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Development and Application of Coupled Optimization-Watershed Models for Selection and Placement of Best Management Practices in the Mackinaw River Watershed

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1. Introduction

Agricultural non-point source (NPS) pollution remains to be one of the biggest challenges in the Midwest due to extensive farming practices and the use of fertilizers to increase agricultural productivity. Excess sediment and nutrient loadings such as nitrogen and phosphorous are major causes of non-point source pollution in rivers and streams. The Mackinaw River watershed, which is one of the tributary watersheds of the larger Illinois River basin, covers a total drainage area of about 2950 square kilometers. Since 1990, this watershed has been one of The Nature Conservancy's (TNC) conservation sites, considered to be an area of biological significance in the Upper Mississippi River basin. The Mackinaw River watershed plan prepared by The Nature Conservancy in 1998 indicates that altered hydrology and sedimentation are the primary threats to the Mackinaw River. The plan provided recommendations to improve river hydrology and reduce sediment yields through changes in the landscape.

Conservation practices serve as crucial control measures in reducing NPS pollutants from agricultural watersheds. The 2008 Farm Bill provided more than $7 billion for promoting agricultural production and environmental quality by supporting implementation of structural or non-structural management practices under its Environmental Quality Incentives Program (EQIP) (Cowan and Johnson, 2008). Successful implementation of such programs, however, requires sound watershed management plans. Watershed management plans involving implementation of best management practices (*BMPs*) can help reduce pollution from agricultural sources. *BMPs* are structural or non-structural control measures that can be implemented in watersheds to control pollutant loads at their source or their transport to receiving water bodies. Implementation of these *BMPs* should focus on critical source areas that may contribute large amounts of pollutant loads. Identifying areas for the placement of *BMPs* should take into account both ecological benefits and associated implementation costs.

The objectives of this study include (1) developing watershed models for Mackinaw River and two of its tributary watersheds, namely Bray Creek and Frog Alley, to simulate streamflows and water quality constituent loads, and (2) developing a coupled optimization-watershed model for cost-effective selection and placement of *BMPs* in Bray Creek and Frog Alley watersheds to reduce nonpoint source pollutants such as sediment and nutrient loads to the streams. An integrated modeling approach that involves interfacing a simulation model with an optimization algorithm has been employed to develop the coupled optimization-watershed model. Such integrated modeling approaches have been demonstrated in solving complex, realistic problems in the areas of watershed management, reservoir operations, groundwater monitoring design, and others. In this study, the coupled optimization-watershed model was developed by interfacing a watershed model known as the Soil and Water Assessment Tool (SWAT) with Non-dominated Sorting Genetic Algorithm II (NSGA-II), a multi-objective optimization algorithm. Figure 1 shows the location map of the Mackinaw River watershed.

Figure 1.1. Location map of the Mackinaw River watershed

This report discusses the development and application of the watershed models and coupled optimization-watershed model. Chapter 2 provides a brief description of the watershed model used in this study. Major hydrologic and water quality processes simulated by SWAT are succinctly explained. Chapter 3 presents the hydrologic modeling of the Mackinaw River watershed. The model is calibrated for daily streamflows from 1995 to 1999 at two gauging stations, one of which is located in the middle of the watershed, whereas the second gauging station is close to the watershed outlet. The calibrated model is validated with flow records from 2000 to 2004, and the model exhibited good model performance in streamflow simulations. The Mackinaw River watershed model was not calibrated for sediment and nutrient loads as there were no available data. The hydrologic and water quality modeling for Bray Creek and Frog Alley watersheds are presented in Chapter 4. Both watersheds were calibrated for daily streamflows from 2002 to 2005 and average daily sediment and nutrient loads over the 2000–2005 period. Calibration results indicate that the model was able to satisfactorily simulate streamflows and water quality constituents. Insufficient data have prohibited further model validation. In Chapter 5, the development and application of the coupled optimization-watershed model are discussed. Brief descriptions of the multi-objective optimization algorithm (i.e., NSGA-II) and the integrated solution framework used in developing the model are provided. The coupled model was applied to both Bray Creek and Frog Alley watersheds in an effort to determine the optimal selection and placement of *BMPs* in the respective watersheds for maximized reduction of pollutants at possible minimal costs. Model simulations generally indicate that *BMPs* such as grassed waterways and filter strips were favored in controlling sediment and total phosphorus loads, respectively, whereas the maximum reduction of total nitrogen loads was obtained through selection and placement of constructed wetlands. The coupled optimization-watershed model can be used as a tool to make informed decisions in watershed management.

Acknowledgments and Disclaimer

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2. Watershed Simulation Model - Soil and Water Assessment Tool

SWAT is one of the most widely used, semi-distributed hydrologic models in the U.S and elsewhere. The model was developed to predict the long-term impacts of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds with varying soils, land use, and management conditions (Arnold et al., 1999). It incorporates a suite of algorithms that is capable of simulating hydrologic and water quality processes such as surface and subsurface flows, sediment transport, nutrient transport and cycling, and crop growth. Weather, topography, soil properties, vegetation, and land management practices are required by the model to simulate aforementioned watershed processes. Simulations can be done in a daily time step. For the contiguous U.S., the model incorporates a weather generator that makes use of long-term monthly average data to generate daily climate data for simulation or fill in gaps in observed records. SWAT has a geographical information systems (GIS) interface that can be used in processing spatial data, including watershed delineation, preparation of input files, and visualization of model outputs. The minimum data required to run SWAT for watersheds are predominantly available from government agencies (Nietsch et al., 2001).

Weather data are the most important input factors required to simulate watershed processes, and SWAT uses weather inputs for simulations of streamflows, potential evapotranspiration, snowmelt, crop growth, and others. Evapotranspiration can be either simulated by the model or computed outside of the model and incorporated into model simulations. Daily weather data required by the model include precipitation depths, minimum and maximum temperatures, solar radiation, relative humidity, and wind speed. SWAT uses a digital elevation model (DEM) for watershed delineation and its subsequent subdivision into subbasins. A user-defined critical source area that sets the minimum drainage area required to form the origin of a stream defines the details of a stream network and thus the number of subbasins in the watershed. The DEM is also used to compute geomorphic parameters for each subbasin in the watershed. Digital land use and soil maps are required by the model to identify land uses and soil types in the subbasins of the delineated watershed. Subbasins can be further subdivided into hydrologic response units (HRUs), which are patches of land areas with a unique intersection of land use, soil, and management conditions. A subbasin can be subdivided into a single HRU or multiple HRUs. A single HRU option represents the entire subbasin with the dominant land use and soil type and thus, in this particular case, HRUs and subbasins are the same entities. The multiple HRUs option employs threshold values for land use and soil categories to subdivide subbasins into two or more HRUs. Subdivision of subbasins into multiple HRUs introduces additional variability of model inputs that could impact the hydrologic and water quality processes in the watershed. This could also be achieved through detailed delineation of the watershed into smaller subbasins. It must be noted that the model identifies the land use and soil types of multiple HRUs without locating their exact positions. The ultimate goal has been to develop a decision support tool that couples the watershed models with a multi-objective optimization algorithm. The resulting coupled model is tasked with optimal selection and placement of *BMPs* in watersheds for maximized reduction of non-point source pollutants at a given implementation cost. For the placement of *BMPs* in watersheds, the exact location of the hydrologic response units should be identified. Therefore, in this study, the single HRU option has been employed with detailed subdivision of the watershed into a number of subbasins.

Major Hydrologic and Water Quality Processes Modeled in SWAT

SWAT incorporates a number of algorithms that simulate hydrologic and water quality processes, including sediment and nutrient yields and their associated transport mechanisms. Plant growth and various agricultural management practices can be modeled using SWAT. A brief description of major hydrologic and water quality processes that are of interest for this study is presented hereafter. A detailed account of these watershed processes can be found in SWAT's user's documentation (Neitsch et al., 2001).

Hydrologic Processes

SWAT simulates the complete hydrologic cycle based on a water balance in a given watershed. The water balance is the main driving force behind everything that occurs in the watershed (Neitsch et al., 2001), and it is expressed as

$$SW_t = SW_o + \sum_{i=1}^{t}\left(R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}\right)$$

where SW_t is the final soil water content (*mm* H_2O), SW_o is the initial soil water content on day i (*mm* H_2O), t is the time (*days*), R_{day} is the amount of precipitation on day i (*mm* H_2O), Q_{surf} is the amount of surface runoff on day i (*mm* H_2O), E_a is the amount of evapotranspiration on day i (*mm* H_2O), W_{seep} is the amount of water entering the vadose zone from the soil profile on day i (*mm* H_2O), and Q_{gw} is the amount of return flow on day i (*mm* H_2O). Surface runoff can be estimated by the SCS Curve Number procedure (SCS, 1972) or by the Green Ampt Infiltration Method (Green and Ampt, 1911); potential evapotranspiration can be estimated by the Penman-Monteith, Hargreaves, or Priestley method; percolation is simulated using a combination of a layered routing technique with a crack flow model; lateral subsurface flow or interflow is simulated using a kinematic storage model that accounts for variations in conductivity, slope, and soil water content; and groundwater flow is simulated using a linear reservoir approach subdividing an aquifer as deep and shallow (Arnold et al., 1993). Water routing through the channel network can be done using the Muskingum river routing method (Brakensiek, 1967; Overton, 1966) or the variable storage routing method (Williams, 1969), which are both variations of the kinematic wave routing model. The Muskingum routing procedure, which is the most widely used water routing model, is applied in this study.

Sediment Yield and Transport

SWAT uses the Modified Universal Soil Loss Equation (MUSLE) (Williams, 1995) to estimate erosion and sediment yield caused by a runoff. MUSLE is a modified version of the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978). USLE predicts erosion as a function of rainfall energy. Unlike USLE, the MUSLE uses runoff energy factor in both detaching and transporting of sediments. MUSLE is given as

$$S_{yield} = 11.8 \times \left(Q_{surv} \times q_{peak} \times A_{hru}\right)^{0.56} \times K \times C \times P \times (LS) \times F_c$$

where S_{yield} is the sediment yield on a given day (metric tons), Q_{surv} is the surface runoff volume ($mm\ H_2O/ha$), q_{peak} is the peak runoff rate (m^3/s), A_{hru} is the area of the HRU (ha), K is the USLE soil erodibility factor, C is the USLE cover and management factor, P is the USLE support practice factor, LS is the USLE topographic factor, and F_c is the coarse fragment factor. Sediment transport through a channel depends on both deposition and degradation processes. For sediment channel routing, SWAT uses a modification of Bagnold's sediment transport equation (Bagnold, 1977), which estimates the transport concentration capacity as a function of peak channel velocity. The modified equation is given as

$$S_{conc} = c_{sp} \times \left(V_{ch,peak}\right)^{sp\exp}$$

where S_{conc} is the maximum concentration of sediment that can be transported by the water (ton/m^3 or kg/L), c_{sp} is the user-defined calibration coefficient, $V_{ch,\,peak}$ is the peak channel velocity (m/s), and *spexp* is the user-defined exponent that varies between 1.0 and 2.0.

Nutrient Transformation and Transport

SWAT simulates the transformation of different forms of nitrogen and phosphorus in the watershed soils as governed by nitrogen and phosphorus cycles, respectively. Nutrients including nitrate, organic nitrogen, soluble phosphorus, and organic phosphorus may be transported downstream by surface runoff and subsurface flows. Nitrate removed with the surface runoff or lateral flow in the top 10 millimeters (mm) of the soil layer is given as:

$$NO_{3,slp} = \beta_{NO_3} \times C_{NO_{3,m}} \times Q_{slp}$$

where $NO_{3,slp}$ is the nitrate removed from the top 10 mm of the soil layer either with the surface runoff or lateral flow or the nitrate removed to the underlying layer by percolation ($kg\ N/ha$), β_{NO3} is the nitrate percolation coefficient, allowing the user to set the concentration of nitrate in the surface runoff with respect to the concentration in the percolate. This coefficient is set to 1.0 while computing nitrate removed with lateral flow in the lower layers and those transported with the percolating water to the underlying layer. $C_{NO3,\,m}$ is the concentration of nitrate in the mobile water for a given soil layer (*kg N/mm* H_2O), and Q_{slp} is either the surface runoff, lateral flow, or percolating water to the underlying layer. Organic nitrogen attached to the soil particles may also be transported by the surface runoff, and its loading is a function of the sediment loading from an HRU. It can be estimated by a loading function developed by Williams and Hann (1978) given as

$$orgN_{surf} = 0.001 \times C_{orgN} \times \frac{S_{yield}}{A_{hru}} \times \varepsilon_{N:S}$$

where $orgN_{surf}$ is the amount of organic nitrogen transported to the main channel in surface runoff (*kg N/ha*), S_{yield} and A_{hru} are as defined earlier, C_{orgN} is the concentration of organic nitrogen in the top 10 mm of the soil layer (*g N/metric ton soil*), and $\varepsilon_{N:S}$ is the nitrogen enrichment ratio, which is defined as the ratio of the concentration of organic nitrogen transported with the sediment to the concentration in the soil surface layer.

Soluble phosphorus has generally low mobility as its movement is primarily by diffusion. It can also be transported with the surface runoff and is computed in SWAT as

$$P_{surf} = \frac{P_{S,surf} \times Q_{surf}}{\rho_b \times D_{surf} \times k_{d,surf}}$$

where P_{surf} is the amount of soluble phosphorus lost in surface runoff (*kg P/ha*), $P_{s,surf}$ is the amount of phosphorus in solution in the top 10 mm of the soil layer (*kg P/ha*), ρ_b is the bulk density of the top 10 mm (kg/m^3), Q_{surf} is as defined earlier, and D_{surf} is the depth of the top soil layer (*10 mm*), and $k_{d,surf}$ is the phosphorus soil partitioning coefficient (m^3/kg), which is the ratio of soluble phosphorus concentration in the top 10 mm of soil layer to the concentration of soluble phosphorus in surface runoff. Organic and mineral phosphorus attached to soil particles can be transported by surface runoff to streams, and the same loading function adjusted for organic and mineral phosphorous is used. It is given as

$$sdP_{surf} = 0.001 \times C_{sdP} \times \frac{S_{yield}}{A_{hru}} \times \varepsilon_{P:S}$$

where sdP_{surf} is the amount of organic and mineral phosphorus transported to the main channel in surface runoff (*kg P/ha*), S_{yield} and A_{hru} are as defined earlier, C_{sdP} is the concentration of phosphorus attached to sediment in the top 10 mm of the soil layer (*g P/metric ton soil*), and $\varepsilon_{P:S}$ is the phosphorus enrichment ratio, which is defined as the ratio of the concentration of phosphorus transported with the sediment to the concentration in the soil surface layer.

Nutrient transformation in the stream can also be modeled using the in-stream water quality component of the SWAT model adapted from QUAL2E (Brown and Barnwell, 1987), which tracks nutrients in the stream that are adsorbed to the sediment.

3. Modeling of the Mackinaw River Watershed

A hydrologic model for the entire Mackinaw River watershed was developed using SWAT's GIS interface and FORTRAN version. The SWAT's GIS interface was used to perform spatial data analysis, watershed delineation, and preparation of model input files including generation of model default parameters. For watershed and subbasin delineations and derivation of topographical information, a 30-m resolution DEM was obtained from the National Elevation Dataset (NED) for the Mackinaw River watershed (downloaded from BASINS's website at http://www.epa.gov/waterscience /ftp/basins/gis_data/huc/. In order to better represent the watershed characteristics, a critical source area of 1,500 hectares has been employed to divide the Mackinaw River watershed into 113 subbasins as shown in Figure 3.1. The critical source area defines the detail of the stream network and hence, determines the total number of subbasins. While setting the critical source area, due consideration has been taken to allow capturing the heterogeneity of input factors such as land use, soils, and weather, which are crucial for watershed hydrology and water quality simulations. In generating hydrologic response units (HRUs), which are patches of land with a unique intersection of land use, soil, and management condition, the single HRU option has been employed, representing a subbasin by a single HRU adopting the subbasin's dominant land use and soil types.

Land Use and Soils

The soil and land use data were obtained from NRCS's STATSGO database and Illinois Interagency Landscape Classification Project (IILCP), which are based on the 1999–2000 land cover inventory, respectively. Figures 3.2 and 3.3 show land use and soil types in the Mackinaw River watershed. More than 90 percent of the watershed area is agricultural land, including corn (42 percent), soybeans (39 percent), and pasture (10 percent). Urban areas, forest, and wetlands compose less than 10 percent of the watershed area.

The STATSGO soil database was used to extract soil physical characteristics such as soil permeability and available soil water capacity, which affect infiltration and runoff generation. In terms of their infiltration capacity or runoff potential, soils of Mackinaw River watershed belong to hydrologic soil group B, exhibiting moderate infiltration capacity.

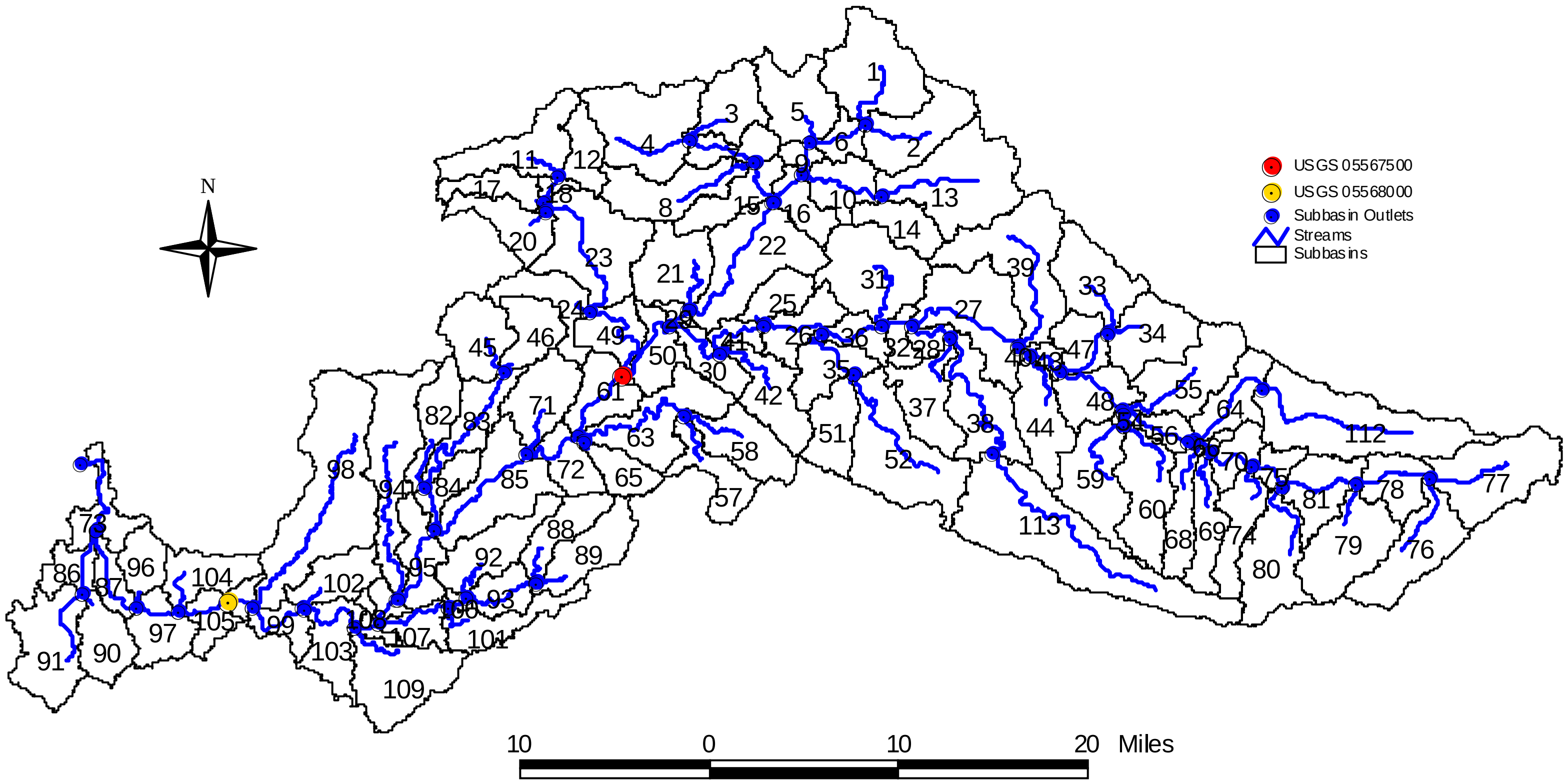


Figure 3.1. Delineations of the Mackinaw River watershed into subbasins

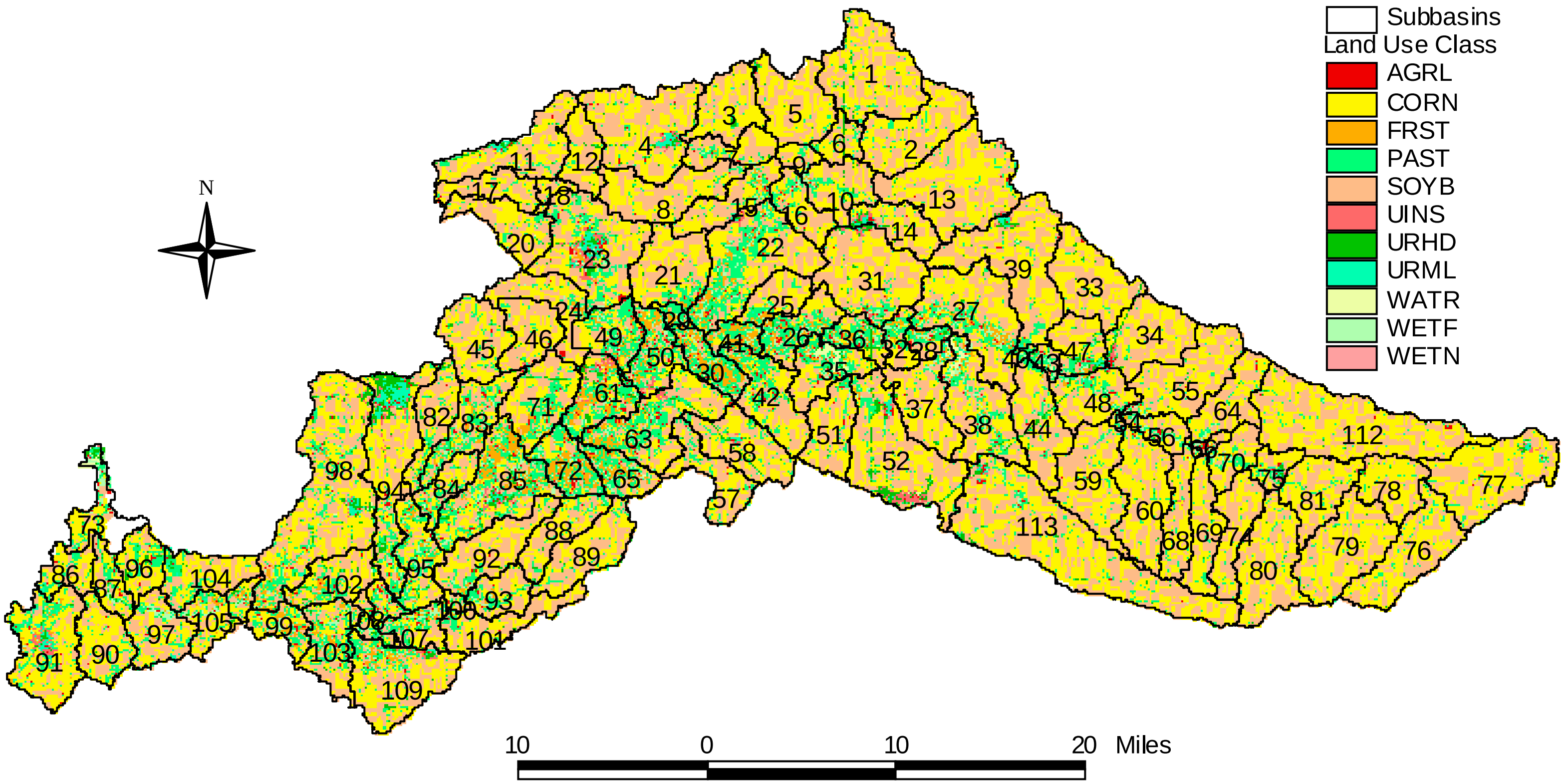


Figure 3.2. Land use types in the Mackinaw River watershed

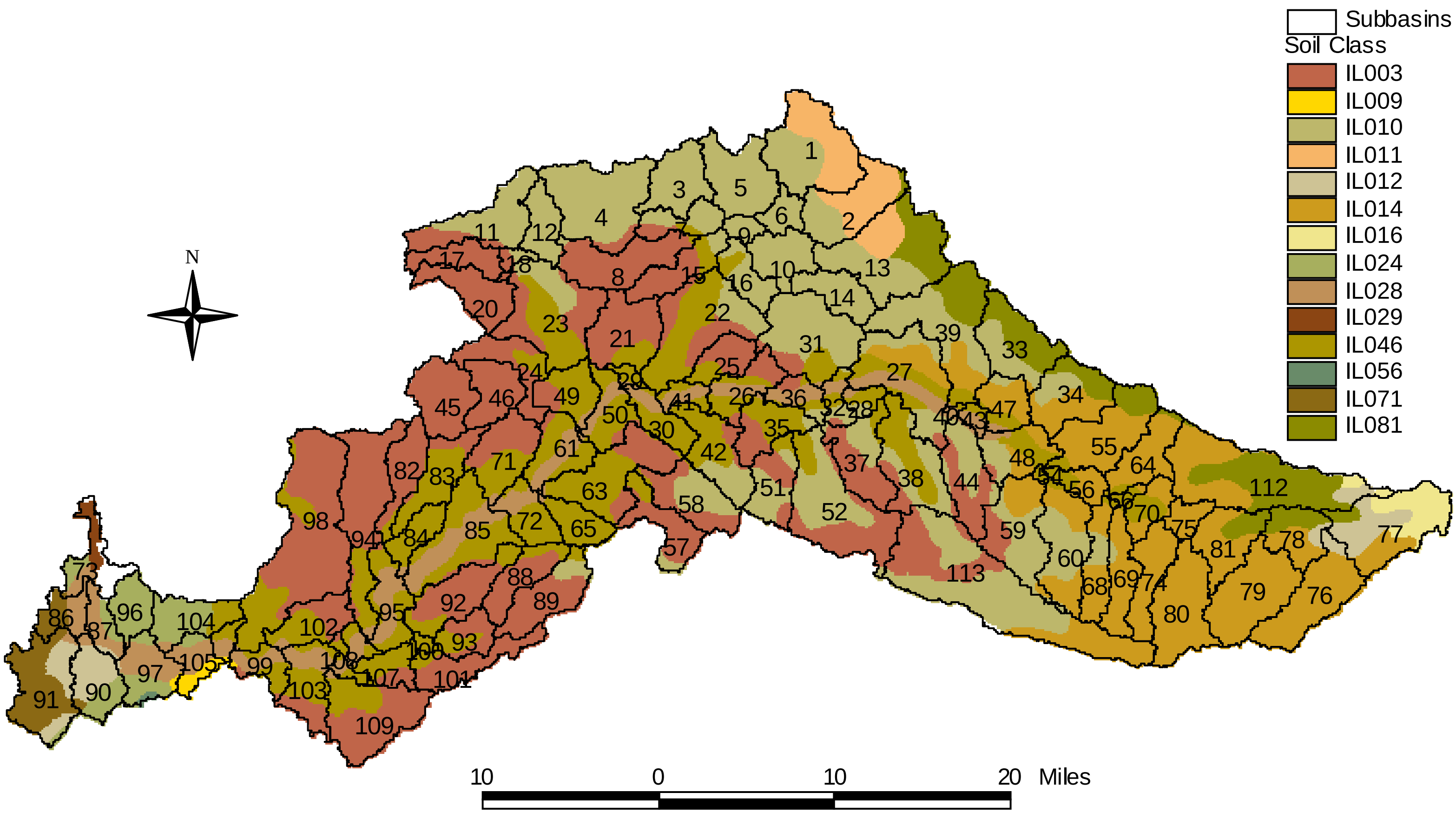


Figure 3.3. STATSGO soil classes in the Mackinaw River watershed

Weather Data

Weather data are one of the most important input factors required by the SWAT model to simulate hydrologic and water quality processes. The watershed model makes use of weather inputs for simulations of streamflows, potential evapotranspiration, snowmelt, crop growth, and others. Daily weather data required by the model include precipitation depths, minimum and maximum temperatures, solar radiation, relative humidity, and wind speed. Precipitation and temperature data from eight stations that are in or close to the watershed were obtained. Missing data gaps were filled in using data from neighboring stations. The mean annual precipitation was 37.8 inches (960 mm) for the period 1995 to 2004. Table 3.1 lists the weather stations used in the watershed simulation. Weather stations were assigned to subbasins based on their proximity to the centroids of the subbasins. Other climate inputs, such as relative humidity, solar radiation, and wind speed, are generated from long-term monthly average values included in SWAT's database using a weather-generator tool. Daily average relative humidity is calculated from a triangular distribution and monthly average values. Daily solar radiation was generated from a normal distribution, and daily wind speed was simulated using a modified exponential function and mean monthly values. Potential evapotranspiration was estimated using the Penman-Monteith method, which requires climate inputs such as relative humidity, solar radiation, and wind speed.

Streamflows

For calibration and validation of the Mackinaw River watershed model, daily streamflow data were downloaded from the United States Geological Survey's website of the National Water Information System (http://waterdata.usgs.gov/il/nwis/) for two gauging stations. One of the gauging stations is near Congerville (*USGS 05567500*), draining 67 percent of the watershed area and the other is located near Green Valley (*USGS 05568000*). The second station is also close to the watershed outlet, draining 94 percent of the watershed area. The average daily flows from 1995 to 2004 were 13.9 and 19.5 cubic meter per second (m^3/s) at *USGS 05567500* near Congerville and *USGS 05568000* near Green Valley gauging stations, respectively.

Table 3.1. Weather Stations Used in the Mackinaw River Watershed Simulation

Site Code	*Station Name*	*Precipitation / Temperature Data*
111475	Chenoa	1994-2004
111627	Chillicothe	1994-2004
110761	Bloomington	1994-2004
115272	Mackinaw	1994-2004
116711	Peoria	1994-2004
116819	Piper City	1994-2004
111250	Canton	1994-2004
113940	Havana	1994-2004

Model Calibration and Validation

Calibration is the process of adjusting model parameters until simulated outputs closely match observed data. SWAT is a semi-distributed watershed model involving a large number of calibration parameters. The number of calibration parameters in a given SWAT model is a function of the number of subbasins delineated and its further subdivisions into hydrologic response units. The finer the delineation, the larger the number of subbasins will be, resulting in a large number of model parameters to be calibrated. Due to a large number of parameters and high level of interaction amongst these parameters, a combination of manual and automatic calibration methods was employed. The manual calibration procedure was employed to improve watershed simulation through further refinement of model parameters. Once the calibration process was completed, validation of the model using input data that was not used when the calibration period was performed.

A total of 39 model parameters that affect stream flow simulations have been identified and calibrated. Some of the most important parameters and their ranges of variation are provided in Table 3.2. Model parameters for streamflow simulation include those that govern the accumulation of snow and snowmelt runoff processes, rainfall-runoff processes, subsurface flow, and tile drainage. For example, parameters such as *SFTMP* and *SMTMP*, which are snowfall and snowmelt base temperatures, respectively, are essential in simulating snow accumulation and snow melt processes. Curve number (*CN2*) and available soil water capacity (*SOL_AWC*) affect surface runoff simulations. The model uses *CN2* to compute depth of accumulated runoff or rainfall excess. *SOL_AWC* is the amount of water available to plants when the soil is at field capacity, and it is expressed as a fraction of the total soil water volume and varies with the soil layer. Groundwater parameters such as *GW_REVAP*, *REVAPMN* and *GWQMN* are used in simulating subsurface flows. Tile drainage contribution to stream is simulated using depth to subsurface drains (*DDRAIN*), time to drain soil to field capacity (*TDRAIN*), and tile drain lag time (*GDRAIN*).

Table 3.2. Selected Calibration Parameters for Streamflow Simulations

Parameter name	*Description of the parameters (units)*	*Parameter Range*		*Calibrated Parameter value*
		Min.	*Max.*	
CN2	SCS runoff curve number (-)	30	70	69.24
SOL_AWC[1]	Available soil water capacity	-10	10	1.09
ESCO	Soil evaporation compensation factor (-)	0.8	1	0.9588
GW_REVAP	Groundwater " *REVAP* " coefficient (-)	0.02	0.2	0.0386
REVAPMN	Minimum Threshold depth of water in the shallow aquifer for "*REVAP*" to occur	1	200	156.2
GWQMN	Minimum threshold depth of water in the shallow aquifer required for return flow to occur (mm)	1	100	2.13
ALPHA_BF	Base flow alpha factor (days)	0	1	0.981
RCHRG_DP	Deep aquifer percolation fraction (-)	0	0.25	0.119
DELAY	Groundwater delay (days)	0	100	15
CH_N2	Manning's "n" value for the main channels (-)	0.025	0.065	0.011
OV_N	Manning's "n" value for overland flow (-)	0.05	0.3	0.29
SURLAG	Surface runoff lag time (days)	0.5	4	2.563
SFTMP	Snowfall temperature (^{o}C)	-3	5	-0.539
SMTMP	Snow melt base temperature (^{o}C)	0	5	-0.397
SMFMX	Melt rate for snow on June 21 (mm/^{o}C day)	1.4	6.9	3.876
SMFMN	Melt rate for snow on December 21 (mm/^{o}C day)	1.4	6.9	5.201
DDRAIN	Depth to subsurface drain	0	2000	591.5
TDRAIN	Time to drain soil to field capacity	0	72	71.87
GDRAIN	Tile drain lag time	0	100	38.891

[1] *Percent change from its orginial value*

With the exception of a few, such as snow melt parameters that assume uniform values over the watershed, most parameters vary by subbasin or hydrologic response units. Parameter change during calibration was done in one of three ways: by replacing with a new parameter value, adding a value to the initial parameter, or by multiplying the initial parameter with a coefficient. The Mackinaw River watershed model was calibrated for daily streamflows from 1995 to 1999 at both gauging stations. The watershed model performance was evaluated using the Nash-Sutcliffe model (*NSE*), which is a normalized statistic that quantifies the relative magnitude of the residual variance compared to the variance of the measured data (Nash and Sutcliffe, 1970). The *NSE* is calculated as

$$NSE = 1 - \left[\frac{\sum_{j=1}^{N} \left(O_j - S_j\right)^2}{\sum \left(O_j - \overline{O}\right)^2} \right]$$

where O_j and S_j are the j^{th} observed and simulated data, respectively, $\overline{O}$ is the mean of observed data, and *N* is the total number of data used during calibration. The *NSE* values range from minus infinity to 1.0 for a perfect model. However, the values should be larger than zero to indicate minimally acceptable performance (Gupta et al., 1999). *NSE* values less than or equal to zero show that observed mean is a better predictor than the model. Percent bias (*PBIAS*) measures the average tendency of the simulated values to be larger or smaller than their observed data (Gupta et al., 1999). A *PBIAS* of zero value indicates exact simulation of observed data, and a lower value of *PBIAS* generally signifies accurate model simulation. The *PBIAS* is given as

$$PBIAS = 100 \times \left[\frac{\sum_{j=1}^{N} \left(O_j - S_j \right)}{\sum O_j} \right]$$

where O_j, S_j, and *N* are as defined earlier.

