have not been programed into the model and is left to be a user defined input. This will ensure that the model does not need to be continuously updated with cost information and remains relevant to the practitioners. When choosing and designing BMPs for nutrient removal, it is important to consider capital cost, operating (maintenance) cost, and performance data. As a refinement of the BMPTRAINS Model, Geosyntec performed a thorough review of the literature to identify sources of reference cost (capital & operating) data for various BMPs such as street sweeping, wet detention ponds, dry retention ponds, bioretention, pervious pavements, green roofs, swales, and filter strips. This data is from both government sources as well as journal articles. Furthermore, Geosyntec identified sources to estimate land value. It is understood that this information will be provided to the Client and the Client will host this information on their website. Geosyntec will provide a button in the model which will redirect model users to the reference information. The Client will then maintain the information as they see fit.

2. Methods

Version 8.0 of the BMPTRAINS model has the capability to perform a cost analysis for any given BMP design within the model. This feature allows the user to evaluate either present worth or capital cost for each design scenario considered for a project. The ability to perform the cost analysis on multiple treatment scenarios to achieve a desired TN and TP reduction goal provides the user with the economic benefits associated with each treatment option. It should be mentioned that in order for such a cost comparison analysis to be relevant, the same removal efficiency should be achieved for each scenario examined.

The cost feature was developed with the goal to find a minimum cost for a specified performance criterion, i.e. 80% removal of TN and TP. A cost function needed to be developed to make comparisons across different stormwater treatment scenarios. The expression for the general form of the equation is shown below in Equation 2-1.

Equation 2-1

$$\boldsymbol{Min\ Cost = \sum_{i=1}^{12} C_i X_i}$$

Where C_i is the cost per unit size of the i^{th} BMP brought to present value and X_i is the size of the i^{th} BMP. The range of “i” varies from 1 to 12 since a maximum of 12 BMPs, out of the 15 available, can be analyzed within a given watershed. The maximum 12 BMPs achievable are based on a maximum of three BMPs per catchment and four catchments.

The cost component of Equation 2-1 includes the cost of constructing, operating, and maintaining the BMP. Equation 2-2 describes the components of the overall cost for the ith BMP:

Equation 2-2

$$C_i = C_{IC} + C_{OM} - C_R$$

C_{IC} is the initial capital cost of the BMP, which includes design costs, mobilization costs, land costs, construction materials and other costs. C_{OM} is the operating and maintenance cost of the BMP. The C_{OM} is a reoccurring cost, usually yearly, that is required to ensure that the BMP operates as intended. C_R is cost recovery achieved by the BMP. Some BMPs can generate revenues, such as harvesting operations, which generate water that can be utilized instead of potable supplies. This cost recovery results in a reduction of cost for the specific BMP which may lead to it having a lower present worth than a BMP that is not able to recover cost. Additionally, the protection of surface water bodies, as well as other natural resources, should have some cost benefit associated with it. This cost benefit can be incorporated into the cost analysis by subtracting the cost benefit from the operating and maintenance cost.

Since the value of money changes with time, money spent in the future may not have the same value as money spent today. Due to this, both the C_{OM} and C_R components must be brought to present value for the desired number of periods to be included in the analysis. The equation used for present worth analysis is that presented by Park (Park, 2002) as expressed in Equation 2-3.

Equation 2-3

$$P = A\left[\frac{(1+i)^N - 1}{i(1+i)^N}\right]$$

Where P is present worth, A is annual cost, "i" is the interest rate, and N is the number of periods. The reoccurring costs, C_{OM} and C_R, would be used in Equation 2-3 above in place of A because each is in terms of annual cost. Life cycle cost will be defined in present worth dollars.

Furthermore, a cost analysis can be based on capital cost if the user is only interested in initial capital cost of the project. The capability of the BMPTRAINS model to perform a cost analysis is provided on the Cost Comparison Worksheet, where multiple scenarios can be selected from a drop-down menu. When examining the capital costs, the future costs associated with operation and maintenance, replacement cost, and future revenue generated are not considered. This is because, for a capital cost analysis, only the up-front costs are considered which will be useful if the user is not the owner and thus will not operate or maintain the BMP.

Since costs for various activities will vary spatially and temporally, the user is required to input all cost data. As noted previously, part of this effort is to collect and review published cost data. The results of this effort are presented in Section 3 below. The use of published cost data allows the designer to make decisions using a common cost metric and while the true cost may be different than what is presented in the literature, it can be assumed that the same difference exists for most BMPs and BMP components.

The cost analysis worksheet allows the user to select between two types of analysis options, capital cost or net present worth. The cost analysis for a net present worth evaluation would require the following information in addition to BMP specific cost information: interest rate, project duration, and cost of water (if relevant). The cost of water is only relevant for BMPs that harvest stormwater, since these BMPs will greatly reduce potable water usage. The user has the option to split the BMP cost into two components, the fixed cost and the variable cost. An example of fixed cost is the cost of mobilization. An example of a variable cost is the cost to excavate soil. The user is required to specify the cost of land needed for the BMP, if applicable, the expected life of the BMP in years, the fixed cost portion of the BMP, the variable cost of the BMP, the estimated annual BMP maintenance cost, and the estimated future cost of replacement. The estimated cost of future replacement is only relevant if the project duration is greater than the expected life of the BMP. The model uses these inputs to calculate the net present worth for each scenario specified by the user. An illustration on the use of the cost feature is presented in the Cost Analysis Example section (Section 5) of this memo.

3. Sources for BMP Cost Data

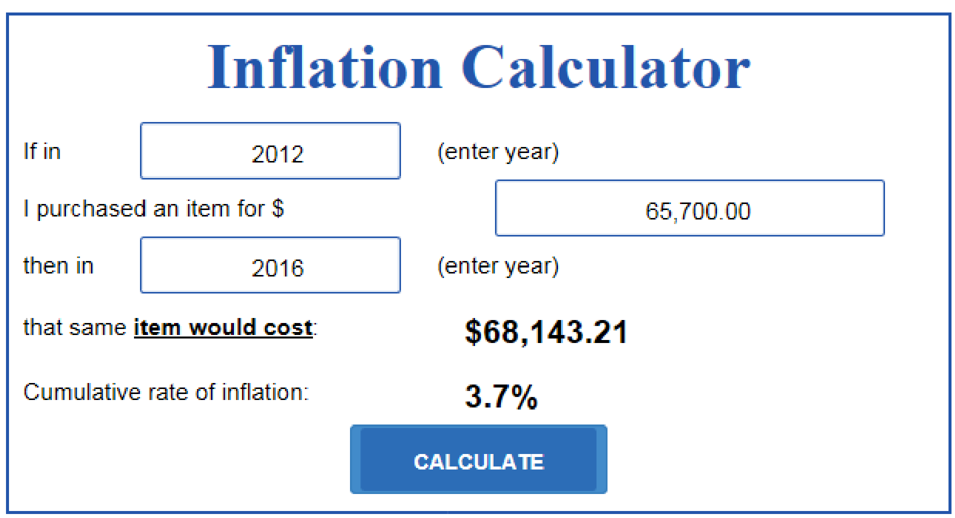
Due to the temporal and spatial variation in price for different construction practices and products, cost is a user input. This will ensure that the model does not need to be continuously updated with cost information and remains relevant to the practitioners. Reliable sources of cost data can be found 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, should the user have better (more recent, site specific, etc.) cost data, that be used.

When using published cost data, it is important to keep in mind inflation if the data is 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; however 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 3-1. 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 for you, see Figure 3-1 (Park, 2002; US Department of Labor Statistics, 2016).

Table 3-1: 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

The US Inflation Calculator measures the buying power of the dollar over time. Just enter any two dates between 1913 and 2016, an amount, and click 'Calculate'.



****Learn how this calculator works*. This US Inflation Calculator uses the *latest US government CPI data* published on April 14, 2016 to adjust for inflation and calculate the cumulative inflation rate through March 2016. The Consumer Price Index (CPI) and inflation for April 2016 is scheduled for release by the United States government on May 17, 2016. (See a chart of recent *inflation rates*.)**

Figure 3-1: US Department of Labor Statistics Inflation Calculator http://www.usinflationcalculator.com/ (US Department of Labor Statistics, 2016)

When determining the present value/worth of a proposed project, data can be adjusted to present worth, or any other year, by using an interest rate. The ability to bring all costs to a present worth is critical when comparing opportunity costs of different design options with varying annual operation and maintenance costs and lifespans. It is recommended to use the World Bank for information on interest rates. The World Bank provides yearly *real interest rates*, as well as other forms of interest rate, for various countries, including the United States (The World Bank), see Table 3-2. Real interest rate, also known as inflation-free interest rate, is an estimate of the true earning power of money once the inflation effects have been removed. Real interest rate is used in *constant dollar analysis*. Constant dollar analysis is used when all cash flow elements needed are provided in constant dollars and you want to compute the equivalent present worth of the constant dollars. Constant dollar analysis is commonly used in the evaluation of long-term public projects since governments do not pay income taxes (Park, 2002). When obtaining costs from journal articles and reports it can be assumed, unless otherwise stated, that the costs presented are in terms of dollars in the year the article was written/submitted. If the year the article is written or submitted is not available, then assume that the cost are in terms of the year prior to publication.

Table 3-2: Real Interest Rates for the United States (The World Bank)

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

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

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

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

* Base year for all cost data: 1997

Table 3-4: Annual Maintenance Costs of BMPs (Strassler, Pritts, & Strellec, 1999)

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

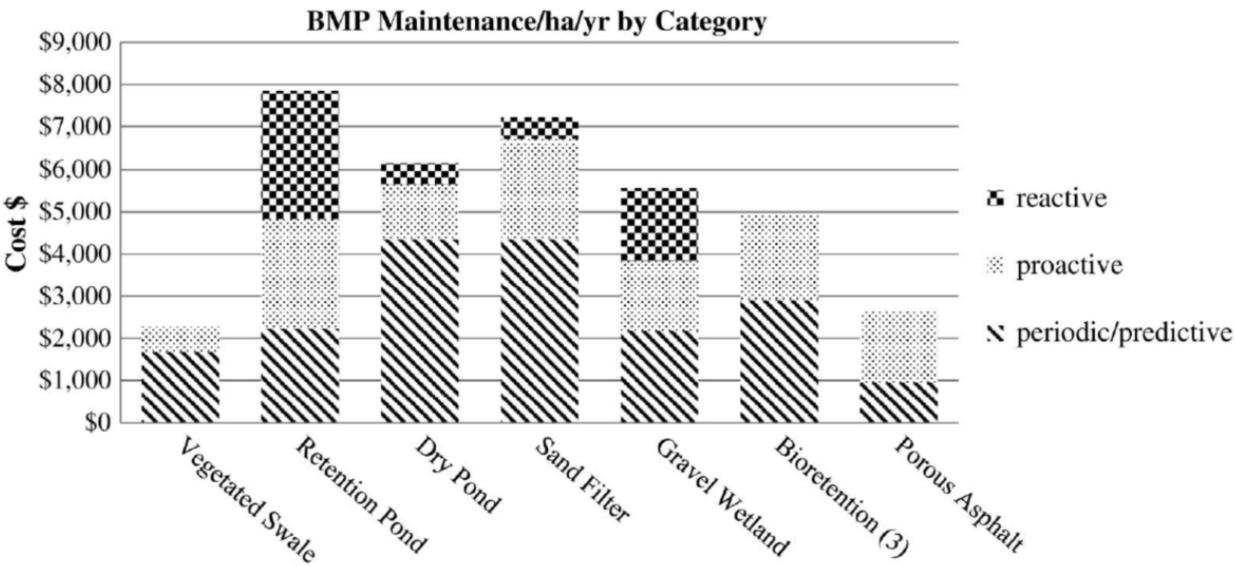
1. Livingston et al (1997) reported maintenance costs from the maintenance budgets of several cities, and percentages were derived from costs in other studies

The Transportation Research Board published a document titled the NCHRP REPORT 792; this report is an excellent source of data for capital cost, operating cost, life span (see Table 3-5), and performance data on a cost basis for various BMPs (Taylor, et al., 2014). It is important to note that several of the tables in this report provide *Whole Life Cycle Costs*. Care must be taken when using *Whole Life Cycle Costs* with the 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 3-5: BMP expected life span (Taylor, et al., 2014)

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

Cost data can also be found in journals such as the ASCE Journal of Environmental Engineering. The article by Houle (Houle, Roseen, Ballestero, Puls, & Sherrard Jr., 2013), which discusses capital and maintenance costs on an area and gram of pollutant removed basis for swales, ponds, bioretention, pervious pavements, and others. A few examples of capital and maintenance costs figures and tables from the article are shown below in Figure 3-2, Table 3-6, & Table 3-7.



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

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

Table 3-6: Capital and Maintenance Cost Data, with Normalization per Hectare of Impervious Cover Treated (Houle, Roseen, Ballestero, Puls, & Sherrard Jr., 2013) **[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.]**

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.

Table 3-7: Summary of Removal Performance and Comparison per kg Removed of TSS and per g Removed of TP and TN as *Dissolved Inorganic Nitrogen (DIN)* (Houle, Roseen, Ballestero, Puls, & Sherrard Jr., 2013) [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.]

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 2012 article by Taylor and Wong discusses the life cycle costs of several types of BMPs including swales, bioretention systems, ponds, filters, and street sweeping (Taylor & Wong, 2002). Table 3-8 below compares the life cycle costs of two different types of street sweepers.

Table 3-8: US Street Sweeping Cost Information (Taylor & Wong, 2002)

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

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

Another example of a BMP cost data source is the Summary of Cost Data (2007) spreadsheet published by the International Stormwater Database (Wrigth Waters Engineers, Inc. and GeoSyntec Consultants, 2007). This Excel workbook published by the International Stormwater Database, prepared by Wright Waters Engineers, Inc. and Geosyntec Consultants, contains cost estimates and the year of the estimate for ponds, green roofs, grass swales, 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 the reports by Curtis, 2002 (Curtis, 2002) and Geosyntec Consultants, 2015 (Geosyntec Consultants, 2015).

4. Land Value Data

An important cost consideration when planning BMPs, especially land intensive ones such as ponds and wetlands, is land cost. For Florida agricultural, commercial, and residential land it is best to check with Florida's local county property appraisers; the Florida Department of Revenue provides a webpage with links to Florida's various county property appraiser offices (http://dor.myflorida.com/dor/property/appraisers.html) (Florida Department of Revenue, 2016). Another source that can have relevant information is www.zillow.com and similar sites. For general values of agricultural land in the United States, the United States Department of Agriculture (USDA) publishes a yearly Land Values Summary (National Agricultural Statistics Service, 2015). The values of farm land, cropland, and pasture land for the various states in the Union are presented below in Figure 4-1, Figure 4-2, and Figure 4-3.

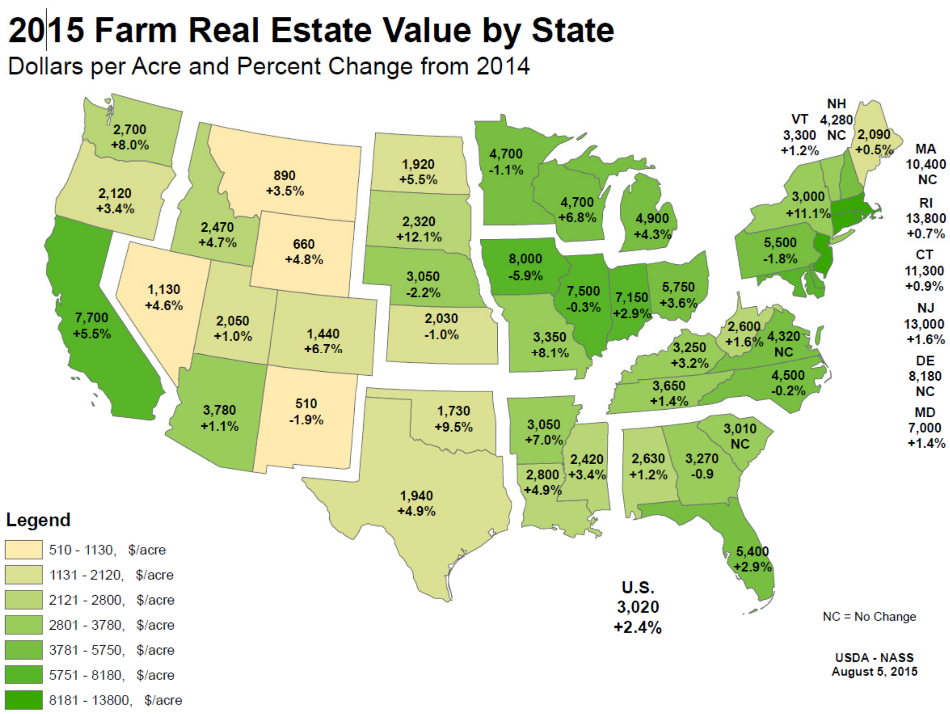


Figure 4-1: Farm Land Value by State (National Agricultural Statistics Service, 2015)

