



***PRedICT***

**VERSION 7.1**

## **USERS GUIDE**

*for the*

*Pollutant Reduction Impact Comparison Tool*

***Barry M. Evans, David W. Lehning,  
and Kenneth J. Corradini***

Penn State Institutes of Energy and the Environment  
The Pennsylvania State University  
University Park, PA 16802

**June 2003**  
***(Revised February 2008)***

## Table of Contents

	<b>Page</b>
1.0 <a href="#">INTRODUCTION</a> .....	1
2.0 <a href="#">AGRICULTURAL BMPs</a> .....	2
2.1 <a href="#">Types of Individual BMPs</a> .....	3
2.2 <a href="#">Agricultural BMP Options in PRedICT</a> .....	8
2.3 <a href="#">Pollutant Reduction Efficiencies</a> .....	9
2.4 <a href="#">Per Unit Implementation Costs</a> .....	10
3.0 <a href="#">FARM ANIMAL-RELATED BMPs</a> .....	11
4.0 <a href="#">STREAM-RELATED ACTIVITIES</a> .....	13
4.1 <a href="#">Types of Stream-Related Activities</a> .....	13
4.2 <a href="#">Stream-Related Options in PRedICT</a> .....	15
5.0 <a href="#">URBAN BMPs</a> .....	17
5.1 <a href="#">Urban BMP Options</a> .....	17
5.2 <a href="#">Pollutant Reduction Efficiencies</a> .....	20
5.3 <a href="#">Per Unit Implementation Costs</a> .....	20
6.0 <a href="#">WASTEWATER DISCHARGE REDUCTION OPTIONS</a> .....	21
6.1 <a href="#">Pollutant Reduction Efficiencies</a> .....	21
6.2 <a href="#">Per Unit Implementation Costs</a> .....	21
7.0 <a href="#">PATHOGEN REDUCTIONS FROM BMPs</a> .....	22
8.0 <a href="#">LOAD REDUCTION AND COST CALCULATION ALGORITHMS</a> .....	23
8.1 <a href="#">Agricultural Load Reductions</a> .....	23
8.2 <a href="#">Farm Animal Load Reductions</a> .....	24
8.3 <a href="#">Streambank Load Reductions</a> .....	25
8.4 <a href="#">Groundwater Load Adjustments</a> .....	25
8.5 <a href="#">Urban Area Load Reductions</a> .....	26
8.6 <a href="#">Wastewater Load Reductions</a> .....	27
8.7 <a href="#">Agricultural BMP Cost Calculations</a> .....	31
8.8 <a href="#">Farm Animal-Related Cost Calculations</a> .....	32
8.9 <a href="#">Stream Activity Cost Calculations</a> .....	32
8.10 <a href="#">Urban BMP Cost Calculations</a> .....	33
8.11 <a href="#">Wastewater Cost Calculations</a> .....	33
9.0 <a href="#">OPTIMIZATION PROCEDURE</a> .....	34
10.0 <a href="#">STEP-BY-STEP INSTRUCTIONS FOR USING PRedICT</a> .....	35
10.1 <a href="#">Installing and Executing PRedICT</a> .....	35
10.2 <a href="#">Creating an Initial Scenario</a> .....	35
10.3 <a href="#">Mean Annual Load Data Editor</a> .....	37
10.4 <a href="#">Rural Land BMP Scenario Editor</a> .....	37
10.5 <a href="#">Urban Land BMP Scenario Editor</a> .....	39
10.6 <a href="#">Septic System and Point Source Discharge Scenario Editor</a> .....	41
10.7 <a href="#">Rural and Urban BMP Load Reduction Efficiency Editor</a> .....	43
10.8 <a href="#">Wastewater Discharge Load Reduction Efficiency Editor</a> .....	44
10.9 <a href="#">BMP Cost Editor</a> .....	45
10.10 <a href="#">Executing a Scenario Run</a> .....	45
10.11 <a href="#">PRedICT Output</a> .....	46
11.0 <a href="#">PRedICT JPEG EXPORT FILE NAME LIST</a> .....	48
12.0 <a href="#">UPDATING PRedICT</a> .....	48
13.0 <a href="#">REPORTING A PRedICT BUG</a> .....	48
14.0 <a href="#">CONTACT INFORMATION</a> .....	49
15.0 <a href="#">REFERENCES</a> .....	50

## 1.0 INTRODUCTION

The Pollution Reduction Impact Comparison Tool (*PRedICT*) software application was developed for use in evaluating the implementation of both rural and urban pollution reduction strategies at the watershed level. This tool allows the user to create various “scenarios” in which current landscape conditions and pollutant loads (both point and non-point) can be compared against “future” conditions that reflect the use of different pollution reduction strategies such as agricultural and urban best management practices (BMPs), stream protection activities, the conversion of septic systems to centralized wastewater treatment, and upgrading of treatment plants from primary to secondary to tertiary. It includes pollutant reduction coefficients for nitrogen, phosphorus, and sediment (*and now pathogens with this newest version*), and also has built-in cost information for an assortment of pollution mitigation techniques. A rather simple cost-accounting approach is used to estimate load reductions and their associated costs. The user initially specifies desired conditions such as the number of acres of agricultural BMPs to be used, the number of septic systems to be converted to centralized wastewater treatment, miles of riparian buffers, percentage of urban areas to be treated by wetlands and detention basins, etc. Based on this information, built-in reduction coefficients and unit costs are utilized to calculate resultant pollutant load reductions and scenario costs.

While information for *PRedICT* can be compiled manually, the most efficient way to accomplish this task is to use the *AVGWLF* watershed modeling system (Evans, 2002; and Evans et al., 2001). Among others things, this tool automatically creates a “scenario” file that can be used as input to *PRedICT*. This input file contains information on watershed conditions and pollutant loads that can serve as the “initial” conditions from which future scenarios can be developed. While information on nutrient and sediment loads, as well as the presence of existing BMPs, can be developed and brought in via the use of *AVGWLF*, full editing capabilities are provided within *PRedICT* to allow for revised data input based on the user’s local knowledge of the watershed being considered.

*PRedICT* was primarily developed using Visual Basic programming software. It is comprised of the following basic components:

- **Input Screens.** These screens (Visual Basic forms) are used to specify data sets and parameter values used in subsequent load and cost calculations.
- **Scenario Files.** These text files with “.scn” extensions are used to import data from an *AVGWLF* model run (if they exist) and to store output from *PRedICT* model runs.
- **Load and Cost Algorithms.** These compiled Visual Basic routines are imbedded in *PRedICT*, and are used to make the load reduction and cost calculations.

Within *PRedICT*, a number of pollution reduction options are provided. An overview of the basis for the load reduction coefficients and unit reduction costs used are described in the following sections. Also included in a later section are discussions of the load and cost calculations employed in *PRedICT*.

## 2.0 AGRICULTURAL BMPs

Broadly speaking, Best Management Practices (BMPs) are structural and non-structural approaches used to reduce pollutant loads in watersheds draining both urban and rural areas. While there is no universally accepted definition of BMPs, the Soil and Water Conservation Society (SWCS) defines a BMP as “a practice or combination of practices that are determined by a state or designated area-wide planning agency to be the most effective and practicable (including technological, economic, and institutional considerations) means of controlling point and non-point source pollutants at levels compatible with environmental quality goals.” Alternatively, Novotny and Olem (1994) state that, “BMPs are methods and practices for preventing or reducing non-point source pollution to a level compatible with water quality goals.” When referring to rural areas, such BMPs are often called *conservation practices* or *agricultural* and *silvicultural* BMPs.

When considering options for BMP implementation, it is often useful to know how effective such BMPs might be in terms of reducing various types of pollutants such as sediment, nitrogen, and phosphorus. There is a very wide range of BMPs that could potentially be employed, as well as a wide range of associated costs and inherent pollutant reduction efficiencies. At the farm scale, it is critical that the most cost-effective BMP be implemented to address the pollutant(s) of concern at specific geographic locations given the marginal economies of this industry. Conversely, when addressing general water quality concerns within a watershed, it is not as important to identify specific BMPs for implementation at exact locations (at least at the planning stage). However, it is very useful to have a good sense of whether or not general types of BMPs would be potentially beneficial in reducing pollutant loads within a watershed in which non-point source pollutants are of primary concern.

### 2.1 Types of Individual BMPs

For the purposes of this document, agricultural BMPs can be aggregated into the following generic types: 1) Crop Residue Management, 2) Vegetated Buffers, 3) Crop Rotation, 4) Cover Crops, 5) Contour Farming/Strip-cropping, 6) Terraces and Diversions, 7) Grazing Land Management, 8) Streambank Protection, and 9) Nutrient Management. Most of the more commonly used non-structural BMPs recognized by the USDA fall into one or more of these categories. Many structural BMPs (e.g., *sediment detention ponds* and *manure storage facilities*) and the more “esoteric” non-structural practices such as *integrated pest management* and *critical area planting* are not addressed since these BMPs are either generally less well-defined, are not discussed in the literature much with respect to pollution reduction efficiencies, and/or are difficult to describe in terms of their effectiveness in reducing pollutant loads at the watershed level. The generic types discussed, however, are useful in trying to answer questions such as “How might water quality in a watershed be affected if a given BMP is implemented on so many stream miles or so many acres?” It is within this context that *PREDICT* and the accompanying documentation have been prepared.

#### Conservation Tillage

Conservation tillage refers to the planned use of crop residue to protect the soil surface. This is one of the most commonly-used BMPs, and includes the use of residue from corn or soybean stalks, small grain straw, or the residue from vegetables and other crops. There are many forms of this management practice including no-till planting,

mulch tillage, and other tillage techniques that leave crop residue on the soil surface as shown in Figure 1. In general, conservation tillage is defined as any production system that leaves at least 30% of the soil surface covered with crop residue after planting to reduce soil erosion by water (Ritter and Shirmohammadi, 2001). Figure 2 shows an example of no-till planting of vegetables into a cover crop.

Other examples of crop residue management include strip tillage, ridge tillage, slit tillage, and seasonal residue management (Ritter and Shirmohammadi, 2001). Strip, ridge, and slit tillage refer to various methods used to till the field along the rows while minimizing the disturbance of crop residue between the rows. With seasonal residue management, the residue is left on the field during the period between harvest and planting. Immediately before planting, most of the residue is then tilled over.



Figure 1. Crop residue left at the soil surface.



Figure 2. No-till planting of vegetables into a cover crop.

## Cover Crops

This BMP refers to the use of annual or perennial crops (see Figure 3) to protect the soil from erosion during the time period between the harvesting and planting of the primary crop. The use of such crops can also improve soil health and offer the opportunity for additional income (as with the planting of winter wheat). Additionally, cover crops can store needed nutrients over the winter, prevent their loss, and act as a type of “green” manure in the spring if the cover crop is left in the field or plowed under before planting the primary crop.



Figure 3. Use of red clover as a cover crop.

## Crop Rotations

This particular conservation practice (often called *conservation crop rotation*) is defined as the use of different crops in a specified sequence on the same farm field, and is a typical BMP used on cropland in Pennsylvania. Crop rotations may be as simple as a 2-year rotation of corn and soybeans or an 8-year rotation of 4 years of silage corn and 4 years of hay. It could also be a more complex scheme involving a mixture of crops such as corn, small grain, soybeans and forages spread over 6-8 years or more.

Although this BMP can be used for several reasons, crop rotations are primarily employed to reduce soil erosion, thereby reducing the quantities of sediment and sediment-bound pollutants such as nitrogen, phosphorus, and pesticides. When addressing excess nutrients on agricultural land, cover crops (as discussed in the previous section) are often included in the rotation sequence. Similarly, crop rotations are often combined with other BMPs. For example, plants that produce large amounts of residue may be selected for a crop rotation in an area where conservation tillage is to be used.

## Contour Farming/Strip-cropping

Contour farming refers to the practice of conducting tillage, planting and harvesting operations perpendicular to the gradient of a hill or slope in order to reduce erosion (see

Figure 4). This practice is usually most effective on moderate slopes of 3-8% when there are measurable ridges left from tillage and/or planting operations (see Figure 5) that serve as miniature terraces, retarding runoff and increasing infiltration. Contour farming is often more effective where some form of tillage is employed, and is typically used on moderate slopes when land is intensively cultivated. This practice is also most effective on shorter slopes or on longer slopes with cropland terraces.



Figure 4. Example of contour farming.



Figure 5. Ridge effect from contour farming.

Contour strip-cropping refers to the system of placing crops in strips or bands on or near the contour as shown in Figure 6. The strips are usually in even widths of 90 to 120 feet, although uneven widths may be required in areas with rolling or irregular topography. Historically, this practice has been defined as the use of alternating strips of

row crops with strips of either small grain or hay. Nowadays, though, strips with high levels of plant residue (> 50%) are often used instead.



Figure 6. Strip-cropping.

### Terraces and Diversions

*Terraces* and *diversions* are essentially earthen channels that intercept runoff on sloping land parcels. These structures act to transform long slopes into a series of shorter ones, thereby reducing runoff velocities and allowing soil particles to settle out. *Terraces* are cross-slope channels that control erosion on cropland, and are usually constructed to permit crops to be grown on the terrace (see Figure 7). They are designed to handle areas of concentrated flow where ephemeral gullies might otherwise form. *Diversions* are also cross-slope channels; however, unlike *terraces*, they are permanently vegetated. These structures are often used on slopes where a terrace would be too expensive or difficult to build, maintain, or grow crops on. *Diversions* may also be used on adjacent non-cultivated land to prevent unwanted surface runoff from flowing across a farmstead or barnyard.



Figure 7. Aerial view of terracing.



Similar to many other BMPs, *terraces* and *diversions* are usually most effective when used in combination with other conservation practices such as *crop residue management*, *contour farming*, *crop rotation*, and the use of *field borders*.

### Grazing Land Management

*Grazing land management* refers to the utilization of practices that ensure adequate vegetation cover in order to prevent excessive soil erosion due to over-grazing and other forms of overuse. It is becoming more common for farmers to reduce feeding costs by establishing *rotational grazing systems* on improved pastureland or by planting hay or legumes to use as feed for their livestock. In addition to providing feed for livestock, establishing grasses and legumes as part of crop rotations also protects land areas from excessive soil erosion and adds needed nitrogen to the soil base.

One form of *rotational grazing* used in dairy production systems is referred to as *intensive rotational grazing*. In this approach, cows are periodically moved among fenced pastures or paddocks (see Figure 8). This practice prevents the overuse of any feeding area and allows forages to recover between periods of intensive feeding.

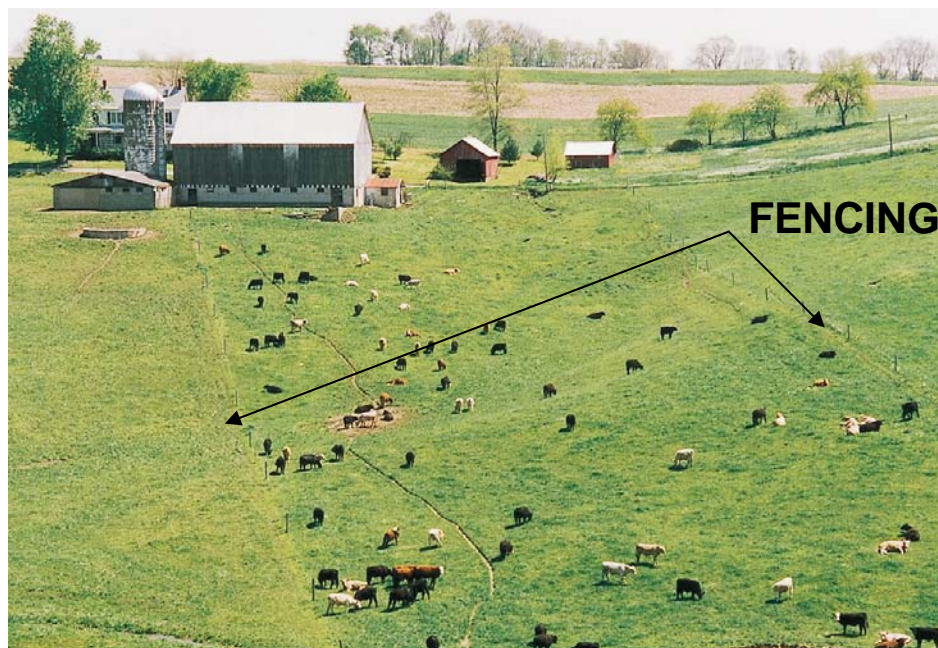


Figure 8. Use of paddocks in a rotational grazing system.