Tables 3.3 and 3.4 show the performance statistics at daily and annual time steps for both calibration and validation periods. Overall, the watershed model effectively simulated streamflows at daily, monthly, and annual time steps. Streamflow calibration precedes calibration of water quality constituents. However, calibration of the Mackinaw River watershed model was limited to streamflows since no water quality data are available for these two gauging stations. The model efficiencies for daily, monthly, and annual streamflow simulations were at least 0.78 during the calibration period. Graphical comparisons of simulated and observed daily streamflows for the calibration period are presented in Figures 3.4 and 3.5 for *USGS 05567500* and *USGS 05568000*, respectively. Both figures exhibit good matches between simulated and observed streamflow values, and model simulation of average daily flows show a percentage bias (*PBIAS*) of less than 8 percent at both stations, indicating model bias towards underestimation of flows. The model performance was good in simulating range of flows at both gauging stations. The calibrated model was validated using streamflow records from 2000 to 2004 at both gauging stations, and a model efficiency of at least 0.68 was obtained for daily, monthly, and annual streamflow simulations. Figures 3.6 and 3.7 display the graphical comparisons of streamflows at both gauging stations, showing a good match between simulated and observed values. The absolute percent bias was less than 7 percent during the validation period, showing slight underestimation and overestimation of streamflows at *USGS 05567500* near Congerville and *USGS 05568000* near Green Valley, respectively.

Table 3.3. Performance Statistics for Streamflow Simulations at *USGS 05567500*

Performance statistic	*Calibration (1995-1999)*	*Validation (2000-2004)*
NSE (-)		
daily	0.82	0.71
Monthly	0.91	0.8
Annual	0.78	0.83
PBIAS (%)	3.4	0.4

Table 3.4. Performance Statistics for Streamflow Simulations at *USGS 05568000*

Performance statistic	*Calibration (1995-1999)*	*Validation (2000-2004)*
NSE (-)		
daily	0.85	0.68
Monthly	0.94	0.8
Annual	0.83	0.74
PBIAS (%)	7.1	-6.3

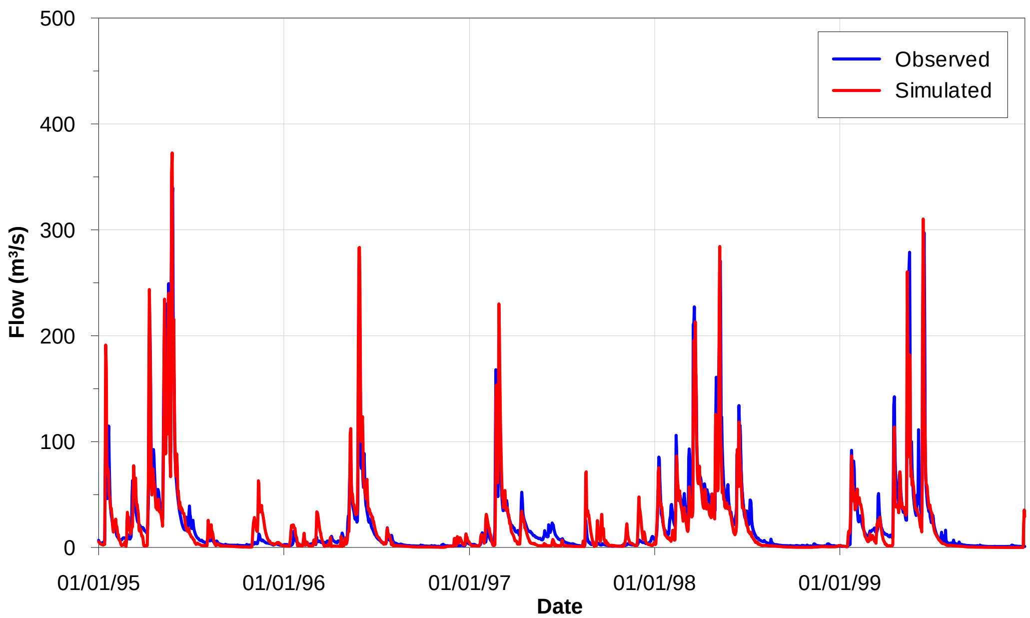


Figure 3.4. Comparison of observed and simulated daily flows at *USGS 05567500* for calibration period

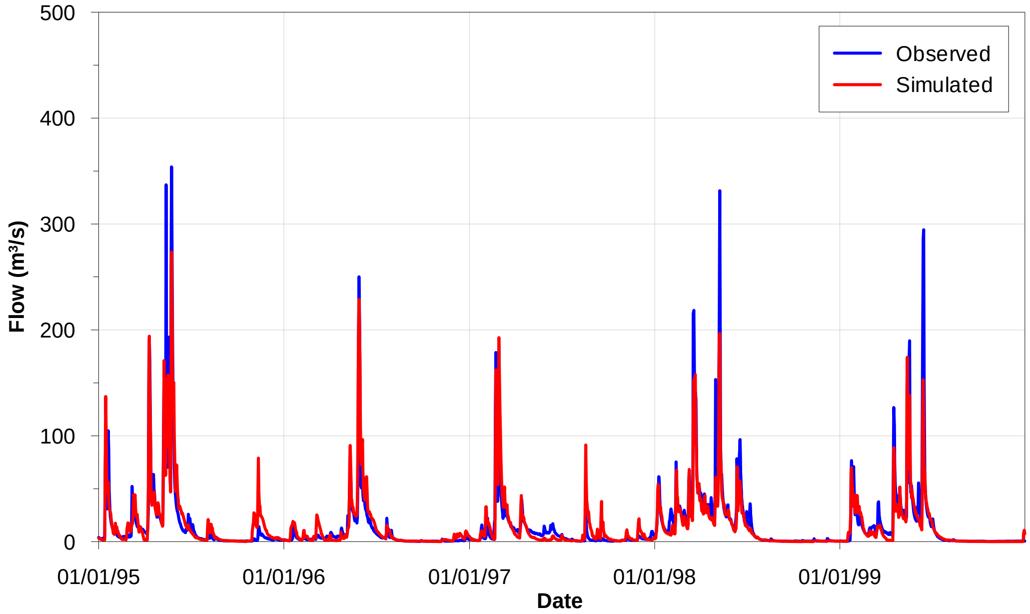


Figure 3.5. Comparison of observed and simulated daily flows at *USGS 05568000* for calibration period

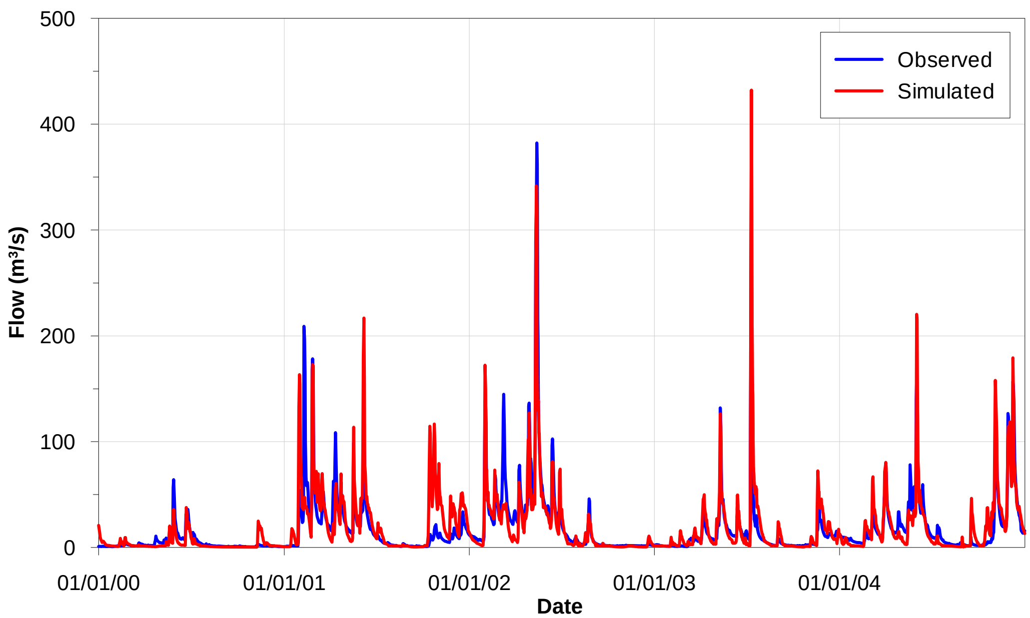


Figure 3.6. Comparison of observed and simulated daily flows at *USGS 05567500* for validation period

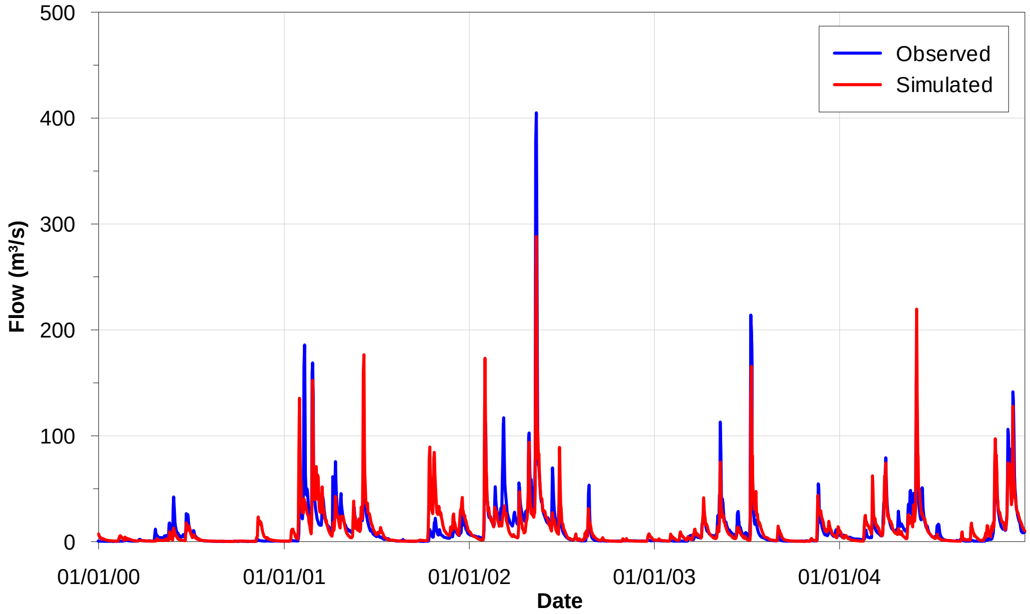


Figure 3.7. Comparison of observed and simulated daily flows at *USGS 05568000* for validation period

4. Modeling of Bray Creek and Frog Alley Watersheds

Hydrologic and water quality models for Bray Creek and Frog Alley, which are tributary watersheds of the larger Mackinaw River watershed, were also developed using SWAT. A 30-m resolution DEM was used for watershed delineation and derivation of topographical information. The Bray Creek and Frog Alley watersheds were subdivided into 74 and 82 subbasins, respectively, based on the minimum allowable critical source area of 25 hectares (see Figure 4.1) for the two watersheds. The critical source area defines the detail of the stream network and thus the number of subbasins. Finer subbasin delineation helps capture the heterogeneity of input factors such as land use, soils, and weather data that are crucial for hydrologic and water quality simulations. Since the watershed models developed here are used to develop decision support models for selection and placement of *BMPs* in the watersheds, the exact location of HRUs should be known. SWAT, however, does not identify the location of HRUs if multiple HRUs are generated in a subbasin. In addition, it is not possible to simulate some of the *BMPs* considered in this study such as grassed waterways at multiple HRU levels. Therefore, dominant land use and soil types in subbasins were used to generate HRUs, resulting in one HRU per subbasin. Alternatively expressed, both HRUs and subbasins are the same entities in this particular case, having both HRU and subbasin properties in the model.

Land Use and Soils

The digital land use map was obtained from the Illinois Interagency Landscape Classification Project (IILCP), which is based on the 1999–2000 land cover inventory. Figure 4.3 and 4.4 show the land use and soil types in Bray Creek and Frog Alley watersheds, respectively. Both watersheds are predominantly agricultural with corn and soybeans accounting for more than 90 percent of the watershed area. Urban areas, pasture, and wetlands make up collectively less than 10 percent of the watershed. The NRCS's SSURGO soil database was obtained for both watersheds and processed for use in the SWAT model. Based on infiltration capacity or runoff potential, the soils of Bray Creek and Frog Alley watersheds mainly belong to hydrologic soil group B.

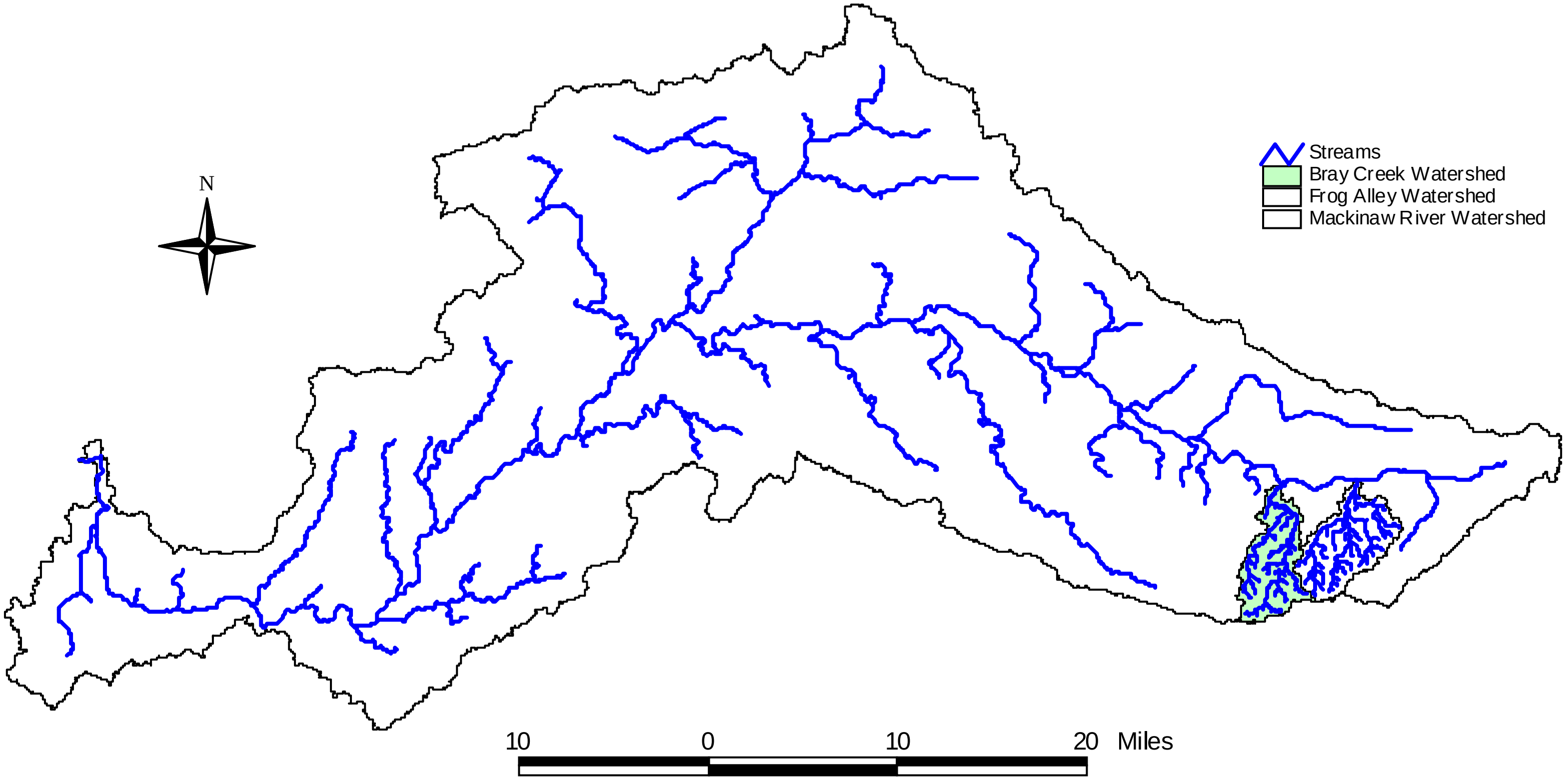


Figure 4.1. Location map of Bray Creek and Frog Alley watersheds

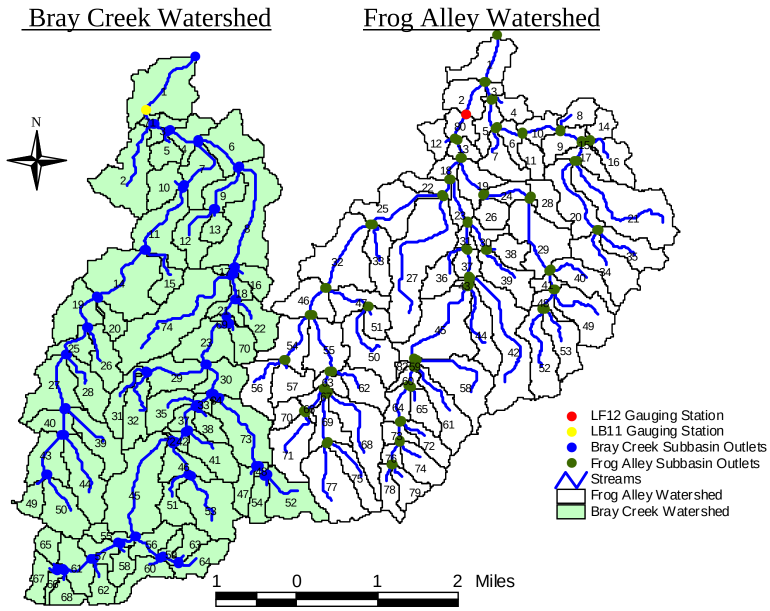


Figure 4.2. Delineations of Bray Creek and Frog Alley watersheds

Weather Data

Weather data from two precipitation stations in Bray Creek and Frog Alley watersheds were obtained and the stations have been operated by the Nature Conservancy (TNC). Temperature data were obtained from a regional weather station near Chenoa (*111475*). All three weather stations were used in preparing complete precipitation data for the two watershed models. The model assigns weather stations to each subbasin of the watersheds based on the proximity of the stations to the centroids of the subbasins. In this particular case, each model uses precipitation and temperature data from a single weather station, resulting in the same weather station being assigned to all subbasins in their respective watersheds. Table 4.1 shows a list of the weather stations used to prepare precipitation and temperature data for the two watersheds. Other climate inputs such as relative humidity, solar radiation, and wind speed were generated from long-term monthly average values included in SWAT's database using its weather-generator tool. Daily average relative humidity was calculated from a triangular distribution and monthly average values. Daily solar radiation was generated from a normal distribution, and daily wind speed was simulated using a modified exponential function and mean monthly values. These climate inputs were used to estimate potential evapotranspiration using the Penman-Monteith method, which is employed in this study during watershed simulation.

Table 4.1. Weather Stations Used in the Bray Creek and Frog Alley Watershed Simulations

Site Code	*Station name*	*Precipitation Data*	*Temperature Data*	*Remark*
-	Bray Creek	2001 to 2005	-	
-	Frog Alley	2002 to 2005	-	Missing: 2002, 2003
111475	Chenoa	2000 to 2005	2000 to 2005	

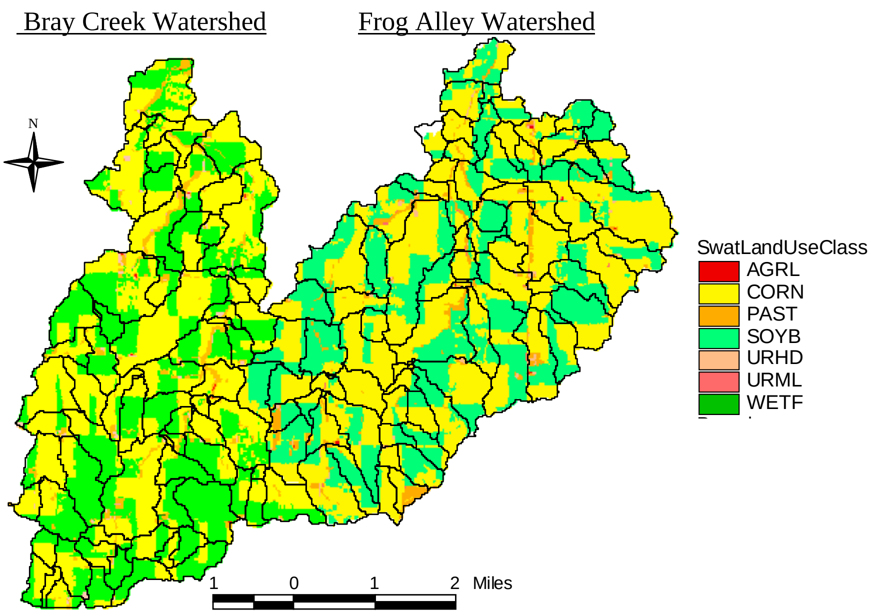


Figure 4.3. Land use types in Bray Creek and Frog Alley watersheds

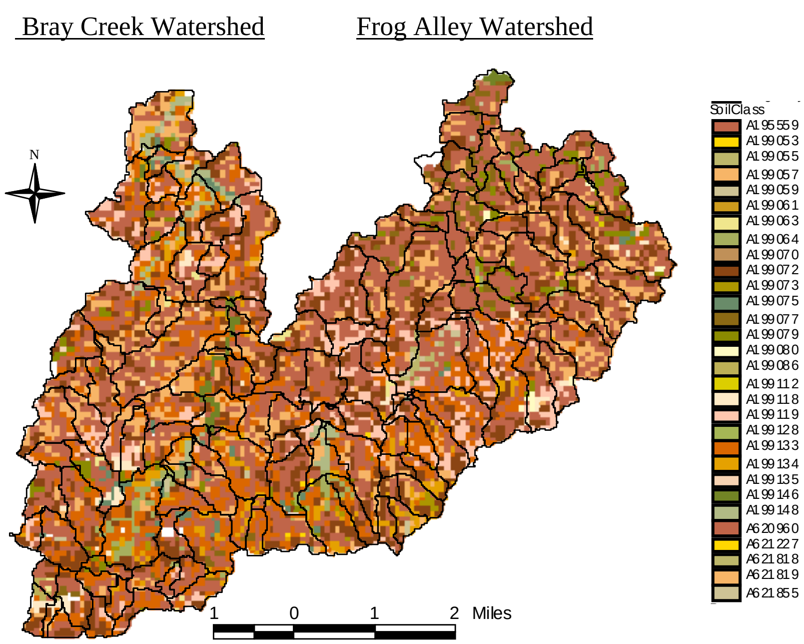


Figure 4.4. SURRGO soil classes in Bray Creek and Frog Alley watersheds

Streamflow and Water Quality Data

Streamflows and water quality data from 2002 to 2005 were obtained for Bray Creek and Frog Alley watersheds from *LB11* and *LF12* gauging stations, respectively, operated by TNC. These two gauging stations are close to their respective watershed outlets as shown in Figure 4.1, and were used to calibrate Bray Creek and Frog Alley watershed models for streamflows and water quality constituents. The water quality data include concentrations of total suspended sediment (*TSS*), total phosphorus (*TP*), and different forms of nitrogen such as $NO_2\text{-}N$, $NO_3\text{-}N$, and $NH_3\text{-}N$. Total nitrogen normally composes organic nitrogen, nitrite-nitrogen, nitrate-nitrogen, and ammonia-nitrogen. In this particular application, however, the total nitrogen (*TN*) does not include organic nitrogen as there were no available data for calibration. Using streamflows at each gauging station, the concentrations were converted into loads. Tables 4.2 and 4.3 show average daily flows, *TSS*, *TP*, and *TN* loads from 2002 to 2005 and their corresponding number of data points. Average flow and water quality data for Bray Creek and Frog Alley watersheds are very much comparable. Streamflow data at *LB11* station have 3 percent missing observations, whereas the *LF12* station has 12 percent missing. The water quality data are less frequent and their availability ranges from 4 percent for *TP* to 12 percent for *TSS* at both *LB11* and *LF12* gauging stations.

Table 4.2. Average Flows and Pollutant Loads for Bray Creek Watershed

Observed Data	*Average Daily Values at LB11 Station (2002-2005)*	*Number of Observations*	*Data Availability*
Flow (m^3/s)	0.44	1416	97%
TSS (*tons/d*)	2.28	171	12%
TN (*kg/d*)	369.1	108	7%
TP (*kg/d*)	4.29	60	4%

Table 4.3. Average Flows and Pollutant Loads for Frog Alley Watershed

Observed Data	*Average Daily Values at LF12 Station (2002-2005)*	*Number of Observations*	*Data Availability*
Flow (m^3/s)	0.51	1287	88%
TSS (*tons/d*)	2.32	158	11%
TN (*kg/d*)	371.2	96	8%
TP (*kg/d*)	3.93	61	4%

Streamflow calibration precedes water quality calibrations as the water quality constituent loads are dependent on the amount of streamflow. Once acceptable streamflow simulations were obtained, sediment calibrations followed. Finally, nutrient calibrations were performed as their simulations are both dependent on fairly accurate streamflow and sediment calibrations. For model calibration, parameters that affect streamflow and water quality simulations have been identified. Some of the most important streamflow parameters were already discussed earlier in Chapter 3. For calibration of *TSS*, SWAT parameters that influence simulation of sediment yield and transport were identified. SWAT uses a modified universal soil loss equation to calculate sediment yield. Model parameters such as *USLE_C*, *USLE_P*, and *SLSUBBSN*, which are parameters of the Universal Soil Loss Equation (USLE) representing input factors related to land cover and management, support practices and topography, respectively, were selected for calibration. In addition, parameters associated with sediment transport, including channel cover (*CH_COV*) and erodibility (*CH_EROD*) factors, were identified for calibration. Finally, model parameters that are important for nutrient simulations were calibrated, including parameters related to nitrogen and phosphorous cycles, fertilizer application, and initial nutrient levels in the soil.

Calibration Results for Bray Creek Watershed

The Bray Creek watershed model was calibrated for daily streamflows at *LB11* gauging station. Model efficiency (*NSE*) of 0.5 was obtained for the calibration period of 2002–2005. A graphical comparison of observed and simulated streamflows at *LB11* is shown in Figure 4.5. Average daily flows were simulated with less than 1 percent error and peak flows during the calibration period were simulated with less than 20 percent error. The observed and simulated average flows were both 0.44 m^3/s, whereas the observed and simulated peak flows were 26.5 and 21.2 m^3/s, respectively. The model is calibrated for average daily loads of total suspended sediment (*TSS*), total phosphorus (*TP*), and total nitrogen (*TN*) from 2002 to 2005. Table 4.4 shows simulated average *TSS*, *TN*, and *TP* loads as compared to their observed counterparts. The calibrated model was able to simulate average daily constituent loads during the calibration period with less than 6 percent error, showing a slight overestimation in all cases.

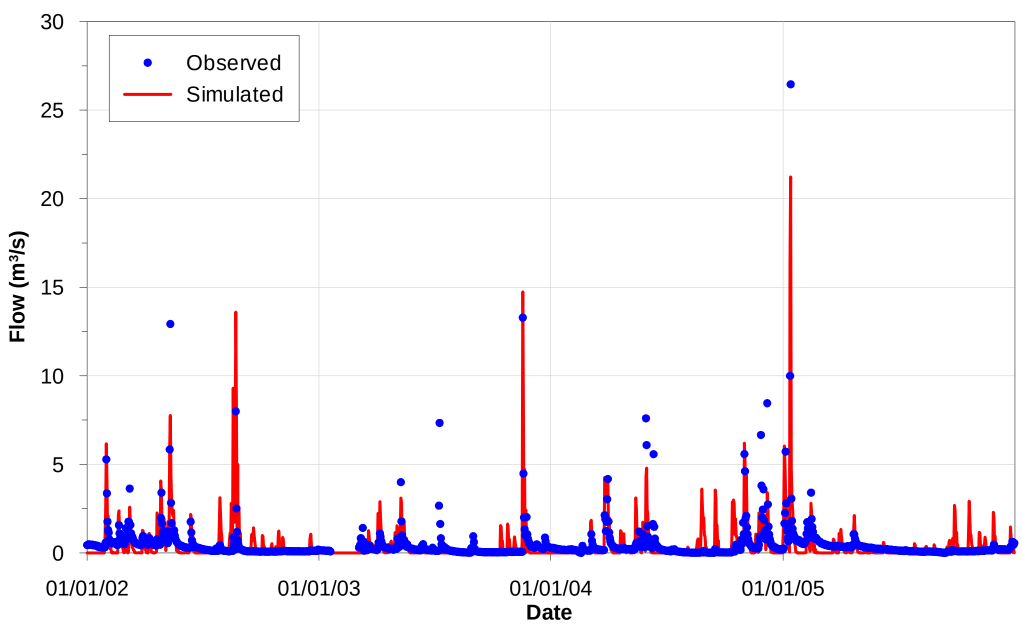


Figure 4.5. Comparison of observed and simulated daily flows at *LB11*

Table 4.4. Observed and Simulated Pollutant Loads for Bray Creek Watershed

Pollutants	*Observed (2002- 2005)*	*Simulated (2002-2005)*
TSS (*tons/d*)	2.28	2.4
TN (*kg/d*)	369.1	379.6
TP (*kg/d*)	4.29	4.44

Calibration Results for Frog Alley Watershed

Calibration of the Frog Alley watershed model was similarly conducted for daily streamflows and average daily *TSS*, *TN*, and *TP* loads at the *LF12* gauging station. For daily streamflow simulations, a model efficiency (*NSE*) of 0.63 was obtained during the calibration period. Observed and simulated flows at *LF12* are compared in Figure 4.6. Average and peak flows during the calibration period were simulated with less than 10 percent error. The observed and simulated average flows were 0.51 and 0.47 m^3/s, respectively. The model was able to simulate peak flows within 6 percent of absolute error during the calibration period. The simulated and observed peak flows were 20.2 m^3/s and 21.5 m^3/s, respectively, which were very comparable. Table 4.5 provides a comparison of observed and calibrated values for average daily *TSS*, *TP*, and *TN* loads. Overall, average daily loads during the calibration period were generally simulated with less than 6 percent absolute error, showing some bias towards overestimation of *TSS* and *TN*. Simulation of average daily *TP* loads is slightly underestimated with a bias of less than 2 percent.

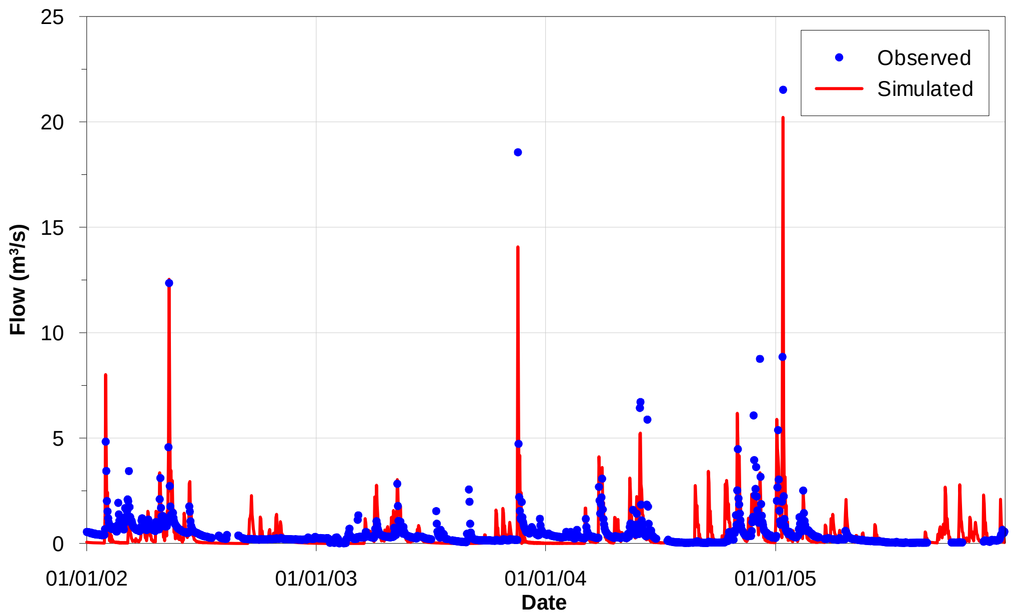


Figure 4.6. Comparison of observed and simulated daily flows at *LF12*

Table 4.5. Observed and Simulated Pollutant Loads for Frog Alley Watershed

Pollutants	*Observed (2002- 2005)*	*Simulated (2002-2005)*
TSS (*tons/d*)	2.32	2.44
TN (*kg/d*)	371.2	383.4
TP (*kg/d*)	3.93	3.85

5. Coupled Optimization-Watershed Model for Selection and Placement of Best Management Practices (*BMPs*)

Agricultural non-point source (NPS) pollution remains to be one of the biggest challenges in the Midwest due to extensive farming practices and the use of fertilizers to increase agricultural productivity. In Illinois, sediment and nutrients are major causes of water quality impairment in streams and rivers. Out of 18 percent assessed streams and river miles for causes of impairment in 2006, sediment and nutrients account for 14 and 25 percent of the assessed river miles (USEPA, 2011), respectively. NPS pollution from agricultural lands can be reduced through implementation of best management practices (*BMPs*). *BMPs* are structural or non-structural control measures that can be implemented to control pollutant loads at their source or their transport to receiving water bodies. Implementation of *BMPs* should focus on critical source areas that contribute large amounts of pollutant loads while taking into account the associated implementation and maintenance costs. It requires assessment of ecological benefits such as improving the water quality and minimizing the associated cost of implementation. Alternatively stated, the selection and placement of *BMPs* should have the goal of optimizing available resources to achieve a maximum possible reduction of pollutants. For example, a watershed with 100 hydrologic response units (HRUs) and 3 possible *BMPs* to select from would require 3^{100} model evaluations to identify the optimal solution, which is computationally very expensive. Therefore, a systematic approach is required that guarantees the selection and placement of *BMPs*, providing an optimal tradeoff between maximizing pollutant reduction and minimizing implementation costs. In this study, an integrated modeling approach is employed to develop a coupled optimization-watershed model for Bray Creek and Frog Alley watersheds. This approach, which has been applied in water resources management and other fields, involves interfacing a simulation model that evaluates system responses with an optimization algorithm. Some recent applications of an integrated modeling approach have been demonstrated in the areas of watershed management (Dorn and Ranjithan, 2003; Bekele and Nicklow, 2005; Bekele, 2008), reservoir operation (Nicklow and Mays, 2000), groundwater monitoring design (Reed and Minsker, 2004), and others.

Multi-objective Optimization Algorithm

Problems involving multiple conflicting objectives always introduce tradeoffs between these competing objectives, rather than providing a single best solution. It is commonplace to apply single-objective optimization methods to solve problems involving multiple objectives by aggregating them into one objective. This is usually done by using one of the objectives as an objective function and others as constraints or by using weighting factors, which requires prior knowledge and could be very subjective. In addition, several model runs with varying weighting schemes should be performed in order to obtain tradeoffs among the multiple objectives. The major caveats of such approaches are loss of significant information about tradeoff characteristics and incomplete evaluation of the search space (Singh et al., 2004). Direct evaluation of tradeoffs has become possible with the recent emergence of multi-objective evolutionary algorithms. These algorithms use the concept of Pareto dominance and optimality and make use of population-based approaches to locate optimal tradeoff solutions, also referred to as Pareto optimal solutions, in a single model execution (Deb, 2001). According to Veldhuizen and Lamont (2000), in a multi-objective minimization problem, the concept of Pareto dominance and optimality can be expressed as follows:

$$\textit{Minimize} \;\; f(x) = (f_1(x), f_2(x), \ldots, f_n(x))$$
$$\textit{subject to:} \;\; g(x) = (g_1(x), g_2(x), \ldots, g_n(x)) \leq 0$$

where $f(x)$ is the vector-valued function, x is the decision vector, and $g(x)$ is a vector of constraints. For two decision vectors S_A and S_B, S_A is said to dominate S_B

$$\textit{if} \; \forall i \in \{1,2,\ldots,n\}: \; f_i(S_A) \leq f_i(S_B) \text{ and } \exists i \in \{1,2,\ldots,n\}: \; f_i(S_A) < f_i(S_B)$$

Alternatively expressed, a decision vector S_A dominates another decision vector S_B if and only if it performs no worse than S_B in all *n* objectives and strictly better than S_B in at least one objective. A decision vector S_C is said to be Pareto optimal with respect to the entire solution space if and only if there is no decision vector S_C' in the solution space for which $f(S_C')$ dominates $f(S_C)$. A set of decision vectors that are Pareto optimal within the search space together form the Pareto optimal front. In this study, a non-dominated sorting genetic algorithm II (NSGA-II, Deb et al., 2001), which is based on the concept of Pareto dominance and optimality, has been used while developing the decision support tool for selection and placement of *BMPs* for pollution control.