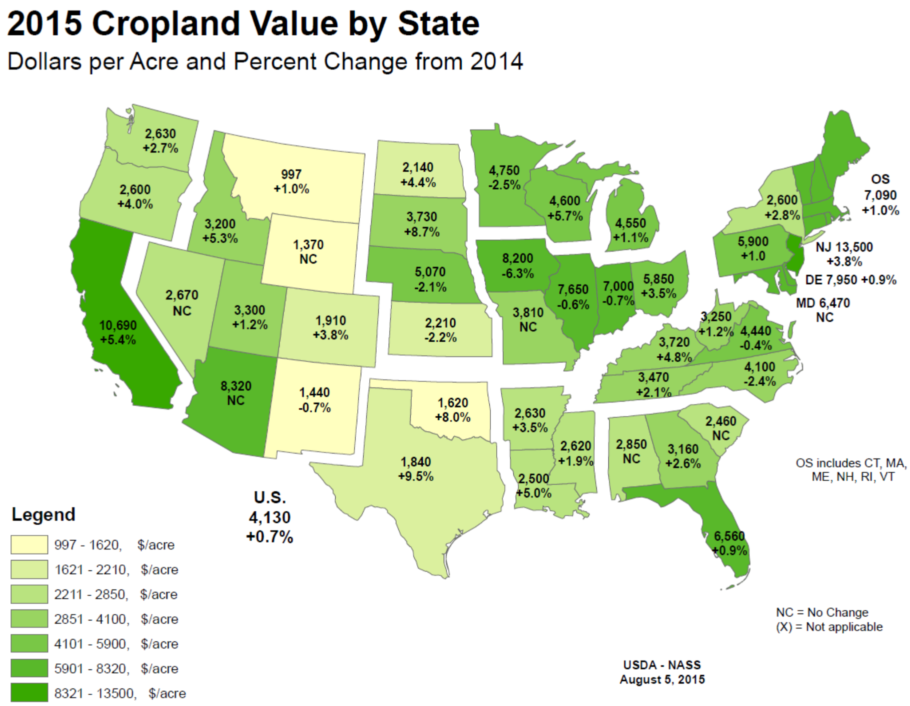


Figure 4-2: Cropland Value by State (National Agricultural Statistics Service, 2015)

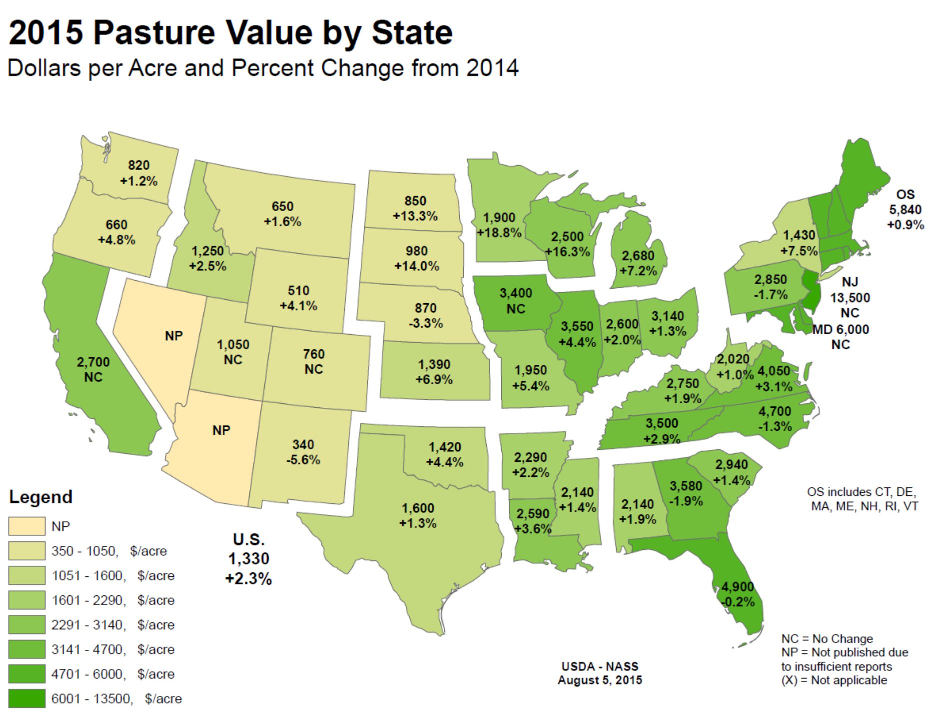


Figure 4-3: Pasture Land Value by State (National Agricultural Statistics Service, 2015)

5. Cost Example

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 were 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 was 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 were 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 were 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 was 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 was 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 was calculated at $200,561.29 per acre-ft. of treatment provided. The cost to maintain the installed pervious concrete was $2,017.28 per year, based on the cost of vacuum sweeping and other maintenance activities. If pervious concrete was not used as a BMP, there was no associated maintenance cost for vacuum sweeping and other activities. The cost to build the retention basin was based on a capital cost of $0.70 per cubic ft. of water treated in 1997 dollars. This value corresponds to a total capital cost of $45,240.53 per acre-ft. of treatment provided in 2016 dollars. The maintenance cost for the retention basin was assumed to be 3% of the capital cost per year (see Table 3-4).

The period analysis for this example was 20 years and an interest rate of 1.8% was assumed, based on the most recent values published by the World Bank in 2014. Table 5-1 shows a summary of the different BMP scenarios examined. For the first scenario, only a pervious concrete parking lot was used, while for the sixth scenario only a retention basin was used. Scenarios two through five have different combinations of the two BMPs in series.

Table 5-1 – Summary of BMP characteristics for the six scenarios evaluated

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. From the introduction page click on the *Click Here to Start* button to proceed to the **General Site Information** worksheet (see Figure 5-1).

   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.

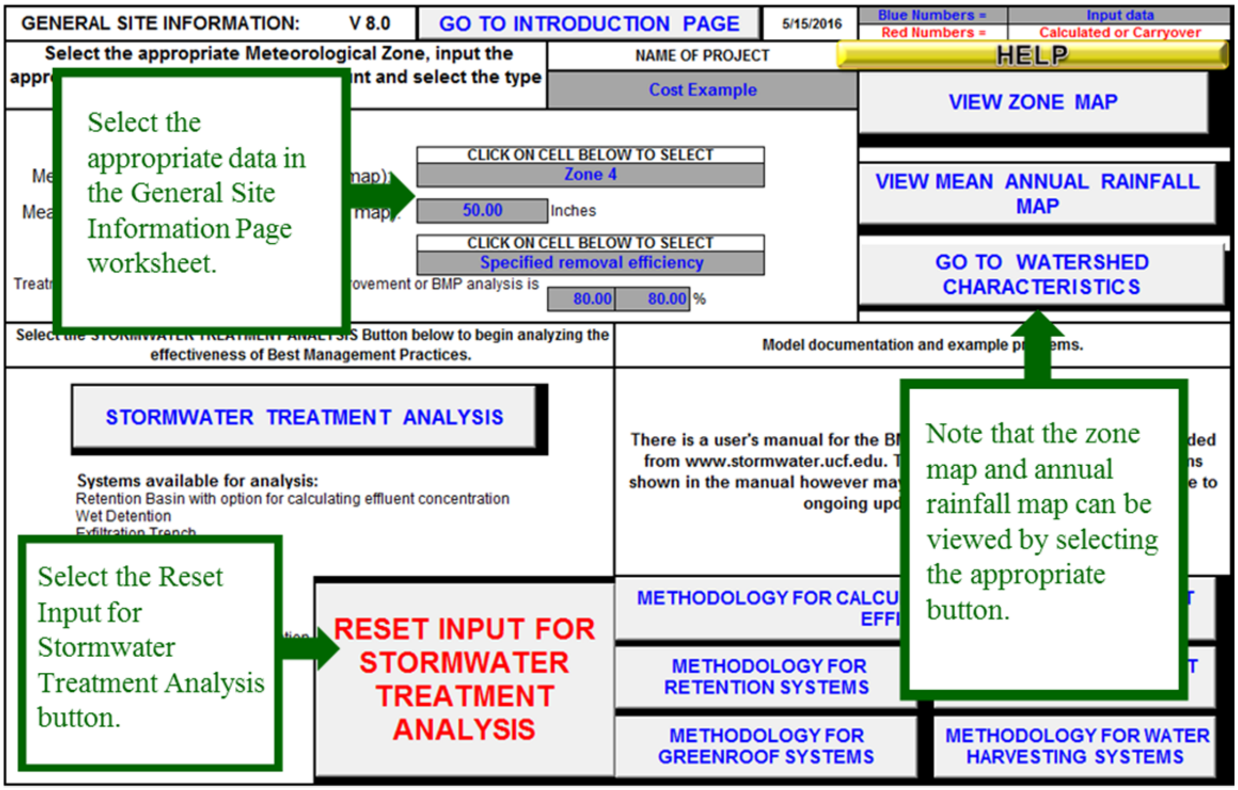


Figure 5-1 – General Site Information worksheet

2. Click **Watershed Characteristics**.

a. In the *Click on Cell Below to Select Configuration* drop-down menu, select **A – Single Catchment** (see Figure 5-2).

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.

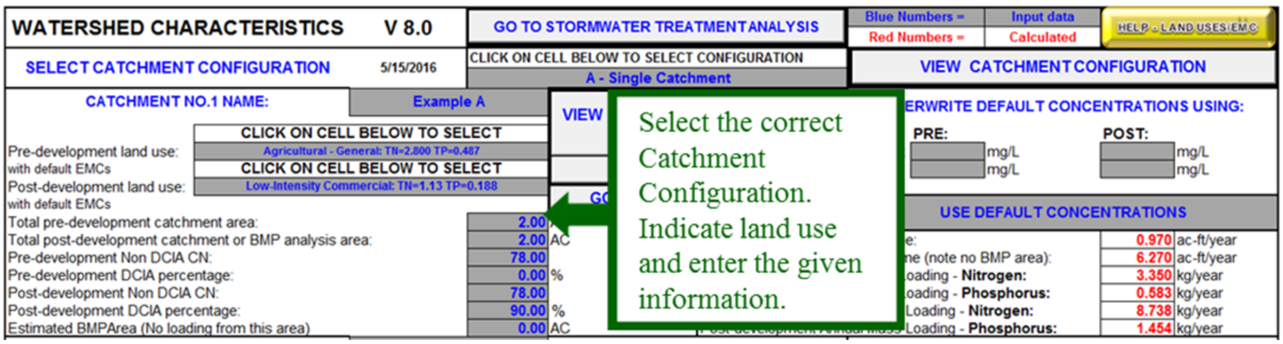


Figure 5-2 – Watershed Characteristics Worksheet

Scenario 1

The pervious concrete area, retention basin volume, and additional land required for Scenario 1 is presented in Table 5-2.

Table 5-2 – Scenario 1

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

3. Click **Go to Stormwater Treatment Analysis.**

   a. Select the **Pervious Pavement** tab (see Figure 5-3).

   b. Enter **Pervious Concrete** in the *Pvmt Name* cell (see Figure 5-4).

   c. Enter **6.0** in the *Pervious Concrete Thickness (in)* cell (see Figure 5-4).

   d. Enter **25.0** in the *Pervious Concrete Operational Porosity (%)* cell (see Figure 5-4).

e. Enter **7.0** in the *#57 rock Thickness (in)* cell (see Figure 5-4).

f. Enter **1.0** in the *Area of the pervious pavement* cell (see Figure 5-4).

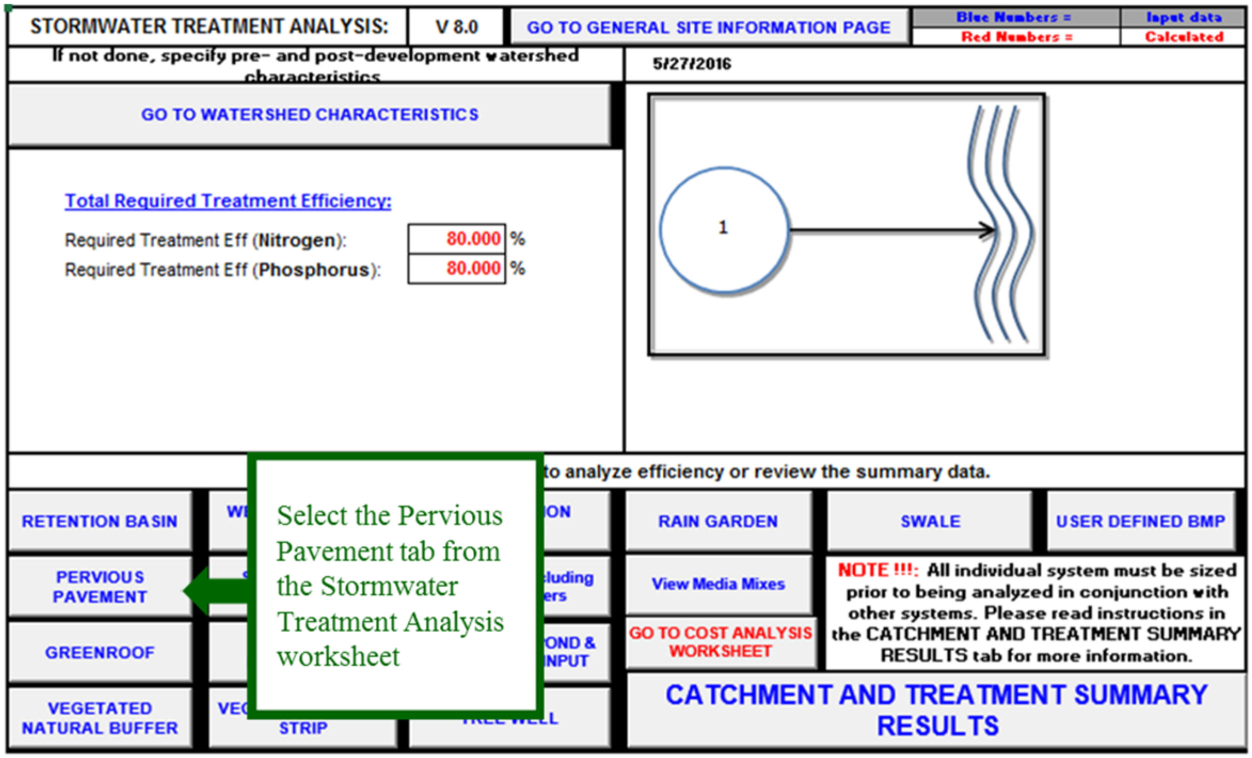


Figure 5-3 – Stormwater Treatment Analysis worksheet

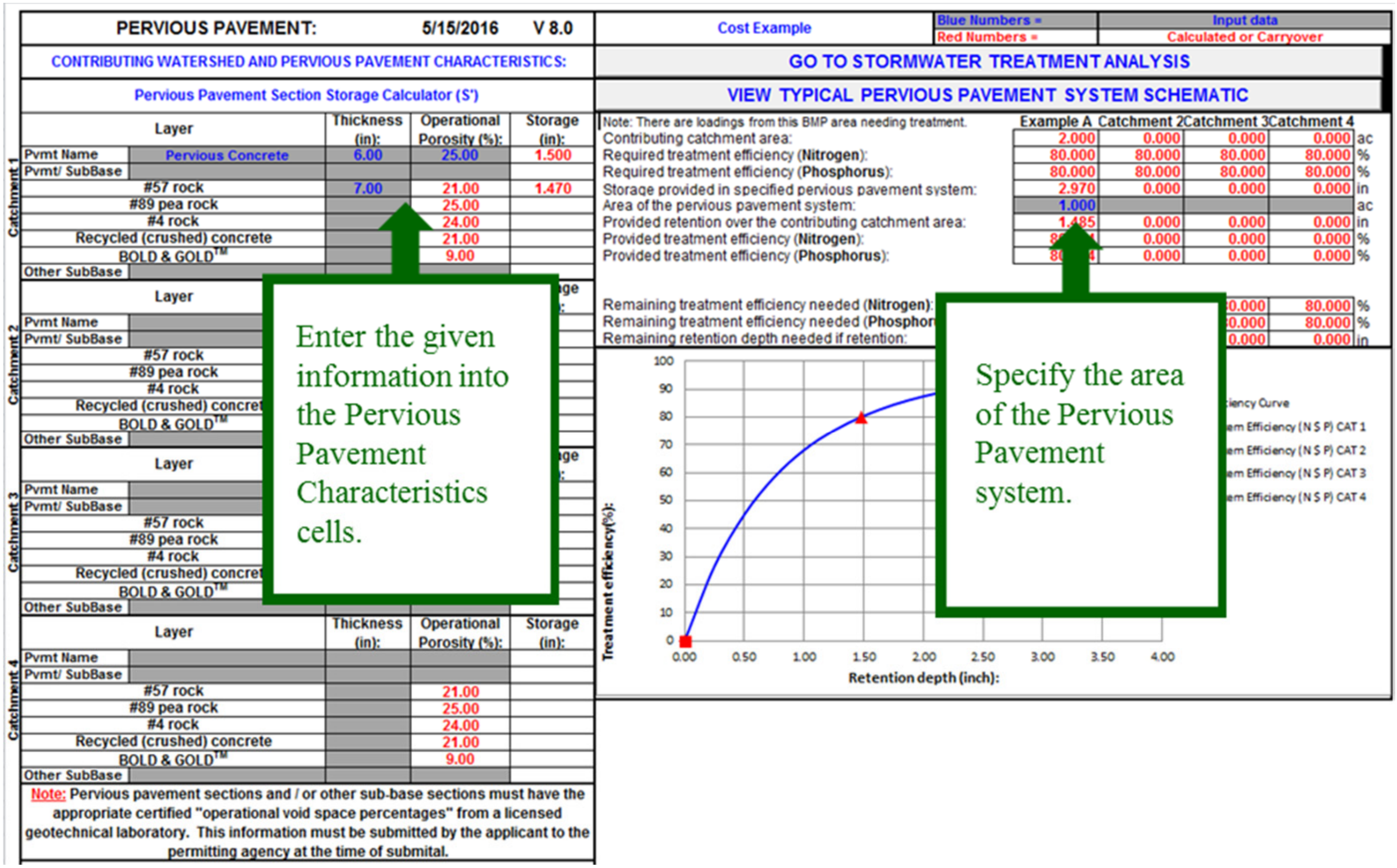


Figure 5-4 – Pervious Pavement BMP tab

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 5-5).

