Nonpoint Source Implementation of the Phase II TMDLs

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Prepared in accordance with condition (# 303o-14) of the United States Environmental Protection Filtration Avoidance Determination of December 1997 and the NYC Watershed Memorandum of Agreement 1997.

This document evaluates and identifies potential management practices and programs for controlling nonpoint source pollution which, if implemented, would provide reasonable assurances that nonpoint source reductions attain the Phase II TMDL Load Allocations.

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1. Introduction

1.1 Goals

This report is one in a long series of technical documents supporting the development of Total Maximum Daily Loads (TMDLs) in the New York City (NYC) watershed. The purpose of this document is to identify the potential management practices which could be used in TMDL implementation for those reservoirs requiring phosphorus load reductions. The overriding goal of the TMDL process is to achieve water quality standards, not to simply calculate the loading levels required. Therefore, plans for implementing the required reductions need to be developed.

TMDL implementation focuses on reductions from existing sources of phosphorus. Several reservoirs are currently exceeding their TMDLs, and reductions in the existing sources are needed to achieve the phosphorus water quality standard in the reservoirs. Management of future sources, such as new development, falls under the category of watershed management. Effective watershed management is a critical component in meeting water quality standards, particularly in the basins that already require phosphorus reductions but it will not be specifically addressed as part of this report.

1.2 Critical Questions

There are a number of critical questions that must be addressed in the planning phase of TMDL implementation:

1. *How much phosphorus must be reduced?*
   The necessary phosphorus load reductions are included as part of the TMDL analyses. The estimated reduction from the wastewater treatment plant upgrade program as well as the effects of upstream compliance with the Phase II TMDLs are also included in the Phase II TMDL Reservoir Reports.

2. *What information is necessary to determine what reductions are possible?*
   The Phase II TMDL Reservoir Reports present phosphorus modeling results for each basin. This provides the initial assessment of sources, but to determine where and how reductions can be obtained requires a more detailed knowledge of each basin.

3. *Do programs exist to address these nonpoint source reductions?*
   This report will examine existing State and City programs that may impact nonpoint sources of phosphorus. This information will allow a future assessment to indicate if existing programs are sufficient or if they require modification to accommodate TMDL implementation and whether new programs are necessary.

4. *How should the reductions be prioritized?*
   The calculated total load reduction required does not indicate how the load reduction should be or can be distributed within the watershed. There are a variety of allocation options available. Several of these options will be described and quantified in later sections of this report.

This report will start to provide answers to these critical questions by compiling pertinent information on City and State programs and conducting some additional analyses of allocation options. However, it must be stressed that the implementation of the New York City watershed TMDLs will require a comprehensive program involving a number of stakeholders.

2. Background

2.1 TMDL Process

The Clean Water Act [CWA§303(D)33U.S.C.A.§1313(D)] requires states to develop TMDLs for water quality-limited waters, or those waterbodies that are not attaining water quality standards with technology based controls alone. These water bodies are listed in the NewYork State (NYS) biennial 303d list, which is developed from waterbodies listed on the Priority Waterbody List. The TMDL process is a watershed-based approach to manage both point and nonpoint sources of a pollutant to achieve water quality standards.

The NYC reservoirs have been on the 303d list for TMDL development since 1994. In the NYC watershed, TMDL development has been a joint effort between the United States Environmental Protection Agency (EPA), New York State Department of Environmental Conservation (DEC), and the New York City Department of Environmental Protection (DEP). DEC is the agency responsible for submitting the TMDLs to EPA. DEP is providing technical assistance to the State, which primarily consists of phosphorus modeling, data analysis, and preliminary TMDL calculations. The TMDL program is being conducted in phases, so that pollution reduction strategies can be implemented as soon as possible in the reservoirs exceeding their TMDLs. Phase I consisted of the application of basic models utilizing available data; Phase II consisted of model refinement and additional data. The TMDL process in the NYC watershed is incorporated in the New York City Watershed Memorandum of Agreement (MOA, 1997), which contains specific project deadlines and Filtration Avoidance Determination (FAD) deliverables for the TMDL modeling and implementation.

Development of the Phase I TMDLs started in 1995. DEP released the Phase I Methodology and nineteen TMDL Reservoir Reports in June and September of 1996. DEC prepared draft Phase I TMDLs which were public noticed in October 1996 and public meetings were held during November 1996. The Phase I TMDLs were submitted to EPA in January and approved in April 1997. DEP and DEC continued work on TMDL implementation during 1997 and 1998, and released several reports on nonpoint implementation of the Phase I TMDLs.

DEP started development of the Phase II TMDLs immediately upon completion of the Phase I TMDL technical reports. The first draft of the Phase II Methodology Report was released as a FAD deliverable in December 1996. A final draft of the methodology was released for public comment in April 1998 and the interagency workgroup formally agreed to the Phase II Methodology in June 1998. This formal approval triggered subsequent due dates for the Phase II TMDL process. DEP released the Phase II TMDL technical reports in March 1999 which consisted of the Phase II TMDL Methodology Report, the Phase II TMDL Phosphorus Guidance Value Report and nineteen Phase II TMDL Reservoir Reports. DEC prepared draft Phase II TMDLs which were public noticed in November 1999 and four public meetings were held between December

1999 and February 2000. The Phase II TMDLs were submitted to EPA in June 2000 and approved in October 2000. As in Phase I, DEP and DEC are continuing the process with this report on potential management practices which will be followed by a second report which will identify potential nonpoint source management practices they will implement and practices to be implemented by other parties.

2.2 Phase II TMDL Results

The Phase II TMDLs are based on attaining a phosphorus value of 15 ug/l for the seven source water reservoirs (Kensico, West Branch, Rondout, Ashokan, New Croton, Cross River and Croton Falls) and attaining the NYS phosphorus guidance value of 20 ug/l for the remaining upstream reservoirs. Ten of the nineteen reservoirs currently exceed their Phase II TMDL and require phosphorus reductions. The Cannonsville Reservoir is the only reservoir in the Catskill / Delaware system that exceeds its Phase II TMDL. The other nine reservoirs exceeding their Phase II TMDLs are located in the Croton System.

A summary of the Phase II TMDLs for the NYC reservoirs are provided in Table 2.1. A variety of calculations are represented which are briefly discussed below. More information on the analyses can be found in the Phase II Methodology and the individual reservoir reports.

TMDL. The TMDL represents the phosphorus load that will achieve the specified guidance value as a geometric mean phosphorus concentration during the reservoir growing season. A five year average of reservoir conditions (1992 - 1996) has been used for the TMDL calculation to accommodate annual variability in either loading or hydrology.

MOS. The Margin of Safety (MOS) is intended to account for the uncertainty about the relationship between the pollutant loads and the water quality of the receiving water body. The Phase II MOS varies between 10% and 20% of the TMDL depending on the variability of the reservoir phosphorus concentrations during the five year period used to determine the TMDL.

Available Load. The Available Load is equal to the TMDL minus the MOS. It represents the phosphorus load available for allocation between point and nonpoint sources within the basin.

WLA. The Wasteload Allocation (WLA) is the portion of the TMDL allocated to point sources. Each wastewater treatment plant in the watershed is assigned a fixed daily phosphorus load based on the permitted flow and phosphorus effluent concentrations contained in the plant's SPDES permit. The WLA represents the maximum permissible load from each wastewater treatment plant.

LA. The Load Allocation (LA) is the portion of the TMDL allocated to nonpoint sources. It is equal to the remaining load in the TMDL after the MOS and WLA are accounted for.

Current Load. The Current Load is calculated from monitored phosphorus concentrations in the reservoir for the same five year period as the TMDL.

Total Load Reduction. The Total Load Reduction represents the total amount of phosphorus that must be reduced in order for the basin to be in compliance with the Phase II TMDL. It is calculated as the difference between the Available Load and the Current Load.

WWTP Reduction. The Wastewater Treatment Plant (WWTP) Reduction represents the reduction in phosphorus load that can be credited to the Total Load Reduction required due to the upgrade of the wastewater treatment plants. It is calculated by comparing the actual WWTP loads during 1996 with the WLAs. If the 1996 WWTP loads are greater, than the difference can be credited toward the required load reduction.

Upstream Reduction. The Upstream Reduction represents the expected reduction to that individual reservoir once all upstream reservoirs are in full compliance with their TMDLs.

Nonpoint Source Reduction. The Nonpoint Source Reduction (NPS) represents any remaining reduction required, after taking into account the WWTP Reduction and the Upstream Reduction, in order to achieve the Phase II TMDL.

The Cannonsville Reservoir is anticipated to be in compliance with its Phase II TMDL once the wastewater treatment plants are fully upgraded. All nine of the reservoirs in the Croton System that exceed their Phase II TMDLs require additional phosphorus load reductions beyond the WWTP upgrades and upstream compliance. Therefore, nonpoint source implementation of the Phase II TMDLs in general, and this report in particular, will focus on these nine Croton System reservoirs (Figure 2.1).

Table 2.1. Phase II TMDL calculations using a combination of guidance values.

	Guidance Value ug/l	TMDL kg/yr	MOS kg/yr	Available Load kg/yr	WLA kg/yr	LA kg/yr	Current Load kg/yr	Total load reduction kg/yr	WWTP reduction kg/yr	upstream reduction kg/yr	NPS reductions kg/yr
Delaware District											
Cannonsville	20	53650	6706	46944	1086	45858	52368	5424	6341	0	0
Pepacton	20	79167	7917	71250	388	70862	37327	0	0	0	0
Neversink	20	22553	2255	20298	0	20298	6863	0	0	0	0
Rondout	15	41413	4141	37272	125	37147	23476	0	0	0	0
Catskill District											
Schoharie	20	29761	2976	26785	789	25996	19864	0	0	0	0
Ashokan East	15	19542	1954	17588	4	17584	16484	0	0	0	0
Ashokan West	15	45399	4540	40859	264	40595	32833	0	0	0	0
Kensico	15	28276	2828	25448	0	25448	16926	0	0	0	0
Croton District											
Amawalk	20	1329	133	1196	390	806	1318	122	0	0	122
Bog Brook	20	375	38	337	28	309	321	0	0	0	0
Boyd Corners	20	966	97	869	0	869	687	0	0	0	0
Croton Falls	15	3565	535	3030	615	2415	5010	1980	1095	0	885
Cross River	15	1007	126	881	108	773	717	57	0	0	57
Diverting	20	2798	406	2392	322	2070	3844	1452	0	469	983
East Branch	20	2822	353	2469	449	2020	3462	993	0	0	993
Middle Branch	20	949	133	816	184	632	1020	204	0	0	204
Muscoot	20	9397	940	8457	1405	7052	11560	3103	226	819	2058
New Croton	15	9731	973	8758	209	8549	11189	2431	0	1075	1356
Titicus	20	1158	174	984	0	984	1124	140	0	0	140
West Branch	15	12760	1276	11484	28	11456	8662	0	0	0	0

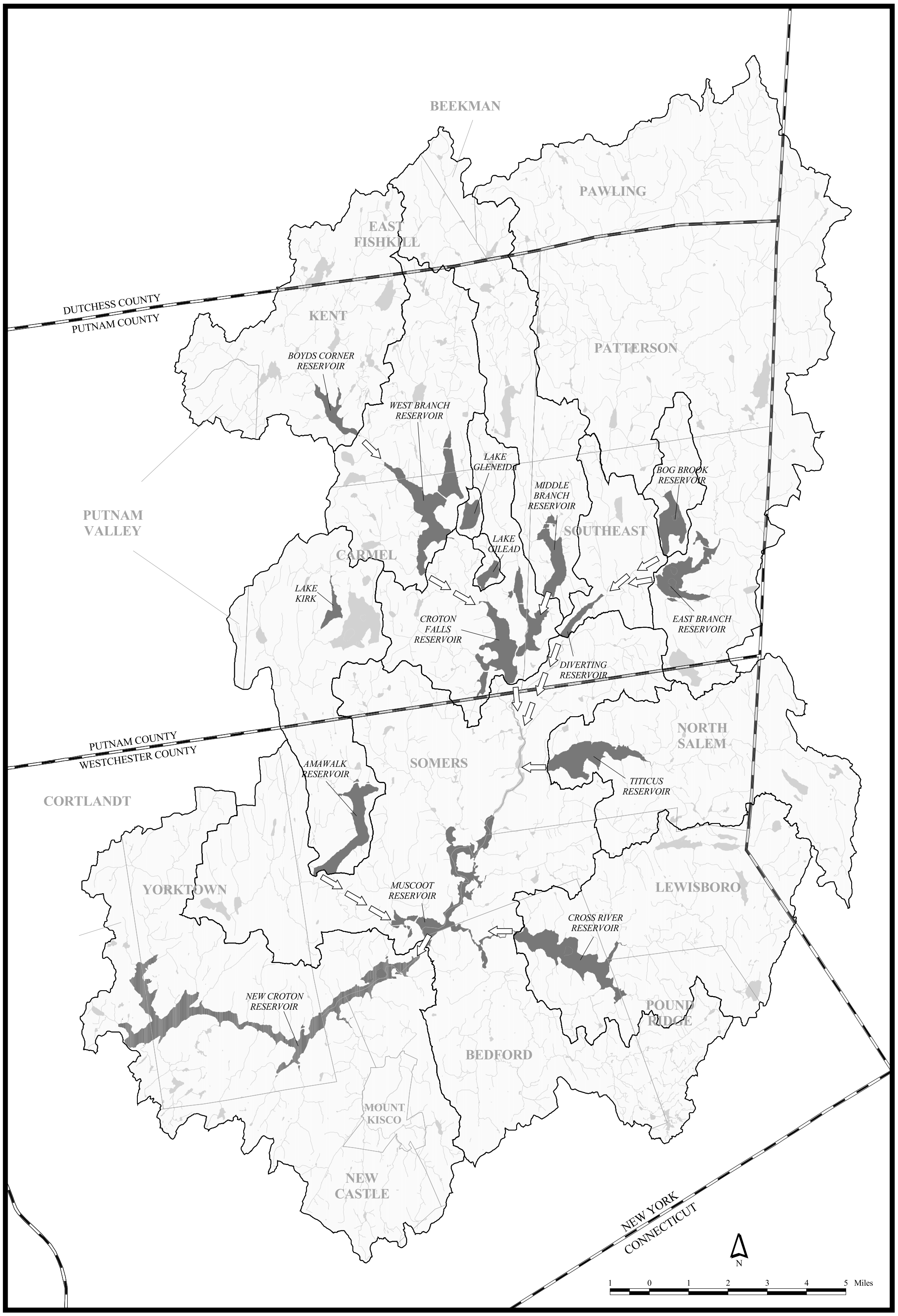

Figure 2.1. Map of the Croton Watershed.

3. TMDL Implementation

3.1 Overview

Significant resources have already been committed to addressing phosphorus reductions in the NYC watershed by a variety of interested parties. This report is not the first effort to reduce non-point source phosphorus in the NYC watershed. However, since the reservoirs currently exceed their TMDLs, it is likely that more reductions are required.

3.2 DEP Ongoing Implementation Efforts

DEP has recognized the need to reduce phosphorus in the reservoirs for many years. Toward this goal, DEP has instituted scientific research projects into the sources and effects of nutrients on water quality, developed reservoir and terrestrial models concentrating on nutrients, provided funding to reduce specific sources of phosphorus and provided funding to watershed parties to institute their own projects to improve water quality. A few of the larger projects are discussed below.

3.2.1 Wastewater Treatment Plant Upgrade Program

DEP has committed approximately $350 million dollars to upgrade all of the existing wastewater treatment plants, public and private, in the NYC watershed so that they comply with the requirements in the Watershed Rules and Regulations. These monies include the costs of designing, permitting, constructing and installing the upgrades as well as annual operation and maintenance costs associated with the upgrade. When fully implemented, this program will significantly reduce phosphorus in the NYC watershed.

3.2.2 Watershed Agricultural Program

The Watershed Agricultural Program strives to maintain and protect the existing high quality of the NYC water supply system from agricultural nonpoint source pollution through the planning and implementation of Best Management Practices (BMPs) on farms. The program is a voluntary partnership between the City and farmers in the watershed to manage nonpoint sources of agricultural pollution, including phosphorus. Since 1992, DEP has committed nearly $60 million dollars to the program and these monies have assisted the Watershed Agricultural Council in obtaining an additional $9 million dollars from Federal government programs and assorted other grants and loans. The Watershed Agricultural Program is discussed in more detail in a later section.

3.2.3 Water Quality Investment Funds

As part of the NYC Watershed Agreement, DEP has provided Westchester County with $38 million dollars and Putnam County with $30 million dollars to support a program of water quality investments in the East of Hudson watershed. The types of projects that could be funded include, but are not limited to, stormwater BMPs, streambank stabilization projects, water quality measures identified through the Croton Planning Process and septic system rehabilitation. Many of these eligible projects will reduce phosphorus in the Croton watershed.

3.3 DEC Ongoing Implementation Efforts

New York State's nonpoint source projects are both federally and state funded. Grant sources include Section 319 of the Clean Water Act (CWA), the Safe Drinking Water Act (SDWA), the Water Resources Development Act (WRDA), and New York State's Environmental Protection Fund (EPF). Listed below are several projects that have recently been funded in the New York City Watershed. The projects listed are located in the East of Hudson portion of the Watershed and are completed or underway.

3.3.1 SDWA

- A residential pesticide and fertilizer use survey form was developed and piloted (by Cornell under contract to DEC) in the Croton Watershed in 1999. This is a first step to conducting a watershed wide pesticide and fertilized use study.
- With funding from the Safe Drinking Water Act, DEP is conducting monthly monitoring and event monitoring for a limited number of storm events within the Croton System watershed to obtain nutrient loading information. The data from this effort would be used to improve the accuracy of DEP's TMDL load estimates and assist in evaluating export coefficients used for these calculations.
- DEC initiated a five-year Macro-Invertebrate Study of streams in the Croton System in 1999 to: develop a profile of pesticides in the water column resulting from runoff, determine if these pesticides impact the resident populations of algae and invertebrates, develop a listing of water quality impacts at 40 stream sites in the Croton System measured by benthic macroinvertebrates, develop a listing of any of these waters with elevated pesticide levels, and develop a correlation of impacts with measured pesticides. This project includes water column sampling for pesticides in the same streams and reservoirs by the United States Geological Survey.
- With Funding from the Safe Drinking Water Act, DEP initiated Model Testing for East-of-Hudson Reservoirs as part of a multi-phase water quality modeling initiative to calibrate a one-dimensional hydrothermal model and a one-dimensional eutrophication model for the Cross River Reservoir for the conditions of 1999 and evaluate speciality data sets of depositional data, optical studies, individual particle characterization, phosphorus fractions and bioavailability, phytoplankton growth kinetics, and zooplankton grazing data.

3.3.2 WRDA

- DEC is working with the Town of Patterson to develop a sewer system for areas of Patterson Hamlet that have failing septic systems.
- DEC is working with Westchester County Soil and Water Conservation District to conduct a stormwater, erosion and sediment control training program.
- DEC is working with the Village of Brewster to design an extension of their sewer collection

system to cover areas with inadequate septic systems.

- DEC is working with DEP on a project to evaluate the effectiveness of stormwater management facilities and the utility of stormwater wetland treatment systems.
- DEC is working with Putnam County to conduct an assessment of agricultural non-point source pollution in the Croton Watershed.
- DEC is working with the Village of Mount Kisco to upgrade the Saw Mill River Stormwater Pump Station to alleviate flooding and stormwater contamination.
- DEC is working with the Westchester County Planning Department to develop a Croton Watershed stormwater conveyance and implementation program.
- DEC is working with the Town of New Castle to develop a sewer system for an area with septic system problems.

3.3.3 Other

- DEC is working with NYS Department of Transportation (DOT) on their study for sediment and pollution reduction in the Turkey Mountain area.
- DEC is working with DOT on their study of BMP effectiveness for highway structures.
- The Department of State is broadening its Master Planning, Zoning and Environmental Enhancement Program by increasing the eligibility to include East of Hudson Watershed municipalities. This MOA based partnership program will help supplement the Croton Planning effort of Putnam and Westchester Counties by providing resources to develop and implement specific water quality protection and environmental enhancement plans and action items.

3.3.4 EPF projects

- Funding has been provided to the Westchester County Soil and Water Conservation District for Agricultural Environmental Management and Geographic Information System development in the Croton/Kensico Watershed.
- Funding has been provided to the Westchester County Soil and Water Conservation District for planning for selected farms within the Croton Watershed.
- Funding has been provided to the Village of Mt. Kisco for a Branch Brook water quality improvement project.

4. Nonpoint Source Reductions

4.1 NPS Features

Pollutant sources are broadly classified as point or nonpoint sources. A point source originates from a single, discrete location (i.e. a “point”). A good example is wastewater treatment plant effluent which is discharged from a pipe. Nonpoint sources are diffuse and do not have a single point of origin. The pollutants are generally carried off the land surface by stormwater runoff during rain events. Because of these fundamental differences, point sources are generally easier to monitor, easier to regulate and easier to predict than nonpoint sources.

Management of nonpoint sources must consider two basic factors: source control and transport control. Source control involves reducing or eliminating the source of a pollutant. For example, fertilizer can be a source of phosphorus. Source control would involve reducing the amount of fertilizer applied, adjusting the chemical formulation of the fertilizer or perhaps eliminating the need for fertilizer by using native species. The export of phosphorus is largely dependent on land use. Some types of land use, such as urban development, export more nonpoint source phosphorus than forested land use. Regardless of the magnitude of an individual source, some sources are more manageable than others. In any given basin, the nonpoint source load of phosphorus from forest land may exceed the load from urban land but the urban load is generated over a smaller area and is more amenable to reduction techniques.

Transport control involves preventing or interrupting the transport of a pollutant from the source to the waterbody. Since the transport of nonpoint sources is generally by stormwater runoff, transport control essentially addresses control of stormwater. This could involve not only standard practices such as stormwater detention but also routing stormwater away from sources of phosphorus (e.g. manure pile) and reducing the amount of stormwater (e.g. less impervious surfaces). Both source control and transport control must be considered in devising a comprehensive nonpoint source management strategy for implementing the phosphorus TMDLs.

4.2 Allocation Options

4.2.1 Important Considerations

As stated previously, the determination of the total load reduction required does not provide information on how to allocate the reductions within the watershed. There are many issues to be considered such as: feasibility, funding availability, local interest and multiple benefits. Some allocation options may not be technically feasible, such as reducing the concentration in a given reservoir to zero in order to reduce the downstream load. Many best management practices are costly, such as stormwater retrofits, and the availability of funding may be a deciding factor for which options are pursued. Implementation projects also have a higher success rate if there is interest from local towns or municipalities, or if the project provides multiple benefits such as reducing phosphorus and pathogens or improving a local waterbody.

All of these issues eventually need to be addressed. There are many stakeholders involved in the NYC watershed and the decision of how and where to obtain the necessary phosphorus reductions cannot be made by one entity. To assist in this ongoing process, several options have been investigated and the results are provided below. It is hoped that quantifying the effects of some of the options will narrow down the list of possible alternatives to be investigated in the future. However, these calculations are provided for future planning purposes and are not intended to actually allocate the load reductions.

4.2.2 Basin Allocations

Within each reservoir basin, there are a number of ways to allocate the required nonpoint source reductions. One logical subdivision of each reservoir basin is by town. The load reduction could be allocated proportional to the town's area within the reservoir basin or proportional to the current load contributed by each town within the basin. Both options have been quantified and are presented in Tables 4.1 and 4.2. In many cases, there is little difference between the allocation methods. The differences that are present reflect the variability in land use, notably the proportion of urban land. It should be clear that these calculations are provided for demonstration purposes only and are not intended to actually allocate the load reductions.

The phosphorus loads for each town represent only the nonpoint source phosphorus loads, based on the land use and the export coefficients used in the Phase II TMDLs. It is assumed that the point source loads, namely the wastewater treatment plants, will be reduced through the wastewater treatment plant upgrade program or the diversion program and it would be inappropriate to incorporate those loads in this analysis. One additional consideration involves the portion of the watershed that is in Connecticut. For the purposes of these calculations, Connecticut has been treated as another watershed town. The load reduction apportioned to Connecticut could be reallocated to the other towns in the basin.

Table 4.1. Example Load Reduction Allocation by Town for Each Reservoir Basin.

	Percent of Basin		Phosphorus Reduction		
	Area	Load	Proportional to Area (kg/yr)	Proportional to Load (kg/yr)	Total Required (kg/yr)
Amawalk Reservoir Basin					122
Carmel	64%	62%	78	75	
Putnam Valley	4%	4%	5	4	
Somers	33%	35%	40	42	
Croton Falls Reservoir Basin					885
Carmel	82%	85%	722	754	
Kent	7%	7%	59	65	
Somers	2%	2%	19	20	
Southeast	10%	5%	85	46	
Cross River Reservoir Basin					57
Bedford	24%	27%	14	16	
Connecticut	10%	8%	6	4	
Lewisboro	49%	56%	28	32	
North Salem	1%	0%	0	0	
Pound Ridge	17%	9%	10	5	
Diverting Reservoir Basin					983
Patterson	3%	1%	29	5	
Southeast	97%	99%	954	978	
East Branch Reservoir Basin					993
Beekman	0%	0%	0	0	
Connecticut	13%	10%	131	100	
Kent	1%	0%	8	5	
North Salem	1%	2%	13	23	
Patterson	40%	33%	396	325	
Pawling	26%	24%	263	239	
Southeast	18%	30%	182	300	
Middle Branch Reservoir Basin					204
Beekman	7%	3%	15	6	
Carmel	4%	4%	8	9	
East Fishkill	18%	11%	37	23	
Kent	33%	45%	67	91	
Patterson	9%	9%	18	17	
Pawling	6%	3%	13	6	
Southeast	23%	25%	46	52	
Muscoot Reservoir Basin					2058
Bedford	26%	27%	530	557	
Carmel	4%	5%	88	97	
Lewisboro	8%	7%	166	140	
North Salem	9%	8%	187	166	
Pound Ridge	6%	2%	117	45	

Table 4.1. Example Load Reduction Allocation by Town for Each Reservoir Basin.

	Percent of Basin		Phosphorus Reduction		
	Area	**Load**	**Proportional to Area (kg/yr)**	**Proportional to Load (kg/yr)**	**Total Required (kg/yr)**
Somers	29%	25%	599	513	
Southeast	6%	5%	117	112	
Yorktown	12%	21%	253	428	
New Croton Reservoir Basin					1356
Bedford	12%	12%	167	157	
Cortlandt	10%	8%	134	105	
Mount Kisco	5%	15%	74	199	
New Castle	25%	30%	345	405	
North Castle	0%	0%	6	3	
Somers	6%	3%	76	44	
Yorktown	41%	33%	554	443	
Titicus Reservoir Basin					140
Connecticut	33%	41%	46	57	
Lewisboro	6%	3%	8	5	
North Salem	62%	56%	86	78	

Table 4.2. Example Total Load Reduction Allocation by Town.

	Phosphorus Reduction	
	Proportional to Area (kg/yr)	**Proportional to Load (kg/yr)**
Bedford	711	730
Beekman	15	6
Carmel	897	935
Connecticut	182	162
Cortlandt	134	105
East Fishkill	37	23
Kent	134	161
Lewisboro	201	176
Mount Kisco	74	199
New Castle	345	405
North Castle	6	3
North Salem	287	268
Patterson	443	348
Pawling	276	245
Pound Ridge	127	50
Putnam Valley	5	4
Somers	734	620
Southeast	1385	1487
Yorktown	807	871

4.2.3 Upstream Load Reductions

The Croton System is a "daisy-chain" of interconnected reservoirs. Several reservoirs that require nonpoint source reductions actually receive the majority of their total phosphorus load from upstream reservoirs. One implementation option is, therefore, a reduction in the load received from the upstream reservoirs.

There are a number of issues that must be considered for this reduction alternative. First of all, the effect of reductions achieved in upstream watersheds are attenuated by the upstream reservoir prior to reaching the target basin. Therefore, additional nonpoint source reductions must be obtained upstream in order to meet the load reduction target downstream. Second, many of the upstream basins already require nonpoint source reductions to meet their TMDLs. Additional nonpoint source reductions may not be feasible. Third, deciding how the reductions are distributed between the target basin and multiple upstream basins is not straightforward. The reductions could be apportioned equally between upstream basins, proportional to the existing loads, or based on equalizing upstream reservoir concentrations. These options were investigated but many proved unfeasible because the predicted upstream load reductions exceeded the existing load in a basin or the predicted upstream reservoir concentration were unreasonably low (i.e. < 5 ug/l).

Given the fact that the upstream reservoirs contribute varying amounts of phosphorus downstream, the most reasonable option appears to be to distribute the reductions proportional to the existing load. Using this method, reservoirs contributing the highest loads are assigned the greatest reductions.

One assumption that must be made is how much of the nonpoint source load reduction can be obtained within the target basin and how much must be obtained from upstream basins. The following scenarios assume that each target basin can reduce 25% of its existing nonpoint source load and the rest of the load reduction is obtained upstream. This value of 25% is used for demonstration purposes only; the load reduction that can actually be obtained in each target basin must be determined by a more in-depth analysis of the individual watersheds.

The attenuation of the phosphorus loads by the reservoirs can be estimated using a retention coefficient. The retention coefficient represents the percentage of phosphorus retained by a lake or reservoir. It can be calculated from the phosphorus load into and out of the water body. The retention coefficient varies between reservoirs, reflecting changes in the water residence time and the trophic status of the reservoir. In the calculations presented here, the retention coefficient was calculated from the modeling results contained in the Phase II TMDL Reservoir Reports (DEP, 1999). Finally, the revised phosphorus concentration for the upstream reservoir has been recalculated even though obtaining a portion of the nonpoint source reductions in an upstream basin does not necessitate a new TMDL for the upstream basin.

Table 4.3. Reservoir "Groups" for the Upstream Load Reduction Analysis

Downstream Reservoir	Contributing Upstream Reservoirs	Percent of Total Upstream Phosphorus Load
New Croton Reservoir	Muscoot Reservoir	100%
Muscoot Reservoir	Cross River Reservoir	11%
	Titicus Reservoir	12%
	Croton Falls Reservoir	21%
	Diverting Reservoir	49%
	Amawalk Reservoir	7%
Croton Falls Reservoir	Diverting Reservoir	74% (81%)*
	Middle Branch Reservoir	18% (19%)*
	West Branch Reservoir	8% (0%)*
Diverting Reservoir	East Branch Reservoir	93%
	Bog Brook Reservoir	7%

* The values in parentheses are the adjusted percentages when West Branch Reservoir is excluded. This is discussed in the Croton Falls section.

The calculations for this reduction alternative are presented in the following sections. The analysis could not be done for the Croton System as a whole because there are too many undecided issues regarding load allocations. For example, Diverting Reservoir contributes phosphorus to both Muscoot and Croton Falls reservoirs. The Phase II TMDL for Diverting Reservoir already requires significant phosphorus load reductions and additional reductions to meet downstream goals may not be possible. Load reduction targets may need to be redistributed to accommodate such feasibility issues. However, additional work is required to identify possible load reduction opportunities before this type of determination can be made. It is hoped that some of this information will be available through the Croton Planning process.

The upstream load reduction analysis presented here groups the reservoirs into four "upstream-downstream" sets and the analysis is conducted for each group individually (Table 4.3). This provides information on the basic impact of transferring load reductions to the upstream basins and the magnitude of such reductions.

New Croton Reservoir

New Croton Reservoir receives approximately 73% of its annual phosphorus load from the Muscoot Reservoir. Under the Phase II TMDLs, New Croton Reservoir requires a total load reduction of 2431 kg/yr in order to meet a guidance value of 15 ug/l in the reservoir (Table 4.4). New Croton Reservoir is expected to benefit from the upstream compliance of Muscoot Reservoir by approximately 1075 kg/yr, leaving a reduction of 1356 kg/yr to be obtained from nonpoint sources.

If we assume that 25% of the current nonpoint source load in the New Croton basin (2709 kg/yr) can be reduced within the New Croton basin, then the remaining reduction to be obtained from upstream is:

$$1356 - (0.25 + 2709) = 679 \text{ kg/yr}$$

This upstream reduction (679 kg/yr) must be achieved at the outflow of Muscoot Reservoir. To account for attenuation of phosphorus in the upstream reservoir, the retention coefficient for Muscoot Reservoir is applied to determine the amount of phosphorus that must be reduced from the upstream watershed:

$$679 / (1 - 0.24) = 893 \text{ kg/yr}$$

In order to attain the 679 kg/yr load reduction to the New Croton Reservoir, a total load reduction of 893 kg/yr is required in the Muscoot watershed. The original Phase II TMDL load reduction of 2058 kg/yr required to achieve the TMDL is added to the additional load reduction of 893 kg/yr to accommodate the downstream TMDL to yield a revised load reduction of 2951 kg/yr. This total load reduction to Muscoot Reservoir will likely result in an in-reservoir concentration 18 ug/l.

Table 4.4. Example Upstream Reductions for New Croton Reservoir.

	Retention Coefficient	Additional Load Reduction	Phase II TMDL Load Reduction	Revised Load Reduction	Revised Phosphorus Concentration
Muscoot Reservoir	0.24	893 kg/yr	2058 kg/yr	2951 kg/yr	18 ug/l

Note: The retention coefficient is calculated as a four year average based on data used in the Phase II TMDL analyses, it represents the percentage of phosphorus retained within the reservoir.

Muscoot Reservoir

Muscoot Reservoir receives approximately 47% of its annual phosphorus load from the upstream reservoirs. Under the Phase II TMDLs, Muscoot Reservoir requires a total load reduction of 3103 kg/yr in order to meet a guidance value of 20 ug/l in the reservoir. Muscoot Reservoir is expected to benefit from the upgrade of the wastewater treatment plants by 226 kg/yr and by upstream compliance with the TMDLs by approximately 819 kg/yr. This leaves a reduction of 2058 kg/yr to be obtained from nonpoint sources.

If we assume that 25% of the current nonpoint source load in the Muscoot basin (= 4259 kg/yr) can be reduced within the Muscoot basin, then the remaining reduction to be obtained from upstream is:

$$2058 - (0.25 + 4259) = 993 \text{ kg/yr}$$

Amawalk Reservoir contributes 7% of the upstream load to Muscoot Reservoir; Croton Falls Reservoir contributes 21%, Diverting Reservoir contributes 49%, Cross River Reservoir contributes 11% and Titicus Reservoir contributes 12%. Therefore the load proportional reductions required are:

Amawalk:	$0.07 \times 993 = 70$ kg/yr
Croton Falls:	$0.21 \times 993 = 213$ kg/yr
Diverting:	$0.49 \times 993 = 486$ kg/yr
Cross River:	$0.11 \times 993 = 109$ kg/yr
Titicus:	$0.12 \times 993 = 116$ kg/yr

To account for attenuation of phosphorus in the upstream reservoirs, a reservoir-specific retention coefficient is applied to calculate the amount of phosphorus that must be reduced from the upstream watersheds. The retention coefficients are provided in Table 4.5. In order to attain a load reduction of 993 kg/yr to the Muscoot Reservoir, a total load reduction of 1633 kg/yr must be achieved in the upstream watersheds.

Table 4.5. Example Upstream Reductions for Muscoot Reservoir.

	Retention Coefficient	Additional Load Reduction	Phase II TMDL Load Reduction	Revised Load Reduction	Revised Phosphorus Concentration
Amawalk Reservoir	0.43	123 kg/yr	122 kg/yr	245 kg/yr	18 ug/l
Croton Falls Reservoir	0.61	546 kg/yr	885 kg/yr	1431 kg/yr	13 ug/l
Diverting Reservoir	0.12	552 kg/yr	983 kg/yr	1535 kg/yr	16 ug/l
Cross River Reservoir	0.47	206 kg/yr	57 kg/yr	263 kg/yr	12 ug/l
Titicus Reservoir	0.44	207 kg/yr	140 kg/yr	347 kg/yr	16 ug/l

Note: The retention coefficient is calculated as a four year average based on data used in the Phase II TMDL analyses, it represents the percentage of phosphorus retained within the reservoir.

Croton Falls Reservoir

Croton Falls Reservoir receives approximately 28% of its annual phosphorus load from West Branch, Middle Branch and Diverting reservoirs. Under the Phase II TMDLs, Croton Falls Reservoir requires a total load reduction of 1980 kg/yr in order to meet a guidance value of 15 ug/l in the reservoir. Croton Falls Reservoir is expected to benefit from the upgrade of the wastewater treatment plants by 1095 kg/yr. This leaves a reduction of 885 kg/yr to be obtained from nonpoint sources.

If we assume that 25% of the current nonpoint source load in the Croton Falls basin (779 kg/yr) can be reduced within the Croton Falls basin, then the remaining reduction to be obtained from upstream is:

$$885 - (0.25 \times 779) = 690 \text{ kg/yr}$$

West Branch Reservoir contributes 8% of the upstream load to Croton Falls Reservoir; Middle Branch Reservoir contributes 18% and Diverting Reservoir contributes 74%. The phosphorus concentration in the West Branch Reservoir is driven by the operations of the Delaware Aqueduct not by loading from its own watershed. In order to reduce the phosphorus load leaving the reservoir, the flow would need to be reduced instead. The West Branch Dam release is predetermined by an agreement with New York State to protect aquatic life in the downstream portion of the Croton River. Therefore, the load has been allocated between the Middle Branch and Diverting reservoirs only. Given the small proportion of flow from the West Branch Reservoir (8% of the upstream input to Croton Falls Reservoir), this does not change the calculations significantly. The proportional load reductions required are:

Middle Branch: $0.19 \times 690 = 133$ kg/yr
Diverting: $0.81 \times 690 = 557$ kg/yr

To account for attenuation of phosphorus in the upstream reservoirs, a reservoir-specific retention coefficient is applied to calculate the amount of phosphorus that must be reduced from the upstream watersheds. The retention coefficients are provided in Table 4.6. In order to attain a load reduction of 690 kg/yr to the Croton Falls Reservoir, a total load reduction of 885 kg/yr must be achieved in the upstream watersheds.

Table 4.6. Example Upstream Reductions for Croton Falls Reservoir.

	Retention Coefficient	Additional Load Reduction	Phase II TMDL Load Reduction	Revised Load Reduction	Revised Phosphorus Concentration
Middle Branch Reservoir	0.33	199 kg/yr	204 kg/yr	403 kg/yr	16 ug/l
Diverting Reservoir	0.12	633 kg/yr	983 kg/yr	1616 kg/yr	15 ug/l

Note: The retention coefficient is calculated as a four year average based on data used in the Phase II TMDL analyses, it represents the percentage of phosphorus retained within the reservoir.

Diverting Reservoir

Diverting Reservoir receives approximately 73% of its annual phosphorus load from the East Branch and Bog Brook reservoirs. Under the Phase II TMDLs, Diverting Reservoir requires a total load reduction of 1452 kg/yr in order to meet a guidance value of 20 ug/l in the reservoir. Diverting Reservoir is expected to benefit from the upstream compliance of East Branch and Bog Brook reservoirs by approximately 469 kg/yr, leaving a reduction of 983 kg/yr to be obtained from nonpoint sources.

If we assume that 25% of the current nonpoint source load in the Diverting basin (606 kg/yr) can be reduced within the Diverting basin, then the remaining reduction to be obtained from upstream is:

$$983 - (0.25 \times 606) = 832 \text{ kg/yr}$$

East Branch Reservoir contributes 93% of the upstream load to Diverting Reservoir; Bog Brook contributes the remaining 7%. Therefore the load proportional reductions required are:

Bog Brook:	$0.07 \times 832 = 55$ kg/yr
East Branch:	$0.93 \times 832 = 777$ kg/yr

To account for attenuation of phosphorus in the upstream reservoirs, a reservoir-specific retention coefficient is applied to calculate the amount of phosphorus that must be reduced from the upstream watersheds. The retention coefficients are provided in Table 4.7. In order to attain a load reduction of 832 kg/yr to the Diverting Reservoir, a total load reduction of 1117 kg/yr must be achieved in the upstream watersheds.

Table 4.7. Example Upstream Reductions for Diverting Reservoir.

	Retention Coefficient	Additional Load Reduction	Phase II TMDL Load Reduction	Revised Load Reduction	Revised Phosphorus Concentration
East Branch Reservoir	0.24	1022 kg/yr	993 kg/yr	2015 kg/yr	13 ug/l
Bog Brook Reservoir	0.42	94 kg/yr	0	94 kg/yr	15 ug/l

Note: The retention coefficient is calculated as a four year average based on data used in the Phase II TMDL analyses, it represents the percentage of phosphorus retained within the reservoir.

5. Nonpoint Source - Related Programs

5.1 Introduction

Programs that address nonpoint sources of pollution already exist in the NYC watershed. These programs need to be evaluated to determine if existing programs are sufficient or if they require modification to accommodate TMDL implementation and whether new programs are necessary. As a first step in this programmatic evaluation, this section will discuss existing State and City programs that may impact nonpoint sources of phosphorus. In addition, DEP has several ongoing research projects that may provide valuable information for reducing nonpoint sources of phosphorus and these will be briefly discussed as well.

Nonpoint source related programs in the watershed can be categorized as either comprehensive or targeted. Comprehensive programs apply watershed-wide and involve multiple sources and land uses. Targeted programs have a narrower scope and typically apply to a specific source or land use. The targeted programs have been organized by source category: urban, residential and agricultural.

5.2 Comprehensive Programs

5.2.1 DEP Nonpoint Program

DEP has a number of regulatory and non-regulatory nonpoint source pollution control programs which are described in the MOA. These programs include: Watershed Protection and Partnership Programs; the Watershed Rules and Regulations and the Filtration Avoidance Determination.

New York City Watershed Protection and Partnership Programs - As established in the MOA's New York City Watershed Protection and Partnership Programs and FAD Programs, non-regulatory elements of the Department's nonpoint source pollution control program reduce existing and future sources of nonpoint pollution through the funding of a wide range of partnership programs.

Regulations - The Regulations were developed to protect and improve New York City's drinking water quality by protecting reservoirs, reservoir stems, controlled lakes, watercourses (including intermittent streams), and wetlands. Nonpoint pollution sources are now controlled through the application of strict performance standards, through the review and approval process, and by the prohibition of certain land use activities established in the Regulations.

Filtration Avoidance Determination - The FAD requires the development and implementation of numerous nonpoint source pollution control programs. The FAD also imposes strict reporting requirements to monitor the Department's progress in implementing its programs and to evaluate whether New York City continues to meet the conditions for avoidance.

Other - Beyond the scope of the MOA, DEP's nonpoint source pollution control program includes active participation in federal, state, regional and local interagency nonpoint source control projects and committees and implementation of non-mandated nonpoint source pollution control programs.

5.2.2 Croton Watershed Strategy

The Croton Watershed Strategy project is a two-year contract that will provide an integrated framework for management of the Croton System, allowing DEP to focus limited resources on critical areas/subbasins to achieve a maximum water quality benefit. Under the contract, pertinent data will be collected from a variety of federal, state, county, and municipal sources, including DEP's extensive data bases, and will be transformed into a Geographical Information System (GIS) format. The consultants will also develop GIS-based management tools for the Department which will allow for more efficient use of available data, better integration of programs and the ability to update the analyses as better data becomes available. The project will identify existing and potential point and nonpoint sources of environmental impairment at the subbasin scale, as well as suggest management alternatives for addressing these sources and prioritizing areas for implementation efforts. An external peer review panel has been retained to review the work on an ongoing basis throughout the contract.

The Croton Watershed Strategy project will provide valuable information for continuing the efforts to reduce nonpoint sources of phosphorus in the Croton watershed. The subbasin-scale analysis will begin to bridge the gap between the basin-wide phosphorus analysis presented in the Phase II TMDL Reservoir Reports and the finer-scale required to implement phosphorus reductions. The subbasins with the highest loading rates of phosphorus can be investigated for BMP opportunities.

5.2.3 Croton Process Studies

The Croton Process Studies project focuses on basic scientific research into the sources and spatial and temporal characteristics of apparent color, phosphorus, organic carbon and disinfection by-product precursors. The project is being conducted by a research consortium from the College of Environmental Science and Forestry (ESF), Syracuse University, Upstate Freshwater Institute and the United States Geological Survey. The multi-year project involves an extensive and in-depth water quality sampling program, including surface and groundwater monitoring at sites located throughout the watershed, and intensive in-reservoir sampling at key locations.

The Croton Process Studies project will provide important, highly detailed information on nonpoint sources of phosphorus and the transport pathways. This, in turn, can be used to develop the most effective management strategies to reduce phosphorus loading.

5.2.4 NYS NPS Management Program

In accordance with Section 319 of the Clean Water Act, DEC has prepared a Nonpoint Source Assessment and a Nonpoint Source Management Program. The Nonpoint Source Assessment was initially completed in 1988 and approved by the EPA in July 1989. An update of this assessment has been prepared every two years. The latest assessment is in the 1996 Priority Waterbodies List. The Nonpoint Source Management Program was approved by EPA in January 1990. The Management Plan was updated and approved by EPA in October, 2000. Copies of the Management Program are available from Gerry Chartier, (518) 457-4117.

New York State's Nonpoint Source Management Program is charged with the control, reduction or treatment of polluted runoff through the implementation of structural, operational or vegetative management practices. It administratively coordinates various state agencies and other interested partners having regulatory, outreach, incentive-based, or funding programs that foster installation of management practices for any of the identified sources of nonpoint pollution threatening or impairing the waters of New York. Local implementation and statewide coordination and evaluation are conducted on a watershed basis.

Nonpoint source pollution usually is best prevented or remediated by employing one or more management practices. A management practice is a means of preventing or reducing the availability, release or transport of substances which adversely affect surface and groundwaters. It is a practice used to prevent or reduce the impact of nonpoint pollutants usually from a specific source category.

New York has developed a series of ten Management Practices Catalogues each containing management practices for a particular source category. From this list of tested and approved practices, the best practice should be selected and used by individuals or groups wherever needed to diminish the impact of nonpoint source pollution. They can be used without a formal planning process or without an identification of a specific problem. They make good environmental sense. Use of appropriate management practices helps build environmental responsibility. A summary of management practices by land use are provided in Appendix A. The complete catalogues are also available from Gerry Chartier, (518) 457 - 4117.

Coastal Nonpoint Pollution Control Program

The Coastal Zone Act Reauthorization Amendments of 1990 (CZARA) included a section devoted to coastal nonpoint pollution control, now known as Section 6217. This federal legislation requires New York and about 30 other states and territories with approved coastal management programs to develop and implement programs to control nonpoint pollution to restore and protect coastal waters. The Croton System falls within the geographic scope of 6217.

The central purpose of Section 6217 is to strengthen the links between federal and state coastal zone management and water quality programs. Another purpose is to enhance state and local efforts to manage land use activities that degrade coastal waters and coastal habitats.

At the federal level, the program is administered jointly byEPA and the National Oceanic and Atmospheric Administration (NOAA), respectively, the federal water quality and coastal management agencies. This approach is echoed at the state level, where DEC and the Department of

State's (DOS) Division of Coastal Resources are jointly responsible for program development and implementation. The two agencies entered into a partnership (through a Memorandum of Understanding) to develop New York State's Coastal Nonpoint Pollution Control Program Document.

The EPA and NOAA guidance lists 57 management measures in six source categories. DEC and DOS have determined, after a review of existing programs, that about two thirds of these management measures are already in place in New York State. Such programs as waste oil recycling and wetland protection programs already achieve many of the goals of the 6217 program. Given the wide range of programs and agencies involved in nonpoint pollution management in New York, DEC and DOS have purposely decided to build on existing programs wherever possible when implementing the 6217 program.

5.2.5 Croton Planning

While Croton Planning is actually a County program, it is funded by DEP and therefore briefly discussed here. The Croton Planning program in the Watershed Agreement was developed to encourage local communities to evaluate water quality protection in their land use decision making; identify water quality problem areas and protect community character. The completed Croton Plans will likely be used as policy guidance, and may result in new local ordinances. The Watershed Agreement allows for some latitude in how the programs are developed, and both Westchester and Putnam Counties have developed approaches which recognize specific local concerns. The Croton Plans are scheduled to be completed by May 2002.

5.3 Targeted Programs

5.3.1 Urban

5.3.1.1 New York State Stormwater Permits - Croton System

Final Phase 2 Stormwater Regulations were adopted by EPA in October 1999 these regulations will significantly affect how New York State regulates stormwater discharges. New York State DEC is currently developing a Stormwater Program in order to meet the federal requirements. The new regulations for storm water permits will increase the scope of the current stormwater permitting program. For example, facility coverage under the regulations includes construction sites greater than one acre.

While the proposed requirements will not impose a performance standard, EPA believes storm water management measures required under the regulations will remove at least 80 percent of total suspended solids from construction site runoff. The agency said that by controlling total suspended solids the measures, or practices, will also control other pollutants, including heavy metals, oxygen demanding pollutants, and nutrients commonly found in stormwater discharges.

There are basically three groups of activities that will be affected by the new stormwater permits:

(1) Phase I activities;

(2) Construction activities disturbing between 1 and 5 acres; and

(3) Small municipalities in designated "urbanized areas" identified by USEPA.

New York State is developing criteria and a process for designating additional "urbanized areas" for inclusion into the stormwater program. Sensitive waters, such as the Croton Watershed, requiring special protection from stormwater will be considered for designation. New York State will also consider the possibility of public petitions for designating additional municipal candidates. This designation must be made by 12/10/2004.

Permits for designated small municipalities would need to be issued by New York State and would require programs which focus on six (6) minimum areas:

- public education and outreach
- public involvement/participation in stormwater program development
- illicit discharge detection and elimination
- construction site runoff control
- post-construction stormwater management control including redevelopment
- pollution prevention for municipal operations

In order to determine the best way to implement the requirement of the Phase II Stormwater in the Croton Watershed, the Department has engaged the services of the Center for Watershed Protection. The Center for Watershed Protection has considerable experience developing watershed specific programs for the control of stormwater runoff, and conducting local stormwater program reviews for communities in Massachusetts, Ohio, Maryland, New Hampshire and Virginia.

The Center for Watershed Protection will:

1. Review existing stormwater programs and policies in the Croton Watershed;
2. Review management measures employed to protect other water supply watersheds;
3. Evaluate alternatives and make recommendations to control pollutants for existing development;
4. Evaluate alternatives and make recommendations for controlling pollutants from new development;
5. Evaluate alternatives and make recommendations for controlling sediment discharge from small construction sites.

Based upon this information, the Department will develop a specific plan to implement the Phase II Stormwater Regulations in the NYC Watershed areas of Westchester and Putnam Counties.

This may include the designation of all municipalities in the Watershed area located east of the Hudson River, requiring a permit for municipal separate storm sewers (MS4s) and special permit conditions for the MS4s and construction permits.

5.3.1.2 Highway Maintenance

Stormwater runoff from roadways can constitute a significant source of pollutants. State, County and local departments of transportation already have highway maintenance programs in place which include such practices as street sweeping, roadway deicing and stormwater best management practices. It is likely that some of these programs could be improved to better address the problem of phosphorus loading. For example, some roadway deicing chemicals contain significant amounts of phosphorus. Eliminating the use of such products and switching to alternate deicing chemicals will reduce the amount of phosphorus entering the water courses and reservoirs. Improvements to the stormwater management system to better address water quality not just water quantity would also reduce phosphorus loading.

5.3.2 Residential

5.3.2.1 Pesticide/Fertilizer Workgroup Recommendations

The NYC Watershed Agreement provided for a technical workgroup to analyze the State's current regulations and standards on pesticides and fertilizers and to recommend any changes to protect the City's water supply from potential contamination or to enhance the City's ability to monitor for any impacts from pesticides and fertilizers. The final report from the workgroup makes a series of recommendations, mostly nonregulatory approaches, which may substantially improve current practices and reduce the threat of contamination to the water supply. With regard to non-agricultural fertilizer usage, the recommendations focus on education/outreach programs, phosphorus-free fertilizer, and residential soil testing.

5.3.2.2 Cornell Cooperative Extension Programs

Cornell Cooperative Extension (CCE) has a number of programs that directly or indirectly work to reduce the amount and extent of non-point source pollution from residential sources. CCE has also implemented some exceptional education programs in efforts to educate the residents of the Croton Watershed. As such, the DEP has worked with and provided funding for a number of programmatic and educational components of key CCE programs. Some of the existing programs that target a reduction in nonpoint source pollution include:

Home*A*Syst.

Home*A*Syst is a self-help program that assists people in evaluating their home and property for pollution risks and health hazards. Educational materials and other forms of assistance are available. The Home*A*Syst guidebook shows how to reduce one's impact on natural systems by identifying pollution risks on your property before expensive problems occur. The guidebook includes information on a number of important topics related to non-point source pollution.

Cornell Nutrient Analysis Lab.

Property owners often lack the information needed to make proper decisions regarding treatment of soil, water and plants in their area. In order to provide individuals with detailed information about the characteristics of their individual situation, CCE created the Cornell Nutrient Analysis Lab (CNAL). CNAL staff analyzes soil, water and plant material for farmers, home garden owners, lawn care professionals, and a wide range of agencies and individuals. A computer program developed at Cornell University generates nutrient management recommendations based on the relationship between the soil nutrient concentration and the outcome of the research calibrations. CCE efforts to increase the property owner's knowledge of the specific conditions of their soil will often prevent the property owners from over fertilizing their lawns, gardens and farms. Reducing the fertilizers applied within the watershed will reduce the potential non-point source run-off of nutrients.

Educational Programs.

Lawn Ranger Volunteer Program - The Lawn Ranger slide set with script was produced to show targeted audiences how their lawn care practices can affect water quality. The DEP has provided funding to the help the CCE offices in Westchester and Putnam Counties to establish and promote this program on a local level. The targeted audience is homeowners residing in the Croton Watershed as many new homeowners are first-time buyers and have limited knowledge of proper environmental stewardship of their newly acquired investments. The program has the potential to greatly effect homeowners' practices.

The Homeowner's Lawn Care and Water Quality Almanac - CCE has created an innovative homeowners guide to proper maintenance of residential lawns. One particular concern that is addressed is non-point sources of pollution, such as fertilizers and pesticides, which can be carried to the water supply by stormwater runoff. The DEP is working with the CCE offices in Westchester and Putnam Counties to promote the Homeowner's Lawn Care and Water Quality Almanac in the watershed. Additionally, DEP has provided funding to present the Almanac on the CCE web site.

Household Hazardous Products - This web-based program educates consumers about the proper use, storage, and safe disposal of household cleaning products and other potentially hazardous chemicals.

Septic System Maintenance - The Septic System Maintenance program is an innovative web-based program that educates homeowners about the proper care and maintenance of their septic systems. Fact sheets, brochures, and videos are also made available.

5.3.3 Agricultural

5.3.3.1 Watershed Agricultural Program

The Watershed Agricultural Program is a comprehensive effort to develop and implement pollution prevention plans on 85% of the commercial farms in the City's Catskill and Delaware watersheds. The program is a voluntary partnership between the City and farmers in the watershed to manage nonpoint sources of agricultural pollution, with particular emphasis on waterborne pathogens, nutrients, and sediment. In addition, the program incorporates the economic and business concerns of each farm into the development of its Whole Farm Plan in order to fully establish the principles and goals of pollution prevention into the farm operation. Fully funded by the City, the Watershed Agricultural Program is administered by the not-for-profit Watershed Agricultural Council, whose board consists of farmers, agri-business representatives and the DEP Commissioner. Local, State, and Federal agricultural assistance agencies, as well as Cornell University, provide planning, technical, educational, engineering, scientific and administrative support for the program under subcontractual agreements with the Council.

The Watershed Agricultural Program strives to maintain and protect the existing high quality of the NYC water supply system from agricultural nonpoint source pollution through the planning and implementation of Best Management Practices (BMPs) on farms. When possible, the Program uses traditional BMPs that are proven to protect and enhance source water quality. In addition, it has become necessary, and proven beneficial for the Program, to experiment with and evaluate non-traditional, innovative BMPs to increase the number of alternatives available to farmers to address nonpoint source pollution issues, while also addressing "non-traditional" agricultural water pollution concerns, especially waterborne pathogens.

While the Program has concentrated its activities on farms located in the Catskill and Delaware watersheds west of the Hudson River, it has begun recently to explore opportunities for agricultural nonpoint source pollution prevention in the Croton System east of the Hudson. Over the past year, the Watershed Agricultural Council has established an East of Hudson Committee, consisting of farmers and agency staff representatives from Westchester, Putnam and Dutchess counties. This committee is coordinating county led agricultural inventory and planning activities with Watershed Agricultural Program technical and limited financial assistance. The approach to farm planning in the Croton System relies heavily on the State's Agricultural Environmental Management (AEM) program, and all the east of Hudson counties are currently in the process of developing Tier I surveys of agricultural operations. Westchester County has recently completed a detailed census and mapping of farmland to support development of an agricultural district. In addition, the Watershed Agricultural Program has established three pilot farms in the Croton System to develop and implement Whole Farm Plans for demonstration purposes.

6. Future Directions

The next steps in achieving the load allocation portion of the Phase II TMDL will build upon this report, additional reservoir basin specific information that will be included in a report to be developed within the next six months and a number of activities undertaken by the Watershed Partners.

In accordance with the MOA six months after the submission of this report, DEC will work with DEP and EPA to develop and submit a second report identifying nonpoint source management practices it will implement and recommend management practices to be implemented by other parties. The next report will also provide additional information on load reductions, management practices, time frames for implementation and funding.

In EPA's October 16, 2000 letter to DEC, EPA recommended that DEC and EPA work together with DEP and Putnam and Westchester Counties such that a number of items be addressed. Most of the recommendations will be addressed in the second nonpoint source report or the Croton Watershed Stormwater Strategy.

The report will continue the process of identifying the following:

- reservoir management practices that will be implemented to achieve standards for each waterbody and downstream waterbodies if necessary;
- implementation mechanism;
- the time frame for implementing the actions;
- the funding sources for implementation;
- management practices specific to land use areas within each basin
- a plan for evaluating/monitoring the effectiveness of management practices; and
- a schedule of implementation mechanisms.

In addition to developing the second nonpoint source report, DEC will work with DEP, EPA and other watershed stakeholders to develop a plan to implement load reductions and ensure that through combined efforts water quality standards in the reservoirs are achieved.

As discussed earlier in this report, a key element of DEC's actions to achieve the load allocations is the implementation of municipal stormwater management in Westchester and Putnam Counties. The first step in the management of stormwater is the project by the Center for Watershed Planning. This project will be completed by Fall of 2001 and will include specific recommendations regarding how the municipal stormwater should be addressed in order to achieve the TMDL objectives. DEC will review and act upon the recommendations in the report by early 2002. At that time, DEC will identify municipalities and other storm sewer systems that will be designated under the Phase II Stormwater Rule.

References

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APPENDIX A

Potential Management Practices

Management practices are used to prevent or minimize the availability, release or transport of substances that degrade water quality. Best management practices (BMPs) are defined as the most effective and practicable means of limiting the quantity of phosphorus exported from a site and transported downstream. This list of BMPs is designed to assist in the selection of appropriate management measures to control nonpoint sources of phosphorus generated by agricultural, urban and forestry land uses in the NewYork City water supply watershed. Each practice should be evaluated for compatibility with the site, cost, pollutant removal abilities and maintenance needs. The ultimate selection of one or a combination of BMPs must consider all water quality goals, pollutant treatment capabilities, site conditions, cost, maintenance, and federal, state, or local regulatory requirements and programs.

There are many excellent compilations on BMPs for various land uses, which give extensive information on design specifications, maintenance procedures and other details (e.g. NYSDEC, 1993c; USEPA, 1993). It is not our intent to reproduce these publications. Instead, this document summarizes those BMPs which are effective in reducing phosphorus, with special consideration to implementation in the NYC watershed. A brief description of each BMP is given, along with any particular advantages or disadvantages if used in the NYC watershed (Tables 3 - 5). Some management practices are applicable to more than one land use category (e.g. riparian buffers). These will only be discussed once.

While the generic management alternatives discussed in this document may be applicable to the entire NYC watershed, the diversity of land use and population patterns in the different watershed districts may limit their use to only one area. For example, the majority of the agricultural land is located West-of-Hudson in the Delaware District and most of the urban land is located East-of-Hudson in the Croton District.

Urban Management Alternatives

Urban centers are often considered the best locations to achieve nonpoint phosphorus reductions. Phosphorus loading is obviously more concentrated than for other nonpoint source categories such as forest land or open spaces. Reducing or preventing increases in phosphorus loads in urban watersheds requires careful planning, thorough watershed assessments and coordinated implementation of a comprehensive program that addresses retrofit and new development needs. An integrated approach that uses a combination of cost-effective BMPs will achieve the maximum phosphorus reduction possible (Table 3).

Extended Detention

An extended detention pond temporarily detains and stores peak runoff flows after a storm event. During extended detention, some pollutants settle out and peak flows are gradually released from the pond. Detention ponds are normally dry between storm events and do not contain permanent standing water. Extended Detention ponds typically consist of an excavated area with an embankment dam, a principal spillway (riser) with an extended detention control device, an emergency spillway and a velocity dissipation device at the riser outlet. Ideal detention time for pollutant removal is 40 hours or greater.

Wet Ponds/Multiple Pond Systems

Wet ponds or retention basins are designed to store and retain runoff. They maintain a permanent pool of water for partial infiltration and evaporation. Ponds are typically excavated according to design needs and contributing drainage areas. They usually have a shallow inlet area 0.5 to 2 feet deep and a permanent pool 3-8 feet in depth. A dam and emergency spillway also control peak runoff and detain stormwater for 2-14 days.

Retention is the preferred method of stormwater management when the water table, bedrock, or soil conditions preclude the use of infiltration. Retention improves stormwater quality by settling, naturally occurring chemical flocculation and biological uptake. They also provide a habitat for wildlife and can be an aesthetic benefit to the surroundings. Retention ponds can reduce the peak discharge during storms to pre-development levels, but they are not effective in controlling post-development increases in the total runoff volume. Use of existing natural wetlands for stormwater management purposes often requires approval from federal, state and local agencies, and care must be exercised so that the wetland is not negatively impacted.

Stormwater Wetland Systems

Constructed stormwater wetlands comprise shallow pools that are designed and constructed to provide suitable growing conditions for marsh plants, and to simulate water quality functions of a natural wetland. These can be newly constructed wetlands, or restored/enhanced wetlands that have been degraded. Stormwater wetlands are not usually designed to replicate all of the ecological functions of natural wetlands. Stormwater wetlands require sufficient baseflow (groundwater) to support the wetland vegetation, and so may not be appropriate at many sites. The maintenance burden is especially high for the first three years, and can be expensive. Wetland regulations may prevent placement of a stormwater wetland in a natural wetland system. These systems also have highly variable, site-specific phosphorus removal capabilities, and are best used for final polishing of the stormwater.

Infiltration Systems

Infiltration systems are excavated areas in which runoff is temporarily collected and stored until it gradually percolates through the permeable soils of the basin or trench floor. Infiltration systems remove pollutants through sorption, precipitation, straining and bacterial breakdown.

Infiltration basins can treat the peak flow rate and volume from large storms, and provide necessary groundwater recharge. However, they are expensive to install, have a high failure rate due to a lack of maintenance and have specific requirements for soil type and maximum slope, depth to groundwater and to bedrock. Properly functioning infiltration systems are most effective in removing pollution.

Grassed Swales

Swales are small vegetated earthen conveyances constructed on permeable soils, usually used to provide pretreatment before runoff is discharged to another BMP. Swales intercept and focus the diffuse overland sheet flow, control peak discharge, provide some detention and limited infiltration. Stormwater pollutants are removed by settling and filtration through vegetation and soil. Vegetative swales are typically applied to single-family residential developments and highway medians as an alternative to curb and gutter drainage systems.

Grassed swales are inexpensive to install and have low maintenance costs. Unfortunately they do not control soluble pollutants effectively. They are best used in conjunction with other methods of stormwater BMPs.

Filter Strips

Filter strips are areas of land with vegetative cover that are designed to accept and attenuate overland sheet flow runoff. Dense vegetative cover facilitates sediment settling and pollutant removal. Filter Strips are appropriate for agricultural practices, such as along the side of a field. Unlike grassed swales, filter strips are only effective for overland sheet flow, not for concentrated flows. Filter strips cannot treat high velocity flows or provide enough storage or infiltration to effectively reduce peak discharges to pre-development rates for design storms. During the growing season they are most effective on low to moderate slopes. Filter strips are recommended for low density development and can be effectively used as one component of an integrated stormwater management system.

Streambank Stabilization/stream Corridor Protection

Minimizing streambank and streambed erosion can reduce phosphorus loadings especially if riparian and floodplain areas have been in agricultural land use, or if riparian (stream-related) areas are used as septic leach fields. Minimizing stream erosion must be based on a systematic evaluation of natural stream channel stability that identifies the cause(s) of the exacerbated erosion rather than simply treating the symptoms (i.e., stabilizing eroding streambanks). Generally, several BMPs are used together to increase stream channel stability, diminish peak velocities and shear stresses on channel bed and banks. BMPs include managing stormwater, realigning stream reaches (slope, width to depth ratio), restoring floodplain and riparian areas, and stabilizing selective streambanks.

The strips of healthy riparian vegetation along streams (called riparian "buffer" areas) are crucial to maintaining stable streambanks and minimizing the natural lateral shifting of stream channels. Streambank stabilization techniques that integrate natural stream vegetation are preferred, because in addition to stabilizing the bank, they restore the natural water quality protective functioning of riparian areas. Well vegetated riparian buffers slow stormwater runoff from farm fields as well as urban areas, and provide an opportunity for roots to take up nutrients dissolved in surface and groundwater. Phosphorus removal rates depend on land-use and the management techniques employed.

Nutrient Management

Nutrient management involves the rate, timing, and placement of fertilizer to encourage maximum nutrient recycling, minimize the expense of fertilizing, and provide optimum soil fertility for the planted landscape.

Nutrient management is a low cost method for reducing phosphorus runoff from heavily managed properties such as golf courses or commercial developments. Lower overall maintenance costs are often achieved by a reduction in the quantity of fertilizer required. The soils must be tested annually and the results interpreted by a qualified analyst.

Agricultural Management Alternatives

Agricultural nonpoint source pollution is highly site-specific and depends on parameters such as the types of crops and the farming practices (Table 4). Since phosphorus is often bound to sediments, any agricultural practices that encourage erosion will contribute to the overall phosphorus load from an individual site. The agricultural management alternatives are numerous, and have been grouped into five general categories: structural methods, livestock management, nutrient management, land use modifications and tillage methods. Structural methods primarily address water movement from the farm to the stream. Livestock management attempts to keep livestock from directly degrading water courses. Nutrient management controls the location and use of fertilizer and manure to maximize the benefit to the farmer while minimizing the impact to the water bodies. Land use modifications involve riparian buffers and alternate field management techniques. Tillage methods reduce the runoff and erosion from tilled fields. Each general category will be discussed below. Details on each management alternative can be found in state and federal publications (NYSDEC, 1993b; USEPA, 1993).

Structural Methods

<u>Field Diversion</u>. A diversion directs runoff away from a particular area of a farm, such as a barnyard or feedlot, where there are high concentrations of pollutants. It consists of an earthen channel constructed across the slope with a supporting ridge that collects and redirects the runoff entering the field. This prevents the contamination of clean water entering the area. Diversions are relatively easy to design and install and take little land out of active production. They are not suitable in areas with high sediment yields and have little impact on runoff volumes.

Subsurface Drainage. Subsurface drainage consists of a conduit, such as corrugated plastic tubing, tile or pipe, installed beneath the ground surface to collect and/or convey drainage water. The purpose is to improve the soil environment for vegetative growth, reduce erosion, and improve water quality by: intercepting and directing water movement away from wet areas, removing surface runoff, and removing water from heavy use areas, such as around barns, barnyards and animal watering facilities. Problems can be experienced by root infiltration by hydrophillic trees.

Grassed Waterway. A grassed waterway is a natural or constructed channel, with a parabolic or trapezoidal cross-section, that is below ground level and is established in suitable vegetation for the stable conveyance of runoff. This practice controls surface runoff by conveying it to protected outlets, thereby preventing gully erosion. Grassed waterways are relatively inexpensive and can effect significant phosphorus reductions. This practice does, however, take land out of crop production and is not suitable where there are high sediment loads or high water tables.

Appendix Table 1. Generic Urban Best Management Practices Summary

MANAGEMENT PRACTICES	RELATIVE COST	LIMITING CONDITIONS	MAINTENANCE	ADVANTAGES	DISADVANTAGES	SPECIAL CONSIDER-ATIONS
Extended Deten-tion Basins	Low	None of special concern, serves drainage areas of 10-400 acres	Frequency: Mod-erate Cost: Low	Controls peak discharge rate and downstream bank erosion	Poor aesthetics, potential for nui-sance	Prone to clog-ging, difficult to achieve detention times, permits may be required
Retention Ponds and Artificial Wet-lands	Moderate	Base flow required, drainage area served depends on type of pond or wet-land	Frequency: Mod-erate Cost: Moderate	Controls peak discharge rate, provides wildlife habitat, recre-ation, aesthetics.	Becomes nuisance if poorly maintained	Requires careful planning, 14-day detention time needed for phos-phorus removal, permits may be required
Infiltration Basin	Varies according to design	Depth to water, rock and hardpan soil permeability, serves drainage areas up to 50 acres	Frequency: High Cost: Moderate/ High	Serves large developments, provides ground-water recharge, can be adapted to control peak rate and volume resulting from large storm	High rate of failure due to unsuitable soils and lack of maintenance, prone to clogging.	Requires effec-tive pretreatment to prevent over-loading with sedi-ment and clogging

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MANAGEMENT PRACTICES	RELATIVE COST	LIMITING CONDITIONS	MAINTENANCE	ADVANTAGES	DISADVANTAGES	SPECIAL CONSIDER-ATIONS
Infiltration Trench	Moderate	Depth to water, rock and hardpan soil permeability, serves drainage areas < 10 acres	Frequency: High Cost: High	Preserves natural topography, provides groundwater recharge, can be adapted to control peak rate and volume resulting from large storm	High failure rate due to lack of maintenance, requires careful construction, potential for groundwater contamination	Requires effective pretreatment to prevent overloading with sediment and clogging
Sand/Peat/Organic Filter Systems	Moderate/ Expensive	Serves drainage areas of ½-50 acres	Frequency: High Cost: Moderate	Effective end-of-pipe retrofit for urban areas, minimal land requirement	Requires frequent maintenance	Shut down peat filters during winter freeze
Vegetated/Grassed Swales	Low	Flow velocity, soil permeability	Frequency: Low Cost: Low	Some infiltration; nutrient/sediment removal	Limited capacity	Best used in combination with other practices
Filter Strips	Low Serves drainage areas _ 5 pervious acres	Flow velocity, slopes _ 15%	Frequency: Moderate Cost: Low	May be applied at any stage during development	Limited capacity	Best used in combination with other practices

Appendix Table 1. Generic Urban Best Management Practices Summary

MANAGEMENT PRACTICES	RELATIVE COST	LIMITING CONDITIONS	MAINTENANCE	ADVANTAGES	DISADVANTAGES	SPECIAL CONSIDER-ATIONS
Streambank Stabilization	Varies with BMP employed	May exacerbate erosion if stream geomorphology isn't accounted for	Frequency: varies Cost: varies	Provides wildlife habitat, aesthetics if bioengineering is used	No control of peak rate, limited pollutant removal, may exacerbate erosion elsewhere.	Natural stabilization techniques preferred over structural techniques where practical; may require permits
Nutrient Management	Low -moderate, varies with tactic	Applies to landscaped portion of site	Frequency and cost depend on soil fertility needs	Reduced chemical use and potential for impacting water quality, improves system's ecology	Must evaluate soil fertility needs yearly	Tailor soil fertility to landscape needs
Site Restoration/ Reclamation	Varies with BMP employed	Varies with BMP employed	Varies with BMP employed	Flexibility, well-established watershed retrofit technique that can be applied pre- or post-construction	Varies with BMP employed	Generally, a combination of tactics is most effective

Livestock Management

Livestock Exclusion. Fencing excludes livestock from highly erodible areas, and limits access to drainage ways and water bodies, thereby limiting the detachment, transport and delivery of sediments, sediment bound pollutants, and the delivery of animal waste to surface waters. Fencing also allows prescribed grazing which improves livestock production and manure distribution. This method is inexpensive but labor intensive to install and may require an alternate water supply if livestock are fenced out of the streams.

Nutrient Management

Fertilizer Management. Fertilizer management is controlling the form, rate, timing, and placement of applications of fertilizer to encourage maximum nutrient recycling, minimize expense of fertilizing and provide optimum soil fertility conditions for the planted landscape. By carefully managing soil fertility and targeting fertilizer to species grown, plant growth will be optimized, nutrient losses to proximate waters will be minimized, and soil conditions will be maintained or improved. Periodic soil tests are required.

Manure Management. Manure management involves the collection, transportation and storage of manure until conditions are suitable for land application or the material is removed from the site. This reduces the quantity of manure and the associated phosphorus carried in the stormwater runoff. When manure is used as fertilizer for the fields, manure and soil testing is critical to ensure proper fertilization (see Fertilizer Management). Proper timing is also important to prevent washoff of the manure into proximal streams prior to its utilization by the plants and soil. The majority of manure management involves planning, however, some manure storage systems can be expensive.

Land Use Modifications

Field Priorities. Field prioritization refers to ranking farm fields according to their runoff, leaching or sediment yield potential, and managing them differently in terms of farming intensity and/or manure application. The purpose of this practice is to control farm losses of sediments and nutrients to water bodies while maintaining total crop production and to minimize manure losses while maximizing nutrient utilization in the context of a daily spreading program. This is an effective, low cost, planning tool.

Cover Crops. Cover crops are close-growing grasses, legumes, or small grains, grown primarily for temporary, seasonal soil protection and improvement. Cover crops are planted after harvesting a crop that leaves little residue on the soil or, when grown between trees and vines in orchards and vineyards. Cover crops protect exposed soil, thus control erosion, add organic matter and nutrients, suppress weeds, remove surplus nitrogen remaining in the soil after harvest, improve soil tilth and fertility. Cover crops are usually only grown for one year at most.

Crop Rotation. Crop rotation is a planned sequence of growing different crops in a recurring sequence on the same field in different years. Rotation is usually one component of a conservation management system that in part, reduces erosion, manages excess plant nutrients, and maintains or improves organic content in the soil. Crop rotation can break cycles of pests, require fewer chemicals, fewer applied nutrients, and ultimately provide greater yields.

Tillage Methods

Conservation Tillage. Conservation tillage refers to any tillage and planting system that maintains at least 30% of the soil surface covered by residue after planting to reduce soil erosion. Types of conservation tillage include minimum-till and no-till. Minimum-till equipment (chisel plows, field cultivators, discs, rototillers, etc.) tills and roughens the soil surface without incorporating all the plant residue. A minimum of 30% of the crop residue remains on the soil surface. No-till provides only a narrow band of tillage in the seed zone. Crop residues remain on the soil surface, virtually undisturbed by the planting operation. This practice benefits water quality by reducing soil erosion, increasing infiltration and decreasing runoff. Conservation tillage is particularly effective at reducing phosphorus losses for row crops, which have large exports of phosphorus with conventional till methods.

Forest Management Alternatives

Timber harvesting, if not carefully planned, can result in significant erosion and nutrient transport to surrounding water bodies (Table 5). Management practices, not previously discussed, are described below (NYSDEC, 1993c; USEPA, 1993). In addition, an ecosystem approach to forest management can also be effective at reducing nutrient runoff. An ecosystem approach involves managing for different components of a forest, such as plant species composition and age-class distributions.

Planned Harvest Operations

A harvest plan incorporates information about soil, slope and water resources to determine the spatial limits and intensity of the harvest so as to reduce the potential for erosion. This practice requires some additional time prior to harvest, but it improves the efficiency of the operation and protects the water quality.

Appendix Table 2. Generic Agricultural Best Management Practices Summary

MANAGEMENT PRACTICES	RELATIVE COST	LIMITING CONDITIONS	MAINTENANCE	ADVANTAGES	DISADVANTAGES	SPECIAL CONSIDER-ATIONS
Field Diversion	$2 - $5 per foot	Slopes must be < 15% not suitable in high sediment producing areas	Periodic inspec-tions	Takes only a small amount of land out of production easy to design and install	Little impact on runoff volumes	Cost may be offset by hay harvesting
Subsurface Drainage	$3.50 per foot				Root infiltration by hydrophyllic trees	
Grassed Waterway	$2 - $5 per foot	Not suitable where base flow exists, or areas with excessive sediment loads	Annual inspec-tions	Easy to design and install; can also act as a filter strip	Can fill up with sedi-ments; takes land our of crop production	
Filter Strip		Not effective in hilly areas	Regular inspec-tions, mowing, sediment removal	Unobtrusive easy to install and maintain; benefits wildlife	Not effective with sol-uble forms of phos-phorus or during winter; short lifetime (< 5 yr.)	Sediment accumu-lation reduces effectiveness
Streambank Stabilization						

Appendix Table 2. Generic Agricultural Best Management Practices Summary

MANAGEMENT PRACTICES	RELATIVE COST	LIMITING CONDITIONS	MAINTENANCE	ADVANTAGES	DISADVANTAGES	SPECIAL CONSIDER-ATIONS
Barnyard Runoff Management	$3,000 ->$50,000		Varies - can be intensive	Improves herd health and milk production	Expensive; requires a high level of management skill	Overland flow systems are more effective than channelized flow systems
Fencing / Livestock Exclusion	$2 - $5 per foot		Regular inspections	Inexpensive but effective	Labor intensive to install	May require alternate water supply
Fertilizer Management	Minimal		Periodic update of plan, soil testing	Cost savings in fertilizer; cost effective approach	High level of management skills	
Manure Management	Minimal		Soil testing and manure analyses	Cost savings on commercial fertilizers	Requires intensive management	
Equipment Calibration	Minimal		Calibration should be performed regularly	Increases fertilizer application effectiveness reduces costs		
Field Priorities	Low cost		Periodic soil tests and manure analyses	Low cost, effective	Requires informed decision making increased costs in terms of time, resources and lab analyses	

Appendix Table 2. Generic Agricultural Best Management Practices Summary

MANAGEMENT PRACTICES	RELATIVE COST	LIMITING CONDITIONS	MAINTENANCE	ADVANTAGES	DISADVANTAGES	SPECIAL CONSIDER-ATIONS
Cover Crops	$20 - $25 per acre		Minimal	Cost effective erosion control program		
Crop Rotation	Minimal		Minimal	Improved soil structure; breaks insect, weed and disease cycles	Limits the years a commodity is grown	
Conservation Tillage	$20 - $40 per acre	Not suitable for all soils	Annual soil tests	Cost effective erosion control; time, fuel, labor savings	Reduced incorporation of fertilizers and chemicals; plant residues can be easily buried	
Strip Cropping	$30 per acre	Not compatible with cash cropping enterprises	Minimal	Improves soil; breaks insect and weed cycle; inexpensive and easy	Limits the years and acreage of a commodity	Irregular field topography may prevent its use

Access Routes/Road Water Management

The proper design of logging roads and skid trail systems can significantly reduce erosion. Critical site features are topography, soils, rock outcrops, wetlands, watercourses, and the future needs of the area. Properly sited existing trails should be utilized as much as possible with a minimum of modification. Logging roads should have proper water management, such as drainage dips, cross-drain culverts or ditches. Care must also be taken not to damage drainage controls by heavy equipment and special attention should be made to roads on highly erodible soils. Properly designed and maintained drainage systems can prolong the useful life of the access road.

Riparian Buffers

See Urban Management Alternatives / Stream Corridor Management

Watercourse Crossings

Water crossings should be avoided unless absolutely necessary. Stable structures can be installed across watercourses to provide temporary access for logging operations to minimize the effects of the crossing. Bridges, culverts, or fords may be applicable depending on the site. The design of watercourse crossings must take into account fish spawning and migration, as well as protecting against increased channel erosion or flooding. All disturbed areas should be stabilized immediately after removal of the water crossing structures.

Sediment Barriers

Sediment barriers typically consist of silt fences and/or straw bale dikes installed as close to the limits of disturbance as possible, to reduce the velocity of sheet flow. These temporary measures can intercept and detail small amounts of sediment from disturbed areas during rain events. Sediment barriers can be installed near roads, skid trails, landings and other disturbed areas to minimize the impact on proximal waterbodies. There is a high percentage of failure if not installed correctly or properly maintained.

Vegetation Establishment/Revegetation

Establishing vegetation on bare soils, particularly on steep slopes, can prevent severe erosion of sediment to surrounding watercourses. The vegetation may be a fast growing grass or legume, later followed by the planting of trees and shrubs. This management practice can also provide a habitat for wildlife. Areas with poor initial establishment should be reseeded.

Appendix Table 3. Generic Forest Best Management Practices Summary

MANAGEMENT PRACTICES	RELATIVE COST	LIMITING CONDITIONS	MAINTENANCE	ADVANTAGES	DISADVANTAGES	SPECIAL CONSIDER-ATIONS
Planned Harvest Operations	Low		Regular inspection of management practices, post-harvest inspection	Improves efficiency of operations, protection of wildlife	Requires planning time	
Access Routes/ Road Water Management	Low	Avoid wet soils, steep slopes, rock outcrops and riparian buffer zones	Routine inspections, frequent maintenance during harvest season	Improves efficiency of operations, protection of wildlife	Requires planning time	Routes must be stabilized and stream crossings removed after harvest operations cease
Riparian Buffer Protection	Low		Boundaries marked before logging begins	Effective, easily implemented; benefits ecosystem	Loss of timber in buffer zone; longer road/trail network may be needed	Buffer distance varies according to soil type, slope, cover and season
Watercourse Crossings	Moderate to high	Natural resources may limit location and types of crossings; vehicle access requirements may restrict use	Periodic removal of debris	Bridges can be removed and reused	May interfere with fish spawning and migration; flooding and channel erosion may result from constrictions	No equipment should be operated in the watercourse; disturbed area after removal should be stabilized immediately

Appendix Table 3. Generic Forest Best Management Practices Summary

MANAGEMENT PRACTICES	RELATIVE COST	LIMITING CONDITIONS	MAINTENANCE	ADVANTAGES	DISADVANTAGES	SPECIAL CONSIDER-ATIONS
Sediment Barriers	Low	Not suited to large drainage areas	Regular inspec-tions; clean out accumulated sedi-ment	Easy to install, fences can be reused; straw bales can be used for mulch	High percentage of failure from poor maintenance	Soil particle size may limit effec-tiveness
Vegetation Establishment	Site dependent	Large sites may require revegeta-tion in stages	Protect area until vegetation is established; peri-odic topdressing of fertilizer may be needed	Food and cover for wildlife	Large sites may require special equipment	Soil tests, seed selection and amendments improve success