NSGA-II is one of the most widely used multi-objective optimization algorithms capable of producing optimal or near-optimal tradeoff solutions among conflicting objectives (i.e., Pareto optimal front). The algorithm incorporates a non-dominating sorting approach that makes it faster than any other multi-objective algorithm and uses a crowded-comparison operator to maintain diversity along the Pareto optimal front. Belonging to the family of evolutionary optimization techniques, NSGA-II begins with random generation of a parent population of potential solutions for the multi-objective optimization problem. The parent population is sorted based on the concept of Pareto dominance described earlier, and each solution is assigned a fitness value equal to its non-domination level (i.e., 1 corresponds to the best non-domination level, 2 is the next best level, and so on). An offspring population of the same size as the parent population is created through recombination of elitist parents based on binary tournament selection and by inducing variations using mutation operators. Comparison of the current population with previously identified non-dominated solutions will be formed at each iteration or generation. The whole procedure is repeated for a number of iterations until the convergence criterion (e.g., maximum number of generations or iterations) has been met. In addition, a jumping gene adaptation is incorporated to improve the speed and convergence of the NSGA-II algorithm. Deb et al. (2002) provides a detailed description of NSGA-II.

Solution Framework of Coupled Optimization-Watershed Model

The solution framework for the coupled optimization-watershed model is illustrated in Figure 5.1. The resulting coupled model was developed by interfacing the watershed model, SWAT, with the multi-objective algorithm, NSGA-II. The watershed model is tasked with evaluating watershed responses such as sediment and nutrient yields (i.e., the state variables) as a result of a given selection and placement of *BMPs* in the watershed (i.e., the decision variables). The implementation and maintenance cost of *BMPs* are calculated using a separate cost function. Based on the evaluation of watershed responses and associated *BMP* costs, the NSGA-II optimization algorithm identifies optimal or near-optimal selection and placement of *BMPs* in the watershed that could achieve maximum pollutant reduction at possibly minimum *BMP* implementation cost.

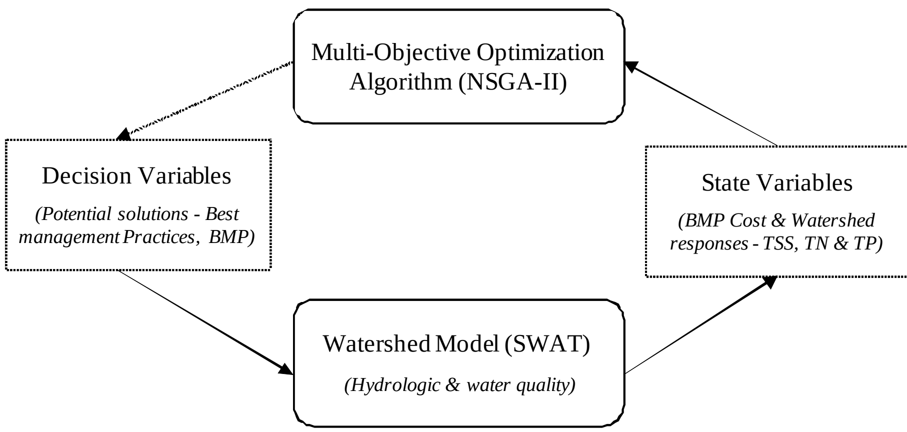


Figure 5.1. Solution framework for coupled optimization-watershed model

Selected *BMPs* and their Representation in the Model

Based on surveys of conservation practices in the study watershed and additional practices in the experimental watersheds, three best management practices (*BMPs*) are considered to be incorporated into the coupled model. These *BMPs* are filter strips, grassed waterways, and constructed wetlands. Filter strips are strips of vegetative cover placed at the edge of the field to reduce erosion and pollutant loadings in the surface runoff. The vegetation cover slows down runoff and traps sediment, nutrients, pesticides, and bacteria as runoff passes through it. Grassed waterways are channels with vegetative cover that are used to protect streams from gully erosion by reducing flow rates. They help increase sediment trapping due to reduced flow velocity. Constructed wetlands are artificial wetlands designed to emulate natural wetland functions, including removal of pollutant loadings in surface and subsurface runoff. Each BMP has its own life span, defined by the Natural Resources Conservation Services (NRCS) as the intended period of time that the BMP will be able to perform its functions successfully with only routine maintenance. Filter strips and grassed waterways have a life span of 10 years, whereas the life span for constructed wetlands is 15 years (USDA, 2010).

The Illinois Chapter of TNC conducted a paired watershed study from 1999 to 2006 to evaluate the effectiveness of filter strips and grassed waterways in controlling total suspended sediment and nutrient concentrations at a watershed scale. Bray Creek and Frog Alley were the paired watersheds used as treatment and reference watersheds, respectively. Both watersheds are agriculturally dominated with extensive tile drainage. According to their study, following the implementation of these *BMPs*, no significant changes were observed in either total suspended sediment or nutrient concentrations, including nitrate-nitrogen and total phosphorus (Lemke et al., in review). The study suggested that subsurface drainage tiles running through the watersheds may have served as the primary pathways for nutrients entering the streams and reduction of nutrient delivery to the streams may require conservation practices such as constructed wetlands (Lemke et al., in review). Since filter strips and grassed waterways are designed to intercept surface runoff, their effectiveness in tile-drained watersheds may be limited. However, optimal placement of those *BMPs* within the watershed is also crucial to see their impact in reducing sediment and nutrient loads at a watershed scale, which is the main focus of this study. Figures 5.2, 5.3, and 5.4 show pictures of filter strips, grassed waterways, and constructed wetlands in the Mackinaw River watershed.

Figure 5.2. Filter strips

Figure 5.3. Grassed waterways

Figure 5.4. Constructed wetlands

SWAT has provisions to directly simulate filter strips. Its filter strip component model uses a simplistic empirical relationship between filter strip width (*FLITERW*) and trapping efficiency for sediment and nutrients as illustrated in Figure 5.5 (Nietsch et al., 2001). This relationship indicates that the effectiveness of filter strips increases with an increase in filter strip width up to 30 meters, at which point it results in the maximum possible trapping efficiency. In this study, a filter strip width of 5 meters was adopted when filter strips were to be placed in an HRU. Representation of grassed waterways in SWAT was done using a set of model parameters that govern channel processes that include channel roughness (*CH_N2*), channel cover (*CH_COV*), and erodibility (*CH_EROD*) factors (Arabi et al., 2006). When a stream reach is selected for placement of grassed waterways, the parameter *CH_N2* is increased, whereas *CH_COV* and *CH_EROD* are decreased from their calibrated values. Consequently, the roughness of that particular stream reach increases, resulting in reduction of its flow velocity and erodibility. SWAT also has a routine to simulate a wetland and is modeled as a water body within a subbasin that drains only a fraction of the subbasin or HRU area (*WET_FR*). Thus, the wetland drainage area can be varied as a function of the HRU area in which the wetland is to be placed. In this study, the wetland drainage area is set to be 50 percent of the HRU area and the minimum wetland drainage area must be at least 5 hectares. In the case of the current watershed delineations, this criterion excludes 8 HRUs of Bray Creek and 6 HRUs of Frog Alley watersheds from qualifying for placement of constructed wetlands. The wetland surface area is calculated as 5 percent of the wetland drainage area or 2.5 percent of the qualifying HRU area. The wetland releases outflows when its normal storage volume is exceeded. For computation of normal and maximum storage volumes, wetland depths of 1.25 and 1.50 meters were used, respectively. The transport of sediment in and out of a wetland is simulated using a simple mass balance model. *TSS* removal by a wetland is computed based on the assumption that the fraction of sediment remaining suspended in impoundment after settling for one day is 50 percent. Nutrient processes in the wetland were simulated using empirical methods, and nutrient transformation is limited to removal by settling. Transformation between different pools of nutrients in the wetland was neglected. Based on data obtained from TNC's Franklin Farm experimental watershed in Illinois, the removal efficiencies for constructed wetlands were set at 35 percent for *TN* and 45 percent for *TP* loads.

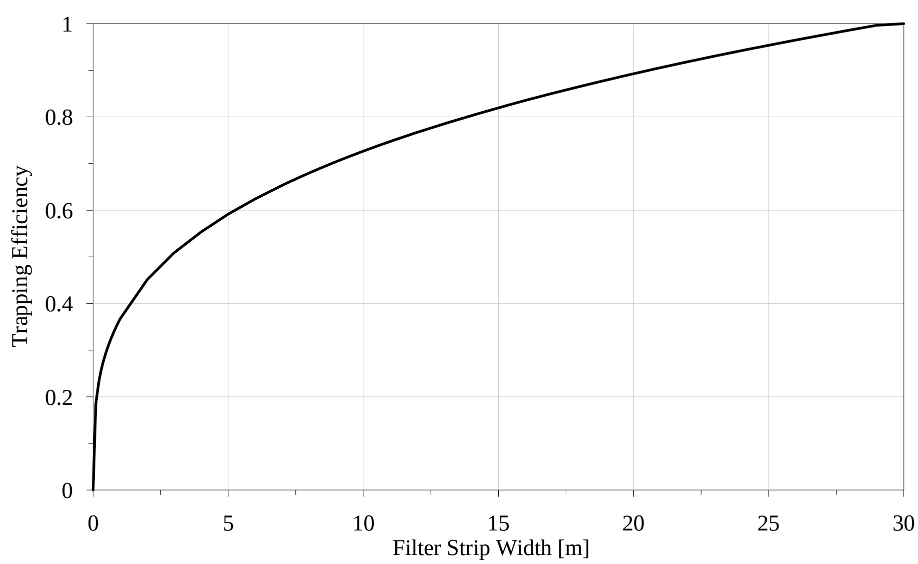


Figure 5.5. Filter strip trapping efficiency for sediment and nutrients

Operation Modes of the Coupled Optimization-Watershed Model

In the real world, the placement of *BMPs* in watersheds may not be as simple as model simulations. Certain *BMPs* such as constructed wetlands require a significant portion of productive farmland, which may not be appealing to landowners. In developing the coupled optimization-watershed model, two modes of operation were incorporated. The first operation mode allows selecting a single *BMP* type such as filter strips, grassed waterways, or constructed wetlands. The second one is the multiple *BMPs* operation mode, in which case the model chooses any one of the three *BMPs* for placement in HRUs of the watershed. They are referred to hereafter as single *BMP* and multiple *BMPs* operation modes.

In the single *BMP* operation mode, the coupled model identifies the optimal placement of predetermined *BMP* type in the watershed. Therefore, a potential solution consists of a single *BMP* type being placed in selected or all qualifying hydrologic response units (HRUs) of the watersheds. The minimum number of HRUs for *BMP* implementation is set at five for both Bray Creek and Frog Alley watersheds, and the maximum is the same as the total number of qualifying HRUs in the watersheds, which is 73 for Bray Creek and 63 for Frog Alley. In the case of constructed wetlands, a minimum wetland drainage area of 5 hectares is considered, excluding HRUs that do not meet this criterion. For example, a potential solution for Bray Creek watershed could have a maximum of 73 decision variables when a *BMP* is placed in all qualified HRUs or stream reaches. The corresponding state variables are watershed responses, including total suspended sediment (*TSS*), total nitrogen (*TN*), and total phosphorus (*TP*) loads, and total cost of *BMP* implementation and maintenance. If, for example, the *BMP* of choice is constructed wetland, the objective would be identifying the locations for placement of wetlands in the watershed that could maximize pollution reduction but with the minimum implementation cost possible.

In the case of the multiple *BMPs* operation mode, the model is tasked with selection and placement of *BMPs* that could provide optimal tradeoffs between pollutant reduction and total *BMP* costs. A potential solution in this particular case comprises a combination of *BMP* types being placed in selected or all qualified HRUs. It should be noted that one *BMP* at a time is allowed to be placed in any given HRU. This operation mode allows the model to identify the effective *BMP* type for controlling a particular pollutant and also helps discriminate HRUs or placement locations for those selected *BMPs*.

The multi-objective optimization problem for a single or multiple mode of operation can be formulated as follows

$$Minimize F(\bar{x}_i) = [f_1(\bar{x}_i), f_2(\bar{x}_i))] \qquad \forall i \in \Omega$$

$$f_2(\bar{x}_i) = \sum_{k}^{nhru} C_k$$

subject to constraints related to hydrologic and water quality simulations

where $F(\bar{x}_i)$ is a vector-valued objective function to be minimized; $f_1(\bar{x}_i)$ is the average daily *TSS*, *TN*, *TP*, or average daily pollutant load during the simulation period; $f_2(\bar{x}_i)$ is the total cost of *BMP* implementation and maintenance; $\bar{x}_i$ is the i^{th} solution from a poll of possible solutions Ω (i.e., different placement combination of a single *BMP* type such as filter strips, grassed waterways, or constructed wetlands in the watershed for single *BMP* operation mode, or different selection and placement combinations of all three *BMPs*); C_k is the cost of a *BMP* in the k^{th} HRU; and $nhru$ is the total number of HRUs considered for *BMP* implementation at a given time.

The model starts by randomly generating a user-specified number of potential solutions for the multi-objective optimization problem. Each potential solution consists of the total number and locations of HRUs for placement of a *BMP*. For each of potential solutions generated, model parameters representing that particular *BMP* will be updated in the HRU or stream reach selected for the *BMP* placement. For example, if 20 HRUs in the watershed are selected for placement of the filter strips, the model invokes the routine that simulates filter strips for those 20 HRUs and updates the filter strip width, which in turn helps compute pollutant trapping efficiency. With all the required information, the coupled model is then executed for a number of iterations or generations to search for optimal tradeoff solutions between pollutants reduction and *BMP* placement costs. During model execution, the SWAT model evaluates the watershed responses including sediment and nutrient loads at the watershed outlet of interest for every potential solution, and the cost function calculates corresponding total cost of *BMP* implementation and maintenance. Based on evaluation of pollutant loads and *BMP* costs, the multi-objective optimization algorithm will search for optimal tradeoff solutions. In order to compare the effectiveness of selected *BMPs*, including filter strips, grassed waterways, and constructed wetlands, four *BMP* application scenarios were considered and associated unit costs of *BMP* implementation plus maintenance were presented in Table 5.1, which were adapted from various sources. The unit costs of constructed wetlands and filter strips were based on information obtained via personal communication with Maria Lemke of TNC. According to the information obtained, the cost of filter strips could vary between \$300 per acre and \$600 per acre depending on the type of vegetation (e.g., native vegetation or trees), and in this application, \$500 per acre was used. The cost of grassed waterways were based on a literature survey (Arabi et al., 2006), which was originally adapted from the Indiana Environmental Quality Incentive Program. A maintenance cost is incorporated into the unit costs as 3 percent of installation costs. It must be noted that all unit cost figures do not include the value of the land, and they are based on year 2004 dollar values. These unit cost figures need to be updated for future application. During simulations of the coupled optimization-watershed model, implementation of filter strips, grassed waterways, and constructed wetlands are considered in *Scenario-I*, *Scenario- II,* and *Scenario-III*, respectively. Unlike the previous scenarios, *Scenario-IV* takes into account implementation of any possible combination of the three *BMPs* in the watershed. Model evaluation with no *BMP* in the watershed represents the baseline condition.

Table 5.1. BMP Application Scenarios and Unit Cost

Scenario	*BMP Application*	*Unit Cost Per Acre*
I	Filter Strips (FS)	$500
II	Grassed Waterways (GW)	$2,600
III	Constructed Wetlands (CW)	$3,000
IV	Any Combination of FS, GW and CW	-

Application of Coupled Optimization-Watershed Model

The coupled optimization-watershed model was run for Bray Creek and Frog Alley watersheds employing all four *BMP* application scenarios and four simulation cases. The baseline conditions, which are model simulations with no *BMP* implementation, correspond to calibrated sediment and nutrient yields for each of the watersheds. *Scenario-I*, *-II*, and *-III* were run in single *BMP* mode of operation to determine the optimal placement of filter strips, grassed waterways, and constructed wetlands in the watersheds, respectively. The coupled model ensures that the optimal *BMP* placement in the watershed results in the maximum pollutant reduction for a given placement cost. In *Scenario-V*, both the selection and placement of any combination of the three *BMPs* were optimized and thus the coupled model was run in multiple *BMPs* operation mode. The percent reduction of a pollutant *i* (PR_i) as a result of *BMP* implementation in the watershed is calculated as follows:

$$PR_i = \frac{P_{i,1} - P_{i,2}}{P_{i,1}} \times 100$$

where *i* is the pollutant load of interest (i.e., *TSS*, *TN*, or *TP*), $P_{i,1}$ is the average daily pollutant load *i* for baseline condition; $P_{i,2}$ is the average daily pollutant load *i* with *BMP* implementation in the watershed. The optimal selection and placement of *BMPs* in the watershed can be evaluated based on reduction of a single pollutant at a time or all pollutants at the same time. Therefore, four simulation cases were considered in applying the coupled model for *Scenario-I* through *-IV* as presented in Table 5.1. Simulation *Case 1*, *2*, and *3* represent model evaluations with the objective of reducing only *TSS*, *TN*, or *TP* loads, respectively. This helps identify those *BMPs* that are effective for a particular pollutant reduction. Simulation *Case 4* is the model evaluation involving an objective function with an average reduction of all three pollutants at the same time. The average pollutant reduction is given as:

$$AR = \frac{\sum_{i=1}^{N} PR_i}{N}$$

where *AR* is the average pollutant reduction, PR_i is as defined earlier, and *N* is the total number of pollutants considered (i.e., three in this application).

Model Application Results for Bray Creek Watershed

For Bray Creek watershed, the optimal tradeoffs between reduction of pollutant loads (i.e., *TSS*, *TN*, and *TP*) and total placement cost of the *BMPs* are provided in Figures 5.6–5.9 for *Scenario-I* to *-IV*. An alternative solution can be chosen from these tradeoff solutions based on available resources, extent of desired pollutant reduction, and additional external factors. The optimal solutions or best alternatives shown in these figures are those solutions that make a compromise between the two conflicting objectives (i.e., maximizing pollutant reduction while minimizing *BMP* placement cost), and they are distinctively marked in the figures for better illustration. For all scenarios and simulation cases, the percentage of pollutant reduction and associated BMP costs are presented in Table 5.2 for ten representative solutions spreading along the tradeoff curves. The table lists the solutions in order of decreasing percentage reduction or total *BMP* cost. The total cost reported in this study does not include the value of the land.

In *Scenario-I*, in which filter strips are the only *BMP* application option, the optimal pollutant load reductions were 18.2 percent for *TSS*, 0.1 percent for *TN*, and 35.1 percent for *TP* at an estimated total cost of \$3,608, \$14,647, and \$15,581, respectively. In each case, the coupled model was run to maximize the reduction of each individual pollutant at a minimal cost. The maximum pollutant load reductions obtained in each case were 20.1 percent for *TSS*, 0.2 percent for *TN*, and 54.1 percent for *TP* at an estimated total cost of \$23,994, \$31,078, and \$31,791, respectively. Simulation results show that the maximum reductions were associated with a higher cost of *BMP* implementation. For *TSS* and *TN*, the difference between the maximum and optimum reductions was minimal but the total cost of *BMP* placement greatly varies in each case. This indicates the importance of having the coupled model to assist watershed management decisions. When the objective was to optimize for all pollutants reduction (i.e., *Case 4*) at the same time, an optimal average reduction of 16.1 percent was obtained at an estimated cost of \$12,048. With respect to individual pollutant reduction, a similar trend was also observed in this case with the highest and lowest reductions of *TP* and *TN* loads, respectively. The application results for *Scenario-I* generally indicate that filter strips were able to bring about a maximum reduction of *TP* loads and a moderate reduction of *TSS* loads, but with no significant *TN* load reductions.

Model simulation results for *Scenario-II*, in which the *BMP* application option was limited to grassed waterways, show that the maximum reduction obtained for *TSS*, *TN*, and *TP* loads were 70.5 percent, 51.1 percent, and 14.6 percent, respectively. The associated costs of achieving these maximum load reductions were estimated to be \$122,957 for *TSS*, \$115,014 for *TN*, and \$107,214 for *TP*, requiring placement of grassed waterways in the majority of the stream reaches, which may not be a feasible option. The optimal load reductions obtained through the placement of grassed waterways were 65.8 percent for *TSS*, 34.7 percent for *TN*, and 10.5 percent for *TP* at an estimated cost of

$48,238, $47,835, and $46,310, respectively. When the coupled optimization-watershed model was tasked with reduction of all pollutants at the same time, optimal average reduction of 36.3 percent at an estimated cost of $50,860 could be achieved. *Scenario-II* gave the maximum *TSS* load reduction, indicating that grassed waterways are more effective in controlling *TSS* loads. It has also resulted in a good reduction of *TN* and a moderate reduction of *TP* loads.

Constructed wetlands are considered as the only *BMP* option in *Scenario-III*, and through its application, maximum load reductions of 15.2 percent for *TSS*, 55.3 percent for *TN*, and 46.3 percent for *TP* loads could be achieved at an estimated total cost of $529,869, $623,500, and $600,595, respectively. Similarly, the coupled model was run to maximize the reduction of each pollutant separately through placement of constructed wetlands. The maximum reductions dictate that constructed wetlands be placed in most of the qualified HRUs, which may not only be costly but also result in loss of large productive lands. The optimal pollutant load reductions for *Scenario-III* were 11.8 percent for *TSS*, 32.7 percent for *TN*, and 27.7 percent for *TP*, and their corresponding placement costs were estimated to be $176,034, $320,802, and $303,479, respectively. In the case of an average reduction of all pollutants at a minimal possible cost, an optimal average load reduction of 22.1 percent was achieved at an estimated cost of $291,188. Simulation results show that constructed wetlands seem to be more effective in *TN* and *TP* load reductions.

Unlike *Scenario-I*, *-II*, and *-III*, where the selection was limited to a single *BMP* type, *Scenario-IV* allows choosing any of the three *BMP* types considered in this study, but only one *BMP* per HRU at a time. Simulation results for *Scenario-IV* indicate that maximum load reductions of 73.4 percent for *TSS*, 60.9 percent for *TN*, and 57.6 percent for *TP* could be achieved at an estimated *BMP* placement cost of $122,939, $344,486, and $74,341, respectively. Optimal load reductions obtained were 67.7 percent ($34,751) for *TSS*, 48.8 percent ($108,621) for *TN*, 53.2 percent ($32,150) for *TP*, and 50.5 percent ($86,827) for a combined average reduction. A similar trend was observed favoring filter strips, grassed waterways, and constructed wetlands for a maximized reduction of *TP*, *TSS*, and *TN* loads, respectively.

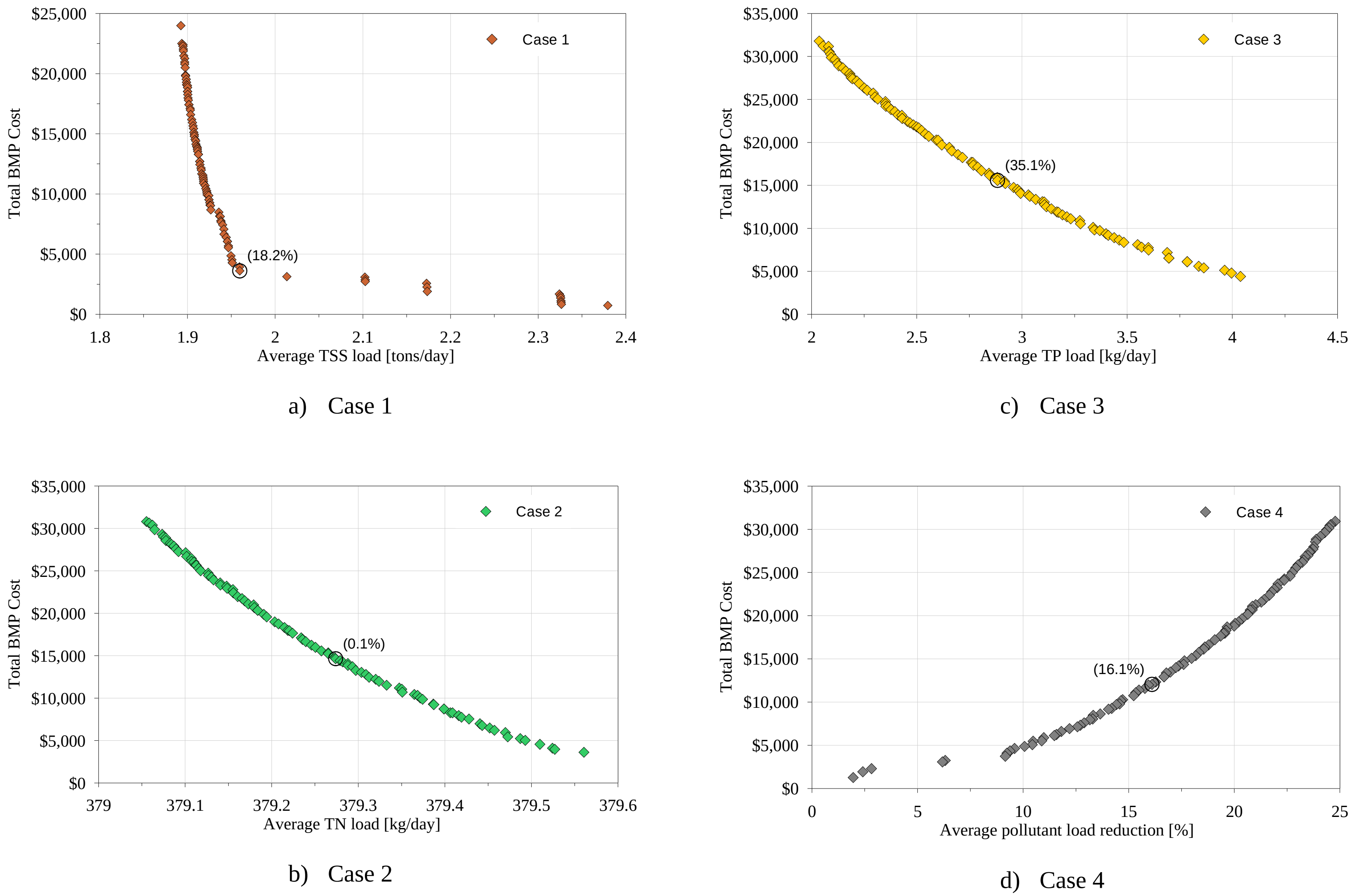


Figure 5.6. Optimal tradeoffs for pollutant reductions in Bray Creek watershed under *Scenario-I* (Simulation *cases 1*, *2*, *3,* and *4*)

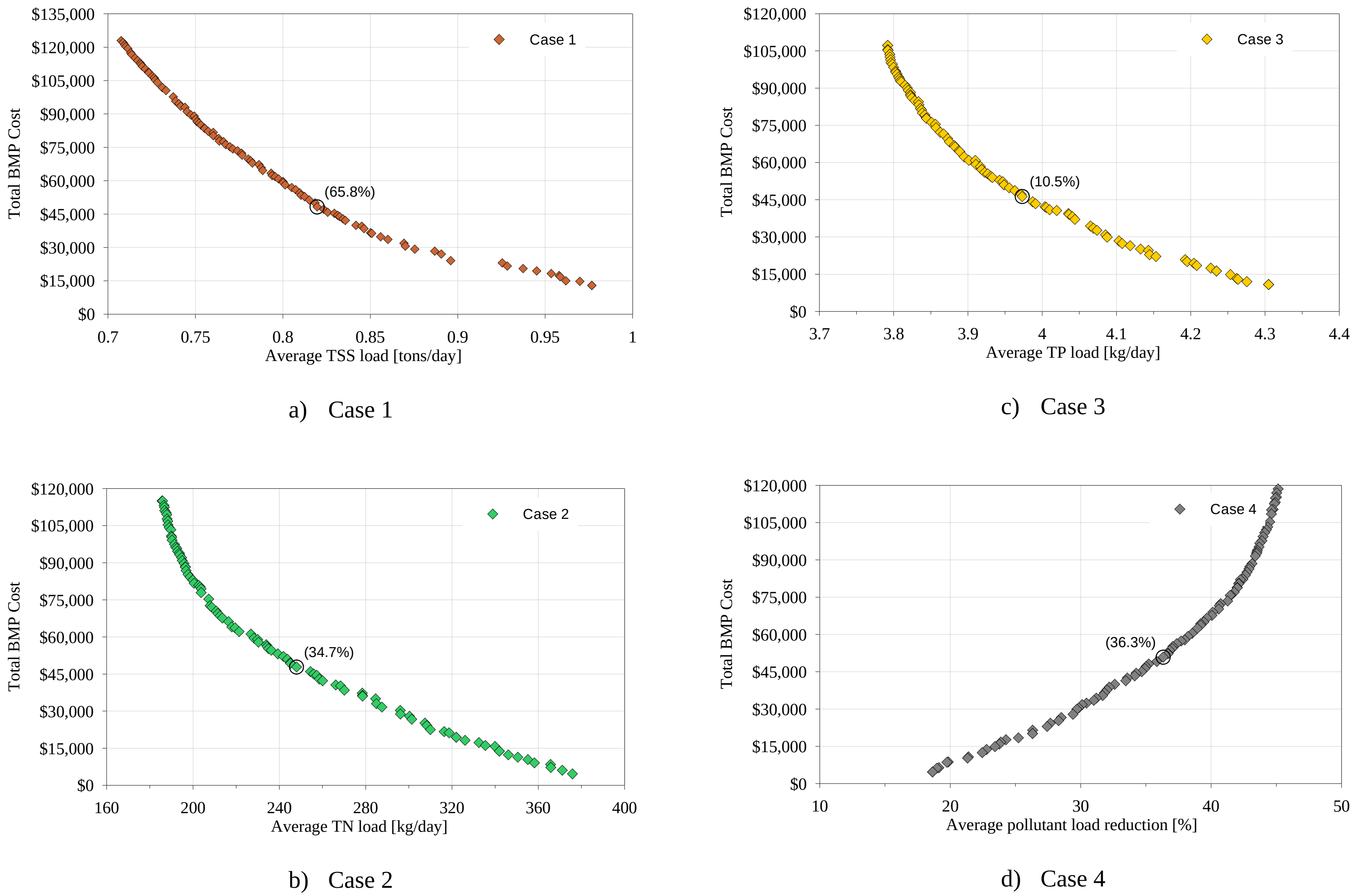


Figure 5.7. Optimal tradeoffs for pollutant reductions in Bray Creek watershed under *Scenario-II* (Simulation *cases 1*, *2*, *3,* and *4*)

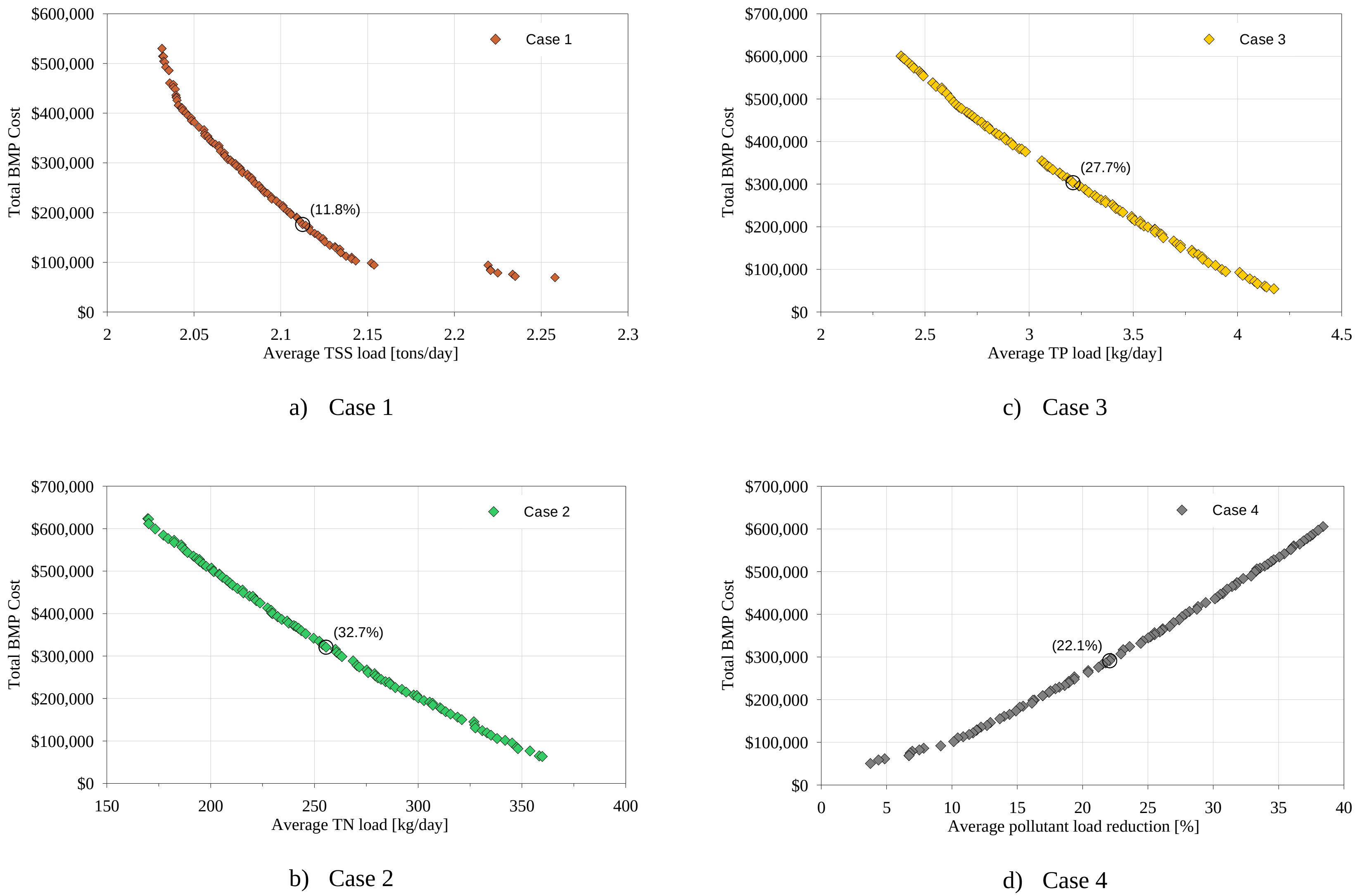
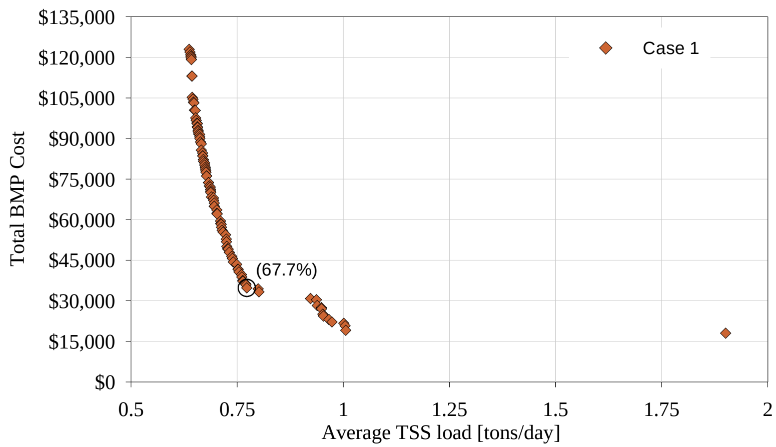
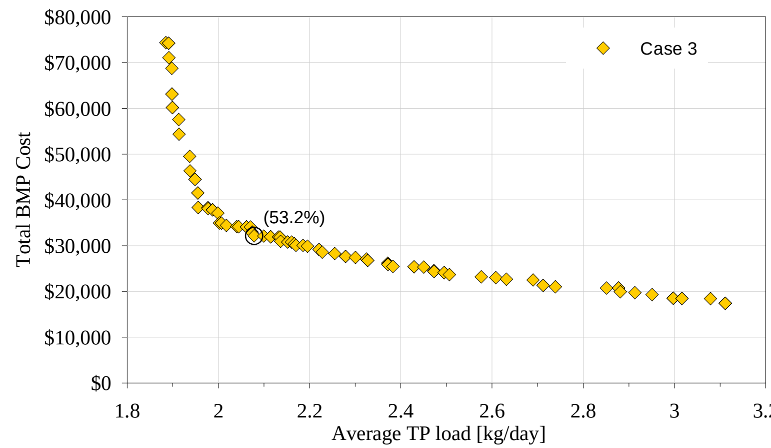