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

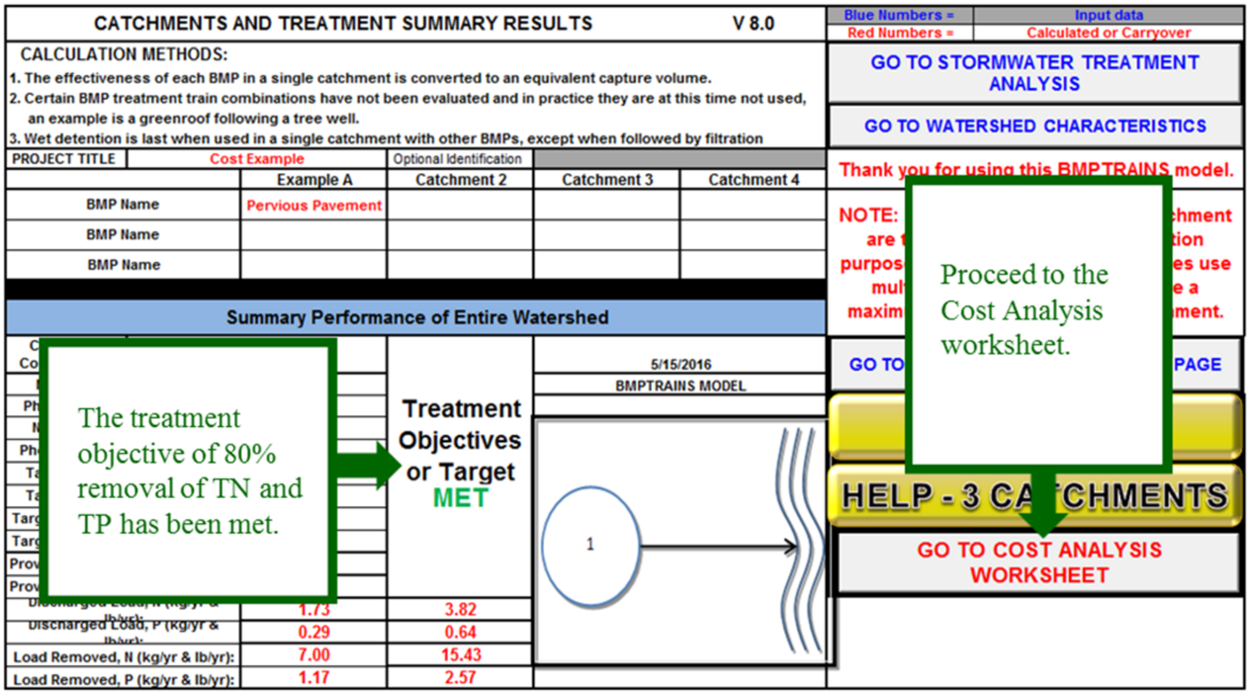


Figure 5-5 – Catchments and Treatment Summary Results

Scenario 1, Costs

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

a. Table 5-3 provides capital and operating costs for pervious pavement. Use these values and adjust the cost to be on a per acre of impervious area treated basis.

Table 5-3 – Costs for pervious pavement per acre

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) so some modifications are needed. For the basis of this conversion, consider the rainfall on the pavement to all be treated; the buildings will also be considered to translate all the rainfall to runoff. 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 (see Table 5-4).

Table 5-4 – Costs for pervious pavement 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	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 values to 2016 dollars using inflation calculator (see Table 5-5).

Table 5-5 – Costs 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

d. 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).

$$Storage\ provided\ in\ specified\ pervious\ pavement\ system\ \text{[inches]} * \frac{1\ ft}{12\ inches} * area\ of\ pervious\ pavement\ [acre] = volume\ [acre - feet]$$

$$2.970\ inches * \frac{1ft}{12\ inches} * 1acre = 0.2475\ acre - feet$$

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

$$\frac{\$49{,}638.92}{0.2475\ acre - ft} = \frac{\$200{,}561.29}{acre - ft}$$

e. Enter capital cost and operating cost data into model.

6. Fill in the remaining fields in the **Life Cycle Cost Comparison Worksheet** (see Figure 5-6).

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**

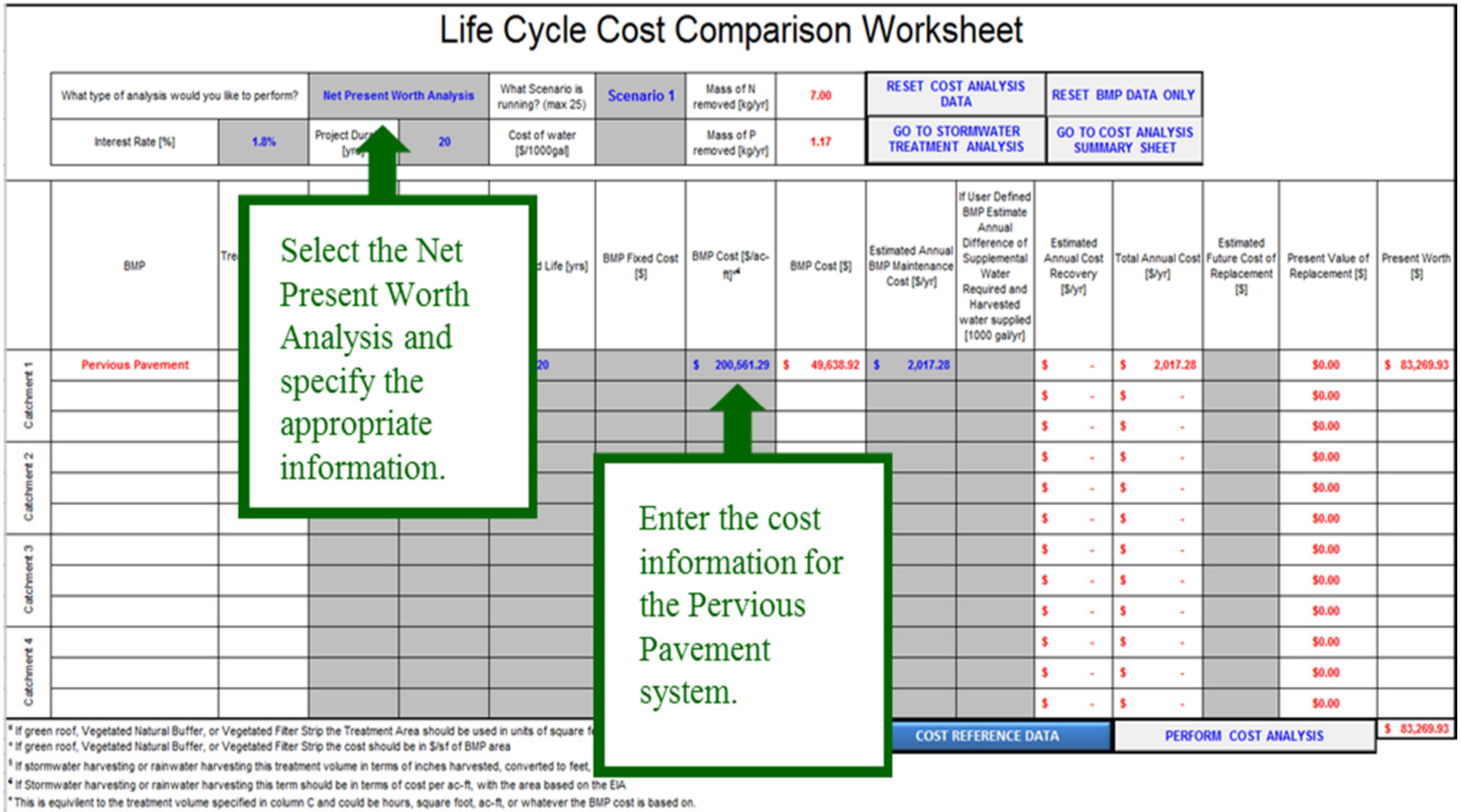


Figure 5-6 – Life Cycle Cost Comparison Worksheet

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 5-7).

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					
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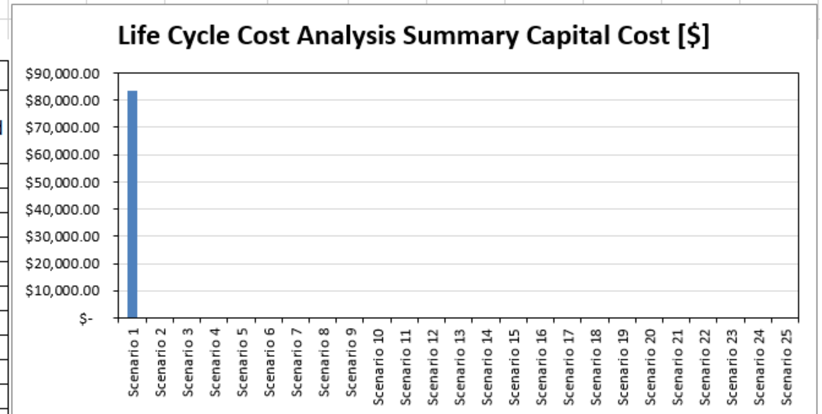
Scenario 24					
Scenario 25					



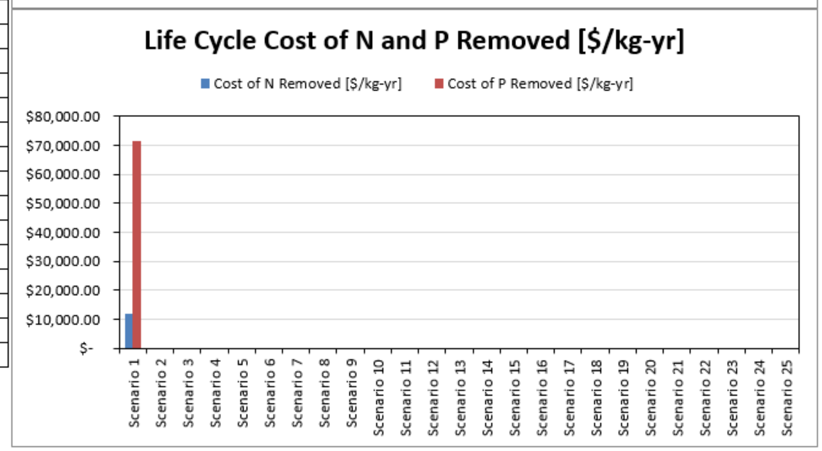


Figure 5-7 – Life Cycle Cost Analysis Summary

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

Scenario 2

The pervious concrete area, retention basin volume, and additional land required for Scenario 2 is presented in Table 5-6.

Table 5-6 – Scenario 2

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

9. 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 5-8).

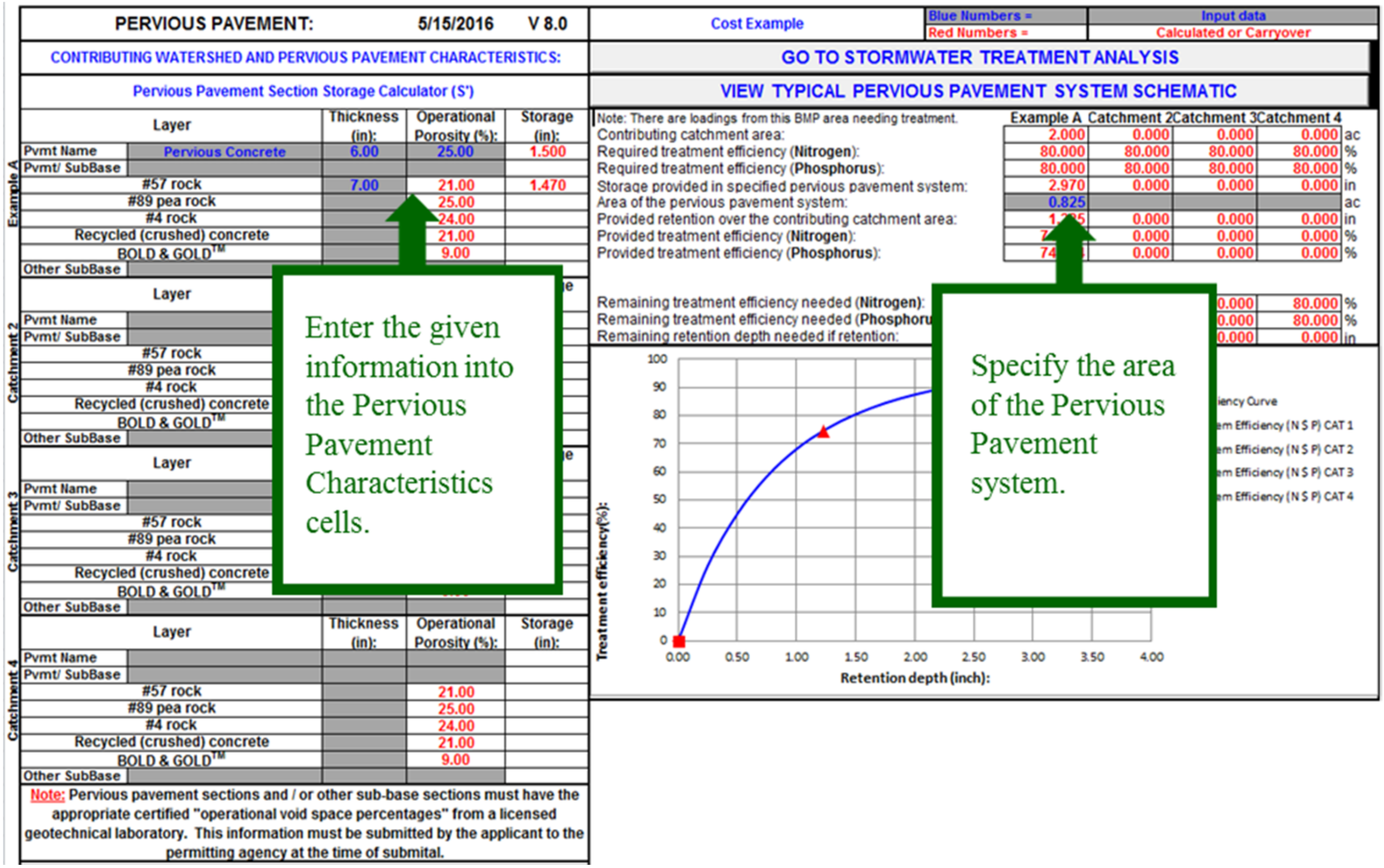


Figure 5-8 – Pervious Pavement BMP tab

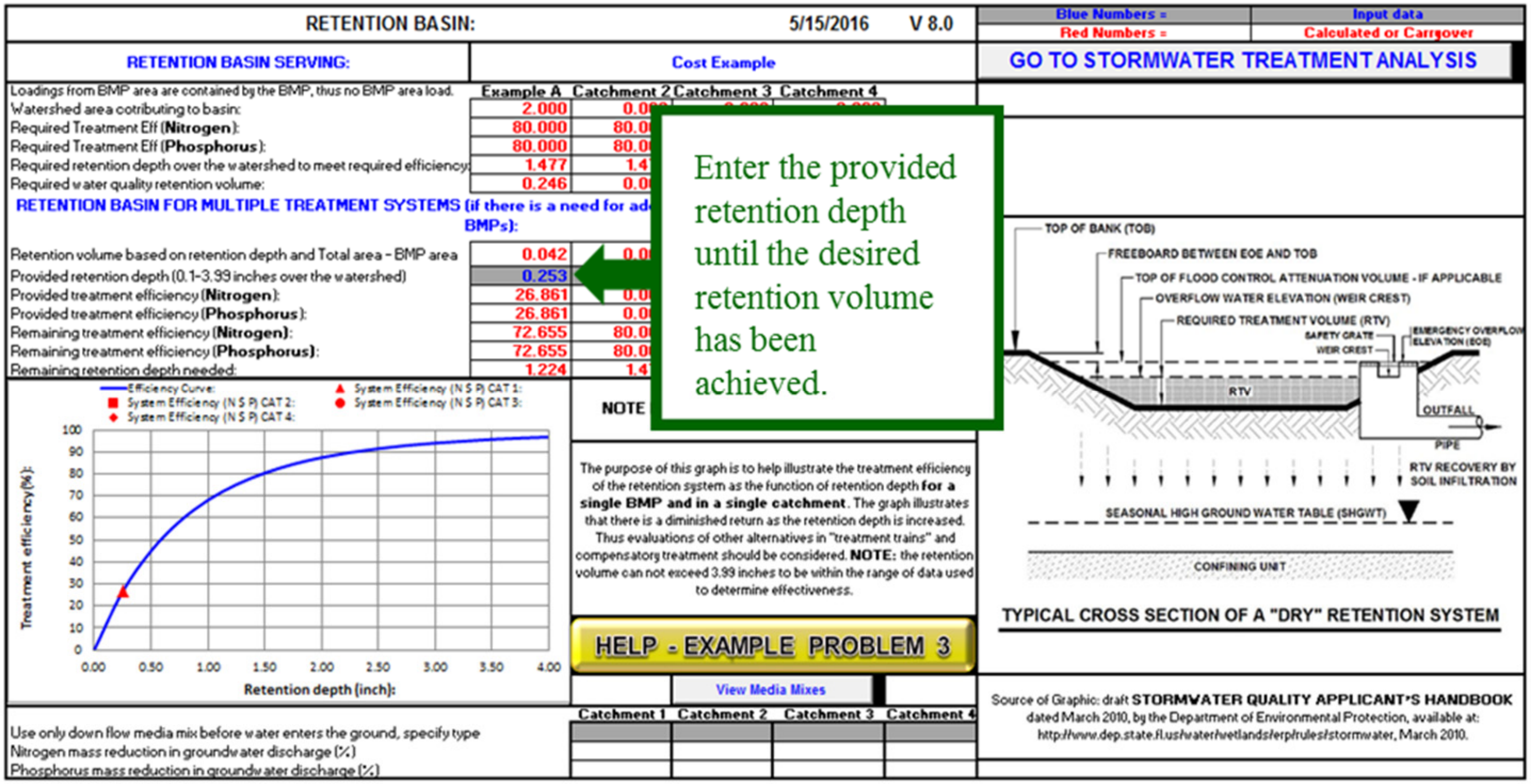


Figure 5-9 – Retention Basin BMP tab

*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 5-9).