### Nutrient Management

This particular BMP refers to the planned use of organic and inorganic sources of nutrients to sustain optimum crop production while at the same time protecting the quality of nearby water resources. The implementation of this practice usually entails the development of a farm-wide *nutrient management plan* that is based on established criteria. An important objective of such a plan is to optimize forage and crop yields while minimizing nutrient loss to surface and ground water resources. This approach often

involves using other BMPs such as providing adequate *cover crops* and devising appropriate *crop rotations* to reduce (or augment) overall nutrients loads on a farm.

As described by Beegle and Lanyon (1994), most farms can be described as having a nutrient deficit, an adequate nutrient balance, or an excess of nutrients. Similarly, farms can usually be categorized as being *crop systems farms*, *crop/livestock farms*, or *intensive livestock systems*. The basic problem in the case of *intensive livestock systems* is that there is not sufficient cropland on the farm to utilize the quantities of nutrients being generated by the livestock. Consequently, the elimination and/or utilization of the excess nutrients is the major issue to be addressed in a *nutrient management plan* in this instance.

The focus of a nutrient management plan is usually placed on either nitrogen or phosphorus removal. However, it is important to remember that planned reductions or increases in one nutrient may well result in unwanted increases or decreases in loads of the other. For example, the amount of fertilizers and manure applied to cropland is typically based on the nitrogen needs of the crop, which may result in over-application of phosphorus. Conversely, a planned reduction in phosphorus loads may result in a less than adequate supply of nitrogen for the crops of concern. Load reduction efficiencies reported in this document are based on the assumption that a balanced approach is used to minimize nutrient loads at a given location. Practically speaking, this may require that phosphorus reductions be concomitant with an under-fertilization of crops with respect to nitrogen.

### Retirement of Agricultural Land

Various programs and financial incentives are occasionally made available to take actively cultivated land out of production. Typically, such retirement involves letting the cultivated land revert back to a “natural” state of vegetative cover to reduce the export of sediment and nutrients due to agricultural activities. Two BMP options provided in *PRedICT* to address this type of activity include the conversion of agricultural land to forest, and the conversion of agricultural land to wetlands.

## **2.2 Agricultural BMP Options in *PRedICT***

Within *PRedICT*, BMP systems rather than individual BMPs as described above are more often used as the basis for agricultural load reductions. This is because, as recognized by the Chesapeake Bay Program, BMPs are typically used in combination rather than individually to mitigate on-farm loss of soil and nutrients. Following this usage, the Pennsylvania Department of Environmental Protection has developed a guidance document that describes the different BMP systems that are recognized and eligible for funding through the State Conservation Commission (PaDEP, 2000) to mitigate water quality problems in agricultural areas. While not necessarily identical, the BMP systems used in *PRedICT* are based on the more generic and widely-used BMPs described in the latter document. Moreover, in this newer version of *PRedICT*, BMP usage and descriptions were revised to more closely follow comparable mitigation strategies used within the Chesapeake Bay Model (USEPA, 1995). The agricultural BMP options used in the current version of *PRedICT* are given in Table 1.

Table 1. Agricultural BMP options used in *PRedICT*

Description	Option	Comments
Cropland protection	BMP 1	Crop rotation, cover crops
Conservation tillage	BMP 2	Involves planting and growing of crops with minimal soil surface disturbance
Strip cropping/contour farming	BMP 3	Strip cropping/contour farming
Ag to forest land conversion	BMP 4	
Ag to wetland conversion	BMP 5	
Nutrient management	BMP 6	
Grazing land management	BMP 7	Rotational grazing with fenced areas
Terraces and diversions	BMP 8	

### 2.3 Pollutant Reduction Efficiencies

While hundreds (if not thousands) of studies have been completed over the last 25 years on the efficiencies of BMPs for reducing various pollutants (primarily sediment and nutrients), most of these studies have focused on the more frequently-used BMPs. Additionally, standard terminology and procedures in describing the BMPs and the reductions achieved have not been uniformly applied.

For the purposes of this document, information on pollutant reduction efficiencies has been drawn primarily from four different sources, including Dillaha, Yagow and Pease (2000), Ritter and Shirmohammadi (2001), Susquehanna River Basin Commission (1998), and U.S. EPA (1990). The first and fourth documents are exhaustive literature reviews of the results of hundreds of BMP efficiency studies conducted across the country over the last 25 years. In both documents, synopses of reduction efficiencies are reported for about two dozen BMPs, which sometimes overlap in terms of terminology and procedures, and sometimes do not. The Susquehanna River Basin Commission document reports the results of a study evaluating pollutant mitigation strategies in the Susquehanna River Basin and the associated potential nutrient reduction. The results are based on the use of non-point source-related reduction efficiency values utilized in the EPA's Chesapeake Bay watershed model (U.S. EPA, 1995). Finally, Ritter and Shirmohammadi (2001) is a recently released textbook that, among other things, presents the results of a number of recent BMP studies completed by various researchers around the country.

Composite pollutant reduction values for the generic BMP options used in *PRedICT* are presented in Table 2. These values essentially reflect the average values for the individual BMPs that comprise each BMP option. As can be seen in the table, efficiency values are provided for nitrogen, phosphorus, and sediment. Due to the nature of the studies used in deriving the individual BMP values (i.e., they were primarily “runoff plot” studies), the efficiency values shown are only used to estimate reductions in surface runoff loads. This is very important with respect to evaluating reductions in nitrogen loads since, at the watershed level, much of the non-point source load can be contributed via the sub-surface movement of nitrates in agricultural areas. As explained later in greater detail, adjustments to loads are also made to groundwater contributions based on the particular BMP option utilized.

Table 2. Estimated BMP reduction efficiencies (%) by pollutant type.

<b>BMP SYSTEM/TYPE</b>	<b>Nitrogen</b>	<b>Phosphorus</b>	<b>Sediment</b>
BMP 1	25	36	35
BMP 2	50	38	64
BMP 3	23	40	41
BMP 4	95	94	92
BMP 5	96	98	98
BMP 6	70	28	-
BMP 7	43	34	13
BMP 8	44	42	71

Notes on Table Usage:

- Values represent estimated reductions in surface runoff-associated loads only.
- Values represent percent reductions. For example, 36% of the surface P load can be reduced by implementing BMP 1.
- No value is reported for sediment for BMP 6 since this BMP (nutrient management) is typically not used for sediment reduction.
- The reduction values given for BMP 6 assume a “balanced” approach to reducing N and P loads. Otherwise, a value of 75 is recommended if the reduction of either pollutant is addressed at the expense of the other in the nutrient management plan. It is rare that a value of 75 would be used to reduce both nutrients at the same time.

## 2.4 Per Unit Implementation Costs

As with the reduction efficiency values, the costs associated with implementing the various individual BMPs were drawn from several sources. The primary one used, however, was the Conservation Catalog prepared by the Pennsylvania Conservation Partnership (2000). In addition to a description of various agricultural conservation practices currently used in Pennsylvania, the publication also has average costs for these practices at the time the document was written. Another useful document was a BMP guidance document prepared earlier by the U.S. EPA (1990).

Within *PRedICT*, only the costs associated with initial BMP implementation and construction are considered; long-term operational and maintenance costs are not included. These costs are shown in Table 3. In calculating the cost for any given BMP system, the separate costs for each individual BMP are calculated and subsequently summed according to the set of individual BMPs comprising each system.

Table 3. Costs by BMP type.

BMP TYPE	COST
Crop residue management	\$30 per acre
Cover crops	\$25 per acre
Grazing land management	\$360 per acre
Streambank fencing	\$15,000 per mile
Contour farming / strip-cropping	\$10 per acre
Vegetated buffer strips	\$1,500 per mile
Terraces and diversions	\$500 per acre
Nutrient management	\$110 per acre
Crop rotation	\$25 per acre
Ag Land Retirement	\$5,000 per acre

### 3.0 FARM ANIMAL-RELATED BMPS

In the newest version of *AVGWLF*, it is now possible to more directly estimate nutrient loads associated with farm animal populations. More specifically, these load calculations are made based on the assumption that nitrogen and phosphorus produced by farm animal populations can be transported to nearby water bodies via three primary mechanisms:

- 1) Runoff from barnyards, feedlots, chicken coops and similar confined areas,
- 2) Runoff from crop and pasture land where livestock and poultry wastes have been applied for fertilizing and/or waste management purposes, and
- 3) Losses that occur as a result of animal grazing. This includes runoff from grazing land (similar to #2 above), as well as “direct deposits” to streams where unimpeded access is available.

Loads calculated from these sources are now also reported separately in the output that results from a *GWLF-E* model run.

To take advantage of the added animal-related load data now provided by *AVGWLF*, concomitant improvements to *PRedICT* have been made to consider potential reductions in nutrient loads that might be achieved via the implementation of various farm animal-related BMPs. The specific BMPs that have been added include:

- Animal waste management systems for livestock
- Animal waste management systems for poultry
- Runoff control in confined feeding areas
- Phytase feed for poultry

Note that the above measures apply mostly to barnyards and similar confined feeding areas. Consequently, it is only those loads originating from these areas that are reduced by using any of the first three BMPs in the list above. In the case of the last BMP, if it is used, all phosphorus loads associated with poultry (i.e., either from confined areas or from manure distributed on adjacent agricultural land) are reduced based on the reduction coefficient applied and the extent to which this BMP is used.

*(Note: the newest version of AVGWLF also allows the user to calculate pathogen loads from farm animal operations. Consequently, the newest version of PRedICT also provides the user with the ability to evaluate potential pathogen load reductions via the use of the above (and other) BMPs. This issue is also addressed in the Section 7).*

Within *PRedICT*, pollutant-specific reduction coefficients associated with each BMP are used to decrease initial animal-generated loads on an annual basis. The coefficients used are given in Table 4. These values are drawn from a number of literature sources, including Ritter and Shimohammadi (2001), Chesapeake Bay Program (1998), USEPA (1999), Zehnder and DiCostanza (1997), Linker et al. (1999), and MDE, 2006. So, for example, let us assume that an initial load of 15,000 kg/year of phosphorus is being “lost” from livestock based on output from *AVGWLF*, and that 4,000 kg of this total is from barnyards. If a user indicates that *AWMS* is being used to address 25% of the livestock population within a given watershed (i.e., with a value of 0.25 ), then the annual load estimate gets re-calculated as:

$$4,000 - (4,000 \times 0.25 \times 0.75) + 11,000 = 14,250 \text{ kg/year.}$$

Note that for simplicity, reductions based on the use of “*AWMS* for livestock” are only applied to animals designated as “livestock” in the input form and “*AWMS* for poultry” is only applied to animals designated as “poultry” . Runoff control BMPs are applied to both types, and Phytase Feed is only applied to poultry populations. For those interested in additional details related to these and other agricultural BMPs, an excellent overview is provided by Ritter and Shimohammadi (2001).

Table 4. Default nutrient reduction coefficients for BMPs

<b>BMP TYPE</b>	<b>N</b>	<b>P</b>	<b>FC*</b>
AWMS/Livestock	0.75	0.75	0.75
AWMS/Poultry	0.14	0.14	0.14
Runoff Control	0.15	0.15	0.15
Phytase Feed	---	0.21	

\*Fecal Coliform (see related discussion in Section 7)

The per unit costs associated with each of the animal-related BMPs are shown in Table 5. In contrast to other BMP costs discussed in this document which are typically based on level of implementation per unit area or per unit distance, these costs are based on implementation per animal equivalent unit (AEU). In this case, an AEU is equal to 1000 pounds of any given animal.

Table 5. Default costs by BMP type.

BMP TYPE	COST/AEU
AWMS/Livestock	\$1250.00
AWMS/Poultry	\$520.00
Runoff Control	\$300.00
Phytase Feed	\$2.50

As with the reduction coefficients, these costs are more or less representative values obtained from a variety of sources. The primary sources include the Maryland Department of Environment (2006), the Chesapeake Bay Commission (2004), and the USEPA (2005).

#### 4.0 STREAM-RELATED ACTIVITIES

Stream-related activities are those conducted along streams for the purpose of reducing loads that might enter them from upland sources or to reduce the impacts associated with stream bank erosion. The types of mitigation activities included in *PRedICT* are described below.

##### 4.1 Types of Stream-Related Activities

###### Vegetated Buffer Strips

*Vegetated buffer strips* (also called *conservation buffers*, *buffer zones*, or *filter strips*) are examples of structural BMPs. Such strips are areas of land maintained in some type of permanent vegetation (i.e., grasses, shrubs, and/or trees) for the purpose of trapping pollutants contained in surface runoff from adjacent land areas. Buffer strips are commonly utilized to treat surface runoff from cropland or confined animal facilities. Vegetated buffer strips can take many forms including: 1) permanently vegetated strips located between larger crop strips on sloping land (Figure 9), 2) bands or strips of permanent vegetation established at the edge of agricultural fields, and 3) areas of trees, shrubs, and/or grasses adjacent to streams, lakes, ponds or wetlands (Figure 10). Pollutants are removed to varying degrees via the processes of filtration, infiltration, absorption, adsorption, uptake, volatilization, and deposition, with the predominant processes tending to be the infiltration of dissolved pollutants and deposition of sediment-attached pollutants.



Figure 9. Contour buffer strip.



Figure 10. Riparian buffer strip.

### Streambank Protection

*Streambank protection* collectively refers to several practices that can be employed for the purpose of mitigating the effects that eroding or slumping stream banks have on adjacent streams. The most frequently used form of protection is fencing that prohibits cattle from trampling stream banks, destroying protective vegetation, and stirring up sediment in the streambed. In addition to reducing direct soil loss caused by stream bank degradation, fencing also reduces nutrient loads caused by defecation and urination of the animals in the stream. *Streambank protection* also often involves the use of *stable crossings* and/or *streambank stabilization* measures. *Stable crossings* (such as the one shown in Figure 11) allow for the movement of animals across streams while at the same time reducing impacts to streambanks. With *streambank stabilization*, rip-rap, gabion walls, or a “bio-engineering” solution of some type are installed along the



edges of a stream to protect the banks during periods of heavy stream flow, thereby reducing direct stream bank erosion. With this approach, the banks are often covered with rocks, grass, trees, shrubs, and other protective surfaces to reduce erosion as well.

As with other BMPs, *streambank protection* is often implemented in combination with other BMPs to reduce overall sediment and nutrient loads. For example, a *prescribed grazing system* that limits livestock access to streams for short periods of time (e.g., 24 hours or less) can provide similar benefits as fencing. Additionally, a buffer zone of vegetation adjacent to the stream can filter out excess sediment, nutrients and chemicals from overland runoff.



Figure 11. Stabilized stream crossing.

#### 4.2 Stream-Related Options in *PRedICT*

The types of stream-related options included in *PRedICT* are those shown in Table 6, and the reduction efficiencies associated with each are given in Table 7. Table 8 provides the costs associated with each option. The values given in Table 7 for the various stream-related options are meant to represent reductions on a “per unit area” basis. That is, for each stream mile (or kilometer) in which that particular BMP is implemented, reductions in nutrient and sediment loads are made on a per acre basis depending upon the percentage of streams protected in agricultural areas within a given watershed (i.e, the “streambank” or “upland” load, respectively, is reduced by the percentage amount shown). For example, if 20% of the streams flowing through agricultural areas are protected by riparian buffers, then 20% of the surface- and subsurface-transported loads are reduced using the reduction coefficients shown. If 20% of the same streams are protected via streambank fencing and/or streambank stabilization, then the “streambank” loads are reduced using the appropriate coefficients.

Table 6. Stream-related options used in *PRedICT*

Description	Comments
Vegetative buffers	Commonly called riparian buffers. They can be grasses, shrubs and/or trees.
Streambank fencing	In addition to fencing, this option often involves the provision of “off-stream” drinking water for grazing animals.
Streambank stabilization	Can include the use of rip/rap, gabion walls, bio-engineered materials, and cement channels

Table 7. Estimated BMP reduction efficiencies (%) by pollutant type.

BMP SYSTEM/TYPE	Nitrogen	Phosphorus	Sediment	Pathogens*
Vegetative buffers	64	52	58	70
Streambank fencing	56	78	76	100
Streambank stabilization	36	95	95	---

\* See related discussion in Section 7

Table 8. Cost by Activity Type

Type	Cost
Vegetative buffers	\$1,500 per mile
Streambank fencing	\$15,000 per mile
Streambank stabilization	\$25 per foot

## 5.0 URBAN BMPs

As described earlier for agricultural areas, urban BMPs can also be structural or non-structural in nature. Typically, non-structural BMPs involve the preservation or enhancement of vegetative cover in selected areas (e.g., along streams) or the use of natural landscape features to act as filtration devices (e.g., as in the use of residential lawns to filter storm water runoff from roof tops). Urban BMPs can also be described in terms of their permanence over time. For example, some BMPs are primarily used during short-term construction activities (e.g., filter bags, silt curtains, and straw bale barriers), whereas others (e.g., infiltration trenches, filter strips, and constructed wetlands) are intended to be in service for much longer time periods. More detailed information on urban BMPs can be found in “Pennsylvania Handbook of Best Management Practices for Developing Areas”, a report prepared by CH2M-Hill (1998

The difficulty with implementing the use of urban BMPs within an evaluation tool like *PRedICT* is that many of these practices are very site-specific (e.g., critical area planting) and others require more information about existing conditions (i.e., existing stormwater sewers) than can be adequately estimated using the GIS data sets currently employed by *AVGWLF*. Moreover, pollutant reduction efficiencies and cost data for many urban BMPs are not widely available. Given these limitations, only a few urban BMPs are included in the current version of *PRedICT* (as described below). It is expected, though, that more urban BMPs will be added as new data become available and as algorithms for accounting for such practices are developed.

Use of the BMPs described below assumes that watershed loads have been estimated utilizing the “standard” simulation option in *AVGWLF*. In the newest version of *AVGWLF* (Version 7.0), a new simulation tool exists that is more specifically designed to address urban landscapes. With this option, users have the ability to directly consider the effects of urban BMPs such as detention basins, riparian buffers and enhanced infiltration/retention practices. If this “urban” option is used, the resulting model output cannot be brought into *PRedICT* for subsequent analysis. Rather, in this case, it is assumed that the user will do all “what if” scenarios using the tools available within that particular option.

### 5.1 Urban BMP Options

#### Detention Basins

These generic structures are designed for the temporary capture and storage of surface runoff during storm events. They are sized based on the amount of water expected to be generated during specific (i.e., design) storm events. For example, a storm producing a given amount of precipitation during a specific period (e.g., day, week, etc.) over an urban landscape having an inherent infiltration capacity will generate an amount of surface water runoff that can be predicted using values estimated for a handful of critical watershed modeling parameters (e.g., hydrologic soil group, SCS curve number, land slope, and rainfall intensity and duration). The settling velocity for sediment and attached pollutants is also considered in determining basin size.

Within *PRedICT*, the type of detention basin assumed is often referred to as a “wet pond” (see Figure 12). Wet ponds are designed to fill with stormwater and subsequently release most of it over a period of a few days, thereby slowly allowing the pond to return

to its normal depth. Water contained in the permanent pool mixes with and dilutes the initial runoff from storm events. Runoff generated early on in a storm typically has the highest concentrations of sediment and dissolved pollutants. Therefore, the concentration of pollutants in runoff released to downstream areas is reduced. Following storm events, pollutants are removed from water retained in the pond. Mechanisms that remove pollutants in wet ponds include settling of suspended particulates and biological uptake, or consumption of pollutants by plants, algae, and bacteria in the water.

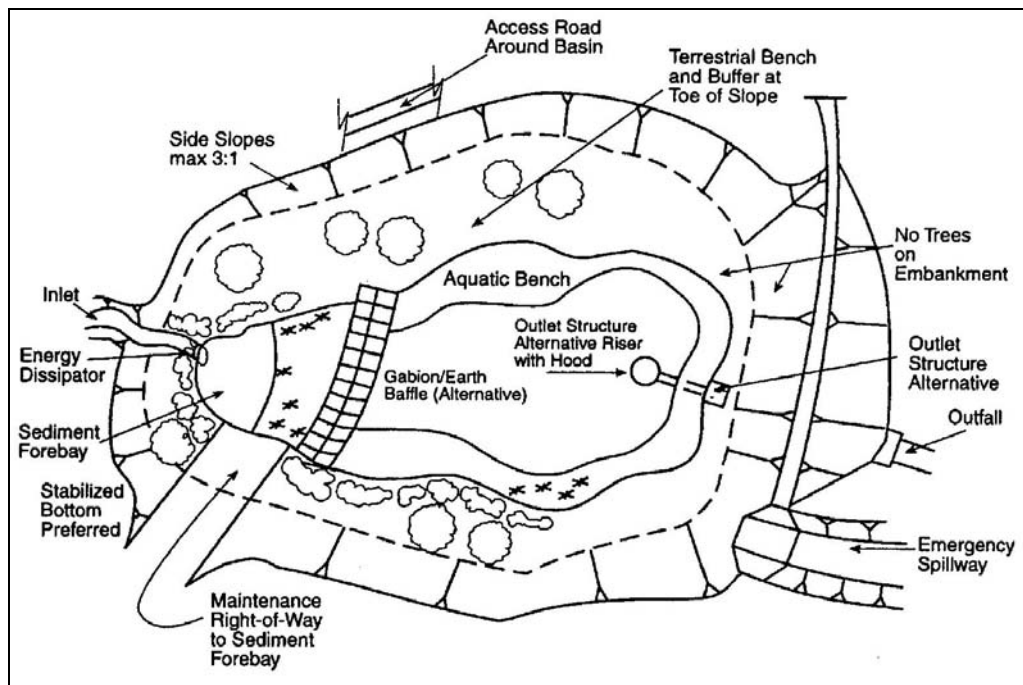


Figure 12. Example layout of a detention basin/wet pond (from CH2M-Hill, 1998).

### Constructed Wetlands

Constructed wetlands (or constructed treatment wetlands) are essentially artificial shallow water-filled basins that have been planted with emergent plant vegetation. They are typically designed to achieve specific water quality objectives before the water is released, and can be an efficient method for removing a wide variety of pollutants including suspended solids, nutrients, heavy metals, toxic organic pollutants, and petroleum compounds. Constructed wetlands are also an effective means of reducing peak runoff rates and stabilizing flow to adjacent natural wetlands and streams. Figures 13 and 14 illustrate some conceptual configurations for constructed wetlands.

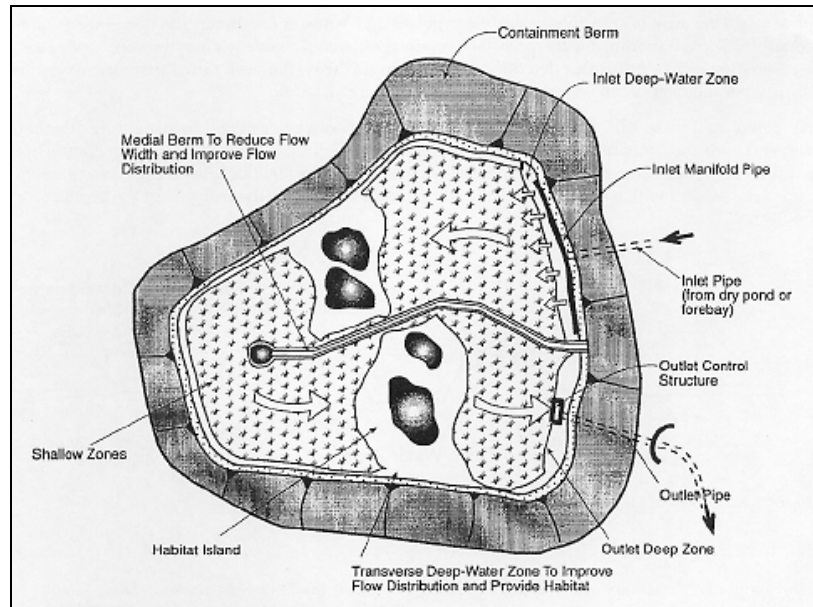


Figure 13. Conceptual layout of a constructed wetland (from CH2M-Hill, 1998).

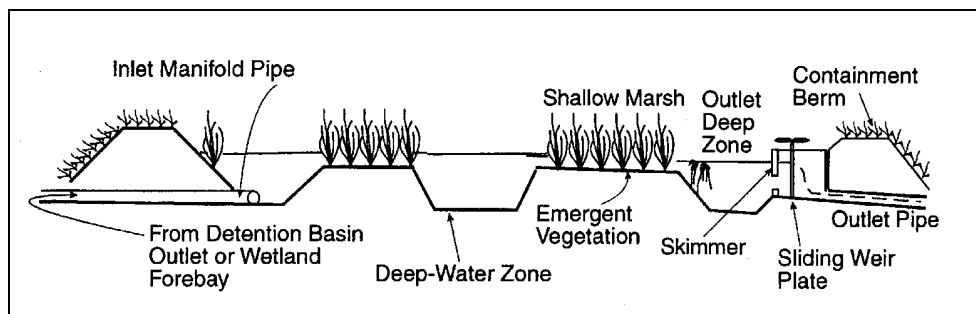


Figure 14. Stylized cross section of a constructed wetland (from CH2M-Hill, 1998).

### Low Impact Development

Low impact development (LID) practices collectively refers to the use of innovative design strategies within an urban setting with the goal of simulating pre-development landscapes with respect to hydrologic function (USEPA, 2000). With such practices, the objective is to generally increase hydrologic storage, retention, infiltration, groundwater recharge, etc. to limit the effects of excessive runoff in urban areas. Although LID practices are typically used for controlling stormwater runoff, they often provide the beneficial secondary effect of reducing pollutant loadings to receiving waters as well. The LID approaches most commonly used and studied include bioretention areas, grass swales, permeable pavements, and vegetated roof tops. Within *PRedICT*, a very rudimentary tool is provided to approximate the effect of using one or more bioretention areas. Additional capability to simulate the effects of implementing infiltration and retention practices is also provided with the “urban” model within *AVGWLF*.

## 5.2 Pollutant Reduction Efficiencies

Within *PRedICT*, default values are used for sediment and nutrient reduction efficiencies. Actual efficiencies, however, can vary depending on local terrain, design and operational factors. As explained in a later section, these values can be changed by the user if so desired. The default values used are based primarily on information provided in Novotny and Olem (1994), Ristenpart and Prigge (2002), U.S. EPA (2000), U.S. EPA, 2001, and U.S. EPA, 2002, and are given in Table 9.

Table 9. Default reduction efficiencies (%) used in *PRedICT* for urban BMPs.

	<b>Sediment</b>	<b>Nitrogen</b>	<b>Phosphorus</b>	<b>Pathogens*</b>
Detention basin	93	40	51	71
Constructed wetland	88	53	51	71
Bioretention area	10	46	61	82

\* Values are for fecal coliform

## 5.3 Per Unit Implementation Costs

Costs for the urban BMPs used in *PRedICT* are based on average costs for construction as determined in telephone calls to several firms involved in stormwater management in Pennsylvania. These costs only consider the cost of constructing the BMPs, and do not include any operational or maintenance costs beyond the initial construction costs. These costs, provided on a per acre basis, are shown in Table 10.

Table 10. Costs for urban BMPs.

<b>BMP TYPE</b>	<b>COST</b>
Detention basin (wet pond)	\$10,700 per acre*
Constructed wetland	\$13,400 per acre*
Bioretention area	\$8,000 per acre*

\* Per acre of urban area drained

## 6.0 WASTEWATER DISCHARGE REDUCTION OPTIONS

Wastewater discharges considered by *PRedICT* include on-lot septic systems and municipal wastewater treatment plants located within the watershed being evaluated. Estimates of the number of people on septic systems within a watershed are calculated as part of the *AVGWLF* modeling process, and are included in the resultant “scenario” (i.e., \*.scn) file associated with any particular *AVGWLF* model run. If *AVGWLF* is not used to prepare an initial scenario file, this septic system estimate must be supplied by the user. In all cases, an estimate of the number of people on centralized sewage treatment systems must be supplied by the user as well.

The specific wastewater reduction options allowed by *PRedICT* include: 1) conversion of septic systems to secondary wastewater treatment plants, 2) conversion of septic systems to tertiary wastewater treatment plants, 3) upgrades of primary treatment plants to secondary treatment, 4) upgrades of primary treatment plants to tertiary treatment, and 5) upgrades of secondary treatment plants to tertiary treatment.

### 6.1 Pollutant Reduction Efficiencies

Default values for nutrient reduction efficiencies (specifically for nitrogen and phosphorus) are used in *PRedICT* for each of the wastewater alternatives described above are shown in Table 11. These values are based on information provided in various wastewater technology textbooks. While these values are believed to be reasonable estimates, there are still only approximate since wastewater treatment technology can vary widely, and it is up to the user to revise them if necessary based on local treatment plant characteristics.

Table 11. Default reduction efficiencies (%) for wastewater reduction.

	Nitrogen	Phosphorus
Septic systems to secondary treatment	14	10
Septic systems to tertiary treatment	56	60
Primary treatment to secondary treatment	14	10
Primary treatment to secondary treatment	56	60
Secondary treatment to tertiary treatment	42	50

### 6.2 Per Unit Implementation Costs

Default cost values for each of the wastewater alternatives are also provided (see Table 12). These values are based on a few telephone calls to wastewater treatment plant operators in Pennsylvania. While these costs are believed to be fairly representative, they are also approximate, and it is incumbent upon the user to revise them to better reflect local upgrade costs if necessary.

Table 12. Costs for wastewater reduction options.

BMP TYPE	COST
Septic systems to centralized treatment	\$15,000 per home
Primary treatment to secondary treatment	\$250 per capita
Primary treatment to secondary treatment	\$300 per capita
Secondary treatment to tertiary treatment	\$150 per capita

## 7.0 PATHOGEN REDUCTIONS FROM BMPs

To complement improvements made to *AVGWLF* (Ver.7.0), a number of new routines have been incorporated into *PRedICT* to estimate potential pathogen load reductions for a number of sources including:

- farm animals
- septic systems
- wastewater treatment plants, and
- urban landscapes

By default, pathogen loads brought into *PRedICT* are assumed to represent fecal coliform. However, it is possible to evaluate loads associated with other pathogens as well as long as the appropriate reduction coefficients are used for different sources.

With respect to farm animals, pathogen load reductions from these sources are estimated using essentially the same routines as those used to estimate nitrogen and phosphorus loads (see Section 3). Consequently, the information presented in that section is not repeated here. The specific reduction coefficients used for animal-related BMPs were given previously in Table 4, and their associated implementation costs are given in Table 5.

In addition to reductions achieved via the implementation of “barnyard-related” measures as described above, pathogen loads emanating from animal wastes distributed on crops and pasture land via manure-spreading and grazing activities can also be reduced in *PRedICT* via the use of the stream protection activities discussed in Section 4. For example, vegetative buffers can be used to reduce pathogen loads from crop and pasture land by a factor of 70% as shown in Table 7. Similarly, streambank fencing can be used to reduce pathogen loads from these same areas as well. However, in the latter case, fencing only reduces the “direct-deposit” portion of these “field-related” loads, and does not effect pathogens carried to nearby streams via erosion and runoff.

In the case of septic systems, it is assumed that a conversion of a septic system (i.e., connection to a treatment plant) will result in a 99% reduction in pathogens from that system due to the typical requirement for chlorination at such plants. With respect to plant discharges, it is assumed that the discharge concentration is 200 coliform-forming units per 100 ml for both “existing” and “future” conditions. This value is an effluent



standard widely-used by states throughout the country (Field, 1990). The user, however, has the ability to edit either value to estimate potential reductions due to treatment plant upgrades. The costs associated with converting septic systems and upgrading treatment plants were given in Tables 11 and 12, respectively.

As discussed in Section 5, there are three different urban BMPs that can be evaluated within *PRedICT*, including detention basins, constructed wetlands, and bioretention facilities. In addition to reducing sediment and nutrients, these can also be used to reduce pathogen loads. The specific reduction coefficients used in *PRedICT* are given in Table 9. These coefficients are more or less average values based on information found in a number of sources, including EPA (2001) and EPA (2003)

## 8.0 LOAD REDUCTION AND COST CALCULATION ALGORITHMS

Calculations of pollutant load reductions and associated costs within *PRedICT* are accomplished via a series of data handling algorithms and mathematical expressions written in Visual Basic. The general approach in most cases is to calculate load reductions for each pollutant based on the number of additional “units” (e.g., acres, stream miles, etc.) for which the particular BMP is being implemented and the appropriate pollutant reduction coefficients specific to that BMP. Examples of how some of these calculations are made are provided in the following sub-sections.

### 8.1 Agricultural Load Reductions

Information on how reductions are to be made in agricultural areas is derived predominantly from the “*Rural Land BMP Scenario Editor*” and “*Agricultural BMP Load Reduction Efficiency Editor*” input screens (see Section 10 for additional details). Based on the number of additional acres or stream miles on which specified BMPs are applied, along with their corresponding pollutant reduction efficiency values, the “future” (i.e., re-calculated) pollutant loads are determined using a series of equations similar to those shown below. While the example given below shows reductions made for phosphorous on row crops, a similar approach is used for other pollutants on other land cover areas as well.

#### Example calculation of reductions from row crops

$$\text{PROWBMP6} = (((\text{FUTAC6} - \text{EXAC6}) / 100) * \text{EXPROW}) * \text{COFP6}$$

$$\text{PROWNM} = \text{EXPROW} - \text{PROWBMP6}$$

$$\text{PROWBMP1} = (((\text{FUTAC1} - \text{EXAC1}) / 100) * \text{PROWNM}) * \text{COFP1}$$

$$\text{PROWBMP2} = (((\text{FUTAC2} - \text{EXAC2}) / 100) * \text{PROWNM}) * \text{COFP2}$$

$$\text{PROWBMP3} = (((\text{FUTAC3} - \text{EXAC3}) / 100) * \text{PROWNM}) * \text{COFP3}$$

$$\text{PROWBMP4} = (((\text{FUTAC4} - \text{EXAC4}) / 100) * \text{PROWNM}) * \text{COFP4}$$

$$\text{PROWBMP5} = (((\text{FUTAC5} - \text{EXAC5}) / 100) * \text{PROWNM}) * \text{COFP5}$$

$$\text{PROWBMP8} = (((\text{FUTAC8} - \text{EXAC8}) / 100) * \text{PROWNM}) * \text{COFP8}$$

$$\text{PROWRED} = \text{PROWNM} - (\text{PROWBMP1} + \text{PROWBMP2} + \text{PROWBMP3} + \text{PROWBMP4} + \text{PROWBMP5} + \text{PROWBMP8})$$

$$\text{PROWBUF} = (((\text{FUTSTRMBUF} / \text{AGSTRM}) - (\text{EXSTRMBUF} / \text{AGSTRM})) * \text{PROWRED}) * \text{COFPBUF}$$

$$\text{FUTPROW} = \text{PROWRED} - \text{PROWBUF}$$

where:

PROWBMP<sub>1-8</sub> = phosphorus reductions (lbs) for BMP systems 1-8  
FUTAC<sub>1-8</sub> = future number of acres (% of total) specified for BMP systems 1-8  
EXAC<sub>1-8</sub> = existing number of acres (% of total) specified for BMP systems 1-8  
EXPROW = existing phosphorus load (lbs) from row crops as specified in the  
“Total Phosphorus” column in the “*Mean Annual Load Data Editor*”  
COFP<sub>1-8</sub> = reduction coefficients for BMP systems 1-8 for phosphorus  
PROWNM = remaining load (lbs) after reduction due to nutrient management  
PROWRED = total phosphorus load (lbs) from row crops after reductions from  
BMP systems 1-8  
PROWBUF = further reduction (lbs) from agricultural areas if vegetation buffers  
are used along streams  
FUTSTRMBUF = future miles of stream buffer in agricultural areas  
EXSTRMBUF = existing miles of stream buffer in agricultural areas  
AGSTRM = stream miles in agricultural areas as specified in the “*Agricultural  
Land BMP Scenario Editor*”  
COFPBUF = reduction coefficient for vegetated buffer strips for phosphorus  
FUTPROW = re-calculated (future) phosphorus load (lbs) from row crops

*(Note: In the above example, loads are first reduced based on the use of nutrient management, then reduced based on the use of other agricultural BMPs, and finally reduced further based on the use of stream buffers).*

## 8.2 Farm Animal Load Reductions

In the newest version of *PRedICT* (Version 2.0), potential load reductions for farm animal operations can be evaluated via the use of various farm animal-related BMPs such as animal waste management systems, runoff control and feed additives. The following example shows how reductions in phosphorus can be made by considering the potential use of animal waste management systems (AWMS) for livestock.

### Example calculation of reductions from the use of livestock AWMS

$$PAWMSL = ((FUTAWMSL - EXAWMSL) / 100) * COFPAWMSL * BARNPL$$

where:

PAWMSL = P reduction from use of AWMS for livestock  
FUTAWMSL = Percentage of livestock addressed by AWMS in future  
EXAWMSL = Percentage of existing livestock treated by use of AWMS  
COFPAWMSL = Reduction coefficient for P for livestock AWMS  
BARNPL = current P loss (in kg) from barnyards having livestock

*(Note: The “barnyard” load (e.g., “BARNPL”) is actually calculated by AVGWLF and passed to the “scenario” file brought into PRedICT. It is not visible in any of the PRedICT forms, but it is in the file).*

### 8.3 Streambank Load Reductions

Within *PRedICT*, “streambank-derived” nutrient and sediment loads can be reduced via the use of streambank fencing and/or streambank stabilization in agricultural areas. These loads can be reduced via the use of streambank stabilization in urban areas as well. An example of how streambank sediment loads are “re-calculated” based on the presence of the extent of fencing and stabilization in agricultural areas is given below. Load reductions in urban areas (not shown below) are estimated in similar fashion.

#### Example calculation of reductions from streambank erosion

$$\text{FUTSEDSTRM} = (((\text{FUTSTRMFEN} - \text{EXSTRMFEN}) / 100) * \text{EXSEDSTRM}) * \text{COFSFEN} + (((\text{FUTSTRMSTAB} - \text{EXSTRMSTAB}) / 100) * \text{EXSEDSTRM}) * \text{COFSSTAB}$$

where:

FUTSEDSTRM = re-calculated (future) sediment load (lbs) from streambank erosion

FUTSTRMFEN = future miles of streambank fencing in agricultural areas

FUTSTRMSTAB = future miles of streambank stabilization in agricultural areas

EXSTRMFEN = existing miles of streambank fencing in agricultural areas

EXSTRMSTAB = existing miles of streambank stabilization in agricultural areas

EXSEDSTRM = existing sediment load (lbs) from streambank erosion as specified in the “Total Sediment” column in the “*Mean Annual Load Data Editor*”

COFSFEN = reduction coefficient for streambank fencing for sediment

COFSSTAB = reduction coefficient for streambank stabilization for sediment

### 8.4 Groundwater Load Adjustments

In agricultural areas, the use of various BMPs (in particular, nutrient management) have been shown to directly effect the amount of nutrients delivered to groundwater. In *PRedICT*, nutrient reductions to groundwater loads are made based on the extent to which nutrient management is used within a given watershed. Algorithmically, groundwater reductions for nutrients (i.e., nitrogen and phosphorous) are calculated more or less as follows:

$$\text{REDGWN}_{\text{N,P}} = ((\text{FUTACNM} - \text{EXACNM}) * \text{PCTAG} * \text{EXGWN}_{\text{N,P}}) * \text{NMCOEFF}_{\text{N,P}}$$

$$\text{FUTGWN}_{\text{N,P}} = \text{EXGWN}_{\text{N,P}} - \text{REDGWN}_{\text{N,P}}$$

where:

REDGWN<sub>N,P</sub> = Load reduction (in lbs or kgs per year) estimated for N or P

FUTACNM = Future extent (% of total ag acres) of nutrient management usage

EXACNM = Existing extent (% of total ag acres) of nutrient management usage

PCTAG = Extent of agricultural land in watershed (% of total acres)

EXGWN<sub>N,P</sub> = Existing groundwater nutrient load for either N or P (in lbs or kgs per year)

NMCOEFF<sub>N,P</sub> = Nutrient management reduction coefficient for N or P

FUTGWN<sub>N,P</sub> = Future groundwater N or P load (lbs or kgs per year)

## 8.5 Urban Area Load Reductions

Information on how reductions are to be made in urban areas is derived primarily from the “*Urban Land BMP Scenario Editor*” and “*Urban BMP Load Reduction Efficiency Editor*” input screens (see Section 10 for additional details). In the first screen, the user is asked to specify the amount (i.e., percentage) of high and/or low density urban land that will be “treated” via the use of detention basins and/or constructed wetlands under a future scenario. Based on the specified values, the “new” (i.e., re-calculated) pollutant loads are determined as follows. Similar load reduction calculations for nitrogen and sediment are carried out as well.

### Example calculation of reduction from urban BMPs

$$\begin{aligned} \text{PURBCW}_{H,L} &= (((\text{FUTACCW}_{H,L} - \text{EXACCW}_{H,L}) / 100) * \text{EXPURB}_{H,L}) * \text{COFPCW} \\ \text{PURBBA}_{H,L} &= (((\text{FUTACBA}_{H,L} - \text{EXACBA}_{H,L}) / 100) * \text{EXPURB}_{H,L}) * \text{COFPBA} \\ \text{PURBDB}_{H,L} &= (((\text{FUTACDB}_{H,L} - \text{EXACDB}_{H,L}) / 100) * \text{EXPURB}_{H,L}) * \text{COFPDB} \\ \text{FUTPURB1}_{H,L} &= \text{EXPURB}_{H,L} - (\text{PURBCW}_{H,L} + \text{PURBBA}_{H,L} + \text{PURBDB}_{H,L}) \\ \text{PURBBUF}_{H,L} &= (((\text{FUTURBBUF} / \text{URBSTRM}) - (\text{EXURBBUF} / \text{URBSTRM})) * \\ &\quad \text{FUTPURB1}_{H,L}) * \text{COFPBUF} \\ \text{FUTPURB2}_{H,L} &= \text{FUTPURB1}_{H,L} - \text{PURBBUF}_{H,L} \end{aligned}$$

where:

$\text{PURBCW}_{H,L}$  = phosphorus reductions (lbs or kgs) based on use of constructed wetlands (CW) in high (H) or low (L) density urban areas  
 $\text{PURBBA}_{H,L}$  = phosphorus reductions (lbs or kgs) based on use of bioretention areas (BA) in high (H) or low (L) density urban areas  
 $\text{PURBDB}_{H,L}$  = phosphorus reductions (lbs) based on use of detention basins (DB) in high (H) or low (L) density urban areas  
 $\text{FUTACCW}_{H,L}$  = future number of acres (% of total) specified for constructed wetlands (CW) in high (H) or low (L) density urban areas  
 $\text{EXACCW}_{H,L}$  = existing number of acres (% of total) specified for constructed wetlands (CW) in high (H) or low (L) density urban areas  
 $\text{FUTACBA}_{H,L}$  = future number of acres (% of total) specified for bioretention areas (BA) in high (H) or low (L) density urban areas  
 $\text{EXACBA}_{H,L}$  = existing number of acres (% of total) specified for bioretention areas (BA) in high (H) or low (L) density urban areas  
 $\text{FUTADBA}_{H,L}$  = future number of acres (% of total) specified for detention basins (DB) in high (H) or low (L) density urban areas  
 $\text{EXACDB}_{H,L}$  = existing number of acres (% of total) specified for detention basins (DB) in high (H) or low (L) density urban areas  
 $\text{EXPURB}_{H,L}$  = existing phosphorus loads (lbs or kgs) in high (H) or low (L) density urban areas  
 $\text{FUTURB1}_{H,L}$  = total phosphorous load from high and low density urban areas after reductions due to detention basins, bioretention areas and wetlands  
 $\text{PURBBUF}_{H,L}$  = further reduction (lbs or kgs) from urban areas if vegetation buffers are used along streams  
 $\text{FUTURBBUF}$  = future miles of stream buffer in urban areas  
 $\text{EXURBBUF}$  = existing miles of stream buffer in urban areas  
 $\text{URBSTRM}$  = stream miles in urban areas as specified in the “*Urban Land BMP Scenario Editor*”

COFPCW = phosphorus reduction coefficient for constructed wetlands  
 COFPBA = phosphorus reduction coefficient for bioretention areas  
 COFPDB = phosphorus reduction coefficient for detention basins  
 COFPBUF = reduction coefficient for vegetated buffer strips for phosphorous  
 FUTPURB<sub>2,H,L</sub> = future phosphorus loads (lbs or kgs) in high (H) or low (L) density urban areas

## 8.6 Wastewater Load Reductions

As described previously, wastewater reduction options include septic system conversions to central wastewater treatment systems as well as upgrades from primary to secondary to tertiary treatment plants. Information on how various wastewater reductions are to be made is derived primarily from the “*Septic System and Point Source Discharge Scenario Editor*” and “*Wastewater Discharge Reduction Efficiency Editor*” input screens (see Section 10 for additional details). In the first screen, the user is asked to provide information on the number of people on septic systems under existing and future scenarios, as well as the percentage of current and future wastewater treatment plant loads undergoing primary, secondary and/or tertiary treatment. Based on the specified values, the loads and corresponding pollutant reduction efficiency values are used to re-compute future loads as follows:

*Step 1: Calculate septic system load reductions based on transfers to wastewater treatment plants*

If the number of septic systems in place under a “future” scenario is greater than the number of existing systems, then septic system loads are computed as follows:

$$\text{FUTNSEP} = (\text{FUTSEPPOP} / \text{EXSEPPOP}) * \text{EXNSEP}$$

$$\text{FUTPSEP} = (\text{FUTSEPPOP} / \text{EXSEPPOP}) * \text{EXPSEP}$$

where:

FUTNSEP = future nitrogen load (lbs or kgs) from septic systems  
 FUTSEPPOP = future population (number of people) on septic systems  
 EXSEPPOP = existing population (number of people) on septic systems  
 EXNSEP = existing nitrogen load (lbs or kgs) from septic systems  
 FUTPSEP = future phosphorus load (lbs or kgs) from septic systems  
 EXPSEP = existing phosphorus load (lbs or kgs) from septic systems

If the number of septic systems in place under a “future” scenario is less than or equal to the number of existing systems, then septic system loads are computed as follows:

$$\text{SEPTNS} = ((1 - (\text{FUTSEPPOP} / \text{EXSEPPOP})) * \text{EXNSEP}) * \text{SEP2ST}$$

$$\text{SEPTPS} = ((1 - (\text{FUTSEPPOP} / \text{EXSEPPOP})) * \text{EXPSEP}) * \text{SEP2ST}$$

$$\text{SEPTNT} = ((1 - (\text{FUTSEPPOP} / \text{EXSEPPOP})) * \text{EXNSEP}) * \text{SEP2TT}$$

$$\text{SEPTPS} = ((1 - (\text{FUTSEPPOP} / \text{EXSEPPOP})) * \text{EXPSEP}) * \text{SEP2TT}$$

$$\text{FUTNSEP} = \text{EXNSEP} - (\text{SEPTNS} + \text{SEPTNT})$$

$$\text{FUTPSEP} = \text{EXPSEP} - (\text{SEPTPS} + \text{SEPTPT})$$

where:

SEPTNS = nitrogen load (lbs) transferred from septic systems to a secondary wastewater treatment plant  
SEPTPS = phosphorus load (lbs) transferred from septic systems to a secondary wastewater treatment plant  
SEPTNT = nitrogen load (lbs) transferred from septic systems to a tertiary wastewater treatment plant  
SEPTPT = phosphorus load (lbs) transferred from septic systems to a tertiary wastewater treatment plant  
FUTSEPPOP = future population (number of people) on septic systems  
EXSEPPOP = existing population (number of people) on septic systems  
EXNSEP = existing nitrogen load (lbs) from septic systems  
EXPSEP = existing phosphorus load (lbs) from septic systems  
SEP2ST = septic system population (%) transferred to a secondary wastewater treatment plant  
SEP2TT = septic system population (%) transferred to a tertiary wastewater treatment plant  
FUTNSEP = future nitrogen load (lbs) from septic systems  
FUTPSEP = future phosphorus load (lbs) from septic systems

*Step 2: Calculate initial point source nitrogen and phosphorus loads based on wastewater treatment plant type*

PRILOADN1 =  $(EXPSPT / 100) * EXPSN$   
PRILOADP1 =  $(EXPSPT / 100) * EXPSP$   
SECLOADN1 =  $(EXPSST / 100) * EXPSN$   
SECLOADP1 =  $(EXPSST / 100) * EXPSP$   
TERLOADN1 =  $(EXPSTT / 100) * EXPSN$   
TERLOADP1 =  $(EXPSTT / 100) * EXPSP$

where:

PRILOADN1 = initial nitrogen load (lbs) from primary treatment plants  
PRILOADP1 = initial phosphorus load (lbs) from primary treatment plants  
SECLOADN1 = initial nitrogen load (lbs) from secondary treatment plants  
SECLOADP1 = initial phosphorus load (lbs) from secondary treatment plants  
TERLOADN1 = initial nitrogen load (lbs) from tertiary treatment plants  
TERLOADP1 = initial phosphorus load (lbs) from tertiary treatment plants  
EXPSPT = existing amount (%) of point source load from primary treatment plants  
EXPSST = existing amount (%) of point source load from secondary treatment plants  
EXPSTT = existing amount (%) of point source load from tertiary treatment plants  
EXPSN = existing nitrogen load (lbs) from municipal point sources  
EXPSP = existing phosphorus load (lbs) from municipal point sources

*Step 3: Calculate nitrogen and phosphorus load reductions based on wastewater treatment plant upgrades*

$$\begin{aligned} \text{PSNPT} &= \text{PRILOADN1} * (\text{PT2ST} / 100) \\ \text{PSPPT} &= \text{PRILOADP1} * (\text{PT2ST} / 100) \\ \text{PTNPT} &= \text{PRILOADN1} * (\text{PT2TT} / 100) \\ \text{PTPPT} &= \text{PRILOADP1} * (\text{PT2TT} / 100) \\ \text{STNPT} &= \text{SECLOADN1} * (\text{ST2TT} / 100) \\ \text{STPPT} &= \text{SECLOADP1} * (\text{ST2TT} / 100) \end{aligned}$$

where:

PSNPT = fraction of initial nitrogen point source load (lbs) shifted from primary treatment to secondary treatment

PSPPT = fraction of initial phosphorus point source load (lbs) shifted from primary treatment to secondary treatment

PTNPT = fraction of initial nitrogen point source load (lbs) shifted from primary treatment to tertiary treatment

PTPPT = fraction of initial phosphorus point source load (lbs) shifted from primary treatment to tertiary treatment

STNPT = fraction of initial nitrogen point source load (lbs) shifted from secondary treatment to tertiary treatment

STPPT = fraction of initial phosphorus point source load (lbs) shifted from secondary treatment to tertiary treatment

PRILOADN1 = initial nitrogen load (lbs) from primary treatment plants

PRILOADP1 = initial phosphorus load (lbs) from primary treatment plants

SECLOADN1 = initial nitrogen load (lbs) from secondary treatment plants

SECLOADP1 = initial phosphorus load (lbs) from secondary treatment plants

PT2ST = fraction (%) of primary treatment load shifted to secondary treatment

PT2TT = fraction (%) of primary treatment load shifted to tertiary treatment

ST2TT = fraction (%) of secondary treatment load shifted to tertiary treatment

*Step 4: Calculate final future nitrogen and phosphorus loads based on wastewater treatment plant upgrades and septic system conversions*

$$\text{PRILOADN2} = \text{PRILOADN1} - (\text{PSNPT} + \text{PTNPT})$$

$$\text{PRILOADP2} = \text{PRILOADP1} - (\text{PSPPT} + \text{PTPPT})$$

$$\text{SECLOADN2} = \text{SECLOADN1} + (\text{PSNPT} * (1 - \text{COFNPS})) + (\text{SEPTNS} * (1 - \text{COFNSEPS})) - \text{STNPT}$$

$$\text{SECLOADP2} = \text{SECLOADP1} + (\text{PSPPT} * (1 - \text{COFPPS})) + (\text{SEPTPS} * (1 - \text{COFPSEPS})) - \text{STPPT}$$

$$\text{TERLOADN2} = \text{TERLOADN1} + (\text{PTNPT} * (1 - \text{COFNPT})) + (\text{STNPT} * (1 - \text{COFNST})) + (\text{SEPTNT} * (1 - \text{COFNSEPT}))$$

$$\text{TERLOADP2} = \text{TERLOADP1} + (\text{PTPPT} * (1 - \text{COFPPT})) + (\text{STPPT} * (1 - \text{COFPST})) + (\text{SEPTPT} * (1 - \text{COFPSEPT}))$$

$$\text{FUTPSN} = \text{PRILOADN2} + \text{SECLOADN2} + \text{TERLOADN2}$$

$$\text{FUTPSP} = \text{PRILOADP2} + \text{SECLOADP2} + \text{TERLOADP2}$$

where:

PRILOADN2 = future nitrogen load (lbs) from primary treatment plants  
PRILOADP2 = future phosphorus load (lbs) from primary treatment plants  
SECLOADN2 = future nitrogen load (lbs) from secondary treatment plants  
SECLOADP2 = future phosphorus load (lbs) from secondary treatment plants  
TERLOADN2 = future nitrogen load (lbs) from tertiary treatment plants  
TERLOADP2 = future phosphorus load (lbs) from tertiary treatment plants  
PRILOADN1 = initial nitrogen load (lbs) from primary treatment plants  
PRILOADP1 = initial phosphorus load (lbs) from primary treatment plants  
SECLOADN1 = initial nitrogen load (lbs) from secondary treatment plants  
SECLOADP1 = initial phosphorus load (lbs) from secondary treatment plants

PSNPT = fraction of initial nitrogen point source load (lbs) shifted from primary treatment to secondary treatment  
PSPPT = fraction of initial phosphorus point source load (lbs) shifted from primary treatment to secondary treatment  
PTNPT = fraction of initial nitrogen point source load (lbs) shifted from primary treatment to tertiary treatment  
PTPPT = fraction of initial phosphorus point source load (lbs) shifted from primary treatment to tertiary treatment  
STNPT = fraction of initial nitrogen point source load (lbs) shifted from secondary treatment to tertiary treatment  
STPPT = fraction of initial phosphorus point source load (lbs) shifted from secondary treatment to tertiary treatment  
SEPTNS = fraction of initial nitrogen load (lbs) shifted from septic systems to secondary treatment  
SEPTPS = fraction of initial phosphorus load (lbs) shifted from septic systems to secondary treatment  
SEPTNT = fraction of initial nitrogen load (lbs) shifted from septic systems to tertiary treatment  
SEPTPT = fraction of initial phosphorus load (lbs) shifted from septic systems to tertiary treatment  
COFNPS = reduction coefficient for nitrogen when shifting from primary to secondary treatment  
COFNSEPS = reduction coefficient for nitrogen when shifting from septic systems to secondary treatment  
COFPNS = reduction coefficient for phosphorus when shifting from primary to secondary treatment  
COFPSEPS = reduction coefficient for phosphorus when shifting from septic systems to secondary treatment  
COFNPT = reduction coefficient for nitrogen when shifting from primary to tertiary treatment  
COFNST = reduction coefficient for nitrogen when shifting from secondary to tertiary treatment  
COFNSEPT = reduction coefficient for nitrogen when shifting from septic systems to tertiary treatment  
COFPPT = reduction coefficient for phosphorus when shifting from primary to tertiary treatment  
COFPST = reduction coefficient for phosphorus when shifting from secondary to tertiary treatment



COFPSEPT = reduction coefficient for phosphorus when shifting from septic systems to tertiary treatment

FUTPSN = future nitrogen load (lbs) from municipal point sources

FUTPSP = future phosphorus load (lbs) from municipal point sources

## 8.7 Agricultural BMP Cost Calculations

Information on how cost calculations are to be made in agricultural areas is derived primarily from the “*Rural Land BMP Scenario Editor*” and “*BMP Cost Editor*” input screens (see Section 10 for additional details). In the first screen, the user is asked to specify the amount of land on which various agricultural BMPs are to be applied. From these responses, the number of future (i.e., additional) acres needed under a future scenario are calculated. Then, based on the number of additional acres calculated for the BMPs, along with the corresponding unit costs specified in the “*BMP Cost Editor*” screen, the total costs associated with each agricultural BMP are determined as follows:

$$\begin{aligned} \text{BMP1COST} &= ((\text{FUTAC1} - \text{EXAC2}) / 100) * \text{EXROWAC} * \text{BMPUNIT1} \\ \text{BMP2COST} &= ((\text{FUTAC2} - \text{EXAC2}) / 100) * \text{EXROWAC} * \text{BMPUNIT2} \\ \text{BMP3COST} &= ((\text{FUTAC3} - \text{EXAC3}) / 100) * \text{EXROWAC} * \text{BMPUNIT3} \\ \text{BMP4COSTRC} &= ((\text{FUTAC4} - \text{EXAC4}) / 100) * \text{EXROWAC} * \text{BMPUNIT4} \\ \text{BMP4COSTHP} &= ((\text{FUTAC4} - \text{EXAC4}) / 100) * \text{EXHAYAC} * \text{BMPUNIT4} \\ \text{BMP5COSTRC} &= ((\text{FUTAC5} - \text{EXAC5}) / 100) * \text{EXROWAC} * \text{BMPUNIT5} \\ \text{BMP5COSTHP} &= ((\text{FUTAC5} - \text{EXAC5}) / 100) * \text{EXHAYAC} * \text{BMPUNIT5} \\ \text{BMP6COSTRC} &= ((\text{FUTAC6} - \text{EXAC6}) / 100) * \text{EXROWAC} * \text{BMPUNIT6} \\ \text{BMP6COSTHP} &= ((\text{FUTAC6} - \text{EXAC6}) / 100) * \text{EXHAYAC} * \text{BMPUNIT6} \\ \text{BMP7COST} &= ((\text{FUTAC7} - \text{EXAC7}) / 100) * \text{EXHAYAC} * \text{BMPUNIT7} \\ \text{BMP8COSTRC} &= ((\text{FUTAC8} - \text{EXAC8}) / 100) * \text{EXROWAC} * \text{BMPUNIT8} \\ \text{BMP8COSTHP} &= ((\text{FUTAC8} - \text{EXAC8}) / 100) * \text{EXHAYAC} * \text{BMPUNIT8} \\ \text{AGBMPCOST} &= \text{BMP1COST} + \text{BMP2COST} + \text{BMP3COST} + \text{BMP4COSTRC} + \\ &\quad \text{BMP4COSTHP} + \text{BMP5COSTRC} + \text{BMP5COSTHP} + \text{BMP6COSTRC} \\ &\quad + \text{BMP6COSTHP} + \text{BMP7COST} + \text{BMP8COSTRC} + \text{BMP8COSTHP} \end{aligned}$$

where:

FUTAC<sub>1-8</sub> = future number of acres (% of total) specified for BMP options 1-8

EXAC<sub>1-8</sub> = existing number of acres (% of total) specified for BMP options 1-8

EXROWAC = existing acres of row crops

EXHAYAC = existing acres of hay/pasture

BMPUNIT<sub>1-8</sub> = unit (per acre) cost of using BMP options 1-8

BMP1COST = aggregate cost for applying BMP 1

BMP2COST = aggregate cost for applying BMP 2

BMP3COST = aggregate cost for applying BMP 3

BMP4COSTRC = aggregate cost for applying BMP 4 on row crops

BMP4COSTHP = aggregate cost for applying BMP 4 on hay/pasture

BMP5COSTRC = aggregate cost for applying BMP 5 on row crops

BMP5COSTHP = aggregate cost for applying BMP 5 on hay/pasture

BMP6COSTRC = aggregate cost for applying BMP 6 on row crops

BMP6COSTHP = aggregate cost for applying BMP 6 on hay/pasture

BMP7COST = aggregate cost for applying BMP 7

BMP8COSTRC = aggregate cost for applying BMP 8 on row crops

BMP8COSTHP = aggregate cost for applying BMP 8 on hay/pasture

AGBMPCOST = total cost for agricultural BMPs

## 8.8 Farm Animal-Related Cost Calculations

As discussed earlier, BMP costs for farm animals are based on implementation per animal equivalent unit (AEU) rather than on area or distance as is done with many of the other BMPs. Information on animal AEU is drawn from the *“Rural Land BMP Scenario Editor”* (See Section 10 for further details). The following is an example of how costs are calculated for the implementation of the phytase feed BMP for poultry:

$$\text{PHYTASECOST} = ((\text{FUTPHYTASE} - \text{EXPHYTASE}) / 100) * \text{POULTRYAEU} \\ \text{POULTRYUNIT}$$

where:

PHYTASECOST = Total cost of phytase implementation  
FUTPHYTASE = Percentage of poultry population given phytase in the future  
EXPHYTASE = Existing percentage of poultry population on phytase feed  
POULTRYUNIT = Unit cost (\$/AEU) for phytase feed

*(Note: The AEU information given in the “Rural Land BMP Scenario Editor” is passed from AVGWLF to the scenario file brought into PRedICT. However, it can also be edited or entered manually as needed).*

## 8.9 Stream Activity Cost Calculations

Information on how cost calculations with respect to stream protection activities is derived primarily from the *“Rural Land BMP Scenario Editor”*, *“Urban Land BMP Scenario Editor”* and *“BMP Cost Editor”* input screens (see Section 10 for additional details). In the first screen, the user is asked to specify the length of stream miles on which various stream-related BMPs are to be applied. From these responses, the number of future (i.e., additional) stream miles or kilometers needed under a future scenario are calculated. Then, based on the number of additional stream length units calculated for the BMPs, along with the corresponding unit costs specified in the *“BMP Cost Editor”* screen, the total costs associated with each stream-related BMP are determined as follows:

$$\text{BUFCOST} = (\text{FUTSTRMBUF} - \text{EXSTRMBUF}) * \text{BUFUNIT} \\ \text{FENCOST} = (\text{FUTSTRMFEN} - \text{EXSTRMFEN}) * \text{FENUNIT} \\ \text{STABCOST} = (\text{FUTSTRMSTAB} - \text{EXSTRMSTAB}) * \text{STABUNIT} \\ \text{STRMCOST} = \text{BUFCOST} + \text{FENCOST} + \text{STABCOST}$$

where:

BUFCOST = cost for using vegetated buffer strips  
FENCOST = cost for using streambank fencing  
STABCOST = cost for using streambank stabilization  
FUTSTRMBUF = future miles of stream buffer in agricultural and urban areas  
EXSTRMBUF = existing miles of stream buffer in agricultural and urban areas  
FUTSTRMFEN = future miles of streambank fencing in agricultural areas  
EXSTRMFEN = existing miles of streambank fencing in agricultural areas  
FUTSTRMSTAB = future miles of stabilized stream in agricultural and urban areas  
EXSTRMSTAB = existing miles of stabilized stream in agricultural and urban areas

BUFUNIT = unit (per mile) cost of vegetated stream buffers  
 FENUNIT = unit (per mile) cost of streambank fencing  
 STABUNIT = unit (per mile) cost of streambank stabilization  
 STRMCOST = total cost for stream-related activities

### 8.10 Urban BMP Cost Calculations

Information on how cost calculations are to be made in urban areas is derived primarily from the “*Urban Land BMP Scenario Editor*” and “*BMP Cost Editor*” input screens (see Section 10 for additional details). In the first screen, the user is asked to specify the amount (i.e., percentage) of high and/or low density urban land that will be “treated” via the use of detention basins, bioretention areas and/or constructed wetlands under a future scenario. Based on the specified values, the amount of additional land (e.g., acres) required to handle surface water runoff from urban areas via each of these options is computed. The costs associated with implementing urban BMPs are then determined as follows:

$$URBCOST_{H,L} = (CWCOST * ADDCWAC_{H,L}) + (DBCOST * ADDDBAC_{H,L}) + (BACOST * ADDBAAC_{H,L})$$

where:

URBCOST<sub>H,L</sub> = total cost of urban BMPs in high (H) and low (L) density areas  
 CWCOST = cost per acre for constructed wetlands  
 ADDCWAC<sub>H,L</sub> = additional acres of constructed wetlands needed beyond existing acreage in high (H) or low (L) density urban land  
 DBCOST = cost per acre for detention basins  
 ADDDBAC<sub>H,L</sub> = additional acres of detention basins needed beyond existing acreage in high (H) or low (L) density urban land  
 BACOST = cost per acre for bioretention areas  
 ADDBAAC<sub>H,L</sub> = additional acres of bioretention areas needed beyond existing acreage in high (H) or low (L) density urban land

### 8.11 Wastewater Cost Calculations

Information on how cost calculations are to be made for various wastewater reduction options is derived primarily from the “*Septic System and Point Source Discharge Scenario Editor*” and “*BMP Cost Editor*” input screens (see Section 10 for additional details). In the first screen, the user is asked to input data relating to septic system conversions and wastewater treatment plant upgrades under a future scenario. Based on the input, wastewater loads are re-distributed and future costs associated with nutrient load reductions from septic system conversions and wastewater treatment plant upgrades are computed as follows:

*Step 1: Calculate septic system conversion costs*

If the number of septic systems in place under a “future” scenario is less than the number of existing systems, then septic system loads are computed as follows:

$$SEPTCOST = ((EXSEPPPOP - FUTSEPPPOP) / 4) * SEPUNIT$$

where:

SEPTCOST = septic system conversion cost  
FUTSEPPOP = future population (number of people) on septic systems  
EXSEPPOP = existing population (number of people) on septic systems  
SEPUNIT = unit (per home) cost of switching to a central sewer system

(Note: In the above calculation, a typical value of 4 persons per home [i.e., per septic system] is used)

*Step 2: Calculate wastewater treatment plant upgrade costs*

UPGRADPS = (EXPSPT / 100) \* EXPOPSEW \* (PT2ST / 100) \* PT2STUNIT  
UPGRADPT = (EXPSPT / 100) \* EXPOPSEW \* (PT2TT / 100) \* PT2TTUNIT  
UPGRADST = ((EXPSST / 100) \* EXPOPSEW \* (ST2TT / 100)) + ((EXSEPPOP - FUTSEPPOP) / 4) \* SEP2ST \* ST2TTUNIT  
WWUPCOST = SEPTCOST + UPGRADPS + UPGRADPT + UPGRADST

where:

UPGRADPS = cost of upgrading from primary to secondary treatment  
EXPSPT = existing amount (%) of point source load from primary treatment plants  
EXPOPSEW = existing population (no. people) on public sewers  
PT2ST = fraction (%) of primary treatment load shifted to secondary treatment  
PT2STUNIT = unit (per capita) cost for converting from primary to secondary treatment  
UPGRADPT = cost of upgrading from primary to tertiary treatment  
PT2TT = fraction (%) of primary treatment load shifted to tertiary treatment  
PT2TTUNIT = unit (per capita) cost for converting from primary to tertiary treatment  
UPGRADST = cost of upgrading from secondary to tertiary treatment  
EXPSST = existing amount (%) of point source load from secondary treatment plants  
ST2TT = fraction (%) of secondary treatment load shifted to tertiary treatment  
EXSEPPOP = existing population (number of people) on septic systems  
FUTSEPPOP = future population (number of people) on septic systems  
SEP2ST = septic system population (%) transferred to a secondary wastewater treatment plant  
ST2TTUNIT = unit (per capita) cost for converting from secondary to tertiary treatment  
WWUPCOST = total wastewater upgrade cost  
SEPTCOST = septic system conversion cost

## 9.0 OPTIMIZATION PROCEDURE

To investigate alternative pollution reduction strategies, an optimization procedure was built into earlier versions of *PRedICT*. The optimization module allowed the user to find BMP combinations that either achieved user-specified pollution reduction with least costs, or allowed maximum decreases in loads for a given BMP budget. While this

appeared to be a useful approach for identifying optimal reduction strategies, many problems were encountered when trying to execute this routine on computers other than those used during the development phase of the project (i.e., those outside of Penn State). This particular routine was developed to access the Microsoft solver that is familiar to many users of Microsoft Excel. However, after some time, it became apparent that not all computers functioned as expected due to differences in operating system, missing graphics and DLL files, etc. Due to the inherent difficulty of trying to make this routine work properly on all computers, it was decided to disable it until such time when a more universally-functional alternative becomes available.

## 10.0 STEP-BY-STEP INSTRUCTIONS FOR USING *PRedICT*

### 10.1 Installing and Executing *PRedICT*

The *PRedICT* software tool is installed automatically upon installation of the *AVGWLF* suite of programs. A description of the installation process for *AVGWLF* can be found in the *AVGWLF* Users Guide (Evans et al., 2006). Once the *PRedICT* folder and the required system files have been copied to your hard drive, you are ready to begin evaluating pollution reduction scenarios using *PRedICT*.

To begin using the software, double-click on the *PRedICT* icon appearing on your computer screen, or click on the *PRedICT* button appearing in the upper tool bar of the *AVGWLF* interface. Doing either of these will initiate the program, and the first screen as shown in Figure 15 will appear.

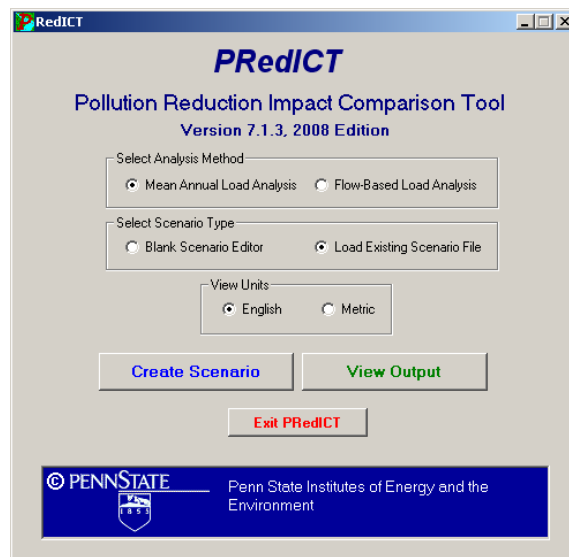


Figure 15. Initial *PRedICT* screen.

### 10.2 Creating an Initial Scenario

To create an initial scenario, first select the analysis method. By default, the **Mean Annual Load Analysis** is selected. Next, select the scenario type. If the user chooses to load a **Blank Scenario Editor** sheet, the next form to appear will be blank and the

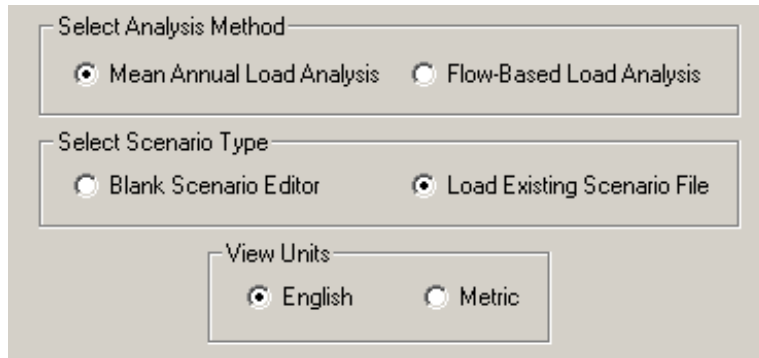


Figure 16. Scenario file selection screen.

user will have to enter the required data manually pertaining to watershed characteristics and loads. Loading an existing scenario file, however, is the most efficient way to begin using *PRedICT*. When the *AVGWLF* model is run, the input scenario files used in *PRedICT* are automatically created. These scenario files are located in the “output” directory created by the user when the *GWLF-E* model is run, and have the file extension “.scn”. When the **Load Existing Scenario File** option is used, the following screen (Figure 17) appears and prompts the user to locate a scenario file. Navigate to the directory containing one or more scenario files that you wish to use, and then double click the file to load the selected scenario file into the *PRedICT* tool. (Note: As shown in Figure 16, the user can opt to view data in either “English” units (feet, pounds, etc.) or in “Metric” units. Also, at the time of the creation of this manual, the Flow-Based Load Analysis method has not been implemented).

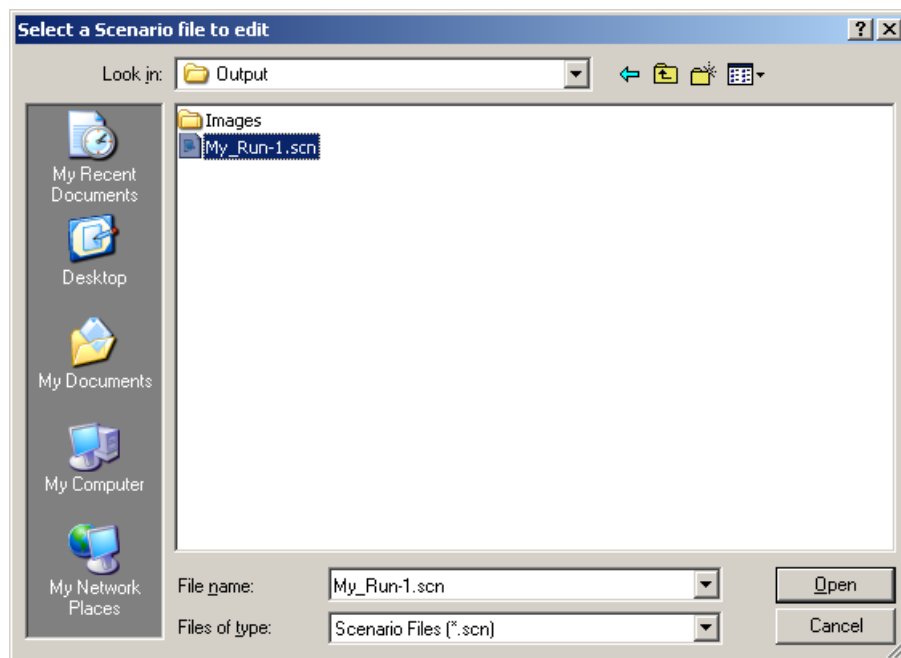


Figure 17. Load scenario file screen.

### 10.3 Mean Annual Load Data Editor

After the user has selected and loaded a particular scenario file, the **Mean Annual Load Data Editor** window as shown in Figure 18 will appear. (Note: if the “blank editor” option is used, all of the screens shown from this point onward will have “empty” cells that will need to be filled in by the user).

If the scenario file has been created via a GWLF-E model run, the cells will be filled in as shown in Figure 18. It is important to note that the values in these cells are editable, and may be changed if more accurate information is available. If the information is correct or has been edited appropriately, click the **Next** button at the bottom center of the form to move onto the next screen.

The screenshot shows a software window titled "RedICT - Project file name: My\_Run-1 Date: Dec, 2007". The main title is "Mean Annual Load Data Editor". The window contains a table with the following data:

Category	Total Sediment (lbs)	Total Nitrogen (lbs)	Total Phosphorus (lbs)
<b>UPLAND EROSION/RUNOFF</b>			
Row Crops	11,635,160	76,388	11,155
Hay/Pasture	1,000,882	20,576	2,519
High Density Urban	29,551	2,643	293
Low Density Urban	574,553	20,815	2,775
Unpaved Road	224,389	809	134
Other	2,154,230	8,322	1,085
<b>FARM ANIMALS</b>		2,059	442
<b>STREAMBANK EROSION</b>	43,775,631	2,189	963
<b>GROUNDWATER/SUBSURFACE</b>		777,981	8,120
<b>POINT SOURCE DISCHARGES</b>		3,476,033	231,769
<b>SEPTIC SYSTEMS</b>		1,385	158
<b>TOTAL</b>	59,394,396	4,389,201	259,412
<b>BASIN AREA (Acres)</b>	92,674		

At the bottom of the window, there are four buttons: "Restart", "Next", "Export to JPEG", and "Close".

Figure 18. Mean Annual Load Data screen.

### 10.4 Rural Land BMP Scenario Editor

The next form to open is the **Rural Land BMP Scenario Editor** (see Figure 19). When the form initially loads, all “% Existing” and “% Future” BMP values are set to zero unless they have been edited via the use of *AVGWLF* (see the *AVGWLF* User Guide for more details on how such edits to a scenario file are made as part on a model run). An explanation of each BMP can be obtained by placing the mouse cursor over the BMP label (BMP 1, BMP 2, etc.) as shown in Figure 20.

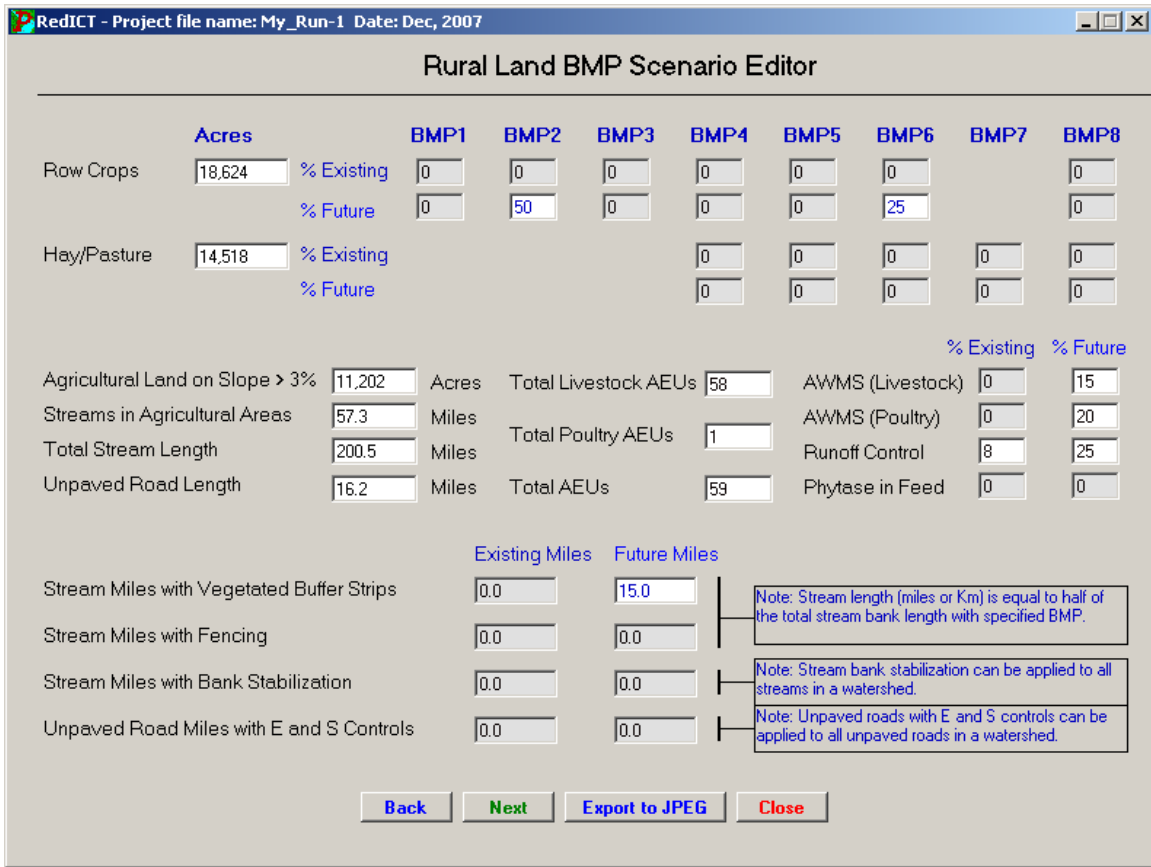


Figure 19. Rural Land BMP screen.

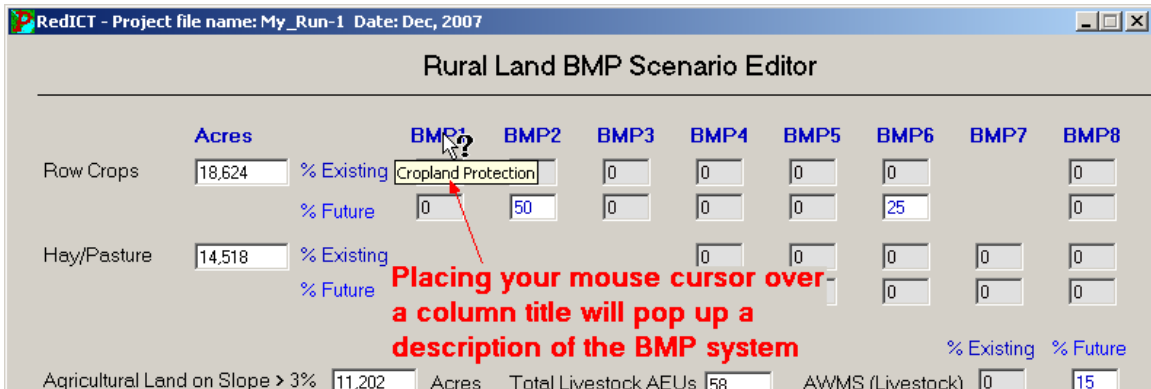


Figure 20. Identifying a BMP type.

To evaluate the impact of planned or proposed pollution mitigation activities, you can adjust values in the “% Future” cells to reflect future implementation of the options provided. Within *PRedICT*, the value specified in the “% Existing” or “% Future” cell is multiplied by the “Acres” value for either “Row Crops” or “Hay/Pasture” to determine the areal extent (e.g., number of acres) on which the particular BMP is used. The difference



between existing and future “implementation acres” is subsequently used to estimate future reductions in nutrient and/or sediment loads.

Within *PRedICT*, certain limitations have been placed on the percentages a user can specify for various BMPs under both existing and future conditions, including:

- The sum of the specified percentages for BMP1 through 5 plus BMP8 cannot be greater than 100%. BMP6 (nutrient management), however, can overlap with other BMPs.
- Terraces and diversions (BMP8) can only be applied on lands with a slope greater than 3%. Therefore, for both existing and future conditions, the percentage of total land to which this BMP can be applied cannot exceed the total number of acres with slopes greater than 3%.
- Similar to the above BMPs, stream protection options cannot be applied to a greater number of stream miles than available in agricultural areas.

When the values specified by the user violate these conditions, a message describing the problem will be provided as shown in Figure 21.

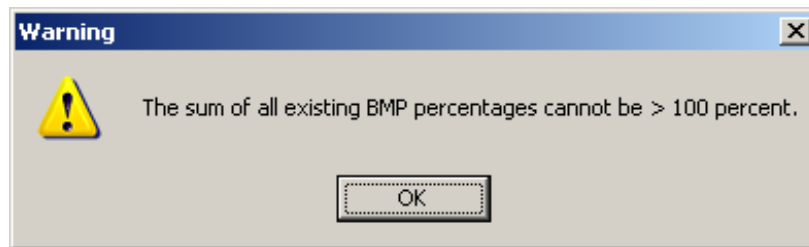


Figure 21. Example error message.

As with the other forms, unless the user enters all data manually the number of acres of row crops, hay/pasture, river miles, etc. are generated by *AVGWLF* automatically using data sets provided during the watershed modeling process. In rapidly developing areas, land use patterns may have changed significantly since the creation of the data sets. Therefore, you may choose to replace the *AVGWLF* estimates with more accurate information. When the **Next** button at the bottom center of this screen is clicked (see Figure 19), the **Urban Land BMP Scenario Editor** form appears as shown in Figure 22.

### 10.5 Urban Land BMP Scenario Editor

This input screen is divided into three parts which contain information pertaining to high density development, low density development, and stream protection activities. Constructed wetlands, bioretention areas, and detention basins are three BMP options for reducing runoff and the transport of sediment and nutrients to a stream from impervious surfaces. *PRedICT* offers the user the ability to set the current and future percentages of land area routed through these BMPs (i.e., % of area drained) for both high and low density urban areas.

RediCT - Project file name: My\_Run-1 Date: Dec, 2007

### Urban Land BMP Scenario Editor

**High Density Urban**

Acres       % Impervious Surface

<b>Constructed Wetlands</b>	<b>Bioretention Areas</b>	<b>Detention Basin</b>
% Existing <input type="text" value="0"/>	% Existing <input type="text" value="0"/>	% Existing <input type="text" value="0"/>
% Future <input type="text" value="0"/>	% Future <input type="text" value="0"/>	% Future <input type="text" value="0"/>
% Drainage Area Used <input type="text" value="5.0"/>	% Drainage Area Used <input type="text" value="6.0"/>	% Drainage Area Used <input type="text" value="3.0"/>
Impervious Acres Drained <input type="text" value="0.0"/>	Impervious Acres Drained <input type="text" value="0.0"/>	Impervious Acres Drained <input type="text" value="0.0"/>
CW Acres Required <input type="text" value="0.0"/>	BA Acres Required <input type="text" value="0.0"/>	DB Acres Required <input type="text" value="0.0"/>

**Low Density Urban**

Acres       % Impervious Surface

<b>Constructed Wetlands</b>	<b>Bioretention Areas</b>	<b>Detention Basin</b>
% Existing <input type="text" value="0"/>	% Existing <input type="text" value="0"/>	% Existing <input type="text" value="0"/>
% Future <input type="text" value="16"/>	% Future <input type="text" value="0"/>	% Future <input type="text" value="0"/>
% Drainage Area Used <input type="text" value="3.0"/>	% Drainage Area Used <input type="text" value="6.0"/>	% Drainage Area Used <input type="text" value="2.0"/>
Impervious Acres Drained <input type="text" value="719.2"/>	Impervious Acres Drained <input type="text" value="0.0"/>	Impervious Acres Drained <input type="text" value="0.0"/>
CW Acres Required <input type="text" value="86.3"/>	BA Acres Required <input type="text" value="0.0"/>	DB Acres Required <input type="text" value="0.0"/>

**Stream Protection**

Stream miles in high density urban areas <input type="text" value="1.5"/>	Stream miles in high density urban areas w/buffers <input type="text" value="0.0"/>	Existing	Future
	High density urban Streambank Stabilization <input type="text" value="0.0"/>	<input type="text" value="0.0"/>	<input type="text" value="0.0"/>
Stream miles in low density urban areas <input type="text" value="38.6"/>	Stream miles in low density urban areas w/buffers <input type="text" value="0.0"/>	<input type="text" value="0.0"/>	<input type="text" value="0.0"/>
	Low density urban Streambank Stabilization <input type="text" value="0.0"/>	<input type="text" value="0.0"/>	<input type="text" value="0.0"/>

Figure 22. Urban Land Scenario Editor.

As with the Rural Land BMP Scenario Editor, certain restrictions have been placed on the percentages that the user can assign to the current and future conditions. For example, the sum of either present or future percent area drained for the three BMP options cannot exceed 100%. If this or any other of the required conditions are violated, the user last entry will be corrected to equal 100%.

Also similar to the **Rural Land BMP Scenario Editor**, you can evaluate the potential effects that projected urban BMPs might have on nutrient and sediment loads by adjusting the “% Existing” (if needed) and “% Future” settings for any or all of the BMP options. As the values in any of the “%” cells are incremented, the estimated values for two other cells (“Impervious Acres Drained” and “Acres Required”) are automatically calculated. The “Impervious Acres Required” value is used to estimate costs for that particular BMP as explained later. This value is calculated as follows:

$$\text{IMPDRAIN} = (\text{FUTBMP}\% - \text{EXBMP}\%) * \text{AREAHD} * \% \text{IMPSURF}$$

where:

- IMPDRAIN = acres of impervious area drained
- FUTBMP% = future percentage of area to which BMP is applied
- EXBMP% = existing percentage of area to which BMP is applied
- %IMPSURF = a value representing the typical percentage of high or low density urban areas that are impervious

*Note that the default values for “% Impervious Surface” for high and low density areas are 50% and 25%, respectively. While these are believed to be representative of such areas in many cases, these values may be changed by the user as appropriate.*

The “Acres Required” cell value for each BMP is intended to give the user a sense of the amount of land area that may be required to construct the particular BMP. This value is computed as:

$$\text{BMPACREQ} = (\text{FUTBMP}\% - \text{EXBMP}\%) * \text{AREAHD} * \% \text{DRAINUSED}$$

where:

BMPACREQ = acres required to construct the BMP  
FUTBMP% = future percentage of area to which BMP is applied  
EXBMP% = existing percentage of area to which BMP is applied  
%DRAINUSED = recommended percentage of area to be used

*Note that the value in the “% Drainage Area Used” cell (%DRAINUSED above) represents the recommended percentage of a drainage area that should be set aside to construct the BMP being evaluated. For example, the “set-aside” values for constructed wetlands, bioretention areas, and detention basins are 5%, 6% and 3%, respectively. These values are based on literature estimates and should be changed if they do not adequately reflect local conditions.*

After all of the cells in the **Urban Land BMP Scenario Editor** have been populated, pressing the **Next** button will load the **Septic System and Point Source Discharge Scenario Editor** as shown in Figure 23.

## **10.6 Septic System and Point Source Discharge Scenario Editor**

This form provides the user with the ability to enter information on the number of persons currently on different types of septic and public sewer systems, and to specify future conditions based upon percentages of the population upgraded from the existing condition to primary, secondary and tertiary sewage treatment plants (STPs).

When the form initially loads, only the cells containing information on the number of persons on septic systems and public sewers are populated. These numbers are estimates generated from *AVGWLF*, and may be altered if more accurate information is available. To investigate the costs of different septic and STP nutrient load reduction strategies, the user is required to enter information on the existing conditions in the watershed. Information on the current distribution of pollutant discharges by treatment type can be entered in the appropriate cells in the center of the form. The sum of these percentages should be equal to 100%. If they are not, a warning message will appear and the user will be prompted to correct the information before continuing (see Figure 24).



## 10.7 Rural and Urban BMP Load Reduction Efficiency Editor

RedICT-Project file name: My\_Run-1 Date: Dec, 2007

### Rural BMP Load Reduction Efficiency Editor

BMP Type	N	P	Sed	Path
BMP 1	0.25	0.36	0.35	
BMP 2	0.50	0.38	0.64	
BMP 3	0.23	0.40	0.41	
BMP 4	0.95	0.94	0.92	
BMP 5	0.96	0.98	0.98	
BMP 6	0.70	0.28		
BMP 7	0.43	0.34	0.13	
BMP 8	0.44	0.42	0.71	
Vegetated Buffer Strips	0.64	0.52	0.58	0.70
Streambank Fencing	0.56	0.78	0.76	1.00
Streambank Stabilization	0.95	0.95	0.95	
Unpaved Road (lbs/ft)	0.02	0.0035	2.55	
AWMS (Livestock)	0.75	0.75		0.75
AWMS (Poultry)	0.14	0.14		0.14
Runoff Control	0.15	0.15		0.15
Phytase in Feed		0.21		

### Urban BMP Load Reduction Efficiency Editor

BMP Type	N	P	Sed	Path
Constructed Wetlands	0.53	0.51	0.88	0.71
Bioretention Areas	0.46	0.61	0.10	0.82
Detention Basins	0.40	0.51	0.93	0.71

Figure 25. Rural and urban BMP efficiency values.

The **Rural and Urban BMP Load Reduction Efficiency Editor** form depicts default values used for BMP efficiency. More specifically, the default values in each of the cells represent the fraction by which pollutant loads are expected to be reduced by implementing a particular BMP type. While these values were obtained from the literature and are considered to be representative in terms of potential reductions, each of the cell values are editable and should be altered if the user believes them to be in error or not representative of local conditions.

As described previously, the coefficients for agricultural BMPs (BMP1 through BMP8) are applied to the loads from areas in crops and/or hay/pasture. Reductions from the use of stream buffers are applied to both agricultural and urban land loads depending upon how these values are set in the “Rural” and “Urban” land forms (Figures 19 and 22, respectively). The “Streambank Stabilization” reduction coefficients are only applied to the “Streambank Erosion” portion of the watershed loads (see Figure 28). In the case of “Streambank Fencing”, the coefficients for nitrogen, phosphorus and sediment shown in Figure 26 are only applied to the “Streambank Erosion” portions of the respective loads. In addition, a reduction coefficient of 1.0 (100%) is applied to the “in-stream deposit” component of the “Animal Load” (see Figure 28) for each fraction of agricultural land protected by streambank fencing.

Once any changes to the BMP efficiencies have been made, clicking the **Next** button will activate the **Wastewater Discharge Reduction Efficiency Editor** shown in Figure 26.

### 10.8 Wastewater Discharge Load Reduction Efficiency Editor

	N	P	Path
Conversion of Septic System to Secondary Treatment Plant	0.14	0.10	0.99
Conversion of Septic System to Tertiary Treatment Plant	0.56	0.60	0.99
Conversion of Primary Treatment to Secondary Treatment	0.14	0.10	
Conversion of Primary Treatment to Tertiary Treatment	0.56	0.60	
Conversion of Secondary Treatment to Tertiary Treatment	0.42	0.50	

	Existing	Future
WWTP Pathogen Distribution (cfu/100mL)	9600	9600

Buttons: Back, Next, Export to JPEG, Close, Reset Defaults

Figure 26. Wastewater upgrade efficiency values.

Similar to the **Rural and Urban BMP Load Reduction Efficiency Editor**, the **Wastewater Discharge Reduction Efficiency Editor** illustrates the reduction in nitrogen and phosphorus loads expected by upgrading existing septic systems and sewage treatment facilities. The default estimates were obtained from the literature, but may be altered given more accurate information on the technology to be implemented.

After making changes to the default values, pressing the **Next** button will load the **BMP Cost Editor** shown in Figure 27.

## 10.9 BMP Cost Editor

**BMP Cost Editor**

**Rural BMPs**

Conservation Tillage (per acre)	\$ <input type="text" value="30.00"/>	AWMS/Livestock (per AEU)	\$ <input type="text" value="1,250.00"/>
Cropland Protection (per acre)	\$ <input type="text" value="25.00"/>	AWMS/Poultry (per AEU)	\$ <input type="text" value="520.00"/>
Grazing Land Management (per acre)	\$ <input type="text" value="360.00"/>	Runoff Control (per AEU)	\$ <input type="text" value="300.00"/>
Strip Cropping/Contour Farming (per acre)	\$ <input type="text" value="10.00"/>	Phytase in Feed (per AEU)	\$ <input type="text" value="2.50"/>
Streambank Fencing (per mile)	\$ <input type="text" value="15,000.00"/>	Nutrient Management (per acre)	\$ <input type="text" value="110.00"/>
Streambank Stabilization (per foot)	\$ <input type="text" value="25.00"/>	Unpaved Road (per foot)	\$ <input type="text" value="5.58"/>
Vegetated Buffer Strip (per mile)	\$ <input type="text" value="1,500.00"/>	Ag to Forest (per acre)	\$ <input type="text" value="5,000.00"/>
Terraces and Diversions (per acre)	\$ <input type="text" value="500.00"/>	Ag to Wetland (per acre)	\$ <input type="text" value="5,000.00"/>

**Urban BMPs\***

Constructed Wetlands	\$ <input type="text" value="13,400.00"/>	Bioretention Areas	\$ <input type="text" value="8,000.00"/>	Detention Basin	\$ <input type="text" value="10,700.00"/>
----------------------	---	--------------------	--	-----------------	---

\*(costs are per impervious acre drained)

**Septic System and Point Source Upgrades**

Conversion of Septic Systems to Centralized Sewage Treatment (per home)	\$ <input type="text" value="15,000.00"/>
Conversion from Primary to Secondary Sewage Treatment (per capita)	\$ <input type="text" value="250.00"/>
Conversion from Primary to Tertiary Sewage Treatment (per capita)	\$ <input type="text" value="300.00"/>
Conversion from Secondary to Tertiary Sewage Treatment (per capita)	\$ <input type="text" value="150.00"/>

Project Name:

Figure 27. BMP cost data.

The **BMP Cost Editor** form contains information pertaining to the per unit costs of implementing various rural and urban BMPs, stream protection activities and wastewater upgrades. These costs were obtained from a variety of sources as explained previously. While the values provided are believed to be reasonable, considerable regional variation in implementation costs may exist. The user is urged to update the provided information based on local consulting and construction company rates, material costs, etc.

## 10.10 Executing a Scenario Run

After the costs associated with the proposed improvements have been updated, you may execute the *PRedICT* model. After specifying a project name, click the **Run** button. Next, select a name for your scenario file, and a location where you wish to save the data you provided. The */PRedICT/* folder is the default directory, but you may save the data anywhere on your computer. If the specified scenario file name already exists on your computer, you will be asked if you want to overwrite the existing file. If you do, simply click **Yes**. Otherwise click the **No** button and rename the scenario file.

## 10.11 PRedICT Output

After PRedICT has computed the load reductions that would result from a given scenario (i.e., user-specified combination of BMP settings), the **Estimated Load Reductions** form containing the results will appear as shown in Figure 28.

	Existing (lbs)			Future (lbs)			
	Total Sed	Total N	Total P	Total Sed	Total N	Total P	
<b>UPLAND EROSION / RUNOFF</b>							
Row Crops	11,635,160	76,388	11,155	6,710,624	39,346	7,259	
Hay/Pasture	1,000,882	20,576	2,519	1,000,882	20,576	2,519	
High Density Urban	29,551	2,643	293	29,551	2,643	293	
Low Density Urban	574,553	20,815	2,775	493,656	19,050	2,549	
Unpaved Roads	224,389	809	134	224,389	809	134	
Other	2,154,230	8,322	1,085	2,154,230	8,322	1,085	
<b>FARM ANIMALS</b>		2,059	442		2,131	452	
<b>STREAMBANK EROSION</b>		43,775,631	2,189	963	43,775,631	2,189	963
<b>GROUNDWATER / SUBSURFACE</b>			777,981	8,120		777,661	8,006
<b>POINT SOURCE DISCHARGES</b>			3,476,033	231,769		3,476,033	231,769
<b>SEPTIC SYSTEMS</b>			1,385	158		1,385	158
<b>TOTALS</b>		59,394,396	4,389,200	259,413	54,388,963	4,350,145	255,186
<b>PERCENT REDUCTIONS</b>					8.4	0.9	1.8
<b>TOTAL SCENARIO COST</b>		\$10,487,788.00					
Rural BMP	7.5%	WW Upgrade Cost	0.0%	Urban BMP Cost	91.9%		
Stream Protection Cost	0.4%	Unpaved Road Protection Cost	0.0%	Animal BMP Cost	0.1%		

Buttons: Pathogen Loads, Export to JPEG, Generate Report, Close

Figure 28. Example output from user-specified settings.

This form contains the initial nitrogen, phosphorus, and sediment load information provided either by *AVGWLF* or manual entry in the **Mean Annual Load Data Editor** form, and the estimates of future loads after implementation of the specified BMPs and other mitigation activities. The cells towards the bottom of the form with yellow and blue background color represent the total existing and future loads and the estimates of the percent reduction in nutrient loads realized through the implementation of the various mitigation activities. Other cells below these totals provide a total scenario cost, as well as a distribution of the total cost by activity type (i.e., rural BMP, urban BMP, animal BMP, stream protection, and wastewater treatment upgrade).

At this point, you can exit the current run by clicking on the **Exit** button. This will bring you back to the initial PRedICT screen as shown in Figure 15, and you can then



opt to exit *PRedICT* completely, or to evaluate another scenario. Or, you can view potential pathogen load reductions that might be achieved via the particular scenario just evaluated. This is done by clicking on the **Pathogen Loads** button shown in Figure 28 to reveal a new screen similar to that presented in Figure 29.

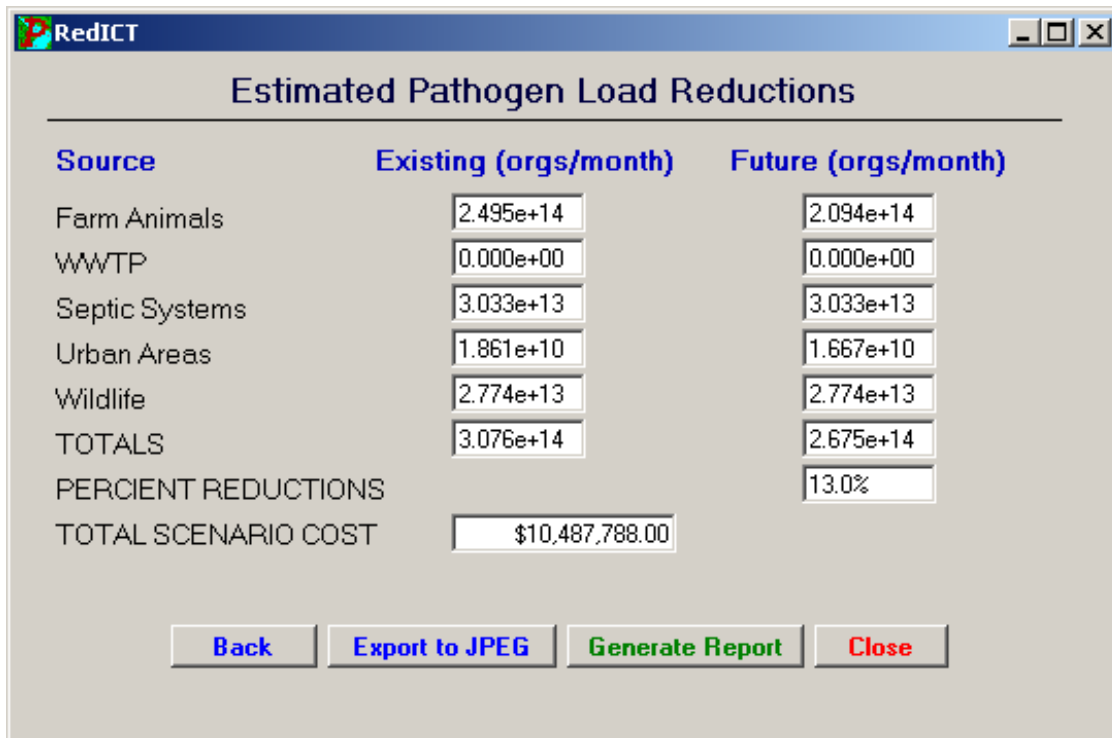


Figure 29. Example pathogen load output.

In conducting multiple scenarios, you can create new scenarios using the initial scenario file or build upon recent scenario files by editing them further. In conducting multiple runs, it is often desirable (in fact, necessary) to evaluate the input settings and resulting output for previous scenarios. To facilitate this activity, a “reporting” function has been built into *PRedICT*. As can be seen in Figure 28, there is a **Generate Report** button located at the bottom of this particular form. Upon clicking on this button, “screen captures” are made of all the preceding input screens and included in a Word file. This Word file is given the name specified in the “Project Name” cell shown in Figure 27, and placed in the same directory as the scenario file. As described earlier in this document, the **Perform Optimization** button has been disabled until a routine that functions better across all computer platforms can be developed. It is anticipated that a new optimization routine will be incorporated into *PRedICT* by the end of 2008.

## 11.0 *PRedICT* JPEG EXPORT FILE NAME LIST

### Input Data Editors:

"Watershed ID"MMYYYY_mald.jpg	- Mean Annual Load
"Watershed ID"MMYYYY_rlbmp.jpg	- Rural Land BMP
"Watershed ID"MMYYYY_ulbmp.jpg	- Urban Land BMP
"Watershed ID"MMYYYY_sspsd.jpg	- Septic System & Point Source Discharge
"Watershed ID"MMYYYY_rulre.jpg	- Rural & Urban Load Reduction Efficiencies
"Watershed ID"MMYYYY_wdre.jpg	- Wastewater Discharge BMP Red. Efficiencies
"Watershed ID"MMYYYY_coste.jpg	- BMP Costs

### Result Data:

"Watershed ID"MMYYYY_elr.jpg	- Estimated Load Reductions
"Watershed ID"MMYYYY_eplr.jpg	- Estimated Pathogen Load Reductions

## 12.0 UPDATING *PRedICT*

As *PRedICT* progresses, new updates will be available for download. To receive the latest updates available, please complete the following steps:

1. After installing *PRedICT* for the first time, register your copy of *PRedICT* by clicking the *Register PRedICT* shortcut located within the Start\Programs\ERR\PRedICT shortcut menu.
2. Next, check for the latest information regarding new updates by clicking the *PRedICT Homepage* shortcut located within the Start\Programs\ERR\PRedICT shortcut menu.
3. If a new update exists that you haven't installed yet, download the new update by clicking the update that you need.
4. When downloading the new files, save them to a "temp" directory. They are not needed once they are installed. Once downloaded, simply click the corresponding executable to begin the update installation. Once installed, you can delete the downloaded executable from the temp directory. Read the "ReadMe" and "ChangeLog" files for important information contained within each update and to learn what changes were made.

## 13.0 REPORTING A *PRedICT* BUG

If you encounter a bug while using *PRedICT*, you can make the development team aware of the problem by reporting it using a built-in tool. To report a bug, choose the *Report a Bug* shortcut located within the Start\Programs\ERR\PRedICT shortcut menu. Your web browser will open to the *PRedICT* Bug Reporter web page. To report a bug, fill out the required information and click Submit. An email containing your information will then be sent to the development team.

## 14.0 CONTACT INFORMATION

If there are any additional questions, feel free to contact one of the following *PRedICT* representatives.

### ***PRedICT* WEB SITE:**

<http://www.predict.psu.edu>

### **FOR ADMINISTRATIVE AND TECHNICAL QUESTIONS:**

BARRY EVANS  
PHONE: (814) 865-3357  
EMAIL: [bme1@psu.edu](mailto:bme1@psu.edu)

### **FOR TECHNICAL QUESTIONS:**

SCOTT SHEEDER  
PHONE: (814) 863-5541  
EMAIL: [sas371@psu.edu](mailto:sas371@psu.edu)

DAVID LEHNING  
PHONE: (814) 865-6965  
EMAIL: [dwl6@psu.edu](mailto:dwl6@psu.edu)

KENNETH CORRADINI  
PHONE: (814) 865-6966  
EMAIL: [kjc139@psu.edu](mailto:kjc139@psu.edu)

## 15.0 REFERENCES

- Beegle, D. and L. Lanyon, 1994. Understanding the nutrient management process. J. Soil Water Conservation.
- CH2M-Hill, 1998. Pennsylvania Handbook of Best Management Practices for Developing Areas.
- Chesapeake Bay Commission, 2004. Cost Effective Strategies for the Bay. 14 pp.
- Chesapeake Bay Program. 1998. *Nutrient Reduction Progress and Future Directions*. Summary Report CBP/TRS 189/97.
- Dillaha, Yagow and Pease, 2000. BMP and Cost Effectiveness Literature Review. Virginia Tech University, Blacksburg, VA.
- Evans, B.M., D.W. Lehning, K.J. Corradini, G.W. Petersen, E. Nizeyimana, J.M. Hamlett, P.D. Robillard, and R.L. Day, 2002. A Comprehensive GIS-Based Modeling Approach for Predicting Nutrient Loads in Watersheds. J. Spatial Hydrology, Vol. 2, No. 2.
- Evans, B.M., S.A. Sheeder, and K.J. Corradini, 2001. AVGWLF, Version 4.03: Users Guide. Environmental Resources Research Institute, Penn State University, 73 pp.
- Field, R., 1990. Combined Sewer Overflows: Control and Treatment, In: *Control and Treatment of Combined Sewer Overflows*, Editor, P.E. Moffa, Van Nostrand Reinhold, New York, NY, pp. 119-190.
- Linker, L.C., G.W. Shenk, R.L. Dennis, and J.L. Sweeney. 1999. Cross-Media Models for the Chesapeake Bay Watershed and Airshed. November, 1999. Chesapeake Bay Program Office, Annapolis, MD.
- Maryland Department of the Environment, 2006. Maryland's 2006 TMDL Implementation Guidance for Local Governments. 179 pp.
- Novotny, V. and O.H. Olem, 1994. Water Quality: Prevention, Identification, and Management of Diffuse Pollution. Van Nostrand Reinhold, New York.
- NRCS, 1998. National handbook of conservation practices. NRCS-USDA, Washington, D.C.
- Pennsylvania Conservation Partnership, 2000. A Conservation Catalog: *Practices for the Conservation of Pennsylvania's Natural Resources*.
- Ristenpart, E. and A. Prigge, 2002. Measures and Methods Against Diffuse Water Pollution Caused by Urban Drainage. In: Proc. International Conference on Diffuse Pollution, Amsterdam, Netherlands, pp. 77-84.
- Ritter, W.F. and A. Shirmohammadi, 2001. Agricultural Non-point Source Pollution: Watershed Management and Hydrology. Lewis Publishers, New York.
- Schardt, L., 1997. Natural Resources Conservation for the New Millennium (Course Manual for Soils 422 at Penn State).

- Susquehanna River Basin Commission, 1998. Nutrient Reduction Cost Effectiveness Analysis, 1996 Update. Harrisburg, PA.
- SWCS, 1982. Resource conservation glossary, 3<sup>rd</sup> edition. Soil Conservation Society of America, Ankeny, IA.
- U.S. EPA, 1990. Guidance Specifying Management Measures for Sources of Non-point Pollution in Coastal Waters. Office of Water, Washington, D.C. Rep. 840-B-92-002.
- U.S. EPA, 1995. Chesapeake Bay Program Watershed Model Application to Calculate Bay Nutrient Loadings. U.S. EPA Chesapeake Bay Program, Annapolis, MD.
- U.S. EPA, 1999. *Protocols for developing nutrient TMDLs*. EPA 841-B-99-007. Office of Water (4503 F), Washington, D.C.
- U.S. EPA, 2000. Low Impact Development (LID). Office of Water, Washington, D.C., Report No. EPA-841-B-00-005.
- U.S. EPA, 2001. *Protocols for developing pathogen TMDLs*. EPA 841-R-00-002. Office of Water (4503 F), Washington, D.C.
- U.S. EPA, 2002. *Urban Stormwater BMP Performance Monitoring: A Guidance Manual for Meeting the National Stormwater BMP Database Requirements*. EPA 821-C-02-005. U.S. Environmental Protection Agency, Office of Water, Washington, D.C. April.
- U.S. EPA, 2003. Managing Urban Watershed Pathogen Contamination. National Risk Management Research Laboratory, Cincinnati, OH, EPA/600/R-03/111.
- U.S. EPA, 2005. Handbook for Developing Watershed Plans to Restore and Protect Our Waters. Office of Water, Washington, D.C., 414 pp.
- Zehnder, C.M. and A. DiCostanzo, 1997. Estimating Feedlot Nutrient Budgets and Managing Manure Output. Minnesota Cattle Feeder Report B-450, 7 pp.