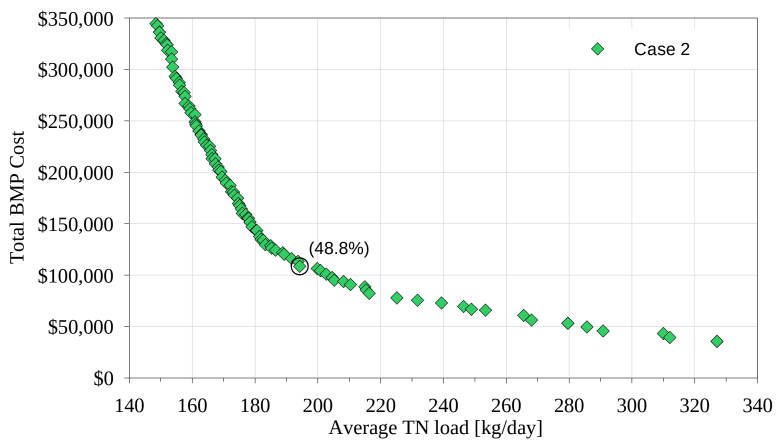
Figure 5.8. Optimal tradeoffs for pollutant reductions in Bray Creek watershed
under *Scenario-III* (Simulation *cases 1*, *2*, *3,* and *4*)



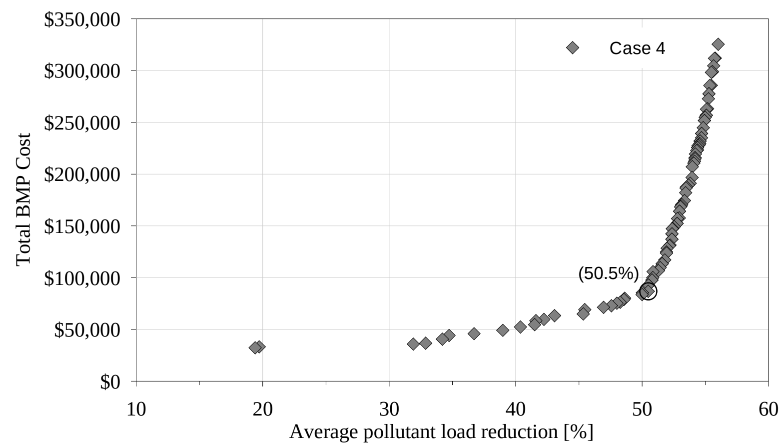
a) Case 1



c) Case 3



b) Case 2



d) Case 4

Figure 5.9. Optimal tradeoffs for pollutant reductions in Bray Creek watershed under *Scenario-IV* (Simulation *cases 1*, *2*, *3,* and *4*)

Table 5.2. Percentage Reduction of Pollutant Loads and Estimated *BMP* Costs for Bray Creek Watershed

Baseline Loads for Bray Creek Watershed at LB11: Total Suspended Sediment (*TSS*) = 2.40 tons/d; Total Nitrogen (*TN*) = 379.65 kg/d; Total Phosphorus (*TP*) = 4.44 kg/d																					
Alternative Solutions		1		2		3		4		5		6		7		8		9		10	
Scenarios and Cases		%	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost
Scenario -I																					
Case 1	*TSS*	21.0	$23,994	20.7	$19,285	20.3	$14,546	19.6	$9,528	18.2	$3,608	15.9	$3,127	9.3	$2,571	9.2	$1,900	3.0	$1,689	0.6	$730
Case 2	*TN*	0.16	$31,078	0.15	$28,255	0.14	$25,295	0.13	$21,748	0.10	$14,647	0.07	$9,863	0.06	$7,534	0.05	$5,434	0.03	$4,094	0.02	$3,614
Case 3	*TP*	54.1	$31,791	52.0	$28,912	48.3	$25,728	44.7	$22,437	35.1	$15,581	26.2	$10,899	20.1	$8,108	16.7	$6,535	13.0	$5,394	9.0	$4,403
Case 4	*Average*	24.8	$30,925	23.6	$27,362	22.1	$23,683	20.4	$19,630	16.1	$12,048	11.0	$5,884	9.2	$3,728	6.3	$3,243	2.8	$2,298	2.0	$1,270
Scenario - II																					
Case 1	*TSS*	70.5	$122,957	69.9	$110,146	69.2	$95,737	68.3	$80,180	65.8	$48,238	63.7	$30,624	62.6	$24,044	61.4	$23,088	60.2	$18,270	59.2	$12,962
Case 2	*TN*	51.1	$115,014	50.0	$100,795	48.3	$88,246	45.2	$72,687	34.7	$47,835	22.0	$28,815	16.7	$21,725	11.6	$16,086	5.6	$9,084	1.0	$4,620
Case 3	*TP*	14.6	$107,214	14.3	$95,665	13.6	$83,287	12.8	$69,603	10.5	$46,310	8.0	$30,873	6.7	$24,608	5.3	$19,411	4.2	$14,851	3.0	$10,836
Case 4	*Average*	45.1	$118,547	44.5	$105,294	43.4	$91,512	41.5	$75,835	36.3	$50,860	29.9	$30,449	26.3	$20,175	23.9	$16,679	21.3	$10,271	18.6	$4,678
Scenario - III																					
Case 1	*TSS*	15.2	$529,869	15.0	$460,628	14.5	$394,934	13.8	$323,798	11.8	$176,034	10.1	$94,374	7.3	$94,003	7.3	$94,003	6.7	$75,758	5.7	$69,318
Case 2	*TN*	55.3	$623,500	51.9	$572,581	48.3	$516,515	43.2	$448,811	32.7	$320,802	21.5	$208,414	16.9	$163,243	12.9	$124,436	9.1	$95,424	5.2	$63,441
Case 3	*TP*	46.3	$600,595	43.9	$554,093	41.0	$502,508	36.9	$435,623	27.7	$303,479	18.8	$187,467	14.8	$144,832	11.6	$99,892	8.6	$77,857	6.0	$54,299
Case 4	*Average*	38.4	$605,473	36.0	$553,286	33.2	$498,693	29.4	$427,288	22.1	$291,188	14.9	$173,614	11.6	$122,208	9.1	$91,800	6.7	$68,972	3.8	$50,509
Scenario - IV																					
Case 1	*TSS*	73.4	$122,939	73.1	$105,196	72.2	$88,007	71.3	$69,968	67.7	$34,751	58.0	$19,071	58.0	$19,071	58.0	$19,071	58.0	$19,071	20.6	$18,020
Case 2	*TN*	60.9	$344,486	59.3	$293,253	57.3	$240,259	55.0	$189,513	48.8	$108,621	39.0	$75,704	33.3	$66,047	26.3	$53,251	18.3	$43,188	13.8	$35,711
Case 3	*TP*	57.6	$74,341	57.2	$63,126	56.9	$54,372	56.1	$44,491	53.2	$32,150	46.3	$25,477	42.0	$23,208	38.3	$21,021	33.5	$19,316	29.9	$17,413
Case 4	*Average*	56.0	$325,310	55.2	$272,675	54.1	$212,484	52.8	$157,106	50.5	$86,827	42.2	$59,787	36.7	$45,982	31.9	$35,883	19.7	$33,256	19.4	$32,304

Each alternative solution for reduction of pollutants that are presented in Figures 5.6 through 5.9 as optimal tradeoffs is associated with unique placement of *BMP* in Bray Creek watershed. As indicated earlier, the maximum pollutant reduction obtained in each simulation case of every scenario was at the expense of *BMP* placement in most of all qualified HRUs and/or stream reaches, resulting in a high total implementation cost. For the best tradeoff solutions in *Scenario-I, -II, -III,* and *-IV,* Figures 5.10 through 5.13 illustrate the placement of filter strips, grassed waterways, constructed wetlands, and any combination thereof, respectively. For Bray Creek watershed, the baseline condition to which pollutant loads under different scenarios were compared was simulated at the *LB11* gauging station. This calibration gauging station is not located at the watershed outlet but rather in a close proximity to it. Therefore, the HRU at the watershed outlet is excluded from search during coupled optimization-watershed model runs as it does not drain into the *LB11* gauging station and is uniquely marked in all *BMP* placement figures. The placement of *BMPs* in Bray Creek watershed for the ten representative solutions listed in Table 5.2 is provided in Appendix A in tabular form. It must be noted that these ten solutions in each case were sampled from optimal tradeoffs presented in Figures 5.6 through 5.9, spreading from a maximum pollutant reduction or total *BMP* cost to that of a minimum reduction.

The optimal placement of filter strips in Bray Creek watershed for average *TSS* load reduction indicates that hydrologic response units close to the watershed outlet generate most of the *TSS* loads (see Figure 5.10a) and that those generated far upstream may have been deposited in the channel. The optimal placements in Figures 5.10b and 5.10c demonstrate that filter strips are more effective in *TP* load reduction in Bray Creek watershed, whereas they are less effective in reducing *TN* loads. Optimal placements of grassed waterways shown in Figure 5.11 indicate its suitability for *TSS* load reduction. Application of grassed waterways in the stream reaches close to the watershed outlet was particularly favored (see Figure 5.11a) as all *TSS* loads should go through these reaches. The grassed waterways were moderately effective in *TN* and *TP* load reductions. The performance of grassed waterways in *TSS, TN,* and *TP* load reductions indicates that a significant portion of these pollutants may come from channel depositions. Even though the width of grassed waterways appears identical in Figure 5.11, it should be noted that it varies from HRU to HRU depending on the stream width, which in turn affects the total cost of placement. According to model simulation results, constructed wetlands seem to be suitable in controlling both *TN* and *TP* loads with an optimal reduction close to 30 percent. For Bray Creek watershed, constructed wetlands are not as effective as grassed waterways and filter strips in reducing *TSS* loads. It must be noted that the surface area of the constructed wetlands shown in Figure 5.12 covers only 2.5 percent of the HRU area where they are placed. When all three *BMPs* compete for reduction of *TSS, TN,* and/or *TP* loads, a similar trend was observed with respect to their optimal placement in the watershed. The optimal *BMP* selections favored grassed waterways, constructed wetlands, and filter strips for *TSS, TP,* and *TN* load reductions, respectively.

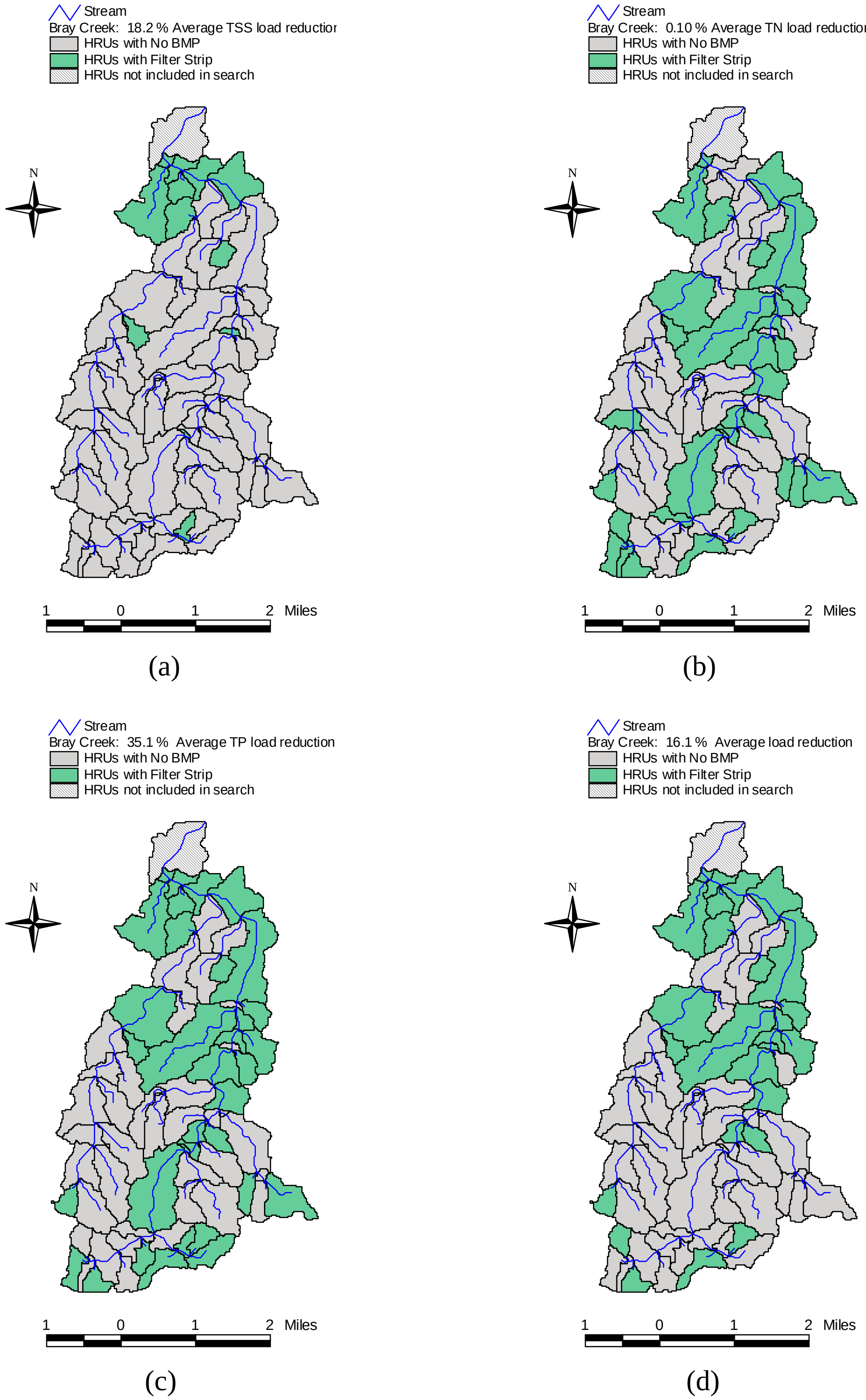


Figure 5.10. Optimal placement of filter strips in Bray Creek watershed for (a) *TSS*, (b) *TN*, (c) *TP*, and (d) average load reductions

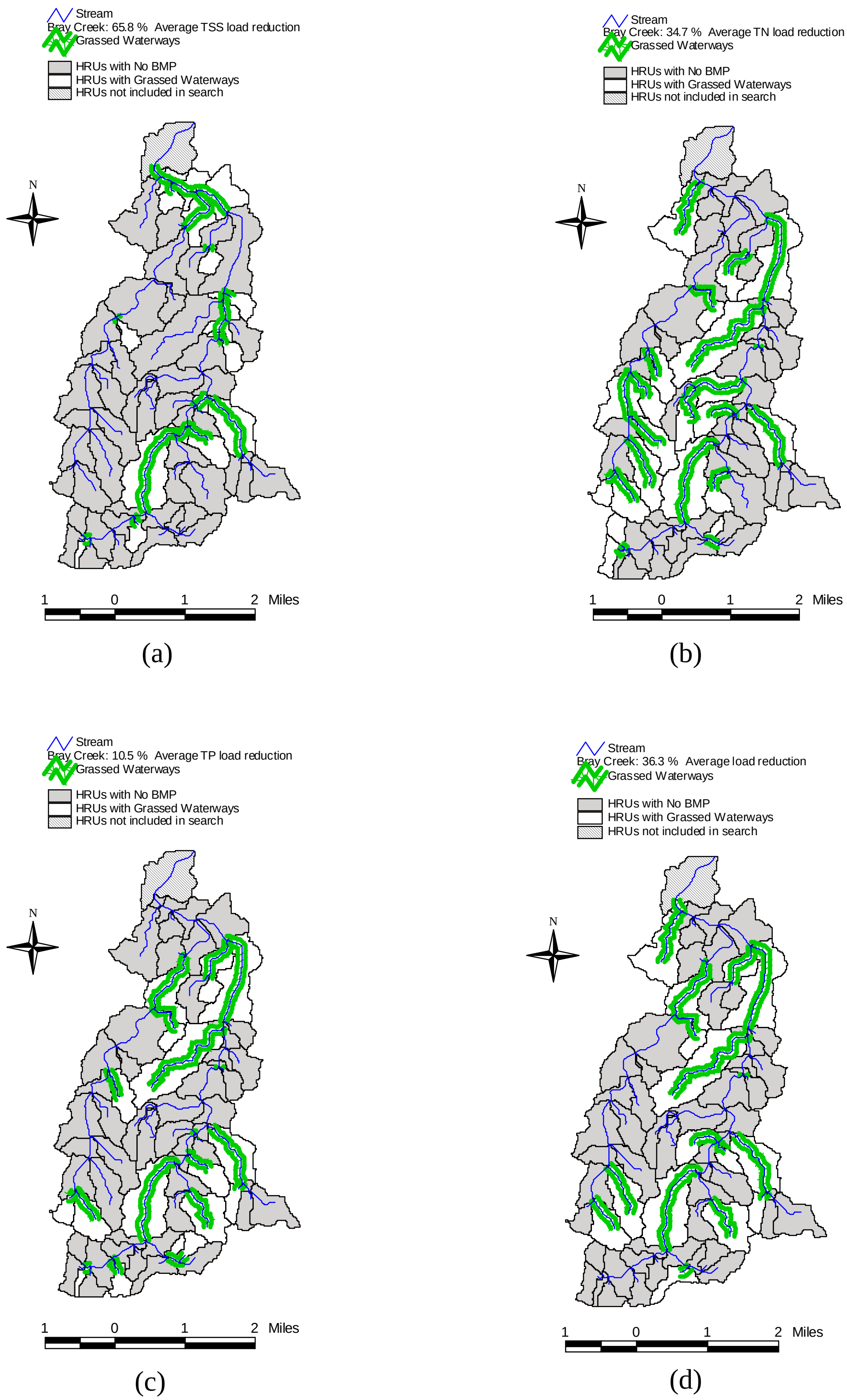


Figure 5.11. Optimal placement of grassed waterways in Bray Creek watershed for (a) *TSS*, (b) *TN*, (c) *TP*, and (d) average load reductions

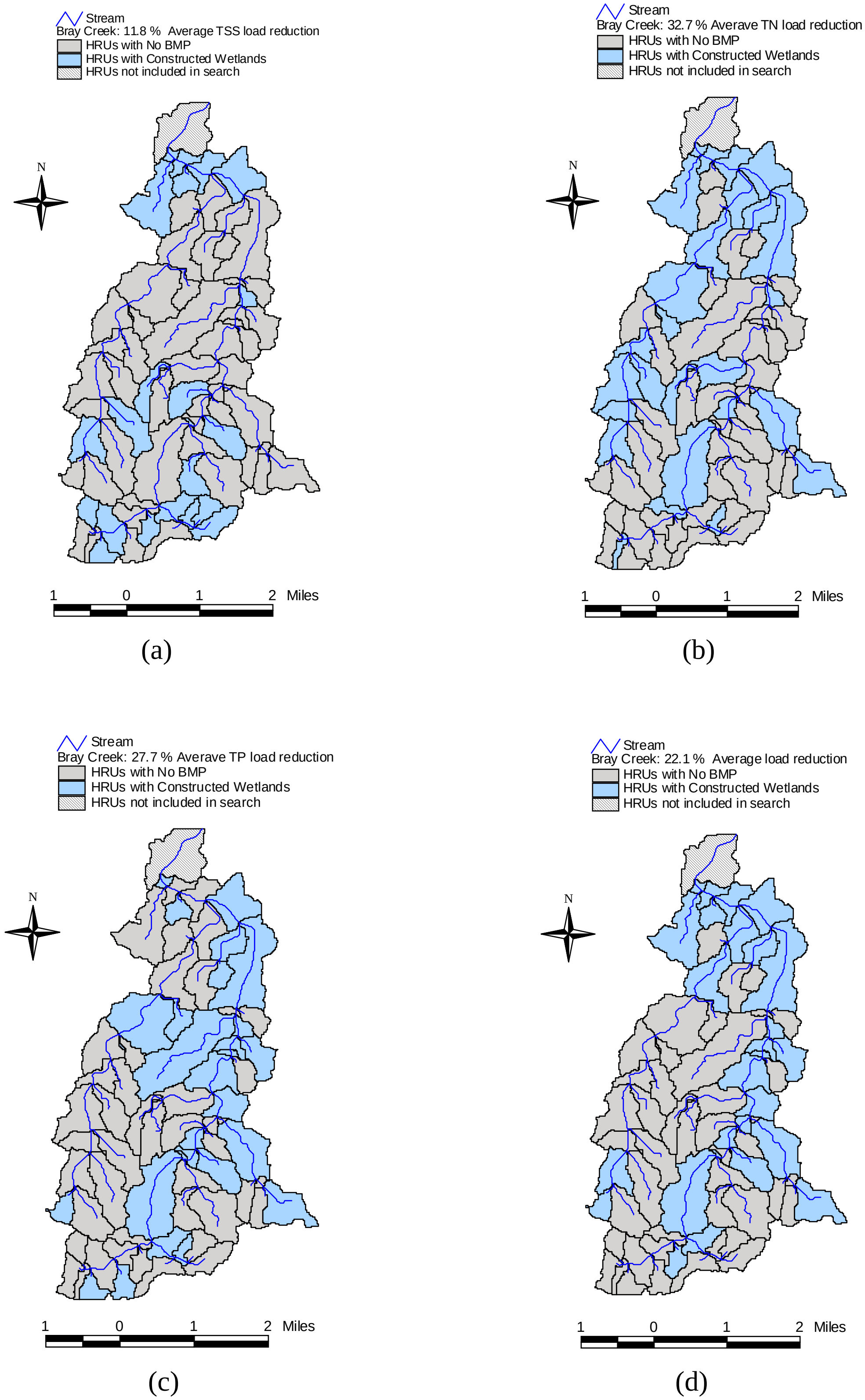


Figure 5.12. Optimal placement of constructed wetlands in Bray Creek watershed for (a) *TSS*, (b) *TN*, (c) *TP*, and (d) average load reductions

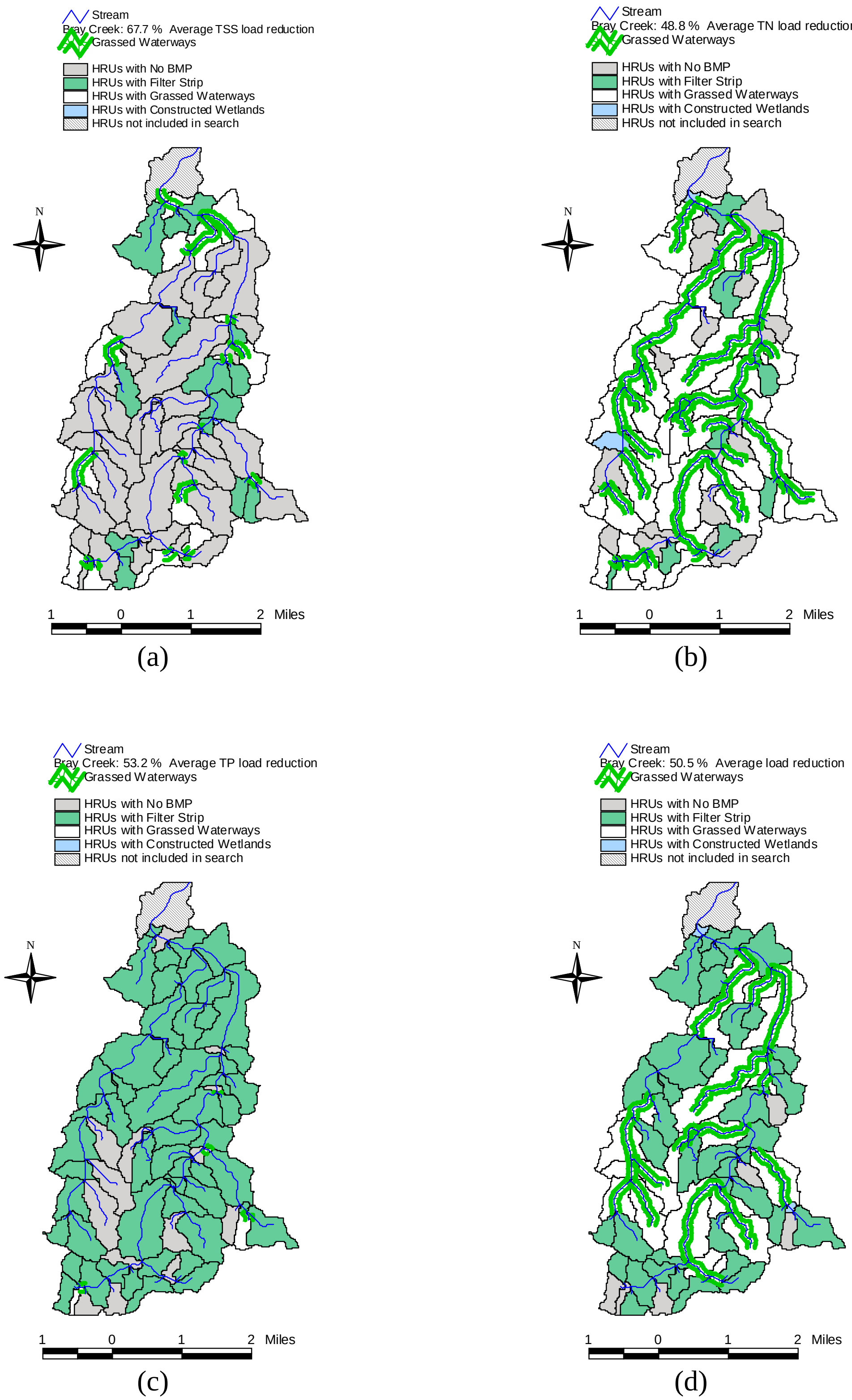


Figure 5.13. Optimal placement of filter strips, grassed waterways, and constructed wetlands in Bray Creek watershed for (a) *TSS*, (b) *TN*, (c) *TP*, and (d) average load reductions

Model Application Results for Frog Alley Watershed

All *BMP* application scenarios and simulation cases were also employed for Frog Alley watershed. As for Bray Creek watershed, the coupled model was run to maximize reductions of each individual pollutant and average of all pollutants in each scenario at a minimal *BMP* cost. Optimal tradeoffs between reduction of pollutant loads and total *BMP* costs are presented in Figures 5.14–5.17 for all scenarios and simulation cases. The percentage of pollutant reduction and associated *BMP* costs are presented in Table 5.3 for ten representative solutions spreading along the tradeoff curves in order of decreasing percentage reduction or total *BMP* cost. Note that total *BMP* costs do not include land values.

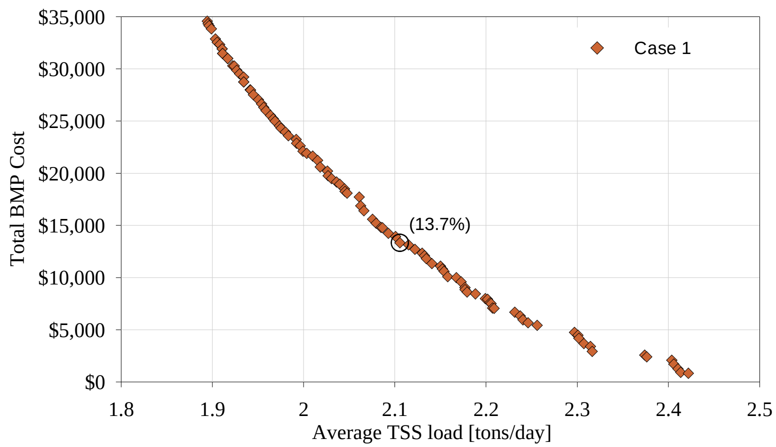
In *Scenario-I*, the simulated optimal pollutant load reductions were 13.7 percent for *TSS*, 0.04 percent for *TN*, and 34 percent for *TP* at an estimated total cost of $13,337, $14,232, and $16,743, respectively. In each case, the maximum pollutant load reductions obtained were 22.4 percent for *TSS*, 0.07 percent for *TN*, and 56.6 percent for *TP* at an estimated total cost of $34,573, $32,137, and $36,420, respectively. When the coupled model was run to maximize average reduction of all pollutants (i.e., *Case 4*), the optimal average reduction was simulated to be 16.1 percent at an estimated cost of $16,576. *Scenario-I* model results show that filter strips are very suitable to control *TP* loads in Frog Alley watershed and they can also result in a moderate reduction of *TSS* loads. As was the case for Bray Creek watershed, no significant reduction of *TN* load was achieved through placement of filter strips in Frog Alley watershed.

Model simulation results for *Scenario-II* estimated a maximum possible load reduction of 72.6 percent for *TSS*, 3.5 percent for *TN*, and 6.4 percent for *TP* at a cost of $96,563, $68,294, and $38,241, respectively. This would require placement of grassed waterways in most stream reaches of Frog Alley watershed, which may not be a practical solution. The optimal load reductions obtained for this scenario were 59.9 percent for *TSS*, 2.5 percent for *TN*, and 4.8 percent for *TP* at an estimated cost of $34,666, $25,796, and $13,609, respectively. When the goal was average reduction of all pollutants at a minimal cost, an optimal average load reduction of 19.2 percent at an estimated cost of $31,779 could be achieved. Grassed waterways seem to be more effective in controlling *TSS* loads in Frog Alley watershed, resulting in the maximum possible reduction as compared to other *BMPs*. In contrast, they are not as effective in controlling *TN* and *TP* loads in this watershed.

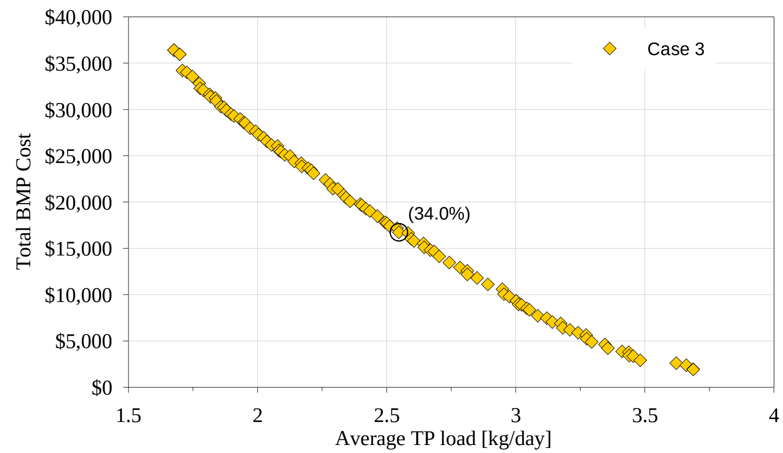
In *Scenario-III*, in which constructed wetlands are considered as the only *BMP* option, maximum possible reductions of 23.3 percent for *TSS*, 51.8 percent for *TN*, and 46.4 percent for *TP* loads could be achieved at an estimated implementation cost of $564,476, $587,715, and $585,410, respectively. These alternative solutions with maximum load reductions may not be the preferred management options as they require placement of constructed wetlands in most of qualified HRUs, resulting in high implementation costs and loss of large productive farmlands. The optimal load reductions for *Scenario-III* were 13.2 percent for *TSS*, 29.6 percent for *TN*, and 26.1 percent for *TP*, and their corresponding placement costs were estimated to be $241,798, $282,693, and

$278,135, respectively. For the case of average reduction of all pollutant loads, an optimal average reduction of 22.7 percent was obtained at an estimated cost of $281,246. Model results indicate that constructed wetlands appear to be more effective in controlling *TN* and *TP* loads as compared to *TSS* load reduction in Frog Alley watershed.

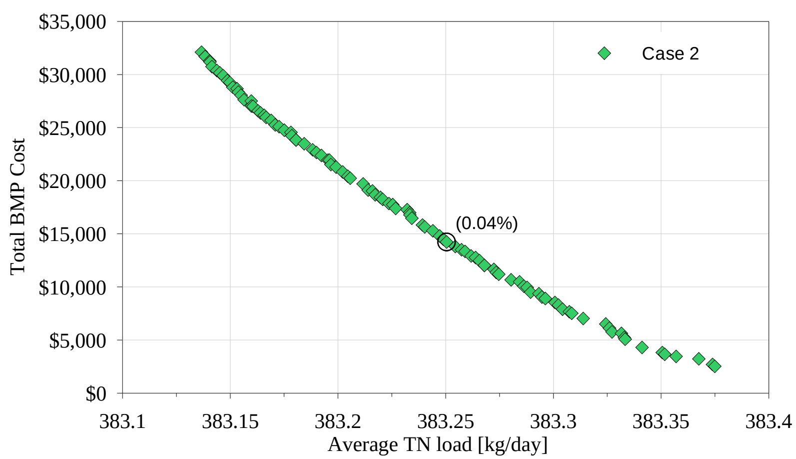
As indicated earlier, *Scenario-IV* allows selecting any of the three *BMP* types (i.e., filter strips, grassed waterways, or constructed wetlands) one at a time. Optimal load reductions obtained for this scenario were 62 percent ($41,735) for *TSS*, 23.7 percent ($218,715) for *TN*, 46.2 percent ($27,007) for *TP*, and 42 percent ($130,342) for a combined average reduction. The maximum possible reductions were 73.3 percent for *TSS*, 42.7 percent for *TN*, and 56.4 percent for *TP* and they could be achieved at an estimated *BMP* implementation cost of $109,361, $459,706, and $43,378, respectively. The optimal selection of the *BMP* types in this simulation scenario follows a similar trend as for *Scenario-I*, *-II*, and *-III*, in which filter strips, grassed waterways, and constructed wetlands were favored for maximized reduction of *TP*, *TSS*, and *TN* loads, respectively.