10. 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 5-10).

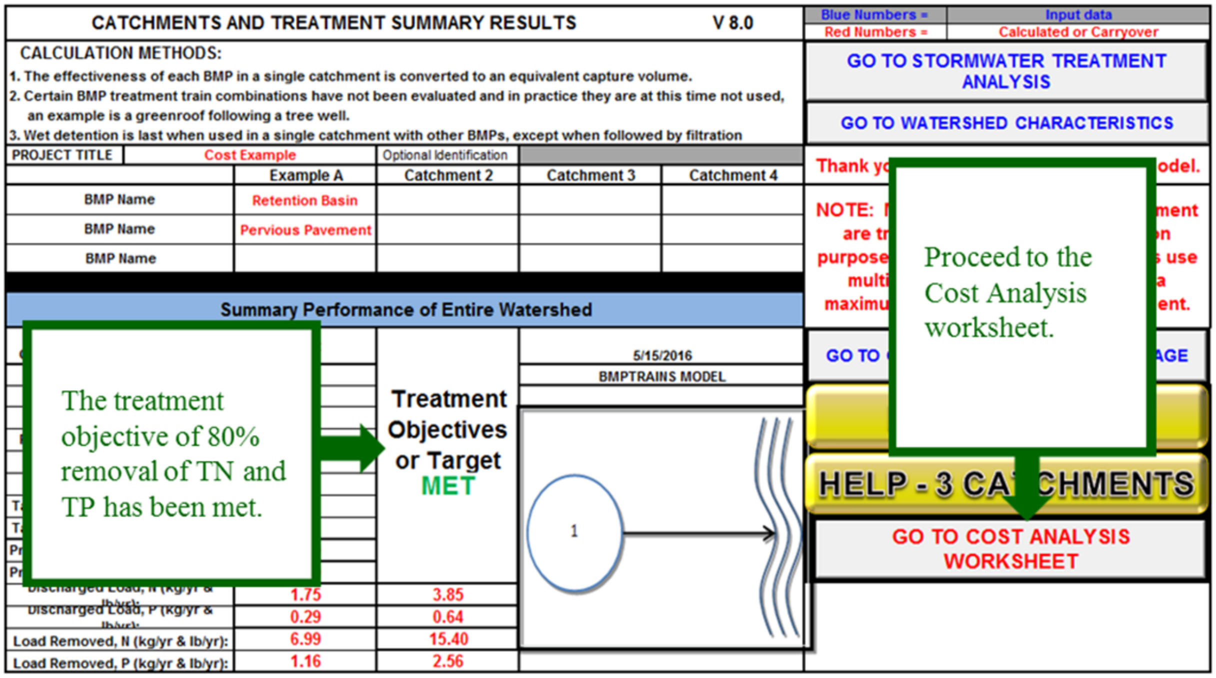


Figure 5-10 – Catchments and Treatment Summary Results

Scenario 2, Costs

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

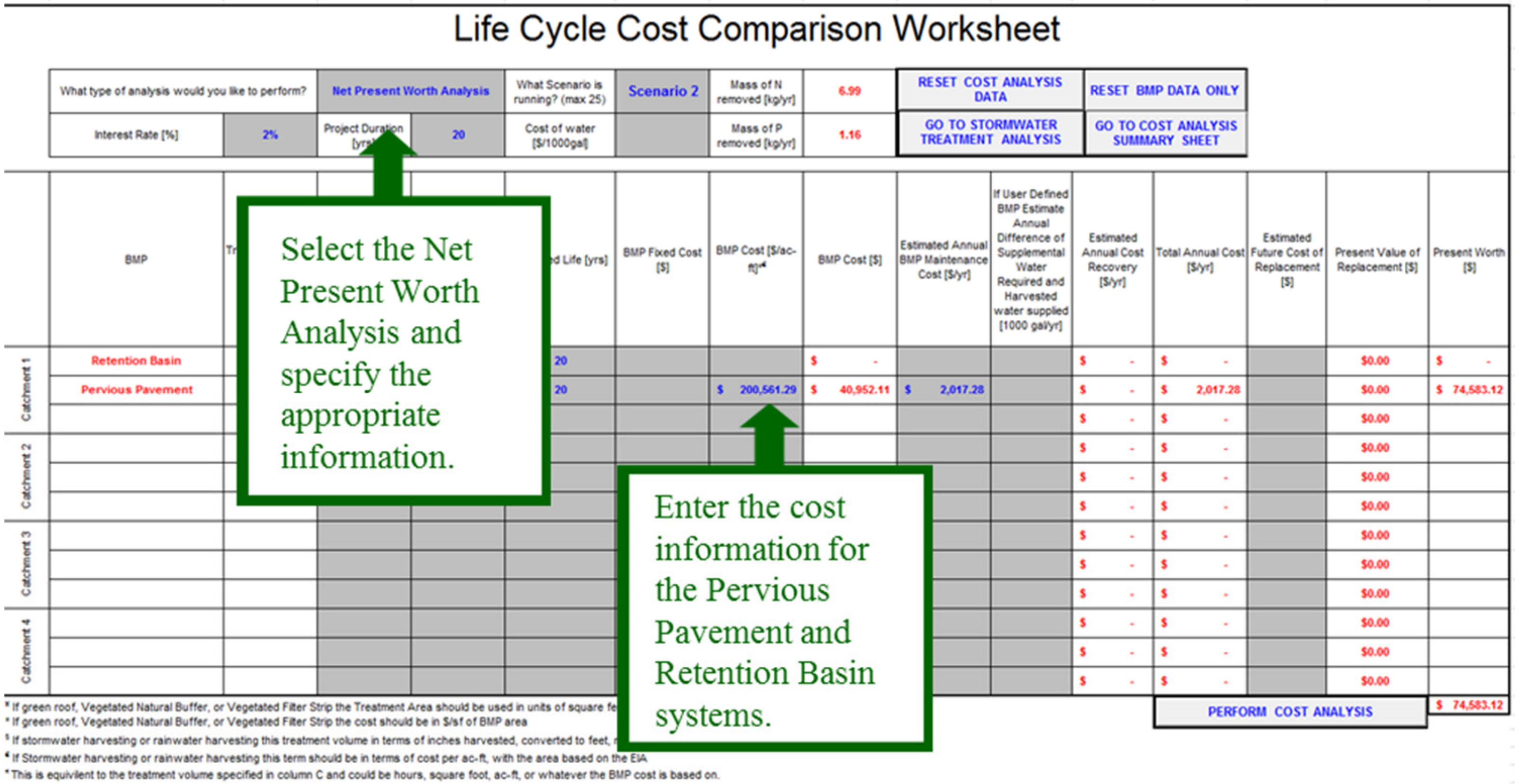


Figure 5-11 – Life Cycle Cost Comparison Worksheet

*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.

a. Table 5-7 provides capital cost data on a volumetric basis (cubic feet) of water treated for retention basins, the operating cost can be calculated as a percentage of capital cost.

- 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 to adjust to 2016 dollars.

b. Calculate the Capital and operating costs.

Table 5-7 – 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% (see Figure 5-11).

12. Fill in the remaining fields (see Figure 5-12).

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 #

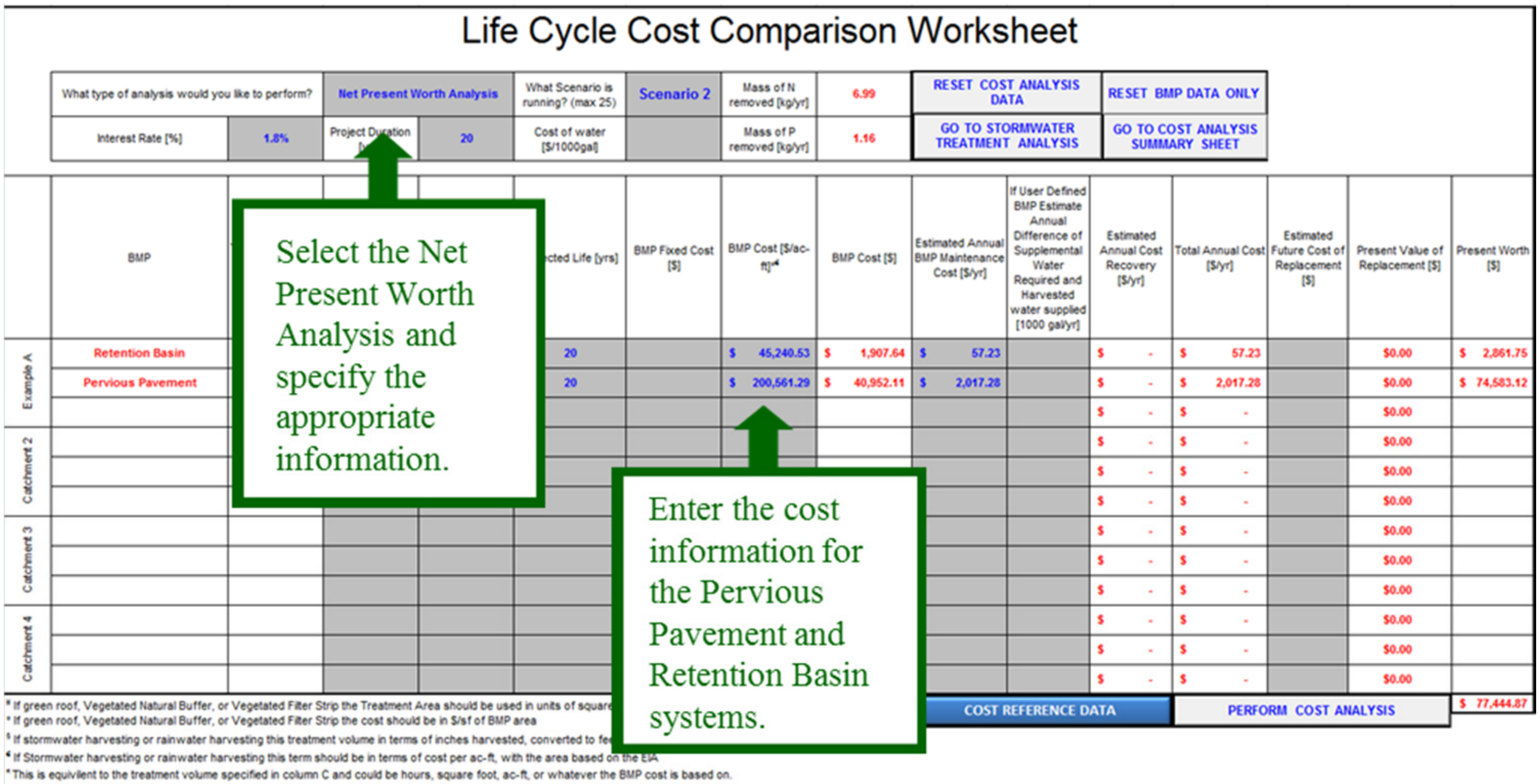


Figure 5-12 – Updated Life Cycle Cost Comparison Worksheet

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					
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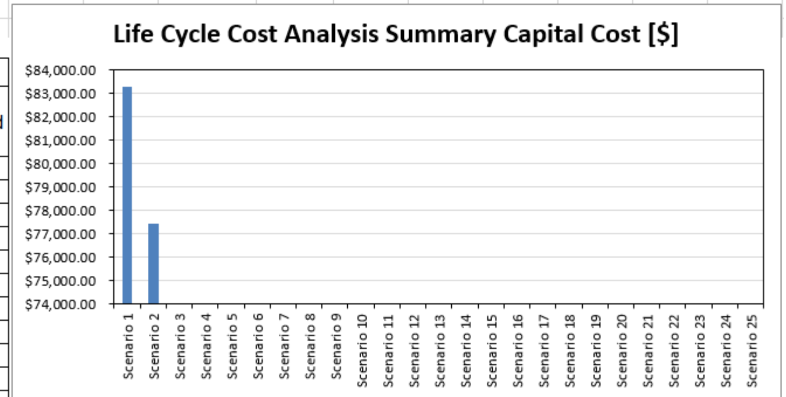
Scenario 25					



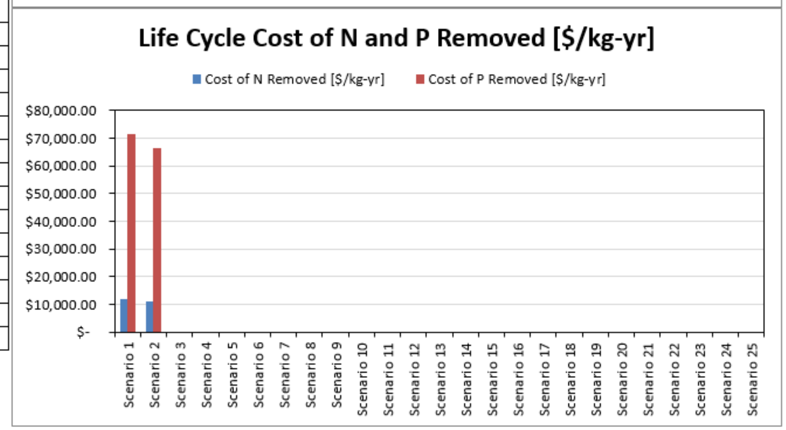


Figure 5-13 – Life Cycle Cost Analysis Summary

13. Return to the **Stormwater Treatment Analysis** worksheet (see Figure 5-13).

Scenario 3

The pervious concrete area, retention basin volume, and additional land required for Scenario 3 is presented in Table 5-8.

Table 5-8 – Scenario 3

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

14. 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 5-14).

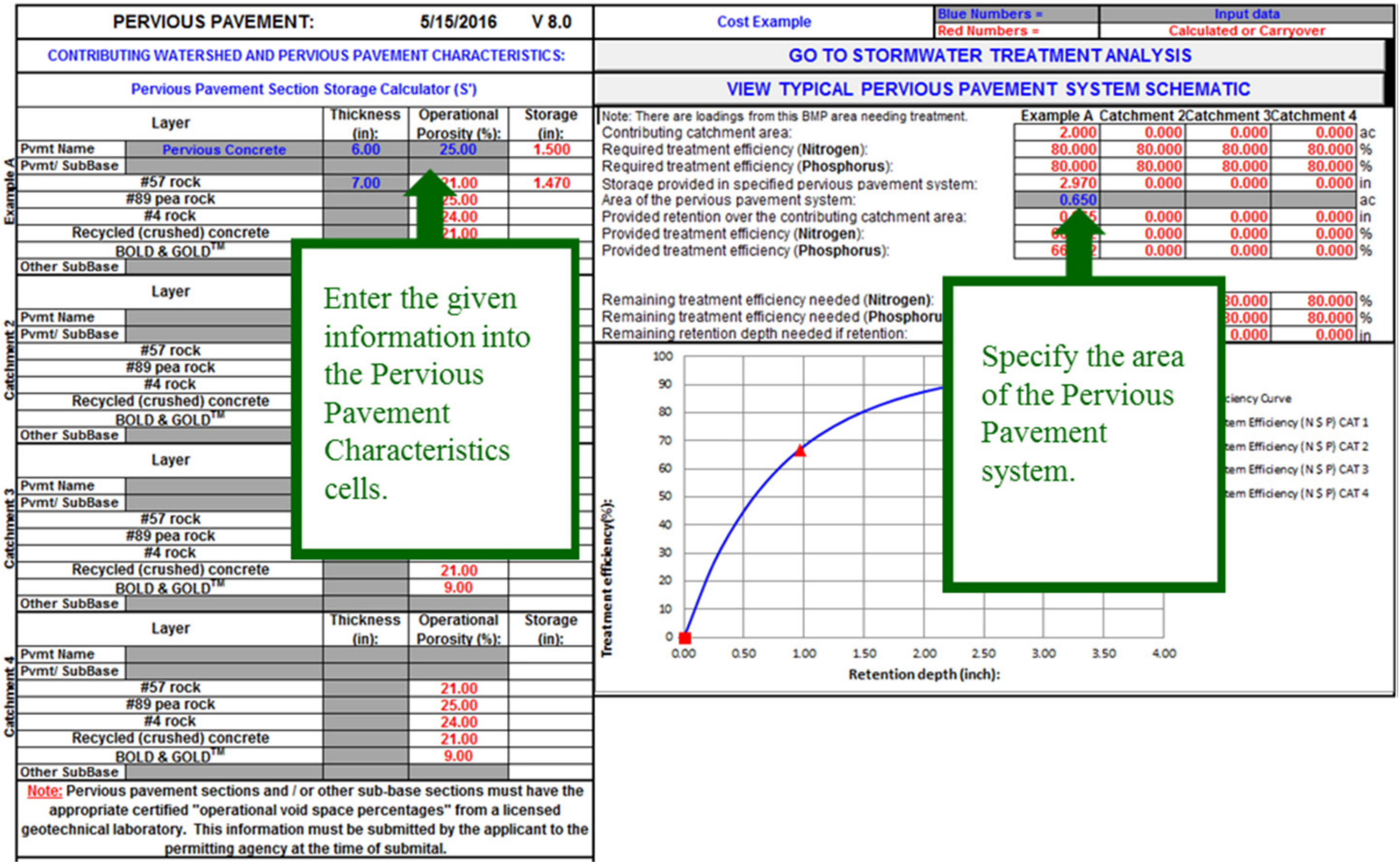


Figure 5-14 – Pervious Pavement BMP tab

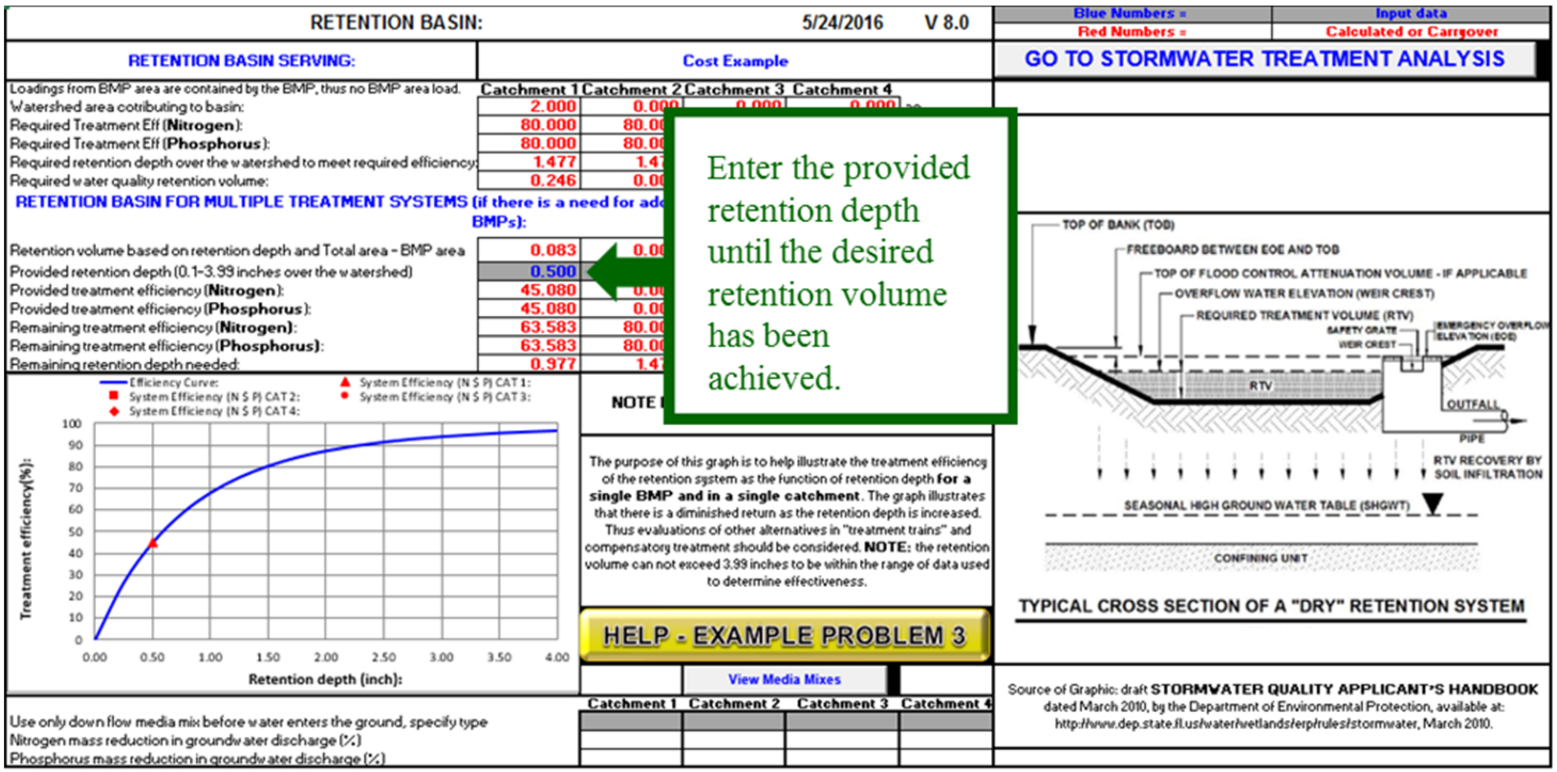


Figure 5-15 – Retention Basin BMP tab

*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 5-15).

15. 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 5-16).

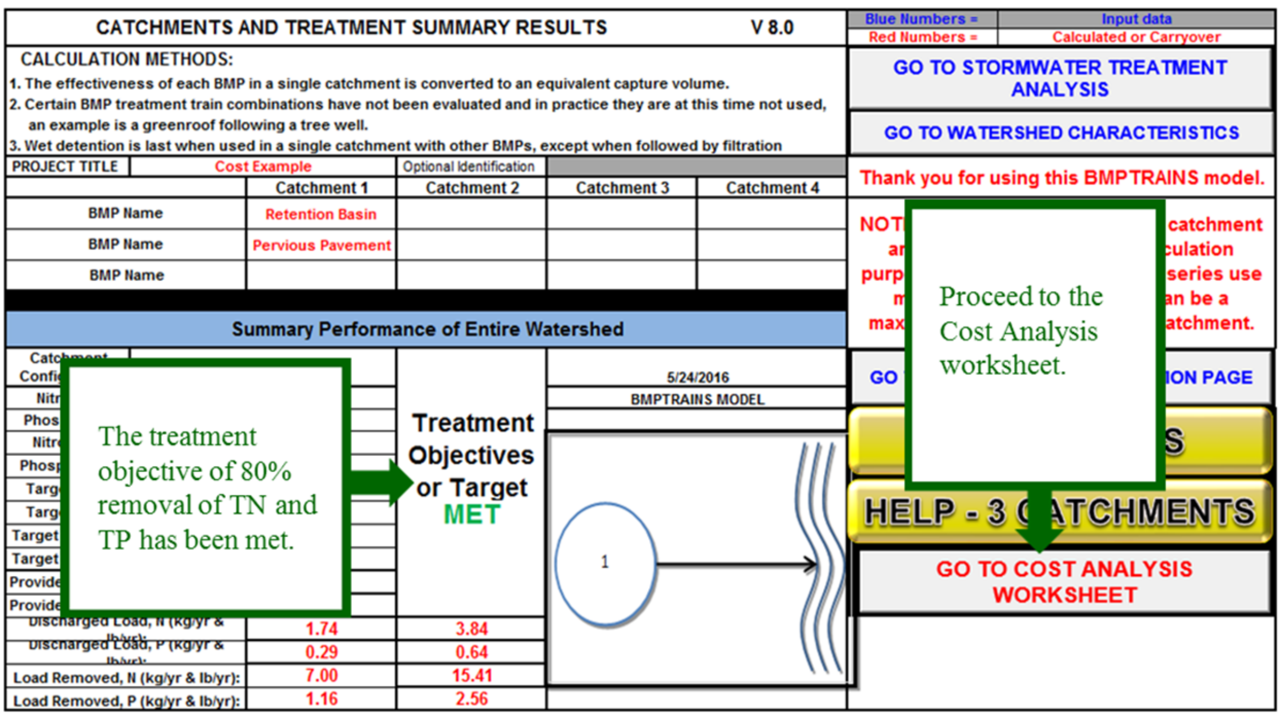


Figure 5-16 – Catchments and Treatment Summary Results

Scenario 3, Costs

16. Table 5-7 provides capital cost data on a volumetric basis (cubic feet) of water treated for retention basins, the operating cost can be calculated as a percentage of capital cost.

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.

17. Fill in the remaining fields (see Figure 5-17).

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 #

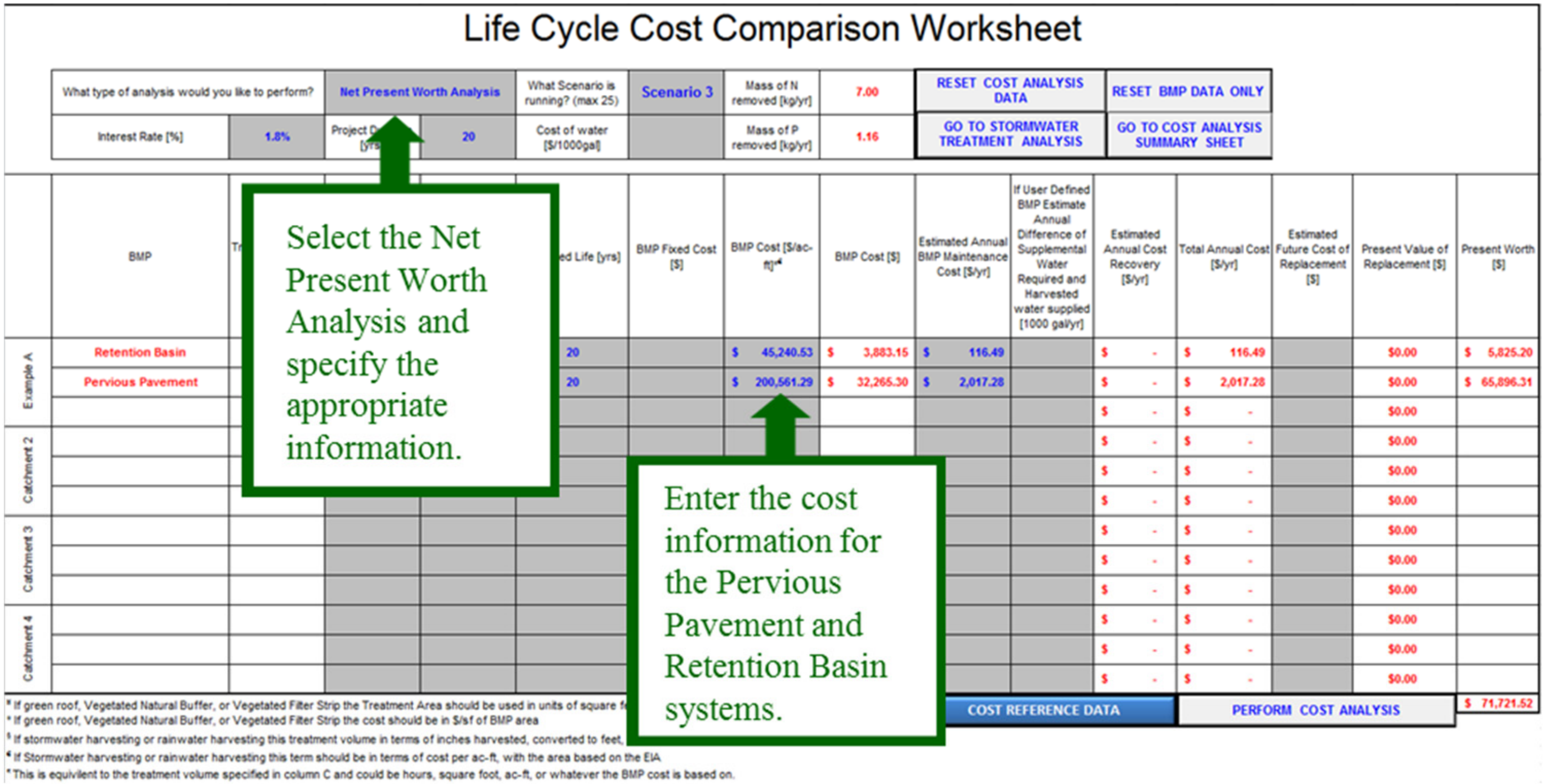


Figure 5-17 – Life Cycle Cost Comparison Worksheet

18. Perform the Cost Analysis (see Figure 5-18).

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					
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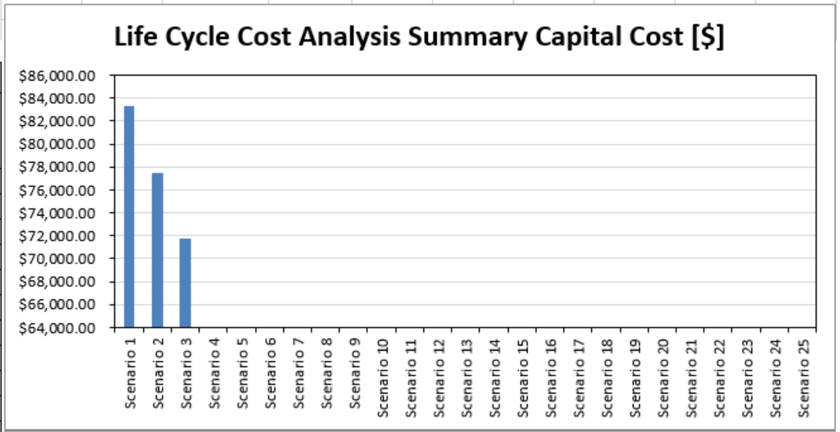
Scenario 25					



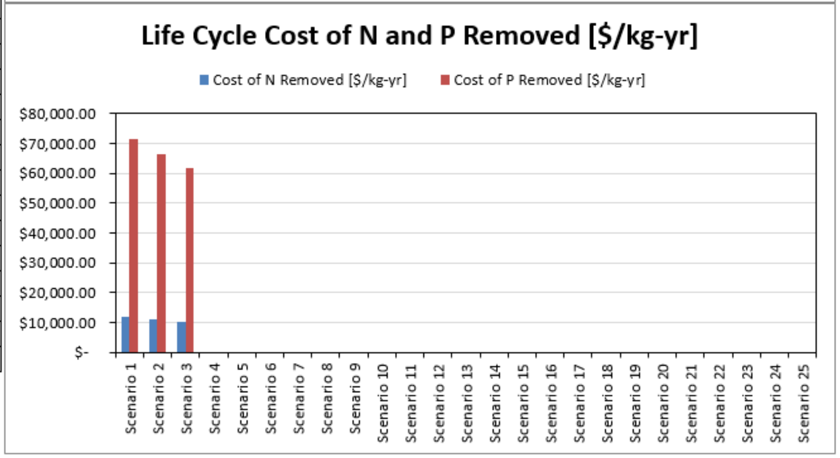


Figure 5-18 – Life Cycle Cost Analysis Summary

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

Scenario 4

The pervious concrete area, retention basin volume, and additional land required for Scenario 4 is presented in Table 5-9.

Table 5-9 – Scenario 4

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

20. 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 5-19).