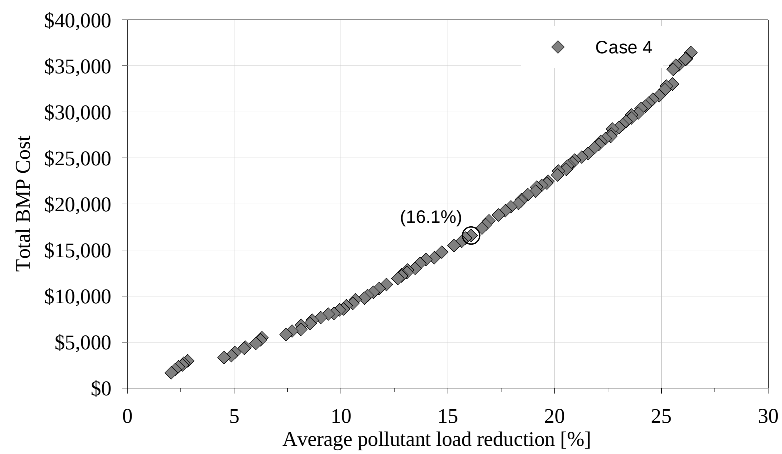
a) Case 1



c) Case 3

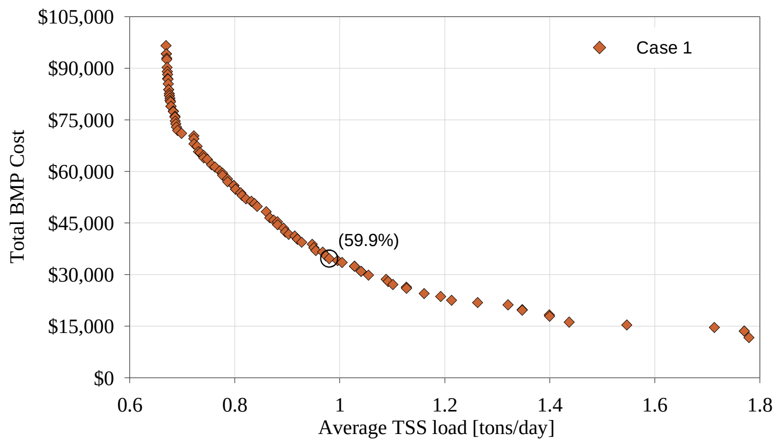


b) Case 2

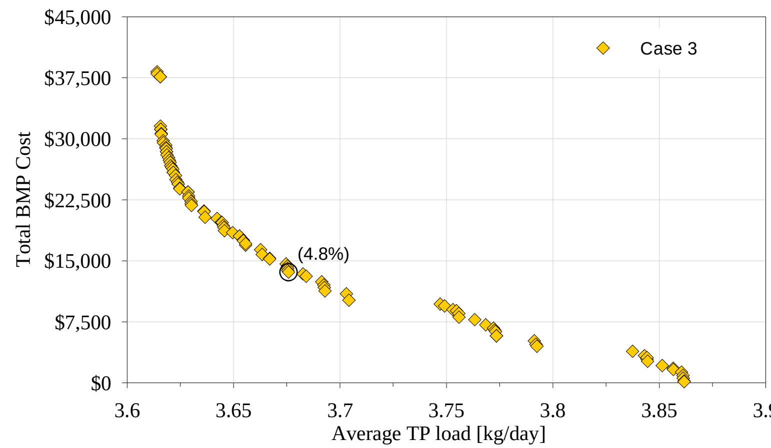


d) Case 4

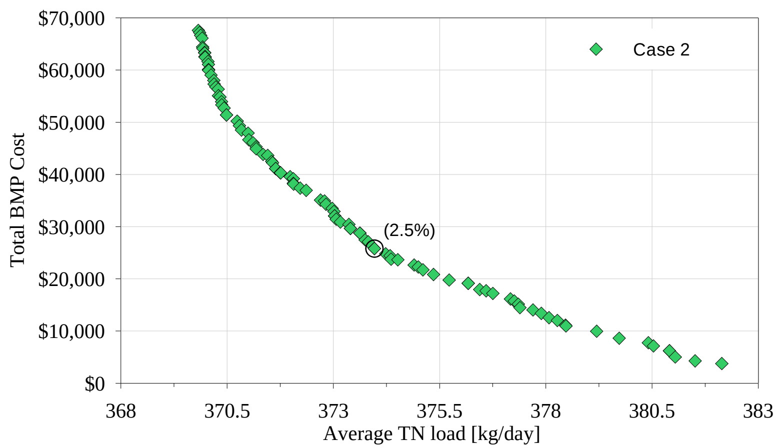
Figure 5.14. Optimal tradeoffs for pollutant reductions in Frog Alley watershed under *Scenario-I* (Simulation *cases 1*, *2*, *3,* and *4*)



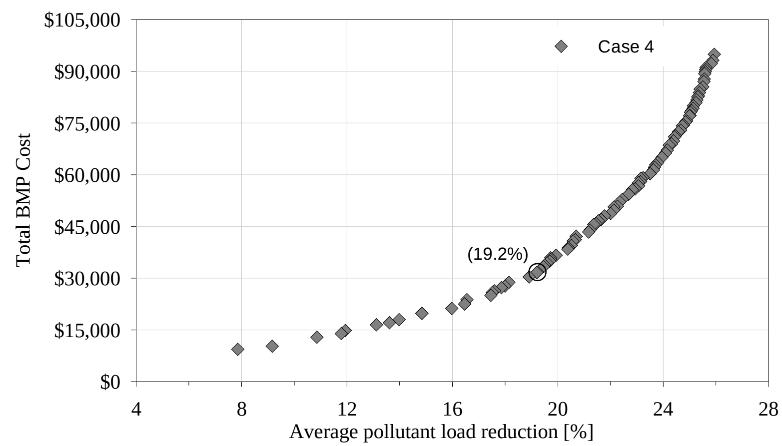
a) Case 1



c) Case 3



b) Case 2



d) Case 4

Figure 5.15. Optimal tradeoffs for pollutant reductions in Frog Alley watershed under *Scenario-II* (Simulation *cases 1*, *2*, *3,* and *4*)

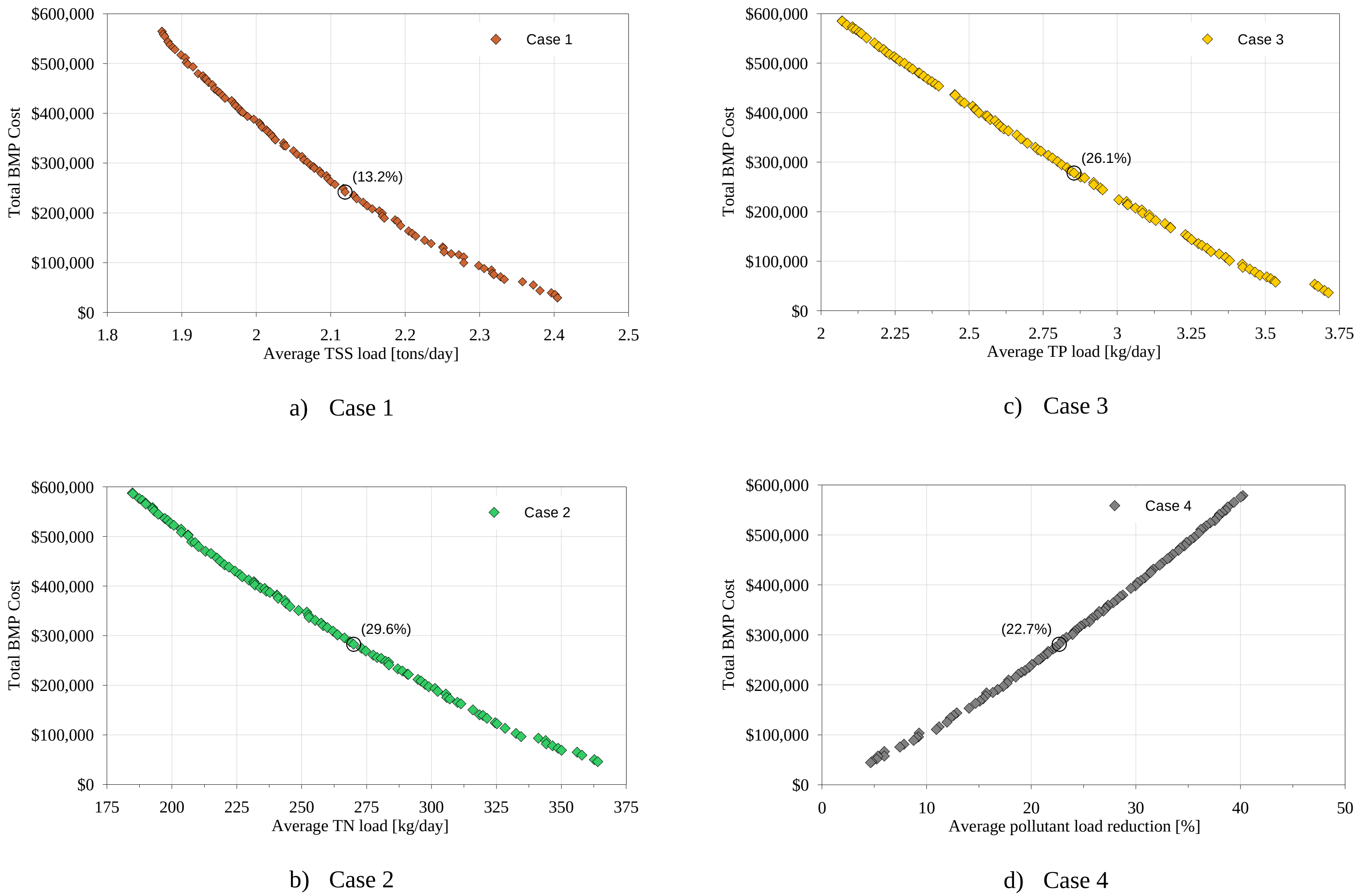
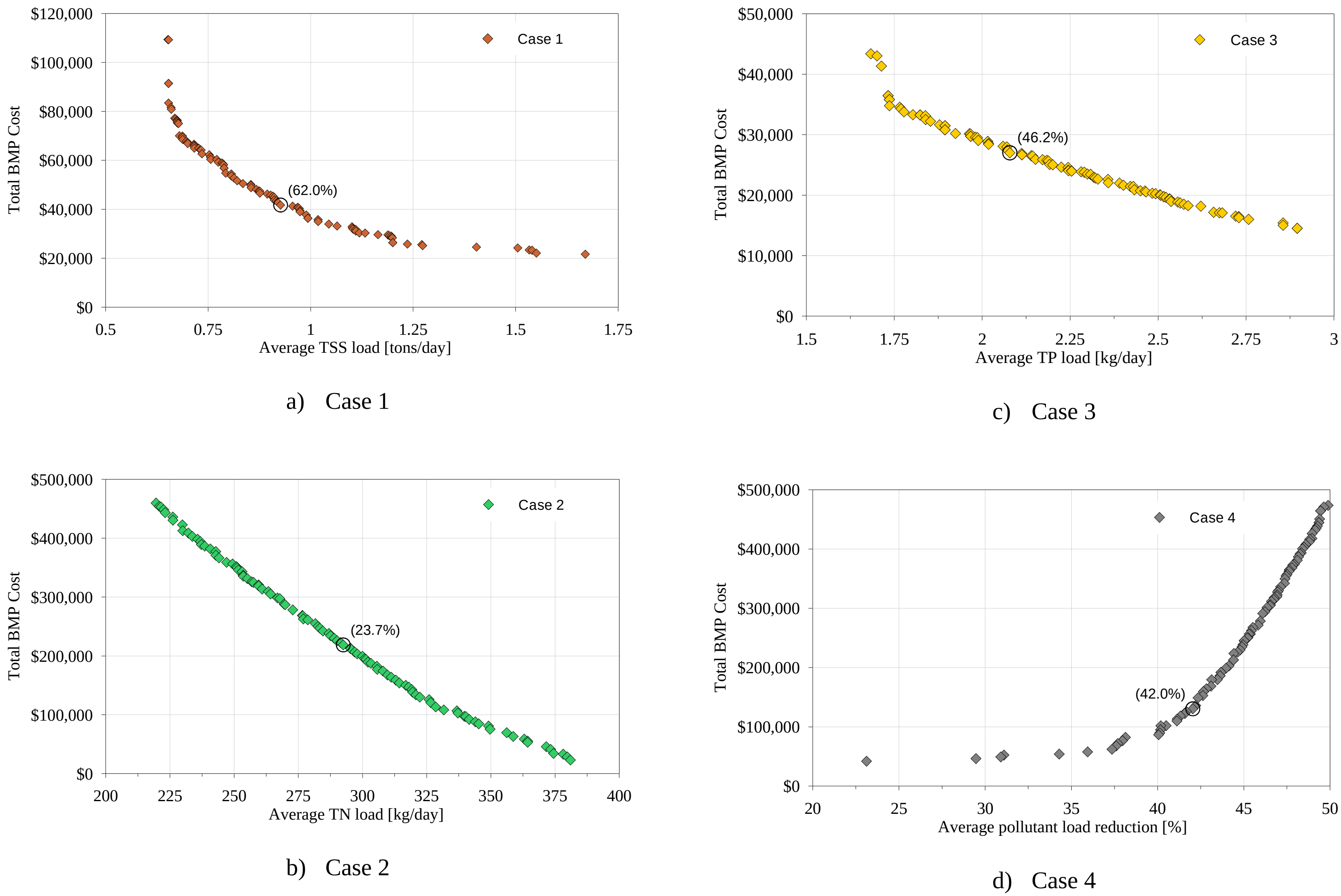


Figure 5.16. Optimal tradeoffs for pollutant reductions in Frog Alley watershed under *Scenario-III* (Simulation *cases 1*, *2*, *3,* and *4*)



a) Case 1

c) Case 3

b) Case 2

d) Case 4

Figure 5.17. Optimal tradeoffs for pollutant reductions in Frog Alley watershed under *Scenario*-IV (Simulation *cases 1*, *2*, *3,* and *4*)

Table 5.3. Percentage Reduction of Pollutant Loads and Estimated *BMP* Costs for Frog Alley Watershed

Baseline Loads for Frog Alley Watershed at LF12: Total Suspended Sediment (*TSS*) = 2.44 tons/d; Total Nitrogen (*TN*) = 383.41 kg/d; Total Phosphorus (*TP*) = 3.86 kg/d

Alternative Solutions		1		2		3		4		5		6		7		8		9		10	
Scenarios and Cases		%	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost
Scenario -I																					
Case 1	*TSS*	22.4	$34,573	21.5	$30,993	20.0	$26,640	17.9	$21,909	13.7	$13,337	10	$7,048	7.6	$5,431	5.1	$2,923	2.7	$2,579	0.8	$827
Case 2	*TN*	0.07	$32,137	0.07	$29,252	0.06	$26,167	0.06	$22,652	0.04	$14,232	0.03	$9,366	0.03	$7,033	0.02	$4,295	0.01	$3,455	0.01	$2,527
Case 3	*TP*	56.6	$36,420	54.0	$32,815	50.9	$29,496	45.5	$25,107	34.0	$16,743	23.0	$9,782	17.6	$6,418	13.1	$4,221	9.8	$2,909	4.5	$1,922
Case 4	*Average*	26.4	$36,433	25.5	$33,018	23.6	$29,331	20.9	$24,757	16.1	$16,576	10.7	$9,598	8.1	$6,383	6.0	$4,864	4.5	$3,328	2.1	$1,666
Scenario - II																					
Case 1	*TSS*	72.6	$96,563	72.4	$83,772	70.4	$70,348	67.8	$56,977	59.9	$34,666	50.3	$22,552	44.8	$19,811	36.6	$15,378	29.8	$14,636	27.1	$11,697
Case 2	*TN*	3.5	$68,294	3.5	$59,957	3.4	$51,401	3.1	$42,236	2.5	$25,796	1.8	$17,956	1.4	$12,546	1.0	$8,621	0.7	$6,217	0.3	$3,778
Case 3	*TP*	6.4	$38,241	6.4	$31,568	6.3	$27,357	6.0	$21,815	4.8	$13,609	3.0	$9,692	2.3	$5,782	1.8	$4,514	0.6	$3,891	0.01	$143
Case 4	*Average*	25.9	$94,930	25.3	$82,855	24.5	$71,300	23.1	$57,991	19.2	$31,779	16.0	$21,239	14.0	$17,979	11.8	$13,927	9.2	$10,288	7.9	$9,365
Scenario - III																					
Case 1	*TSS*	23.3	$564,476	22.0	$511,482	20.5	$457,412	18.2	$388,234	13.2	$241,798	9.3	$153,311	6.9	$115,758	5.0	$75,990	3.4	$61,483	1.5	$29,320
Case 2	*TN*	51.8	$587,715	48.5	$536,116	45.5	$487,628	41.0	$423,367	29.6	$282,693	20.2	$175,539	15.4	$124,529	12.8	$96,681	8.7	$69,025	5.1	$46,144
Case 3	*TP*	46.4	$585,410	43.1	$533,286	39.7	$480,420	34.9	$413,137	26.1	$278,135	17.6	$167,395	13.4	$114,683	9.9	$71,790	8.5	$57,770	3.9	$36,401
Case 4	*Average*	40.2	$578,817	37.8	$534,708	34.7	$478,282	31.4	$424,494	22.7	$281,246	15.6	$177,830	12.6	$138,933	9.2	$95,951	7.4	$75,555	4.6	$44,557
Scenario - IV																					
Case 1	*TSS*	73.3	$109,361	73.2	$91,445	73.0	$80,873	70.7	$66,585	62.0	$41,735	53.6	$30,287	47.8	$25,128	42.5	$24,541	36.9	$23,267	31.6	$21,613
Case 2	*TN*	42.7	$459,706	40.1	$422,758	36.7	$377,268	32.3	$320,580	23.7	$218,715	14.3	$113,438	10.3	$88,128	7.1	$69,575	3.1	$45,811	0.6	$23,204
Case 3	*TP*	56.4	$43,378	55.6	$41,345	55.1	$36,448	52.4	$33,132	46.2	$27,007	38.1	$22,000	34.4	$19,408	30.7	$17,102	28.6	$16,002	25.0	$14,524
Case 4	*Average*	49.9	$473,626	48.5	$403,063	47.0	$329,992	45.2	$250,529	42.0	$130,342	37.4	$62,115	34.3	$53,997	29.5	$46,300	29.5	$46,300	23.1	$42,023

For the best tradeoff solutions shown in Figures 5.14–5.17, the corresponding placements of *BMPs* in the Frog Alley watershed are presented in Figures 5.18–5.21. As shown earlier in the tradeoff plots, these solutions strike a balance between pollutant reductions and total *BMP* implementation costs in all scenarios and simulation cases considered. For ten representative alternative solutions shown in Table 5.3, the placements of *BMPs* in the watershed are tabulated and provided in Appendix B for all scenarios and simulation cases. The baseline condition was calculated at *LF12*, which was used as the calibration gauging station for streamflows and water quality constituents. Although close to the watershed outlet, the *LF12* gauging station drains only 78 percent of Frog Alley watershed, leaving out 19 HRUs in the northeastern part of the watershed. Thus, those HRUs were excluded during coupled optimization-watershed model runs since they do not contribute to *LF12* gauging stations. In the BMP placement figures, these HRUs are therefore marked as "HRUs not included in search."

For *TP*, *TSS*, and average load reductions, the optimal placements of filter strips in Frog Alley watershed were similar for the most part (see Figures 5.18a, 5.18b, 5.18d), showing potential target areas for *TN* and *TSS* control. Although filter strips are not effective in controlling *TN* loads in this watershed, their placement may be indicative of the source location of this pollutant. Figure 5.19a shows optimal placement of grassed waterways for *TSS* load reduction in Frog Alley watershed. The optimal placement suggests that grassed waterways, which were found to be very suitable to control *TSS* load, should be placed primarily in the main stem of the stream and close to the watershed outlet, where all loads should pass through. The good performance of grassed waterways in controlling *TSS* loads implies that a major portion of *TSS* loads may come from sediment depositions in the channel. For *TN* and *TP* load reductions in Frog Alley watershed, grassed waterways were not found to be as effective. As was the case for Bray Creek watershed, simulation results indicate that constructed wetlands appear to be more effective in *TN* and *TP* load reductions in Frog Alley watershed, resulting in an optimal load reduction of more than 25 percent. In this watershed, constructed wetlands were found to be as effective as filter strips in controlling *TSS* loads. The optimal placements of constructed wetlands for *TSS* and *TP* load reductions look nearly the same (see Figure 5.20a and 5.20b), showing a possible source location of these two pollutants. In cases in which the selection of any of the three *BMPs* for pollutant reduction were considered, the optimal selection of the *BMPs* follows a similar trend as before, favoring grassed waterways, constructed wetlands, and filter strips for *TSS*, *TN,* and *TN* load reductions, respectively.

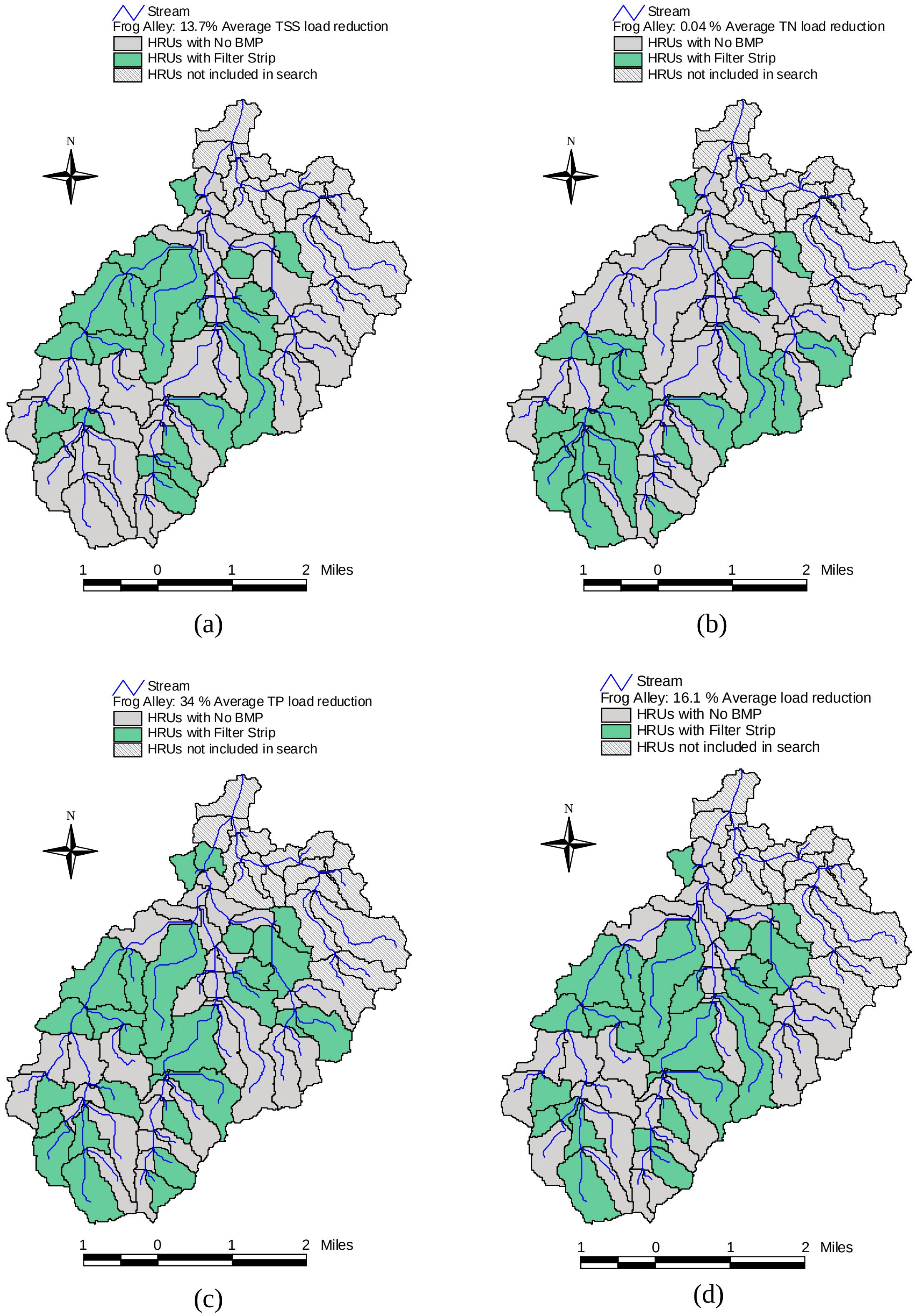


Figure 5.18. Optimal placement of filter strips in Frog Alley watershed for (a) *TSS*, (b) *TN*, (c) *TP*, and (d) average load reductions

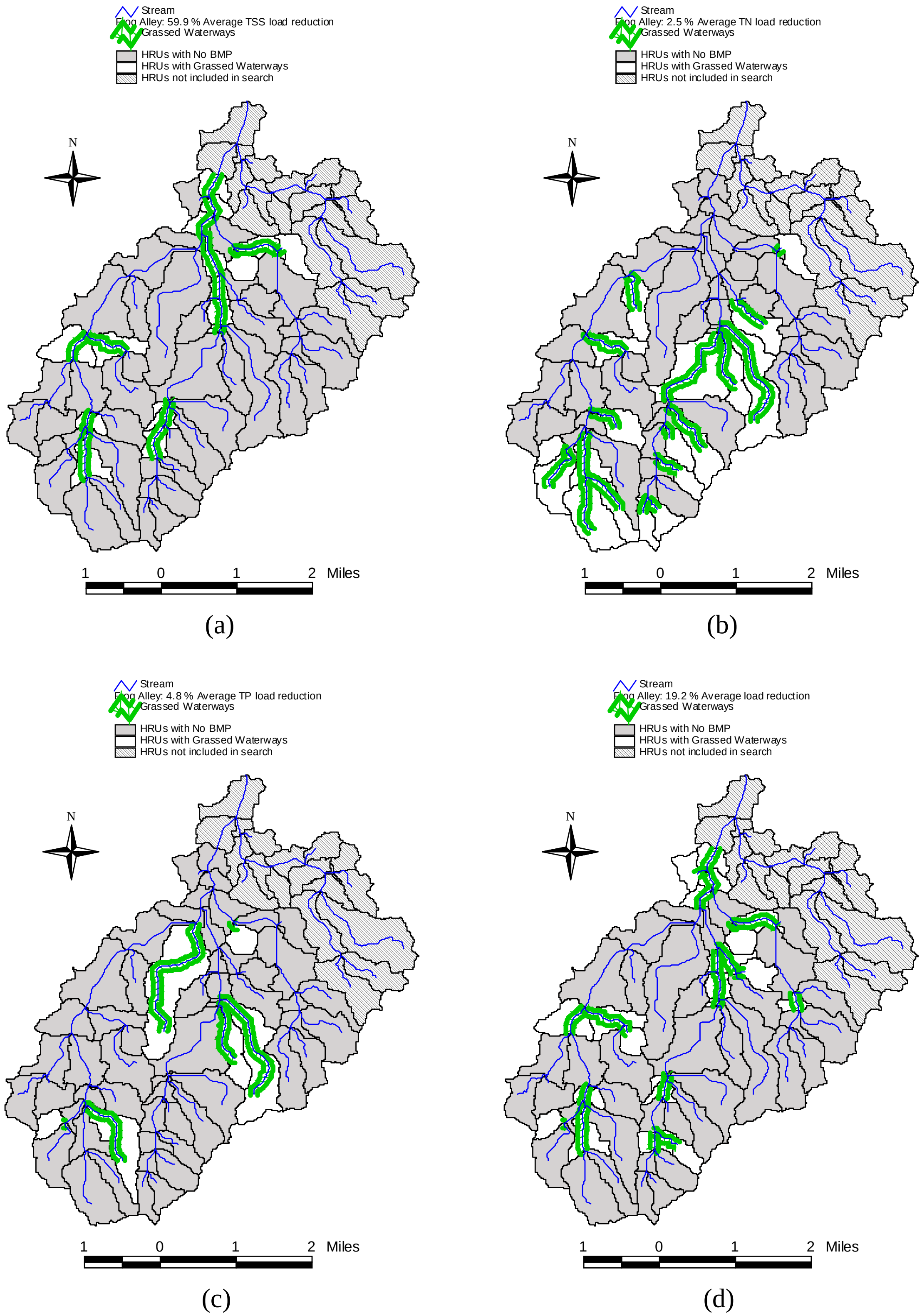


Figure 5.19. Optimal placement of grassed waterways in Frog Alley watershed for (a) *TSS*, (b) *TN*, (c) *TP*, and (d) average load reductions

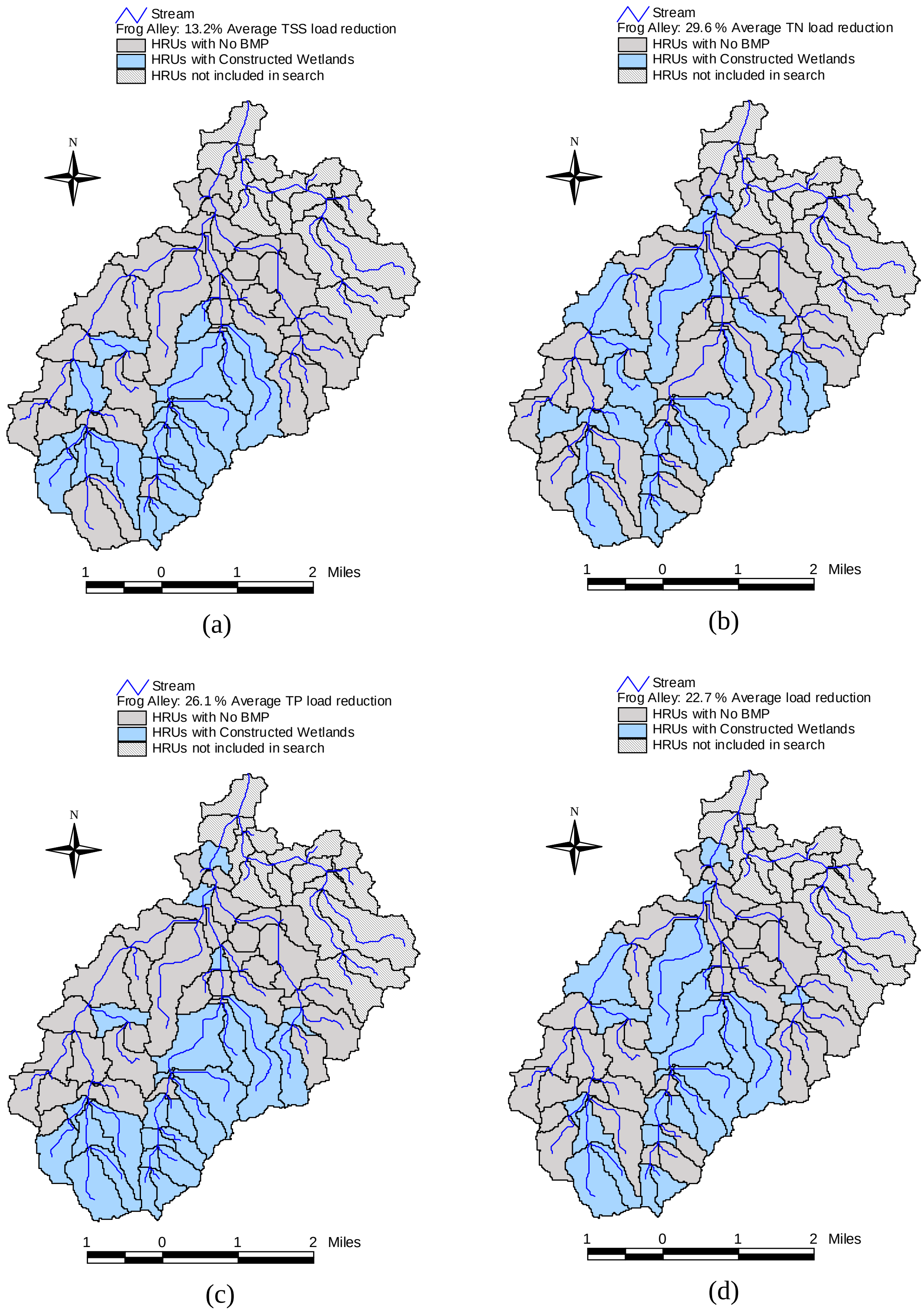


Figure 5.20. Optimal placement of constructed wetlands in Frog Alley watershed for (a) *TSS*, (b) *TN*, (c) *TP*, and (d) average load reductions

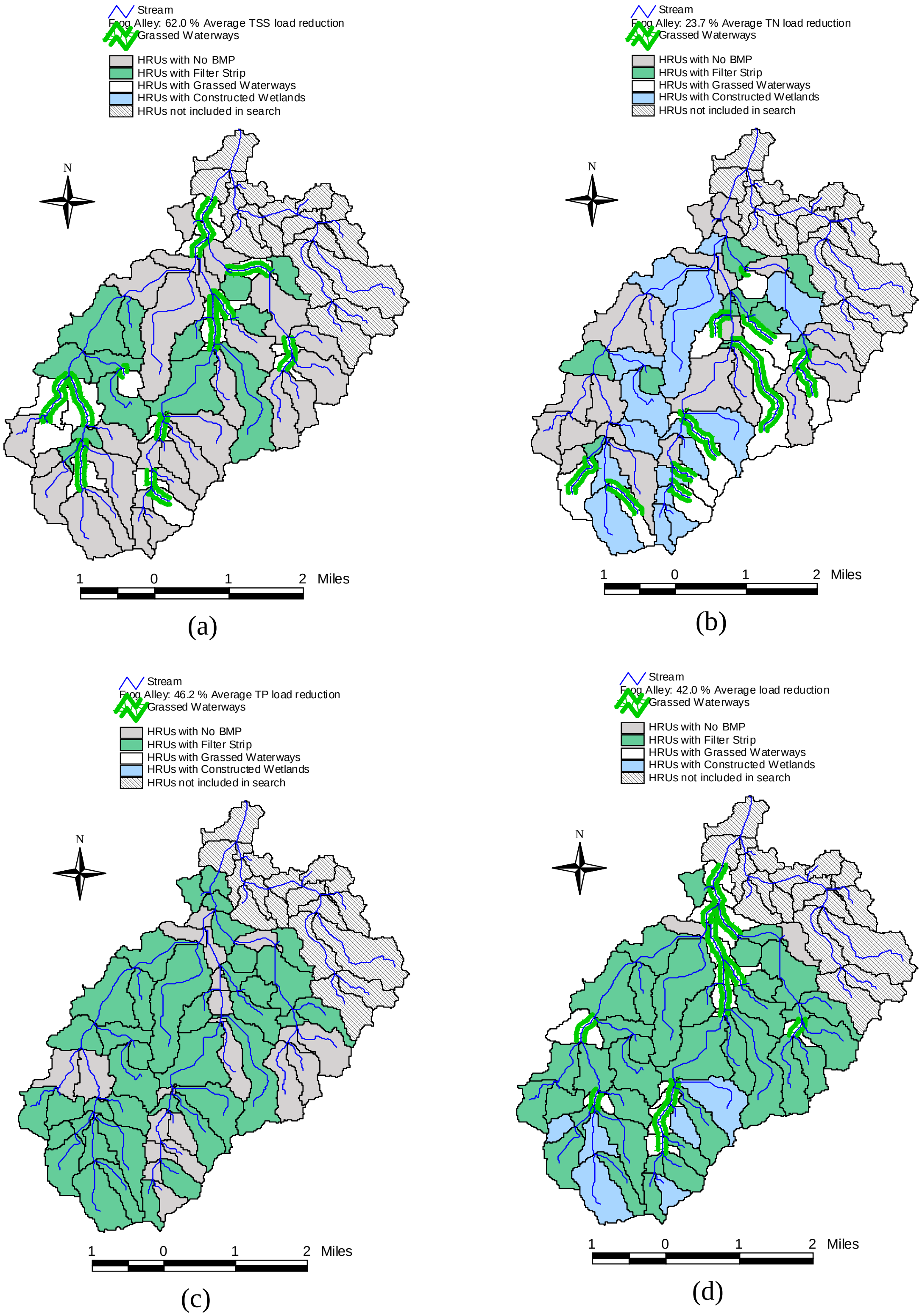


Figure 5.21. Optimal placement of filter strips, grassed waterways, and constructed wetlands in Frog Alley watershed for (a) *TSS*, (b) *TN*, (c) *TP*, and (d) average load reductions

6. Summary and Conclusions

The objectives of this project were to (1) develop a hydrologic model for the Mackinaw River watershed and hydrologic and water quality models for two of its tributary watersheds, namely, Bray Creek and Frog Alley, (2) develop a coupled optimization-watershed model for optimal selection and placement of best management practices (*BMPs*), and (3) apply the developed coupled model to Bray Creek and Frog Alley watersheds. The SWAT model, which is a distributed hydrologic and water quality model, was employed in developing the watershed models. The GIS interface of the SWAT model was used for spatial data processing, watershed delineation, preparation of input files, and generation of default parameters for different hydrologic and water quality processes. Once all required model components were prepared, the FORTRAN version of SWAT was used for further model development because it allows incorporating an automatic calibration tool and coupling it with the multi-objective optimization algorithm for selection and placement of *BMPs*. Based on surveys of conservation practices in the study watershed and additional practices in the experimental watersheds, three *BMPs* are considered in this study. The *BMPs* incorporated in the coupled model are filter strips, grassed waterways, and constructed wetlands. SWAT has provisions to directly simulate filter strips and constructed wetlands. The minimum wetland drainage area was set at 5 hectares. Grassed waterways are represented in the model using parameters governing channel processes such as channel roughness, cover, and erodibility factors.