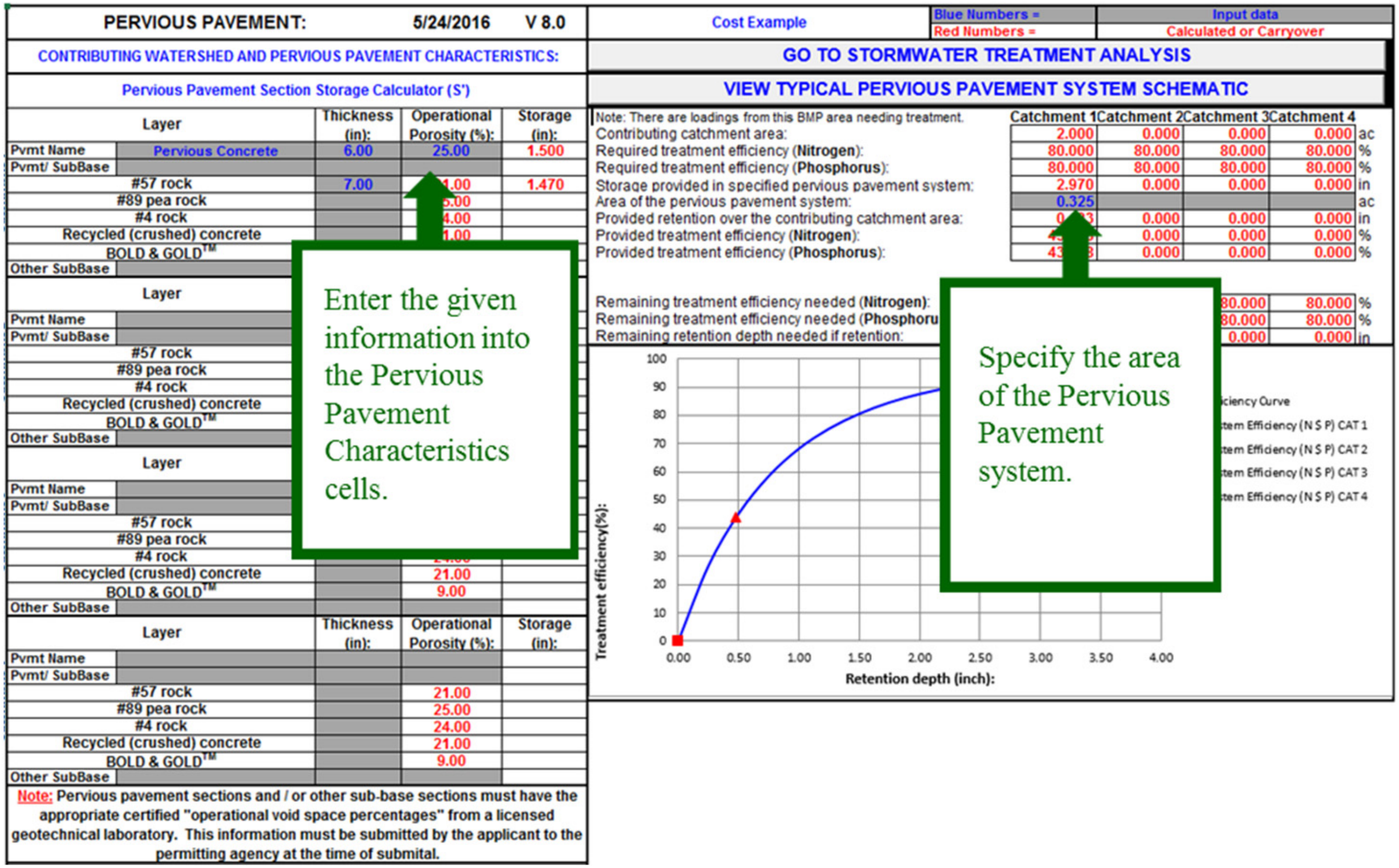


Figure 5-19 – Pervious Pavement BMP tab

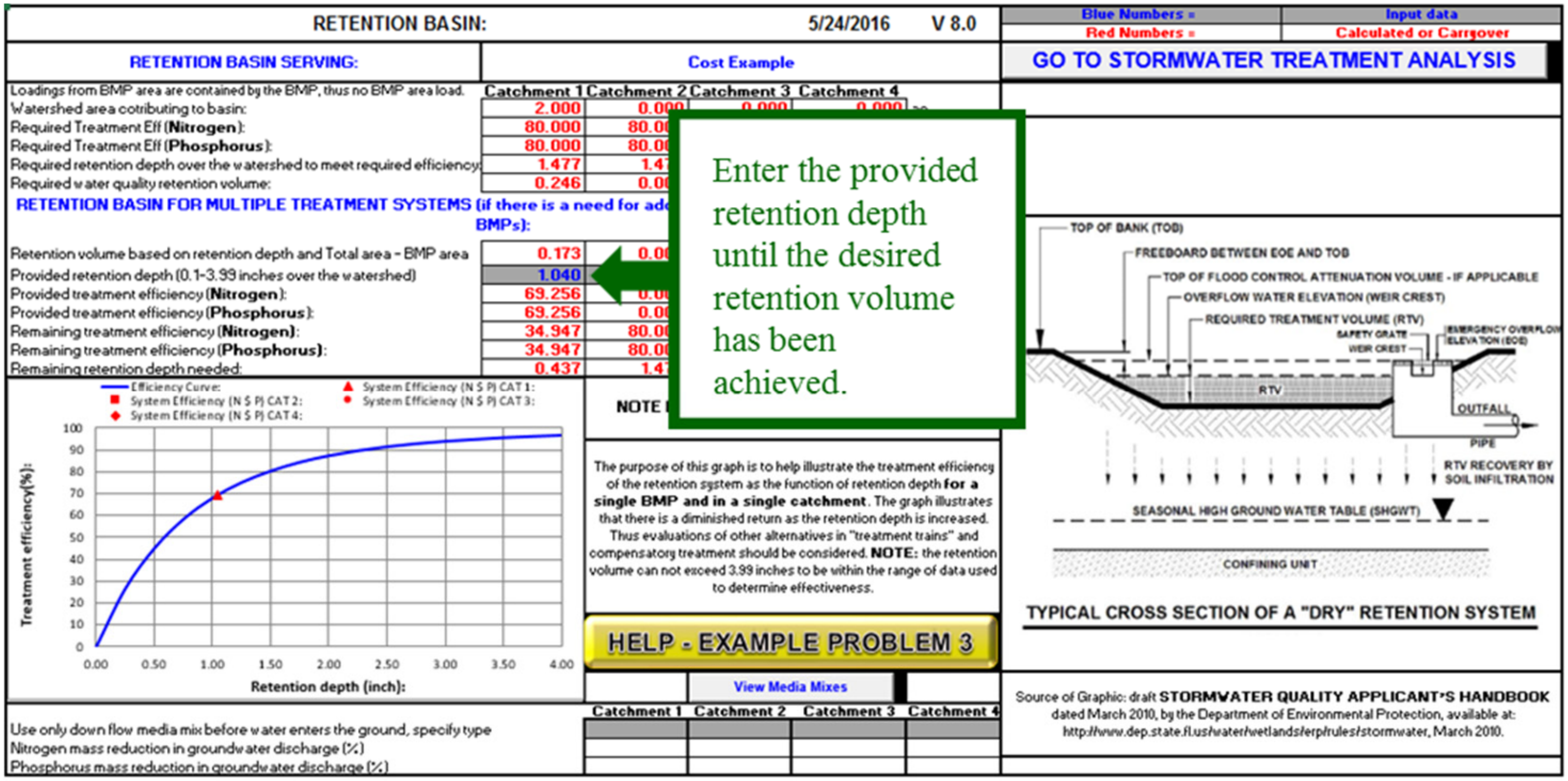


Figure 5-20 – Retention Basin BMP tab

*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 5-20).

21. Return to the **Stormwater Treatment Analysis** worksheet and click **Catchment and Treatment Summary Results** (see Figure 5-21).

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

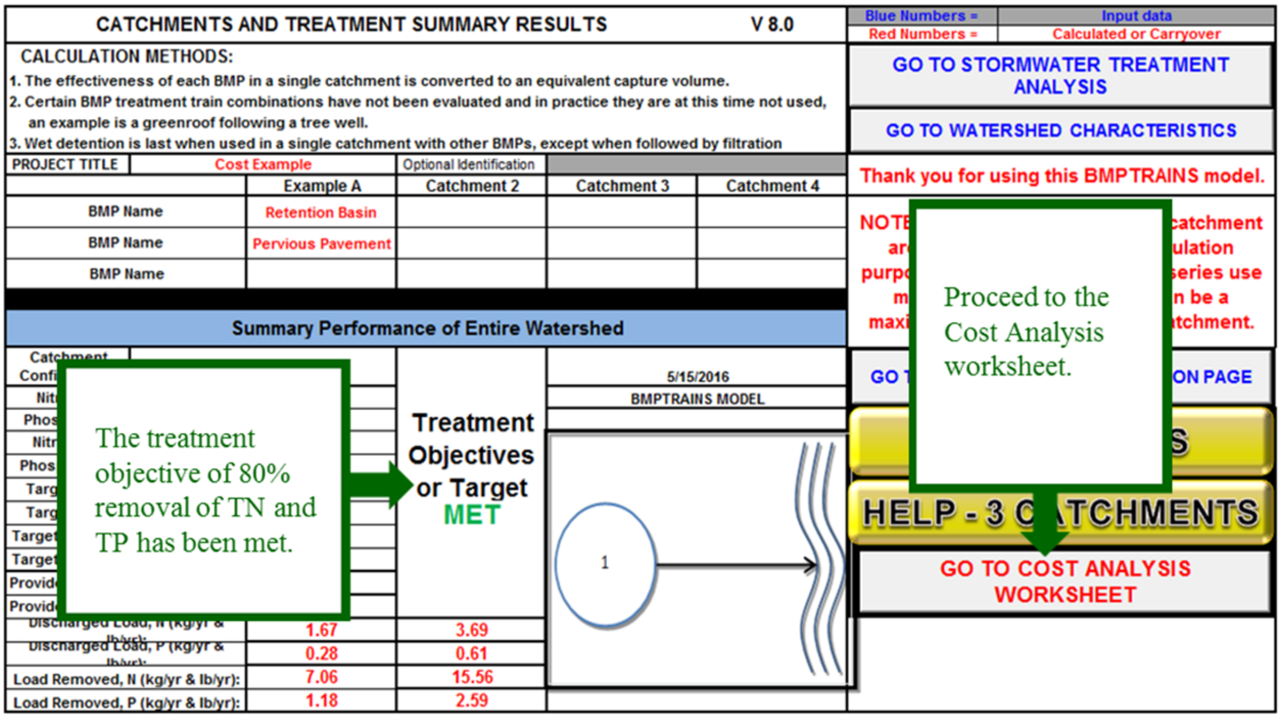


Figure 5-21 – Catchments and Treatment Summary Results

Scenario 4, Costs

22. 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 $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.

23. Fill in the remaining fields (see Figure 5-22).

    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 #

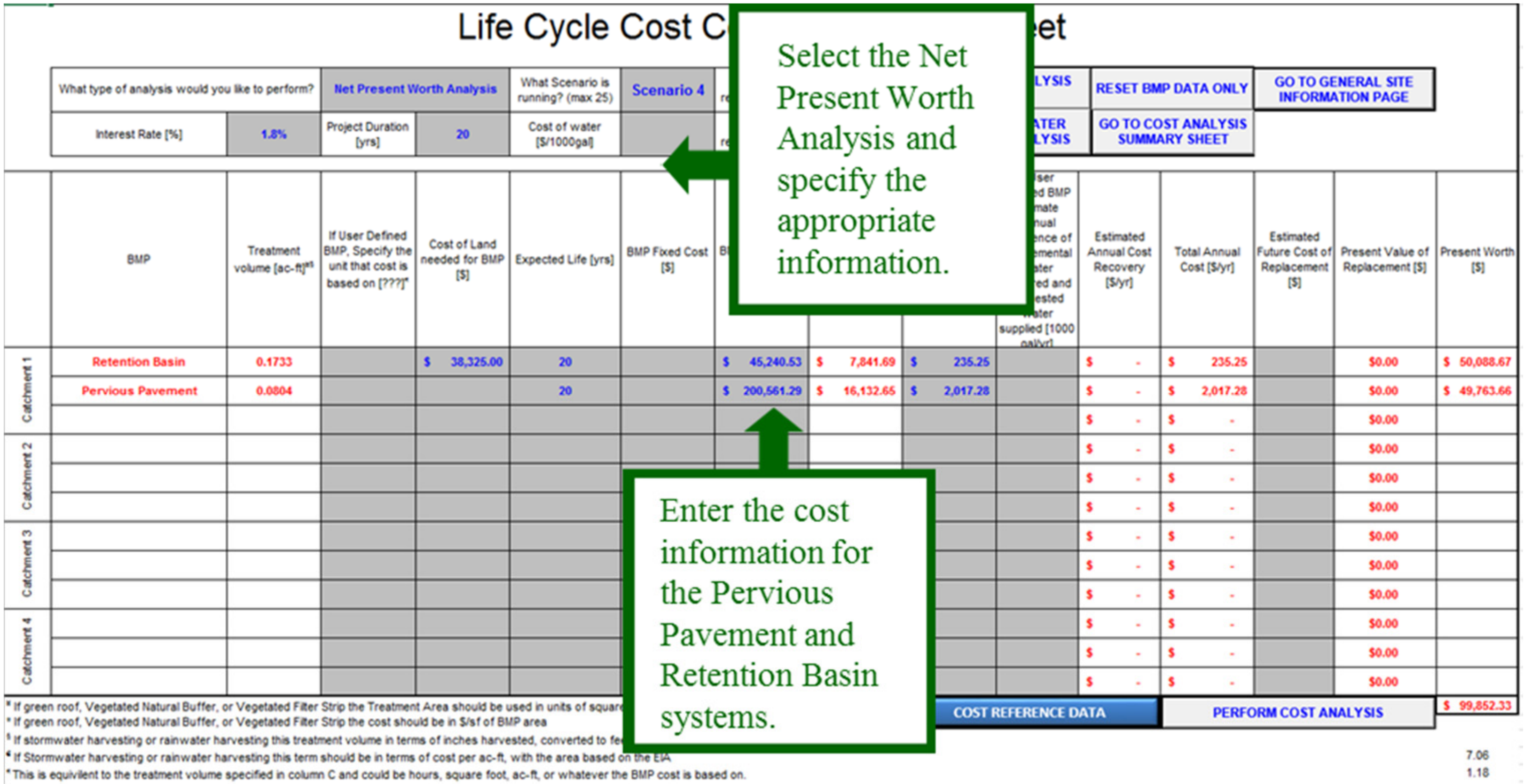


Figure 5-22 – Life Cycle Cost Comparison Worksheet

24. Perform Cost Analysis (see Figure 5-23).

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					
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Scenario 18					
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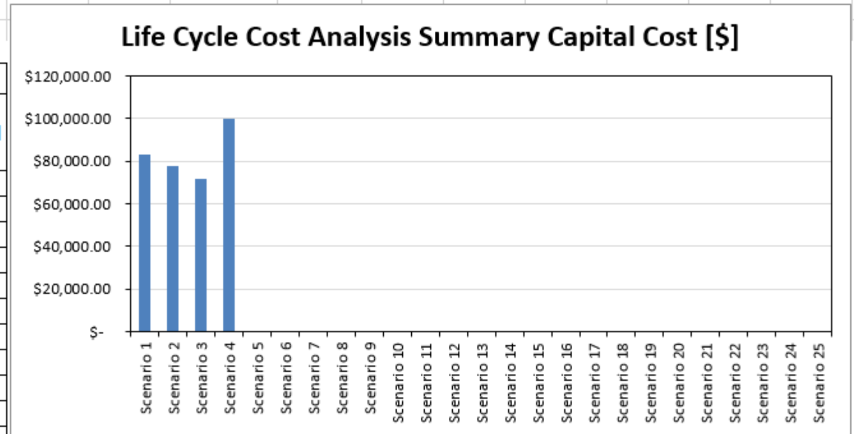
Scenario 20					
Scenario 21					
Scenario 22					
Scenario 23					
Scenario 24					
Scenario 25					



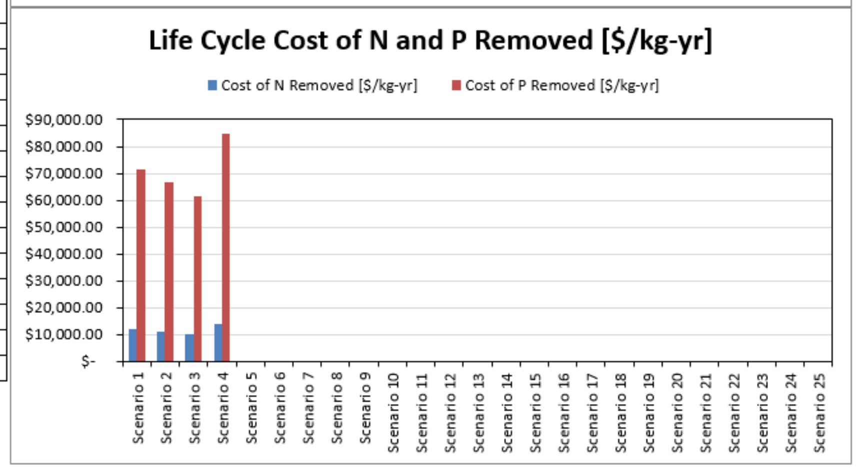


Figure 5-23 – Life Cycle Cost Analysis Summary

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

Scenario 5

The pervious concrete area, retention basin volume, and additional land required for Scenario 5 is presented in Table 5-10.

Table 5-10 – Scenario 5

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

26. 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 5-24).

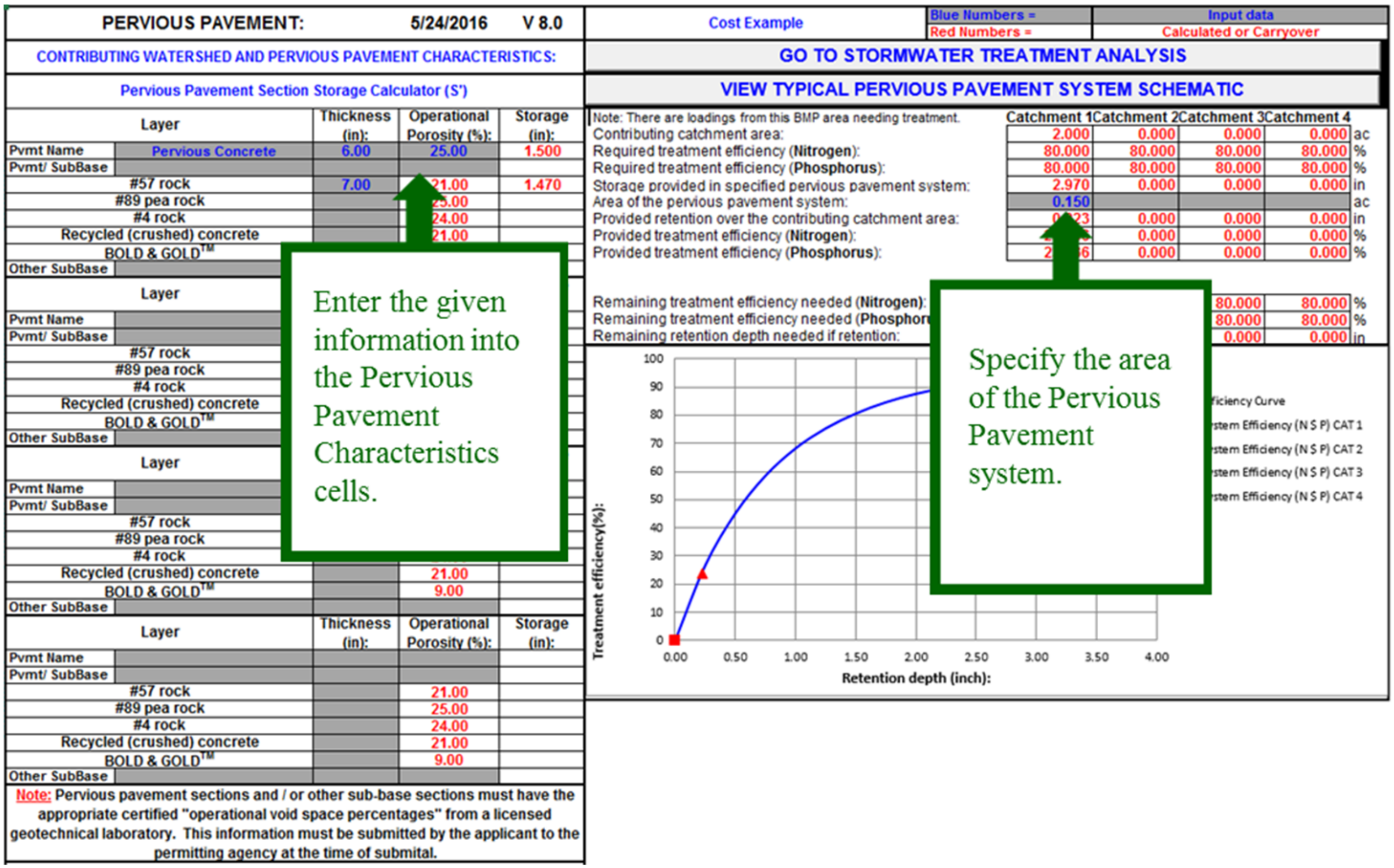


Figure 5-24 – Pervious Pavement BMP tab

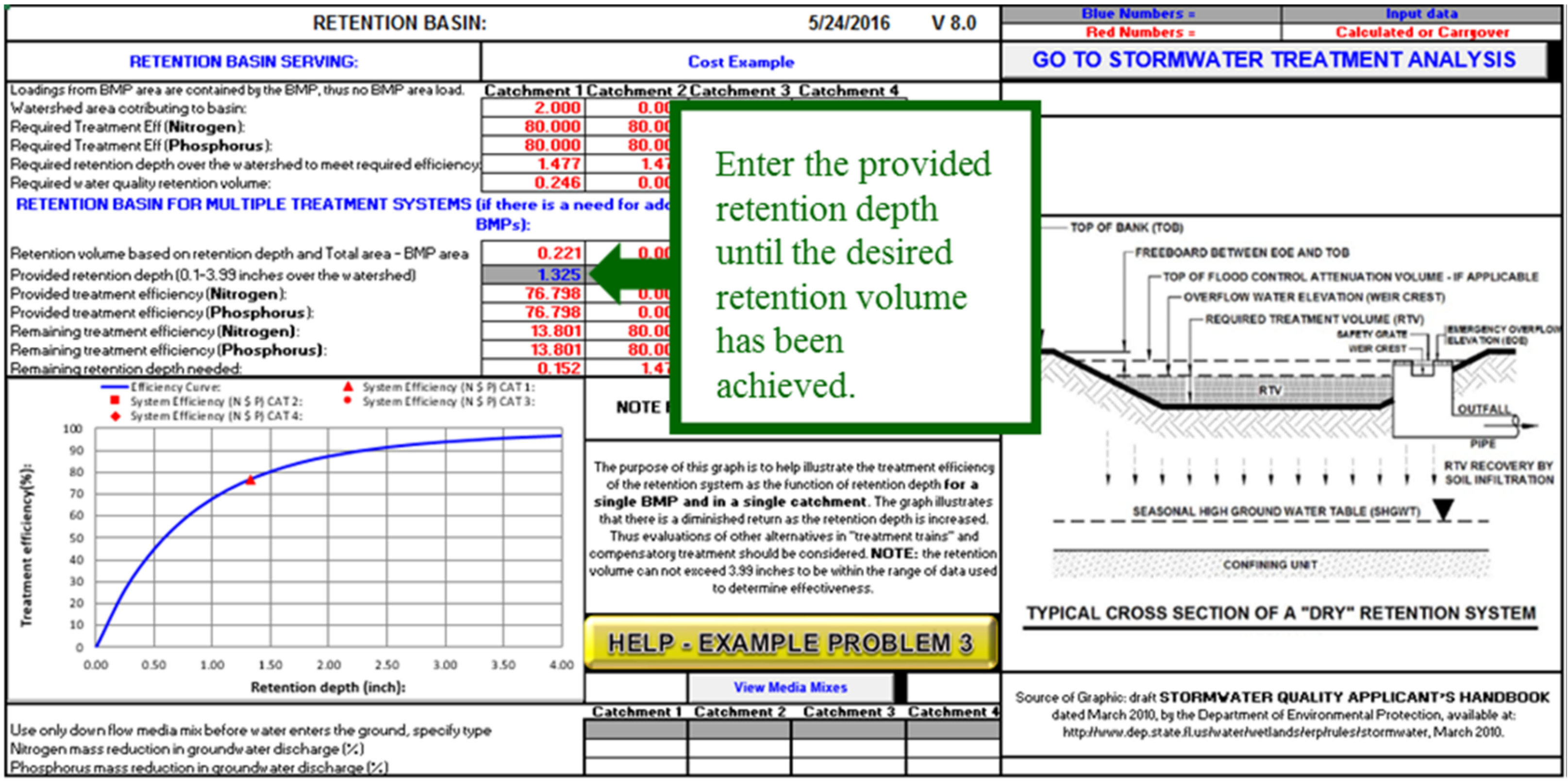


Figure 5-25 - Retention Basin BMP tab

*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 5-25).

27. Return to the **Stormwater Treatment Analysis** worksheet and click **Catchment and Treatment Summary Results** (see Figure 5-26).

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

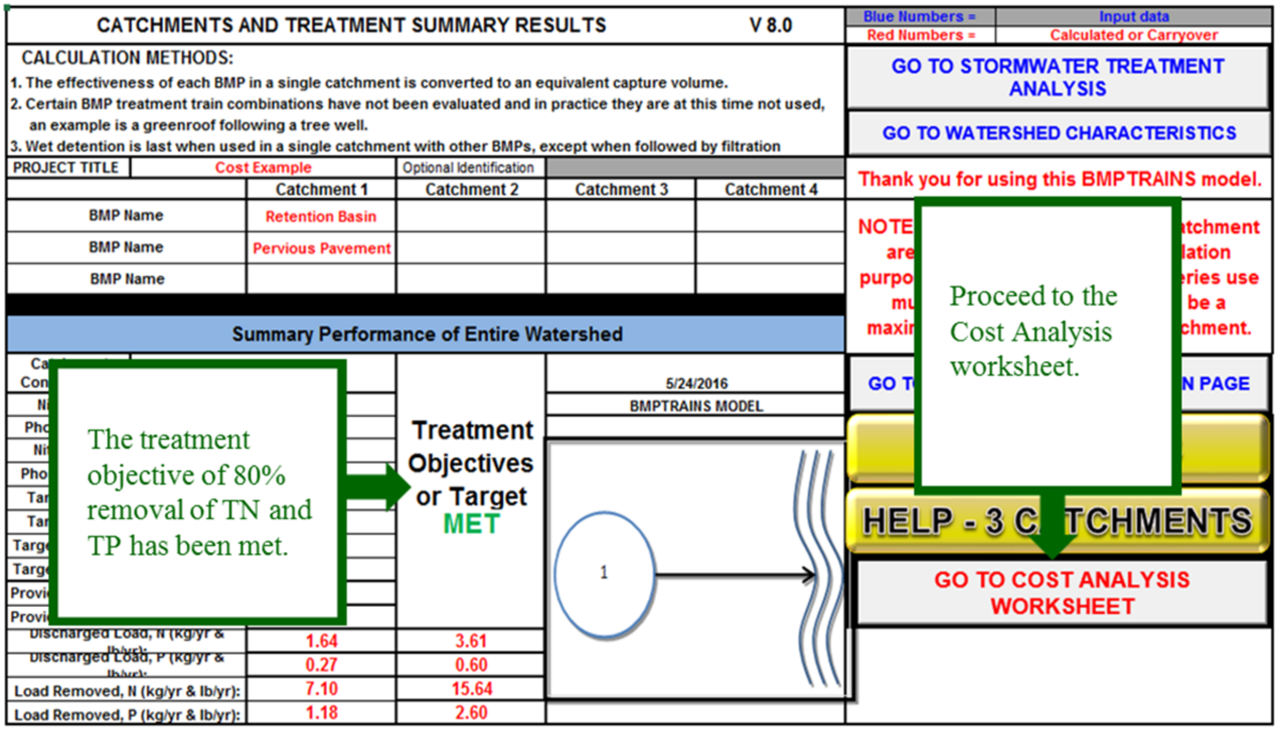


Figure 5-26 – Catchments and Treatment Summary Results

Scenario 5, Costs

28. 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.

29. Fill in the remaining fields (see Figure 5-27).

    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 #

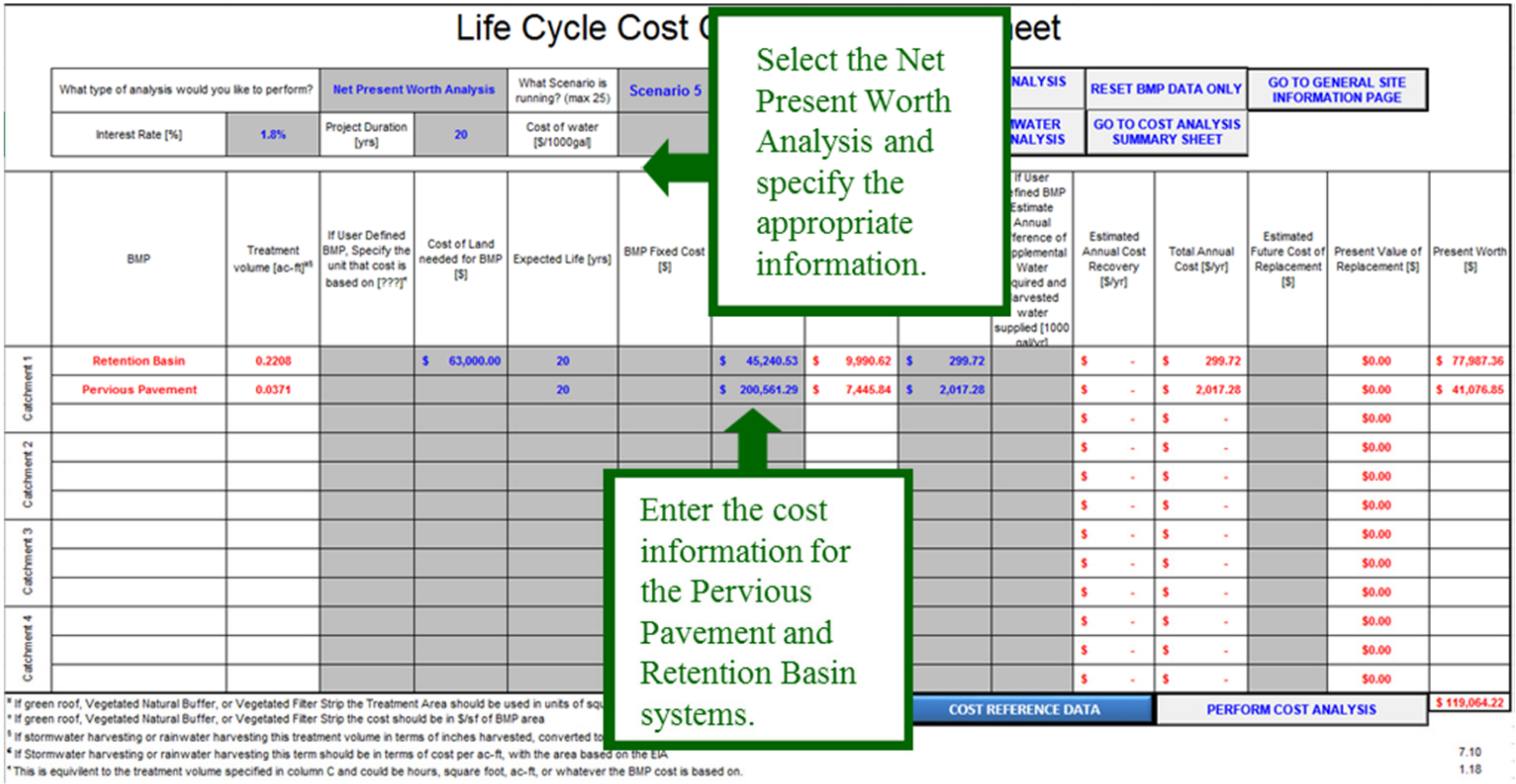


Figure 5-27 – Life Cycle Cost Comparison Worksheet

30. Perform Cost Analysis (see Figure 5-28).

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					
Scenario 12					
Scenario 13					
Scenario 14					
Scenario 15					
Scenario 16					
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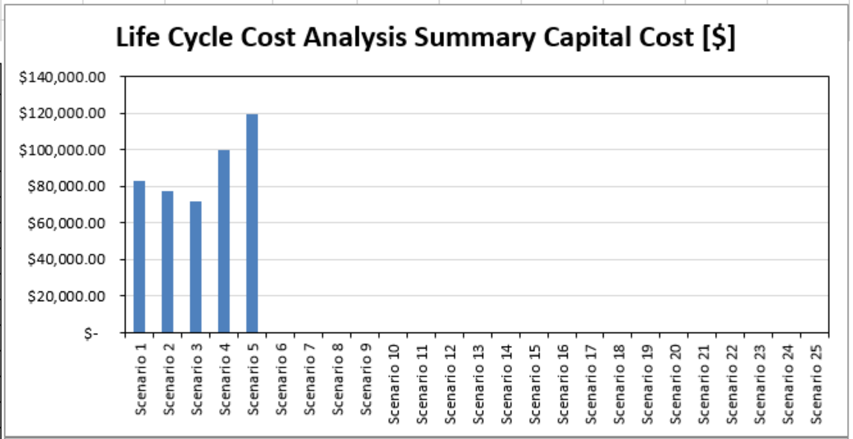
Scenario 19					
Scenario 20					
Scenario 21					
Scenario 22					
Scenario 23					
Scenario 24					
Scenario 25					



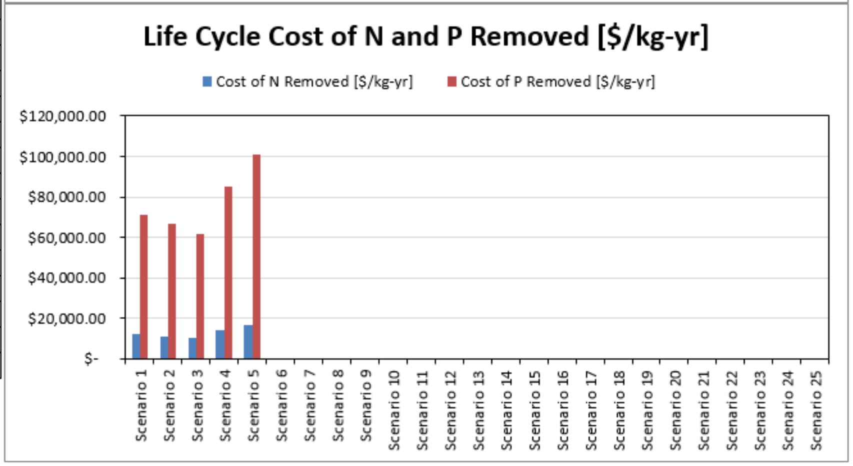


Figure 5-28 – Life Cycle Cost Analysis Summary

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

Scenario 6

The pervious concrete area, retention basin volume, and additional land required for Scenario 6 is presented in Table 5-11.

Table 5-11 – Scenario 6

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

32. 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 5-29).

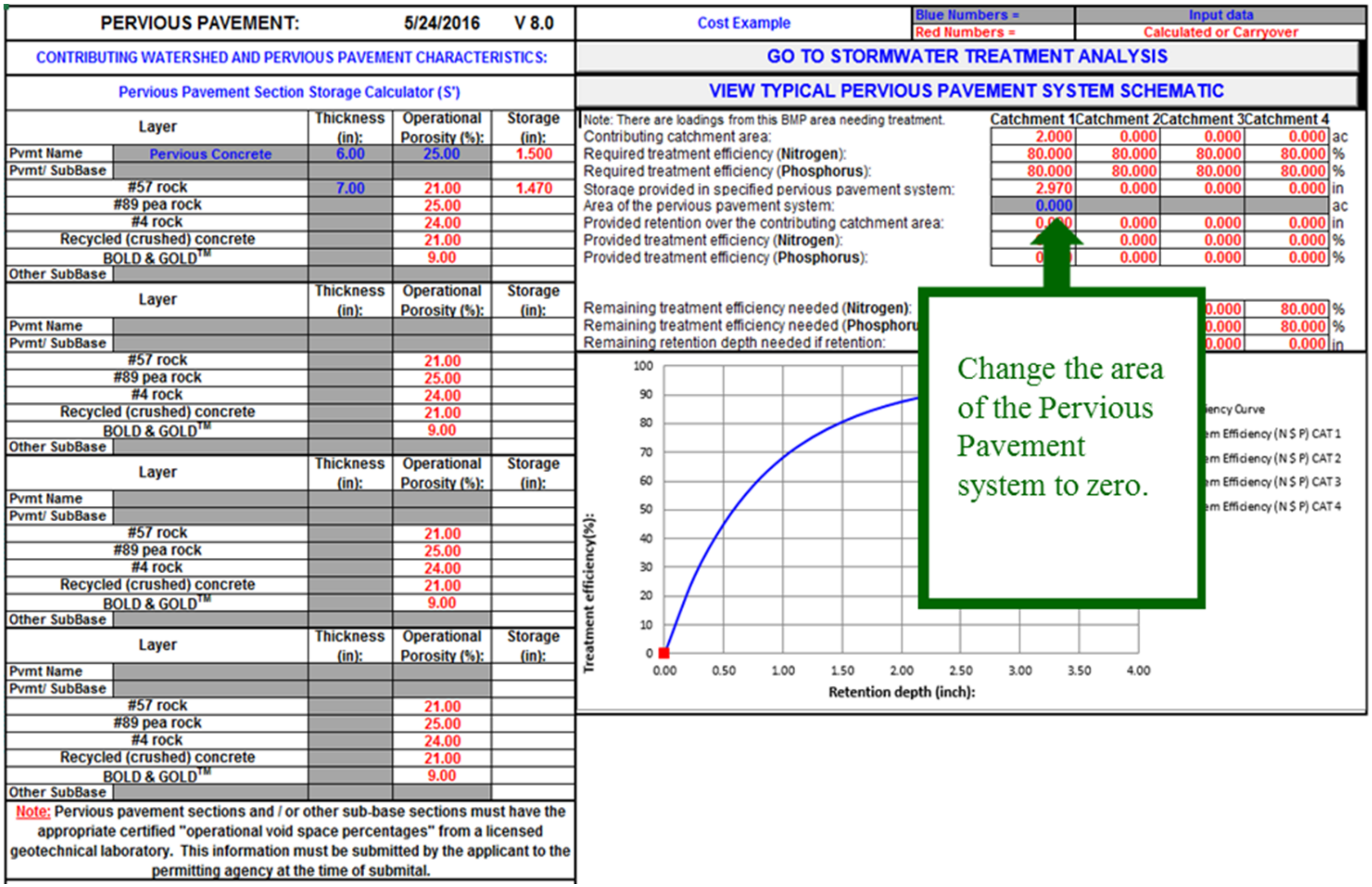


Figure 5-29 – Pervious Pavement BMP tab

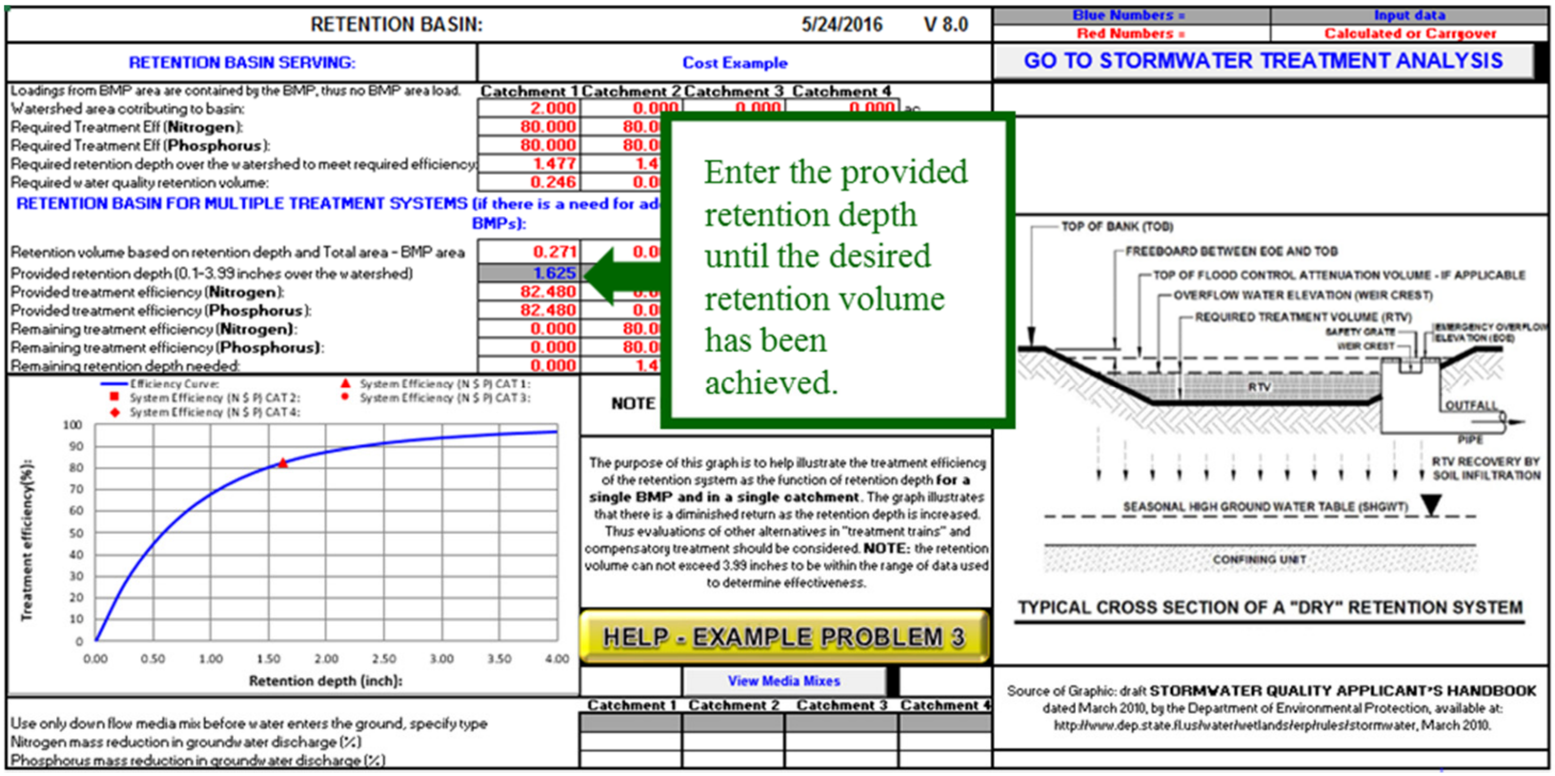


Figure 5-30 – Retention Basin BMP tab

*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 5-30).

33. Return to the **Stormwater Treatment Analysis** worksheet and click **Catchment and Treatment Summary Results** (see Figure 5-31).

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

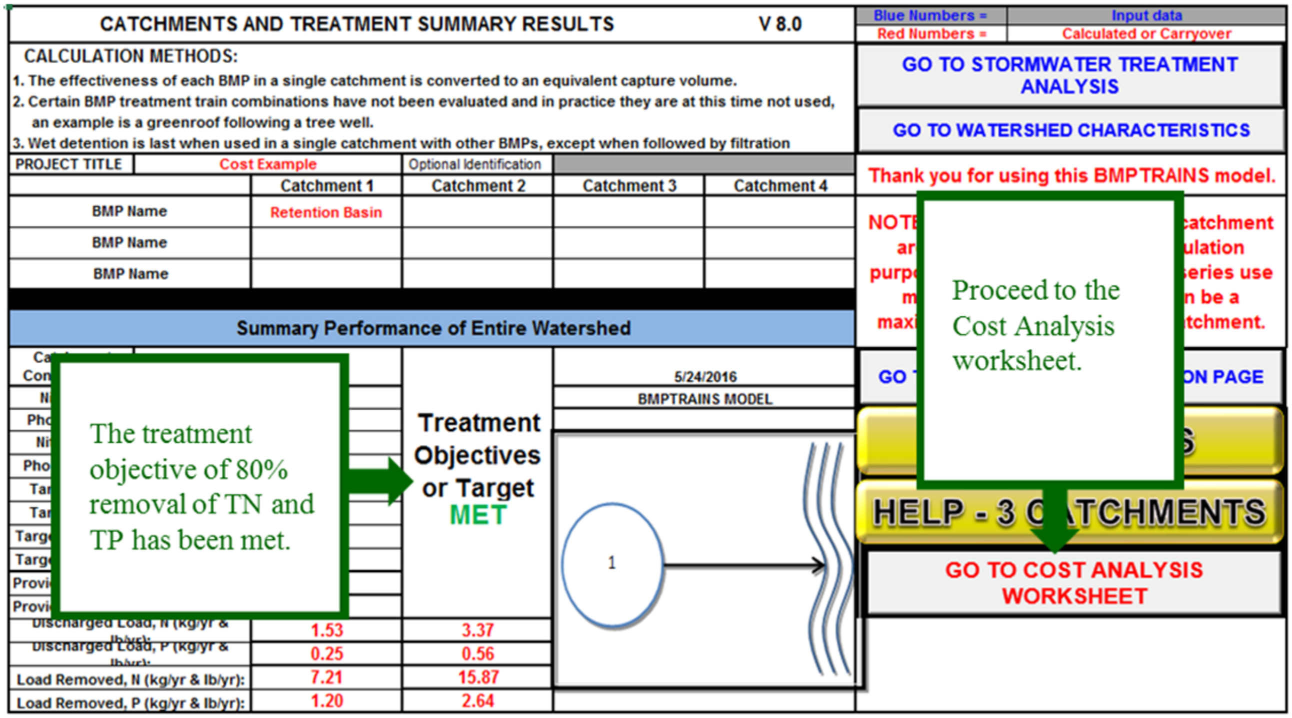


Figure 5-31 – Catchments and Treatment Summary Results

Scenario 6, Costs

34. 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 still 3% of the capital *BMP Cost*.

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

35. Fill in the remaining fields (see Figure 5-32).

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 #

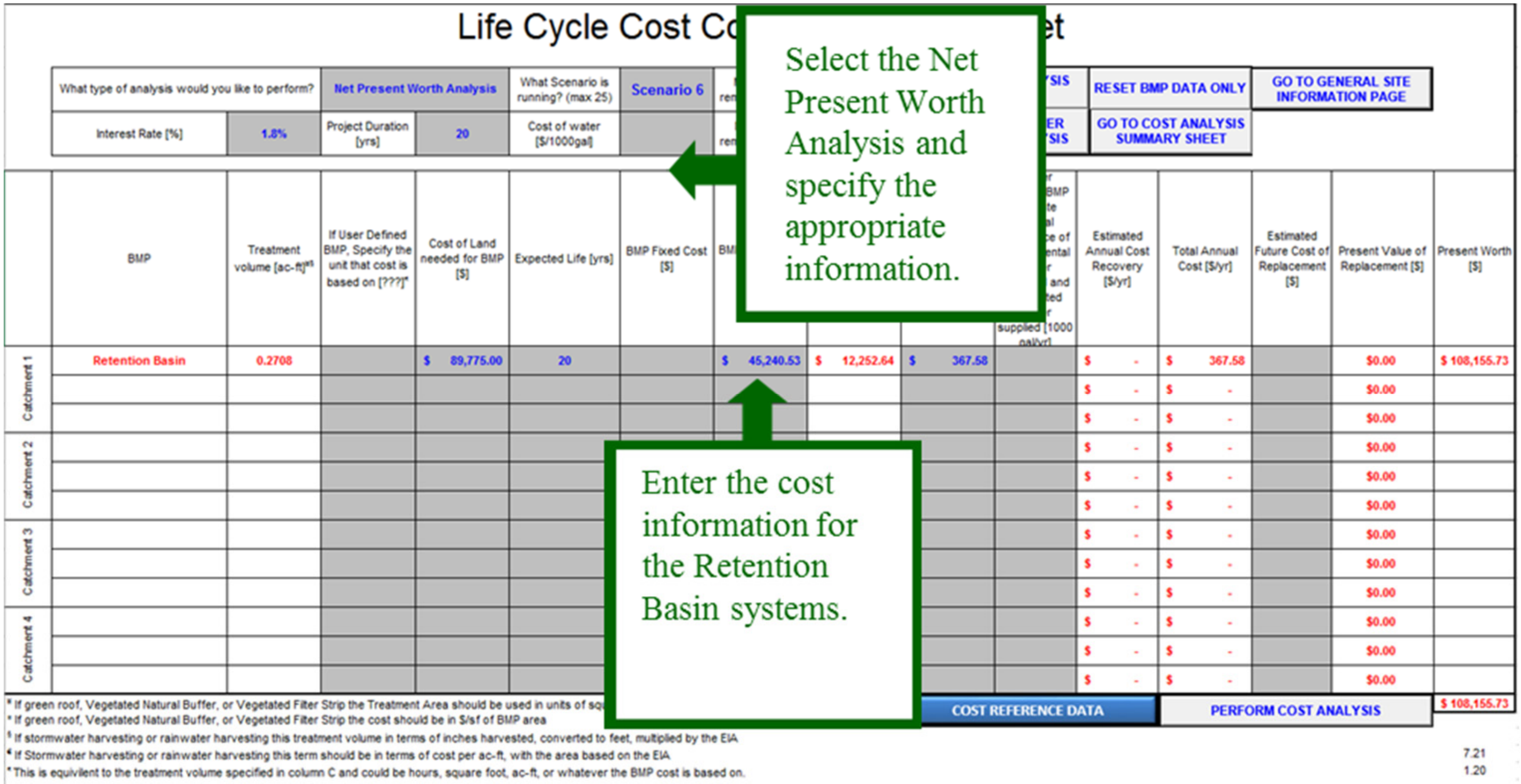


Figure 5-32 – Life Cycle Cost Comparison Worksheet

36. Perform Cost Analysis (see Figure 5-33).

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					
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Scenario 18					
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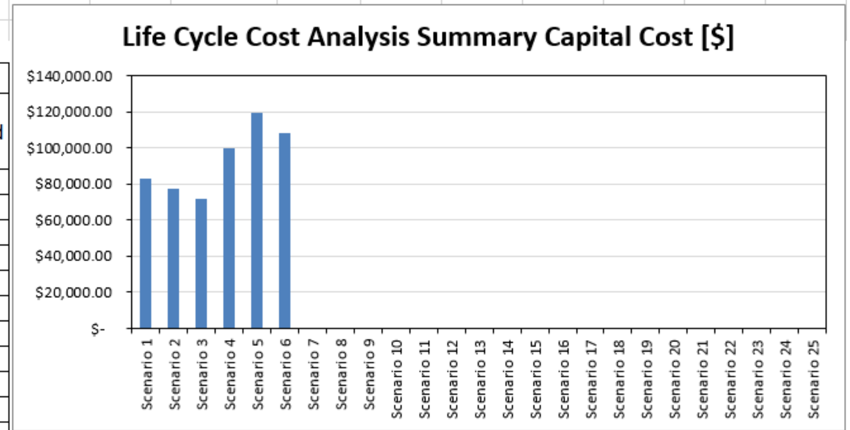
Scenario 20					
Scenario 21					
Scenario 22					
Scenario 23					
Scenario 24					
Scenario 25					



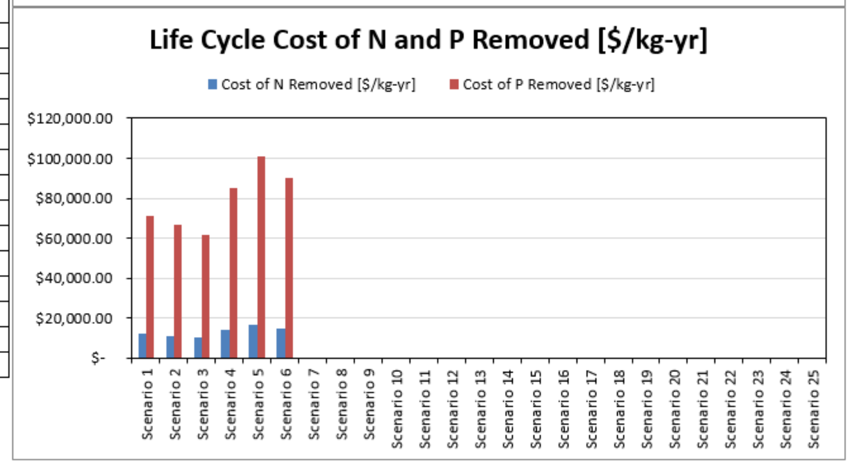


Figure 5-33 – Life Cycle Cost Analysis Summary

37. 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.

6. Conclusions

The previous BMPTRAINS model was a useful tool for comparing various BMP options for performance. The cost updates will enhance the BMPTRAINS model and assist engineers in choosing the most economical BMP option that achieves the required performance level. As shown in this memo, cost inputs for the model can be found in journal articles, government reports, and other similar documents.

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