A standalone hydrologic model was developed for the Mackinaw River watershed. The Mackinaw River hydrologic model is calibrated and validated for streamflows at two USGS gauging sites (i.e., Congerville and Green Valley). The *NSE* for streamflow calibration and validation at both gauging stations was at least 0.68 for the daily, monthly, and annual time step, showing the model's good performance. For the tributary watersheds (i.e., Bray Creek and Frog Alley), hydrologic and water quality simulation models were developed. In addition to streamflow calibration, the Bray Creek and Frog Alley watershed models were also calibrated to simulate sediment and nutrient loads (i.e., total nitrogen and phosphorus) at gauging stations close to their respective watershed outlets. Sediment and nutrient data were intermittent and thus, model calibration was performed using average daily sediment and nutrient loads during the calibration period. Bray Creek and Frog Alley watersheds were satisfactorily calibrated for streamflows, sediment, total nitrogen, and phosphorus loads. The developed watershed models were then interfaced with a multi-objective optimization algorithm (i.e., NSGA-II) to develop the coupled optimization-watershed model for optimal selection and placement of *BMPs* in Bray Creek and Frog Alley watersheds.

The coupled optimization-watershed model was developed to run in two modes of operation that can be used in different circumstances. The first mode of operation allows selecting one *BMP* type at a time and thus, placement of a single *BMP* type in the watershed can be optimized. Unlike the single *BMP* mode of operation, selection of *BMPs* can be done from multiple *BMP* types but only one *BMP* per HRU. The coupled model was run for Bray Creek and Frog Alley watersheds applying four scenarios and four simulation cases. The first three scenarios were run in a single *BMP* mode of operation using filter strips, grassed waterways, and constructed wetlands separately. In the fourth scenario, a multiple *BMP* operation mode was employed in which the selection and placement of filter strips, grassed waterways, or constructed wetlands were possible. For each scenario, four simulation cases were considered. The first three simulation cases search for optimal tradeoffs between *BMP* placement cost and reduction of sediment, total nitrogen, or total phosphorus loads separately, identifying the most effective *BMP* type for load reduction of a particular pollutant. The last simulation case was tasked with finding optimal tradeoffs between reduction of all three pollutants and *BMP* placement costs. This helps identify preferred placement locations or HRUs in the watershed for a particular *BMP* type with the overall goal of reducing pollutants at the watershed outlet and minimizing *BMP* costs.

The coupled optimization-watershed model was applied to Bray Creek and Frog Alley watersheds to determine the selection and placement of *BMPs* in the watersheds that result in optimal tradeoffs between pollutant reduction and total *BMP* costs. Model simulation results for Bray Creek watershed show that the placement of grassed waterways in 78 percent of the stream reach lengths could result in a maximum *TSS* load reduction of 70.5 percent at an estimated cost of $122,957; a maximum *TN* load reduction of 55.3 percent could be achieved with constructed wetlands covering 2 percent of the watershed at an estimated implementation cost of $623,500, and filter strips in 77 percent of the HRUs could bring about a maximum *TN* load reduction of 54.1 percent at an estimated cost of $31,791. Similarly, for Frog Alley watershed, a maximum *TSS* load reduction of 72.6 percent could possibly be obtained if grassed waterways were to be applied to 73 percent of the stream reach lengths. If 1 percent of the watershed were to be constructed wetlands, a maximum *TN* load reduction of 51.8 percent could be achieved at an estimated cost of $587,715, and placement of filter strips to 65 percent of the HRUs in the watershed could result in a maximum *TP* load reduction of 56.6 percent at an estimated cost of $36,420. However, the maximum possible reduction may not be a feasible management option because of the fact that placement of all these *BMPs* in the watersheds would take a huge area of farming lands out of production. This would not be attractive to private landowners, whose willingness is required to implement these *BMPs*. In the case of grassed waterways, for example, it may not be possible to place them in every stream reach. In addition, the cost of *BMP* placement and maintenance could be prohibitive to implement on such a large scale for maximized reduction of pollutants.

Model simulation results for both Bray Creek and Frog Alley watersheds include the best tradeoff solutions that strike a balance between pollutant reduction and total *BMP* costs. The best tradeoff solutions for Bray Creek watershed could bring about load reductions of 65.8 percent for *TSS*, 32.7 percent for *TN*, and 35.1 percent for *TP* through applications of grassed waterways, constructed wetlands, and filter strips, respectively. The associated implementation cost was estimated to be $15,550 for grassed waterways, $44,113 for constructed wetlands, and $15,581 for filter strips. Similarly, the optimal placement of grassed waterways, constructed wetlands, and filter strips in Frog Alley watershed could result in 59.9 percent *TSS* load reduction at an estimated implementation cost of $13,333, 29.6 percent *TN* load at an estimated cost of $28,269, and 34 percent *TP* load reduction at an estimated cost of $16,743, respectively. Simulation results for both watersheds indicate that filter strips are favored for a maximum reduction of *TP* loads, whereas grassed waterways and constructed wetlands are selected for a maximized reduction of *TSS* and *TN* loads, respectively. Filter strips appear to be ineffective in controlling *TN* loads but help moderately reduce *TSS* loads in both watersheds. Significant reductions of *TN* and *TP* loads were obtained through placement of constructed wetlands in both watersheds. Grassed waterways appear to be more effective in controlling *TN* loads in Bray Creek watershed than in Frog Alley watershed. The optimal placement of grassed waterways in both Bray Creek and Frog Alley watersheds indicates that main stems of the respective streams close to the watershed outlets are crucial. Its good performance in controlling *TSS* loads implies that a major portion of *TSS* loads may come from sediment depositions in the channel. For all three *BMPs*, their optimal placement may be indicative of source location of a particular pollutant and this facilitates selection of target areas for *BMP* implementation.

The coupled optimization-watershed model was able to provide optimal tradeoff solutions that could aid decision-makers in selecting the best alternative in terms of maximizing the reduction of pollutant loads into streams and identifying the best *BMP*, its placement location in the watershed, and its associated implementation cost. It must be noted that the implementation costs provided in this study as total *BMP* cost do not include the land value. These costs can always be adjusted to reflect increasing commodity prices or land values. Each of the optimal tradeoff solutions gives the maximum possible pollutant reduction for a particular *BMP* implementation cost. Overall, the solution methodology employed in this study provides optimal tradeoffs between the two conflicting objectives (i.e., percent reduction of pollutants versus total *BMP* implementation cost). In addition, it provides useful information in setting up pollutant reduction goals based on availability of funding for *BMP* implementation in these watersheds and thus, gives decision-makers added flexibility in terms of selecting the best alternative. It must be noted that unit costs of *BMP* implementation used in this study are partly based on TNC's experience in the watershed and the 2004 dollar value. Thus, they may not be representative of the current situation. For future application, the current unit cost of *BMP* implementation and maintenance costs that take into account the design life of the BMP should be used. Accordingly, the total cost figures provided in this report should be adjusted based on the model simulation results, showing the selection and placement of *BMPs* in the watersheds. The coupled optimization-watershed model can be adapted to other watersheds and the model framework can be utilized in evaluating other *BMPs* provided that proper representation of those *BMPs* in watershed models is plausible. The coupled optimization-watershed model can be expanded to simulate several *BMPs* together in a hydrologic response unit for maximized reduction of pollutants.

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Appendix A. Alternative Placements of *BMPs* in Bray Creek Watershed for reduction of *TSS*, *TN,* and *TP* Loads

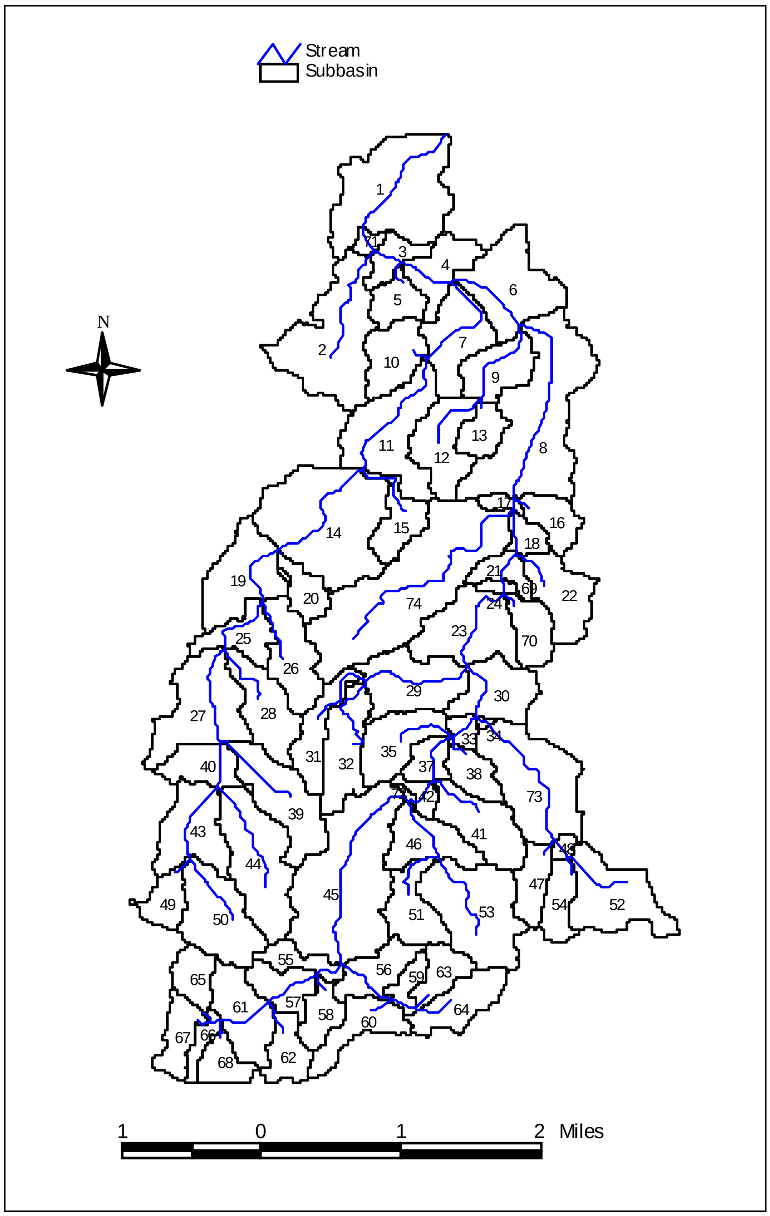

Figure A. Reference figure for subbasin numbers of Bray Creek watershed

A.1. Placement of Filter Strips in Bray Creek Watershed for *TN* Load Reduction (*Scenario-I, Case-1*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	FS	FS	FS	FS	FS	FS	FS	FS	NB	NB
3	FS	FS	FS	FS	FS	FS	NB	NB	NB	NB
4	FS	FS	FS	FS	FS	FS	NB	NB	NB	NB
5	FS	FS	FS	FS	FS	NB	FS	FS	FS	NB
6	FS	FS	FS	FS	FS	FS	NB	NB	NB	NB
7	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
8	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
9	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
10	FS	FS	FS	FS	FS	FS	FS	NB	FS	FS
11	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
12	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
13	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
14	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
15	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
16	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
17	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
18	FS	FS	FS	FS	NB	NB	NB	NB	FS	NB
19	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
20	FS	FS	FS	NB	FS	FS	FS	FS	FS	FS
21	FS	FS	NB	NB	NB	NB	FS	NB	NB	NB
22	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
23	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
24	FS	NB	NB	FS	FS	FS	NB	FS	FS	FS
25	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
26	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
27	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
28	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
29	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
30	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
31	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
32	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
33	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
34	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
35	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
36	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
37	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
38	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
39	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
40	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
41	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
42	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
43	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
44	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
45	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
46	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
47	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
48	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
49	FS	FS	NB	FS	NB	NB	NB	NB	NB	NB
50	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
51	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
52	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
53	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
54	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
55	NB	NB	NB	NB	NB	NB	FS	NB	NB	NB
56	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
57	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
58	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
59	NB	NB	NB	NB	FS	FS	FS	FS	FS	FS
60	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
61	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
62	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
63	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
64	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
65	FS	NB	FS	FS	NB	NB	NB	NB	FS	NB
66	FS	NB	FS	FS	NB	NB	NB	NB	NB	NB
67	FS	NB	FS	FS	NB	NB	NB	NB	NB	NB
68	FS	NB	FS	FS	NB	NB	NB	NB	NB	NB
69	FS	FS	FS	FS	FS	NB	NB	NB	FS	NB
70	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
71	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
72	FS	FS	FS	FS	FS	NB	NB	NB	FS	NB
73	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
74	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB

A.2. Placement of Filter Strips in Bray Creek Watershed for *TN* Load Reduction (*Scenario-I, Case-2*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	FS	FS	FS	FS	FS	FS	NB	NB	NB	NB
3	FS	NB	NB	FS	NB	FS	NB	NB	NB	NB
4	NB	FS	FS	FS	NB	NB	NB	NB	NB	NB
5	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
6	FS	FS	FS	FS	FS	FS	NB	NB	NB	NB
7	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
8	FS	FS	FS	FS	FS	FS	FS	NB	NB	NB
9	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
10	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
11	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
12	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
13	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
14	FS	FS	FS	FS	FS	FS	FS	FS	NB	NB
15	FS	FS	FS	NB	NB	NB	NB	NB	NB	FS
16	FS	FS	FS	FS	FS	FS	FS	FS	FS	NB
17	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
18	FS	FS	FS	FS	FS	FS	FS	FS	NB	NB
19	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
20	FS	FS	FS	FS	FS	FS	FS	FS	FS	NB
21	FS	FS	FS	FS	FS	FS	FS	NB	FS	FS
22	FS	NB	NB	FS	NB	NB	NB	NB	NB	NB
23	FS	FS	FS	FS	FS	FS	FS	FS	FS	NB
24	NB	FS	NB	NB	NB	NB	NB	FS	FS	NB
25	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
26	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
27	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
28	FS	FS	FS	FS	NB	NB	NB	NB	NB	FS
29	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
30	FS	FS	FS	FS	FS	FS	FS	FS	FS	NB
31	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
32	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
33	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
34	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
35	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
36	NB	NB	FS	NB	NB	NB	NB	NB	NB	NB
37	FS	FS	FS	FS	FS	FS	FS	FS	NB	NB
38	FS	FS	FS	FS	FS	NB	FS	FS	NB	NB
39	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
40	FS	FS	NB	FS	FS	FS	FS	FS	FS	FS
41	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
42	FS	FS	NB	FS	FS	FS	FS	NB	FS	FS
43	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
44	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
45	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
46	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
47	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
48	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
49	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
50	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
51	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
52	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
53	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
54	FS	FS	FS	NB	FS	NB	NB	NB	NB	NB
55	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
56	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
57	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
58	FS	NB	FS	NB	NB	NB	NB	NB	FS	NB
59	FS	NB	FS	NB	NB	NB	NB	NB	NB	NB
60	FS	FS	FS	FS	FS	FS	NB	FS	NB	NB
61	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
62	NB	FS	NB	NB	NB	NB	NB	NB	NB	NB
63	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
64	NB	NB	FS	FS	NB	NB	NB	NB	NB	NB
65	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
66	FS	FS	NB	FS	FS	FS	NB	NB	NB	NB
67	FS	FS	FS	FS	FS	FS	FS	NB	FS	FS
68	FS	FS	FS	FS	FS	FS	NB	NB	NB	NB
69	FS	FS	NB	NB	NB	NB	FS	NB	FS	FS
70	FS	FS	FS	NB	FS	FS	NB	NB	NB	NB
71	FS	FS	NB	FS	FS	FS	FS	FS	FS	FS
72	NB	NB	FS	NB	FS	FS	FS	FS	FS	FS
73	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
74	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB

A.3. Placement of Filter Strips in Bray Creek Watershed for *TP* Load Reduction (*Scenario-I, Case-3*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
3	FS	FS	*NB*	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
4	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
5	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
6	FS	FS	FS	FS	FS	FS	FS	FS	FS	*NB*
7	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
8	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*
9	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
10	FS	FS	FS	FS	FS	FS	FS	FS	FS	*NB*
11	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
12	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
13	FS	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*
14	FS	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*
15	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
16	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*
17	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
18	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
19	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
20	FS	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*
21	FS	FS	FS	FS	FS	FS	FS	*NB*	FS	FS
22	FS	FS	FS	FS	FS	*NB*	FS	*NB*	*NB*	*NB*
23	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*
24	FS	FS	FS	FS	FS	*NB*	FS	FS	*NB*	*NB*
25	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
26	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
27	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
28	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
29	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
30	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
31	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
32	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
33	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
34	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
35	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
36	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
37	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
38	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
39	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
40	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
41	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
42	*NB*	*NB*	*NB*	FS	FS	FS	FS	FS	FS	FS
43	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
44	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
45	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
46	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
47	*NB*	FS	FS	FS	FS	FS	FS	FS	FS	FS
48	*NB*	*NB*	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
49	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
50	*NB*	*NB*	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
51	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
52	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*
53	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
54	FS	FS	FS	FS	*NB*	*NB*	FS	FS	FS	FS
55	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
56	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
57	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
58	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
59	FS	FS	FS	*NB*	FS	*NB*	FS	FS	FS	FS
60	FS	FS	FS	FS	FS	FS	FS	FS	FS	*NB*
61	FS	FS	FS	FS	*NB*	FS	*NB*	*NB*	*NB*	*NB*
62	FS	FS	FS	*NB*	*NB*	FS	*NB*	*NB*	*NB*	*NB*
63	FS	FS	FS	FS	FS	FS	*NB*	FS	*NB*	*NB*
64	FS	FS	FS	FS	FS	FS	*NB*	FS	*NB*	*NB*
65	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	FS	*NB*	FS	FS
66	*NB*	*NB*	*NB*	*NB*	*NB*	FS	FS	*NB*	FS	FS
67	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
68	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*
69	*NB*	*NB*	*NB*	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
70	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
71	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*
72	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
73	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
74	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*

A.4. Placement of Filter Strip in Bray Creek Watershed for Average Pollutant Load Reduction (*Scenario-I, Case-4*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	FS	FS	FS	FS	FS	FS	FS	FS	NB	NB
3	FS	FS	FS	FS	FS	FS	FS	FS	NB	NB
4	FS	FS	FS	FS	FS	FS	FS	FS	NB	NB
5	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
6	FS	FS	FS	FS	FS	FS	FS	NB	NB	NB
7	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
8	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
9	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
10	FS	FS	FS	FS	FS	FS	NB	NB	FS	NB
11	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
12	FS	FS	FS	FS	NB	FS	NB	NB	NB	NB
13	FS	FS	FS	FS	FS	FS	NB	NB	NB	NB
14	FS	FS	FS	FS	FS	FS	NB	NB	NB	NB
15	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
16	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
17	NB	NB	NB	NB	NB	NB	NB	NB	FS	NB
18	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
19	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
20	FS	FS	FS	FS	FS	NB	FS	NB	FS	NB
21	FS	FS	FS	FS	FS	FS	FS	FS	NB	NB
22	FS	FS	FS	FS	FS	NB	NB	NB	FS	NB
23	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
24	NB	NB	FS	NB	NB	FS	FS	FS	FS	FS
25	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
26	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
27	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
28	FS	NB	FS	NB	NB	NB	NB	NB	NB	NB
29	FS	NB	FS	NB	NB	NB	NB	NB	NB	NB
30	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
31	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
32	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
33	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
34	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
35	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
36	NB	FS	FS	NB	FS	NB	NB	FS	NB	NB
37	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
38	FS	FS	FS	FS	FS	NB	NB	NB	NB	FS
39	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
40	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
41	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
42	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
43	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
44	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
45	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
46	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
47	NB	FS	FS	FS	NB	NB	NB	NB	NB	NB
48	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
49	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
50	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
51	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
52	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
53	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
54	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
55	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
56	NB	FS	NB	NB	NB	NB	NB	NB	NB	NB
57	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
58	FS	FS	NB	FS	NB	NB	NB	NB	NB	NB
59	FS	FS	FS	NB	NB	NB	NB	NB	FS	NB
60	FS	FS	FS	FS	FS	NB	NB	NB	FS	NB
61	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
62	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
63	FS	NB	FS	FS	FS	FS	FS	FS	FS	FS
64	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
65	NB	FS	FS	NB	FS	NB	NB	NB	NB	NB
66	NB	NB	NB	FS	NB	NB	NB	NB	NB	NB
67	NB	FS	FS	FS	NB	FS	FS	FS	FS	FS
68	FS	NB	FS	NB	FS	NB	NB	FS	NB	NB
69	FS	FS	NB	NB	FS	NB	NB	NB	NB	NB
70	FS	FS	FS	NB	NB	FS	NB	NB	NB	NB
71	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
72	FS	FS	NB	FS	NB	FS	NB	NB	NB	NB
73	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
74	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB

A.5. Placement of Grassed Waterways in Bray Creek Watershed for *TSS* Load Reduction (*Scenario-II, Case-1*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
3	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
4	GW	GW	GW	GW	GW	*NB*	*NB*	GW	*NB*	*NB*
5	*NB*	GW	GW	GW	GW	*NB*	*NB*	GW	*NB*	*NB*
6	GW	GW	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*
7	GW	GW	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*
8	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
9	GW	GW	GW	GW	*NB*	*NB*	*NB*	GW	*NB*	GW
10	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW	GW	GW	GW
11	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
12	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
13	*NB*	GW	GW	GW	GW	*NB*	GW	GW	GW	GW
14	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
15	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW	*NB*	*NB*
16	*NB*	GW	*NB*	GW	GW	GW	GW	*NB*	GW	*NB*
17	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
18	GW	GW	GW	GW	GW	GW	*NB*	*NB*	GW	*NB*
19	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
20	*NB*	*NB*	*NB*	GW	GW	GW	*NB*	GW	GW	*NB*
21	GW	GW	GW	GW	GW	GW	*NB*	GW	GW	*NB*
22	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
23	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
24	*NB*	*NB*	GW	GW	*NB*	*NB*	GW	*NB*	*NB*	GW
25	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
26	*NB*	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
27	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
28	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
29	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
30	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
31	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
32	GW	*NB*	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
33	GW	GW	GW	GW	GW	GW	*NB*	GW	GW	*NB*
34	GW	*NB*	*NB*	*NB*	*NB*	*NB*	GW	*NB*	*NB*	GW
35	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
36	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
37	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
38	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
39	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
40	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
41	*NB*	*NB*	*NB*	GW	GW	GW	*NB*	GW	GW	*NB*
42	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
43	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
44	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
45	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
46	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
47	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
48	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
49	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
50	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
51	*NB*	*NB*	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
52	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
53	GW	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
54	GW	GW	*NB*	*NB*	*NB*	GW	GW	GW	*NB*	GW
55	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
56	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
57	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
58	*NB*	*NB*	GW	GW	GW	GW	GW	GW	GW	GW
59	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
60	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
61	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
62	GW	GW	*NB*	*NB*	*NB*	GW	GW	GW	*NB*	GW
63	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW	*NB*
64	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW	*NB*
65	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW	*NB*
66	GW	GW	GW	GW	GW	GW	GW	GW	*NB*	GW
67	*NB*	*NB*	*NB*	*NB*	*NB*	GW	GW	GW	*NB*	GW
68	*NB*	*NB*	*NB*	*NB*	*NB*	GW	GW	GW	GW	GW
69	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
70	*NB*	*NB*	*NB*	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*
71	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
72	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
73	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
74	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*

A.6. Placement of Grassed Waterways in Bray Creek Watershed for *TN* Load Reduction (*Scenario-II, Case-2*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
3	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
4	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
5	GW	GW	GW	GW	*NB*	*NB*	*NB*	GW	*NB*	GW
6	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
7	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
8	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
9	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
10	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
11	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
12	GW	*NB*	*NB*	*NB*	GW	*NB*	*NB*	*NB*	GW	*NB*
13	*NB*	*NB*	*NB*	*NB*	*NB*	GW	GW	GW	GW	GW
14	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
15	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
16	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
17	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
18	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
19	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
20	*NB*	*NB*	*NB*	GW	*NB*	*NB*	GW	*NB*	GW	GW
21	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
22	GW	GW	*NB*	GW	*NB*	GW	*NB*	GW	*NB*	*NB*
23	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
24	GW	*NB*	GW	GW	GW	*NB*	GW	GW	GW	GW
25	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
26	GW	*NB*	*NB*	*NB*	GW	*NB*	*NB*	GW	*NB*	*NB*
27	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
28	GW	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*
29	GW	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*
30	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
31	GW	GW	GW	GW	*NB*	GW	*NB*	GW	GW	GW
32	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
33	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
34	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
35	GW	GW	GW	GW	GW	GW	*NB*	GW	*NB*	*NB*
36	*NB*	*NB*	GW	GW	*NB*	*NB*	*NB*	*NB*	GW	GW
37	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
38	GW	GW	GW	GW	*NB*	*NB*	GW	GW	*NB*	*NB*
39	GW	GW	GW	GW	GW	GW	GW	GW	*NB*	*NB*
40	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
41	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
42	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
43	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
44	GW	GW	GW	GW	GW	GW	GW	GW	*NB*	*NB*
45	GW	GW	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*
46	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
47	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW	GW
48	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW	*NB*	*NB*	*NB*
49	GW	GW	GW	*NB*	GW	GW	GW	GW	GW	GW
50	GW	GW	GW	GW	GW	GW	GW	GW	*NB*	*NB*
51	GW	GW	GW	GW	GW	GW	*NB*	GW	*NB*	*NB*
52	GW	GW	GW	GW	*NB*	*NB*	GW	*NB*	*NB*	*NB*
53	GW	GW	GW	GW	*NB*	*NB*	GW	*NB*	*NB*	*NB*
54	GW	*NB*	*NB*	GW	*NB*	*NB*	GW	GW	GW	GW
55	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
56	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	GW	*NB*	*NB*
57	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
58	GW	*NB*	GW	*NB*	*NB*	*NB*	GW	*NB*	*NB*	*NB*
59	GW	GW	*NB*	GW	GW	GW	GW	GW	*NB*	GW
60	GW	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	GW	*NB*
61	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
62	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
63	GW	GW	*NB*	GW	*NB*	*NB*	*NB*	GW	*NB*	GW
64	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	GW	GW	*NB*
65	GW	GW	GW	*NB*	GW	GW	*NB*	*NB*	GW	*NB*
66	*NB*	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
67	GW	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*
68	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	GW	GW	*NB*
69	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
70	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
71	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
72	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
73	GW	GW	GW	GW	GW	GW	GW	GW	GW	*NB*
74	GW	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*

A.7. Placement of Grassed Waterways in Bray Creek Watershed for *TP* Load Reduction (*Scenario-II, Case-3*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	GW	*NB*
3	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
4	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
5	*NB*	GW	GW	*NB*	*NB*	*NB*	GW	*NB*	GW	GW
6	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
7	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
8	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
9	GW	GW	GW	GW	GW	GW	*NB*	GW	*NB*	*NB*
10	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW
11	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
12	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	GW	*NB*
13	GW	GW	GW	GW	GW	*NB*	GW	*NB*	*NB*	*NB*
14	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
15	GW	GW	GW	GW	GW	*NB*	GW	*NB*	GW	*NB*
16	*NB*	*NB*	*NB*	GW	*NB*	GW	*NB*	GW	*NB*	GW
17	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
18	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
19	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
20	GW	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	GW	*NB*
21	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
22	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
23	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
24	GW	GW	GW	*NB*	GW	GW	GW	GW	*NB*	GW
25	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
26	GW	GW	GW	GW	GW	GW	GW	GW	*NB*	GW
27	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
28	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
29	GW	GW	GW	GW	*NB*	GW	*NB*	*NB*	*NB*	*NB*
30	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
31	GW	GW	GW	GW	*NB*	GW	*NB*	*NB*	*NB*	*NB*
32	GW	GW	GW	GW	*NB*	GW	GW	*NB*	GW	*NB*
33	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
34	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
35	GW	GW	GW	GW	*NB*	GW	*NB*	GW	*NB*	*NB*
36	GW	*NB*	GW	GW	GW	*NB*	GW	*NB*	GW	GW
37	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
38	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW	*NB*	*NB*
39	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
40	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
41	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
42	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
43	GW	GW	GW	GW	*NB*	*NB*	GW	*NB*	*NB*	*NB*
44	GW	GW	*NB*	*NB*	*NB*	GW	*NB*	*NB*	*NB*	*NB*
45	GW	GW	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*
46	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
47	GW	*NB*	*NB*	*NB*	GW	GW	GW	*NB*	GW	GW
48	GW	GW	GW	GW	*NB*	GW	*NB*	*NB*	*NB*	*NB*
49	GW	GW	GW	GW	GW	GW	GW	*NB*	GW	*NB*
50	GW	GW	GW	GW	GW	*NB*	*NB*	GW	*NB*	*NB*
51	GW	GW	GW	GW	*NB*	GW	*NB*	GW	*NB*	*NB*
52	GW	GW	GW	GW	*NB*	GW	*NB*	GW	*NB*	*NB*
53	GW	GW	GW	GW	GW	GW	*NB*	GW	*NB*	GW
54	GW	GW	GW	GW	*NB*	GW	*NB*	GW	*NB*	GW
55	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW
56	GW	GW	GW	GW	*NB*	*NB*	GW	*NB*	*NB*	*NB*
57	*NB*	*NB*	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
58	GW	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
59	GW	GW	*NB*	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*
60	GW	*NB*	*NB*	*NB*	*NB*	GW	*NB*	*NB*	*NB*	*NB*
61	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW	GW	*NB*	*NB*
62	GW	*NB*	GW	GW	GW	GW	*NB*	*NB*	GW	GW
63	*NB*	*NB*	*NB*	GW	GW	GW	GW	GW	*NB*	*NB*
64	GW	*NB*	GW	GW	*NB*	GW	GW	GW	*NB*	*NB*
65	*NB*	GW	*NB*	GW	*NB*	GW	*NB*	GW	GW	GW
66	*NB*	*NB*	*NB*	GW	GW	*NB*	*NB*	GW	*NB*	*NB*
67	GW	*NB*	*NB*	*NB*	*NB*	GW	*NB*	GW	*NB*	GW
68	GW	*NB*	GW	*NB*	*NB*	*NB*	GW	GW	*NB*	*NB*
69	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
70	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
71	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
72	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
73	GW	GW	GW	GW	GW	GW	GW	GW	GW	*NB*
74	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW

A.8. Placement of Grassed Waterways in Bray Creek Watershed for Average Pollutant Load Reduction (*Scenario-II, Case-4*)

Subbasin	Alternative Solutions									
No	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	GW	GW	GW	GW	GW	GW	*NB*	GW	*NB*	*NB*
3	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
4	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
5	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW	GW
6	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
7	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
8	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
9	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
10	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
11	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
12	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
13	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
14	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
15	GW	GW	GW	GW	GW	*NB*	GW	*NB*	*NB*	*NB*
16	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
17	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
18	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
19	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
20	*NB*	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
21	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
22	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
23	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
24	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
25	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
26	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
27	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
28	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
29	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
30	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
31	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	GW	*NB*
32	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	GW	*NB*
33	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
34	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW	*NB*
35	GW	GW	GW	GW	GW	GW	*NB*	*NB*	GW	*NB*
36	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
37	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
38	GW	*NB*	*NB*	GW	GW	GW	GW	GW	GW	GW
39	GW	GW	GW	GW	*NB*	GW	*NB*	*NB*	*NB*	*NB*
40	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	GW	*NB*	*NB*
41	GW	GW	GW	GW	*NB*	GW	*NB*	*NB*	*NB*	*NB*
42	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
43	GW	GW	GW	GW	*NB*	GW	*NB*	*NB*	*NB*	*NB*
44	GW	GW	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*
45	GW	GW	GW	GW	GW	GW	GW	GW	*NB*	*NB*
46	*NB*	GW	GW	*NB*	*NB*	*NB*	*NB*	GW	*NB*	*NB*
47	*NB*	GW	GW	*NB*	GW	GW	*NB*	*NB*	*NB*	GW
48	GW	GW	*NB*	*NB*	*NB*	*NB*	GW	*NB*	*NB*	*NB*
49	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	GW	*NB*
50	GW	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*
51	GW	GW	*NB*	GW	*NB*	*NB*	GW	*NB*	GW	*NB*
52	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	GW	*NB*
53	GW	GW	GW	GW	GW	GW	GW	*NB*	GW	*NB*
54	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW	GW	*NB*	GW
55	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
56	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
57	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
58	GW	*NB*	*NB*	*NB*	*NB*	*NB*	GW	GW	GW	GW
59	GW	*NB*	GW	*NB*	*NB*	*NB*	*NB*	GW	GW	GW
60	GW	*NB*	*NB*	GW	GW	GW	GW	*NB*	*NB*	*NB*
61	*NB*	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
62	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
63	GW	GW	*NB*	GW	*NB*	*NB*	GW	*NB*	*NB*	*NB*
64	GW	*NB*	*NB*	GW	*NB*	*NB*	*NB*	GW	*NB*	GW
65	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW	GW	GW
66	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW	*NB*	*NB*	*NB*
67	*NB*	*NB*	*NB*	GW	*NB*	GW	*NB*	*NB*	*NB*	*NB*
68	GW	*NB*	GW	*NB*	*NB*	GW	*NB*	GW	*NB*	GW
69	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
70	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
71	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
72	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
73	GW	GW	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*
74	GW	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*

A.9. Placement of Constructed Wetlands in Bray Creek Watershed for *TSS* Load Reduction (*Scenario-III, Case-1*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	9	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	CW	CW	CW	CW	CW	CW	NB	NB	NB	NB
3	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
4	CW	CW	CW	CW	CW	CW	CW	CW	CW	NB
5	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
6	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
7	CW	NB	NB	NB	NB	NB	NB	NB	NB	NB
8	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
9	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
10	CW	NB	NB	NB	NB	NB	NB	NB	NB	NB
11	CW	NB	NB	NB	NB	NB	NB	NB	NB	NB
12	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
13	CW	NB	NB	NB	NB	NB	NB	NB	NB	NB
14	CW	CW	CW	NB	NB	NB	NB	NB	NB	NB
15	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
16	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
17	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
18	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
19	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
20	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
21	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
22	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
23	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
24	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
25	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
26	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
27	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
28	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
29	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
30	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
31	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
32	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
33	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
34	CW	CW	NB	NB	NB	CW	CW	CW	NB	CW
35	CW	CW	CW	CW	CW	NB	CW	CW	CW	CW
36	NB	NB	CW	NB	NB	CW	CW	CW	CW	CW
37	CW	CW	CW	CW	NB	CW	NB	NB	CW	NB
38	CW	CW	CW	CW	NB	CW	CW	CW	NB	CW
39	CW	CW	CW	CW	CW	NB	CW	CW	NB	NB
40	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
41	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
42	CW	CW	NB	NB	NB	NB	CW	CW	NB	NB
43	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
44	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
45	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
46	CW	NB	NB	NB	NB	NB	NB	NB	NB	NB
47	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
48	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
49	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
50	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
51	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
52	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
53	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
54	CW	NB	NB	NB	NB	NB	NB	NB	NB	NB
55	CW	NB	NB	NB	NB	NB	NB	NB	NB	NB
56	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
57	CW	NB	NB	NB	NB	NB	NB	NB	NB	NB
58	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
59	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
60	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
61	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
62	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
63	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
64	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
65	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
66	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
67	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
68	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
69	CW	CW	CW	NB	NB	CW	NB	NB	CW	CW
70	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
71	CW	CW	CW	CW	CW	NB	CW	CW	NB	NB
72	CW	CW	CW	NB	CW	CW	CW	CW	CW	CW
73	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
74	CW	CW	CW	NB	NB	NB	NB	NB	NB	NB

A.10. Placement of Constructed Wetlands in Bray Creek Watershed for *TN* Load Reduction (*Scenario-III, Case-2*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	9	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
3	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
4	CW	CW	CW	CW	CW	CW	CW	CW	CW	NB
5	NB	NB	NB	NB	NB	NB	NB	NB	NB	CW
6	CW	CW	CW	CW	CW	CW	CW	CW	NB	NB
7	CW	CW	CW	CW	CW	NB	CW	CW	CW	NB
8	CW	CW	CW	CW	CW	CW	NB	NB	NB	NB
9	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
10	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
11	CW	CW	CW	CW	CW	NB	CW	CW	NB	NB
12	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
13	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
14	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
15	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
16	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
17	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
18	NB	CW	CW	CW	CW	CW	CW	CW	CW	CW
19	CW	NB	NB	NB	NB	NB	NB	NB	NB	NB
20	CW	NB	NB	NB	CW	NB	NB	NB	NB	NB
21	CW	CW	CW	CW	NB	NB	NB	CW	NB	NB
22	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
23	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
24	NB	NB	CW	CW	CW	CW	CW	CW	CW	CW
25	CW	CW	CW	CW	CW	NB	CW	CW	NB	NB
26	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
27	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
28	CW	CW	CW	CW	CW	NB	NB	CW	NB	CW
29	CW	CW	CW	CW	CW	CW	CW	NB	CW	NB
30	CW	CW	NB	NB	NB	NB	CW	NB	NB	NB
31	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
32	NB	NB	CW	NB	NB	NB	NB	NB	CW	NB
33	CW	CW	CW	NB	NB	NB	CW	NB	NB	NB
34	CW	CW	NB	NB	NB	NB	NB	CW	CW	CW
35	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
36	CW	CW	NB	NB	NB	NB	CW	NB	NB	NB
37	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
38	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
39	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
40	CW	CW	CW	CW	CW	CW	NB	NB	NB	NB
41	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
42	CW	CW	CW	CW	NB	NB	NB	NB	CW	NB
43	CW	CW	CW	CW	CW	CW	NB	NB	NB	NB
44	CW	CW	CW	NB	NB	NB	NB	NB	NB	NB
45	CW	CW	CW	CW	CW	CW	NB	NB	NB	NB
46	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
47	NB	NB	CW	CW	NB	NB	NB	CW	CW	CW
48	NB	CW	CW	NB	NB	NB	CW	CW	CW	CW
49	NB	CW	CW	CW	NB	NB	NB	NB	NB	NB
50	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
51	CW	CW	CW	CW	NB	NB	NB	CW	CW	CW
52	CW	CW	CW	CW	CW	CW	CW	NB	NB	NB
53	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
54	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
55	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
56	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
57	CW	CW	NB	NB	NB	CW	NB	NB	NB	NB
58	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
59	CW	CW	NB	NB	CW	CW	NB	NB	NB	NB
60	CW	CW	CW	NB	NB	CW	CW	CW	CW	CW
61	NB	CW	NB	NB	NB	NB	NB	NB	NB	NB
62	CW	CW	CW	NB	NB	NB	NB	NB	NB	NB
63	CW	NB	CW	NB	NB	NB	NB	NB	NB	NB
64	CW	NB	CW	NB	NB	NB	NB	NB	NB	NB
65	CW	CW	CW	NB	NB	NB	NB	NB	NB	NB
66	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
67	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
68	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
69	CW	CW	CW	NB	NB	CW	CW	NB	NB	NB
70	CW	CW	CW	CW	NB	CW	CW	NB	NB	NB
71	NB	CW	CW	CW	CW	CW	CW	CW	CW	NB
72	NB	NB	NB	NB	NB	NB	NB	CW	CW	CW
73	CW	CW	CW	CW	CW	CW	CW	NB	NB	NB
74	CW	NB	NB	NB	NB	NB	NB	NB	NB	NB

A.11. Placement of Constructed Wetlands in Bray Creek Watershed for *TP* Load Reduction (*Scenario-III, Case-3*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	9	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
3	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
4	CW	CW	CW	CW	*NB*	*NB*	*NB*	CW	*NB*	*NB*
5	CW	CW	CW	CW	CW	CW	CW	CW	*NB*	*NB*
6	CW	CW	CW	CW	CW	CW	CW	CW	*NB*	*NB*
7	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
8	CW	CW	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*
9	CW	CW	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*
10	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
11	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
12	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
13	CW	CW	CW	CW	CW	CW	*NB*	CW	CW	CW
14	CW	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*
15	CW	CW	CW	*NB*	CW	CW	CW	*NB*	*NB*	*NB*
16	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	CW	CW
17	*NB*	CW	*NB*	CW	*NB*	CW	*NB*	CW	CW	CW
18	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
19	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
20	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	CW	CW
21	CW	CW	CW	CW	CW	CW	CW	CW	*NB*	*NB*
22	CW	CW	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*
23	CW	CW	CW	CW	CW	CW	*NB*	CW	CW	CW
24	CW	*NB*	CW	*NB*	CW	*NB*	*NB*	*NB*	*NB*	*NB*
25	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
26	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
27	CW	*NB*	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
28	CW	*NB*	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
29	CW	CW	CW	*NB*	*NB*	*NB*	CW	*NB*	*NB*	*NB*
30	CW	CW	CW	CW	CW	CW	CW	CW	CW	*NB*
31	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
32	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
33	CW	CW	CW	CW	*NB*	*NB*	CW	*NB*	CW	*NB*
34	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	CW	*NB*
35	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
36	*NB*	*NB*	*NB*	*NB*	CW	CW	CW	CW	CW	*NB*
37	CW	CW	CW	CW	CW	CW	CW	CW	CW	*NB*
38	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
39	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
40	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
41	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
42	*NB*	*NB*	*NB*	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
43	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
44	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
45	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
46	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
47	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
48	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
49	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
50	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
51	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
52	CW	CW	CW	CW	CW	CW	CW	CW	CW	*NB*
53	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
54	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	CW
55	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
56	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
57	*NB*	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
58	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
59	CW	*NB*	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
60	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
61	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
62	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
63	CW	CW	*NB*	*NB*	*NB*	CW	*NB*	*NB*	*NB*	*NB*
64	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
65	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
66	CW	CW	*NB*	*NB*	*NB*	CW	*NB*	*NB*	*NB*	*NB*
67	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
68	*NB*	*NB*	CW	CW	CW	CW	CW	CW	CW	*NB*
69	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
70	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	CW
71	CW	CW	CW	CW	CW	CW	CW	CW	*NB*	CW
72	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
73	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
74	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*

A.12. Placement of Constructed Wetlands in Bray Creek Watershed for Average Pollutant Load Reduction (*Scenario-III, Case-4*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	9	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	CW	CW	CW	CW	CW	CW	CW	CW	*NB*	*NB*
3	CW	CW	CW	CW	CW	CW	CW	CW	CW	*NB*
4	CW	CW	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*
5	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
6	CW	CW	CW	CW	CW	CW	CW	CW	CW	*NB*
7	CW	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*
8	CW	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*
9	CW	CW	CW	CW	CW	*NB*	CW	CW	CW	CW
10	CW	*NB*	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
11	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
12	CW	*NB*	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
13	CW	CW	CW	*NB*	*NB*	CW	*NB*	*NB*	*NB*	*NB*
14	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
15	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
16	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
17	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	CW	*NB*	*NB*	CW
18	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
19	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
20	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	CW
21	*NB*	CW	*NB*	*NB*	CW	CW	*NB*	CW	CW	*NB*
22	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
23	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
24	*NB*	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
25	*NB*	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
26	CW	*NB*	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
27	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
28	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
29	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
30	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
31	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
32	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
33	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
34	*NB*	CW	*NB*	*NB*	*NB*	CW	CW	*NB*	*NB*	*NB*
35	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
36	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
37	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
38	CW	CW	*NB*	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
39	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
40	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
41	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
42	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
43	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
44	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
45	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
46	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
47	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
48	CW	CW	*NB*	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
49	CW	CW	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*
50	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
51	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
52	CW	CW	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*
53	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
54	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
55	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
56	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
57	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
58	*NB*	*NB*	*NB*	*NB*	CW	*NB*	CW	*NB*	*NB*	*NB*
59	*NB*	CW	*NB*	*NB*	*NB*	CW	*NB*	*NB*	*NB*	*NB*
60	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
61	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
62	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
63	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
64	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
65	CW	CW	*NB*	*NB*	*NB*	CW	*NB*	*NB*	*NB*	*NB*
66	CW	*NB*	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
67	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
68	CW	CW	CW	*NB*	*NB*	CW	*NB*	*NB*	*NB*	*NB*
69	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
70	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
71	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
72	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
73	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
74	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*

A.13. Placement of Filter Strips, Grassed Waterways, and Constructed Wetlands in Bray Creek Watershed for *TSS* Load Reduction (*Scenario-IV, Case-1*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
3	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
4	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
5	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
6	GW	GW	GW	GW	GW	FS	FS	FS	FS	FS
7	GW	GW	GW	GW	GW	FS	FS	FS	FS	FS
8	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
9	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
10	*NB*	*NB*	*NB*	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*
11	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
12	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
13	CW	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
14	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
15	GW	*NB*	*NB*	*NB*	FS	FS	FS	FS	FS	FS
16	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
17	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
18	GW	GW	GW	GW	FS	FS	FS	FS	FS	FS
19	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
20	CW	FS	FS	FS	*NB*	GW	GW	GW	GW	GW
21	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
22	*NB*	GW	FS	FS	GW	*NB*	*NB*	*NB*	*NB*	*NB*
23	GW	GW	GW	FS	FS	FS	FS	FS	FS	FS
24	FS	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
25	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
26	FS	GW	FS	GW	FS	*NB*	*NB*	*NB*	*NB*	*NB*
27	FS	*NB*	FS	FS	*NB*	FS	FS	FS	FS	FS
28	FS	FS	FS	*NB*	*NB*	GW	GW	GW	GW	GW
29	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
30	GW	GW	GW	GW	FS	*NB*	*NB*	*NB*	*NB*	*NB*
31	*NB*	*NB*	GW	GW	*NB*	GW	GW	GW	GW	GW
32	*NB*	*NB*	*NB*	*NB*	*NB*	FS	FS	FS	FS	FS
33	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
34	GW	GW	GW	GW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
35	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
36	GW	GW	GW	GW	GW	CW	CW	CW	CW	FS
37	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
38	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
39	FS	FS	FS	FS	*NB*	FS	FS	FS	FS	FS
40	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
41	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
42	GW	FS	FS	FS	*NB*	FS	FS	FS	FS	FS
43	GW	GW	GW	GW	GW	GW	GW	GW	GW	*NB*
44	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
45	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	FS
46	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
47	*NB*	*NB*	FS	FS	FS	FS	FS	FS	FS	FS
48	FS	FS	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	GW
49	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
50	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
51	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
52	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
53	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
54	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
55	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
56	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW
57	GW	GW	FS	FS	FS	FS	FS	FS	FS	FS
58	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
59	GW	GW	GW	GW	*NB*	GW	GW	GW	GW	GW
60	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
61	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
62	FS	FS	*NB*	*NB*	FS	FS	FS	FS	FS	GW
63	GW	GW	*NB*	*NB*	GW	GW	GW	GW	GW	*NB*
64	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
65	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
66	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
67	*NB*	*NB*	GW	GW	GW	GW	GW	GW	GW	GW
68	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
69	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
70	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
71	GW	GW	GW	GW	GW	GW	GW	GW	GW	*NB*
72	FS	FS	GW	GW	GW	GW	GW	GW	GW	GW
73	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
74	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*

A.14. Placement of Filter Strips, Grassed Waterways, and Constructed Wetlands in Bray Creek Watershed for *TN* Load Reduction (*Scenario-IV, Case-2*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	GW	GW	GW	GW	GW	FS	GW	GW	GW	GW
3	CW	CW	CW	CW	GW	*NB*	FS	FS	FS	FS
4	CW	CW	CW	CW	FS	FS	FS	FS	FS	FS
5	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
6	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
7	GW	GW	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*
8	GW	GW	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*
9	CW	CW	CW	GW	GW	*NB*	FS	*NB*	FS	FS
10	CW	CW	CW	*NB*	*NB*	*NB*	GW	*NB*	GW	GW
11	GW	GW	GW	GW	GW	GW	*NB*	GW	FS	FS
12	CW	CW	CW	FS	FS	GW	*NB*	FS	*NB*	*NB*
13	*NB*	*NB*	*NB*	*NB*	*NB*	FS	FS	FS	FS	FS
14	GW	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*
15	GW	GW	GW	GW	*NB*	GW	GW	GW	GW	GW
16	CW	CW	CW	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
17	*NB*	*NB*	*NB*	*NB*	GW	GW	FS	FS	FS	FS
18	*NB*	*NB*	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
19	CW	CW	GW	CW	GW	FS	FS	FS	FS	FS
20	*NB*	*NB*	*NB*	FS	*NB*	FS	FS	FS	FS	FS
21	GW	CW	FS	GW	GW	GW	GW	GW	GW	GW
22	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
23	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
24	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
25	GW	GW	GW	GW	GW	FS	FS	FS	FS	FS
26	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
27	GW	GW	GW	GW	GW	*NB*	GW	GW	GW	GW
28	CW	CW	CW	CW	GW	FS	*NB*	*NB*	*NB*	*NB*
29	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
30	GW	GW	GW	GW	GW	FS	FS	FS	FS	FS
31	GW	GW	GW	GW	GW	FS	FS	FS	FS	FS
32	GW	GW	GW	GW	GW	FS	FS	FS	FS	FS
33	CW	CW	CW	CW	*NB*	FS	*NB*	FS	FS	FS
34	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
35	GW	GW	GW	GW	GW	GW	GW	FS	FS	FS
36	GW	GW	GW	GW	CW	*NB*	*NB*	CW	GW	GW
37	CW	CW	CW	CW	FS	FS	FS	FS	FS	FS
38	CW	CW	GW	GW	*NB*	FS	FS	FS	FS	FS
39	CW	CW	GW	GW	GW	*NB*	*NB*	FS	FS	FS
40	CW	CW	CW	FS	CW	*NB*	FS	GW	*NB*	*NB*
41	*NB*	*NB*	GW	GW	GW	GW	*NB*	GW	FS	FS
42	*NB*	*NB*	CW	CW	*NB*	GW	CW	GW	*NB*	*NB*
43	CW	CW	*NB*	GW	*NB*	*NB*	*NB*	*NB*	FS	FS
44	GW	GW	GW	GW	GW	GW	GW	GW	FS	FS
45	GW	GW	GW	GW	GW	GW	GW	GW	GW	*NB*
46	CW	CW	GW	GW	GW	GW	GW	GW	GW	*NB*
47	CW	CW	CW	CW	FS	*NB*	FS	*NB*	FS	*NB*
48	FS	FS	GW	GW	GW	GW	GW	GW	GW	GW
49	CW	CW	GW	GW	GW	GW	GW	GW	GW	GW
50	GW	GW	GW	GW	GW	FS	FS	FS	FS	FS
51	CW	CW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
52	CW	CW	GW	GW	GW	GW	FS	GW	FS	GW
53	CW	GW	GW	GW	GW	GW	*NB*	GW	*NB*	GW
54	CW	*NB*	GW	GW	GW	*NB*	GW	*NB*	GW	GW
55	*NB*	GW	CW	GW	*NB*	GW	*NB*	GW	*NB*	*NB*
56	CW	GW	GW	GW	GW	*NB*	FS	*NB*	FS	GW
57	*NB*	*NB*	*NB*	FS	*NB*	*NB*	GW	*NB*	GW	*NB*
58	CW	CW	FS	GW	FS	*NB*	GW	FS	GW	*NB*
59	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	GW
60	GW	CW	GW	FS	GW	GW	FS	GW	FS	GW
61	CW	GW	CW	GW	GW	GW	GW	GW	GW	GW
62	CW	GW	CW	GW	GW	GW	*NB*	GW	*NB*	*NB*
63	GW	FS	GW	CW	FS	GW	FS	GW	FS	FS
64	CW	GW	CW	CW	*NB*	FS	*NB*	FS	*NB*	*NB*
65	CW	CW	CW	*NB*	*NB*	FS	*NB*	FS	*NB*	*NB*
66	CW	GW	CW	*NB*	FS	GW	FS	GW	FS	FS
67	CW	GW	CW	CW	GW	GW	GW	GW	GW	GW
68	CW	CW	CW	GW	GW	FS	FS	FS	FS	GW
69	CW	CW	CW	FS	FS	GW	FS	GW	FS	FS
70	CW	CW	CW	CW	FS	*NB*	GW	*NB*	GW	GW
71	CW	CW	CW	CW	CW	*NB*	GW	*NB*	*NB*	*NB*
72	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
73	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
74	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW

A.15. Placement of Filter Strips, Grassed Waterways, and Constructed Wetlands in Bray Creek Watershed for *TP* Load Reduction (*Scenario-IV, Case-3*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	FS	FS	FS	FS	FS	FS	FS	FS	FS	*NB*
3	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
4	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
5	FS	FS	FS	FS	FS	*NB*	GW	GW	GW	GW
6	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
7	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*
8	FS	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*
9	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
10	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
11	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*
12	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
13	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
14	FS	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*
15	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*
16	FS	FS	FS	FS	FS	FS	*NB*	GW	*NB*	*NB*
17	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
18	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
19	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
20	CW	*NB*	*NB*	*NB*	FS	*NB*	FS	*NB*	*NB*	*NB*
21	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
22	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
23	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
24	FS	GW	GW	GW	GW	GW	GW	GW	GW	GW
25	FS	FS	FS	FS	FS	*NB*	FS	FS	FS	FS
26	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*
27	FS	FS	FS	FS	FS	FS	*NB*	*NB*	FS	*NB*
28	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
29	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
30	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*
31	CW	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
32	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	FS
33	GW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
34	*NB*	FS	CW	CW	GW	*NB*	CW	CW	CW	*NB*
35	FS	FS	FS	FS	FS	*NB*	FS	FS	FS	*NB*
36	FS	FS	*NB*	FS	*NB*	FS	FS	FS	FS	FS
37	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
38	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
39	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
40	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
41	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
42	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
43	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
44	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
45	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
46	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
47	CW	CW	GW	CW	*NB*	GW	GW	GW	GW	GW
48	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
49	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
50	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
51	CW	CW	CW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
52	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
53	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
54	CW	CW	CW	GW	GW	GW	GW	GW	GW	GW
55	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
56	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
57	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
58	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
59	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
60	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
61	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
62	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
63	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
64	FS	FS	FS	FS	FS	FS	FS	*NB*	FS	FS
65	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
66	CW	CW	CW	GW	GW	*NB*	*NB*	*NB*	*NB*	GW
67	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
68	FS	FS	FS	*NB*	*NB*	FS	FS	FS	FS	GW
69	FS	*NB*	*NB*	FS	*NB*	*NB*	FS	FS	FS	FS
70	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
71	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
72	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	FS
73	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*
74	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS

A.16. Placement of Filter Strips, Grassed Waterways, and Constructed Wetlands in Bray Creek Watershed for Average Pollutant Load Reduction (*Scenario-IV, Case-4*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
3	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
4	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
5	FS	FS	FS	FS	FS	NB	NB	NB	FS	FS
6	FS	FS	FS	FS	FS	FS	FS	NB	FS	FS
7	GW	GW	GW	GW	GW	NB	NB	NB	NB	NB
8	GW	GW	GW	GW	GW	FS	FS	NB	NB	NB
9	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
10	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
11	GW	GW	GW	GW	GW	GW	GW	NB	NB	NB
12	CW	CW	CW	FS	FS	FS	FS	FS	FS	FS
13	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
14	CW	FS	FS	FS	FS	FS	FS	FS	FS	FS
15	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
16	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
17	CW	FS	FS	CW	FS	FS	FS	FS	FS	FS
18	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
19	CW	CW	CW	FS	FS	FS	FS	NB	NB	NB
20	FS	FS	FS	GW	FS	GW	GW	FS	FS	FS
21	GW	GW	GW	NB	GW	NB	NB	GW	GW	GW
22	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
23	FS	FS	FS	FS	FS	FS	FS	NB	NB	NB
24	CW	CW	CW	NB	GW	NB	NB	GW	GW	GW
25	GW	CW	CW	GW	GW	FS	FS	FS	FS	FS
26	CW	CW	CW	FS	FS	FS	FS	NB	NB	NB
27	GW	GW	GW	GW	GW	NB	NB	NB	NB	NB
28	CW	FS	FS	FS	FS	NB	NB	NB	NB	NB
29	CW	CW	GW	GW	GW	GW	NB	NB	NB	NB
30	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
31	FS	CW	CW	GW	GW	GW	GW	GW	GW	GW
32	FS	GW	GW	FS	FS	FS	FS	FS	FS	FS
33	GW	GW	GW	GW	FS	FS	GW	GW	GW	GW
34	CW	CW	CW	CW	NB	NB	FS	FS	FS	FS
35	CW	CW	FS	FS	FS	FS	GW	GW	GW	GW
36	CW	CW	CW	GW	NB	NB	NB	NB	GW	NB
37	CW	CW	CW	CW	FS	FS	NB	NB	NB	NB
38	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
39	GW	GW	GW	GW	GW	GW	FS	FS	FS	NB
40	CW	CW	CW	FS	GW	GW	NB	NB	NB	NB
41	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
42	CW	CW	CW	CW	FS	FS	GW	GW	GW	GW
43	CW	CW	CW	CW	GW	GW	NB	NB	NB	NB
44	GW	GW	GW	GW	GW	GW	FS	FS	FS	FS
45	GW	GW	GW	GW	GW	GW	NB	NB	NB	NB
46	GW	GW	GW	GW	GW	NB	GW	GW	GW	GW
47	CW	CW	CW	CW	FS	GW	FS	FS	FS	FS
48	CW	CW	CW	CW	CW	CW	GW	GW	GW	GW
49	FS	FS	FS	FS	FS	FS	NB	NB	NB	NB
50	CW	CW	CW	CW	FS	FS	NB	NB	NB	NB
51	CW	CW	CW	FS	FS	GW	FS	FS	FS	FS
52	CW	CW	FS	FS	FS	FS	FS	FS	FS	FS
53	CW	CW	GW	GW	GW	GW	NB	NB	NB	NB
54	FS	FS	FS	NB	NB	NB	FS	FS	FS	FS
55	CW	CW	NB	FS	FS	FS	GW	GW	GW	GW
56	CW	CW	CW	GW	GW	GW	FS	NB	NB	NB
57	CW	CW	FS	FS	FS	GW	FS	NB	NB	NB
58	CW	CW	FS	FS	FS	GW	FS	FS	FS	FS
59	NB	NB	NB	GW	GW	GW	GW	GW	GW	GW
60	NB	FS	FS	FS	FS	FS	FS	FS	FS	FS
61	CW	FS	FS	CW	FS	FS	FS	FS	FS	FS
62	FS	CW	CW	CW	NB	GW	GW	GW	GW	GW
63	FS	FS	FS	FS	FS	FS	NB	FS	FS	FS
64	CW	FS	CW	CW	FS	GW	FS	GW	GW	GW
65	CW	FS	CW	CW	FS	FS	FS	FS	FS	FS
66	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
67	CW	FS	FS	FS	NB	NB	GW	NB	NB	NB
68	CW	CW	FS	FS	FS	FS	FS	FS	FS	FS
69	GW	GW	FS	FS	FS	FS	FS	FS	CW	CW
70	FS	FS	FS	FS	NB	FS	FS	FS	NB	NB
71	GW	GW	GW	GW	CW	GW	GW	GW	NB	NB
72	FS	FS	FS	FS	CW	FS	FS	FS	GW	GW
73	GW	GW	GW	GW	GW	GW	GW	GW	FS	FS
74	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW

Appendix B. Alternative Placements of *BMPs* in Frog Alley Watershed for Reduction of *TSS*, *TN,* and *TP* Loads

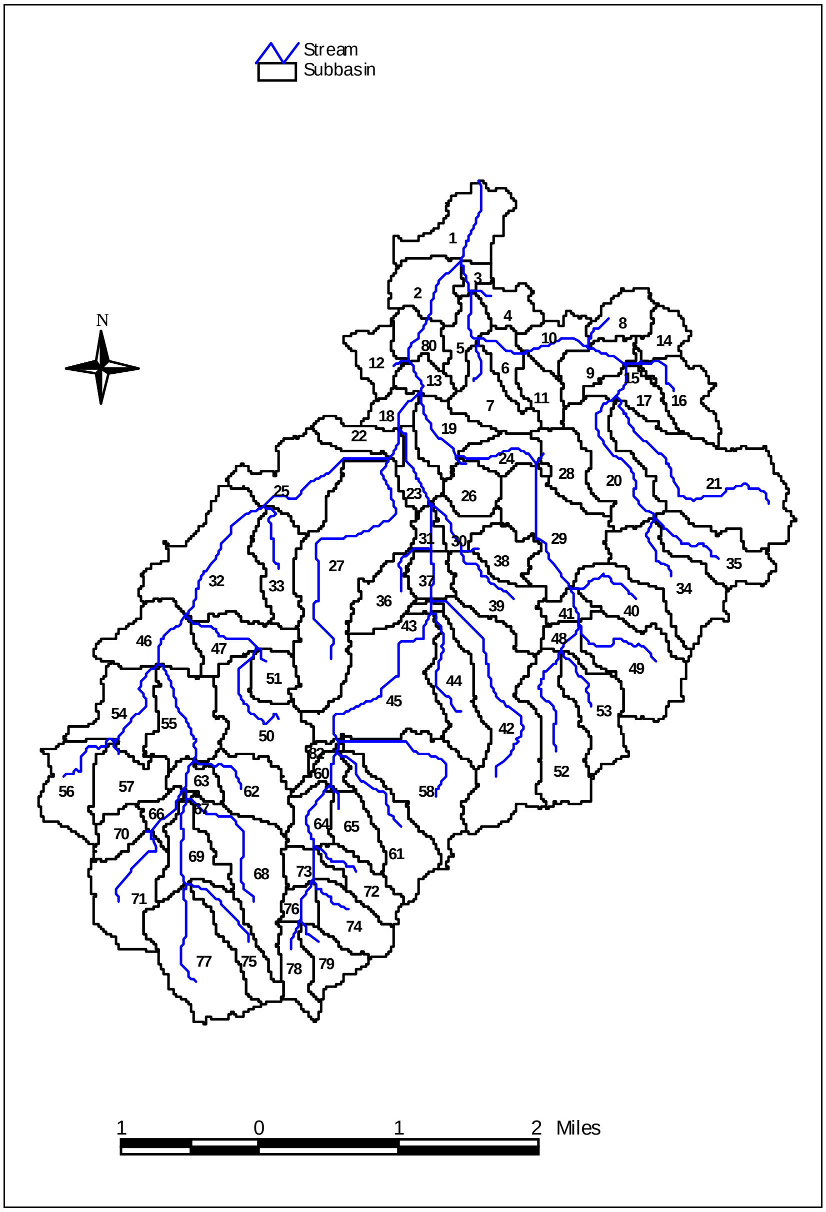

Figure B. Reference figure for subbasin numbers of Frog Alley watershed

B.1. Placement of Filter Strips in Frog Alley Watershed for *TSS* Load Reduction (*Scenario-I*, *Case-1*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	FS	FS	FS	NB	FS	FS	FS	NB	FS	NB
13	NB	FS	FS	NB	NB	NB	NB	NB	NB	NB
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18	NB	FS	FS	NB	NB	NB	NB	NB	NB	NB
19	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
23	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
24	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
25	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
26	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
27	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
28	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
29	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
30	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
31	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
32	FS	FS	FS	FS	FS	FS	NB	NB	NB	NB
33	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
34	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36	FS	FS	FS	FS	FS	FS	FS	NB	NB	NB
37	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
38	NB	FS	FS	NB	FS	NB	NB	NB	NB	NB
39	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
40	FS	NB	FS	NB	NB	NB	NB	NB	NB	NB
41	NB	FS	NB	NB	NB	NB	NB	NB	NB	NB
42	FS	FS	FS	FS	FS	FS	FS	FS	NB	NB
43	FS	NB	FS	NB	NB	NB	FS	FS	FS	FS
44	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
45	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
46	FS	FS	FS	FS	FS	FS	NB	NB	NB	NB
47	FS	FS	FS	FS	FS	FS	NB	NB	NB	NB
48	NB	FS	NB	NB	NB	NB	NB	NB	NB	NB
49	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
50	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
51	FS	FS	FS	FS	NB	FS	NB	NB	NB	NB
52	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
53	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
54	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
55	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
56	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
57	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
58	FS	FS	FS	FS	FS	FS	FS	NB	FS	NB
59	NB	FS	NB	NB	NB	NB	NB	NB	NB	NB
60	FS	NB	NB	NB	NB	NB	FS	NB	FS	FS
61	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
62	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
63	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
64	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
65	FS	FS	FS	FS	FS	FS	FS	FS	FS	NB
66	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
67	FS	NB	FS	NB	NB	FS	FS	FS	FS	FS
68	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
69	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
70	FS	FS	FS	FS	FS	NB	FS	FS	FS	FS
71	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
72	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
73	FS	FS	FS	FS	FS	NB	FS	NB	NB	NB
74	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
75	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
76	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
77	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
78	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
79	FS	FS	NB	FS	NB	NB	NB	NB	NB	NB
80	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
81	FS	NB	FS	NB	FS	NB	NB	NB	NB	NB
82	FS	FS	FS	FS	NB	NB	FS	NB	FS	NB

B.2. Placement of Filter Strips in Frog Alley Watershed for *TN* Load Reduction (*Scenario-I*, *Case-2*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	FS	NB	FS	NB	FS	NB	NB	NB	NB	NB
13	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
19	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
23	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
24	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
25	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
26	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
27	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
28	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
29	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
30	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
31	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
32	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
33	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
34	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
37	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
38	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
39	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
40	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
41	NB	NB	NB	FS	NB	FS	NB	NB	NB	NB
42	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
43	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
44	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
45	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
46	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
47	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
48	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
49	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
50	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
51	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
52	FS	FS	FS	FS	FS	NB	NB	NB	NB	NB
53	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
54	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
55	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
56	FS	FS	FS	FS	NB	NB	NB	NB	NB	NB
57	FS	FS	FS	FS	FS	FS	FS	FS	FS	NB
58	FS	FS	FS	FS	FS	FS	FS	NB	NB	NB
59	NB	NB	NB	NB	NB	NB	NB	NB	NB	FS
60	FS	FS	FS	NB	NB	NB	FS	NB	NB	NB
61	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
62	FS	FS	FS	FS	FS	FS	NB	FS	FS	NB
63	FS	FS	NB	NB	FS	FS	FS	NB	NB	NB
64	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
65	FS	FS	FS	FS	FS	FS	FS	NB	NB	NB
66	FS	FS	FS	FS	FS	FS	FS	NB	NB	NB
67	FS	NB	NB	NB	NB	NB	NB	NB	NB	NB
68	FS	FS	FS	FS	FS	FS	NB	NB	NB	NB
69	FS	FS	FS	FS	FS	FS	FS	FS	FS	NB
70	FS	FS	FS	FS	FS	FS	NB	FS	FS	NB
71	FS	FS	FS	FS	FS	FS	FS	NB	NB	FS
72	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
73	FS	FS	NB	NB	NB	NB	NB	NB	FS	NB
74	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
75	FS	FS	NB	NB	NB	NB	NB	NB	NB	NB
76	NB	FS	NB	NB	NB	NB	NB	NB	NB	NB
77	FS	FS	FS	FS	FS	FS	FS	FS	NB	NB
78	FS	FS	FS	FS	NB	FS	NB	NB	NB	FS
79	FS	FS	FS	FS	FS	FS	FS	FS	FS	NB
80	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
81	FS	FS	FS	NB	NB	NB	NB	NB	NB	NB
82	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS

B.3. Placement of Filter Strips in Frog Alley Watershed for *TP* Load Reduction (*Scenario-I*, *Case-3*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
13	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
19	FS	*NB*	*NB*	*NB*	*NB*	FS	*NB*	*NB*	*NB*	*NB*
20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
23	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
24	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
25	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
26	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
27	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
28	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
29	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
30	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
31	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
32	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*
33	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*
34	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
37	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
38	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
39	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*
40	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
41	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	FS	FS	FS	FS
42	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
43	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
44	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
45	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
46	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*	FS
47	FS	FS	FS	FS	FS	FS	FS	FS	FS	*NB*
48	FS	FS	*NB*	*NB*	FS	*NB*	*NB*	*NB*	*NB*	*NB*
49	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
50	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
51	FS	FS	FS	FS	FS	*NB*	FS	*NB*	*NB*	*NB*
52	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
53	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	FS	FS	FS
54	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
55	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
56	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
57	FS	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*
58	FS	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*
59	*NB*	*NB*	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
60	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
61	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
62	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*
63	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
64	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
65	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*
66	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
67	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*
68	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
69	FS	FS	FS	FS	FS	FS	FS	FS	FS	*NB*
70	FS	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*
71	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
72	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
73	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
74	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
75	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
76	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
77	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*
78	FS	*NB*	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
79	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*
80	FS	FS	FS	*NB*	FS	FS	*NB*	*NB*	*NB*	*NB*
81	*NB*	*NB*	*NB*	FS	*NB*	*NB*	FS	*NB*	*NB*	*NB*
82	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS

B.4. Placement of Filter Strips in Frog Alley Watershed for Average Pollutant Load Reduction (*Scenario-I*, *Case-4*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
13	*NB*	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18	*NB*	*NB*	*NB*	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
19	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
23	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
24	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
25	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
26	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
27	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
28	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
29	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
30	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
31	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
32	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*
33	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*
34	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*
37	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
38	FS	FS	FS	FS	FS	FS	FS	FS	FS	*NB*
39	FS	FS	FS	*NB*	FS	*NB*	*NB*	*NB*	*NB*	*NB*
40	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
41	*NB*	*NB*	*NB*	FS	*NB*	FS	FS	*NB*	FS	*NB*
42	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*
43	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
44	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
45	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
46	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*
47	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*
48	FS	FS	*NB*	*NB*	*NB*	FS	*NB*	*NB*	*NB*	*NB*
49	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
50	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
51	FS	FS	FS	FS	FS	*NB*	*NB*	FS	*NB*	*NB*
52	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
53	FS	FS	*NB*	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
54	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
55	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
56	FS	*NB*	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
57	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
58	FS	FS	FS	FS	FS	FS	FS	FS	FS	*NB*
59	FS	FS	FS	*NB*	*NB*	FS	*NB*	*NB*	*NB*	*NB*
60	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
61	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
62	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
63	FS	FS	FS	FS	*NB*	FS	*NB*	FS	*NB*	FS
64	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
65	FS	FS	FS	FS	FS	FS	*NB*	FS	*NB*	FS
66	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	FS
67	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	FS	*NB*
68	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
69	FS	FS	FS	FS	FS	FS	FS	FS	FS	*NB*
70	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
71	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
72	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
73	FS	FS	FS	FS	FS	FS	FS	FS	FS	*NB*
74	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
75	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
76	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
77	FS	FS	FS	FS	FS	*NB*	*NB*	FS	*NB*	*NB*
78	FS	*NB*	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
79	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
80	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
81	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
82	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS

B.5. Placement of Grassed Waterways in Frog Alley Watershed for *TSS* Load Reduction (*Scenario-II*, *Case-1*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	GW	*NB*	GW	*NB*	*NB*	GW	GW	GW	*NB*	*NB*
13	GW	GW	GW	GW	GW	GW	GW	GW	*NB*	*NB*
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
19	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
23	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
24	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
25	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
26	*NB*	GW	*NB*	GW	GW	GW	GW	*NB*	GW	GW
27	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
28	GW	*NB*	*NB*	*NB*	GW	GW	GW	*NB*	GW	GW
29	GW	GW	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
30	GW	GW	*NB*	GW	*NB*	GW	GW	GW	GW	GW
31	GW	GW	GW	GW	GW	GW	GW	GW	*NB*	*NB*
32	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
33	GW	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
34	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36	GW	*NB*	GW	*NB*	*NB*	*NB*	*NB*	GW	*NB*	*NB*
37	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
38	GW	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
39	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
40	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
41	GW	GW	GW	GW	*NB*	*NB*	*NB*	GW	*NB*	*NB*
42	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
43	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
44	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
45	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
46	GW	GW	GW	GW	GW	GW	GW	*NB*	GW	GW
47	GW	GW	GW	GW	GW	GW	GW	*NB*	GW	GW
48	GW	GW	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
49	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
50	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
51	GW	*NB*	*NB*	*NB*	*NB*	GW	GW	*NB*	GW	GW
52	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
53	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
54	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
55	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
56	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
57	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
58	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
59	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
60	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
61	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
62	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW	*NB*	*NB*
63	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
64	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
65	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW	*NB*	*NB*
66	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
67	GW	GW	GW	GW	GW	GW	GW	*NB*	GW	*NB*
68	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
69	GW	GW	GW	GW	GW	*NB*	GW	*NB*	GW	*NB*
70	GW	GW	*NB*	*NB*	*NB*	GW	*NB*	GW	GW	*NB*
71	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
72	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
73	GW	GW	GW	*NB*	*NB*	*NB*	GW	GW	GW	GW
74	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
75	*NB*	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
76	GW	GW	GW	*NB*	*NB*	GW	*NB*	*NB*	GW	*NB*
77	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
78	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
79	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
80	GW	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*
81	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
82	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW

B.6. Placement of Grassed Waterways in Frog Alley Watershed for *TN* Load Reduction (*Scenario-II*, *Case-2*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW	*NB*	GW	GW
13	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
19	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
23	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
24	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
25	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
26	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
27	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
28	*NB*	*NB*	*NB*	*NB*	GW	GW	GW	GW	GW	GW
29	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
30	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
31	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
32	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
33	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
34	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
37	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
38	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	GW	*NB*	*NB*
39	GW	GW	GW	GW	GW	GW	GW	GW	GW	*NB*
40	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
41	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
42	GW	GW	GW	GW	GW	GW	GW	GW	*NB*	*NB*
43	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW
44	GW	GW	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*
45	GW	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*
46	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
47	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
48	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
49	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
50	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
51	*NB*	*NB*	GW	GW	*NB*	*NB*	*NB*	GW	GW	GW
52	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
53	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
54	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
55	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
56	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
57	GW	GW	*NB*	*NB*	*NB*	GW	*NB*	GW	GW	GW
58	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
59	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW	*NB*	*NB*	*NB*
60	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
61	GW	GW	GW	GW	GW	*NB*	GW	*NB*	*NB*	*NB*
62	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
63	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
64	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
65	GW	GW	GW	GW	GW	*NB*	GW	GW	GW	*NB*
66	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
67	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	GW	*NB*
68	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
69	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
70	*NB*	*NB*	*NB*	*NB*	GW	*NB*	*NB*	GW	*NB*	GW
71	GW	GW	GW	GW	GW	GW	GW	*NB*	GW	*NB*
72	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
73	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
74	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
75	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
76	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
77	GW	GW	GW	*NB*	GW	*NB*	*NB*	*NB*	*NB*	*NB*
78	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
79	GW	GW	GW	GW	GW	GW	*NB*	*NB*	GW	*NB*
80	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
81	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
82	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*

B.7. Placement of Grassed Waterways in Frog Alley Watershed for *TP* Load Reduction (*Scenario-II*, *Case-3*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
13	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
19	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
23	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
24	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
25	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
26	GW	GW	NB	NB	GW	GW	GW	GW	GW	NB
27	GW	GW	GW	GW	GW	GW	GW	NB	NB	NB
28	GW	GW	GW	NB	NB	GW	NB	NB	NB	NB
29	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
30	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
31	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
32	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
33	GW	GW	NB	NB	NB	NB	NB	NB	NB	NB
34	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36	GW	GW	NB	NB	NB	NB	NB	NB	NB	NB
37	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
38	GW	GW	NB	NB	NB	GW	NB	NB	NB	NB
39	GW	GW	GW	NB	NB	NB	NB	NB	NB	NB
40	GW	GW	GW	NB	NB	NB	NB	NB	NB	NB
41	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
42	GW	GW	GW	GW	GW	NB	NB	GW	NB	NB
43	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
44	GW	GW	GW	GW	GW	NB	NB	NB	NB	NB
45	GW	NB	NB	NB	NB	NB	NB	NB	NB	NB
46	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
47	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
48	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
49	GW	GW	GW	NB	NB	NB	NB	NB	NB	NB
50	GW	GW	GW	NB	NB	NB	NB	NB	NB	NB
51	NB	NB	NB	NB	NB	NB	GW	GW	GW	GW
52	GW	GW	GW	GW	NB	GW	NB	NB	NB	NB
53	GW	GW	NB	NB	NB	NB	NB	NB	NB	NB
54	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
55	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
56	GW	GW	GW	NB	NB	NB	NB	NB	NB	NB
57	NB	GW	GW	NB	NB	NB	NB	NB	NB	NB
58	GW	GW	GW	GW	NB	NB	NB	NB	NB	NB
59	GW	NB	NB	NB	NB	NB	NB	NB	NB	NB
60	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
61	GW	GW	GW	GW	NB	NB	NB	NB	NB	NB
62	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
63	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
64	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
65	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
66	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
67	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
68	GW	GW	GW	GW	GW	GW	NB	NB	GW	NB
69	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
70	GW	GW	NB	NB	GW	GW	GW	GW	GW	GW
71	GW	GW	NB	NB	NB	NB	NB	NB	NB	NB
72	GW	GW	NB	NB	NB	NB	NB	NB	NB	NB
73	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
74	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
75	GW	GW	GW	GW	NB	NB	NB	NB	GW	NB
76	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
77	GW	GW	GW	GW	NB	NB	NB	NB	NB	NB
78	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
79	NB	GW	NB	NB	NB	NB	NB	NB	GW	NB
80	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
81	NB	NB	GW	GW	NB	NB	NB	NB	NB	NB
82	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB

B.8. Placement of Grassed Waterways in Frog Alley Watershed for Average Pollutant Load Reduction (*Scenario-II*, *Case-4*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
13	GW	GW	GW	GW	GW	GW	GW	GW	GW	NB
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18	GW	GW	GW	GW	GW	GW	NB	NB	NB	NB
19	GW	GW	GW	NB	NB	NB	NB	NB	NB	NB
20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
23	GW	GW	GW	NB	NB	NB	NB	NB	NB	NB
24	NB	NB	NB	GW	GW	NB	NB	NB	NB	NB
25	GW	GW	NB	NB	NB	NB	NB	NB	NB	NB
26	GW	NB	GW	GW	GW	NB	NB	NB	NB	NB
27	GW	GW	GW	GW	NB	NB	NB	NB	NB	NB
28	NB	GW	GW	NB	NB	NB	NB	NB	NB	NB
29	GW	GW	GW	NB	NB	NB	NB	NB	NB	NB
30	GW	GW	GW	GW	GW	NB	NB	NB	NB	GW
31	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
32	GW	NB	NB	NB	NB	NB	NB	NB	NB	NB
33	GW	NB	NB	NB	NB	NB	NB	NB	NB	NB
34	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
37	GW	GW	GW	GW	GW	NB	NB	NB	NB	NB
38	NB	GW	GW	GW	GW	GW	GW	NB	NB	NB
39	NB	NB	NB	NB	NB	GW	GW	GW	GW	NB
40	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
41	GW	GW	GW	GW	GW	NB	NB	NB	NB	NB
42	GW	GW	GW	GW	NB	NB	NB	NB	NB	NB
43	GW	GW	GW	GW	GW	GW	GW	GW	GW	NB
44	GW	GW	GW	GW	NB	NB	NB	NB	NB	NB
45	GW	GW	GW	GW	NB	NB	NB	NB	NB	NB
46	GW	GW	GW	GW	GW	NB	NB	NB	NB	GW
47	GW	GW	GW	GW	GW	GW	GW	NB	NB	NB
48	GW	GW	GW	GW	NB	GW	GW	NB	NB	GW
49	NB	NB	GW	NB	NB	NB	NB	NB	NB	NB
50	GW	NB	NB	NB	NB	NB	NB	NB	NB	NB
51	NB	GW	GW	GW	GW	GW	GW	GW	GW	GW
52	GW	NB	GW	NB	NB	NB	NB	NB	NB	NB
53	GW	NB	NB	NB	NB	NB	NB	NB	NB	NB
54	GW	GW	GW	GW	NB	NB	NB	NB	NB	NB
55	GW	GW	GW	GW	NB	NB	NB	NB	NB	NB
56	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
57	NB	GW	GW	GW	NB	NB	NB	NB	NB	NB
58	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
59	GW	GW	GW	GW	GW	GW	GW	NB	NB	GW
60	GW	GW	GW	GW	GW	NB	NB	GW	GW	GW
61	GW	GW	NB	NB	NB	NB	NB	NB	NB	NB
62	NB	GW	NB	NB	NB	NB	NB	NB	NB	NB
63	GW	GW	GW	GW	GW	GW	NB	NB	NB	NB
64	GW	GW	NB	NB	NB	NB	NB	NB	NB	NB
65	GW	GW	NB	NB	NB	NB	NB	NB	NB	NB
66	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
67	GW	GW	GW	GW	GW	GW	GW	NB	NB	NB
68	GW	GW	NB	NB	NB	NB	NB	NB	NB	NB
69	GW	GW	GW	GW	GW	NB	GW	NB	NB	NB
70	GW	GW	GW	GW	GW	NB	NB	NB	NB	NB
71	GW	GW	NB	NB	NB	NB	NB	NB	NB	NB
72	GW	NB	NB	NB	GW	GW	NB	NB	NB	NB
73	GW	GW	GW	GW	GW	GW	GW	GW	NB	NB
74	NB	NB	NB	NB	NB	NB	NB	NB	GW	GW
75	GW	GW	GW	GW	NB	NB	NB	NB	NB	NB
76	GW	NB	GW	GW	NB	NB	NB	NB	GW	GW
77	GW	GW	GW	NB	NB	NB	NB	NB	NB	NB
78	NB	GW	NB	NB	NB	NB	NB	NB	NB	NB
79	GW	NB	NB	GW	NB	NB	NB	NB	GW	GW
80	GW	GW	GW	GW	GW	GW	GW	GW	NB	NB
81	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
82	GW	GW	GW	GW	GW	GW	GW	GW	GW	NB

B.9. Placement of Constructed Wetlands in Frog Alley Watershed for *TSS* Load Reduction (*Scenario-III*, *Case-1*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	CW	NB	NB	NB	NB	NB	NB	NB	NB	NB
13	CW	NB	NB	NB	NB	NB	NB	NB	NB	NB
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
19	CW	NB	NB	NB	NB	NB	NB	NB	NB	NB
20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
23	CW	CW	CW	NB	NB	NB	NB	NB	NB	NB
24	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
25	CW	CW	CW	NB	NB	NB	NB	NB	NB	NB
26	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
27	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
28	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
29	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
30	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
31	CW	CW	NB	CW	NB	CW	NB	NB	CW	CW
32	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
33	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
34	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
37	CW	CW	NB	CW	NB	NB	NB	NB	NB	NB
38	NB	CW	CW	CW	NB	NB	NB	NB	NB	NB
39	CW	CW	CW	NB	NB	NB	NB	NB	NB	NB
40	CW	NB	NB	CW	NB	NB	NB	NB	NB	NB
41	CW	CW	NB	NB	NB	NB	NB	NB	CW	NB
42	CW	CW	CW	CW	CW	CW	CW	CW	NB	NB
43	NB	NB	NB	NB	NB	NB	NB	NB	CW	CW
44	CW	CW	CW	CW	CW	CW	CW	CW	NB	NB
45	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
46	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
47	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
48	CW	CW	CW	CW	NB	CW	CW	CW	NB	CW
49	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
50	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
51	CW	CW	CW	NB	NB	NB	CW	CW	CW	NB
52	CW	CW	CW	NB	NB	NB	NB	NB	NB	NB
53	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
54	CW	CW	CW	NB	NB	NB	NB	NB	NB	NB
55	CW	CW	CW	CW	CW	CW	NB	NB	NB	NB
56	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
57	CW	CW	CW	NB	NB	NB	NB	NB	NB	NB
58	CW	CW	CW	CW	CW	CW	NB	NB	NB	NB
59	NB	NB	NB	NB	CW	NB	CW	CW	CW	NB
60	CW	CW	CW	CW	CW	CW	NB	NB	NB	NB
61	CW	CW	CW	CW	CW	CW	CW	NB	CW	NB
62	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
63	CW	CW	CW	CW	NB	NB	NB	NB	CW	NB
64	CW	CW	CW	CW	CW	CW	CW	NB	CW	NB
65	CW	CW	CW	CW	CW	CW	NB	NB	CW	NB
66	CW	CW	CW	NB	CW	NB	CW	NB	NB	CW
67	CW	NB	NB	CW	NB	NB	CW	NB	CW	CW
68	CW	CW	CW	CW	CW	CW	NB	NB	NB	NB
69	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
70	CW	CW	CW	CW	CW	NB	NB	CW	NB	NB
71	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
72	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
73	CW	NB	CW	CW	CW	NB	NB	NB	NB	NB
74	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
75	CW	NB	CW	NB	NB	NB	NB	NB	NB	NB
76	CW	CW	NB	CW	NB	NB	NB	NB	NB	NB
77	CW	NB	NB	NB	NB	NB	CW	NB	NB	NB
78	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
79	NB	CW	CW	CW	CW	NB	NB	NB	NB	NB
80	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
81	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
82	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW

B.10. Placement of Constructed Wetlands in Frog Alley Watershed for *TN* Load Reduction (*Scenario-III*, *Case-2*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	CW	CW	NB	CW	NB	NB	NB	NB	NB	NB
13	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18	CW	CW	CW	CW	CW	CW	NB	CW	NB	NB
19	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
23	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
24	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
25	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
26	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
27	CW	CW	CW	CW	CW	CW	NB	NB	NB	NB
28	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
29	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
30	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
31	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
32	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
33	CW	CW	CW	NB	NB	NB	NB	NB	NB	NB
34	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
37	NB	NB	CW	NB	NB	NB	NB	NB	NB	CW
38	CW	CW	NB	NB	NB	NB	NB	NB	NB	CW
39	CW	CW	CW	CW	CW	NB	NB	NB	CW	NB
40	CW	CW	CW	NB	NB	NB	NB	NB	NB	NB
41	CW	CW	CW	NB	NB	NB	NB	NB	NB	NB
42	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
43	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
44	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
45	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
46	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
47	CW	CW	CW	CW	CW	CW	NB	NB	NB	NB
48	CW	CW	CW	NB	NB	NB	NB	CW	CW	CW
49	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
50	CW	CW	CW	CW	CW	NB	CW	NB	NB	NB
51	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
52	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
53	CW	CW	CW	CW	CW	CW	NB	NB	NB	NB
54	CW	CW	CW	CW	NB	CW	NB	NB	NB	NB
55	CW	CW	CW	NB	NB	NB	NB	NB	NB	NB
56	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
57	CW	CW	CW	CW	CW	CW	CW	CW	NB	NB
58	CW	CW	CW	CW	CW	CW	CW	CW	NB	NB
59	NB	NB	CW	NB	NB	CW	NB	NB	NB	CW
60	NB	NB	NB	NB	NB	NB	CW	NB	NB	NB
61	CW	CW	CW	CW	CW	NB	CW	NB	NB	NB
62	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
63	CW	CW	CW	NB	CW	NB	NB	NB	NB	CW
64	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
65	CW	CW	CW	CW	CW	CW	CW	NB	NB	NB
66	NB	CW	CW	NB	NB	NB	NB	NB	CW	NB
67	NB	CW	CW	CW	CW	CW	CW	CW	CW	NB
68	CW	NB	NB	NB	NB	NB	NB	NB	NB	NB
69	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
70	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
71	CW	NB	CW	NB	NB	NB	NB	NB	NB	NB
72	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
73	NB	CW	CW	CW	CW	CW	CW	CW	CW	CW
74	CW	NB	NB	NB	NB	NB	NB	NB	NB	NB
75	CW	NB	NB	NB	NB	NB	NB	NB	NB	NB
76	CW	CW	CW	CW	CW	CW	CW	CW	NB	NB
77	CW	CW	CW	CW	CW	CW	CW	CW	CW	NB
78	CW	CW	CW	CW	CW	CW	NB	CW	NB	NB
79	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
80	CW	NB	NB	NB	NB	NB	NB	NB	NB	NB
81	CW	CW	NB	NB	CW	NB	CW	NB	CW	NB
82	CW	CW	CW	CW	CW	CW	CW	CW	CW	NB

B.11. Placement of Constructed Wetlands in Frog Alley Watershed for *TP* Load Reduction (*Scenario-III*, *Case-3*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
13	*NB*	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	CW	*NB*
19	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
23	*NB*	CW	*NB*	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
24	CW	*NB*	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
25	CW	*NB*	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
26	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
27	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
28	CW	CW	CW	CW	*NB*	CW	*NB*	*NB*	CW	*NB*
29	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
30	*NB*	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
31	CW	CW	CW	*NB*	CW	CW	CW	CW	CW	CW
32	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
33	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
34	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
37	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
38	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
39	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
40	CW	CW	*NB*	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
41	*NB*	*NB*	CW	*NB*	*NB*	CW	*NB*	*NB*	*NB*	*NB*
42	CW	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*
43	*NB*	*NB*	*NB*	*NB*	*NB*	CW	CW	CW	CW	CW
44	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
45	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
46	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
47	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
48	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
49	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
50	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
51	*NB*	*NB*	*NB*	*NB*	*NB*	CW	CW	CW	*NB*	CW
52	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
53	CW	CW	CW	CW	*NB*	*NB*	CW	*NB*	*NB*	*NB*
54	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
55	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
56	CW	CW	*NB*	CW	*NB*	*NB*	*NB*	*NB*	CW	*NB*
57	CW	CW	*NB*	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
58	CW	CW	CW	CW	CW	CW	*NB*	CW	*NB*	*NB*
59	CW	CW	*NB*	*NB*	CW	*NB*	*NB*	*NB*	*NB*	*NB*
60	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	CW
61	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
62	CW	CW	*NB*	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
63	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
64	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
65	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
66	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
67	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
68	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*
69	CW	CW	CW	CW	CW	CW	CW	CW	CW	*NB*
70	CW	CW	CW	CW	*NB*	CW	CW	CW	*NB*	CW
71	CW	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	*NB*
72	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*	CW	*NB*
73	CW	CW	CW	CW	CW	*NB*	CW	CW	*NB*	*NB*
74	CW	CW	CW	CW	CW	*NB*	CW	CW	*NB*	*NB*
75	CW	CW	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*
76	CW	CW	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*
77	CW	CW	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*
78	CW	CW	CW	CW	CW	CW	CW	*NB*	*NB*	CW
79	CW	CW	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*
80	CW	CW	CW	CW	CW	CW	CW	*NB*	*NB*	*NB*
81	CW	*NB*	*NB*	CW	*NB*	*NB*	*NB*	*NB*	*NB*	CW
82	CW	CW	CW	CW	CW	CW	CW	CW	CW	*NB*

B.12. Placement of Constructed Wetlands in Frog Alley Watershed for Average Pollutant Load Reduction (*Scenario-III*, *Case-4*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
13	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
19	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
23	CW	NB	NB	NB	NB	NB	NB	NB	NB	NB
24	CW	CW	CW	NB	NB	NB	NB	NB	NB	NB
25	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
26	NB	NB	NB	NB	NB	CW	CW	CW	NB	NB
27	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
28	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
29	CW	NB	CW	CW	NB	NB	NB	NB	NB	NB
30	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
31	NB	NB	NB	NB	NB	CW	CW	CW	CW	CW
32	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
33	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
34	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
37	CW	CW	NB	NB	NB	CW	CW	CW	CW	CW
38	NB	NB	CW	CW	NB	NB	NB	NB	NB	NB
39	CW	CW	CW	CW	NB	CW	NB	NB	NB	NB
40	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
41	CW	CW	NB	NB	CW	CW	NB	NB	NB	NB
42	CW	CW	CW	CW	CW	CW	NB	NB	NB	NB
43	CW	CW	CW	CW	NB	CW	CW	CW	CW	CW
44	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
45	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
46	CW	NB	CW	NB	NB	NB	NB	NB	NB	NB
47	CW	CW	CW	CW	CW	CW	CW	CW	NB	NB
48	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
49	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
50	CW	CW	CW	NB	NB	NB	NB	NB	NB	NB
51	CW	NB	NB	NB	NB	NB	NB	NB	NB	NB
52	CW	CW	CW	NB	NB	NB	NB	NB	NB	NB
53	CW	CW	CW	NB	NB	NB	NB	NB	NB	NB
54	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
55	CW	CW	NB	NB	NB	NB	NB	NB	NB	NB
56	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
57	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
58	CW	CW	CW	CW	CW	CW	CW	CW	NB	NB
59	NB	NB	NB	NB	CW	CW	CW	CW	NB	NB
60	CW	CW	CW	CW	NB	NB	NB	CW	NB	CW
61	CW	CW	CW	CW	CW	CW	CW	NB	NB	NB
62	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
63	NB	NB	NB	NB	NB	NB	NB	NB	CW	CW
64	CW	CW	CW	CW	CW	NB	NB	CW	NB	NB
65	CW	CW	CW	CW	CW	CW	CW	CW	CW	NB
66	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
67	NB	CW	CW	CW	CW	CW	CW	NB	CW	CW
68	CW	CW	CW	CW	NB	NB	CW	NB	NB	NB
69	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
70	NB	NB	CW	NB	NB	NB	NB	NB	NB	NB
71	CW	CW	NB	CW	NB	NB	NB	NB	NB	NB
72	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
73	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
74	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
75	CW	CW	CW	CW	CW	CW	NB	NB	NB	NB
76	CW	CW	CW	CW	NB	NB	CW	NB	NB	NB
77	CW	CW	CW	CW	CW	CW	CW	NB	CW	NB
78	CW	CW	CW	CW	CW	CW	NB	CW	CW	NB
79	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW
80	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
81	NB	NB	NB	NB	NB	NB	NB	NB	CW	CW
82	CW	CW	CW	CW	CW	CW	CW	CW	CW	CW

B.13. Placement of Filter Strips, Grassed Waterways, and Constructed Wetlands in Frog Alley Watershed for *TSS* Load Reduction (*Scenario-IV*, *Case-1*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	FS	FS	FS	FS	*NB*	*NB*	FS	*NB*	*NB*	*NB*
13	GW	GW	GW	GW	GW	GW	GW	GW	*NB*	*NB*
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
19	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
23	GW	GW	GW	GW	*NB*	*NB*	FS	FS	FS	FS
24	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
25	GW	GW	GW	GW	*NB*	FS	*NB*	*NB*	*NB*	*NB*
26	GW	GW	GW	GW	FS	FS	FS	FS	FS	FS
27	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
28	FS	FS	*NB*	*NB*	FS	FS	FS	FS	*NB*	FS
29	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
30	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
31	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
32	FS	FS	GW	FS	FS	FS	FS	FS	FS	FS
33	FS	FS	GW	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
34	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36	FS	FS	GW	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
37	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
38	*NB*	*NB*	GW	*NB*	FS	FS	FS	FS	FS	FS
39	GW	GW	GW	*NB*	*NB*	*NB*	GW	GW	GW	GW
40	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
41	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
42	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
43	GW	GW	GW	GW	GW	CW	FS	GW	FS	FS
44	CW	CW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
45	GW	GW	GW	GW	FS	*NB*	*NB*	FS	*NB*	*NB*
46	GW	GW	GW	FS	FS	FS	FS	FS	FS	FS
47	GW	GW	FS	GW	FS	*NB*	*NB*	*NB*	*NB*	*NB*
48	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
49	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
50	GW	GW	FS	*NB*	FS	*NB*	*NB*	*NB*	FS	FS
51	*NB*	*NB*	*NB*	GW	GW	GW	GW	GW	GW	GW
52	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
53	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	FS	*NB*	*NB*
54	GW	GW	GW	GW	GW	*NB*	*NB*	GW	*NB*	*NB*
55	GW	GW	GW	GW	GW	GW	*NB*	*NB*	GW	GW
56	*NB*	*NB*	FS	*NB*	*NB*	FS	*NB*	FS	FS	FS
57	GW	GW	FS	GW	GW	GW	FS	FS	GW	GW
58	CW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
59	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
60	GW	GW	GW	GW	GW	GW	*NB*	*NB*	GW	GW
61	*NB*	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
62	*NB*	*NB*	*NB*	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
63	GW	GW	GW	FS	FS	GW	GW	GW	FS	FS
64	GW	GW	GW	*NB*	*NB*	*NB*	FS	*NB*	*NB*	*NB*
65	*NB*	*NB*	*NB*	*NB*	*NB*	FS	*NB*	FS	*NB*	*NB*
66	GW	GW	GW	FS	FS	*NB*	GW	*NB*	*NB*	FS
67	GW	GW	GW	GW	GW	GW	GW	*NB*	CW	GW
68	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
69	GW	GW	GW	GW	GW	GW	*NB*	*NB*	GW	*NB*
70	FS	FS	FS	FS	*NB*	FS	*NB*	*NB*	FS	FS
71	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
72	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	FS	FS	*NB*	FS
73	GW	GW	GW	GW	GW	GW	*NB*	*NB*	GW	*NB*
74	*NB*	*NB*	*NB*	GW	GW	*NB*	GW	GW	GW	GW
75	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
76	GW	GW	*NB*	FS	*NB*	*NB*	*NB*	FS	FS	FS
77	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
78	*NB*	*NB*	*NB*	FS	*NB*	*NB*	*NB*	*NB*	FS	*NB*
79	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
80	GW	GW	GW	GW	GW	GW	GW	FS	*NB*	FS
81	GW	GW	GW	GW	GW	GW	GW	GW	GW	FS
82	GW	GW	GW	GW	GW	*NB*	GW	GW	GW	FS

B.14. Placement of Filter Strips, Grassed Waterways, and Constructed Wetlands in Frog Alley Watershed for *TN* Load Reduction (*Scenario-IV*, *Case-2*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	CW	NB	NB	NB	NB	GW	NB	NB	NB	NB
13	CW	NB	CW	NB	NB	NB	CW	NB	NB	NB
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18	CW	GW	CW	CW	CW	NB	NB	CW	NB	NB
19	CW	CW	CW	NB	FS	NB	NB	FS	NB	NB
20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
23	CW	NB	NB	NB	NB	NB	NB	NB	NB	NB
24	NB	CW	CW	NB	NB	NB	NB	NB	NB	NB
25	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
26	NB	GW	NB	GW	GW	FS	GW	GW	GW	GW
27	CW	CW	CW	CW	CW	NB	NB	NB	NB	NB
28	NB	FS	NB	FS	FS	GW	GW	GW	GW	GW
29	CW	CW	CW	CW	CW	FS	NB	FS	FS	FS
30	CW	CW	GW	FS	FS	GW	GW	GW	GW	GW
31	NB	NB	NB	NB	FS	FS	FS	FS	FS	FS
32	CW	CW	CW	CW	NB	NB	NB	NB	NB	NB
33	CW	GW	CW	GW	NB	NB	NB	NB	NB	NB
34	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36	CW	CW	GW	FS	GW	GW	GW	GW	GW	GW
37	CW	CW	NB	FS	NB	FS	FS	FS	FS	NB
38	NB	GW	NB	FS	FS	FS	FS	FS	FS	FS
39	CW	CW	GW	GW	GW	GW	GW	GW	GW	NB
40	CW	GW	GW	GW	NB	NB	NB	NB	NB	NB
41	GW	CW	NB	FS	FS	NB	FS	FS	FS	FS
42	CW	CW	CW	GW	GW	GW	NB	GW	GW	NB
43	FS	FS	FS	GW	FS	FS	GW	FS	FS	GW
44	GW	GW	GW	FS	NB	NB	FS	NB	NB	FS
45	CW	CW	CW	CW	NB	NB	FS	NB	NB	FS
46	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
47	CW	CW	CW	CW	CW	CW	NB	CW	CW	FS
48	GW	NB	CW	CW	GW	GW	FS	GW	CW	FS
49	CW	CW	FS	FS	NB	NB	GW	NB	FS	NB
50	CW	CW	CW	CW	CW	FS	GW	FS	GW	NB
51	FS	FS	FS	FS	FS	FS	NB	FS	CW	GW
52	CW	CW	CW	CW	NB	GW	GW	GW	GW	GW
53	CW	CW	CW	CW	GW	FS	NB	FS	NB	NB
54	CW	CW	CW	CW	NB	FS	NB	FS	NB	NB
55	NB	NB	NB	NB	NB	NB	FS	NB	FS	FS
56	NB	FS	FS	FS	NB	FS	GW	NB	GW	GW
57	CW	CW	NB	NB	NB	FS	FS	NB	GW	GW
58	CW	CW	CW	CW	CW	CW	CW	NB	FS	FS
59	CW	CW	FS	NB	FS	NB	NB	FS	CW	CW
60	GW	GW	NB	CW	CW	CW	CW	GW	GW	GW
61	GW	GW	NB	GW	GW	GW	GW	GW	GW	GW
62	CW	CW	CW	NB	CW	GW	NB	NB	NB	NB
63	CW	CW	NB	FS	NB	NB	FS	CW	FS	FS
64	CW	CW	NB	CW	NB	NB	NB	NB	GW	GW
65	CW	CW	CW	CW	CW	CW	CW	CW	FS	FS
66	GW	GW	FS	CW	FS	FS	FS	FS	GW	GW
67	GW	GW	CW	CW	CW	CW	CW	CW	GW	GW
68	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
69	CW	CW	CW	CW	CW	CW	NB	CW	NB	NB
70	NB	NB	CW	NB	NB	NB	FS	NB	FS	FS
71	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
72	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
73	CW	CW	CW	CW	CW	CW	NB	NB	NB	NB
74	CW	GW	GW	GW	GW	GW	FS	FS	FS	FS
75	GW	GW	GW	GW	GW	GW	NB	GW	NB	FS
76	CW	CW	CW	CW	CW	CW	FS	NB	NB	NB
77	CW	CW	CW	CW	CW	CW	CW	FS	FS	NB
78	CW	CW	CW	CW	CW	CW	CW	CW	FS	FS
79	CW	CW	CW	CW	CW	CW	CW	CW	FS	GW
80	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
81	FS	FS	FS	FS	FS	FS	FS	FS	FS	NB
82	CW	GW	CW	CW	GW	CW	GW	CW	GW	GW

B.15. Placement of Filter Strips, Grassed Waterways, and Constructed Wetlands in Frog Alley Watershed for *TP* Load Reduction (*Scenario-IV*, *Case-3*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
13	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18	FS	*NB*	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
19	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
23	FS	*NB*	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	FS
24	FS	*NB*	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
25	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*
26	GW	FS	GW	GW	FS	GW	GW	GW	GW	GW
27	FS	FS	FS	FS	FS	FS	FS	FS	FS	*NB*
28	FS	FS	FS	FS	FS	FS	FS	FS	FS	GW
29	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
30	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
31	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
32	FS	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*
33	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
34	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*
37	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
38	FS	FS	FS	FS	FS	FS	FS	GW	GW	GW
39	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
40	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
41	FS	FS	*NB*	FS	FS	FS	FS	FS	FS	FS
42	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*
43	GW	GW	GW	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
44	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
45	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
46	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
47	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
48	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
49	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
50	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
51	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
52	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
53	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
54	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
55	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
56	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
57	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
58	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*
59	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
60	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
61	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
62	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
63	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*
64	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
65	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
66	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
67	GW	GW	CW	CW	CW	FS	FS	FS	FS	FS
68	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
69	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
70	FS	FS	FS	FS	FS	GW	GW	GW	GW	GW
71	FS	FS	FS	FS	FS	*NB*	FS	FS	FS	FS
72	FS	FS	FS	FS	*NB*	FS	*NB*	*NB*	*NB*	*NB*
73	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
74	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
75	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
76	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
77	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
78	FS	FS	FS	FS	FS	FS	*NB*	FS	FS	FS
79	CW	CW	GW	GW	*NB*	FS	*NB*	*NB*	*NB*	*NB*
80	FS	FS	FS	FS	FS	*NB*	FS	FS	FS	FS
81	CW	FS	CW	CW	FS	*NB*	FS	FS	FS	FS
82	FS	FS	FS	FS	*NB*	FS	FS	FS	FS	FS

B.16. Placement of Filter Strips, Grassed Waterways, and Constructed Wetlands in Frog Alley Watershed for Average Pollutant Load Reduction (*Scenario-IV*, *Case-4*)

Subbasin	Alternative Solutions									
No	1	2	3	4	5	6	7	8	9	10
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
13	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
19	CW	GW	GW	GW	GW	GW	GW	*NB*	*NB*	GW
20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
23	GW	GW	GW	GW	GW	GW	GW	FS	FS	FS
24	FS	FS	FS	FS	FS	FS	FS	GW	GW	GW
25	CW	CW	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*
26	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
27	CW	CW	CW	CW	FS	FS	FS	FS	FS	FS
28	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*	*NB*
29	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
30	FS	FS	CW	FS	GW	GW	GW	FS	FS	*NB*
31	GW	GW	GW	GW	GW	GW	GW	FS	FS	*NB*
32	CW	CW	FS	FS	FS	FS	FS	FS	FS	*NB*
33	CW	FS	FS	FS	FS	FS	FS	FS	FS	*NB*
34	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36	FS	FS	FS	FS	FS	FS	FS	*NB*	*NB*	GW
37	GW	GW	GW	GW	GW	GW	GW	FS	FS	FS
38	CW	FS	CW	FS	FS	FS	FS	FS	FS	FS
39	CW	CW	FS	FS	FS	FS	FS	FS	FS	FS
40	CW	CW	FS	FS	FS	FS	FS	FS	FS	FS
41	GW	GW	CW	FS	FS	FS	FS	FS	FS	FS
42	CW	CW	FS	FS	FS	FS	FS	FS	FS	FS
43	GW	GW	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*
44	CW	CW	CW	FS	FS	FS	FS	FS	FS	FS
45	CW	CW	CW	FS	FS	FS	*NB*	*NB*	*NB*	*NB*
46	CW	GW	GW	GW	GW	GW	FS	*NB*	*NB*	*NB*
47	CW	CW	CW	CW	FS	FS	FS	FS	FS	FS
48	CW	GW	GW	GW	GW	GW	*NB*	GW	GW	FS
49	CW	FS	FS	FS	FS	FS	FS	GW	GW	GW
50	CW	CW	CW	FS	FS	FS	FS	FS	FS	FS
51	CW	CW	CW	FS	FS	FS	FS	FS	FS	*NB*
52	CW	CW	CW	CW	FS	FS	FS	GW	GW	GW
53	CW	CW	CW	CW	FS	FS	FS	*NB*	*NB*	*NB*
54	CW	CW	CW	CW	FS	FS	FS	GW	GW	GW
55	GW	GW	GW	GW	FS	FS	*NB*	*NB*	*NB*	*NB*
56	FS	FS	FS	FS	FS	FS	GW	GW	GW	GW
57	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
58	CW	CW	CW	CW	CW	FS	FS	FS	FS	FS
59	GW	GW	GW	GW	GW	CW	GW	GW	GW	GW
60	GW	GW	GW	GW	GW	GW	*NB*	*NB*	*NB*	*NB*
61	CW	CW	FS	CW	FS	GW	*NB*	GW	GW	GW
62	CW	CW	CW	CW	FS	*NB*	*NB*	*NB*	*NB*	*NB*
63	CW	CW	CW	CW	GW	GW	*NB*	*NB*	*NB*	*NB*
64	CW	CW	CW	CW	GW	*NB*	*NB*	*NB*	*NB*	*NB*
65	CW	CW	CW	CW	CW	*NB*	GW	*NB*	*NB*	*NB*
66	FS	FS	FS	FS	FS	GW	FS	FS	FS	FS
67	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
68	CW	FS	CW	FS	FS	FS	FS	FS	FS	FS
69	CW	CW	CW	CW	CW	FS	FS	FS	FS	FS
70	CW	CW	CW	GW	CW	*NB*	GW	GW	GW	GW
71	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
72	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
73	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
74	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
75	FS	FS	FS	FS	FS	FS	FS	FS	FS	FS
76	FS	FS	FS	FS	FS	*NB*	*NB*	*NB*	*NB*	*NB*
77	CW	CW	CW	CW	CW	FS	FS	FS	FS	GW
78	FS	FS	FS	CW	FS	FS	FS	FS	FS	GW
79	CW	CW	CW	CW	CW	FS	GW	FS	FS	*NB*
80	GW	GW	GW	GW	GW	GW	GW	GW	GW	*NB*
81	GW	GW	GW	GW	GW	GW	GW	GW	GW	*NB*
82	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW