New York City Department of Environmental Protection

Watershed Agricultural Program Evaluation

Prepared in accordance with condition 306q-3 of the United States Protection Agency's Filtration Avoidance Determination of 1997

Submit evaluation of the Watershed Agricultural Program based upon the evaluation criteria

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Watershed Agricultural Program Evaluation

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Watershed Agricultural Program 1999 Evaluation

Introduction and Summary

1. Background

The New York City water-supply system is one of the largest surface-storage and supply complexes in the world, consisting of over 1,900 square miles, or 1,216,000 acres, covering parts of eight counties north and northwest of the City. Portions of the watershed are located as far as 125 miles from New York City. On average, 1.34 billion gallons of water are conveyed to the City each day. In addition to its 8 million residents, the City supplies high quality drinking water to one million residents in upstate counties, as well as millions of daily commuters, tourists and visitors to the City.

Agriculture is one of the major land uses in New York City's upstate watershed. Dairy and livestock farming in particular present one of the greatest challenges to the City's comprehensive watershed management program. Agriculture is potentially a significant source of pathogens, nutrients and other forms of pollution to surface waters. There are approximately 350 dairy and livestock farms in the City's watershed.

While non-point agricultural pollution is a must-solve problem, farmers are often bitterly antagonistic toward traditional regulatory programs. That makes for the following challenge: reconciling the public health and environmental resource protection interests of a large and distant city with the farm community's desire to maintain a fragile agricultural economy and way of life in the watershed region. This challenge is further compounded by the standards and requirements of the federal Safe Drinking Water Act, the Surface Water Treatment Rule, and EPA's Filtration Avoidance Determination for New York City.

In response to farmers' concerns about the potential economic impact of proposed revisions to New York City's watershed rules and regulations in 1990, the City put aside its purely regulatory approach and entered into partnership with the watershed farm community to carry out a locally developed and administered voluntary Watershed Agricultural Program. The City committed $3.9 million over the first two years (September 1992 to September 1994) to refine and demonstrate an environmentally sound approach to farm management, called "Whole Farm Planning," on ten pilot farms in five counties in the watershed, and use those ten farms to market the approach throughout the region. In the second phase of the program, again with the City's financial support ($35.2 million), Whole Farm Planning expanded to all willing farmers in the watershed over the next seven years (October 1994 to September 2001)

The farmer-led Watershed Agricultural Council, Inc. was established in 1993 to provide a forum for farm industry input and leadership in the Watershed Agricultural Program. The watershed's agricultural leadership had itself committed to a goal of 85% farm participation in this program by 1997, at which date the program would be evaluated and assessed. If the Program were not judged a success, the City would have then considered more traditional regulatory approaches as needed.

In addition, the Watershed Agricultural Council, consisting of farmers and federal, New York City and State representatives, assumed administrative and operational responsibility for the Watershed Agricultural Program. This is desirable because the success of the program depends on farmers marketing the program to farmers. To be able to assume these significant responsibilities under its $35.2 million agreement with New York City, the Council incorporated itself and received 501(c)(3) nonprofit status.

As part of this collaborative pollution prevention effort, Cornell faculty and staff have been active participants in the development and implementation of the Agricultural Program and in providing scientific research and data to guide the program.

Locally, county soil and water conservation districts and cooperative extension associations are likewise actively involved in developing and implementing the Watershed Agricultural Program. Soil and water conservation districts work directly with individual farmers to provide funding from New York City and technical assistance in implementing the management practices called for in Whole Farm Plans. Cooperative extension professionals provide agronomic assistance to the farmers so that they are able to integrate Whole Farm Plans fully into their farm operations. The U.S. Natural Resources Conservation Service provides engineering and technical support for the design of best management practices.

2. *Model Program*

The Watershed Agricultural Program has become a model for reconciling environmental and public health protection with the economic and operational concerns of the farm industry. The Program has already received attention nationally, and has served as a model for other water-supply watersheds in New York State.

The Watershed Agricultural Program is guided by the following principles:

- scientifically based risk assessment framework for pollution prevention;
- regulatory relief for affected industry that does not compromise environmental and public health goals;
- public-private partnership involving industry, government and academic stakeholders;
- urban-rural partnership.

3. Institutional and Administrative Challenges

In putting together the Watershed Agricultural Program, New York City and the watershed farm community had to confront and overcome numerous significant institutional and administrative obstacles, many of which are unique to New York City and State. The establishment of the not-for-profit Watershed Agricultural Council as the central administrative agent of the Program was key to overcoming these challenges, which include:

- long standing watershed-New York City animosities and mistrust, dating back to the condemnation of lands for the City's reservoirs beginning in the early 20th Century;
- lack of institutional cooperation across county political lines in the watershed;
- weak institutional links and coordination among the traditional Federal, state and local agricultural agencies;
- rigorous City budgeting, contracting and procurement rules, by which the financing of the innovative and complex Watershed Agricultural Program had to abide;
- tensions inherent to the desire for flexibility and innovation while adhering to established Federal standards and specifications for conservation best management practices;
- undertaking a thorough environmental and financial assessment of each farm, including the identification of actual and potential pollution sources, while assuring adequate individual landowner confidentiality.

At times, it appeared that some of these obstacles might be insurmountable, and many of these issues still require constant attention. Keeping together and advancing the Watershed Agricultural Program demands patience, open-mindedness and frankness from all participants. Nevertheless, or as a result, the strength of the City-watershed farm community partnership is best expressed in the ability to work through and resolve conflicts while maintaining the focus and direction of the Program on mutual goals and objectives.

4. Objectives of the Watershed Agricultural Program[1]

A. The objective of the program is to protect the sources of the New York City's water supply while keeping farms in operation. Agriculture should be continued and promoted as a preferred land use in the City's watersheds.

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[1] Source: *Policy Group Recommendations*, Ad Hoc Task Force on Agriculture and New York City Watershed Regulations (December 1991)

Except for a general prohibition to safeguard against individual farm operators who exhibit a willful and irresponsible intent to pollute in a manner that threatens to significantly increase the farm's pollution levels, the program has been substituted for the initial agriculture regulations the City proposed in 1990.

B. While entirely voluntary as to any individual farmer, farmer participation in the program will be strongly driven by incentives, including 100% "cost-sharing" for Best Management Practice (BMP) planning and implementation, to be provided by the City and supplemented by State, federal and local funding sources, if available.

C. The preferred approach to source protection for farms is the use of BMPs developed to meet water-pollution control policies under the 1989 New York State Nonpoint Source Water Pollution Control Act and Section 319 of the Federal Clean Water Act amendments of 1987. Cornell University faculty will assist in the development of new BMPs, based on on-farm research and experience gained through the program, particularly to address pathogens.

D. The mechanism of choice for selecting agricultural BMPs is preparation of a Whole Farm Plan for each farm. A collateral objective for each Whole Farm Plan is to sustain and improve the economic viability of the farm.

Whole Farm Plans should be prepared by local County Project Teams, including professional staff from the county Soil and Water Conservation District, Cooperative Extension and the federal Natural Resources Conservation Service.

Whole Farm Plans should address agricultural contaminants in the form of nutrients, pathogens, sediments, toxicants and organic matter. The level of control required for each Whole Farm Plan should depend on the location of hydrologically sensitive areas on the farm and the farm's location in the watershed.

In managing agricultural contaminants, Whole Farm Plans should involve these components: soil erosion control, animal waste management, plant nutrient management, domestic animal pathogen management and chemical and pesticide management.

E. Continuing education, professional training and local involvement are essential components of the Whole Farm Planning approach to agriculture.

While many of these mechanisms and approaches for farm management are not new, combining them into a whole package for each individual farm represents a significant innovation and challenge. Agencies that did not work closely together in the past, such as Soil and Water Conservation Districts and Cooperative Extensions, now sit down together with farmers to develop and implement plans for protecting water quality and the economic health of the farm.

In addition, in the past, the process of selecting BMPs often overlooked the farm's broader economic strategy and business needs. Whole Farm Planning seeks to harmonize these objectives. To our knowledge, the Watershed Agricultural Program is unique in its holistic approach to addressing farm sources of pollution, including pathogens, as well as the individual farmer's operational and financial circumstances.

5. Multiple Barrier Approach

The Whole Farm Planning process takes a "multiple barrier" approach to best management practice planning and implementation on the farms. These on-farm barriers control or eliminate to the best extent possible the generation, transport and viability of agricultural pollutants before they enter the surface waters of the City's watershed system, whose size and natural features act as a further off-farm barrier. Examples of the three "barriers" include:

- *First Barrier - Pollutant Source Controls.* These controls might include herd health maintenance, sanitary improvements, calf housing improvements, separation of young and old stock to eliminate or minimize pathogen infection in livestock; soil sampling, grass/hay production to reduce need for excess fertilizer; Integrated Pest Management (IPM) to reduce amounts of pesticides used on farms; and conversion of fields from row crops to grass/hay and altering rotational patterns to reduce soil runoff.

- *Second Barrier - Landscape Controls.* These controls might include barnyard improvements, manure storage, scheduled and directed spreading of manure, and composting to control application of animal waste to the landscape to reduce or eliminate the risk of pathogens, nutrients, sediments and pesticides from reaching surface waters.

- *Third Barrier - Stream Corridor Controls.* These controls might include streambank stabilization, stream crossings, animal watering systems, and vegetated buffers to keep animals out of watercourses and slow down and reduce transport of pollutants into watercourses.

6. Watershed Agricultural Program Evaluations

In its *Policy Group Recommendations* (December 1991), the Ad Hoc Task Force on Agriculture and the New York City Watershed Regulations proposed that the Watershed Agricultural Program should be reviewed during 1997 to determine the effectiveness of the Program and determine what changes, if any, should be made to ensure that agricultural sources of water pollution are adequately managed. Under the heading,"Review of Progress in 1997," the Policy Group Recommendations state:

> *During 1997, the City, with the assistance of the Watershed Agricultural Council and other appropriate public and private parties, should engage in a review of the results of the voluntary agricultural best management program.*

This review should assess the extent to which the practices and facilities called for by the whole farm plans have been, or are being, adopted on schedule and are being properly maintained. Also needed is an evaluation of whether the results are consistent with the requirements of the avoidance criteria and the City's anti-degradation water quality objectives. If the review does not justify a continuation of the program in its adopted form, the City should submit to the NYS Department of Health such revisions to the watershed regulations as it deems necessary to continue to meet its obligations and responsibilities.

The City will work with the Watershed Agricultural Council on developing parameters and criteria for evaluating the agricultural program in 1997, including a variety of program and regulatory options to consider in the event that changes may be needed. The Policy Group has concluded that all options must be available for consideration in 1997. In any case, as noted above, farm operators voluntarily participating in the Whole Farm Planning Program should be held harmless in the event that a regulatory program is pursued by the City after the 1997 review period.[2]

At the time, and to this date, the only quantifiable criterion established for the Watershed Agricultural Program was the goal of 85% farmer participation in the Program by 1997.[3]

The Department of Environmental Protection and Watershed Agricultural Council developed evaluation criteria and an evaluation strategy for 1997 for the Watershed Agricultural Program. To help guide that effort, the Council established an Advisory Committee, consisting of Federal and State agencies, including the US Environmental Protection Agency and the State Department of Health, as well as industry representatives and environmental organizations. In 1996, the Advisory Committee met during the Spring and Fall to review and comment on the Council's efforts to establish a sound basis for evaluating the Program in 1997.

In addition, DEP, the Watershed Agricultural Council, Cornell University and the USDA Natural Resources Conservation Service established an Evaluation Working Group to develop the necessary tools to provide for both a Program evaluation in 1997 and to support Whole Farm Plan decision making at the field level.

As a result of these efforts, DEP and the Watershed Agricultural Council settled on seven basic criteria that range from administrative accounting of farmer participation through qualitative and quantitative measures of Whole Farm Plan effectiveness. Criteria also address the efficacy of the Whole Farm Planning process and a review of the scientific support provided by Cornell

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[2] *Policy Group Recommendations*, Ad Hoc Task Force on Agriculture and New York City Watershed Regulations (December 1991), p. 7

[3] *Policy Group Recommendations*, p. 6

University and others. It should be noted that criteria relating to quantifiable reduction of pollutant export from farms (#4, 5 below) were not be applicable by 1997, but it was the intention to establish a program for validation and application in 1999.

<u>1997 Watershed Agricultural Program Evaluation Criteria</u>

1. Farmer Participation (measured against the goal of 85%)
2. Acceptance, Implementation and Maintenance of Whole Farm Plans by Farmers
3. Reduction or, where possible, elimination of risk of contaminant generation and transport from farm to water supply watercourse
4. Quantifiable reduction of nutrient export from farms
5. Quantifiable reduction in sediment, pathogen and nutrient export from farms
6. Efficacy of Whole Farm Planning and Implementation process
7. Science of Whole Farm Planning

The evaluation criteria and the tools developed to measure them are supported by the ongoing water monitoring by the State Department of Environmental Conservation at the individual farm scale and by DEP at the basin and watershed scale. In 1999, these seven criteria were streamlined by combining criterion #2 with #1 and #5 with #4.

The Watershed Agricultural Program is fundamentally a *watershed management* program for agriculture. There are two scales on which watershed management for agriculture is possible: the whole farm scale and the reservoir watershed scale. These are two *management scales* for which the results of the Watershed Agricultural Program evaluation can be used directly as feedback and guidance to the Program in its ongoing mission to reduce the risk of agricultural non-point source pollution in the NYC Watersheds while maintaining and improving the economic viability of farms. Therefore, these two discrete scales are the appropriate scales for evaluating the effectiveness of the Watershed Agricultural Program.

The first management scale is the <u>whole farm scale</u> where agricultural activities are organized and integrated by the farm manager in the operation of his/her farm. While it is the whole farm that is managed, one objective of whole farm management plans is to minimize or eliminate any adverse water quality impacts from individual farm practices. Yet, individual farm practices are all interrelated in the whole farm operation; a change in one practice typically implies some change elsewhere on the farm. The Whole Farm Planning process has therefore recognized that any evaluation and resultant changes in individual farm practices must be done within the context of the farm as a whole, i.e., the farm as a management unit. And, as the whole farm is the management unit to which the Whole Farm Planning process is directed, it is also the most appropriate scale for evaluating the effectiveness of a Watershed Agricultural Program.

The second scale on which watershed management for agriculture can be effective is the <u>reservoir watershed</u>. There exists at the reservoir watershed scale a regulatory and management framework whereupon the relationship between multiple landscape patterns, land uses, pollution sources (point and non-point), and government jurisdictions are able to be considered in efforts to protect water quality. Of primary importance to protecting reservoir water quality are The Surface Water Treatment Rule and the Clean Water Act which set water quality standards for water quality in the reservoirs and establish the TMDL process (Total Maximum Daily Load). The TMDL process:

1. establishes the pollutant loading capacity of a reservoir, defined as the greatest amount of loading a water can receive without violating water quality standard;

2. estimates the TMDL's from a watershed that would be allowable without exceeding the loading capacity;

3. establishes both the loads from different point and non-point sources in the watershed and the Waste Load Allocations (WLAs) as part of an overall watershed management plan to maintain or reduce total watershed loads to levels below reservoir loading capacities.

The whole farm scale is of most immediate concern to the Watershed Agricultural Program as this is the scale at which Whole Farm Planning administered through the Watershed Agricultural Program is now being implemented. A reservoir watershed scale evaluation of the Watershed Agricultural Program is both a broader and a longer-term process because on this scale the effectiveness of the Watershed Agricultural Program in improving or maintaining high water quality conditions in the NYC Reservoirs can only be evaluated in the context of an assessment of water quality impacts from *all* non-point and point sources that contribute pollution to the reservoir. Nevertheless, the two scales of evaluation intersect and will proceed in parallel, with focus on those areas of intersection.

The Town Brook Research Program, described further below, is the outgrowth of these considerations for evaluating the effectiveness of the Watershed Agricultural Program at multiple scales. The establishment of this program consumed an enormous amount of effort and energy in 1998 and 1999. A great deal of time was spent in bringing farmer and scientific interests together in order to create a solid foundation of support for this complicated process.

In addition to the 1997 self evaluation, the Watershed Agricultural Program has been subjected to several other reviews: in 1998 by the Conservation Technology and Information Center (CTIC) under subcontract to the Watershed Agricultural Council; and in 1999 by the Research Council (NRC) as part of its review of the New York City's overall watershed management strategy under contract to the New York City Comptroller. Each of these evaluations has provided valuable guidance to Watershed Agricultural Program managers at DEP and WAC.

7. *Evaluation and the Importance of Protecting Farmer Confidentiality*

Protecting the confidentiality of information is a high concern for watershed farmers. All the partners involved in the Watershed Agricultural Program agree that farm specific data collected by the program in order to develop and implement whole farm plans need to be kept confidential. The farmers have voluntarily agreed to participate in the program and provide personal and financial information about their farming enterprises with the understanding that this information will be reasonably protected.

This same confidentiality applies to research sponsored by the Watershed Agricultural Program in agricultural watersheds. WAC's Manure Infrastructure Committee (MIC) established a protocol on how researchers can request and utilize data from participating farms for research activities. This protocol found in MIC's "Guiding Principles for Operation and Administration of Manure Management Strategies and Tasks" states, "all data must be maintained in a manner that protects the identity of the individual farm from whom the research data was collected." DEP and the other agency members of the team assembled to conduct farm and basin scale research in support of the Watershed Agricultural Program have accepted these principles and believe that the interests of confidentiality and sound scientific research can be satisfactorily balanced.

8. Observations

Performance monitoring and modeling

One the major criticisms of the Watershed Agricultural Program has been directed at the lack of monitoring and modeling data to document the effectiveness of the program in protecting water quality.[4] DEP and the Watershed Agricultural Council have recognized this weakness, and have worked diligently to develop a comprehensive water quality based evaluation program since 1997. The result of this effort is the Town Brook Research Program described later in this report, in addition to the continuing paired watershed study at the Robertson Farm and Shaw Road.

While establishing such a monitoring and modeling program are critical to supporting the Watershed Agricultural Program, several factors combine to make this task extremely difficult. The National Research Council has noted that "[a]lthough it is technically feasible to monitor performance standards for all these [nonpoint source] activities, it can be difficult and expensive because of the diffuse and episodic nature of pollutant transport."[5] And further, "linking the performance of BMPs with nearby water quality conditions is *much* more difficult to accomplish than determining the number of farms in the program or the number of plans implemented."[6]

Further complicating the establishment of a monitoring and modeling program is the need

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[4] *Watershed Management for Potable Water Supply: Assessing New York City's Approach*. Committee to Review the New York City Watershed Management Strategy. Water Science and Technology Board. Commission on Geosciences, Environment and Resources. National Research Council (Prepublication Copy. September 1999), p. 310.

[5] *ibid*, p. 296

[6] *ibid*, p. 302

to gain farmer support for such an effort that directly impacts their businesses and livelihoods. This is especially complicated by the simmering suspicions and mistrust among many farmers and watershed opinion makers about the City's intentions. Overcoming these obstacles consumed a great deal of time and effort, and the job is not completely done. DEP recognizes the leadership of the Watershed Agricultural Council and its individual farmer members in working to bridge the gaps of trust and understanding on both sides of this important issue. We also hope that New York State agencies with a direct role in funding and implementing monitoring programs would play a more constructive role in this difficult process.

Administrative Mechanisms

While the current administrative mechanism for developing and implementing Whole Farm Plans has succeeded, the Watershed Agricultural Program needs to look beyond the traditional USDA-Extension-Soil and Water Conservation District planning team arrangement to take full advantage of other models, in particular: private sector agricultural planning and consulting firms, the New York State Agriculture and Environmental Management (AEM) program, and the New York State Cattle Health Assurance Program (NYSCHAP). The USDA Natural Resources Conservation Service has itself adopted a policy that promotes and "encourages third party vendors [to] be a focal point for providing nutrient management and related technical assistance to farmers who apply nutrients for plant production."[7] By exploring the full range of pollution prevention delivery models, the Watershed Agricultural Program can constantly strive for a more efficient and effective program.

Of special note is the New York State Animal Health Assurance Program (NYSCHAP), an integrated disease prevention program, which utilizes a team approach (herd veterinarian, the producer and the State Department of Agriculture and Markets) to develop a farm specific health plan. This is a voluntary, flexible, tailored-to-the-farm program initiated by New York State in 1997. The objective is to encourage producers and veterinarians to engage in establishing best management practices that help maintain animal health and have potential to enhance the quality of products leaving the farm. This approach can provide benefits to productivity, profitability, the environment and consumer confidence of a farm and its produce.

Like the Watershed Agricultural Program, NYSCHAP works by the Team meeting at the farm and conducting an on-farm inspection and completing a risk assessment survey. Observations made during the farm visit are recorded in the risk assessment survey. BMPs are then recommended to the producer that will modify the risk of disease introduction or transmission within a livestock operation. There are several disease specific modules, including one for cryptosporidium and giardia (under development) that help to target the plan towards the needs of the producer. The Watershed Agricultural Council has recently met with NYSCHAP representatives to integrate the Program into whole farm plans to improve pathogen management and cattle health on farms.

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[7] Federal Register/Vol. 63. No. 77/April 22. 1998/p. 19890

Other observations:

1. WAC needs to continue developing and maintaining a comprehensive database of Whole Farm Plans, BMP implementation schedules and completed BMPs to improve the management and tracking of planning and implementation.

2. Whenever feasible and/or practical BMP implementation should be scheduled and implemented according to pollutant category priority.

1. Farmer Participation

A. Summary of Progress Reaching FAD Goals and Milestones

The following table describes the progress of the Watershed Agricultural Program in meeting its various Filtration Avoidance Determination milestones for 1999. The Program has met or exceeded its goals, including those for executing Whole Farm Plan implementation agreements (306p-3); commencing implementation of Whole Farm Plans (306p-8); and completing Whole Farm Plans (306p-115). In addition, the Watershed Agricultural Council has begun performing follow-up visits with farms that have completed implementation of their Whole Farm Plans (Annual Follow Up) in order to ensure and support farm management changes to protect water quality.

Filtration Avoidance Determination Condition	**Goal** 12/99	**Achieved** 12/99
Farms Signed Up	297	310
Whole Farm Plans (WFPs) Approved *(306p-3)*	225	229
WFPs Commenced Implementation *(306p-8)*	136	167
Whole Farm Plans Complete *(306p-15)*	47	50
Annual Follow Up	30	179

B. GIS/GPS Maps Depicting the Following (See Attached Maps):

1. Whole Farm Plan Activities
2. Conservation Reserve Enhancement Program Activities
3. Follow-up Activities

C. Land Area and Animals Treated

Table 1 provides a comparison of approximate acreage of agricultural land in approved whole farm plans at the end of 1997 and 1999.

Table 1
Acreage of Agricultural Land in Approved Whole Farm Plans

Agricultural Land	1997	1999
Rotated Cropland Owned	7507	8271
Rotated Cropland Rented	4500	12284
Permanent Hayland Owned	4002	5766
Permanent Hayland Rented	3828	5646
Pasture Owned	9578	11970
Pasture Rented	5713	4580
Woodland Owned	17,694	21306
Woodland Rented	2727	3301
Total Acres	**55,551**	**73,124**

Table 2
Animal Census Farms Participating in WAP as of 12/31/1999
(Source: WAC Database)

Animal Type	*Number of Animals*
Mature Dairy	10,625
Dairy Heifers	7,494
Veal	630
Beef	1,214
Sheep	425
Goats	63
Pigs	185
Horses	475
Chickens	2,606
Pheasant	300
Rabbits	100
Emu	7
Ostrich	15
Llama	74
Deer	380

D. BMP Implementation

Table 3 below summarizes all the BMPs that were implemented during Phase I and II between the years 1992 through 1999. Practices with Natural Resources Conservation Service code numbers are fully described in the National Handbook of Conservation Practices (http://www.ncg.nrcs.usda.gov/nhcp_2.html).

Watershed Agricultural Program BMP Implementation 1992 -1999 (Includes Phase I and II Implementation)		
NRCS Code #	Best Management Practice Name	Number of BMPs
190	Waste Transfer System	5
193	Waste Field Storage	3
313	Waste Storage Structure	17
314	Brush Management	4
328	Conservation Crop Rotation	85
329	Conservation Tillage	2
340	Cover & Green Manure Crop	6
342	Critical Area planting	6
362	Diversion	52
382	Fencing	73
393	Milkhouse Waste System	28
393a	Filter Strip	6
408	Forest land Erosion Control	1
411	Grasses & Legumes in Rotation	7
412	Grassed Waterways	7
468	Lined Waterway	14
472	Use Exclusion	2
500	Obstruction Removal	5
510	Pasture & Hayland Planting	8
511	Forage Harvest Management	2
512	Pasture & Hayland Management	32
516	Pipeline	4
528a	Prescribed Grazing	32
558	Barnyard Runoff Management System	10
560	Access Road	39
561	Heavy Use Area protection	32
574	Spring Development	43
575	Animal Trails & Walkways	20
580	Streambank Protection	9
584	Stream Channel Stabilization	1
585	Contour Stripcropping	4
586	Field Stripcropping	18
587	Structure for Water Control	6
590	Nutrient Management	115
595	Pesticide Management	8
606	Subsurface Drain	77
612	Tree/Shrub Establishment	1
614	Trough or Tank	14
620	Underground Outlet	8
633	Waste Utilization	27
634	Waste Transfer	3
707	Barnyard Water Management System	75
749	Manure Pile Areas	4
	BMP's without NRCS Specifications (i.e. Pathogen Mgt. , Ventilation, Herd Health Mgt., etc.)	211
	Total No. of Best Management Practices	1126
	Total Cost	$8,298,724.68

E. Watershed Agricultural Council (WAC) Database

To maintain control over Program expenditures and track other elements of Program activities, WAC has established a database of information. The most important function served by the database is to assure the WAC Finance office that the reimbursement requests from partnering agencies for Best Management Practices implemented on watershed farms do not exceed the funding approved by the Watershed Agricultural Council. To date all expense reimbursement requests have been within Council approved Plan totals.

The database is also a source of information on acreage, livestock, BMP implementation by NRCS and WAC code, Whole Farm Plans approved with watershed locations, and the current status -- operating or non-operating -- of Program farms. To keep the data up to date, WAC employs a part-time staff person to enter information from applications to participate in the agricultural program, from Whole Farm Plans, revisions, supplemental funding approvals and payment data from WAC and its subcontracted agencies. The database is also a comparative tool for analyzing detailed implementation schedules against the broader Whole Farm Plans and revisions presented to the Council for approval.

2. Acceptance, Implementation and Maintenance of WFPs by Farmers

A. Summary of In Person Farmer Interviews

The key to the success of the Watershed Agricultural Program is its full acceptance and support in the farm community. The Watershed Agricultural Council Evaluation Committee randomly selected 10 percent of all the farms that have signed up to participate in the program and conducted an on farm interview. This gave Council Directors an opportunity to meet with the farmers and their families and asked them a series of questions to determine farmers attitudes about the program and their whole farm plan. A few of the selected farms are no longer in business for various reasons and were not interviewed. A total of 24 program participants were interviewed.

The survey questions and responses are included in the Appendix. In summary the interviews showed:

- A significant majority (71%) of farmers agreed with the process of identifying water quality issues on their farm and they felt that their Whole Farm Plan will adequately address them.
- In regards to nutrient management plans it is clear that more education is needed to teach farmers the importance of these plans and how they should use them.
- The majority of responses indicated that the BMPs selected in their plan did not have a negative impact on the farm enterprise.

- Most farms that had BMP implementation were satisfied with the contractual work done although some, especially those that had no implementation yet, felt the process should be speeded up.
- Most farmers stated the program has met their initial expectations.

The Council Directors who conducted the interviews had the following suggestions to strengthen the program:

1. There is a need to improve communication between the farmers and the Council. A few farmers had problems with the plan and did not tell any one. It was suggested that each Council Director be assigned a group of farmers in their area, so that if a problem arises the farmer knows a Council Member who he/she can discuss it with. The farmer may feel more comfortable discussing issues with a peer, instead of one of the program staff.
2. Engineers, implementation staff and contractors should be more considerate to avoid disturbing the day to day operations on the farm.
3. Nutrient management plans should be developed in a format that can be posted in the barn for easy reference.
4. Low bid contractors should be investigated to determine if they are capable of handling a job in a professional and timely manner.
5. BMPs (i.e. solar calf houses and fuel storage) should be bid together (in group bid packages) to attract more experienced contractors to the area and speed up implementation.

B. Annual Whole Farm Plan Review on Farms

The Watershed Agricultural Council is also monitoring farmer acceptance of whole farm planning and the operation and maintenance of BMPs by conducting an "Annual Whole Farm Plan Review." While the Filtration Avoidance Determination milestones require those farms that are substantially complete to have annual follow-up visits by the planners, WAC firmly believes that all farms with an approved Whole Farm Plan should also be visited at least once a year to meet with the farmer to discuss his/her WFP, review the operation and maintenance agreements for any BMPs already implemented and review proposed implementation schedules for remaining BMPs. This annual visit also provides an opportunity to discuss and answer the farmer's questions regarding the farm's nutrient management plan and identify any new water quality issues not covered in the WFP. In 1999, WAC initiated a policy that all farms with an approved WFP have an annual review conducted by one of the planners.

A three page form was developed by WAC and the planners to record the information collected during the annual review. Unfortunately, the form was not completed until September of this past year and wasn't used for all annual reviews in 1999. In future years, WAC plans to utilize these annual reviews to better manage BMP implementation and gauge farmer compliance, satisfaction and acceptance of the program.

C. Contractors' Survey

A survey was sent out to a list of 60 contractors who have participated in the program, either through implementing BMPs, submitting bids and/or attending the WAP Annual Contractors meeting. The purpose of this survey was to identify any possible problems and/or difficulties the contractors were having with the WAC BMP procurement procedures. Unfortunately only eight responses to the survey were received. Survey questions and responses can be found in the appendix of this report.

Of the few responses received most were satisfied with the procurement procedures. However, one respondent felt that it was unfair that he spent a great amount of time developing a bid and even though he was the lowest bid the farmer had an option to pay the difference and select another higher bidder. One contractor commented that he was so busy this year he had no time to bid on WAP projects.

Competition for qualified local contractors among different watershed protection programs has become acute and may lead to difficulties in BMP implementation in the future unless new contractors enter the area or existing contractors expand their operations.

Note: The WAC Evaluation Committee conducted two additional surveys one for WAP Advisory Committee Members and the Partnering Agencies and one for WAC Directors. Both of these surveys have been included in the appendix.

3. Reduction of Phosphorus and Parasite Loading Risk From Farm to Water Course

A. Comprehensive Nutrient Management Plans (CNMP)

The following New York State NRCS policy went into effect on 1/19/99. In the spring of 1999, WAC passed a resolution stating that all Whole Farm Plans will have a Comprehensive Nutrient Management Plan (CNMP) completed prior to any structural BMP implementation. This resolution is consistent with the updated New York State NRCS policy and is an important advance in the evolution of nutrient management planning in the Watershed Agricultural Program.

COMPREHENSIVE NUTRIENT MANAGEMENT PLAN POLICY & PROCEDURE

USDA - NATURAL RESOURCES CONSERVATION SERVICE, NEW YORK

USDA - Natural Resources Conservation Service (NRCS) technical assistance for Comprehensive Nutrient Management Plan (CNMP) results in implementation of total resource management systems which are in concert with the NRCS mission and watershed objectives. Systems will be formulated to manage agricultural waste products from the point of origin to its ultimate use with consideration given to both on-site and off-site soil, water, air, plant, animal *and human resources effects. Landowners will be encouraged to implement these plans within the development of a total resource management plan.*

This policy of NRCS in New York State is based on the following definition. It is applicable for use by both public and private sector planners who provide technical assistance to producers for development of a Comprehensive Nutrient Management Plan.

COMPREHENSIVE NUTRIENT MANAGEMENT PLAN:

A Comprehensive Nutrient Management Plan identifies actions or priorities that will be followed to meet clearly defined nutrient management goals for agricultural operators which will, when applied, lead to meeting established environmental, public health and water quality objectives.

The nutrient management goal of a Comprehensive Nutrient Management Plan is to achieve the level of nutrients required to grow the planned crops and support a viable livestock operation by balancing the nutrients that are already in the soil and from other sources with those that will be applied in manure, biosolids and fertilizer.

Comprehensive Nutrient Management Plans will address, at minimum, feed management, manure handling and storage, land application of manure, nutrient management, land management, record keeping, and acceptable alternatives for use or disposal of excess nutrients produced or imported onto the farm.

Comprehensive Nutrient Management Plans are site specific and written to address the goals and needs of the individual owner/operator in consideration of environmental, public health and water quality considerations.

Comprehensive Nutrient Management Plans shall be planned in accordance with the procedures identified in the USDA Natural Resources Conservation Service National Planning Procedures Handbook (NPPH), Amendment 2, and designed, constructed and operated in accordance with NRCS Conservation Practice Standard NY312 - Waste Management System.

The policy includes:

1. *Technical assistance may be provided in one or more of the following: planning, design, or implementation of a Comprehensive Nutrient Management Plan; based on landowner needs and consistent with watershed objectives.*

2. *No design or implementation assistance will be provided until a complete Comprehensive Nutrient Management Plan has been developed although preliminary survey and soil investigations are allowed as needed for preparation of the CNMP.*

3. *Comprehensive Nutrient Management Plans will insure that an adequate land base exists for utilization of farm generated and imported nutrients or provide alternative methods, which minimize environmental risk, where insufficient land base exists.*

4.Technical assistance, including plan revisions, may be provided to all landowners/operators who request assistance and who have decision making authority, within established priorities.

5.For each Comprehensive Nutrient Management Plan, a complete inventory and evaluation will be conducted in accordance with NRCS Conservation Practice Standard NY312 - Waste Management System.

6.On land receiving manure applications soil erosion and concentrated flow control measures will be included as needed.

Chapter 2 of the Agricultural Waste Management Field Handbook is an excellent reference for developing a Comprehensive Nutrient Management Plan.

(Reprinted from: http://www.ny.nrcs.usda.gov/standards/cnmp_pol.htm)

B. Update of the Robertson Farm and Shaw Road Research Whole Farm Monitoring Study

A research study, which relies on event-based monitoring to track water quality, is being conducted by scientists at the NYS Department of Environmental Conservation in the New York City Watershed to help determine the effectiveness of whole farm planning (WFP) and implementation. The study aims to test the ability of the WFP process to correctly identify significant sources of on-farm pollution, and subsequently recommend and implement cost effective management practices that substantially reduce pollutant losses from those sources. A paired watershed design is utilized consisting of one dairy farm and one non-agricultural control site close to one another and of similar size, shape, elevation and soils. The agricultural watershed is 160 ha and consists almost entirely of the farm itself. It is the headwaters of a small tributary that arises on the farm. Land use in the watershed is approximately two-thirds forested; the remaining acreage consists of rotated cropland, permanent hayland and pasture, and the farmstead area. The control site is also a headwater watershed, drains 90 ha, and is composed of forest land, abandoned field returning to forest, and shrub land. There is one permanent residence and several weekend residences in the watershed.

Both sites were monitored for two years (June 1993 - May 1995) prior to any management practice installation on the farm in order to establish an accurate relationship between the hydrologic responses of the agricultural watershed and the control watershed. The farm was then treated with all practices recommended in its Whole Farm Plan. These include a 9-month capacity manure storage, a rotational grazing system, barnyard water management, manure spreading schedules, farm road improvement, milkhouse waste diversion to the manure storage, stream diversion away from the barnyard area, tile drainage, relocation of the silage storage area, and upland diversion installations. Monitoring began again in November 1996 and is continuing for five years. Water quality before and after implementation is being compared to determine to what degree Whole Farm Planning and implementation of practices improved agricultural runoff from the monitored farm. Detailed records of farm activities, such as location and amount of manure spreading, fertilizer used, and so on, are being kept in order to relate changes in water quality to changes in farm practices.

Stream discharge and precipitation are measured continuously at the sites. Approximately 1400 water samples were collected during the two years of pre-implementation monitoring; the vast majority of which represented runoff event periods. In the three years of post-implementation monitoring so far, approximately 1900 samples have been collected, again, with the major emphasis being on runoff periods. Water samples are analyzed for three forms of phosphorus, three forms of nitrogen, organic carbon and suspended sediment. Runoff volumes, and nutrient and sediment loads are calculated for both sites. In addition, pathogen samples have been collected during both pre- and post-implementation periods and analyzed for *Cryptosporidium* and *Giardia*. The macroinvertebrate community is also being sampled once a year to determine changes in stream biota.

The paired watershed design produces flow and nutrient data that can be compared regardless of the annual variations in weather and stream flow that will occur over the life of the study due to differences in precipitation intensity, runoff volumes, timing of snowmelt and spring thaw, and other factors. In order to distinguish these variations from those changes attributable to installation of BMPs, loading rates are compared after taking into account amount and intensity of precipitation, runoff volume, and watershed area. In this way, the effects of BMPs on pollutant loads can be estimated, after first determining what portion of the difference is the result of meteorological and site variations.

Results of the study so far indicate that the study sites have very similar responses to hydrological events. Considerable differences were evident in nonpoint source pollutant loadings between the control and farm sites in the two years of pre-implementation monitoring, however. Unit loading rates of nutrients and sediments were much greater at the farm than at the control site, as much as 40 times for some parameters. Comparison of event mean concentrations showed elevated concentrations for all measured parameters at the farm site. These findings were expected, though. The intent of the study design was to elucidate how close to background water quality farm runoff could come after treatment with recommended BMPs.

The results of the first two years of post-implementation sampling indicate a decrease in concentrations loads of dissolved phosphorus leaving the farm. This would be consistent with storage of manure during critical runoff periods in winter and spring. There is also some evidence of reductions in ammonia loads and concentrations. Results of the macroinvertebrate sampling show clear-cut improvements at the farm in the diversity of the stream biota and the prevalence of desirable species. The latest complete report on this study is included in the Appendix.[8]

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[8] Longabucco, Rafferty, Lojpersberger: *Effectiveness of Whole Farm Planning and Implementation in Achieving Water Quality Improvement and Protection of New York City Water Supplies, Preliminary Analysis aof*

C. Phosphorus Index

Dairy farms accumulate phosphorus because they import more phosphorus in feed and fertilizer than they export in milk, meat and crops sold. The remaining phosphorus is cycled on the farm and is manifest as increased soil phosphorus levels. One strategy employed to manage the on farm pool of phosphorus is nutrient management planning (NMP). In developing the NMP for the farm WAP Planners work to increase the efficiency of on farm phosphorus cycling by targeting fields lowest in phosphorus fertility and to decrease the chance for phosphorus loss in runoff by targeting fields with lower hydrologic sensitivity.

Stu Klausner of Cornell University's Extension Program adapted a Phosphorus Index for use by WAP with cooperation of WAP whole farm planners. The P-Index is a tool to assess the potential for phosphorus runoff from individual fields based on soil and field characteristics and management factors. Planners use P-Index to identify fields with high risk for phosphorus transport and to evaluate management changes to lower that risk. Cornell Cooperative Extension staff are currently part of a statewide effort to update and improve the P-Index.

P-Index provides a site-specific risk assessment tool to target nutrient management changes for greatest effectiveness. A more detailed description of the P-Index can be found in the Appendix.

D. Cornell Net Carbohydrate and Protein System Model

Using the Cornell Net Carbohydrate and Protein System in Pasture Based Dairy Diets

Continued use of intensive pasture-based systems on Watershed dairy farms faces both economic and environmental challenges. Profitability is often limited due to difficulty of achieving high levels of milk production with grazing dairy cattle. Environmentally, while converting highly erodible land into permanent pasture grassland is an established soil conservation practice, the impacts on dairy farm nutrient management are less clear.

In an effort to address the economic and environmental challenges facing pasture based dairy farms, a field study was conducted over the course of the 1996 grazing season by researchers in the Department of Animal Science at Cornell University. The objectives of this study were: 1) to apply the Cornell Net Carbohydrate and Protein System (CNCPS) to pasture-based diets in the field; 2) to characterize the pasture composition information needed for the CNCPS on a well-managed intensively grazed pasture under Northeastern US farm conditions;

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the First Year of Sampling Data Following BMP Implementation at the Robertson Farm, Bureau of Watershed Management, NYS Department of Environmental Conservation (January, 1999) and 3) to investigate nutrient management issues on a pasture-based dairy. A Watershed dairy farm utilizing intensive rotational grazing and selling over 19,800 lbs milk per cow per year was chosen for the study.

Pasture forage was of high, but variable, quality (CP,20-31%; soluble CP, 16-30% of CP; NDF digestibility 56-93%; lignin, 5-17% of NDF). Biological impact of the variation in pasture forage quality, predicted using the CNCPS, was greatest for CP, NDFCP, and lignin contents.

Using animal and feed inputs measured monthly, the CNCPS was used to model herd performance and explore more effective supplementation strategies. Using the CNCPS to balance diets resulted in an average 15% reduction in excess rumen nitrogen across all diets. The lower producing, late lactation cows were predicted to be consuming the protein at a substantial excess relative to requirement. As such, the greatest changes in supplementation strategy were predicted for this group. Predicted manure nitrogen and phosphorus excretion was reduced 10% and 25% respectively across the herd. Reductions in purchased N in balanced diets had little effect on whole farm N balance, but % P remaining on the farm was reduced 8%. Balanced diets resulted in 10-20% reductions in concentrate costs, with greater savings for lower producing cows. Total savings over the grazing season were approximately $50 per cow.

Pasture manure and soil nutrient distribution and manure production were studied. Pasture manure density was nearly twice as high in a 100 ft radius around the paddock gate and water source. In another paddock, soil P and K levels were 42% and 62% higher respectively ($P = 0.008$, $P<0.000$, respectively) in watering, shade, gate, and high traffic areas as opposed to the rest of the paddock. The CNCPS was used to predict total daily manure production, which was then compared to barn collected manure for lactating and dry cows. Although cattle spent only 17-38% of their time in the barn, 37-56% of manure was deposited there, with 44-63% deposited on pasture and in laneways.

Results of these studies suggest that pasture can be of high but variable quality and that the CNCPS can be used to identify more efficient supplementation strategies, which may, in turn, result in reduced nitrogen and phosphorus imports on the farm. From a nutrient management perspective, while pasture based systems present unique manure nutrient distribution challenges that suggest a need to consider lane, gate and watering location in pasture system design, a substantial amount of the manure nutrients produced by pastured dairy cattle may still be subject to control through mechanical distribution means.

Application of the Cornell Net Carbohydrate and Protein System in Delaware County and the NYC Watershed 1997 -1999

Cornell Cooperative Extension of Delaware County has continued to implement the Cornell Net Carbohydrate and Protein System (CNCPS), a computerized dairy cow nutritional and environmental model, in Delaware County and the New York City Watershed during the period 1997-1999. This tool has been used directly on farms, as a teaching aid and as a decision aid with agriservice.

The CNCPS has been used by Cornell Cooperative Extension (CCE) of Delaware County on five farms in Delaware County in the period 1997-1999, three of which are in the NYC watershed. In these herds CCE has assisted the farmers in optimizing their ration supplementation strategies in an effort to make better use of homegrown forages and minimize the use of purchased concentrates. This would have the potential of reducing nutrient imports on these farms. In all cases the CNCPS was used as a decision aid to evaluate the current diet and then identify alternative supplemental strategies. This on farm work was carried out as part of the regular programming of Cornell Cooperative Extension of Delaware County.

In addition to use in individual herds Cornell Cooperative Extension of Delaware County has used the CNCPS as a teaching tool in dairy nutritional seminars and forage management publications offered to dairy farmers in Delaware County. The CNCPS has been used in these seminars and publications as a decision aid in evaluating forage replacement alternatives as well as to illustrate the animal production and nutrient management advantages of improved forage quality.

Lastly, Cornell Cooperative Extension of Delaware County has used the CNCPS as a decision aid in working with a local feed company who was evaluating the suitability of a new feed product. In working closely with this feed company, we reinforced their confidence in the CNCPS as a practical and valuable tool for the feed industry. In doing so we have laid the groundwork for more extensive application of the CNCPS in the field by the feed industry itself, an important multiplier channel for implementing this software and its nutrient management capabilities throughout the watershed and other parts of New York State.

Precision Feed Management for Phosphorus Reduction

Cornell Cooperative Extension of Delaware County and the Delaware County Board of Supervisors have begun to expand the use of the CNCPS with Watershed Farmers under a two stage (1 year) project that is partially funded by a Watershed Environmental Assistance Program grant. This project will focus on identifying, modeling and implementing potential strategies to reduce phosphorus importation on dairy farms through feed supplementation.

E. Description of the Town Brook Research Project

A cooperative research program to provide necessary scientific support for evaluating and managing agricultural phosphorus was developed by the Watershed Agricultural Council, U.S. Geological Survey, Department of Agricultural and Biological Engineering, Cornell University, USDA Agricultural Research Service and NYC DEP. The research program focuses on the Town Brook watershed, which is characteristic of agricultural land use in the area. The objectives of the Town Brook Research Program are 1) to develop, implement, and evaluate BMPs for minimizing phosphorus loss from farms represented by those within the Town Brook Watershed, and 2) To apply and improve field-scale and watershed-scale indices and models to support nutrient management planning within the Town Brook Watershed, as well as extend the findings of this project to the Cannonsville Reservoir Watershed and other Catskill Watersheds. A full description of the Town Brook Research Program is included in the appendix.

The first phase of the Town Brook Project began at the end of 1999. With an initial budget of approximately $100,000, phase 1 consists of four tasks which focus on developing, implementing, and evaluating selected BMPs for minimizing P loss from farming operations typified by those of the TBW. The following project description outlines the phase 1 initial BMP investigations of the Town Brook Research Program.

Evaluation and Management of Phosphorus in the Town Brook Watershed: Initial BMP Investigations

A cooperative research, demonstration, and evaluation project between: The Watershed Agricultural Council, U.S. Geological Survey, Department of Agricultural and Biological Engineering, Cornell University, USDA Agricultural Research Service and NYC DEP

Introduction:

The Town Brook Watershed (TBW) is characteristic of agricultural land use within the phosphorus-restricted Cannonsville Reservoir Watershed. Consequently, the TBW offers us a unique opportunity to study the effectiveness of existing and proposed Best Management Practices (BMPs) in minimizing phosphorus (P) losses from agriculture to the Cannonsville Reservoir. The generalized objectives of this phase of the comprehensive TBW project are to develop, implement, and evaluate selected BMPs for minimizing P loss from farming operations typified by those of the TBW.

Task 1 – Soil P Amendments: This task evaluates BMPs targeted for high-P soils that have the potential to reduce P loss in runoff.

Phosphorus Immobilizing Soil and Manure Amendments (PISMAs) are compounds that reduce the solubility of P, and hence limit its mobility in the environment. Research conducted by USDA-ARS suggests that some widely available PISMAs, such as coal combustion by-products, can reduce P solubility while leaving soil Pin a plant-available form. This study will assess the relative efficacy of five PISMAs – wollastonite, water treatment sludge, gypsum, anthracite coal ash, and steel-processing sludge – in TBW soils. A high-P soil will be collected from the watershed and incubated in the lab with various PISMAs. Following incubation, the amount and forms of soil P will be compared with a control (no PISMA) to assess the relative efficacy of each PISMA. A rudimentary economic analysis will also be conducted to assess the relative cost of each PISMA per unit of immobilized P. Results of the study will determine the feasibility of using PISMAs as a BMP in the TBW, and also enable PISMAs to be represented as BMPs in the Phosphorus Index.

Task 2 – Stream Bank Fencing and Riparian Buffer Strips: These related tasks evaluate potential benefits of stream bank fencing and riparian buffers in the TBW.

Stream Bank Fencing. Free access to watercourses by dairy animals within the TBW result in direct input of P to the steam by deposition of urine and feces. This study assesses the potential benefit of eliminating this input by installation of stream exclosures within the watershed. A survey of pastures will be conducted to identify the potential for stream bank fencing within the watershed. From this survey, one or more pastures will be selected for an observational study to determine the frequency of "walk in" P inputs. Specifically, the behavior of cattle left to graze in the pasture will be observed over a minimum of three days (one in spring, one in summer, one in fall). Stream loitering and in-stream deposition of manure and urine will be recorded. Based upon these observations and handbook values of manure amounts and P concentrations, the water quality benefits of stream bank fencing at the farm and watershed scales will be determined.

Riparian Bufferstrips. Related to installation of streambank fencing, it is also important to determine if riparian bufferstrips can act as significant sinks for dissolved and particulate P loss from the watershed farms. Their effectiveness to act as sinks is dependent on several factors, including flow path, vegetation type, soil depth, aerobic status, and soil chemistry. Existing riparian bufferstrips within the TBW will be surveyed and classified with regards to time since installation, extent of maintenance, and apparent effectiveness (condition). Two of these (one well-maintained and one in poor condition) will be instrumented with shallow ground water wells, piezometer nests, and wick pan samplers to measure subsurface water chemistry, and with overland flow collectors to measure surface water chemistry upgradient, within, and downgradient of the strips. By locating instrumentation above, within, and below riparian zones, the direction of subsurface flow and observed changes in surface and subsurface water chemistry can be used to determine the effectiveness of these zones in removing P from farm runoff within the TBW.

Task 3 – Barnyard-related BMPs: These related tasks are directed toward barnyard improvement, as well as filter strips used to treat barnyard runoff.

Barnyard installation. Barnyards are considered a primary BMP within the TBW. We have a unique opportunity to begin quantification of their effectiveness because one farm within the watershed will be installing a barnyard within the next two years. In cooperation with the farm planner and based on his projection of barnyard location and configuration, we will establish instrumentation (primary surface runoff collectors) to document pre-barnyard conditions related to volume and timing of surface runoff and its related transport of P locally, as well as to the stream. The purpose of this monitoring is to establish "before" conditions that can be compared to those existing after the barnyard is installed.

Barnyard Filter Strip Study. Barnyard runoff represents a potential point source of P input to Town Brook. A survey of barnyards on the TBW will be conducted to identify existing barnyard filter strips, a BMP commonly used to treat barnyard runoff. These filter strips are costly, but their effectiveness in removing P over extended periods of time, especially during the winter months, has not well been documented. Two filter strips will be selected for study, one representing a breached filter with obvious flow channels, and one representing an unbreached filter with no evidence of channelized flow. Runoff flumes will be installed at selected locations below each filter and equipped with water quality samplers. Samples will be periodically collected and analyzed for dissolved P, total P and suspended sediments. Based on runoff and water quality analyses, efficacy of filter strips in removing P will be assessed and, where possible, management recommendations will be offered.

Task 4 – Subsurface transport of P: This task quantifies the potential for subsurface transport of P below cropped and pasture land within the TBW.

Phosphorus is transported to water supply reservoirs primarily via surface runoff (in soluble and particulate form), and to a lesser extent by subsurface leaching (in soluble form). Subsurface leaching of dissolved P (DP) may occur through shallow soils, or more slowly if leaching reaches deeper ground water. Laboratory experiments under controlled conditions can provide insight into the processes controlling P mobilization and transport, as well as the potential effectiveness of BMPs directed toward subsurface transport. Soil phosphorus, manure, and commercial fertilizers are three important sources of DP losses from agricultural land. Consequently, it is important to examine the relationship between the source and P concentration in runoff and interflow and how source contributions can be reduced by BMPs. Preliminary experiments will be performed to establish the relationships between P source concentrations, initial soil water content, rainfall intensity, and resultant P concentrations in surface and subsurface flow. Potential BMPs that may be investigated include manure amendments to reduce available DP, manure composting, and incorporation of manure after spreading. The manure and fertilizers will be applied at agronomic nitrogen rates.

Two types of undisturbed soil samples with intact macropores will be used in the laboratory testing: undisturbed mini-hillsides (20 cm W x 90 cm L x 40 cm D), and undisturbed soil cores (30 cm dia. x 40 cm D). Additionally, small cores taken at the same locations will be dissected in 5-cm depth increments to determine background P levels by a variety of procedures (Morgan, Mehlich-3, hot water- and $CaCl_2$-extractable P). In the laboratory, the various treatments will be applied to the soil blocks which will then subjected to artificial rain. Composite runoff and subsurface flow samples will be tested for dissolved and particulate P.

Pathogen Research

In addition to studying Phosphorus issues in Town Brook a research proposal has been developed by the Town Brook Research Team (Tammo Steenhuis et. al.) to study both phosphorus and cryptosporidium transport in runoff and through soil columns and evaluate agricultural BMPs effectiveness in protecting water quality. This proposal was submitted for funding to the USDA at the end of 1999.[9]

F. Update of DEP Farm Pathogen Monitoring Data and Site Locations

In order to monitor pathogen levels leaving a farm before and after implementation of agricultural best management practices (BMP) DEP established a Farm BMP Research project. Monthly samples are collected at six stream sites before and after BMPs are implemented. One set of sites represents an agricultural watershed with a paired watershed with a paired undisturbed watershed which represents a control that is located within the same watershed. The Robertson Farm (RFU) was selected as the location of a stream site with agricultural influences from a farm. An unnamed tributary that runs along Shaw Road (SHR) represents the control site, since it has no agricultural influences and minimal other human impacts. In addition, pathogen samples are collected upstream and downstream of a farm with a dairy herd that may be infected with *Cryptosporidium*(FFU, FFD); at the outlet of an agricultural sub- watershed, where all the farms in the watershed are participating in the Watershed Agricultural Program (FB4); and at the discharge of an agricultural sub-watershed located east of the Hudson River (TRTIT).

Sampling began at these sites in June of 1993 and will continue at least two to three years after all BMPs are implemented on these farms.

The DEP Pathogen Program routinely monitors over fifty sites within the watersheds of the NYC water supply system (including the agricultural sites mentioned above) for pathogens. Preliminary findings of this monitoring include:

1. *Giardia* spp. cysts and *Cryptosporidium* spp. oocysts are infrequently detected in the watershed. *Cryptosporidium* spp. oocysts are detected less frequently (found in about 20% of the samples) than *Giardia* spp. cysts, which are found in about 26% of the samples. Confirmed detections are found even less frequently (less than 5% of the samples).
2. *Cryptosporidium* spp. oocysts and *Giardia* spp. cysts, are detected most often in the discharge of wastewater treatment plants, followed by urban watersheds; agricultural watersheds; and than least detection in undisturbed watersheds.
3. Water released from reservoirs generally have lower detections of *Cryptosporidium* spp. oocysts and *Giardia* spp. cysts than the water entering the reservoir.
4. The concentration of cysts may be much greater in urbanized streams during storm events than at base flow conditions.
(Source: EPA FAD 308e-1, 1/28/00)

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[9] Steenhuis, et. al., *Evaluation and Management of Cryptosporidium parvum and Phosphorus Contributions in the Town Brook Watershed, A proposal submitted to the United States Department of Agriculture National Research Initiative Competitive Grants Program by Cornell University*

4. Efficacy of Whole Farm Planning and the Implementation Process

A. Introduction

Whole Farm Planning is an evolving process that balances water quality objectives of the program while at the same time ensuring that the plan safeguards the economic viability of the farm. There have been several improvements to the planning and implementation process since January 1998 that have helped to strengthen the program. These include modifying the Environmental Review/Problem Diagnosis (ER/PD) Tool, which is used to identify environmental issues on farms, revise the Filtration Avoidance Deliverables milestones to place greater emphasis on implementation, incorporation of the Conservation Reserve Enhancement Program into whole farm planning and adapting a more comprehensive approach to nutrient management planning.

B. Changes to the Environmental Review/ Problem Diagnosis (ER/PD)

During the November 6, 1998 Watershed Agricultural Council (WAC) Advisory Committee meeting, Gary Lamont, WAP Program Manager for the USDA Natural Resources Conservation Service (NRCS), gave a presentation on a document developed by the WAP Action Staff entitled, "Level of Treatment". This document recommended several changes to the ER/PD survey, which is used in the planning process to identify and prioritize environmental issues on farms. The Advisory Committee passed a resolution stating that a working group be developed to evaluate the recommendations. WAC Chair Dick Coombe asked Maureen Krudner, US EPA Region II, to oversee the review of these recommendations with the work group. Participants of this work group included representatives from the following organizations: NYS Ag & Markets, NYS Department of Health, NYC Department of Environmental Protection, Riverkeeper and Environmental Protection Agency.

The document recommended the following:

1. Reversing pollutant categories V "Nutrients - Concentrated Sources" and VI "Nutrient Management".
2. Re-prioritize 11 pollutant categories in ER/PD by reservoir basin.

Dean Frazier, WAC Special Projects Coordinator at the time, provided clarification and the rationale behind these recommendations in a letter dated 1/15/99. Category V (Nutrients - Concentrated Sources) includes barnyard runoff, direct discharge of milkhouse waste, silo leachate and other concentrated sources of nutrients. These environmental issues are usually addressed with structural BMPs (i.e. heavy use area pad, filter strips, clean water diversions etc.). Category VI (Nutrient Management), on the other hand, evaluates and provides recommendations on management of nutrients across the farm. This would include the development of a nutrient management plan with a manure spreading schedule, fertilizer recommendations and recommendations for improving feed rations to improve nutrient utilization.

The rationale for reversing the priority of Categories V and VI is that the vast majority of manure is spread on the land and not in the barnyard. Therefore, developing a nutrient management plan first to ensure that manure is being spread during the least hydrologically sensitive times of the year and on the most appropriate fields should be a higher priority than building the structural BMPs associated with concentrated nutrient sources. Nutrient and manure management plans also require extensive technical and management support from the planning staff.

In regards to re-prioritizing pollutant categories by reservoir basin the Level of Treatment document recommends that the limiting pollutant of concern should be the highest priority in a given reservoir. For example, the Cannonsville Reservoir is a phosphorus restricted basin and agriculture is identified as the primary source of phosphorus, therefore phosphorus should be the highest priority. In addition, it was recommended that Pollutant Categories I, II and III, which address catastrophic situations (i.e. manure storage failure, pesticide spills etc.) and rarely considered an issue on watershed farms, should be given a lower priority in the ER/PD.

Maureen Krudner provided WAC with the committee's findings in a letter to Richard Coombe, dated May 5, 1999. Regarding the reversing pollutant categories V and VI in the ER/PD, the committee supports the proposed changes. The letter stated, " Reversing Parts V and VI should result in higher phosphorus reductions at a lower cost. Prioritization of practices to remedy problems identified in Parts V and VI, based upon their effectiveness to reduce phosphorus, should be considered so that an increased level of phosphorus reduction can be achieved with available resources."

Regarding the second recommendation on setting pollutant target priorities by reservoir basin, the committee responded, "although it is recognized that phosphorus management is important for water quality protection, we believe the current priorities in the ER/PD are appropriate at this time. Parts I, II and III are designed to address catastrophic situations which have not been found to be applicable in the NYC watershed, therefore there should be little if any impact on resources available to implement whole farm plans. However, if these types of situations do exist they must be addressed."

C. Revision to the Filtration Avoidance Deliverable, April 1998

It became evident to WAC and WAP staff early in 1997 that the program needed to shift its emphasis from developing plans to doing more BMP implementation. For this reason, WAC and DEP developed a proposal to change the Filtration Avoidance Deliverable milestones for the program. The proposal was sent with a letter from DEP Commissioner Miele to Jeanne Fox, Regional Administrator, US EPA in October 1997.

Ms. Fox responded to Commissioner Miele's letter on April 20,1998 and stated that EPA supported the revised milestones (see chart on following page), which place a greater emphasis on Whole Farm Plan implementation and recognizes the increased benefits to water quality protection. This was the first time that the FAD had been modified and it required extensive interagency and public review.

There was a clear benefit to revising the milestones in BMP implementation demonstrated in 1998. In 1997, there were 281 BMPs implemented at a cost of $1.8 million and in 1998, there were 375 BMPs implemented at a cost of $2.6 million.

D. Conservation Reserve Enhancement Program

In August 1998, New York City entered into a Memorandum Of Agreement (MOA) with United States Department of Agriculture (USDA) and New York State to implement a Conservation Reserve Enhancement Program in the Catskill and Delaware Watersheds. These watersheds furnish 90% of the 1.34 million gallons of water used daily by the NYC water supply system, which serves 8 million City residents in addition to 1 million residents in Westchester, Putnam, Orange and Ulster Counties.

This MOA will allow watershed farmers to enter into 10 to 15 year contracts with the USDA to retire environmentally sensitive lands from production. This program will help establish forested riparian buffers and retire highly erodible cropland. The USDA will pay the farmer on average $90.00 per acre per year as well as 50 percent of the cost of all BMPs associated with establishing riparian buffers and/or permanent vegetative cover. The City, through its agreement with the Watershed Agricultural Council (WAC), will pay the remaining 50 percent of BMP costs for participating farms.

The program's goals are to enroll 3000 acres of highly erodible cropland and establish 2000 acres of riparian forest buffers in 5 years. These conservation measures will help to protect at least 165 miles of streams in the Catskill/Delaware watershed.

As of December 31, 1999 seventy five landowners representing 95 tracts of land have signed a CRP-2 expressing interest in enrolling land in CREP. Eleven CP22 contracts were developed with a total of 100.1 acres of riparian buffers. In addition 34 farms have incorporated 363 acres of CREP Riparian Forest Buffers and Filter Strips into their whole farm plan. WAC has approved $391,789 to implement BMPs associated with CREP projects in whole farm plans, which will be matched by USDA funds.

Conservation Reserve Enhancement Program	**As Of 12/99**
Farms who have notified FSA and want to participate in CREP	75
Signed FSA CREP Contracts	11
Total Acreage of Riparian Buffers and Filter Strips	100.1
Estimated Miles of Riparian Areas Protected	15.3

Riparian Forest Buffer Coordinator: WAC has received a $150,000.00 grant from the USDA Forest Service to establish a Riparian Forest Buffer Coordinator position for a two year period. This position was established to accomplish the following:

1. Serve as a single point of contact to landowners for technical and financial assistance on the use of riparian forest buffers.
2. Work with agency personnel to establish priorities for the location and demonstration of riparian forest buffers.
3. Conduct training on the design and establishment of riparian forest buffers. Develop riparian forest buffers on non-agricultural lands.

This position was filled November, 1999 and it is anticipated that the candidate will help accelerate efforts to implement forest riparian buffers through CREP. A copy of New York City's 1999 CREP Annual Report is attached in the Appendix.

E. Evolution of Nutrient Management Planning

The Watershed Agricultural Program (WAP) has developed in phases. At first, the nutrient management plan process included a simplistic approach of identifying the annual amount of manure generated from all sources and allocating it to all identified crop acres that were close enough for spreading. Manure was applied in order to satisfy the crop's nitrogen needs.

Initial components of nutrient management plans included:

1. Soil Testing , to determined the amount of soil test nutrients that existed at a specific point in time.
2. Manure Spreader Calibration - to calculate the rate of application with current equipment.
3. Manure testing - to determine amount of nutrients in manure.
4. Crop rotations - to determine the crop requirements of nutrients.
5. Fertilizer usage and application - to determine off the farm nutrients being applied to crops

In 1995-96 our nutrient management plan started to look different. A risk and management field ranking system was developed to assist with the plans development . Manure spreading recommendations were based upon various risk levels using specific field characteristics (i.e. slope, concentrated flow paths, flood prone areas etc.) to determine the sensitivity to leaching and runoff. The amount of manure produced on the farm was estimated and crop needs were determined. Manure applications were calculated based on loads per field and additional nutrient requirements, if any were identified.

In 1997, a number of Whole Farm Plans had been developed, and approved byWAC. Most plans had some sort of cursory field manure application recommendation attached, primarily to determine if enough acres existed to completely accept all the manure being generated on the farm. Out of concern for minimizing pathogen risks, manure from calves especially was to be collected separately where possible and spread only on risk level "1" fields (fields least likely to have runoff). At this time BMP implementation, especially structural BMP implementation had taken a back seat to planning and the number of plans began to accumulate.

A mid course correction occurred in the fall of 1997, resulting in the integration of planning and implementation staff into the **self directed team approach**, as well as the proposal to adjust Filtration Avoidance Determination goals (see above). The program enhanced the six planning teams by including implementation staff, engineers and technicians. Each team is now responsible for planning, developing *and* implementing the Whole Farm Plan. Through this self directed team approach and placing a greater emphasis on BMP implementation, implementation occurred at the faster rate and in 1997, 1998, and 1999 a record amount of annual farm implementation occurred ($1.8 and $2.3 million, $1.6 million respectively) versus approximately $300,000 in the early years. Nutrient management plan development however, was not given a high priority at this time and very few were being developed.

In 1998, WAC asked the teams to begin reporting the number of Nutrient Management Plans developed on farms. Although some 165 whole farm plans were indeed completed by 1998, only sixty eight nutrient management plans (meeting NRCS 590 standards) were reported in 1998.

The NMPs were becoming much more sophisticated than the earlier years and included: color coded field spreading maps and identified substantially uneven distributions of nutrients from field to field. Spreading patterns were suggested to optimize the use of nitrogen by making judicious applications to corn ground and eliminate over applications in other areas. NMPs also identified Waste Field Storage areas for farms who needed to store small amounts of manure in the winter due to limited winter access.

In 1999, Federal and State Regulatory Programs relating to disposing of farm produced manures became a reality on larger farms. Handling nutrients from Concentrated Feeding Operations/Animal Feeding Operations is now a regulated activity. Although originally designed for very large farms with lots of livestock, the evolution of this type of regulation sends a clear message to all who farm in the watershed. In 1999, in anticipation of these new regulations, WAC passed a resolution that all WAP plans meet the NRCS Comprehensive Nutrient Management Plan (CNMP) Standard . A Whole Farm Plan meets the CNMP standard except for proper record keeping. Record keeping will now be included as a component of all whole farm plans.

In addition, CNMPs will take into consideration phosphorous indexing that includes factoring in additional soil field barriers. They will include maps, spreading loads, timing and field storage designated and monthly calendars that will help identify where and when the field is spread with manure.

5. Science of Whole Farm Planning

Since its inception in 1991, the Watershed Agricultural Program has maintained a close working relationship with Cornell Universtiy faculty and staff. This relationship has continued through the development of the Town Brook Research Program, whose development was led by Cornell faculty. The university provides the Program with an essential foundation in science and up-to-date research. Following is a list of papers and publications produced by Cornell University relating to the Watershed Agricultural Program.

A. Papers and Publications from Research Supported by New York City Through the Watershed Agricultural Council and Cornell University (1998-1999)

Brush, C. F., W. C. Ghiorse, L. J. Anguish, J.-Y. Parlange and H. G. Grimes. 1999. Transport of *Cryptosporidium parvum* oocysts through saturated columns. J. Environ. Qual. **28**:809-815.

Brush, C. F., M. F. Walter, L J. Anguish, and W. C. Ghiorse. 1998. Influence of pretreatment and experimental conditions on electrophoretic mobility and hydrophobicity of *Cryptosporidium parvum* oocysts. Appl. Environ. Microbiol. **64**:4439-4445.

Frankenberger, J.R., E.S. Brooks, M.T. Walter, M.F. Walter, and T.S. Steenhuis. 1999. A GIS-Based Variable Source Area Hydrology Model. Hydrological Processes **13**:805-822.

Frankenburger, J. R., E. S. Brooks, M. T. Walter, M. F. Walter and T. S. Steenhuis. A GIS-Based Variable Source Area Hydrology Model. Hydrologic Processes. In Press.

Jenkins, M. B., D. D. Bowman, and W. C. Ghiorse. 1998. Inactivation of *Cryptosporidium parvum* oocysts by ammonia. Appl. Environ. Microbiol. **64**:784-788.

Jenkins, M. B., M. J. Walker, D. D. Bowman, L. C. Anthony, and W. C. Ghiorse. 1999. Use of a sentinel system for field measurements of *Cryptosporidium parvum* oocyst inactivation in soil and animal waste. Appl. Environ. Microbiol. **65**:1998-2005.

Kleinman, P.J.A., R.B. Bryant and W.S. Reid. 1999. Development of Pedotransfer Functions to Quantify Phosphorus Saturation of Agricultural Soils. J. Environ. Qual. **28**: 2026-2030.

Kleinman, P.J.A. 1999. Examination of Phosphorus in Agricultural Soils of New York's Delaware River Watershed. Ph.D. Thesis, Dept. Soil, Crop and Atmospheric Sciences, Cornell University, Ithaca, NY.

Kleinman, P.J.A., A.N. Sharpley, R.B. Bryant and W.S. Reid. 1999. Phosphorus and Agriculture II: Phosphorus Chemistry. What's Cropping Up? 9(5):4-5.

Kleinman, P.J.A., R.B. Bryant, W.S. Reid and A.N. Sharpley. 1999. Phosphorus and Agriculture I: Environmental Underpinnings. What's Cropping Up? 9(4):4-5.

Kuo, W.-L., T.S. Steenhuis, C.E. McCulloch, C.L. Mohler, D.A. Weinstein, S.D. DeGloria, and D.P. Swaney. 1999. Effect of Grid Size on Runoff and Soil Moisture for a Variable-Source-Area Hydrology Model. Water Resources Research **35**:3419-3428.

Parlange, J.-Y., T.S. Steenhuis, R. Haverkamp, D.A. Barry, P.J. Culligan, W.L. Hogarth, M.B. Parlange, P. Ross, and F. Stagnitti. 1999. Soil Properties and Water Movement. Chapter 4, In:

Vadose Zone Hydrology - Cutting Across Disciplines, M.B. Parlange and J.W. Hopmans, Eds. Oxford University Press, New York, NY. pp. 99-129.

Scott, C.A., L.D. Geohring, M.F. Walter. 1998. Water quality impacts of tile drains in shallow, sloping structured soils as affected by manure applications. Applied Engineering in Agriculture. Vol. 14(6): 599-603.

Scott, C.A., M. F. Walter, E.S. Brooks, J. Boll, M.B. Hes, M. D. Merrill. 1998. Historical Changes in Land Use and Dairy Herds on Water Quality in the Catskills Mountains. J. Environ. Qual. 27:1410-1417. 8 pp.

Scott, C. A., M. F. Walter, E. S. Brooks and J. Boll. 1998. Water Quality Imports of Historical Changes in Land Use and Dairy Herds. Accepted to J. Environmental Quality ASA. Madison, WI.

Scott, C.A., M. F. Walter, N. V. Sierra, E. S. Brooks and M. T. Walter.1997. Residual Phosphorus in Runoff from Successional Forest and Abandoned Agricultural Land. Water Resources Research (submitted).

Steenhuis, T.S. J. –Y. Parlange, W.E. Sanford, A. Heilig, F. Stagnitti, and M.F. Walter. 1999. Can we distinguish Richards' and Boussinesq's equations for hillslopes?: The Coweeta experiment revisited. Water Resources Research. Vol. 35(2), pp. 589-593.

Steenhuis, T.S., J.-Y. Parlange, W.E. Sanford, A. Heilig, F. Stagnitti, and M.F. Walter. 1999. Can We Distinguish Richards' and Boussinesq's Equations for Hillslopes? The Coweeta Experiment Revisited. Water Resources Research **35**:589-593.

Walker, M. J., Walter, M. F. and K. McDonough. 1997. Large volume samples for Cryptosporidium and Giardia from small streams. J. of Environmental Quality, ASCE. Vol. 123, No. 1.

Walker, M. J., C. Montemagno, J. C. Bryant, and W. C. Ghiorse. 1998. Method detection limits of PCR and immunofluorescence assay for *Cryptosporidium parvum* in soil. Appl. Environ. Microbiol **64**:2281-2283.

Walter, M.T., J. Y. Parlange, M. Walter, X. Xin and C.A. Scott. 1998. Rainfall, runoff and pollutant release from a crusted source. Submitted to J. of Environmental Quality.

Walter, M.T., M.F. Walter. 1999. The New York City Watershed Agricultural Program (WAP): A Model for Comprehensive Planning for Water Quality and Agricultural Economic Viability. Water Resources IMPACT. Vol. 1(5), pp. 5-8.

Walter, M.T., E.S. Brooks, M.F. Walter, T.S. Steenhuis, J. Boll, K.R. Weiler. <in press>. Hydrologically Sensitive Areas: Variable Source Area Hydrology Implications for Water Quality Risk Assessment. J. Soil and Water Conserv.

Weiler, K.R., M.T. Walter, E.S. Brooks, and C.A. Scott. 1998. Temporally dependent risk analysis for flood plains in the Delaware River Basin. Submitted to J. Water Resource Planning and Management.

B. Incorporating Science into Whole Farm Planning to Strengthen the Watershed Agricultural Program

1. Manure Management and Composting

The Manure Infrastructure Committee (MIC) was created by the Council in 1998 to explore issues associated with potential surplus phosphorus and manure and potential loadings of pathogens on farms. This Committee has encouraged and supported the efforts of the scientific research team that has developed Town Brook Research Project (Section 3E). In addition, MIC has sought and received grants to demonstrate innovative manure management technologies on farms.

New York State Environmental Protection Fund: With the support of WAC and DEP, the Delaware County Soil and Water Conservation District was awarded a $64,000 grant from the New York State Environmental Protection Fund to construct a manure composting/biodrying facility on a 160 cow dairy. This facility will consist of a 40 feet by 100 feet three sided roofed shed, five, two horse power fans with piping to promote proper aeration of the compost piles and controls that regulate when the fans are turned on according to humidity and temperature. Based upon the manure production on this farm this facility will produce 912 cubic feet of compost at approximately 40% moisture in 21 days. Yearly production of compost would be 700 tons or 2600 cubic yards. The composted material will be used as bedding, spread on the farmers field according to a nutrient management plan and any surplus can be sold off the farm as a soil amendment. The construction of this facility is planned for the summer of 2000.

NYS Energy Research Development Authority (NYSERDA) Grant: The Watershed Agricultural Council (WAC) has also submitted a preliminary proposal to NYSERDA in October 1999 to establish two research demonstration projects for treating and handling manure on dairy farms in the NYC water supply watershed. One project would utilize "Anaerobic Fixed- Film Digestion" technology and the second would be an "Aerobic Composted Biodrying" system. NYSERDA informed WAC that these pre-proposals has been approved and WAC should prepare a full proposal for final consideration. A full proposal was submitted in December and notification of award for this grant will be made by NYSERDA in January 2000.

2. Cornell Soil Moisture Routing Model GIS & Farm Field Digitizing

Research conducted by USDA Agricultural Research Service and others has shown that a large percentage of the phosphorus that leaves a watershed comes from a very small portion of that watershed area due to hydrologic processes. Obviously, identifying these areas on a farm is a critical piece of information in the development of the manure spreading schedule portion of the comprehensive nutrient management plan. Researchers in the Cornell Department of Agricultural and Biological Engineering have developed a GIS based model (Cornell Soil Moisture Routing Model) that predicts the probability of runoff occurring from fields for each month.

Creating a digital file of the farm's field boundaries is an essential requirement of the model. A GIS specialist has been hired to improve and enhance the GIS capabilities of the Watershed Agricultural Program. One of the primary goals is to develop a method that will enable these field boundaries to be easily digitized. To date the GIS specialist is the only staff person creating these digital files so the time to complete this task remains formidable. The plan at this point is to provide GIS capability to each team so that in the process of preparing the whole farm plan maps, the teams can also be creating the needed digital field boundaries

3. Subsurface Drainage

Subsurface tile drainage is currently used as a BMP in the Watershed Agricultural Program to improve access and reduce concentrated flows on agricultural fields. Recent research supported by the Program (C.A. Scott, L. D. Geohring and M. F. Walter, 1998) suggest that tile drain effluent from manure applied fields can have a significant water quality impact. As a result, Delaware County Soil and Water Conservation District, which is largely responsible for maintaining the technical integrity of most BMPs for the Program, developed the following policy for the application of sub-surface drainage systems (adopted 5/27/99).

1. Sub-surface drainage systems will be used only in conjunction with another Best Management Practice (i.e. strip cropping, crop rotation, nutrient management plan).
2. Perforated tubing shall be used only in the immediate area of the wet area for the purpose of intercepting sub-surface flow. Solid tubing will be used for the remainder of the system conveyance to a safe outlet.
3. Sub-surface drainage systems shall not be outlet directly to a watercourse. All systems must outlet to a filter/absorption area or a vegetated area that in your professional judgement will provide adequate treatment of the outflow prior to entering a watercourse.
4. Manure and fertilizer application over perforated sections of sub-surface drainage systems must be restricted during saturated soil conditions. This provision shall be a condition of the Operation and Maintenance Plan for all subsurface drainage systems.

4. Nitrogen Application Demonstration – Impact on Forage Grass Yield and Quality

Most of the phosphorus coming onto dairy farms is in purchased feeds. The climate and soils of the Catskills are not conducive to profitable grain production, but are well adapted for production of forages. Dairy farmers in the region focus their attention on forage production and purchase the supplemental feeds necessary to achieve high milk production. The yield and quality of the forage produced is critical to farm profitability, and also has an important effect on nutrient imports.

Cornell Cooperative Extension of Delaware County initiated a series of field plots (Hamden, NY) in 1998 and 1999 to demonstrate improved fertilizer and harvest management of forage grasses. Forage grasses have long been viewed as low yielding and of poor quality. Recent testing has shown that with more aggressive fertilizer and harvest management yield and quality are greatly improved and can be more profitable than conventional crops and methods. Because these grasses are well adapted, stands require less frequent reseeding, reducing erosion rates.

The demonstration plots have been very successful showing almost a doubling of yield while improving the feeding value of the forage. Old habits change slowly, however, and continued reinforcement and one on one follow-up with farmers is needed to see these management practices widely implemented.

In the Catskill/Delaware Watersheds the steep slopes, moist climate and short growing season is very conducive to growing perennial grasses. Most of the grassland in this area is being under utilized. However, through one on one education water quality and farm profitability can be improved by harvesting higher quality grass from permanent hayland and pastures. Well managed permanent grass will require no reseeding, which reduces soil erosion, eliminates pesticide use and drastically reduces fossil fuel use as compared to raising annual field crops.

6. Acknowledgments

The following individuals contributed directly to the preparation of this report.

Dave Cammer, WAC Director
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Tammo Steenhuis, Cornell University
Jon Verhoeven, WAC Director
Rick Weidenbach, Delaware County Soil and Water Conservation District
Alan White, WAC Executive Director
Sandy Whittaker, Delaware County Soil and Water Conservation District

APPENDIX

A. *Evaluation and Management of Phosphorous Contributions in the Town Brook Watershed*, a cooperative research, demonstration and evaluation project between: The Watershed Agricultural Council, US Geological Survey, Cornell University Department of Agricultural and Biological Engineering, US Department of Agriculture Agricultural Research Service, New York City Department of Environmental Protection (October 10, 1999).

B. Longabucco, Rafferty, Lojpersberger: *Effectiveness of Whole Farm Planning and Implementation in Achieving Water Quality Improvement and Protection of New York City Water Supplies, Preliminary Analysis of the First Year of Sampling Data Following BMP Implementation at the Robertson Farm,* Bureau of Watershed Management, NYS Department of Environmental Conservation (January, 1999)

C. **Summary of Responses to the In Person Farmer Interviews**

D. **Contractors Survey**

E. **Survey of WAP Advisory Committee Members and the Partnering Agencies**

F. **WAC Director Surveys**

G. *Conservation Reserve Enhancement Program for the New York City Water Supply Watersheds, Federal Fiscal Year 1999 Annual Report*, New York City Department of Environmental Protection, Bureau of Water Supply Quality and Protection (December 30, 1999)

H. **Evaluation and Management of *Cryptosporidium parvum* and Phosphorus Contributions in the Town Brook Watershed** (Proposal)

I. **Field Phosphorus Index Tool**

EVALUATION AND MANAGEMENT OF PHOSPHORUS CONTRIBUTIONS IN THE TOWN BROOK WATERSHED

A cooperative research, demonstration, and evaluation project between:

The Watershed Agricultural Council
Walton, NY

U.S. Geological Survey
Albany, NY

Department of Agricultural and Biological Engineering
Cornell University, Ithaca, NY

Agricultural Research Service
U.S. Department of Agriculture, University Park, PA

New York City Department of Environmental Protection
Kingston, NY

For presentation at the:

Manure Infrastructure Committee
and
Program Evaluation Committee Meetings

Wednesday, October 20, 1999
Walton, NY

Evaluation and Management of Phosphorus Contributions in the Town Brook Watershed

PROJECT SUMMARY

Introduction:

The Cannonsville Reservoir Watershed is currently designated as phosphorus-restricted because of eutrophic conditions within the reservoir. Within this watershed, the Town Brook subwatershed is characteristic of agricultural land use in the area. Thus, the Town Brook Watershed offers us an opportunity to study the role of agriculture, as well as the major factors contributing to phosphorus input to the Cannonsville Reservoir. We will apply what we learn to develop, implement, and evaluate Best Management Practices (BMPs) to minimize agricultural phosphorus losses within the Town Brook Watershed. In cooperation with ongoing stream gaging and water quality monitoring in the region, we will be able to provide land management options for farmers at the scale of the Cannonsville Reservoir Watershed, as well as throughout the watershed of other New York City water supply watersheds.

Objectives:

Develop, implement, and evaluate BMPs for minimizing phosphorus loss from farms represented by those within the Town Brook Watershed.

Apply and improve field-scale and watershed-scale indices and models to support nutrient management planning within the Town Brook Watershed, as well as extend the findings of this project to the Cannonsville Reservoir Watershed and other Catskill watersheds.

Tasks:

1. Assess current and future BMPs in the Town Brook Watershed
2. Assimilate prior research, monitoring, and modeling efforts
3. Develop, implement, and evaluate BMPs
4. Monitor flow and phosphorus loss from characteristic land uses
5. Model at farm and watershed scales for BMP evaluation and extension of results
6. Develop a GIS database to support all phases of the project

Products:

We will develop a suite of BMPs that efficiently and effectively reduce phosphorus loss from farms typical of those within the Town Brook Watershed.

We will integrate chemical and hydrologic processes controlling phosphorus loss from agricultural areas in the Town Brook Watershed and build them into a suite of user-friendly indices and models that allow planners to evaluate effects of applying these BMPs at the watershed scale.

We will develop and refine a phosphorus indexing tool to identify sites most vulnerable to phosphorus loss which will assist NRCS and other state agencies to target specific parts of the landscape, or "hot spots," for more careful treatment to reduce the risk of phosphorus loss at the watershed scale.

We will develop technically defensible and reliable decision-making tools to aid nutrient management planning for phosphorus and manure.

1. INTRODUCTION

Agriculture is a major land use in the New York City (NYC) West-of-Hudson water supply watersheds, and is considered to be a significant potential source of phosphorus (P) to the water supply reservoirs. Excessive P inputs to a water body can cause eutrophication and resulting impairment of water quality. The NYC Cannonsville Reservoir is currently eutrophic and the contributing watershed has consequently been designated as P-restricted.

The Watershed Agricultural Program (WAP) is a land use management program overseen and funded by the Watershed Agricultural Council (WAC) and the NYC Department of Environmental Protection (NYCDEP). WAP is charged with developing and implementing agricultural best management practices (BMPs) to minimize sediment, nutrient, and pathogen losses from farms, while maximizing economic viability of farming within the NYC water supply watersheds. Minimizing P losses, in particular, from farms is one of the primary goals of the WAP. They expect to make progress toward realization of this goal by development and implementation of nutrient management plans and installation of BMPs as part of whole-farm planning for each participating farm within the Program.

Traditional non-point source BMPs have demonstrated only limited success in reduction of P loss from farms (Walter et al., 1979). Design, implementation, and evaluation of BMPs directed toward agricultural P non-point sources as are now being done is problematic due to the complexity of non-point source generation of P and its transport over the landscape. To effectively minimize P inputs to surface waters, BMPs must consider both P source and transport factors, as well as how these factors interact (Gburek and Sharpley, 1998). Phosphorus source factors are controlled by the farmer in his/her decisions relative to land management, animal nutrition, where and when to locate animals, and storage and spreading of fertilizer and manure. Conversely, transport factors are part of the natural system – they are the result of the hydrologic processes and flow paths that control water movement to streams and reservoirs as surface runoff and sub-surface flow. Transport factors do not recognize farm or field boundaries; rather, they are operational at the landscape or watershed scale. Thus, effective agricultural management for controlling P loss requires a watershed-scale analysis of source and transport factors so that BMPs can be effectively designed and implemented to target specific and critical locations of P loss at the farm scale. Additionally, the watershed-scale analysis provides the basis for accounting for other land uses in the watershed that, along with agriculture, contribute to total P loss from the watershed.

Based on these considerations, objectives of this project are:

- Develop, implement, and evaluate BMPs for minimizing phosphorus loss from farms represented by those within the Town Brook Watershed
- Apply and improve field-scale and watershed-scale models to support nutrient management planning within the Town Brook Watershed as well as to extend the findings of this project to the Cannonsville Reservoir Watershed and other Catskill watersheds

2. APPROACH

The 37-km^2 Town Brook Watershed (TBW), a sub-area of the upper Cannonsville Reservoir Watershed (CRW), has been identified by the WAP as an area for intensive experimental nutrient management for reducing P loss from farms. All farms within the TBW are signed up and actively participating in the WAP, and one of the farms has served as a pilot study for preliminary evaluation of the program (Beckhardt and Blouin, 1997). At a meeting held on April 26, 1999 between TBW farmers and several of the principal investigators (hereafter referred to as the Research Team) involved in this proposal, the farmers agreed in principal to the investigators conducting research within the TBW pending a detailed work-plan outlining what and where research will be conducted within the watershed.

Intensive water-quantity and quality monitoring, laboratory and field experiments, and associated data collection will be conducted at varying scales to document the mechanisms controlling P loss from farms within the TBW and the effects of BMPs on the farm and landscape processes controlling P mobilization and transport.

- Laboratory and small plot studies will be used to determine relationships between form and concentration of P in surface and subsurface runoff and P concentration in the soil, amount of manure applied, and time after application.

- Paired plot- and field-scale studies will be conducted to elucidate the source and transport processes that are influenced by different BMPs. In the paired-plot studies, surface and subsurface runoff during storm events and/or during simulated rainfall will be collected from one plot to which the BMP is applied and from a control plot. Analysis of soil, crop, topographic, and management variables against runoff hydrographs and associated patterns of P concentration will be performed to derive relationships between predictor variables and P concentrations in surface and subsurface flows at the plot scale.

- Field- and subwatershed-scale studies conducted in association with the paired-plot studies will elucidate transport factors effective at the field scale. These studies will include monitoring of surface and subsurface runoff in drainage ditches, tile lines, field edges, and first-order streams draining control fields and fields subject to BMPs.

- Watershed-scale stream monitoring will be conducted at varying watershed scales. Long-term continuous stream monitoring of the outlet of TBW and of active agricultural, previously farmed, and forested headwater watersheds will be used to calculate nutrient mass balances, quantify the amount of P contributed by different land uses within TBW, provide data for model development, and track long-term changes in P loads due to BMP implementation at the watershed scale. Subwatershed monitoring will include experimental determination of storm flow pathways using conservative and non-conservative tracers to elucidate watershed-scale transport factors. Survey-scale monitoring of stream water nutrient concentrations of a number of small watersheds with varying land use, soils, and landscape characteristics throughout the CRW will be performed periodically to put Town Brook research results into the broader context of the CRW.

Existing agricultural management practices as well as potentially effective traditional and innovative BMPs for the TBW farms will be the focus of this project. TBW farmers, WAP staff, and the research team will jointly select proposed practices for investigation. Examples of potentially effective BMPs for reducing P losses to be investigated include: animal feeding strategies to reduce phosphorus levels in feed and consequently in manure; manure management as related to timing, rates, and locations of application; deep tillage to reduce soil P levels and increase infiltration; manure amendments or composting to reduce P available for transport; use of fall cover crops; and riparian buffer strips. BMP investigations will include laboratory and field experiments to quantify the influence of BMPs on the landscape processes controlling P mobilization and transport followed by performance monitoring.

Results of these process-based studies will be incorporated into models which, when tested and verified, can be used to evaluate effectiveness of BMPs in the more generic watershed context. Such models, based on the processes controlling P mobilization and transport, provide an integrating framework for the proposed research as well as a means for extrapolating research results to larger scales and more widespread geographic areas.

Finally, a Geographic Information System (GIS) database will be developed and maintained to support the research program and associated farm planning efforts. All information collected on farms, as well as other background data for the TBW, will be incorporated into this GIS database to provide an inventory of conditions within the watershed, a link to the analytic tools and models developed and applied in the research program, the farm and watershed planning process, and a means of extending and evaluating results of BMP implementation at the larger scale.

3. TASKS

3.1. Assess current and future BMPs in Town Brook Watershed

The Research Team, TBW farmers, and WAP staff will document, review, and evaluate current farm practices, BMPs which have already been implemented, are planned, or in process of implementation; consider potentially effective new BMPs which could be implemented; and select specific existing and new BMPs for detailed investigation.

3.2. Assimilate prior research, monitoring, and modeling efforts

Since the 1980s, several institutions and individuals have been conducting research on hydrology and water quality within the Catskills. Areas of research have included nutrients, pathogens and turbidity along with their sources, transport and management. Research suggests that surface runoff occurs on only a small portion of the watershed area for much of the year. By identifying these limited areas and runoff pathways, application of potential pollutants to the land surface can be limited to areas having lowest risk of transport to a watercourse. Implementation of BMPs can only be efficient and effective if these research findings are taken into account. Water quantity and quality has been monitored at selected locations throughout the area for decades. Today, research is being conducted as part of efforts by the WAP and NYC to ensure their water supply systems is compliant with U.S. Environmental Protection Agency water quality standards.

Some of the research institutions previously involved with TBW and CRW studies include:

- U.S. Geological Survey (USGS): The Survey provides surface water data collection and analysis support. USGS also assembles a bibliography on all watershed-related research in the Catskills for more specific data on water quality status and trends.

- New York State Department of Environmental Conservation (NYDEC): DEC is responsible for protecting and preserving the quality of NYS waters. It is an ex officio member of the WAC and provides technical expertise on water quality and nonpoint source issues to program participants.

- NYC Department of Environmental Protection: Conducts research on water quality and quantity within the NYC water supply watersheds.

- Cornell University Departments of: Agricultural and Biological Engineering; Agricultural Resource and Managerial Economics; Animal Science; Microbiology; Soil, Crop and Atmospheric Sciences; and Veterinary Clinical Science.

Research conducted to date on P within the CRW falls logically into three general areas: 1) identification of specific sources of P, 2) characterization of P transport mechanisms, and 3) development of cost- effective BMPs.

Source identification: In general, agricultural phosphorous is a nonpoint source pollutant, that is, its source is not easily identified. Various studies have shown that a small number of sources areally distributed within the watershed can contribute a significant share of total P load (Sharpley et al., 1993, 1996; Pionke et al., 1997). These sources may behave like point sources during particular time periods, and as such, could facilitate the implementation of targeted and concentrated management efforts. For example, one study of the CRW considered several years of data, including samples collected during high flow rates when the highest P concentrations occur (Longabucco and Rafferty, 1998). Analyses revealed that in 1996, a single period of precipitation caused 74%, 34%, and 75% respectively, of that year's particulate P, soluble P, and total suspended solids input to the reservoir.

Cornell researchers in the Department of Agricultural and Biological Engineering have developed an analytical framework for classifying critical source-areas by their runoff potential. Three different types of critical areas have been identified: 1) shallow, sloping lands (Frankenberger et al., 1999), 2) barnyards (Kellog and Lander, 1999), and 3) flood plains (Weiler et al., 1999). Each of these areas is governed by different hydrological properties that create different patterns of phosphorus contribution. Accordingly, Hydrologically Active Areas (HAAs) refer to any area or field that has, on average, greater than 30% probability of runoff. Hydrologically Sensitive Areas (HSAs) are a subset of HAAs and are distinguished by their potential for contributing pollutants to water reaching a stream or drinking water. For management purposes however, limited knowledge regarding pollutant transport in the watershed suggests that all HAAs be managed as HSAs (Porter et al., 1997).

Transport of Agricultural Phosphorus: Phosphorus is transported to water reservoirs primarily via surface runoff (in soluble and particulate form), but also by subsurface leaching (in soluble form). Particulate P (PP) transport is usually associated with erosion of the upper layers of soil. Subsurface leaching of dissolved P (DP) may occur through shallow soils (Scott et al., 1998a) or more slowly if leaching reaches a deeper ground water table. PP is often the major portion (75-90%) of total P (TP) transported from cultivated lands, while DP is the major contributor from non-cultivated lands. Rainstorms have a particularly strong influence on P movement.

The relative concentration of chemical species of P is important to management efforts because of varying reactivity and bioavailability to algae. It is generally assumed that DP is immediately available to algal growth in receiving water. By contrast, the immediate availability of PP to plants and algae ranges from just 10% to 90% of TP, depending on the concentration of TP in the receiving water (Correll, 1998).

Quantifying the impact of individual farms on water quality is difficult. The environmental characteristics of a farm in context of the watershed, including soils, topography, and hydrology, are complex and without direct monitoring, accurate estimation of pollutant loss may be hard to determine (Scott et al., 1998b). In addition, analysis must also control for variations in farm management over time due to weather conditions, management preferences, and resource availability. Use of models in planning will make it possible to deal with this complexity.

Best Management Practices: Phosphorus management is a complex problem involving a range of uncertainties and several "myths" (Sharpley, 1998). The approach taken by WAP in developing cost-effective management practices has focused on Whole-Farm Planning (WFP). WFP is a farm systems approach to pollution prevention that attempts to integrate watershed hydrology, animal science, crop science, and farm economics. WFP produce farm-specific pollution prevention strategies that account for the farm's business interests. In practice, WFP explores various BMPs to determine which ones reduce pollution given a farm's specific land use and features. In this process, farmers are directly involved, receive professional training, and cooperatively make decisions with technical field staff from various

Examples of BMPs having the potential to address the problem of P loss from agricultural land use within the TBW are given in the following two sections. These sections are not meant to provide and all-inclusive list; rather, they are meant to illustrate possibilities and provide insight into the research and demonstration necessary for their evaluation.

3.3.1.1. BMPs to moderate existing conditions

Deep Tillage: A potential source of P to streams draining agricultural land use is high levels of soil test P that raise P concentrations in runoff, interflow and tileflow. Additionally, existence of fragipan soils within the TBW enhances runoff production, compounding the problem. One way to temporarily reduce high soil test P levels, as well as to reduce the effects of the fragipan, is deep tillage (Sharpley, 1999). Half the plots in this demonstration will be subjected to deep tillage, while the other half will be tilled as per common practice(s) within the TBW. Sampling protocols described above will be used to demonstrate and evaluate the effectiveness of this BMP.

Bufferstrips: There is evidence that near-stream riparian zones bordering agricultural uplands can act as sinks for dissolved and particulate nitrogen and phosphorus (Peterjohn and Correl, 1984; Cooper, 1990; Brüsch and Nilsson; 1993). Nonetheless, the effectiveness of such zones is dependent on several factors including flow path, vegetation type, soil depth, aerobic status, and soil chemistry (Peterjohn and Correll, 1984; Cooper, 1990; Basnyat et al., 1999). These factors can have a substantial impact on the amount or occurrence of nutrient removal in riparian zones (Basnyat et al., 1999; Cet et al., 1999; Griffith et al., 1997). Therefore, it is important to identify if riparian zones within the TBW can act as significant sinks of P loss from the watershed farms.

Two riparian buffer strips will be installed within the TBW. The buffer strips will be instrumented with ground water sampling wells, piezometer nests, and wick pan samplers to measure subsurface water chemistry, and overland flow collectors to measure surface water chemistry upgradient, within, and downgradient of the strips. By locating instrumentation above, within, and below riparian zones both the direction of subsurface flow and changes in surface and sub-surface water chemistry will be measured to determine the effectiveness of these zones to remove P from farm runoff within the TBW. This work will be conducted during the first two years of research. After initial research is completed within the TBW, additional research will be completed in riparian zones throughout the CRW.

Cover Crops: Use of fall cover crops to utilize excess P and N in the soil profile before the winter/spring runoff season and maintain a vegetative ground cover over the soil to minimize erosional losses of P and N in runoff will be evaluated. Paired plots (approximately 100 m^2 area) will be established within the watershed on soils containing amounts of P in excess of crop requirements. Treatments will include fallow and grassed controls, barley, rye, winter wheat, and other suitable cover crops that will not enhance the risk of disease or compromise tillage operations in current rotations. In an additional treatment, the cover crop will be plowed into the soil rather than harvested. Each treatment will be replicated four times. Soil samples (0 to 5 cm and 0 to 15 cm depths) will be collected at the beginning and end of the cover crop cycle for determination of the amount and form of P in soil. Surface and subsurface runoff will be generated using a rainfall simulator to determine the effect of cover crop on P and N loss in runoff. Rainfall will be applied during cover crop establishment, once the crop is established, and after harvest or incorporation. This phase of the research will determine the efficiency of cover crops as a potential BMP within the TBW to minimize the potential for P and N transport in surface runoff from high P soils and to better utilize (or deplete) soil P which is in excess of crop requirements.

Reducing phosphorus availability in manure by additives and/or composting: A plot study will be conducted to evaluate the effect of P-inmobilizing manure additives (PIMA) and manure composting on P losses in surface runoff and leachate from TBW soils, as well as the agronomic impact of these additives on crop yields. Research by ARS and Cornell has identified a variety of PIMAs that can reduce the solubility of manure P prior to application and hence limit the potential for P loss in runoff and leaching. Three PIMAs, including aluminum chloride, anthracite fly ash, and wollastonite (a calcium silicate mineral mined in northern New York) will be assessed. Composting also reduces the amount of dissolved phosphorus in the manure. Thirty 100 m^2 bounded plots will be established on 12 fields within the watershed. Plots will be paired to allow for side-by-side comparison of treated and untreated manure. Manure application and cropping patterns will follow those of the farmers whose fields are included in the study. An economic assessment, including cost and potential yield impacts, will be conducted to determine the cost per unit of immobilized P.

3.3.1.2. BMPs to improve manure and fertilizer management

Manure application scheduling: Runoff is produced from selected areas within the farm – as described previously, these areas vary with season and short-term climatic conditions (Gburek et al., 1996). Avoiding manure application to these areas when they are hydrologically active will reduce P loss from the farm. In consultation with the TBW farmers, paired plots will be established on selected fields within the watershed that exhibit hydrologic activity either seasonally or as the result of severe storm events. Manure will be spread on one of each pair when the plots are dry and heavy rain is not forecast. On the other of each pair, daily spreading of manure will be practiced as is now done on the TBW. Runoff from all plots and associated P concentrations will be monitored to evaluate the effectiveness of the manure application scheduling protocols.

Reducing phosphorus input in feeds: Implementation and testing the effect of reducing P inputs in feed will require discussions between ARS and Cornell animal scientists and the TBW farmers related to the feasibility of evaluating this practice. If agreement can be reached on the form and substance of the research, paired herd studies will be conducted on one or more TBW farms with one herd continuing to be fed as is now done, while the other will receive reduced levels of P in their feed. Routine manure testing will demonstrate the potential beneficial environmental effects of reducing P in animal feed, while animal health and productivity monitoring will demonstrate that this reduction does not come at the expense of economic viability of the farmer or health of the dairy herds.

3.3.2. Process-based investigations as the bases for BMP development

3.3.2.1. Laboratory experiments

Laboratory experiments under controlled environmental conditions can provide insight quickly into the processes controlling P mobilization and transport, as well as the potential effectiveness of BMPs under field conditions. Dissolved phosphorus from manure recently spread on the land surface is potentially an important source of P loss, and it is important to examine BMPs as they affect this P contribution. We will conduct laboratory investigations to augment the deep tillage, manure amendment, composting, and manure scheduling BMP evaluations.

Laboratory experiments will be conducted in undisturbed soil columns (15 cm dia. by 30 cm deep) taken from fields where surface runoff and lysimeters are installed. The columns will be transported to Cornell or the ARS facility in Pennsylvania, as appropriate for the specific experiment, and subjected to differing manure management treatments and simulated rainfalls at predetermined intervals. Leachate will be collected from the cores and analyzed for P and N loss. Following the simulated rainfall study, the columns will be destructively sampled to quantify the amount and forms of soil P through the soil profile. This will include Morgan, Mehlich-3, water and $CaCl_2$ extractable P. Preliminary studies have shown that surface runoff P is most closely related to water extractable soil P, while leachate P is most closely related to $CaCl_2$ extractable soil P. This phase of the project will provide a more detailed understanding of P movement through Town Brook soils than can be obtained from water quality monitoring and field studies alone.

3.3.2.2. Plot experiments

The effect of fertilizer, manure, and soil management on the transport of P and N in surface and subsurface runoff will be investigated at selected sites within the TBW which represent local P and land management practices. Surface runoff from natural rainstorms will be evaluated with plots, 2 m long and 1 m wide, equipped with a downslope gutter to divert surface runoff to an in-ground bottle. After each flow event, surface runoff will be pumped from the collection bottle for analysis of P and N forms. This will include dissolved O, algal-available, and total P; nitrate-N and total N; and suspended sediment. At each site, six plots will be installed with a control, while the others will vary in manure application rate and timing. Pan lysimeters will also be installed adjacent to each surface runoff plot to collect percolate for P and N analyses similar to surface runoff, and sampled after each event. This data will allow a detailed understanding of the relationship between soil nutrient content, land management, and P transport in surface and subsurface flow.

We will also determine the relationship between soil P and the concentration of P in surface runoff, to provide a sound scientific basis for establishing threshold soil P levels in areas where P enrichment of surface and subsurface runoff P inputs may impair water quality. We will use portable 1.5 m^2 plots (2 m long and 0.75 m wide) on several soil types, ranging in P content (<5 to >350 mg kg^{-1} as Mehlich-3 P), selected with the help of land owners. Sites will not have had manure or fertilizer P additions in the last six months, so that we will be investigating the effect of soil P on runoff P rather than recent land management. Soil P will be determined by agronomic (Morgan and Mehlich-3 extractable P) and environmental soil tests (water extractable, Fe-oxide strip, and P sorption saturation). Surface runoff generated using a rainfall simulator will be collected and analyzed. At each site, rainfall will be applied at two intensities: 6.5 cm/hr for 30 minutes and the 5-year return-period storm intensity for 30 minutes appropriate to TBW conditions. This phase of the study will determine a protocol for establishing threshold soil P levels for use in P-based manure management and quantification of the weighting of the soil P factor of the P index to be used in the Town Brook watershed.

3.3.2.3. Field/subwatershed-scale studies

The BMPs detailed previously, as well as others that show promise at the laboratory or plot scales, must ultimately be implemented and evaluated at the field or subwatershed scale. It is important to incorporate the variabilities inherent in climate and landscape into any BMP evaluation, because lab- and plot-scale studies do not always include these effects. Because testing at the plot scale will take a minimum of two years, selected fields and/or subwatersheds within the TBW will be selected for monitoring and experimentation before and after BMP implementation. In this way, the effects of selected BMPs can be evaluated. It is recognized that effects of climate might not be the same before and after the implementation of the practices, therefore installation of the climate stations detailed in section 3.4. is critical to this phase of the overall project.

Phosphorus concentration can change along surface and subsurface flowpaths within a watershed above, within, and downgradient of a BMP. Thus, it is critical that we characterize the extent of these changes under conditions prior to BMP installation. Additionally, such characterization can help in designing and implementing targeted BMPs because it points out watershed locations having the potential to control P loss.

Flow pathway monitoring: Surface and subsurface water quality monitoring stations will be installed at selected locations within the agricultural subwatershed to enable eventual field-scale assessment of the effect of BMP implementation on P transport from land to water. These stations will complement the monitoring stations described for the plot and field studies described previously. Surface monitoring stations will be established within existing drainage ditches and first-order streams, while subsurface flow will be monitored using existing tile lines. These monitoring stations will provide a continuous flow-integrated P load under current conditions, and also give insight into the watershed processes controlling P loss prior to implementation of BMPs. Particulate, soluble and organic phosphorus fractions will be measured in all flow components, as will soluble organics (as dissolved organic carbon, DOC) and nitrogen species.

This water quality monitoring will begin prior to BMP implementation. At the field scale, monitoring will focus on determining the effectiveness of BMP implementation on reducing field P losses. Monitoring will be conducted in areas of BMP implementation as well as on control areas where no BMPs are implemented. These data will also be used to test watershed phosphorus loading models.

Storm Flow Pathways and Tracer Studies: Accurate simulation of the partitioning of storm water into surface and subsurface flow paths is critical to estimating nutrient loads since different flow paths have different inherent nutrient concentrations associated with them. We will experimentally determine the separate contributions of runoff rates and volumes from surface and sub-surface flows to the channel and their associated P concentrations and loads using both conservative and non-conservative tracers. Results of these experiments will be used to improve and verify the flow separation predictions for use in nutrient loading models.

Hydrograph separations are accomplished by sampling potential sources of stream water (i.e., precipitation, shallow soil water, groundwater, groundwater seeps, overland flow) and stream water during storms. Conservative and non-conservative solutes within the water are used as tracers to quantify the relative contributions of each source. Conservative tracers will include the natural isotopes ^{18}O and ^{2}H. These non-reactive solutes make excellent conservative water tracers because they are part of the water molecule (Pearce et al., 1986). Non-conservative tracers will include dissolved organic carbon (DOC) and chloride, both of which have been used successfully elsewhere to identify stream water sources (Brown et al., 1998; Bazemore et al., 1994; Eshleman et al., 1993; Pilgrim et al., 1979).

Hydrograph separations will be completed in the agricultural sub-basin. Eight to twelve storms will be sampled throughout the study. Storms will be sampled during snowmelt, during the growing season and during the fall. Two summer and two fall storms will be sampled each year. The storms will be selected so both wet and dry antecedent moisture conditions are included. Therefore, the effect of different moisture conditions on sources of storm flow will be determined.

Precipitation will be sampled using a sequential precipitation collector in the agricultural sub-basin. Soil water will be sampled from existing tile drains. Ground water will be sampled from several wells that will be installed at the beginning of the project. Water from ground water seeps will be collected from seeps that will be identified in the early stages of the project. Overland flow will be sampled using several overland flow collectors that will be installed at the beginning of the study. All end members will be sampled throughout each storm to account for temporal variability of stream water sources. Stream water will be sampled as part of the long-term monitoring described in section 3.4. Stream samples needed for this portion of the study will also be analyzed for $^{16}O/^{18}O$ and $^{1}H/^{2}H$ ratios.

3.4. Monitoring

Streamflow and stream water chemistry monitoring will be conducted at several scales within the Town Brook and Cannonsville Reservoir watersheds. Objectives of this long-term monitoring program are to: 1) calculate nutrient mass balances and quantify the amount of P contributed by different land uses within TBW, 2) put the results of intensive research within the TBW into the context of nutrient concentrations throughout the CRW, 3) provide data for model development, and 4) help evaluate the ultimate effectiveness of the Watershed Agricultural Program.

3.4.1. General monitoring protocols

Monitoring activities will begin in 1999, and continue for approximately 10 years. To provide a base for all watershed monitoring and experimentation, two meteorological stations will be installed within the TBW, one near the watershed outlet and one in the headwaters of the watershed. These stations will be equipped with wind speed and direction sensors, rain gages, air temperature and relative humidity probes, solar pyronometers and wet deposition collectors for chemical analyses of atmospheric inputs. Four additional basic meteorological stations equipped with rain gages, air temperature probes, and wet deposition collectors will also be installed within the watershed adjacent to areas of intensive research. The meteorological stations will be used to quantify atmospheric inputs of nutrients for watershed nutrient budgets and to provide data for watershed modeling efforts.

Streamflow will be continuously measured at the outlets of a completely forested sub-basin, a mostly agricultural sub-basin, and at the TBW outlet. Stream water chemistry samples will be collected weekly and on a storm event basis (using automated samplers) at all three sites. The stations will be capable of transmitting data to remote locations via telephone line or satellite.

During the first two years of study, all runoff events will be sampled to ensure accurate nutrient load estimates. While large fall and spring runoff events have been shown to deliver the bulk of the annual load of many constituents, preliminary reservoir modeling completed by NYCDEP and Upstate Freshwater Institute has suggested that smaller growing-season storms may have a disproportionately large effect on summer algal growth (Owens et al., 1998). Consequently, it is important to sample both large and small runoff events.

After two years, an evaluation of data from the three sites will be completed to determine whether a less rigorous sampling strategy can be used with minimal loss of accuracy in estimating nutrient loads. The minimum analytical suite for all samples will be: total phosphorus (TP), total dissolved phosphorus (TDP), soluble reactive phosphorus (SRP), nitrate+nitrite (NOX), total nitrogen (TN), total organic carbon (TOC), and total suspended solids (TSS). Analytical methods, QA/QC procedures, and event sampling protocols have been established via a written Quality Assurance Protection Plan.

3.4.2. Upper and lower node monitoring

Stream water chemistry and flow data from the forested and abandoned farmland sub-basins will be used to calculate the nutrient loads contributed from those areas of the watershed to compare to the contribution from the agricultural sub-basin. Nutrient loads calculated at the agricultural sub-basin and at the watershed outlet will be used to determine whether implementation of BMPs on farms within TBW succeeds in decreasing nutrient loads and to assess success of alternative manure management practices installed on farms within the watershed. Monthly water samples and flow measurements will be also taken at the outlet of a sub-basin consisting of abandoned fallow farmland to determine the contribution of this characteristic land use to stream nutrient loads. Data from the agricultural, fallow, and forested tributaries will also assist in the calibration, refinement, and validation of watershed models used to predict nutrient loads based on field soil test values and other parameters.

3.4.3. Survey scale monitoring

To place the results from intensive research and monitoring within the TBW into the context of the greater CRW, a survey of water quality and quantity will be conducted on small watersheds throughout the CRW. Twenty to thirty watersheds will be selected to represent the range of land use mixtures within the CRW including various combinations of active agriculture, abandoned farms, urban and residential, and forested. The purpose of this monitoring will be to provide data to: 1) put the results from intensive work in the Town Brook watershed in the context of small agricultural watersheds throughout the CRW, 2) put nutrient loads from agricultural watersheds in the context of those from other land uses within CRW, and 3) identify whether abandoned farmland, urban and residential, or forested landscapes are a significant sources of nutrients to CRW streams. In addition to conducting a survey of small watersheds throughout the CRW, experiments will be completed on intact soil cores from a subset of these watersheds to identify the rate of and factors that effect P release from these representative land uses.

Stream water quality samples and flow measurements will be collected quarterly at the outlet of the selected watersheds for a four-year period. Sampling of surface-water quality during storm events will be done at selected sites that are also part of the USGS-NYCDEP stream-gaging network. Crop types and herd sizes will be cataloged in agricultural watersheds at the beginning and end of the study. In urban and residential watersheds, the extent of urbanization and the area of non-urban land upstream from urban or residential centers will be characterized. Land-use history for the selected abandoned farmland watersheds will be established using historic aerial photographs and town records. Ten phosphorus soil tests will be conducted randomly throughout each watershed at the beginning and end of the study period to document changes in the amount of soil P during the study period. In addition, three intact soil cores will be taken from each of eight watersheds (two sets of cores for each land use type) for laboratory analyses. Cores will be taken in near-stream, mid-slope and ridge-top positions within these watersheds. The cores will be subjected to rainfall simulation experiments to quantify the amount of phosphorus that is leached from the soil columns and the amount that is exported as surface runoff for each land use type. Previous research on forest runoff in CRW suggests that previous phosphorus inputs to soils may be a significant factor in continued elevated P loads during forest regeneration of abandoned farmland (Scott, 1997). Watersheds comprised of abandoned farmland will be selected to cover a range in years-since-last-farmed. Results from those watersheds will be used to identify the relation between years since farmed and stream water nutrient loading. This research will begin during the second year of the overall project and continue through year six.

3.5. Modeling

A suite of field- and watershed-scale models will be developed to support nutrient management planning and to extrapolate the findings of Town Brook to Cannonsville and other NYC water supply watersheds. The proposed strategy is to gain knowledge of the physical processes that govern phosphorus transport at the field and watershed scale. Experimental research as outlined before is, therefore, an integral part of the model development. The knowledge gathered in the experimental studies will be used to refine, apply and test a set of models useful for planning and evaluating effectiveness of BMPs at scales ranging from plot to watershed. Model user interfaces to assist in data management and model application and interpretation will be developed to facilitate their use.

The modeling suite will include: 1) a dairy farm simulation model for tracking the effects of farm management decisions on P levels; 2) a phosphorus index model to gauge the relative risk of P loss from agricultural watersheds based on analysis of P source and transport factors; 3) a spatially distributed hydrology-water quality model to map critical hydrologic source-areas and quantify P loadings by simulating the small-scale processes that govern P transport and determine the effectiveness of BMPs; 4) a broad-scale watershed loading model to evaluate P loadings to the TBW outlet and the Cannonsville Reservoir as a function of P source and transport factors; and 5) a farm- and watershed-scale P mass-balance model to evaluate all major sources and sinks of P. In concert, these models will provide a comprehensive approach to tracking phosphorus flows and evaluating phosphorus reductions due to implementation of BMPs. Following, we describe each of these models and specific improvements that will be implemented.

3.5.1. Phosphorus Index

The Phosphorus Index (PI) model is a user-oriented tool for identifying critical source areas controlling phosphorus export from agricultural watersheds. Originally developed by the NRCS (Lemunyon and Gilbert, 1993), the PI was subsequently improved by Gburek and Sharpley (1998) to account for risk of P transport from field to stream. In the modified PI, the interaction of P source factors (soil test P levels and fertilizer and manure application rates and methods) and transport factors (local runoff and soil erosion and surface runoff contributing areas with associated hydrologic return periods) determine the relative risk of P loss from different fields (or portions of fields) within the watershed. The PI will be modified for Catskill conditions to reflect local complex relationships between land features, hydrology, and P transport potential. Among the complex relationships to be determined is the relationship between soil phosphorus test levels at different depths of the soil profile and the phosphorus concentration in runoff, interflow and tile flow.

To obtain information for the development of the P Index for the acidic glacial till soils characteristic of the TBW and CRW, the effect of fertilizer, manure, and soil management on the transport of P and N in surface and subsurface runoff will be investigated at selected sites within the TBW. Surface and subsurface runoff will be evaluated with plot scale experiments described in section 3.3.2.2. Based on these experiments, we will determine the relationship between soil P and the concentration of P in surface runoff and interflow to provide a sound scientific basis for establishing threshold soil P levels in areas where P enrichment of surface and subsurface runoff P inputs may impair water quality.

3.5.2. DAFOSYM

Dairy herds within the farms on the TBW are likely receiving excessive P in their feed rations. Using data gathered from on-farm surveys conducted by ARS and Cornell Animal Scientists, the Dairy Forage Systems Model (DAFOSYM; Rotz et al., 1989), along with qualitative assessments by the Animal Scientists, the feed ration strategies of the TBW farmers will be evaluated for potential to reduce amount of P being fed, and consequently, to reduce manure P being produced and applied to the land. Based upon these evaluations, we hope to establish a definitive BMP demonstration/evaluation using control groups of animals within one or more farms to test the environmental consequences of reducing P in rations while maintaining animal productivity and health. Routine manure testing will demonstrate the potential beneficial environmental effects of reducing P in animal feed, while animal health and productivity monitoring will demonstrate that this reduction does not come at the expense of economic viability of the farmer or health of the dairy herds.

3.5.3. SMR

The generation and transport of dissolved P from the landscape is dependent on a number of hydrologic processes such as runoff generation, overland flow, and subsurface flow. These physical processes can be effectively modeled using distributed hydrologic models. Such models are designed to incorporate the small-scale processes which control the hydrologic water balance. The water balance, in turn, controls the generation and transport of dissolved and sediment-borne P. A goal of this phase of the project is to take a spatially distributed model appropriate for the hydrologic and geologic characteristics of the Catskill region and incorporate a P generation and transport component. The modified distributed model will be based on the Soil Moisture Routing (SMR) Model (Zollweg et al., 1996; Frankenberger et al., 1999; Kuo et al., 1999), but may also incorporate facets of TOPMODEL (Bevin and Kirkby, 1979). Below we describe each of these models and the possible water quality components to be added.

The SMR model is a spatially distributed water-balance model designed and tested for the sloped, shallow soils typical in Catskill mountain watersheds. The model simulates variable runoff source-areas (areas on the landscape where runoff is generated) by identifying zones of saturation excess. It has been refined through discussions with farm planners to include a prediction of the probability of frozen soils. Output can be as graphical GIS images depicting the spatial and temporal distribution of soil moisture patterns across the farm, or as a tabular listing of months ranked according to their probability of producing runoff.

TOPMODEL is also a spatially distributed water balance model. It incorporates spatial variability in topography and has been improved to include soil variability (Sivapalan, et al., 1987; Famiglietti et al., 1992). This model has many of the same features as SMR, including simulation of variable runoff source-areas. Additionally, TOPMODEL is designed to run on shorter time steps to improve the performance during storm events. Currently, there is no user friendly graphical interface for TOPMODEL.

Nutrient transport will be incorporated into the final spatially distributed model through links to a series of process-based nutrient loading function submodels. These loading function submodels will include functions to simulate P sources and runoff concentrations in surface and subsurface runoff under various management conditions. Although more refinements are needed, working versions of several of these submodels are currently in use. The Manure Allocation Simulation Model (MASM) (Kleinman et al., 1999c) is a spreadsheet-based source model developed to predict manure spreading patterns when actual records of manure spreading are not available. The Soluble Phosphorus Export Model (SPEX) (Brooks et al., 1999) relates dissolved P concentrations to manure spreading.

3.5.4. GWLF

The Generalized Watershed Loading Function (GWLF) model, developed at Cornell University (Haith and Shoemaker, 1987; Haith et al., 1992) simulates dissolved and particulate nutrients in surface and subsurface runoff from different land uses. Non-point source loadings from each land use along with point source loads are integrated to produce a monthly watershed nutrient load. GWLF has been used by NYCDEP to estimate nutrient loads to Cannonsville Reservoir (Schneiderman et al., 1998), and has been linked to a receiving water model to evaluate the effects of watershed loadings on the eutrophication status of Cannonsville Reservoir (Owens et al., 1998).

Improvements in estimation of parameter values will focus on dissolved P concentrations in runoff and subsurface flow. In the current version of GWLF, dissolved P concentrations are constants which are based on regional surveys of nutrient concentrations associated with runoff from different land uses, and thus, describe average conditions without specific reference to local site characteristics, land use practices and BMPs. These dissolved P concentration parameters will be improved based on the results of the experimental studies to quantified relationships between dissolved phosphorus concentration and the source and transport factors identified in the Phosphorus Index. The results of forested sub-basin sampling will be used to improve estimates of dissolved P concentrations in runoff associated with forested land.

Further improvement of the GWLF estimation of dissolved P concentrations associated with runoff will utilize the results of spatially distributed modeling. The spatially distributed model accounts for topographic landscape effects at a level of resolution not possible in the GWLF model. Results of spatially distributed modeling will be used to develop improved hydrologic and loading function parameterizations within the GWLF model framework. Another possible model improvement would be inclusion of the effects, as determined, of long-term changes in soil P in abandoned agricultural lands on both ground water and surface runoff dissolved P concentrations.

3.5.5. Watershed-scale phosphorus mass balance model

Nutrient mass balances provide insight into the contributions of major factors controlling P imports and exports for a farm or watershed. Mass balances are critical to identification of the watershed-specific variables that influence P loss. Mass balance accounting can be used to ensure correct identification of variables responsible for changes in watershed P dynamics and is particularly useful in monitoring management practices that involve coordination between multiple land users.

An annual watershed phosphorus mass-balance model will be developed and applied to the TBW. The model will constructed along lines similar to the Watershed Ecosystem Phosphorus Model (WEP) (Cassell et al., 1998), but customized for the specific characteristics of the NYC watersheds. If suitable information is available, we will also apply the P mass-balance concept to the individual farms within the TBW, both to evaluate their P balance status and to provide a check on the watershed-scale P balance findings.

3.5.6. Model integration and validation

Tool and model testing will occur throughout the duration of the project using the experimental data collected at the different scales. Because model processes are not always well defined, it is risky to develop a module without interim testing of the entire model.

An independent validation of the enhanced GWLF model will use the long-term monitoring data for the experimental watersheds and for the West Branch Delaware River watershed at Beerston. The SMR Model will be tested for the TBW and for the smaller upper node watersheds (agriculture, fallow, and forest) that USGS will be sampling. In addition, the Phosphorus Index and DAFOSYM are continually being applied, tested, and evaluated at numerous locations throughout the northeastern U.S. as part of the ongoing ARS research effort independent of this project.

An important goal of this task is to develop software packages that can be used directly by the WAP farm planners, watershed managers, and farmers. During the first three years of the project, we will achieve prototype status of one or more of the models described. Two additional years will be needed to develop software that is fully functional in a user-friendly mode. We envision software in which a map of a farm or watershed can be displayed on the monitor, and by using simple Windows-based menus, hydrologic simulations can be conducted to identify hydrologically sensitive areas. Overlaying these simulations with soil P saturation data will provide an optimum manure-spreading schedule. Finally, the software will provide suggestions on how to minimize P loss at both the farm and the watershed scale, thereby reducing agricultural-based P loads to the Cannonsville Reservoir.

3.6. GIS database development

An important part of model development, testing, and validation, eventual extrapolation of the models to other areas and conditions, and use of the models to evaluate effects of whole-farm planning and related BMP implementation at the larger scale, is development of a comprehensive and accurate database. Applications of the analytic tools and models will require spatial data from a variety of sources and on a variety of scales integrated into a common GIS. Such data include land use, topography, soils, hydrography, stream- and field-monitoring data, and management practice data. Geo-referenced data related to field boundaries, field treatments (e.g., tillage, crop type, fertilizer and manure applications), and soil properties will be stored in temporal data sets, allowing for time series analysis of field trends. Linkages between these data and stream data from monitoring stations will enable independent evaluation of trends, potentially identifying alternative approaches to predicting stream P loadings.

Terrain-related information for the GIS will build upon the NYC watershed datasets that have been or are being assembled by NYCDEP, USGS, and other agencies. This effort is already well under way: Landsat Thematic Mapper satellite images have been analyzed to derive land-use data at 25-meter resolution; digital ortho quads (DOQs) are one-meter resolution image maps derived from aerial photography which has been scanned and orthorectified; digitized farm field boundaries based on the DOQs have been completed for several of the participating farms. DOQ images now exist for a portion of the upper CRW including the TBW, with the remainder of the DOQs for the watershed expected to be completed by NYCDEP by the fall of 2000.

With permission of participating farmers and the WAC, additional GIS datasets will be developed from sources such as WAP farm plans and on-farm surveys. ARS, in conjunction with the NRCS and WAP planning teams, will conduct the on-farm surveys to gather information to: a) catalog the conventional nutrient management plans currently used in the TBW, and b) provide input data to apply DAFOSYM to individual farms within the watershed. All data will be geo-referenced and integrated into the larger GIS. This one-time survey will be supplemented with a continuing data collection effort by the TBW farmers themselves to provide the Research Team and planners with farm management information (e.g., feed purchases, crop production, milk production, soil testing, amount, location, and timing of manure spreading, and manure testing). The farmers will be compensated by the project for time and inconvenience associated with this phase of the data collection.

Lastly, soil transect sampling will be conducted three times each year (March, July, November) for all fields in the agricultural sub-basin to monitor soil conditions at the field scale. Soils will be sampled at designated geo-referenced points along predetermined transects. For each transect, samples will be combined and mixed to produce a homogenized aggregate sample. This technique provides an efficient method of sampling average soils conditions for an area of land (Kleinman, 1999). Agricultural soils will be sampled to at several depths. The depths depend on the to-be-developed relationship of P concentration in runoff and subsurface flow verses P levels in different parts of the soil. A subset of the samples will be analyzed for soil P saturation as well as for P sorption/desorption characteristics.

This GIS, along with related information, will become part of a World Wide Web-based "Information Center" designed and maintained for internal use by farmers, planners, the Research Team, and others associated with the project. Selected portions of the Information Center (e.g., project description, findings determined by project participants to be publicly available) will be made accessible to users outside the project. The general purpose of this Information Center is to document the project, share data and ideas, and provide information about ongoing efforts. The Information Center will be located at the WAC offices, where the data will also be held in original and summarized forms. The data will be freely available to Town Brook farmers, planners, and the Research Team; fulfilling requests for data from others would be at the discretion of the WAC in consultation with the Research Team.

4. PROJECT STRUCTURE

4.1. Timeline

During the first three months of the project, past research and experiences with BMPs will be reviewed. Then, in cooperation with the TBW farmers and with assistance of farm planners, selection of the candidate

BMPs for implementation and evaluation will be finalized. Testing these practices will start at a small plot or field scale during the first year and continue throughout the duration of the project, making adaptations after understanding the P removal mechanisms better. Once we are satisfied that a particular BMP reduces the amount of P entering the stream at the smallest scale, we will implement and evaluate the practice at a field or subwatershed scale. This stem will require the assistance of the farm planners. By comparing the water quality before and after implementation, we can judge the effectiveness of the practice.

Laboratory and plot studies will be initiated before the end of the first year of the project. They will be used primarily to establish the basic relationships between soil P, rate, timing, and type of manure applied, and concentration of P in surface and subsurface flow.

Stream monitoring at the TBW outlet and forest site has already begun and will continue throughout the project duration, not to exceed 10 years. Monitoring of the agricultural site, as well as the survey-scale monitoring effort, will begin within six months.

Tool development and model improvement will go hand in hand with the experimentation. As we gain understanding of processes, they will be added to the appropriate model(s). Once any model is properly validated, it will be modified to a form more easily used by non-scientists. We expect that the first prototype will finished approximately four years after the start of the project. The GIS database will be completed at approximately that same time.

4.2. Products

In addition to the research results and BMP evaluations realized from successful completion of this project, we will also produce a series of tangible "products" applicable to evaluation and management of P loss from agriculture characterized by the farms within Town Brook Watershed. These products are:

- A suite of BMPs that will efficiently and effectively reduce P loss from farms typical of those within the TBW
- Integration of the chemical and hydrologic processes controlling P loss from agricultural areas within the TBW and resulting construction of a suite of user-friendly indices and models that will allow planners to evaluate effects of applying these BMPs at the watershed scale
- Development and refinement of a P Indexing tool to identify sites most vulnerable to phosphorus loss which will assist NRCS and other state agencies to target specific parts of the landscape, or "hot spots," for more careful treatment to reduce the risk of P loss at the watershed scale
- Development of technically defensible and reliable decision-making tools to aid nutrient management planning related to phosphorus and manure

5. REFERENCES

Basnyat P., L.D. Teeter, K.M. Flynn, and B.G. Lockaby. 1999. Relationships between landscape characteristics and nonpoint source pollution inputs to coastal estuaries. Environ. Management 23:539-549.

Bazemore, D.E., K. Eshleman, and K.J. Hollenbeck. 1994. The role of soil water in stormflow generation in a forested headwater catchment: Synthesis of natural tracer and hydrometric evidence. J. Hydrol. 162:47-75.

Beckhardt, L. and E. Blouin. 1997. Watershed Agricultural Program Preliminary Evaluation. NYC DEP, Division of Water Quality Control. Valhalla, NY.

Bevin, K.J. and M.J. Kirkby. 1979. A physically based, variable contributing area model of basin hydrology. Hydrol. Sci. Bull. 24:43-69.

Brooks, E.S., M.T. Walter, J. Boll, M.F. Walter, C.A. Scott, P. Kleinmann, and T.S. Steenhuis. 1999. Soluble phosphorus transport from manure-applied fields under various spreading strategies. Submitted, J. Environ. Qual.

Brown, V.A., J.J. McDonnell, D.A. Burns, and C. Kendall. 1998. The role of event water, a rapid shallow flow component, and catchment size in summer stormflow. J. Hydrol. (in review).

Brüsch, W. and B. Nilsson. 1993. Nitrate transformation and water movement in a wetland area. Hydrobiologia 251:103-111.

Cassell, E.A., J.M. Dorioz, R.L. Kort, J.P. Hoffmann, D.W. Meals, D. Kirschtel, and D.C. Braun. 1998. Modeling phosphorus dynamics in ecosystems: Mass balance and dynamic simulation approaches. J. Environ. Qual. 27:293-298.

Catskill Center for Conservation and Development. 1997. Summary Guide to the terms of the Watershed Agreement. Arkville, NY.

Cey, E.E., D.L. Rudolph, R. Aravena, and G. Parkin. 1999. Role of the riparian zone in controlling the distribution and fate of agricultural nitrogen near a small stream in southern Ontario. J. Contam. Hydrol. 37:45-67.

Cooper, A.B. 1990. Nitrate depletion in the riparian zone and stream channel of a small headwater catchment. Hydrobiologia 202:13-26.

Correll, D.L. 1998. The role of phosphorus in the eutrophication of receiving waters: A review. J. Environ. Qual. 27:261-266.

Doerr, S.M., E.M. Owens, R.K. Gelda, M.T. Auer and S.W. Effler. 1998. Development and testing of a nutrient phytoplankton model for Cannonsville Reservoir. Lake and Reservoir Manage. (in press).

Eshleman, K.E., J.S. Pollard, and A.K. O'Brien. 1993. Determination of contributing areas for saturation overland flow from chemical hydrograph separations. Water Resour. Res. 29:3577-3587.

Famiglietti, J.S., E.F. Wood, M. Sivapalan and D.J. Thongs. 1992. A catchment scale water balance model for FIFE. J. Geophys. Res. 97(D17):18997-19007.

Frankenberger, J.R., E.S. Brooks, M.T. Walter, M.F. Walter, and T.S. Steenhuis. 1998. A GIS-based variable source area hydrology model. Hydrol. Process. 13:805-822.

Gburek, W.J. and A.N. Sharpley. 1998. Hydrologic controls on phosphorus loss from upland agricultural watersheds. J. Environ. Qual. 27:267-277.

Gburek, W.J. and J.A. Zollweg. 1999. A surface runoff generation field study. Water Resour. Res. (in press).

Gburek, W.J., A.N. Sharpley, and H.B. Pionke. 1996. Identification of critical source areas for phosphorous export from agricultural catchments. In: Advances in Hillslope Processes, Vol. 1, M.G. Anderson, and S.M. Brooks, eds., John Wiley and Sons, pp. 263-282.

Griffith S.M., J.S. Owen, W.R. Horwath, P.J. Wigington, J.E. Baham, and L.F. Elliott. 1997. Nitrogen movement and water quality at a poorly-drained agricultural and riparian site in the Pacific Northwest (Reprinted from Plant nutrition for sustainable food production and environment, 1997). Soil Sci. and Plant Nutrition 43:1025-1030.

Haith, D.A., R. Mandel and R.S. Wu. 1992. GWLF generalized watershed loading functions Version 2.0 USER'S Manual. Department of Agricultural & Biological Engineering, Cornell University.

Haith, D.A. and L.L. Shoemaker. 1987. Generalized watershed loading functions for stream flow nutrients. Water Resour. Bull. 23:471-478.

Kellogg, R.L. and C.H. Lander. 1999. Trends in the potential for nutrient loading from confined livestock operations. NRCS/USDA Conference Poster Presentation for "The State of North America's Private Land," Chicago, IL, January 19-21, 1999.

Kleinman, P.J.A. 1999. Examination of phosphorus in agricultural soils of New York's Delaware River Watershed. Ph.D. Dissertation, Cornell Univ., Ithaca, NY.

Kleinman, P.J.A., R.B. Bryant, and W.S. Reid. 1999a. Development of pedotransfer functions to quantify phosphorus saturation of agricultural soils. J. Environ.Qual. 28 (in press).

Kleinman, P.J.A., R.B. Bryant, W.S. Reid, A.N. Sharpley, and D. Pimentel. 1999b. Identifying environmental thresholds of soil phosphorus from Quantity/Intensity relationships. Submitted, Soil Science.

Kleinman, P.J.A., M.N. Marshall, W. Tone, R.B. Bryant, and A.N. Sharpley. 1999c. Use of decision simulation model to evaluate alternative manure management strategies. Submitted, J.Soil and Water Conserv.

Kleinman, P.J.A., R.B. Bryant, W.S. Reid, and A.N. Sharpley. 1999d. Phosphorus in agriculture: I Environmental underpinnings. What's Cropping Up? (in press).

Kleinman, P.J.A., A.N. Sharpley, R.B. Bryant, and W.S. Reid. 1999e. Phosphorus in agriculture: II. Soil phosphorus chemistry. What's Cropping Up? (in press).

Kuo, W.L., T.S. Steenhuis, C.E. McCulloch, C.L. Mohler, D.A. Weinstein, S.D. DeGloria, and D.P. Swaney. 1999. Effect of grid size on runoff and soil moisture in a GIS-based, variable-source-area hydrology model. Water Resour. Res. (in press).

Lemunyon, J.L. and R.G. Gilbert. 1993. The concept and need for a phosphorus assessment tool. J. Prod. Agric. 6:483-496.

Longabucco, P. and M.R. Rafferty. 1998. Analysis of material loading to Cannonsville Reservoir: Advantages of event-based sampling. J. Lake and Reservoir Manage. 14:197-212.

Owens, E.M., S.W. Effler, S.M. Doerr, R.K. Gelda, E.M. Schneiderman, D.G. Lounsbury, and C.L. Stepczuk. 1998. A strategy for reservoir model forecasting based on historic meteorological conditions. J. Lake and Reservoir Manage. 14:322-331.

Pearce, A.J., M.K. Stewart, and M.G. Sklash. 1986. Storm runoff generation in humid headwater catchments 1. Where does the water come from? Water Resour. Res. 22:1263-1272.

Peterjohn W.T. and D.L. Correll. 1984. Nutrient dynamics in an agricultural watershed: Observations on the role of a riparian forest. Ecology 65:1466-1475.

Pilgrim, D.H., D.D. Huff, and T.D. Steele. 1979. Use of specific conductance and contact time relations for separating flow components in storm runoff. Water Resour. Res. 15:329-339.

Pionke, H.B, W.J. Gburek, A.N. Sharpley and J.A. Zollweg. 1997. Hydrological and chemical controls on phosphorus loss from catchments. In: Phosphorus Loss from Soil to Water, H. Tunney, O.T. Carton, P.C. Brookes and A.E. Johnston (ed.). New York, NY. Cab International, chapter 10, pp. 225-242.

Porter, M.J., L. Beckhardt, K.S. Porter, B.Y. Perigard, ed. Pollution Prevention through Effective Agricultural Management. Progress Report: Watershed Agricultural Program for the New York City Watersheds. Watershed Agricultural Council, December 1997.

Rotz, C.A., J.R. Black, D.R. Mertens, and D.R. Buckmaster. 1989. DAFOSYM: A model of the dairy forage system. J. Prod. Agric. 2:83-91.

Scott, C.A., L.D. Geohring, and M.F. Walter. 1998a. Water quality impacts of tile drains in shallow, sloping, structured soils as affected by manure application. App. Engrg. in Agric. 14:599-603.

Scott, C.A., M.F. Walter, E.S. Brooks, J. Boll, M.B. Hes, and M.D. Merrill. 1998b. Impacts of historical changes in land use and dairy herds on water quality in the Catskills Mountains. J. Environ. Qual. 27:1410-1417.

Schneiderman, E.M., D.G. Lounsbury, and R. Lohre. 1998. Application of generalized watershed loading function (GWLF) model to Catskill and Delaware Reservoirs. New York City Dept. Environ. Protection, Valhalla, NY (January 1998).

Sharpley, A.N. 1998. Keep P in place. Farm Chemicals. Business Management, February 1998, p. 21.

Sharpley, A.N., T.C. Daniel, and D.R. Edwards. 1993. Phosphorus movement in the landscape. J. Prod. Agric. 6:492-500.

Sharpley, A.N. 1999. Soil inversion by plowing decreases surface soil phosphorus content. Presented at 1999 SSSA Meeting.

Sivapalan, M., K. Bevin and E.F. Wood. 1987. On hydrologic similarity, 2. A scaled model of storm runoff production. Water Resour. Res. 23:2266-2278.

Walter, M.F., T.S. Steenhuis, and D.A. Haith. 1979. Nonpoint source pollution control by conservation practices. Trans. ASAE 22:834-840.

Weiler, K., M.T. Walter, M.F. Walter, E.S. Brooks, and C.A. Scott. 1999. Temporarily dependent risk analysis for flood plains in the Delaware River Basin. (in press).

Zollweg, J.A., W.J. Gburek, and T.S. Steenhuis. 1996. SMoRMod - A GIS-integrated rainfall-runoff model applied to a small Northeast U.S. watershed. Trans. ASAE 39:1299-1307.

6. RESEARCH TEAM CVs (attached)

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M.S., Civil Engineering, SUNY Buffalo, 1967
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Research Activities
Hydrology of the near-stream environment; hydrology/water quality interactions at the watershed scale with emphasis on hydrologic controls on phosphorus transport; modeling of surface and subsurface flow/water quality processes.

Honors and Awards
USDA-ARS Competitive Post-Doctoral Research Associate position; $40,000 for two years, 1995-1996.
USDA Certificate of Merit and cash award for Superior Performance; 1992, 1993, 1995.

Selected publications

Gburek, W.J., A.N. Sharpley, L. Heathwaite, and G.J. Folmar. 1999. Phosphorus management at the watershed scale. J. Environ. Qual. (accepted for publication, 11/98).

Gburek, W.J., and J.A. Zollweg. 1999. A surface runoff generation field study. Water Resour. Res. (accepted for publication, 9/99).

Gburek, W.J., G.J. Folmar, and J.B. Urban. Field data and ground water modeling in a layered fractured aquifer. Ground Water 37(3)175-184. 1999.

Gburek, W.J., and G.F. Folmar. Patterns of contaminant transport in a layered fractured aquifer. J. Contaminant Hydrol. 37(1999):87-109. 1999.

Gburek, W.J., and G.F. Folmar. Flow and chemical contributions to streamflow in an upland watershed: a baseflow survey. J. Hydrol. 217(1999):1-18. 1999.

Gburek, W.J., and A.N. Sharpley. 1998. Hydrologic controls on phosphorus loss from upland agricultural watersheds. J. Environ. Qual. 27:267-277.

Gburek, W.J., A.N. Sharpley, and H.B. Pionke. 1996. Identification of critical source areas for phosphorous export from agricultural catchments. In: Advances in Hillslope Processes, Vol. 1, M.G. Anderson, and S.M. Brooks, eds., John Wiley and Sons, pp. 263-282. 1996.

Gburek, W.J., J.A. Zollweg, H.B. Pionke, and A.N. Sharpley. 1996. Delineation of nutrient source-areas via GIS: Management implications for upland agricultural watersheds. In: Proceedings of Conserv96: Responsible Water Stewardship, American Water Works Association, pp. 947-951.

Gburek, W.J., and H.B. Pionke. 1995. Management strategies for land-based disposal of animal wastes: Hydrologic implications. In: Animal Waste and the Land-Water Interface, K. Steele, ed., Lewis Publishers, NY, pp. 313-323

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Research Activities

Project coordination, project proposal development, and communication with potential cooperators. Watershed water quality analyses, watershed nutrient flux evaluation, watershed assessment and evaluation, data editing and database management, conducting watershed hydrologic and bio-geochemical research.

Selected publications

McHale, MR, (1999) Hydrologic controls of nitrogen cycling in an Adirondack watershed Ph.D. Thesis, Faculty of Forestry, State University of New York College of Environmental Science and Forestry, Syracuse, NY

McHale, MR, Mitchell, MJ, McDonnell, JJ and Cirmo, CP (1999) Nitrogen solutes in an Adirondack forested watershed: Importance of dissolved organic nitrogen. Biogeochemistry (in press)

McHale, MR, Kendall, KA and McDonnell, JJ (1999) A laboratory study of capillary fringe induced rapid water table rise. Journal of Hydrology (in review)

McHale, MR, Cirmo, CP, Mitchell, MJ and McDonnell, JJ (1999) The impact of near-stream riparian wetlands on stream water nitrogen chemistry during snowmelt. Manuscript in preparation

McHale, MR, McDonnell, JJ, Cirmo, CP and Mitchell, JJ (1999) Flushing and draining of soil water and groundwater nitrate in an Adirondack forested watershed. Manuscript in preparation

Lincoln, TA, Horan-Ross, DA, McHale, MR and Lawrence, GB (1999) Quality-Assurance data for routine water analyses by the U.S. Geological Survey Laboratory in Troy, N.Y., 1993-1995 Manuscript in preparation.

Lincoln, TA, Horan-Ross, DA, McHale, MR and Lawrence, GB (1999) Quality-Assurance data for routine water analyses by the U.S. Geological Survey Laboratory in Troy, N.Y., 1995-1997 Manuscript in preparation.

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Research Activities

Simulation modeling of watershed hydrology and water quality; loading functions that tie nutrient concentrations to hydrologic flow paths; evaluating loading reductions due to landuse management practices on field and watershed scales; link watershed and receiving water models to gauge effects of landuse management on reservoir water quality; Geographic Information System (GIS) development and applications linked to modeling.

Selected publications

Schneiderman, E.M., D.G. Lounsbury, and R. Lohre. 1998. Application of GWLF Non-Point Source Loading Model to the Catskill and Delaware System Watersheds. NYC DEP, Division of Water Quality Control. Valhalla, NY (Jan, 1998).

Owens, E.M., S.W. Effler, S.M. Doerr, R.K. Gelda, E,M. Schneiderman, D.G. Lounsbury, and C.L. Stepczuk, 1998. A Strategy for Reservoir Model Forecasting Based on Historic Meteorological Conditions. Journal of Lake and Reservoir Management 14:2-3, pp. 322-331.

Schneiderman, E.M., Tone J.W., Thongs, D.J., Lounsbury, D.G., Dibeler, B.J., Lohre, R.F., 1997. Assessment of GWLF Model Applications for the Catskill Delaware Reservoirs. NYC DEP, DWQC. Shokan, N.Y. (June, 1997).

Schneiderman, E.M., D.G. Lounsbury, and R. Lohre. 1997. Set-up of Application of the Generalized Watershed Loading Function (GWLF) Models for the Catskill/Delaware Watersheds. NYC DEP, Division of Water Quality Control. Valhalla, NY (March, 1997).

Tone, J.W., E.M. Schneiderman and E. Blouin, 1997. NYC Watershed Agricultural Program Water Quality Risk Reduction Evaluation. NYC DEP, Division of Water Quality Control. Valhalla, NY (Dec, 1997).

Beckhardt, L., E.M. Schneiderman, and J.W. Tone, 1996. NYC Watershed Agricultural Program Evaluation Criteria. NYC DEP, Division of Water Quality Control. Valhalla, NY (Dec, 1996).

Schneiderman, E.M., M. Zion, D.L. Lounsbury, B. Dibeler, and J.W. Tone, 1998, 1999. Status Reports on Catskill and Delaware System Terrestrial and Reservoir Modeling. NYC DEP, Division of Water Quality Control. Valhalla, NY (April 1998, October 1998, April 1999, July 1999).

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Research Activities

Cycling of P in soil-plant-water systems relative to soil productivity and water quality, including management of fertilizers, crop residues, and manures; basic processes of the P cycle and incorporation of their formulations into comprehensive models for evaluating management of field-size units; targeting agricultural sites vulnerable to P loss in runoff for effective implementation of remedial strategies.

Honors and Awards

USDA Distinguished Service Unit Award, 1984 (Erosion-Productivity Modeling)
Fellow, American Society of Agronomy, 1990
Fellow, Soil Science Society of America, 1991
American Society of Agronomy's Environmental Quality Research Award, 1994

Selected publications

Sharpley, A.N. An innovative approach to estimate bioavailable phosphorus in agricultural runoff using iron oxide-impregnated paper. J. Environ. Qual. 22:597-601. 1993.

Sharpley, A.N., S.J. Smith, and R. Bain. Effect of poultry litter application on the nitrogen and phosphorus content of Oklahoma soils. Soil Sci. Soc. Am. J. 57:1131-1137. 1993.

Sharpley, A.N., and S.J. Smith. The prediction of bioavailable phosphorus loss in agricultural in runoff. J. Environ. Qual. 22:32-37. 1993.

Sharpley, A.N. Assessing phosphorus bioavailability in agricultural soils and runoff. Fert. Res. 36:259-272. 1994.

Sharpley, A.N., and A.D. Halvorson. The management of soil phosphorus availability and its transport in agricultural runoff. P. 1-84. *In* R. Lal (ed.), Soil Processes and Water Quality. Adv. Soil Sci. 1994.

Sharpley, A.N., G. Pierzynski, and J.T. Sims. Innovative soil phosphorus availability indices: Assessing inorganic phosphorus. P. 113-140. *In* J. Havlin, J. Jacobsen, P. Fixen, and G. Hergert (eds.) New Directions in Soil Testing for Nitrogen, Phosphorus, and Potassium. Am. Soc. Agron., Madison, WI. 1994.

Sharpley, A.N., S.C. Chapra, R. Wedepohl, J.T. Sims, T.C. Daniel, and K.R. Reddy. Managing agricultural phosphorus for protection of surface waters: Issues and options. J. Environ. Qual. 23:437-451. 1994.

Sharpley, A.N. Dependence of runoff phosphorus on extractable soil phosphorus. J. Environ. Qual. 24:920-926. 1995.

Sharpley, A.N. Identifying sites vulnerable to phosphorus loss in agricultural runoff. J. Environ. Qual. 24:947-951. 1995.

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Research activities

Delineation of surface and subsurface flow pathways in glacial landscapes; hydrologic controls on nutrient loss from soils; role of preferential pathways in flow and chemical movement through soils; adaptation and synthesis of this information into models of watershed performance.

Selected publications

Zollweg, J.A., W.J. Gburek, and T.S. Steenhuis. 1996. SMoRMod - A GIS-Integrated Rainfall-Runoff Model Applied to a Small Northeast U.S. Watershed. Trans. ASAE 39:1299-1307.

Boll, J., J.S. Selker, G. Shalit, and T.S. Steenhuis. 1997. Frequency Distribution of Water and Solute Transport Properties Derived from Pan Sampler Data. Water Resources Research 33(12):2655-2664

Haverkamp, R., J.-Y. Parlange, R. Cuenca, P.J. Ross, and T.S. Steenhuis. 1999. Scaling of the Richards Equation and Its Application to Watershed Modeling. Chapter 7, In: Scale Dependence and Scale Invariance in Hydrology, G. Sposito, Ed. Cambridge University Press. (In press.)

Wallach, R., T.S. Steenhuis, and J.-Y. Parlange. 1998. Modeling the Movement of Water and Solute Through Preferential Flow Paths. Chapter 7, In: The Handbook of Groundwater Engineering, J. Delleur, Ed. CRC Press. pp. 7-1 - 7-21.

Wallach, R. and T.S. Steenhuis. 1998. Model for Nonreactive Solute Transport in Structured Soils with Continuous Preferential Flow Paths. Soil Science Society of America Journal 62:881-886.

Steenhuis, T.S., M.B. McBride, B.K. Richards, and E. Harrison. 1999. Trace Metal Retention in the Incorporation Zone of Lane-Applied Sludge. Environmental Science and Technology. (In press.)

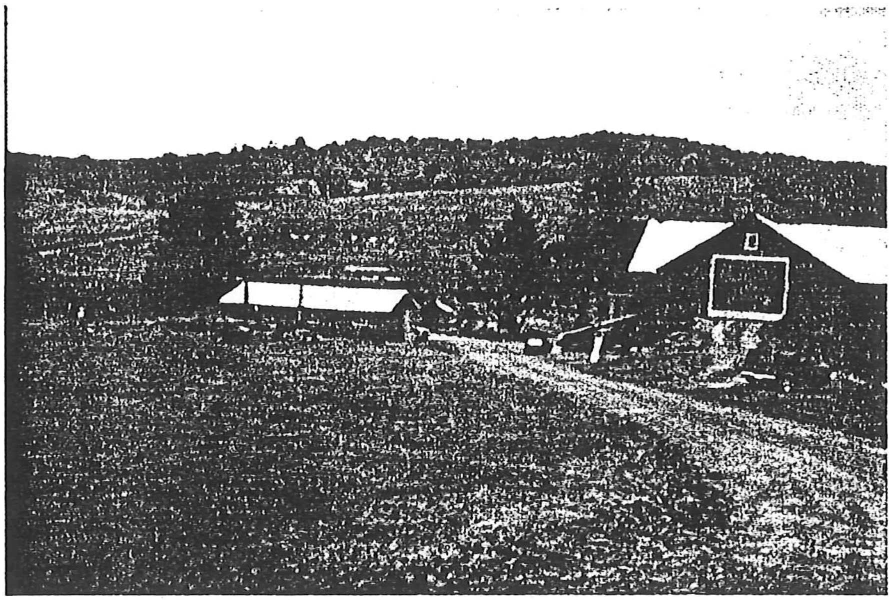
Frankenberger, J.R., E.S. Brooks, M.T. Walter, M.F. Walter, and T.S. Steenhuis. 1999. A GIS-Based Variable Source Area Hydrology Model. Hydrol. Processes. 13: 805-822.

Kuo, W.L., T.S. Steenhuis, C.E. McCulloch, C.L. Mohler, D.A. Weinstein, S.D. DeGloria, and D.P. Swaney. 1999. Effect of Grid Size on Runoff and Soil Moisture in a GIS-Based, Variable--Source-Area Hydrology Model. Water Resources Research. In press.

Steenhuis, T.S., J.Y. Parlange, W.E. Sanford, A. Heilig, F. Stagnitti, and M.F. Walter. 1999. Can We Distinguish Richards's and Boussinesq's Equations for Hillslopes? The Coweeta Experiment Revisited. Water Resources Research 35:589-593.

EFFECTIVENESS OF WHOLE FARM PLANNING AND IMPLEMENTATION IN ACHIEVING WATER QUALITY IMPROVEMENT AND PROTECTION OF NEW YORK CITY WATER SUPPLIES

PRELIMINARY ANALYSIS OF THE FIRST YEAR OF SAMPLING DATA FOLLOWING BMP IMPLEMENTATION AT THE ROBERTSON FARM



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INTRODUCTION

Whole Farm Planning (WFP) was adopted under the New York City (NYC) Watershed Agricultural Program as the primary means of protecting NYC water supplies from the nonpoint source (NPS) impacts of farming as well as maintaining a viable agricultural community in the watershed. The major purpose of this research study is to test the ability of the Whole Farm Planning process to: 1) correctly identify significant sources of on-farm pollution; and 2) recommend and implement cost effective management practices that will substantially reduce pollutant losses from those sources. The study will accomplish this by determining the degree of water quality improvement achieved on a monitored farm after implementation of best management practices (BMPs) recommended by WFP. Also, the water quality data gathered from this study, along with other data collected by New York State Department of Environmental Conservation (NYSDEC) from the West Branch of the Delaware River (WBDR) at Beerston, are being used by other researchers as input to watershed simulation models. The results of modeling will provide a basis for estimating pollutant reductions that might be expected for the entire watershed after treatment of all farms participating in the Whole Farm program.

The complete results of the two years of water quality monitoring done *prior* to implementation of WFP BMPs on the study farm will soon be available from NYSDEC, Bureau of Watershed Management. However, due to the amount of interest in NYC Watersheds agricultural activities, preliminary results of the first year of monitoring *after* implementation of BMPs at the study farm are presented here.

METHODS

Study Design

The design for the study is a modified paired watershed approach where two small watersheds, similar in size, slope, shape, and soils, are being continuously monitored for streamflow and pollutant loading. They are situated at the headwaters of tributaries of the WBDR and are located within five miles of one another (Fig. 1). One watershed, the Robertson farm, contains a single active, farm representative of upland dairy agriculture in the WBDR watershed. The farm is 150 ha (370 acres) in size and consists of about 86 ha (213 acres) of forestland with the remaining acreage comprised of rotated cropland, permanent hayland, permanent pasture, and the farmstead area. The runoff and pollutant loads entering the tributary that drains the area are derived almost exclusively from the farm because it comprises nearly the entire contributing watershed. This enables farm losses to be accurately identified and quantified.

The other watershed, Shaw Road, is located approximately 6.5 km (4 miles) southeast of the Robertson farm (Fig. 1) and is approximately 90 ha (222 acres) in size. It is mostly forested or old fields reverting to forest with no farms located within it and represents the background/control site.

Both sites were monitored for two years (June 1993 - May 1995) prior to BMP installation on the farm in order to establish hydrologic response and pollutant loading relationships between the agricultural watershed and the background watershed, and to determine the level of loading from the farm in the untreated condition. The farm was then treated with all BMPs recommended in the Whole Farm Plan within a 1.5-year period during which monitoring was suspended. Monitoring resumed at both sites in November 1996 and will continue for a minimum of three years. Water quality before and after implementation at the farm is being compared to determine the effectiveness of the BMPs in improving farm runoff quality. Careful and detailed records of farm activities, such as location and amount of manure spreading, fertilizer used, etc., are being kept in order to relate changes in water quality to changes in farm practices.

The Shaw Road site is being used as an indicator to help differentiate changes in farm loads that are related to meteorological and hydrological (natural) factors, such as precipitation amounts, runoff volumes, and event intensities, from changes related to BMPs. Because Shaw Road's land use will remain virtually unchanged during the life of the study, any changes in pollutant loads from year to year will most likely be due to natural variations. Therefore, we can say, with some confidence, that if phosphorus losses decreased at both sites the first year after implementation, most, if not all, of that decrease at the control site and some of that decrease on the farm was due to natural variability (i.e., less precipitation and/or runoff). Once we account for this natural variability by comparing the farm to Shaw Road, we can then look to see if further decreases occurred at the farm that are likely associated with implementation of BMPs.

Shaw Road also serves as a yardstick against which water quality at the farm can be compared to background water quality before and after implementation of BMPs. In other words, we will be able to see the degree to which runoff quality from the farm may begin to approach runoff quality from a background site as a result of practices.

As stated above, a modified paired watershed approach is being used in this study. The traditional paired watershed design usually utilizes two study sites that are similar in not only important factors such as size, slope, and soils, but in *land use* as well. Our approach is modified because instead of using two agricultural sites, one treated with practices and one not treated, we used sites with different land uses, that is, farm and non-farm sites. The reason for this is that when using another farm as the control site, variables other than meteorological/hydrological ones are present that could cause differences in pollutant loadings at the control site from year to year. A farmer on the control farm may, for instance, change his patterns of crop rotation, manure spreading, and fertilizer use each year as part of his normal operation. As researchers, we have no way to control what he does on his farm. Therefore, these "operational" differences, in addition to natural differences in precipitation and runoff, will affect the amounts and timing of pollutant loading each year, and hence, introduce variability that can not be easily accounted for. When trying to compare the control farm to the treated Robertson farm, it would not be clear whether changes in loads at the control were due to weather or to operational changes or a combination of both. For example, we might see a decrease in phosphorus at the Robertson farm the first year after implementation. The first thing we would look at is what the phosphorus load did at the control farm. If it also decreased, we would not know how much was due to less runoff occurring that year (natural variability) versus how much was due to other factors such as less manure being spread near the stream or less fertilizer used or some other operational difference. Thus, when comparing the control farm to the treated farm, it would be difficult to assess change at the treated farm by comparing it to the control because the indicator (the control farm) is not static but, rather, ever-changing due to human influence.

Monitoring, Sample Collection and Analyses

Precipitation and streamflow are continuously monitored and recorded at both sites. Streamflow can be considered as all the precipitation that fell on the watershed and reached the stream, either as surface runoff or as subsurface, including groundwater, runoff (not all precipitation runs off: some evaporates, some is used by plants or hydrates the soil). Annual runoff is computed in centimeters (cm), and can be envisioned as all of the precipitation that ran off as streamflow in a year spread evenly over the entire watershed surface. Since runoff is normalized to the watershed area, runoff from the Robertson farm can be directly compared to that of Shaw Road.

Sample collection at the sites is automated and keys off of precipitation and changes in stream stage. Particular emphasis is placed on sampling during runoff events when large quantities of nutrients and sediment wash off the land. Water samples are analyzed for total phosphorus (TP), total dissolved phosphorus (TDP), and soluble reactive phosphorus (SRP). Particulate phosphorus (PP) is calculated as the difference of TP and TDP. Other analyses include nitrate + nitrite (NO_X), total ammonia ($T\text{-}NH_3$), total Kjeldahl nitrogen (TKN), total organic carbon (TOC), total suspended solids (TSS), pH and alkalinity.

Samples are also collected on a bi-weekly basis for *Giardia* and *Cryptosporidium*. However, the results are reported to New York City Department of Environmental Protection (NYCDEP) and will not be presented here.

Benthic invertebrate community sampling is conducted at both sites once a year in the summer by the Stream Biomonitoring Unit of the NYSDEC. Collection methods follow those specified in Bode et al. (1995). The first sampling took place in the summer of 1996. Although practice implementation had begun on the farm by this time, conditions in the stream were still representative of the pre-implementation situation. Results of subsequent samplings in the summers of 1997 and 1998 are considered reflective of the post-implementation condition.

Phosphorus is the most important nutrient we are investigating because when available in excess amounts in freshwater systems, it is largely responsible for causing eutrophication. Phytoplankton and higher plants will usually use as much phosphorus as is available to them to continue to grow. Thus, it is often said that because other nutrients, such as nitrogen and carbon are generally available in sufficient amounts, phosphorus is the "limiting" nutrient in freshwater systems, i.e., algae will keep producing as long as there is phosphorus available. The Cannonsville Reservoir, which drains the WBDR, is a eutrophic water body and is considered phosphorus limited for most of the year, although in 1995, at least, there was a shift to nitrogen limitation for several summer months (Effler and Bader 1998). There is evidence this shift may occur in other years as well.

Sources of phosphorus at the Robertson farm include manure, fertilizer, silage leachate, milkhouse waste, eroded soil, and organic matter (decomposing crop residue, leaves, animal detritus, etc.). Sources at the control site consist predominantly of eroded soil and organic matter. Precipitation may contain small quantities of phosphorus and larger amounts of certain forms of nitrogen.

Phosphorus exists in nature in several forms that we can define with chemical methods. TDP is the total of all forms of phosphorus dissolved in the water. SRP (nominally orthophosphate) is the soluble reactive portion of TDP and is generally considered to be that form of phosphorus immediately available for phytoplankton and higher plant uptake. PP is phosphorus associated with sediment (particles of soil and organic matter), and can be either strongly or loosely bound to these particles. When sediment enters a water body, phosphorus loosely bound to it can give up its affiliation with the sediment and enter the water column in the dissolved state if the phosphorus concentration in the water is less than on the sediment. Similarly, dissolved phosphorus can attach itself to particles and become sediment-bound when the phosphorus concentration in the water is greater than on the particles. Chemical reactions that strive to achieve equilibrium between the dissolved and particulate forms control this movement of phosphorus in water systems.

Nitrogen is also an important nutrient in eutrophication, although it is usually available in large enough amounts in freshwater systems and, thus, is less likely to limit primary production. TKN is a measure of all organic forms of nitrogen plus T-NH_3. NO_X is a measure of the inorganic (oxidized) forms of nitrogen. Both T-NH_3 and NO_X are forms of nitrogen used by phytoplankton for growth in lakes and rivers, although T-NH_3 is the preferred form. The major sources of nitrogen on farms are manure, fertilizer and organic matter. TOC is the total of all organic forms of carbon and derives from plant and animal matter, including excretory by-products (manure). TSS is a measure of soil and organic matter particles (sediment) carried in streamflow. PP is typically highly correlated with TSS.

RESULTS

Annual Runoff and Loads

The first year of pre-implementation sampling (June 1993 – May 1994) will be referred to as Pre-1, the second year (June 1994 – May 1995) as Pre-2, and the first year of post-implementation (November 1996 – October 1997) as Post-1. Annual loads and runoff for these periods at the Robertson farm and Shaw Road control site are shown in Table 1.

There was more runoff in Post-1 than in either of the two Pre years at both sites. Accordingly, loads of PP, NO_X, TKN, TOC, and TSS were highest in this year at both sites. TDP and T-NH_3 loads were also highest in Post-1 at the control site. Greater loads as a result of greater runoff is an obvious relationship – as more precipitation and snow-melt runs off the land and through the soil, more sediment and nutrients are expected to be carried with it, assuming all other factors remain essentially equal.

Table 1. Annual runoff and nutrient/sediment loads for pre-implementation period (Pre-1 and Pre-2) and first year of the post-implementation (Post-1) period.

SITE	PERIOD	RUNOFF (cm)	PP	TDP	SRP	TSS	NO_X	$T\text{-}NH_3$	TKN	TOC
			(kg)							
Farm	Pre-1	70	91.7	74.6	51.5	34825	605	168.	437.	4663
	Pre-2	53	97.8	77.9	59.6	37023	355	80.4	318.	4785
	Post-1	77	167.	43.2	21.0	71752	709	73.2	550.	5273
Control	Pre-1	60	6.76	4.50	0.833	4016	67.9	3.61	68.7	1329
	Pre-2	49	8.83	3.64	0.612	5479	43.0	4.21	81.4	1338
	Post-1	74	15.2	6.17	0.326	8381	75.7	5.34	126.9	1947

However, a number of factors changed significantly at the Robertson farm due to the installation of numerous management practices as recommended in the Whole Farm plan for the farm. Loads of pollutants are expected to decrease in amounts sufficient enough to be observable in the water quality data being collected. Annual loads of three analytes, TDP, SRP and $T\text{-}NH_3$, were, in fact, smaller in Post-1 at the farm than in either Pre-1 or Pre-2 (Table 1) despite the greater amount of runoff that occurred in Post-1. This may be an indication of the effects of management practices. It should be noted, however, that the SRP load was lowest in Post-1 at the control site as well, an indication of natural variability.

It is possible that loads of the other analytes, although greater in Post-1 than in the two Pre years, may be "less great" than they would have been if practices had not been installed. But in order to determine this and make better sense of the data, we need to examine more than just annual loads. As runoff events are exceedingly important in the delivery of nonpoint pollutants, a detailed analysis of these periods should provide a clearer understanding of what the results of Post-1 actually mean.

Nutrient/Sediment Concentrations during Event and Non-event Periods

Annual mean concentrations of analytes during event and non-event periods are shown in Table 2. An event was defined as any period of rise in streamflow due to precipitation and/or snowmelt. The event was considered to be over once either streamflow or pollutant concentrations returned to approximately pre-event levels. The annual flow-weighted mean event concentration was simply the total of all individual event loads for the year divided by the total flow volume during those events. Non-events include periods of both high and low baseflow, i.e., periods of little or no surface runoff from the watershed. The mean annual non-event concentration was the total load delivered during all non-event periods of the year divided by the total non-event flow volume.

It is apparent from Table 2 that at both sites mean concentrations for all analytes were higher during event periods than non-event periods, regardless of year. This is expected since events are dominated by surface runoff, which usually has higher concentrations of pollutants, especially particulates (e.g., TSS, PP).

Table 2. Flow-weighted mean concentrations of nutrients and sediment at the farm and control sites during event and non-event periods.

Analyte	Mean Event Concentration						Mean Non-event Concentration					
	Farm			Control			Farm			Control		
	Pre-1	Pre-2	Post-1	Pre-1	Pre-2	Post-1	Pre-1	Pre-2	Post-1	Pre-1	Pre-2	Post-1
PP[a]	152	294	304	24	60	47	33	42	26	6	10	13
TDP[a]	74	132	54	12	12	14	61	76	23	6	7	7
SRP[a]	49	99	31	2	2	1	43	59	8	1	1	<1
NO_X[a]	660	510	570	160	120	140	450	380	580	110	90	100
T-NH_3[a]	203	186	94	8	14	10	111	58	37	6	8	7
TKN[a]	510	650	700	150	260	270	300	270	280	120	170	160
TSS[b]	63.7	125.4	135.1	15.7	39.9	27.2	8.4	10.3	8.3	2.7	5.4	6.5
TOC[b]	4.9	8.8	6.4	2.9	4.7	4.5	3.6	4.4	2.9	2.2	2.6	2.3

[a]Concentrations in µg/L
[b]Concentrations in mg/L

With respect to concentration, the sites tended to respond similarly in the pre-implementation years. For example, the event and non-event concentrations in Pre-2 that were higher than in Pre-1 at the farm were also higher at the control. This indicates that the same environmental factors that influenced pollutant losses from year to year were operating similarly at both sites. Thus, when we look for evidence of BMP effect in Post-1 at the farm, we can use the control with some confidence to differentiate between changes due to natural variability and those due to BMPs.

Examining TDP first (Table 2), we see that at the control site in Post-1, the mean event concentration (14 µg/L) was slightly higher than in Pre-1 or Pre-2, a result most likely due to natural variability. The mean non-event concentration (7 µg/L) was about the same as in Pre-2 and slightly higher than in Pre-1. Based on these results, we would expect the farm mean event concentration of TDP in Post-1 to be a little higher than in Pre-1 and Pre-2, and the non-event TDP concentration to be about the same as in Pre-2, *if only natural variability influenced the farm loads in Post-1*. But, in fact, event and non-event means of TDP were each considerably *less* than in pre-implementation years. A similar effect is seen in farm SRP and T-NH_3 concentrations, which were lower for both event and non-event periods in Post-1, although some of this may be due to natural variability as SRP and T-NH_3 concentrations at the control site were slightly lower in Post-1 as well.

PP, TSS and TOC mean event concentrations at the control site in Post-1 were higher than in Pre-1 but lower than in Pre-2. At the farm, however, Post-1 PP and TSS event means were higher than in either Pre-1 or Pre-2, suggesting that some factor, other than natural variability, *increased* concentrations of these pollutants at the farm during events in Post-1. On the other hand, farm means of TOC during event and non-event periods farm followed the pattern as control means in all years, suggesting that any changes from year to year were due predominantly to natural variability.

Mean annual event concentrations of NO_X at the farm followed the same pattern as at the control site: highest in Pre-1, lowest in Pre-2 and midway between in Post-1. This pattern was repeated for non-event means at the control site, but not at the farm. At that site in Post-1, the non-event NO_X mean concentration was *higher* than concentrations in either of the two Pre years.

Event Loads

Much of the annual loading of nonpoint pollutants tends to occur during the relatively few days of the year on which runoff events occur. While some small events last only a few hours, other, larger events can continue for several days. These larger events are of greatest magnitude during spring snowmelt and fall rainy periods. The impact of runoff events on annual loading at the farm and control site can be seen in Table 3.

Table 3. Total duration of time (as days) each year during which events occurred, and percentages of annual streamflow volume and pollutant loads delivered during those days.

Site	Period	Events (days)	Volume	PP	TDP	SRP	TSS	NO_X	T-NH_3	TKN	TOC
			(%)								
Farm	Pre-1	34	41	76	45	44	84	50	55	54	49
	Pre-2	32	29	74	42	41	83	35	57	50	45
	Post-1	35	39	88	61	72	91	39	63	62	59
Control	Pre-1	30	37	68	51	46	77	45	46	42	43
	Pre-2	29	20	61	30	35	65	26	29	28	31
	Post-1	31	30	61	45	54	64	35	38	41	46

The total load delivered during events typically constituted 30 - 90% of the annual load of most analytes (Table 3). However, the amount of time events occurred was small, only about 30 - 35 days, or less than 10% of the year. The portion of annual streamflow conveyed during these events ranged between 20 - 41%. For most analytes, the percent annual load delivered during events was substantially larger than the percent annual streamflow associated with those events (for example, at the farm site in Pre-1, 41% of the annual streamflow produced 84% of the annual TSS load). This is due to the much higher concentrations of nutrients and sediment that tend to occur during events (see Table 2).

One difference between sampling years noted at the farm, but not at the control, was that a greater portion of the annual load of TDP occurred during events in Post-1 than in the Pre years (Table 3). Sixty-one percent of the annual TDP load was delivered during events in Post-1 compared to 45% and 42% in Pre-1 and Pre-2, respectively. This pattern was not evident at the control site, however, suggesting that this change was not a result of natural variability.

Event Mean Concentrations

Event mean concentrations (EMCs), the total event load divided by total event flow volume for each individual event, give an indication of the levels of pollutants carried in runoff during that event. EMCs, by season, for both sites and all periods are plotted on logarithmic scales in Figs. 2a-h. It is important to note that the logarithmic scales on these graphs indicate ten-fold differences between major tickmarks.

During small, intensive events, like thunderstorms in the summer, instream pollutant concentrations often reach very high levels at the farm as pollutants are washed off local, intensive-use sites, such as the farmstead area and farm roads, and are delivered rapidly to the monitoring point. Yet, because soils at these times are typically dry and rain is of short duration, relatively little runoff is produced and streamflow during the event may rise and fall very quickly. Summer and early fall events at the farm generally had high EMCs, as illustrated by summer TSS EMCs of 100 - 1000 mg/L (Fig. 2d). The highest farm EMCs for most of the other analytes were also observed during summer and early fall. The EMCs at the control site were higher in summer and early fall for some analytes, but for others, EMCs remained relatively constant throughout the year, or were higher during other times of the year.

Events resulting from rainy periods without snowmelt, usually later in the fall and in late spring, tended to have lower EMCs than the summer events. This is because greater stream volumes are produced and cleaner water from the forested portions of the farm watershed reaches the monitoring site and tends to dilute the concentrations in runoff from the more intensively used areas. Events involving just snowmelt (warming), usually in late winter and early spring, sometimes had lower EMCs due to cleaner water from melted snow that diluted concentrations even further. Manure spread on snow-covered fields that washes into the stream during the event and increases concentrations can offset this effect, however. Events involving rainfall and snowmelt usually produced the largest events in terms of loads and runoff volume. Depending on antecedent conditions, these events produced higher or lower EMCs. For example, a heavy snowpack may initially act like a "mulch" when rain occurs, absorbing the rain and preventing raindrop energy from dislodging soil particles, thus resulting in cleaner runoff and lower EMCs. Once this saturated snow begins to melt, though, the large volume of runoff can effectively scour and erode the landscape, producing higher EMCs.

If BMPs implemented at the Robertson farm, like the storage of manure during critical runoff and snowmelt periods, spreading of manure on more remote fields, livestock excluded from hydrologically sensitive areas, and reduction of soil-test P levels through nutrient management, are having an effect on water quality at the farm, we would expect to see EMCs begin to decline, and ideally, start to approach those at the control site. Visual examination of Figs. 2a-h show that, for the most part, Post-1 farm EMCs (blue triangles) do not appear to be much different from farm EMCs of Pre-1 (red diamonds) and Pre-2 (green squares), with a few exceptions. There does appear to be a trend toward somewhat lower EMCs for both TDP (Fig. 2b) and SRP (Fig. 2c), and possibly T-NH_3 (Fig. 2f) in the winter and spring months.

Individual Event Loads

Since events play such an important role in nonpoint losses from the landscape, loading during individual events at both sites was also examined. Earlier it was stated that an objective of the paired watershed approach was to establish relationships between the two sites in terms their hydrologic and loading responses. This will help us distinguish differences in loads due to natural variability (weather) from those due to practice implementation. Figures 3-8 show the relationships for runoff and loads of the various nutrients and sediment for individual events.

In Figs. 3a-b, runoff (expressed as streamflow) at the farm was correlated with runoff at the control site for each event during the Pre years (Fig. 3a) and Post-1 (Fig. 3b). The number of events used in each analysis (n) and the regression equation describing the farm flow in terms of control flow are shown above each graph. For the Pre years (Fig. 3a), the equation ($\text{Rob Flow}_{Pre} = 525 + 2.33 * \text{Shaw Flow}_{Pre}$) says that farm flow for a particular event can be estimated by multiplying the control site flow by 2.33 and adding 525. Also shown above each graph is the correlation coefficient (r). The closer the value of r is to +1 or −1, the stronger the relationship between the two variables. In both graphs the r values (.92 and .99) are close to 1, indicating a strong relationship between runoff at the farm and runoff at the control site during events. This supports the expectation in the paired watershed approach that the two sites would behave similarly in terms of runoff during events. The equations describing the lines for the two periods are quite similar, indicating that hydrologic response at the farm in relation to the control site did not change much after implementation of practices. For example, in the Pre years, an event that produced 10,000 m^3 of flow at the control site was expected to produce a flow at the farm of about 24,000 m^3. In Post-1, 10,000 m^3 of flow at the control corresponded to about 27,000 m^3 at the farm.

One event was excluded from the correlation of Post-1: the unusually large 11/8/96 event. This event produced a flow volume of nearly 90,000 m^3 at the farm and 52,000 m^3 at the control site, much more than any event produced during Pre-1 or Pre-2. Outliers, such as this relatively rare event, can have a extreme effect on the slope of the regression line and r value, even though they reflect only one point in the relationship. It is better, at least initially, to compare events during the Pre and Post years that occurred within the same approximate range. Since we did not have an event of the magnitude of the 11/8/96 event in the Pre years, we have excluded it from this and most of the other correlational analyses of Post-1 that will be examined.

If event loads decreased as a result of BMPs at the farm, we would expect to see the slope of the regression line in a correlational analysis of loads to decrease after implementation; that is, for a given event load at the control site we would expect a smaller corresponding load at the farm in the Post years than in the Pre years. Figures 4-11 show the results of correlational analyses for event loads of the various analytes measured.

The r values for PP load correlations (Fig. 4) and TSS load correlations (Fig. 7) were not as high as the ones for streamflow, but the relationships are still strong and statistically significant ($p<.05$). The Post-1 regression equations describing PP and TSS actually predict *larger* farm loads for a given control site load, than do the Pre years regression equations (e.g., an event TSS load of 300 kg at the control had a corresponding farm load of about 2500 kg in the

Pre years, whereas in Post-1 it was about 4500 kg). However, it should be noted that the Post-1 lines (Figs. 4b and 7b) are being "pulled upward" by the 5/19/97 and 12/1/96 events which had much higher loads than what would have been predicted by the relationship in the Pre years. Interestingly, without these two events, the lines in Figs. 4b and 7b would have plotted much lower, down near the 2/21/97 event, suggesting an effect of practices. Preliminary examination of farm records showed that substantial spreading of stored manure occurred just prior to the 5/19/97 event. This would likely explain why this event delivered a much higher than expected load compared to other Post-1 events, many of which occurred when manure was being stored and was not spread on the land. Further analysis of records will be done to try to explain the higher loads delivered during the 12/1/96 event.

Plots of TDP event loads before and after implementation (Fig. 5) appear to show a distinct difference. The 1/28/94 event was removed from the Pre analysis because it was an outlier with considerable effect on the relationship (there may have been a lab problem with some samples taken from Shaw Road during this event as concentrations of TDP were suspiciously high). With this point removed, the regression line describing the relationship between the farm and control site indicates larger farm loads of TDP during Pre years than does the line describing the relationship in Post-1. For example, we would expect a farm load of about 3400 g when the load at the control was 200 g in the Pre years, while in Post-1, the farm load would be expected to be only about 1700 g when the control load was 200 g.

The relationship between farm and control SRP loads in the Pre years (Fig. 6a) had a fairly low r value (.59) and there was a great deal of scatter around the line. This means that for a given load at the control site, the corresponding load at the farm had numerous values. For example, events producing loads of about 25 g at the control site had corresponding farm loads ranging from 340 g to nearly 3000 g. Therefore, in the Pre years, loads at the control were not as good a predictor of loads at the farm for SRP as they were for other analytes. For the Post-1 analysis (Fig. 6b), the r value was .41, even lower than for the Pre years. However, the farm load values are considerably lower than those seen in the Pre years. It is difficult to make clear sense of the SRP data because concentrations, and hence loads, of this nutrient were typically very low at the control site, even for the largest events, and were extremely low during Post-1. While it does seem as if few events produced farm loads greater than 1000 g in Post-1, compared to numerous ones which did in the Pre years, more data from successive post-implementation years is likely needed to uncover the effects of practices on this analyte. As with PP and TSS, the 12/1/96 and 5/19/97 SRP event loads plot high when compared to other events in Post-1.

The relationship for T-NH_3 in the Pre years is quite different from the one for Post-1 (Fig. 8). During the Pre years, event loads at the farm were not readily predictable by the event loads at the control site, i.e., the r value (.37) was low (though still statistically significant at $p<.05$) and, like SRP_{Pre}, there was considerable scatter around the line. For example, event loads between 0 and 50 g at the control had corresponding loads at the farm ranging from 5 g to more than 8000 g. T-NH_3 loads at the control did not vary much because, again like SRP, not much T-NH_3 was lost from this site, no matter how large the event. Whereas, at the farm in the Pre years, event losses were quite variable, no doubt related to such things as timing of manure spreading, as well as other factors. The relationship for T-NH_3 in Post-1, on the other hand, was quite strong (r = .91). While the equation for the Post-1 regression line predicts farm loads similar to those predicted by the Pre years regression line for a given control site load (e.g., an event load of 200 g at the control corresponds to a farm load of about 4000 g in both Fig. 8a and 8b), the very large farm loads (>5000 g) seen in the Pre years are absent. Additionally, if the 11/8/96 event is left in the analysis, that outlier actually "pulls down" the line, causing the Post-1 regression equation to predict lower loads than that of the Pre years. Both of these observations may provide evidence of reduction in event loads of ammonia due to practices.

The remaining analytes, NO_X, TKN, and TOC, do not show distinct downward trends in Post-1. The analysis of NO_X (Fig. 9) includes the 11/8/96 event because that point was not out of the range of loads seen in the Pre years. The lines describing NO_X (Fig. 9) and TKN (Fig. 10) in Post-1 are being "pulled up" by the 12/1/96 and 5/19/97 events, respectively. Similar to what was seen with PP (Fig. 4), these events produced greater than expected nitrogen loads at the farm site. Without those outliers, the lines may be showing a downward trend. TOC (Fig. 11) seems to be unchanged, as the equations describing the line in both Pre years and Post-1 are quite similar, but again, the 5/19/97 event pulls the line upward in Post-1.

Stream Benthic Communities

The results of benthic community sampling are summarized from Bode et al. (1998). Organisms collected during annual sampling are identified to the lowest possible level. Five indices are used to measure potential stream impairment: species richness, EPT richness, biotic index, percent model affinity, and species dominance. Communities that have little or no impact from pollutants generally exhibit higher species diversities (richness), and greater numbers of mayflies (*Ephemeroptera*), stoneflies (*Plecoptera*) and caddisflies (*Tricoptera*). The EPT species are sensitive to impacts related to animal and human wastes entering the stream, such as low dissolved oxygen and high nutrient and sediment concentrations, and, thus, are rarely found in systems where these conditions exist.

Composition of the stream communities at the two sites showed clear differences in 1996 before implementation. Dominant species at the farm site were midges and aquatic worms (Fig. 12a), organisms tolerant of conditions found at impacted sites. The control site, on the other hand, had a variety of organisms, dominated by the desirable EPT groups (Fig. 12b). Based on four of the five water quality indices, the control site in 1996 had an "excellent" water quality rating (Fig. 13) and met the biological impairment criteria for non-impacted streams. The 1996 farm stream community indices were all poorer, resulting in a water quality rating of only "fair" (Fig. 13). Particularly affected was the EPT richness (number of mayflies, stoneflies and caddisflies), which averaged only 1 species per subsample at the farm compared to 9 species per subsample at the control. Application of impact criteria indicated significant biological impairment at the farm site in 1996.

Some improvements in the macroinvertebrate community at the farm site were evident in the first year after implementation (Post-1). Aquatic worms were much less numerous and were replaced by caddisflies, although midges continued to dominate (Fig 12c). Several clean-water species appeared that were not found in 1996, including one stonefly. Both the EPT richness index and the biotic index in 1997 improved substantially compared to 1996, and the water quality rating increased from "fair" to the low end of "good" (Fig. 13). The control site remained essentially unchanged (Fig. 12d and Fig.13).

Results of sampling in the second year after implementation (Post-2), showed even more improvement at the farm site. Caddisflies and mayflies comprised a much greater portion of the community (Fig. 12e), while midges and worms species decreased to about the same levels as at the control site (Fig. 12f). Stoneflies, the least tolerant of the three desirable groups to low dissolved oxygen, was still present in only very small numbers at the farm, however. Species richness and EPT richness continued to improve in 1998 resulting in a water quality rating of "very good" (Fig. 13).

DISCUSSION

Based on the results of chemical sampling in Post-1, there are indications that, unrelated to natural variation, nonpoint losses of some nutrients have changed at the farm when compared to the pre-implementation years. It is difficult to know how these differences should be interpreted based on only the first year of post-implementation sampling. We need to see if the patterns continue in the next few years. Some tentative explanations for the changes seen in Post-1 are offered, however.

Event loads and concentrations of PP and TSS seemed to be somewhat higher in Post-1 than in the Pre years. One possible explanation for this is the fact that some BMP work had continued almost until the time monitoring began in November 1996. Areas that had been recently disturbed, such as sections of the streambank and around the manure storage pit, had not had time to revegetate completely before cold weather set in. These disturbed areas may have produced higher than usual losses of sediment and associated PP during events, thereby increasing levels seen in Post-1. This effect should be absent, however, in succeeding years of monitoring if this, in fact, was the cause since these areas are now completely revegetated.

Based on the results of correlational analyses, certain events produced higher than expected loads of some analytes. Farms records show that considerable manure spreading occurred just prior to the 5/19/97 event. Further examination of records may show that something occurred, such as recent fall plowing, to explain the high loads of the 12/1/96 event. It should be noted that if spreading of manure from the storage pit or fall plowing does explain the higher-than-expected loads, these practices would still reflect the normal operation of the farm in Post-1 and could continue to be a source of pollutant losses in the future.

There is some evidence that losses of TDP, SRP and T-NH_3 may have been reduced in Post-1 as a result of BMPs, specifically the storage of manure during runoff periods in fall, winter and spring. The total loads of these analytes in Post-1 were smaller (Table 1), annual event means were less (Table 2), the EMCs for individual events often appeared to be somewhat lower (Figs. 2b and 2c), and the correlational analyses for individual event loads (Figs. 5, 6 and 8) suggest a downward trend in Post-1.

There is evidence of reduction of TDP and SRP during non-event periods as well. Non-event mean concentrations (Table 2) were lower in Post-1 than in either of the Pre years. Additionally, a greater percentage of the annual load of each of these analytes was delivered during events than in the two Pre years (Table 3). Both of these effects may be related to one of the BMPs implemented: the removal of the milkhouse waste discharge to the stream. During low flow periods in Pre-1 and Pre-2, instream TDP concentrations were often quite high due to the milkhouse waste which acted, essentially, like a point source discharge. This relatively constant (non-event related) source appeared to account for a significant portion of the annual TDP and SRP loads during pre-implementation years. With the removal of the milkhouse discharge, it is possible that proportionally more of the TDP and SRP that was loaded during Post-1 was accounted for by events than in Pre years.

Interestingly, there was a considerable increase observed in mean NO_X concentration during non-event periods in Post-1 (Table 2) at the farm, but no corresponding increase at the control site. This may be a reflection of the tile drainage installed at the farm as part of Whole Farm practices. NO_X leached from the soil and delivered in subsurface runoff to the stream during periods of high or medium baseflow that usually follows events (but in this analysis is not considered part of the event), would be expected to increase with the addition of subsurface tile drainage.

Finally, the steady improvement of the benthic community in the farm stream indicates that there has likely been a reduction or elimination of the chronic impact to the organisms from high nutrient and sediment levels. But while the overall biological health of the stream may have improved at the farm, and loads of some pollutants seemed to have been reduced, overall levels of nutrients and sediments at the end of Post-1 were still well above those at the control site.

CONCLUSIONS

The results of one year of post-implementation monitoring do not provide enough information to make conclusions about the success or failure of WFP, in terms of water quality improvement, on the Robertson farm. Analysis of the chemical data from Post-2 (November 1997 - October 1998) and Post-3 (November 1998 - October 1999) will help us determine if some analytes, such as TDP and T-NH_3, continue to show a decreasing trend, and whether other analytes, such as PP and TSS, begin to show a reduction. Results from the benthic sampling are encouraging, but must be interpreted with caution. The chronic impacts to macroinvertebrates may have been largely removed, allowing an improvement in community health, but nutrient and sediment losses from the farm watershed were still relatively high in Post-1. The next technical report will include results from Post-2, an analysis of on-farm management changes, and the effects these changes appear to be having on water quality on the Robertson farm.

REFERENCES

Bode, R.W., M.A. Novak and L.E. Abele. 1998. Biological effects of farm runoff in a small stream and subsequent improvements following implementation of best management practices. Biomonitoring Unit of the NYS Dept. of Env. Conserv., Albany, NY.

Effler, S.W., and A.P. Bader. 1998. A limnological analysis of Cannonsville Reservoir, NY. Lake and Reservoir Management 14(2-3):125-139.

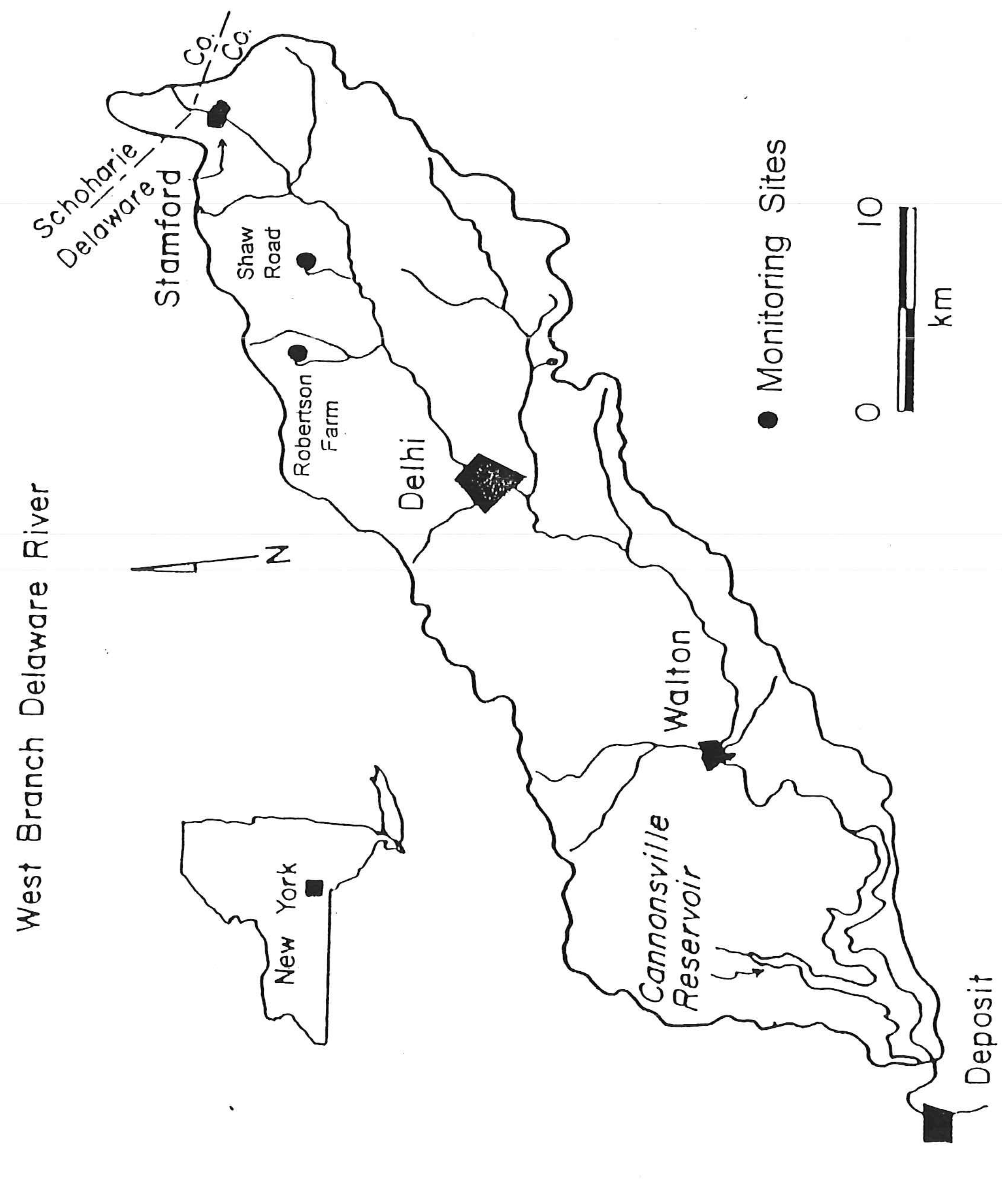


Figure 1. Location of monitoring sites in the West Branch of the Delaware River watershed.

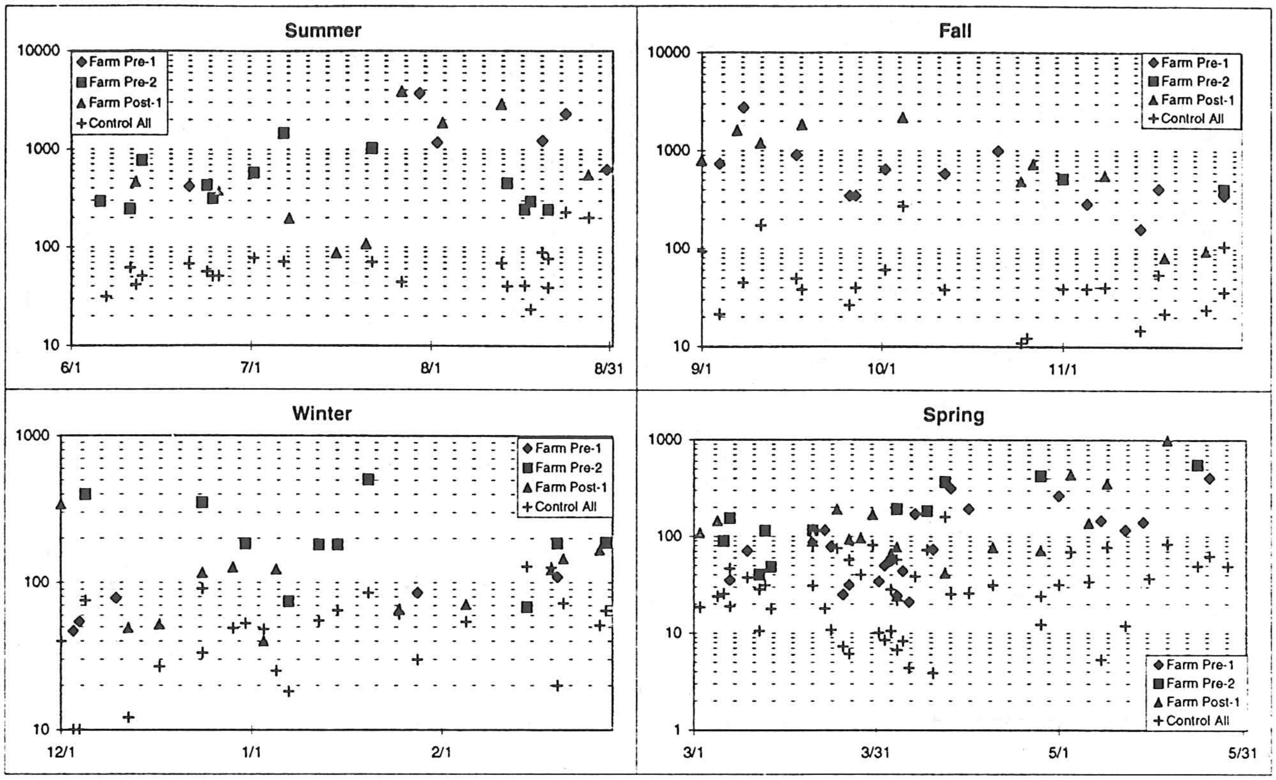


Figure 2a. PP EMCs (mg/L) plotted seasonally by month.

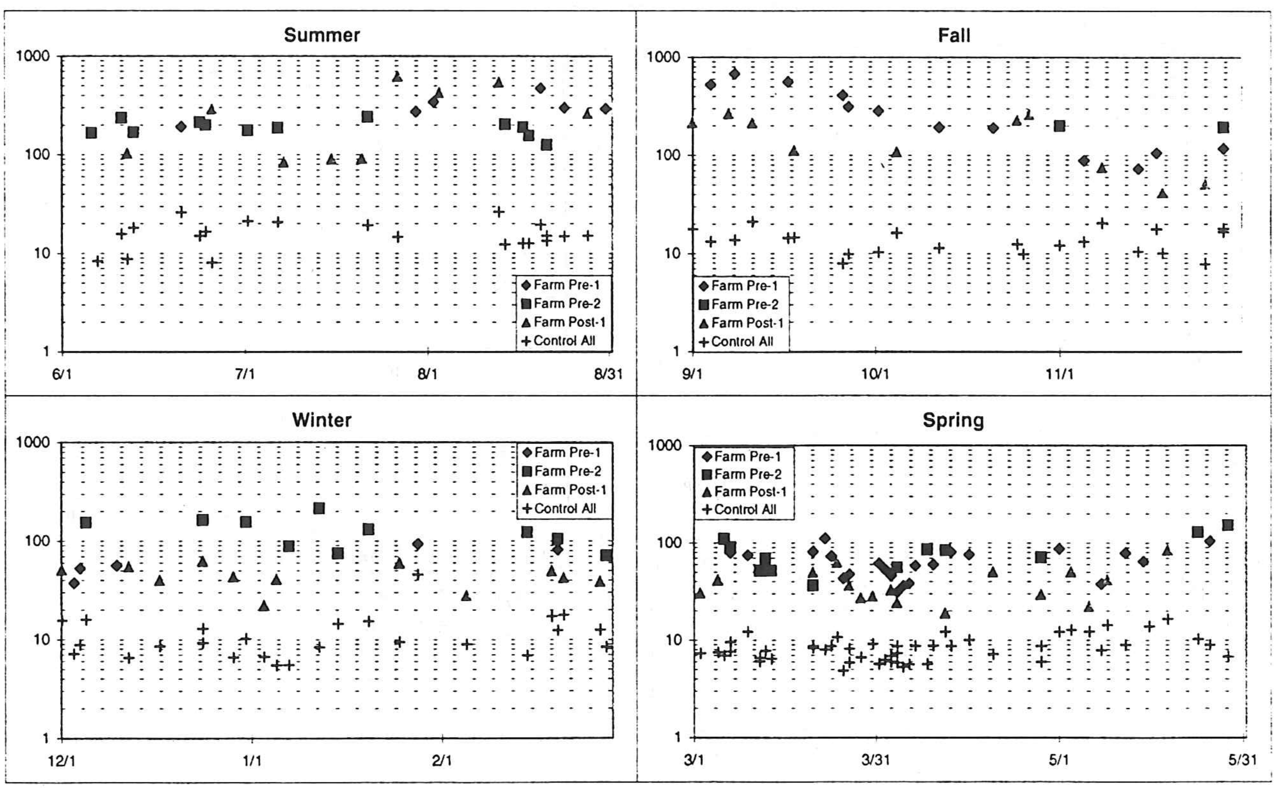


Figure 2b. TDP EMCs (mg/L) plotted seasonally by month.

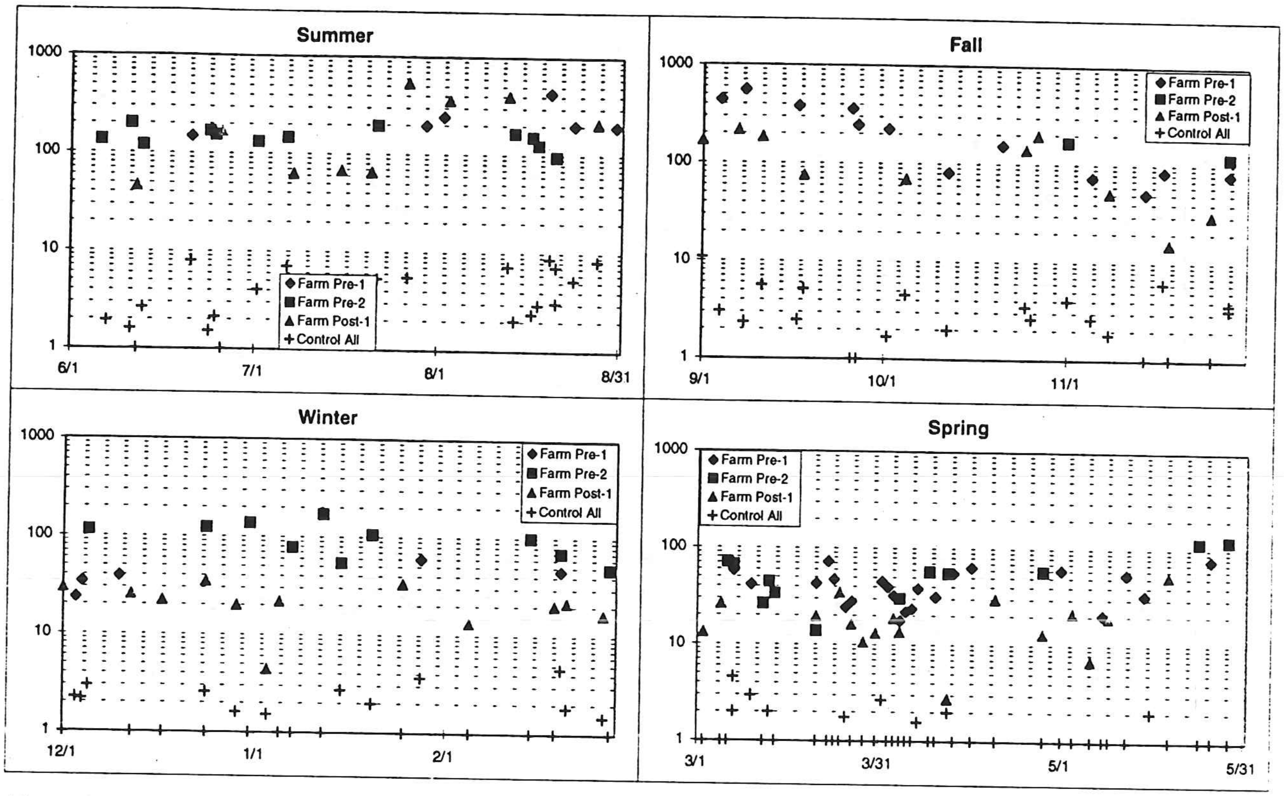


Figure 2c. SRP EMCs (mg/L) plotted seasonally by month.

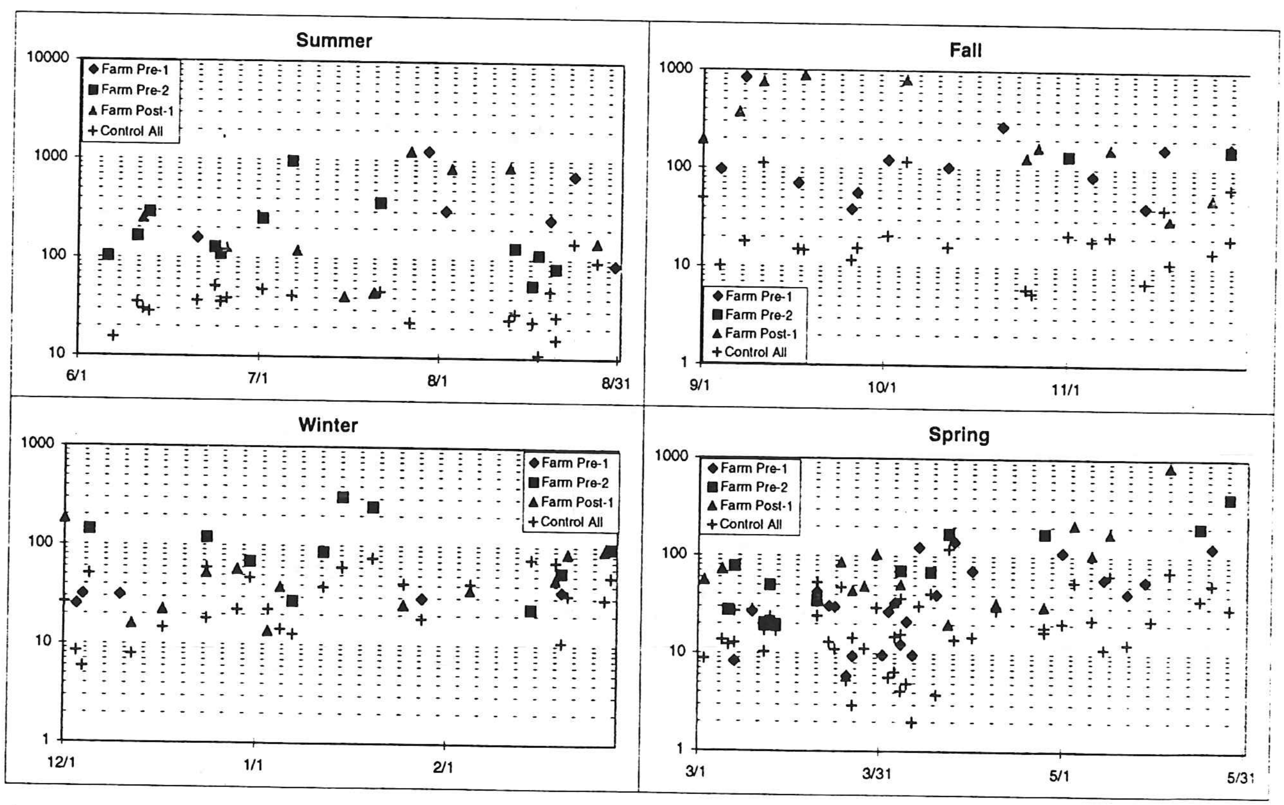


Figure 2d. TSS EMCs (mg/L) plotted seasonally by month.

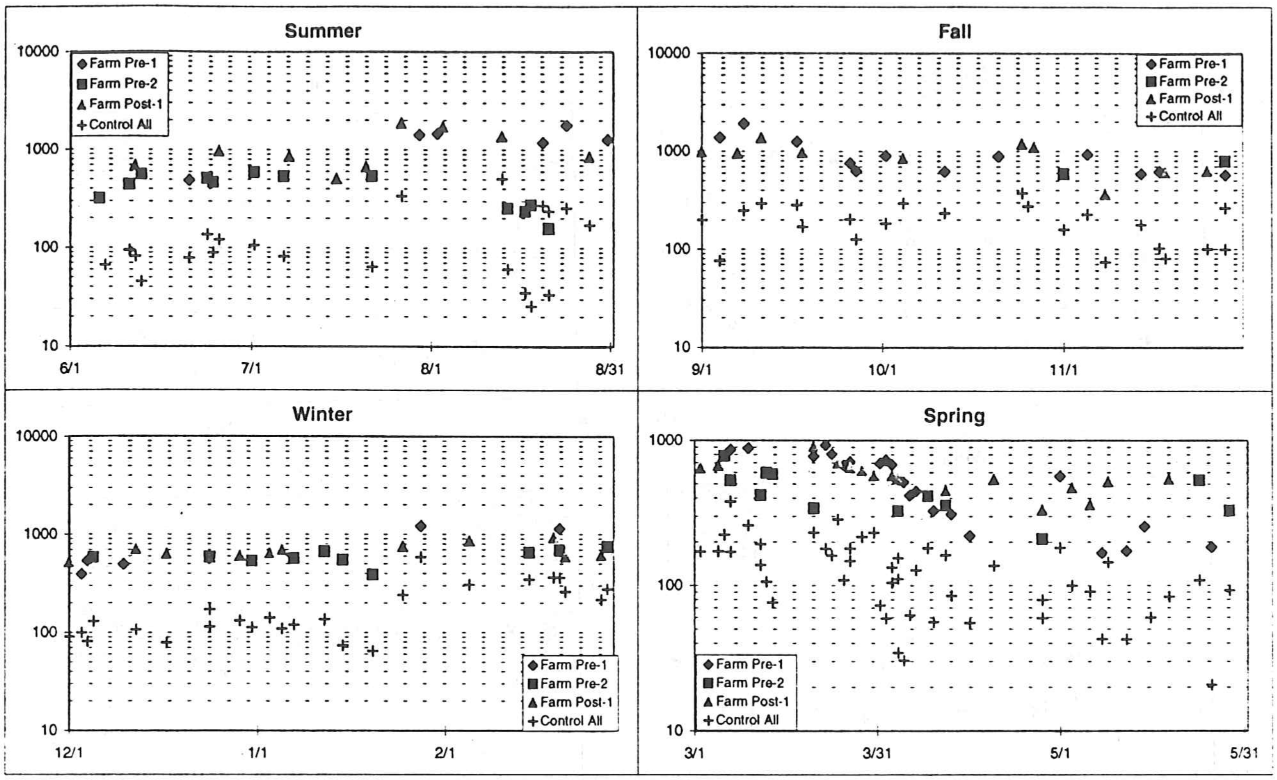


Figure 2e. NO_X EMCs (mg/L) plotted seasonally by month.

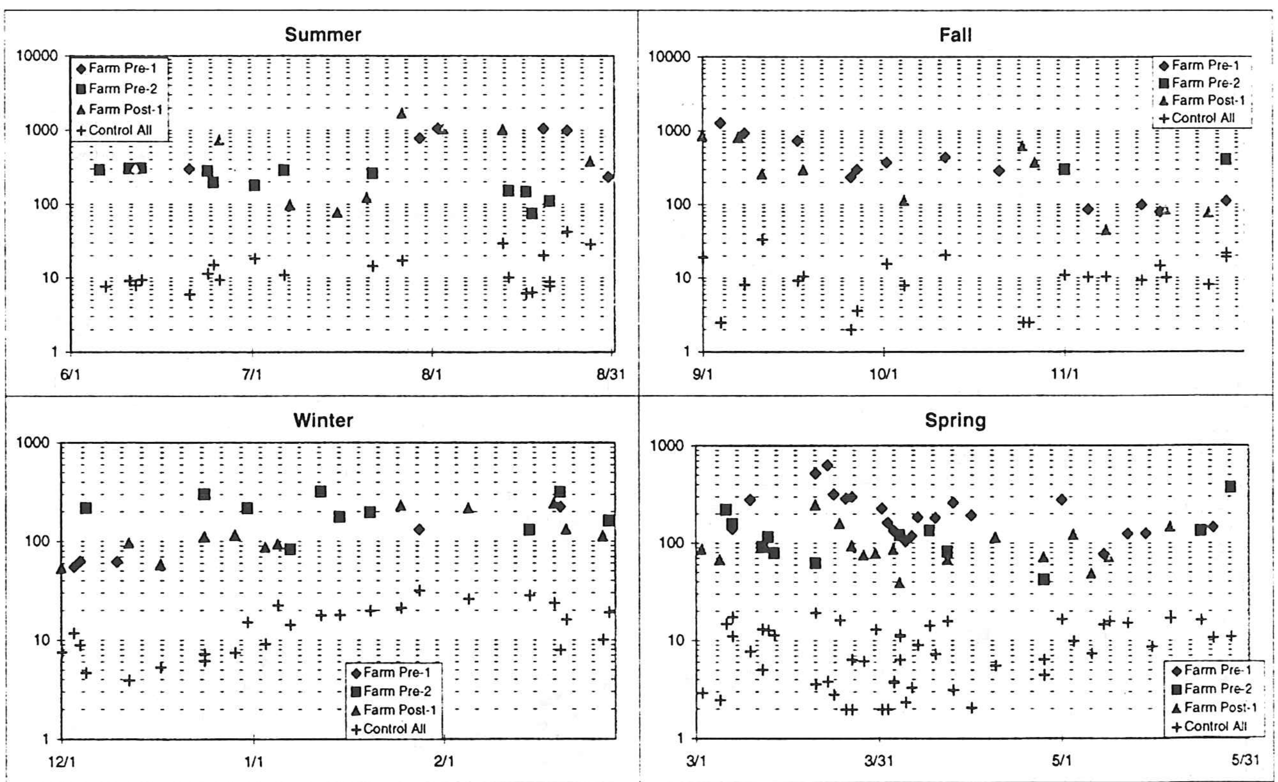


Figure 2f. T-NH_3 EMCs (mg/L) plotted seasonally by month.

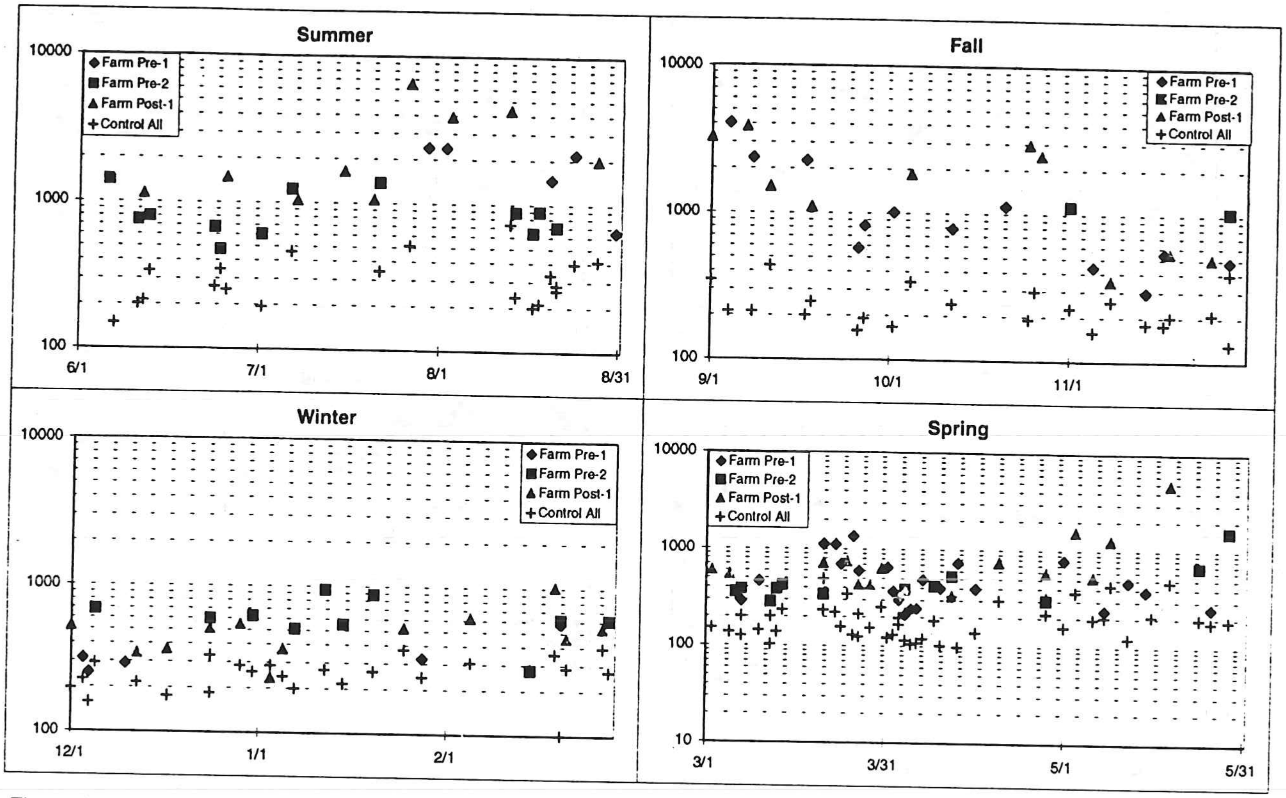


Figure 2g. TKN EMCs (mg/L) plotted seasonally by month.

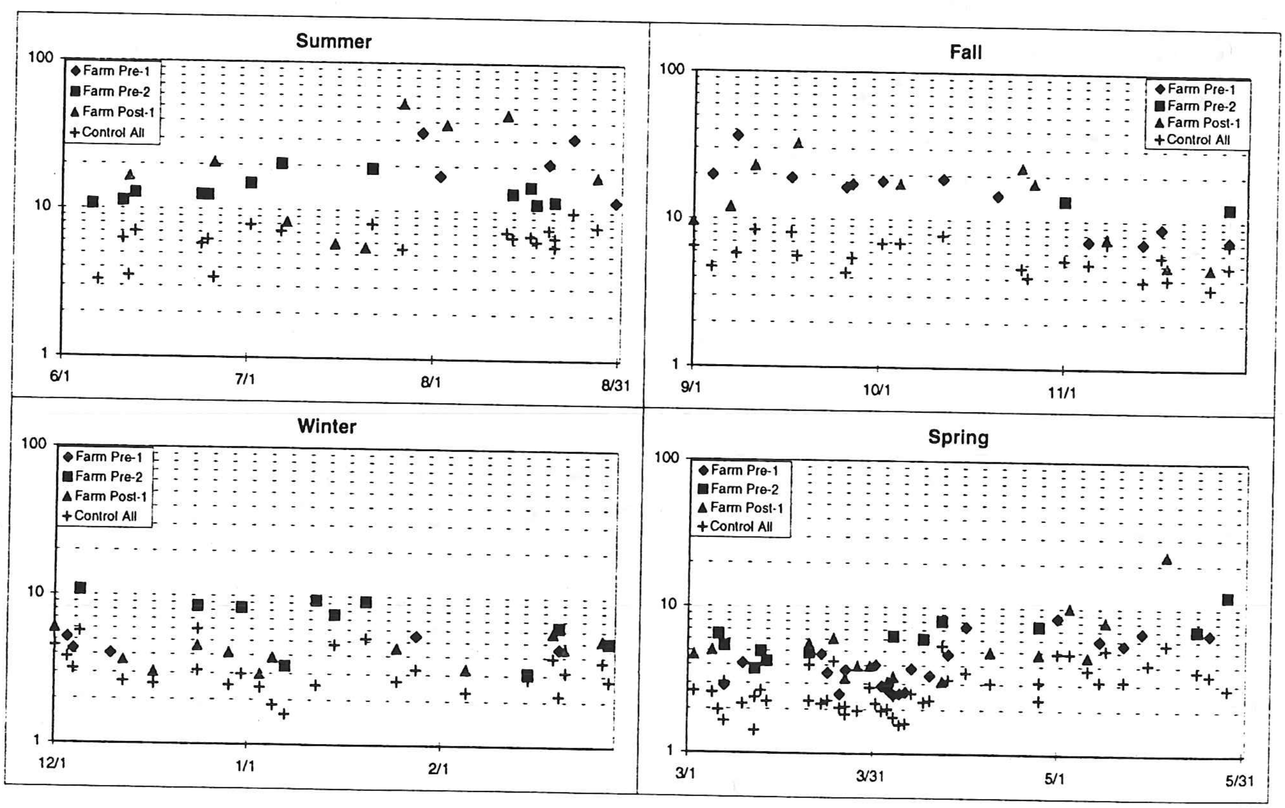
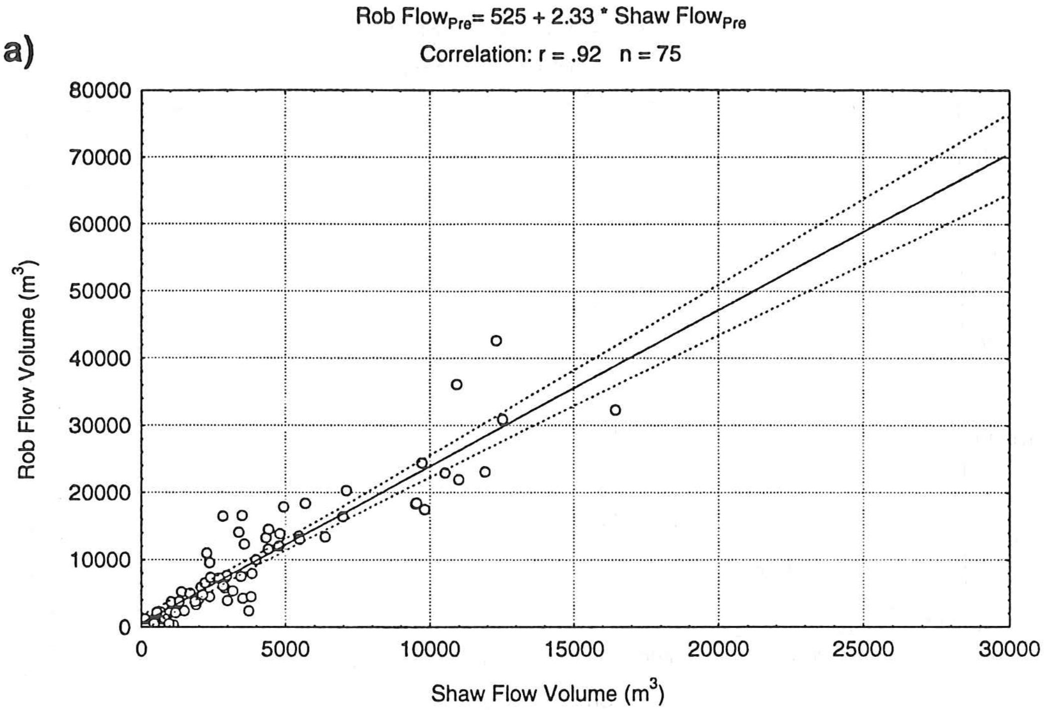


Figure 2h. TOC EMCs (mg/L) plotted seasonally by month.

a)



b)

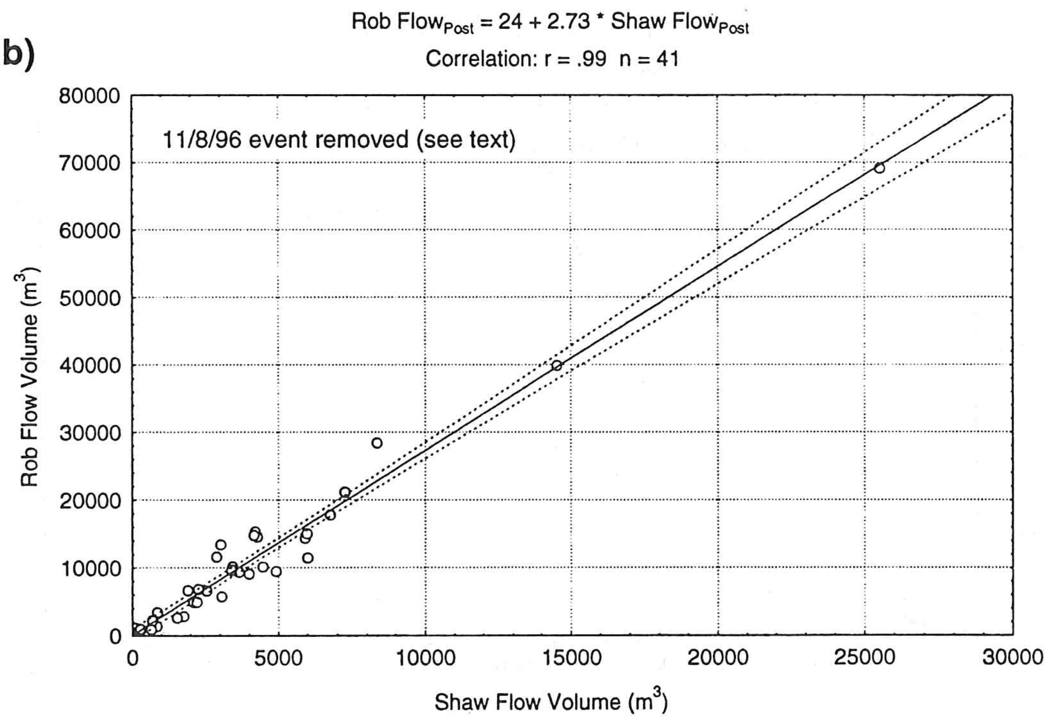
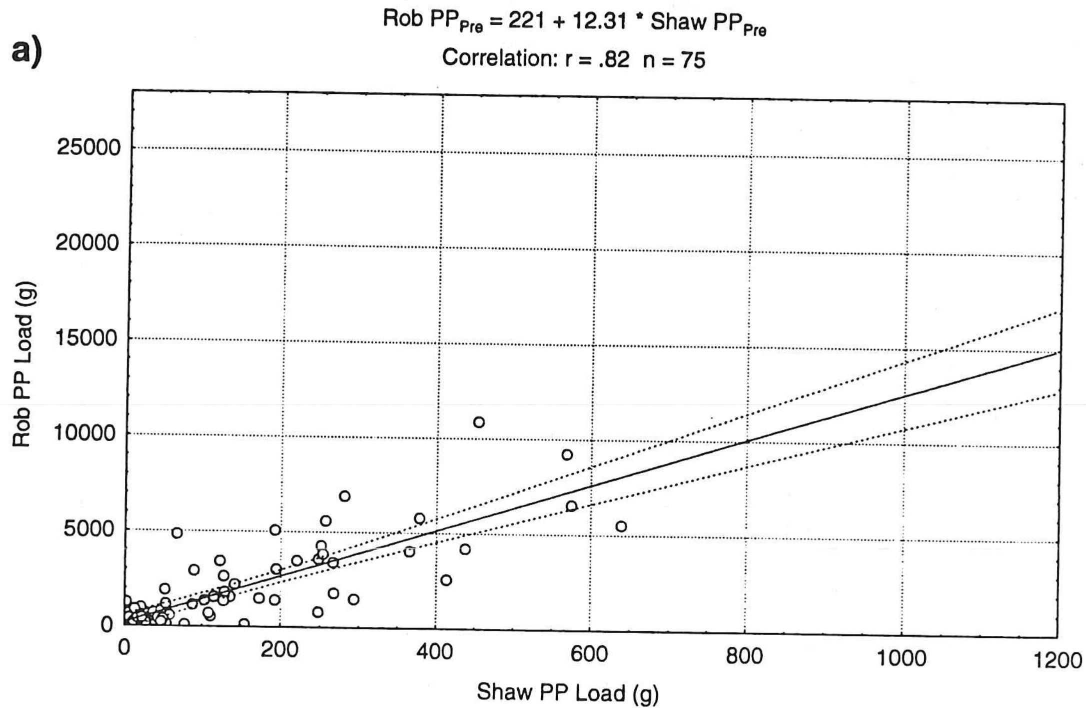


Figure 3. Relationship of event runoff (measured as streamflow) at the farm to runoff at the control site for a) Pre years, and b) Post-1.

a)



b)

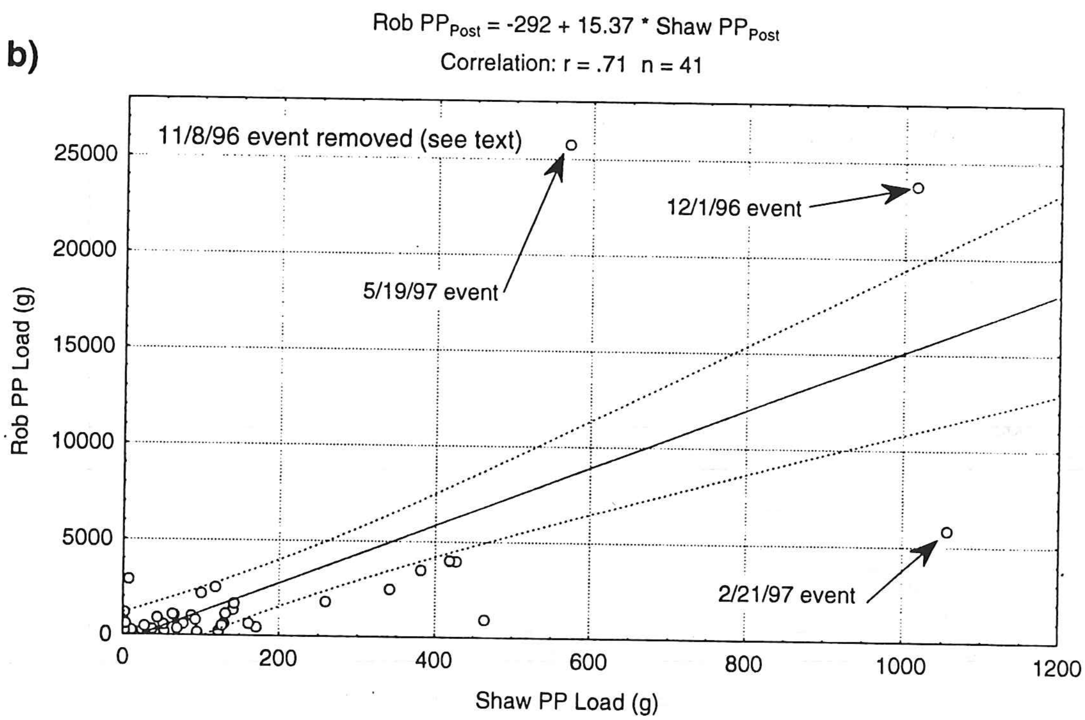


Figure 4. Relationship of particulate phosphorus (PP) event loads at the farm to PP loads at the control site for a) Pre years, and b) Post-1.

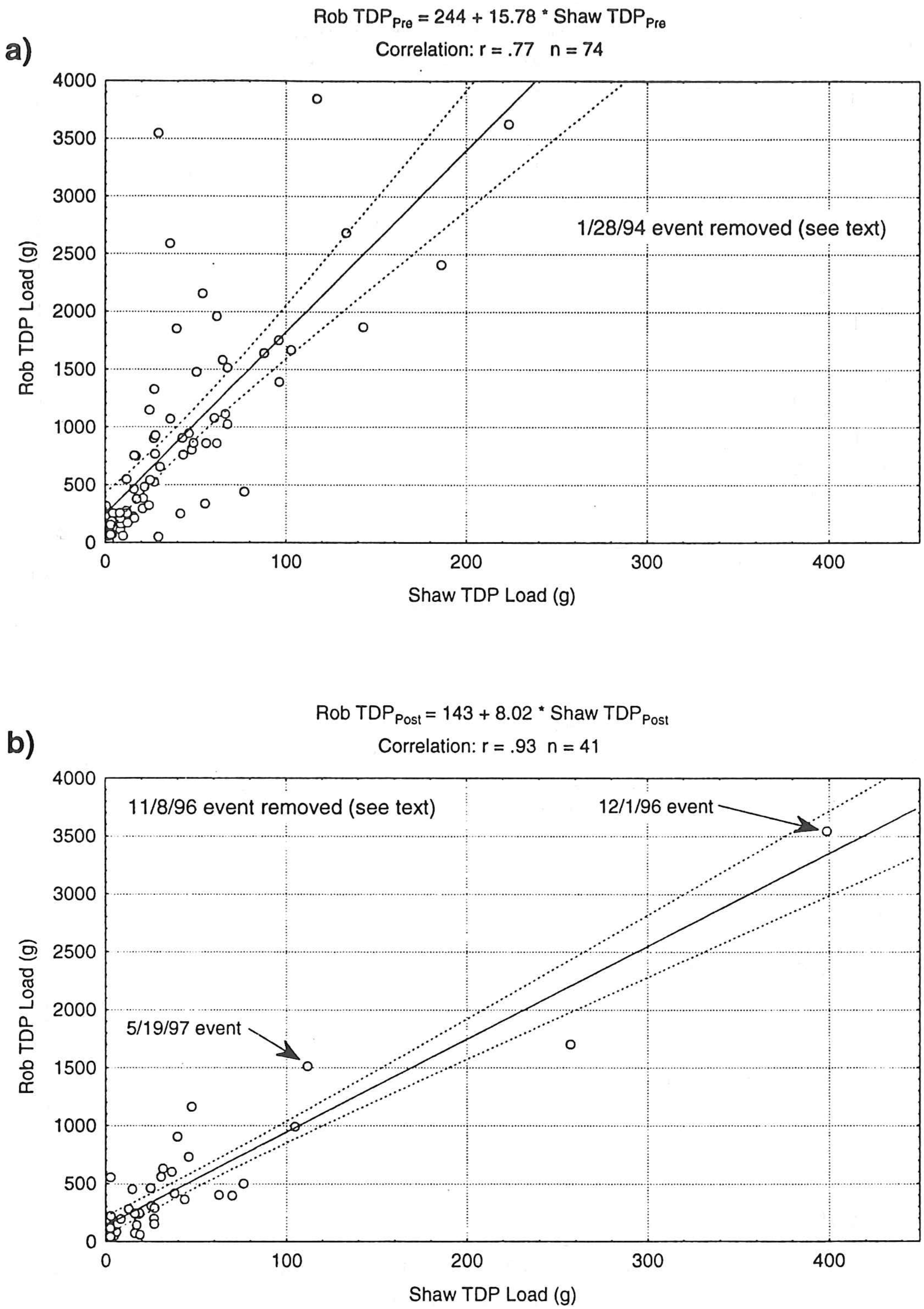
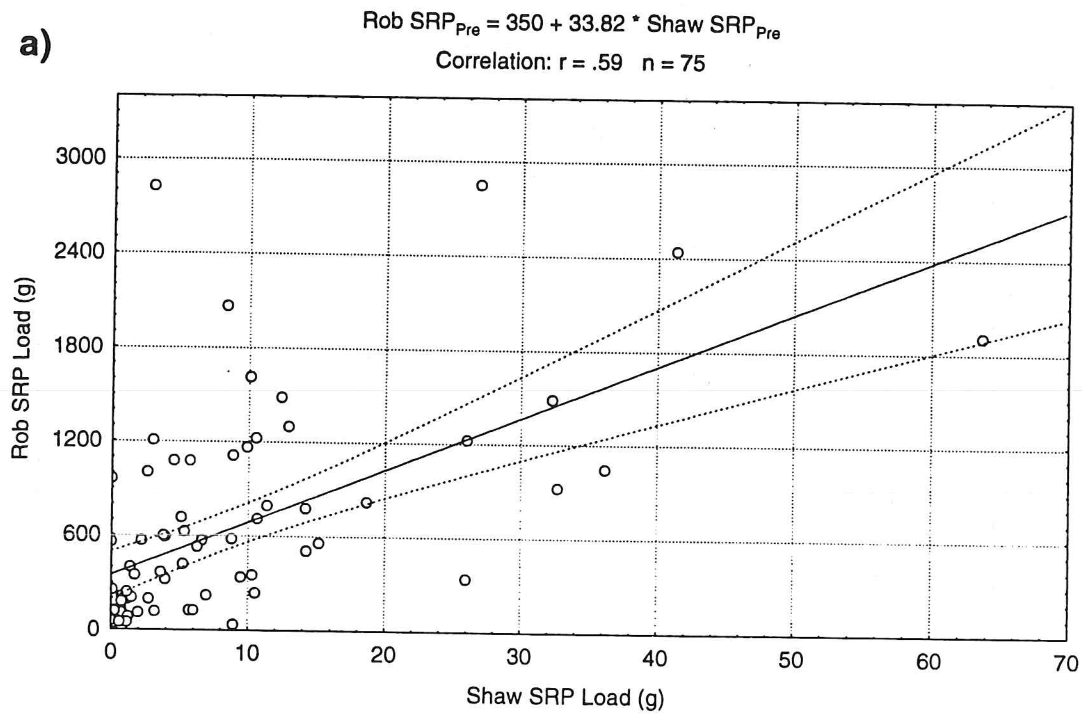


Figure 5. Relationship of total dissolved phosphorus (TDP) event loads at the farm to TDP loads at the control site for a) Pre years, and b) Post-1.

a)



b)

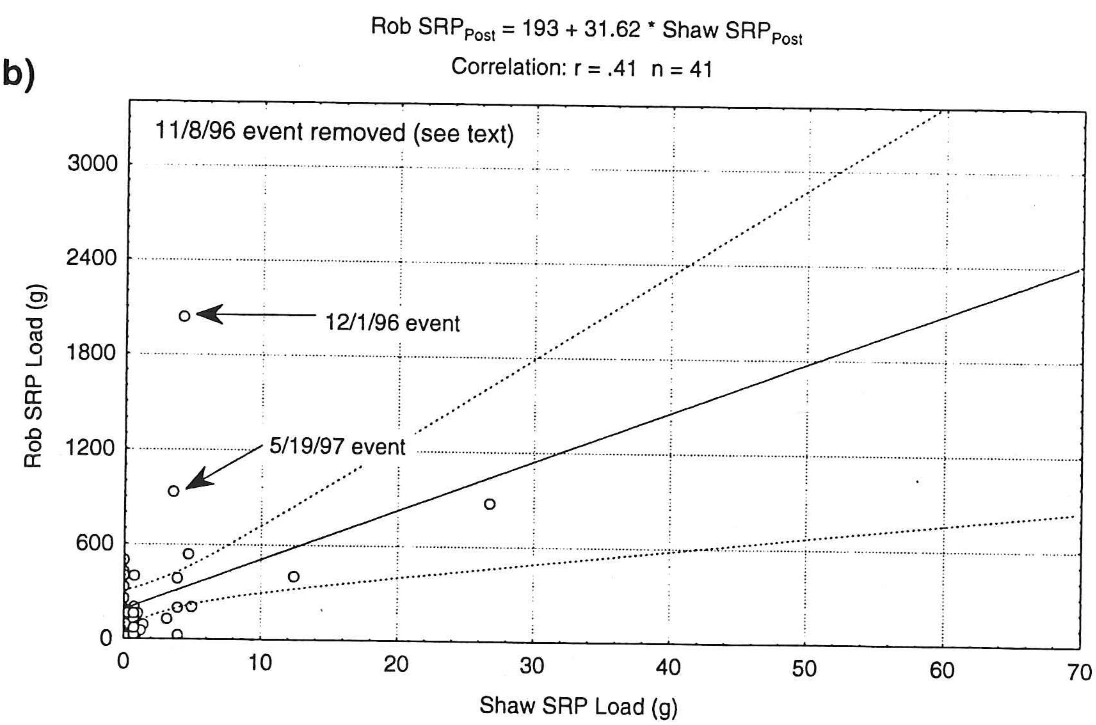


Figure 6. Relationship of soluble reactive phosphorus (SRP) event loads at the farm to SRP loads at the control site for a) Pre years, and b) Post-1.

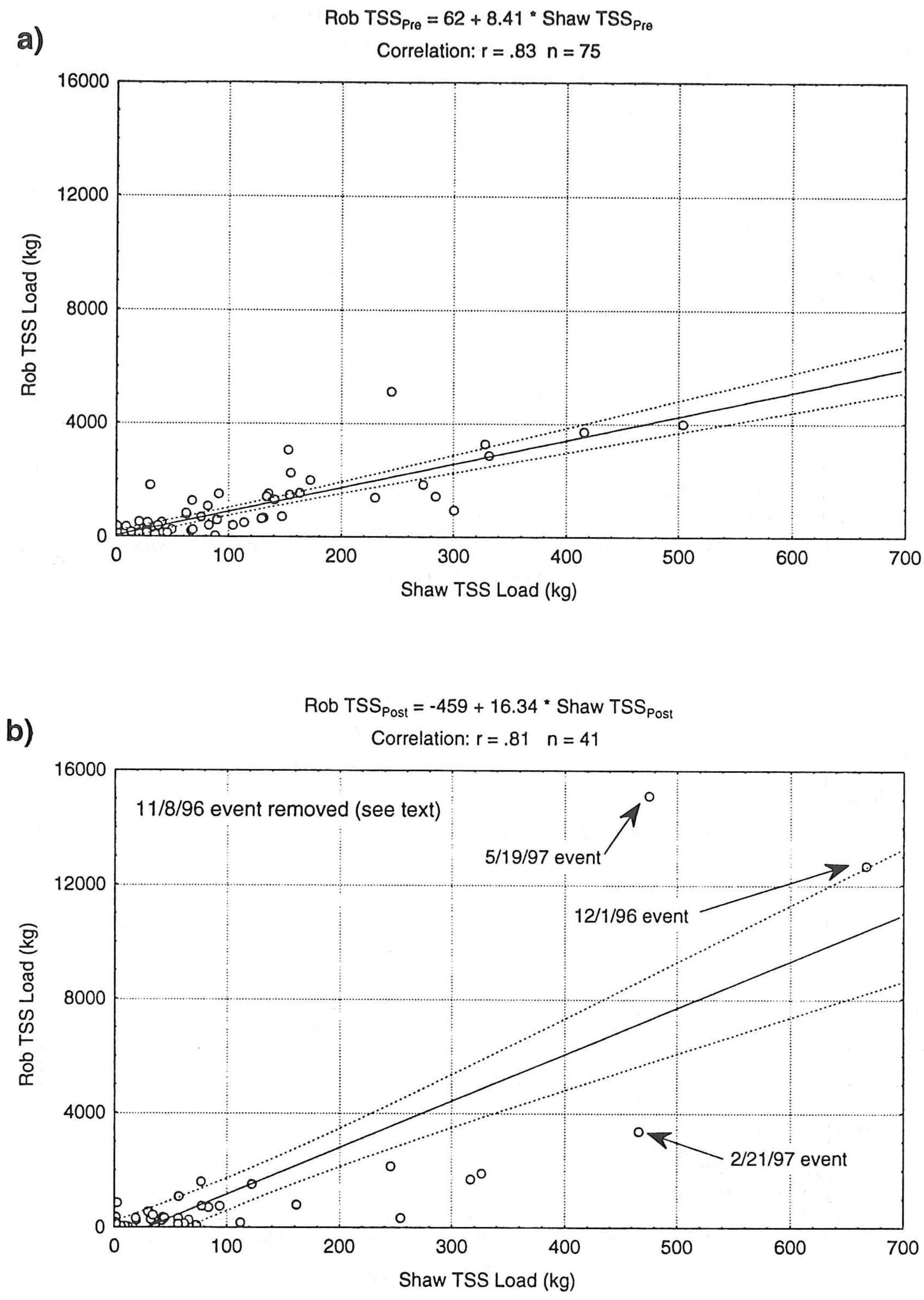
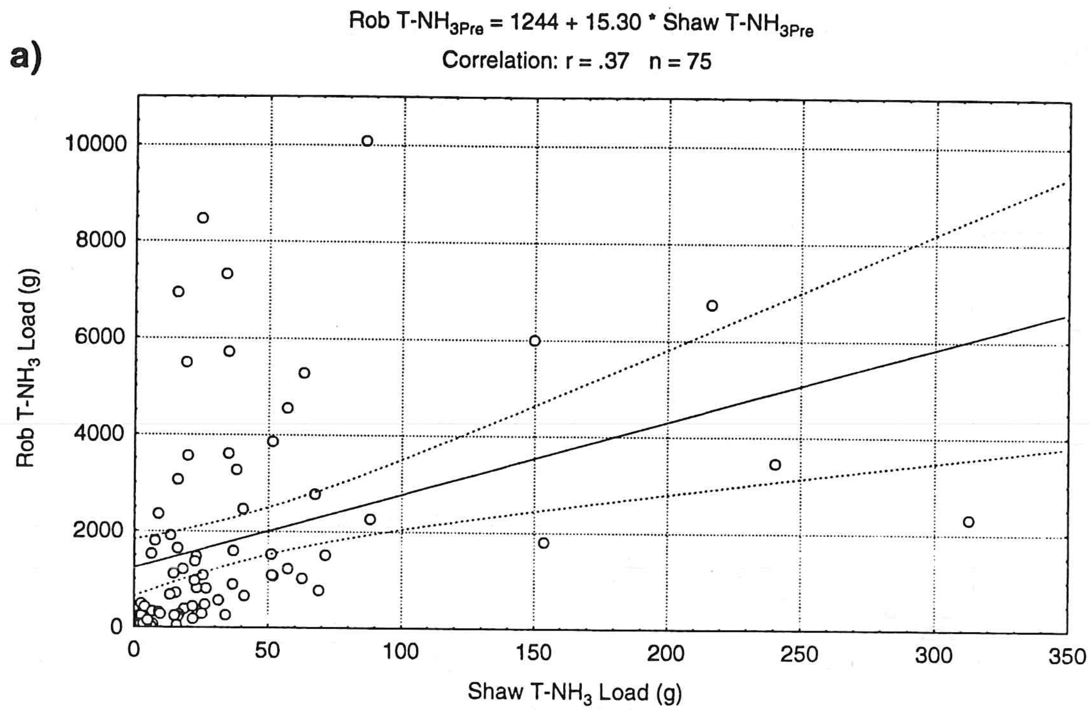


Figure 7. Relationship of total suspended solids (TSS) event loads at the farm to TSS events at the control site for a) Pre years, and b) Post-1.

a)



b)

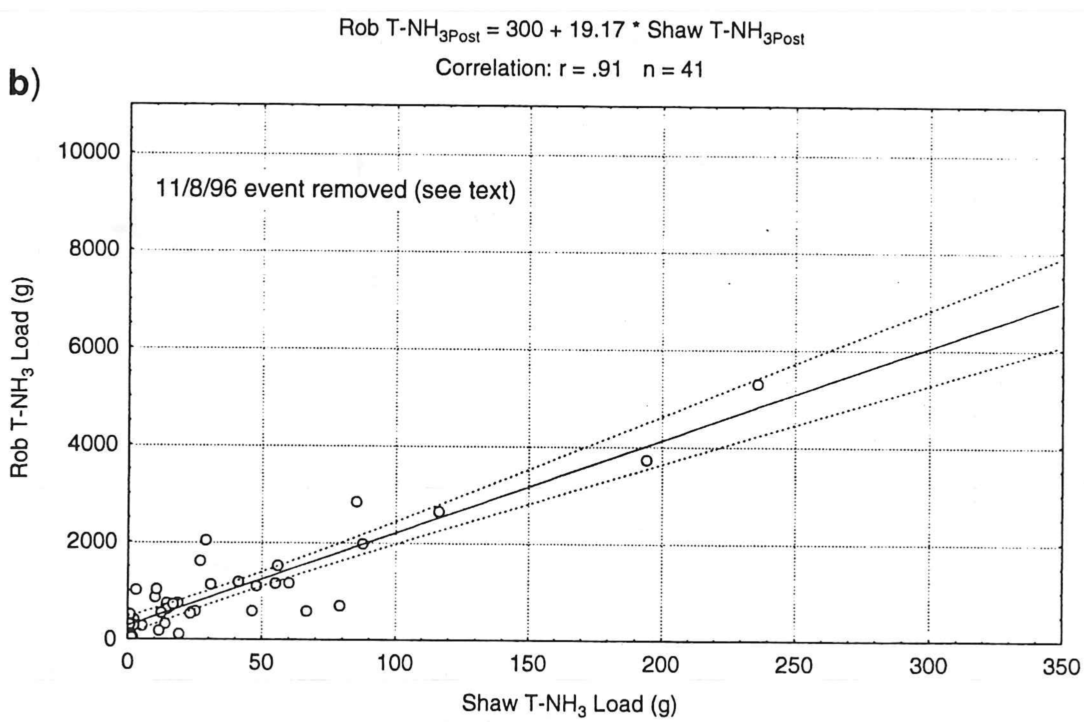
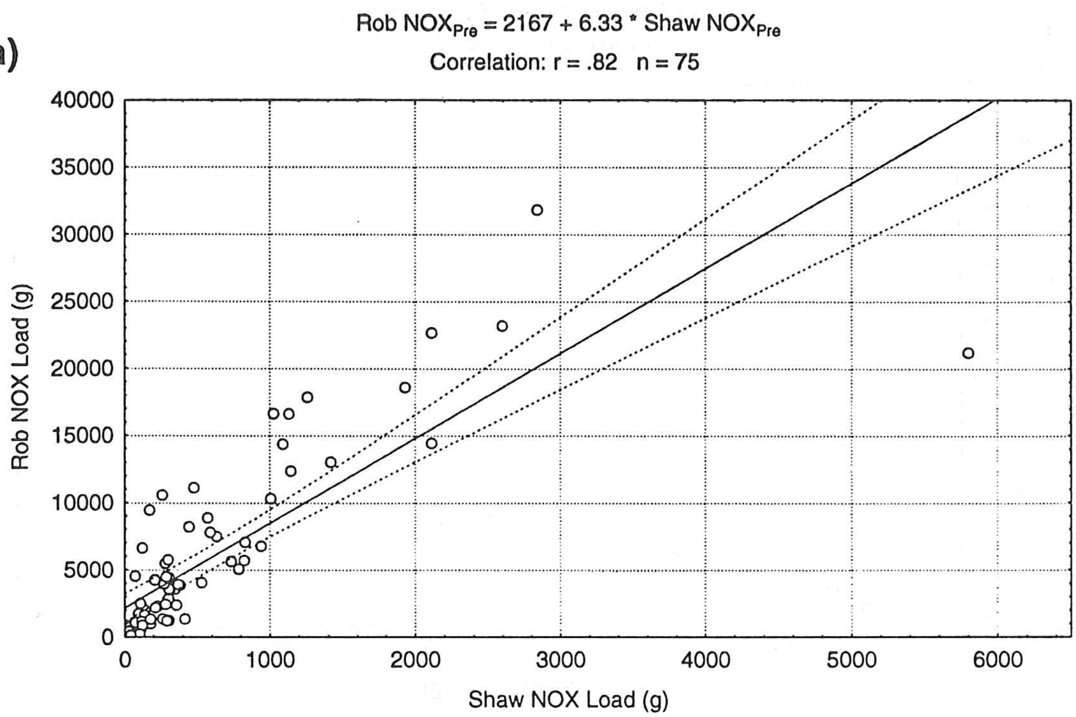


Figure 8. Relationship of total ammonia ($T\text{-}NH_3$) event loads at the farm to $T\text{-}NH_3$ loads at the control site for a) Pre years, and b) Post-1.

a)



b)

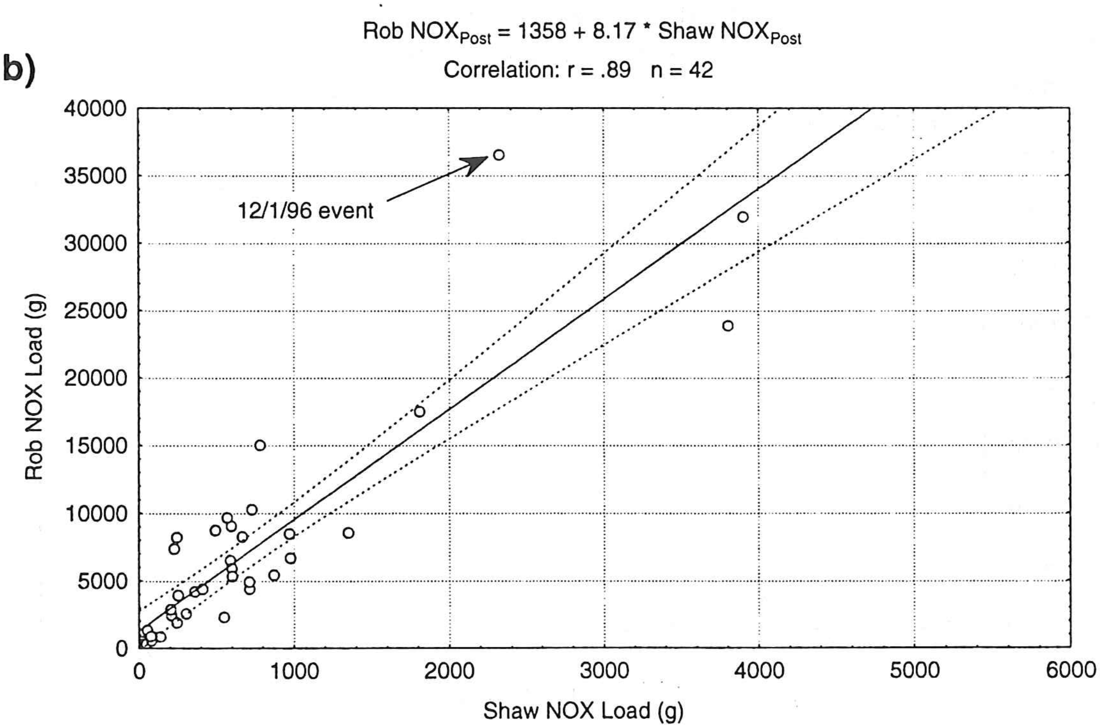
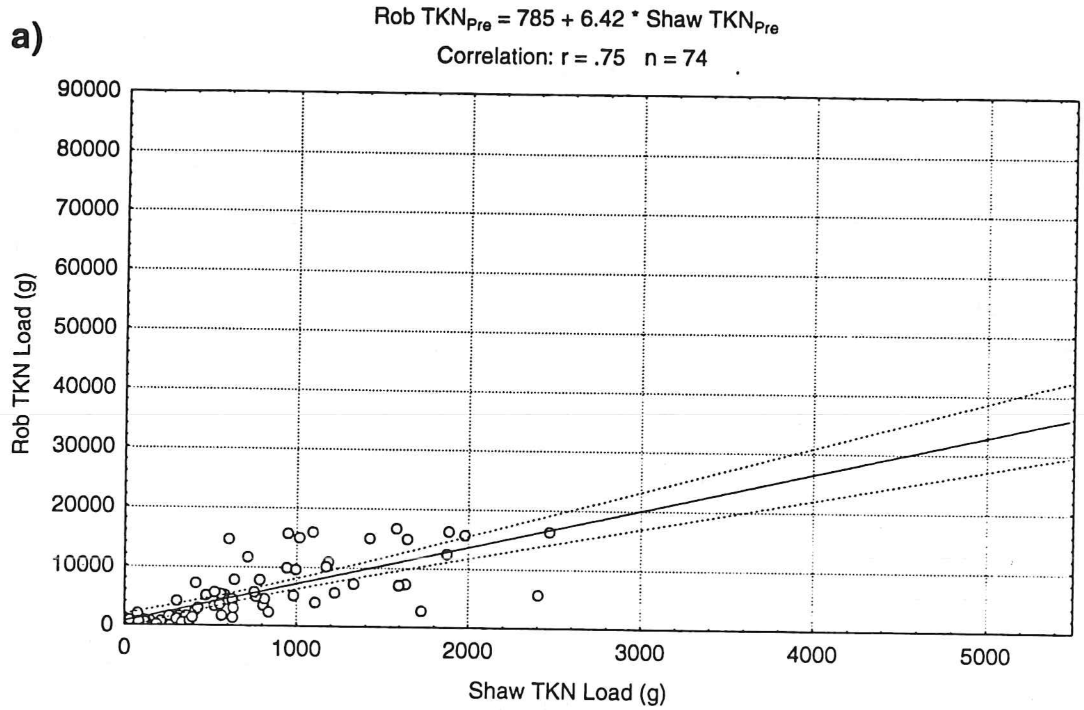


Figure 9. Relationship of nitrate + nitrite (NOX) event loads at the farm to NOX loads at the control site for a) Pre years, and b) Post-1.



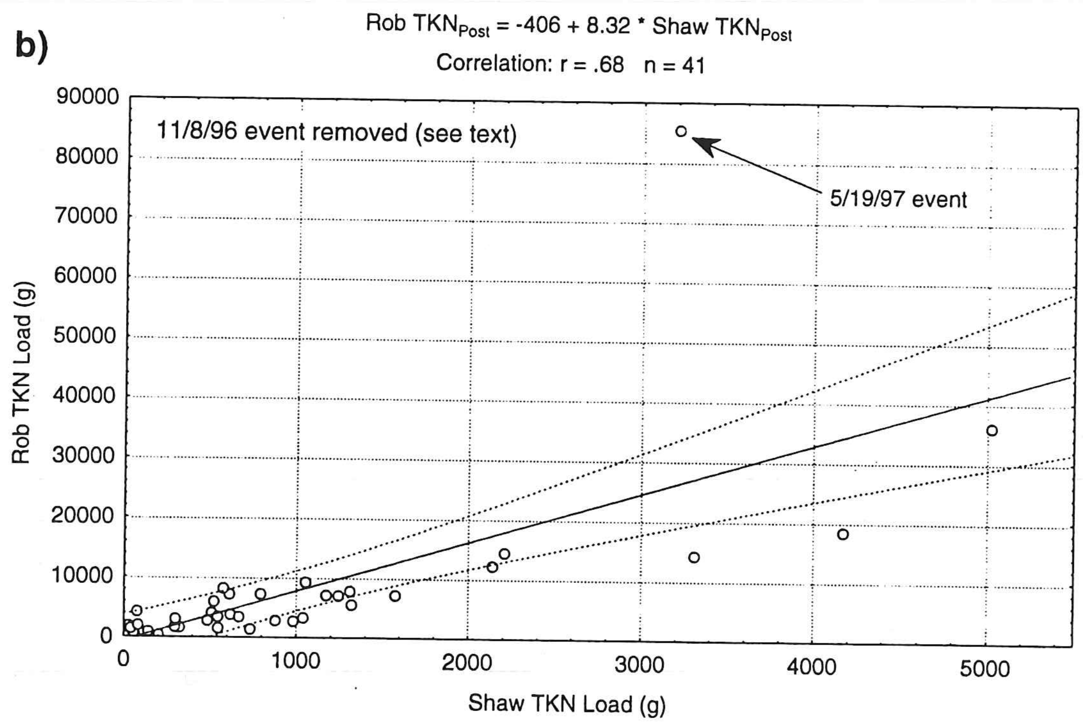
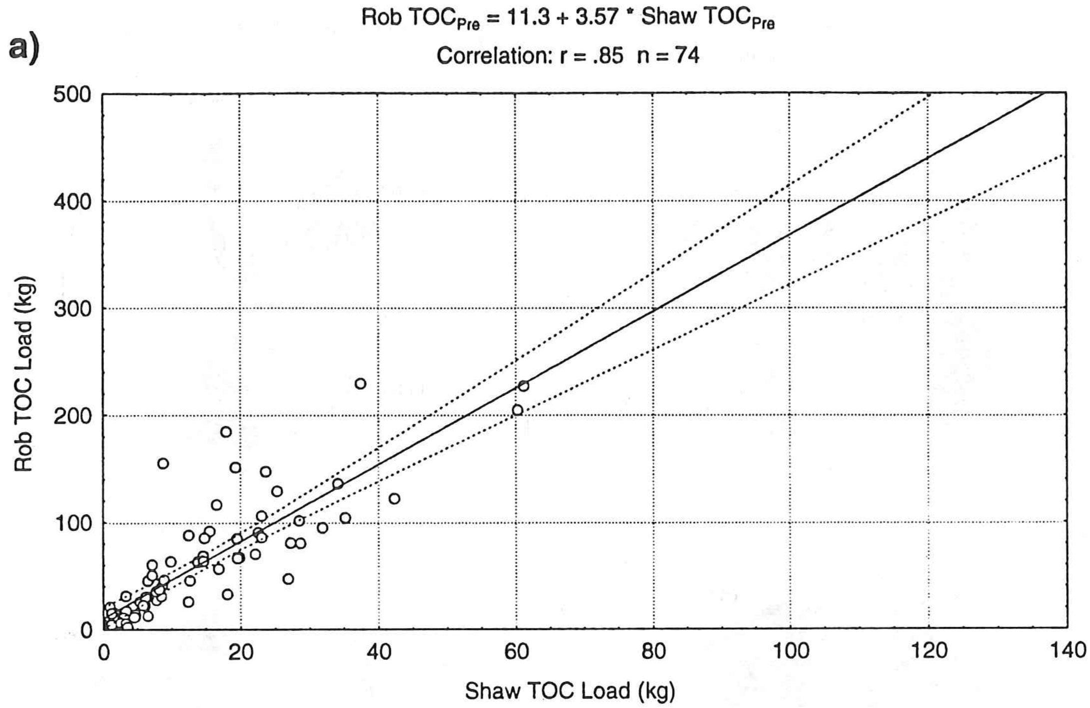


Figure 10. Relationship of total Kjeldahl nitrogen (TKN) event loads at the farm to TKN loads at the control site for a) Pre years, and b) Post-1.

a)



b)

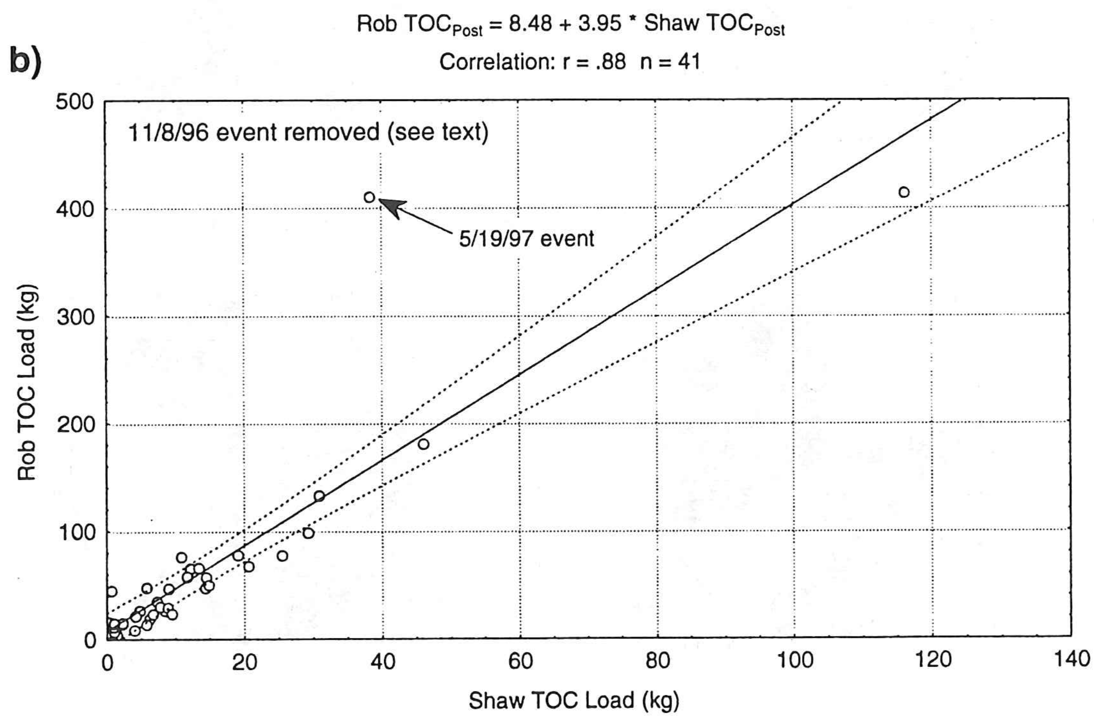


Figure 11. Relationship of total organic carbon (TOC) event loads at the farm to TOC loads at the control site for a) Pre years, and b) Post-1.

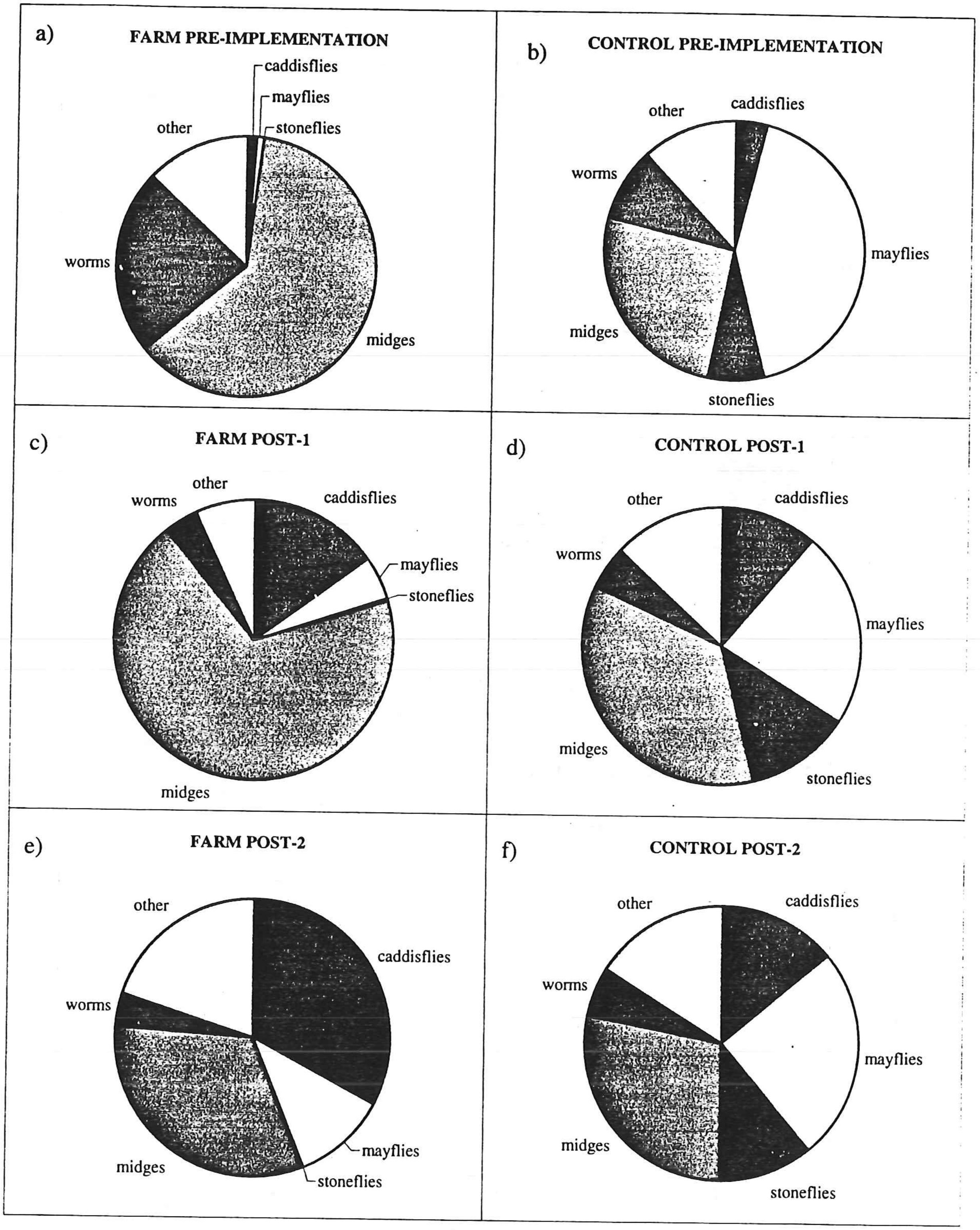


Figure 12. Benthic community composition at farm and control sites in 1996 (a,b), 1997 (c,d) and 1998 (e,f).

Figure 13. Summary of water quality indices from the control and farm sites in 1996, 1997 and 1998.

C. Summary of Responses to the In Person Farmer Interviews

1. Does your Whole Farm Plan adequately address the potential water quality issues on your farm?
   Yes = 17
   Yes except gravel buildup in streambank not addressed.
   Yes needs revision (sold cows)
   No = 2
   Fuel storage inadequate
   Has no plan yet

2. Do you agree with how water quality issues were identified on your farm?
   Yes = 17
   yes. Question priorities
   yes. Also concerned about acid rain
   no. other issues more important
   not sure = 2

3. a. Were the right Best Management Practices chosen for your farm? (And are these BMPs still suitable to your plan?)
   yes = 17
   no = 1
   don't know yet
   took a long time – 2 years
   plan is working for at least 5 yrs
   may have to change barnyard. Cattle guards don't work
   n/a = 2

   b. Do you have a copy of your nutrient management plan? If yes, do you understand it? Is it Practical? When was it last updated?
   No = 6
   Yes = 13
   It has not been updated. Plan in effect for 3 yrs
   Some questions on where spreading allowed
   Soil sampled in 1998
   Updated Spring 1999.
   Not practical. Updated 4/99
   Don't remember seeing it. Soil tested. Planners have been back periodically
   Practical, updated 9/99
   Yes. Never changes
   Farmer thinks it is not needed.
   Updated 1997
   Updated 5 years ago
   Updated in 1998

Planner dropped it off but never explained how to use it, so we don't use it
Just received one
Never updated

4. Are the farm profitability issues adequately addressed in your Whole Farm Plan?

Yes = 11
No = 3
Not sure. Increased operating and maintenance costs
Yes except when extra labor is involved
Exploring internal markets
Neutral results for business
Does not affect profitability
Questionable. Grows potatoes

5. Is the funding for the Practices chosen for your farm adequate to protect you from negative economic impact?

Yes = 13
No = 3
Hope so
unsure
n/a = 2
Maintenance and upkeep a big issue
Not enough money in plan to do everything should be done (pasture)

6. Which Practice in your Whole Farm Plan will be of the most benefit to you?
Barnyard = 4
access road
plan for the horses and barnyard management
between manure storage and greenhouse
no till reseeding
solving fuel problem
all
access road and barnyard equal = 2
fuel tank facility
composting facility and spreader
WFP not yet completed
Access road only thing done
Access road. Nobody has been back on farm
Silage storage area
Nutrient management
Barnyard diversion

7. Do you agree with how management and labor issues were handled in your Plan?
Yes = 15

yes on management. No on labor
no problem
n/a = 3
labor issues were not addressed
no

8. Did you have enough input into the planning of your farm? If not, what is your opinion as to why?
Yes = 21
Farmer was part of the process
No. Wouldn't listen to me

9. Is there any part of your Plan that you don't understand? If yes, what is it?
No = 18
question manure management on some fields
drain to catch runoff may freeze
when will it be completed?

10. If you have had contractual work done, were you satisfied with the work? If not, what recommendations do you have for ensuring that the work is done to your satisfaction?

Nothing done. Plan is 4 to 5 years old.
Very satisfied = 2
No. work had to be redone. Problem with plan
No not yet =2
Not happy with quality of workmanship
Contract work done by family. No complaints
Satisfied = 7
n/a = 6
planner worked with contractor to control costs
Chose 2nd bidder. Happy with him

11. What recommendations for improving the contracting procedure do you have?

Speed the process
Pay attention to what farmer says
Don't break up project into components and become a general contractor. Rather see it bid out
N/A = 7
Have specs clearly outlined prior to the beginning of a job
Spend money as if it's farmer's dollars instead of NYC dollars
Bid out more practices to save money
Reduce engineering
Able to use contractor of choice

None = 5

12. How much staff assistance/time will be required by project staff to help you follow the long-term components of your Plan?

<u>Choose One</u>: None Small Amount Large Amount Don't Know
Small amount = 11
Large amount = 1
None = 5
Don't know = 2
One morning a month
Mostly just NMP

13. Has the Program met your initial expectations? If not, please explain.

Yes = 15
N/a
No. slow, wasteful and overbuilt on other farms
No. not timely enough
Wasted too much time on engineering
Absolutely not. Lackluster approach to accomplishing plan. Barnyard not yet designed.

14. Are there any specific changes that could be made which would benefit the Program?

No = 9
More focus on one plan at a time
Streamline engineering practices
Less bureaucracy
Provisions for modifications
Listen to farmer about what works
Speed up planning and implementation = 5
More farmer friendly
Planners should understand farmers lifestyle. Not a 9-5 job
Want to see planners on farm more
Less paperwork.
Water quality issues fine. Alternative agriculture has not met expectations

15. Are you interested in an easements program? Forestry program? Specialty crops?
Specialty crops = yes = 9
None = 6
Forestry = yes = 10
Easements = uncertain = 3
Easements = yes = 7

16. Are you interested in assistance with estate planning?
Not sure = 3
No = 17
Yes = 3

17. Are you receiving enough information about the Watershed from the agencies?
Yes = 20
Not sure = 2
No = 1

Is the Watershed Agricultural News Newsletter useful?

Yes = 15
No = 2
maybe
Articles on individual farms are interesting.
Don't receive it
No time to read
Want more info on EOH
Interesting little paper

What recommendations do you have for improving communications about the Program?
None = 13
create link on web page. Put in info on education
get needed info from planning team
contact farmer regularly
articles in newspapers so people can understand what's being done in watershed
a newsletter with updates from Delaware County or NYC
Catskill Family Farms needs better communication. Financial info too scarce

18. A) Do you know what Giardia and Cryptosporidium are and their significance with regard to drinking water? B) If yes, did you know 5 years ago?

A) yes = 17	B) no = 11
A) no = 7	B) yes = 6

19. A) Do you know what the significance of phosphorus is for drinking water? B) If yes, did you know 5 years ago?

A) yes =14	B) no = 8
A) no = 7	B) yes = 5

20. What do you like most about the Program?
100 % funded
not much
assistance in technical projects

did away with mud problem
our relationship with planning team
all of it
no till
don't know
planners are courteous, friendly and take an interest in farm operation
educational aspects
n/a
free practices
implement BMPs we couldn't do ourselves
its potential
doing something to help farmers
voluntary and allowed farmer input
barnyard improved working environment on farm
barnyard

21. What do you like least about the Program?
Too little action
Too much time spent to accomplish too little
Nothing = 3
Haven't seen any results (recently signed up)
Bureaucracy & politics
Future uncertainties
Doing things that aren't necessary
Not fulfilling its potential
Amount of time to get things done
Bureaucratic propensities
No complaints
Uncertain whether practices will work after they are in place
Too much paperwork
Don't see planning team enough
Too many people around when implementing interfered with getting farm work done
Better quality contractors participating in sealed bids
Red tape
Alternative agriculture program

22. Other comments/suggestions?
Interested to see how it turns out
Should consider farmers long-term plans. Be pro-active rather than reactive
Very positive thing for locals and region and watershed.
Want to visit other planned farms.
Glad to think of estate planning possibilities
Watershed farmer meeting (Jan or Feb) for info on Program & research.
Recreation on reservoirs
Speed up the process

Get city to run program. Get rid of office on Route 10
Need clarification of cost guidelines
Cost guideline not available to producer
More contact with planners
Too much spent on staff, not enough on farms
Better communication between engineers and contractors
Very happy with program and work done

D. Contractors Survey

A survey was sent out to a list of 60 contractors who have participated in the program, either through implementing BMPs, submitting bids and/or attended the WAP Annual Contractors meeting. The purpose of this survey was to identify any possible problems and/or difficulties the contractors were having with the WAC BMP procurement procedures. Unfortunately only eight responses to the survey were received. Survey questions and responses can be found in the appendix of this report.

Of the few responses received most were satisfied with the procurement procedures. However, one respondent felt that he or she spent a great amount of time developing a bid and even though he was the lowest bid the farmer had an option to pay the difference and select another bidder.

1. Are you satisfied with the overall quality of the bid documents (drawings & specifications)?
   Yes = 7

2. Are the drawings clear and easy to read?
   Yes = 7

3. Do the bid documents adequately define the proposed work?
   Yes = 7

4. Are you satisfied with the site showing and bidding process?
   Yes = 6
   No – need to be compensated for low bid if farmer pays up to use his contractor for job

5. Are you satisfied with the payment process?
   No. Need money up front 10% on signing contract
   No. Progress payments would be helpful
   Yes = 5

6. Are you satisfied with the construction process?
   Yes = 6

No = should start more projects early summer rather than Fall

7. Are your questions and/or problems you encounter during construction addressed promptly?
   yes = 6
   yes and no = 1

8. Do you need technical assistance with layout and setting elevations?
   no = 4
   yes = 3
   Speeds up process when field changes need to be made

9. Are you satisfied with the Annual Contractors' Meeting?
   yes = 7

10. Would you like training in any areas of construction for the Program?
   no = 6
   yes = 1

11. Do you see any areas where construction costs can be reduced without compromising quality?
   no = 4
   Use sandstone crusher instead of limestone
   Dimensions of material/lack of waste

12. Overall, are you satisfied with the Program?
   yes = 7

13. Do you find it difficult to obtain the materials called for in designs?
   no = 6
   yes, some pipe fittings and some of the stainless steel screens

14. If you have been reluctant to bid on Watershed Ag Program projects, what was the reason?
   Too much other work. Lack of time to bid
   Spending time & cost of bidding when farmer has option to pick own contractor when you have a successful bid
   Distance from office
   one contractor wrote back that they were too busy in Otsego County to even bid on watershed work this year.

E. Survey of WAP Advisory Committee Members and the Partnering Agencies

The following survey was sent out to all WAP Advisory Committee members and to all partnering agencies who have sub-contracts with WAC.

1. Are the WAP evaluation criteria appropriate?

   Yes = 6

- One respondent felt that criteria 1 & 4 are not appropriate.
- Another stated that criteria 3-5 are not appropriate.
- The DOH recognizes the importance of implementation of the WAP within the NYC watershed and would like to compliment the WAC and technical staff for high level of professionalism and dedication to Program. Dept. feels evaluation criteria appropriate, efforts needed to formulate a program or procedure to assess acceptance, implementation and maintenance of WAP by farmers as well as efficacy of BMPs to improve water quality in short term/long term

2. Does WAP address mission and objectives of program?

   Yes =5
   Somewhat = 1

- WAP has positive impact on water quality within agricultural community but scientifically acceptable criteria for documenting improvement is needed
- Adopting management techniques aspect lacking because of need to meet EPA goal numbers

3. What directions should the program be pursuing?

- Education. Farmers need to believe in the benefit of NMPs, rotational grazing etc
- Stress voluntary program. Seems dictatorial
- Engage wider farming community
- Encourage people to get abandoned farms back into business
- Address phosphorus. Build partnership with Delaware County
- Direction is diversified and adequate
- Expand to Croton watershed = 2
- DOH feels Program should concentrate on protection of water quality by implementation of BMPs on farms and incorporation of novel scientific data and operational techniques to mitigate negative impact of farming on water quality. Educational aspect of WAP should be stressed even further. For example, emphasizing benefits of CREP may stimulate more farmers to participate in Program. Not only farmers but local community as whole should be given opportunity to learn about importance of maintaining high water quality and become aware of outcome of poor farm management.

4. What are the strengths of program?

- Farmer input, team approach, dedicated staff = 2
- Meets its purpose
- Partnering with agencies = 2
- Helping small farms survive
- Funding
- Farmer support
- Locally led
- Staff responsiveness
- DOH – Collaboration of farmers with technical staff and staff from various scientific institutions and regulatory agencies make Program a success and it benefits from both practical knowledge and scientific resources. Program increasingly becoming accepted by farmers and local communities

5. What are the weaknesses of program?

- Follow-ups should be educational so BMPs will continue to be maintained. Too much questioning by the Council of planners approach
- Small farmers perceive being forced to participate in program.
- Projects over-engineered
- Work harder to ensure continuance of Program
- Program needs to be implemented in Croton system
- Costs of BMPs may be prohibitive outside the watershed where grant monies are unavailable
- Agency relationship poor.
- Pathogen and phosphorus program technically weak. WAC credibility
- Control in Catskill Delaware system
- Communication between planning teams and districts could be better
- DOH recommends better communication between WOH and EOH farmers so Program would benefit from different knowledge and experience. More informational meetings and scientific presentations should be organized to educate public on importance of BMPs implemented on farms.

6. Are you adequately informed about WAP activities?

Yes= 7
No = 2

- DOH staff will be in contact with Program staff to do some on-site evaluation of the WAP

7. Are there any issues you feel the Council should place a higher priority on?

No = 4

- Phosphorus management
- Appoint a EOH program director to spearhead efforts on the other side of the river and help bring agencies together and secure necessary funding
- Improve WAC-agency relationship.
- WAC should become an elected group representing the geographic areas of the watershed
- Continue the pursuit of long-term funding
- DOH - See item 1 above

F. WAC Director Surveys

1. How well are you being kept informed about the issues facing the Council?

Well informed = 12
Not well informed = 1

2. Are you adequately informed about the activities and issues being handled by the WAC Executive Committee. Any suggestions?

Well informed = 6
On the committee = 3
Minutes keep me informed = 3
Not well informed = 2

- Believe in full disclosure at some point.
- No – informed after the fact. Need more openness.
- Issues covered by Exec Committee should be brought up at WAC meeting
- No. no suggestions
- Like to get minutes sooner than WAC meeting

3. Are you getting enough time to discuss policy issues due to the large amount of business to be conducted at WAC meetings? Meeting restructuring suggestions.

Yes = 6
No = 2
Should have additional meetings = 5

- Conduct more business at 1st Reading = 2
- Better – last meeting went well
- Add extra meeting for policy issues = 2
- Meeting going as well as can be expected with a complex business
- Not enough time. Written reports useful
- Separate meetings for WFP approvals and other WAC business
- Handle more work at the committee level
- Move plan approvals to committee level

4. Any complaints about the program?

No = 2

- Too much engineering = 2

- Need new Council directors = 2
- Frustrated with the political process and bureaucrats (DEP)
- Elect rather than appoint Council directors. Management costs too high
- Phosphorus hard to understand because of personalities and complexity of issue
- Bidding process leads to shortage of contractors – should be able to use contractor of choice
- Too much engineering leads to higher costs. = 2
- Recruit new Board members on a regular basis
- Not enough time or resources
- Penny pinching organization (cost guidelines too restrictive). Change the manure spreader policy. Explain WAP and WAC
- Planning team costs too high for number of WFPs /revisions produced. Contracting agencies need more accountability for deliverables. Resources spread too thin. WAC's main purpose is WAP
- Goals need to be reviewed = 2
- Political process hampers the Program. Phosphorus issue confusing. Change bidding process. Change cost guideline policy. Change manure spreader policy. Hold agencies more accountable for deliverables. Staff costs high.

5. What are you pleased with about the program?

- Implementation = 6
- New Finance office = 2
- Farmers as Council directors having a voice in how the Program is run and being supportive =3
- The overall program.
- Farms getting practices they wanted but couldn't afford
- Participation, attendance and interest of a volunteer board
- Economic impact of program on the local economy
- General sense of goodwill. Farmers are supportive. Willing to accept different points of view

6. A) Do you have any questions about the committee structure?

- No suggestions = 12
- Too many committees = 1

B) Suggestions for additional committees or changes to committees

- no = 6
- Less favoritism in committee assignments = 3
- Have more Council members = 1
- Economic Development Comm. should concentrate efforts on dairy industry = 1
- Keep committees small and focused = 2

- Need professional help on MIC = 1

7. As a Council Director, when visiting with farmers, have their attitudes changed about the Program?

Farmers are more positive and less suspicious of the program = 6
Farmers are better informed = 1
Thankful for help with environmental problems = 1
Concerns about slowness to design and implement = 2
Farmers have signed up and heard nothing from planners = 1
Cost guidelines too restrictive = 1
Over-engineering greenhouses = 1

Conservation Reserve Enhancement Program
for the
New York City Water Supply Watersheds

FEDERAL FISCAL YEAR 1999 ANNUAL REPORT

December 30, 1999

Introduction

New York City has entered into a Memorandum of Agreement (MOA) with United States Department of Agriculture (USDA) and New York State to implement a Conservation Reserve Enhancement Program (CREP) in the Catskill and Delaware Watersheds in conjunction with the Watershed Agricultural Program, which is administered by the farmer-led Watershed Agricultural Council under contract to the City. These watersheds furnish ninety percent of the approximately 1.34 billion gallons of water used daily by the New York City water supply system, which serves eight million City residents in addition to one million residents in Westchester, Putnam, Orange and Ulster Counties. CREP is an area specific enhancement to the nation wide Conservation Reserve Program (CRP).

This MOA, which was signed on August 26, 1998, will allow watershed farmers to enter into 10 to 15 year contracts with the USDA to retire environmentally sensitive lands from production, establish forested riparian buffers, and retire highly erodible cropland. The USDA will pay the farmer on average $90.00 per acre annually as well as fifty percent of the cost of all BMPs associated with establishing riparian buffers and/or permanent vegetative cover. The City, through its agreement with the Watershed Agricultural Council (WAC), will pay the remaining fifty percent of BMP costs for participating farms, as well as the cost of technical and administrative assistance.

The program's goals are to enroll 3,000 acres of highly erodible cropland and establish 2,000 acres of riparian forest buffers in five years. These conservation measures will help to protect at least 165 miles of streams in the Catskill/Delaware watershed.

Program Participants

Seventy five landowners representing 95 tracts of land have signed a CRP-2 expressing interest in enrolling land in CREP. Four CP22 contracts were developed with a total of 42 acres of riparian buffers.

The table below is a list of farms that have incorporated CREP into their Whole Farm Plans. It includes an estimate of the amount of acres to be enrolled in the program, the funds requested from the Watershed Agricultural Council to implement conservation practices associated with CREP acreage, the date approved by the Council and the date the CREP contract went into effect. It is anticipated that contracts will be developed for all the farms in this table during the coming year.

TABLE 1. CREP Projects Approved BY WAC In A Whole Farm Plan

FARM NAME	CREP ACRES*	USDA FUNDS REQUESTED FOR BMPS	WAC FUNDS REQUESTED FOR BMPS	DATE APPROVED BY WAC	FSA CONTRACT DATE
Frost Valley	2.0	$6,700.00	$6,700.00	07/27/99	
Wayland Gladstone	9.6	$7,000.00	$7,000.00	07/27/99	
Jim Robertson	5.0	$14,500.00	$14,500.00	07/27/99	
Weinland Farms	21.4	$18,500.00	$18,500.00	07/27/99	
James Gray	22.7	$26,128.00	$26,128.00	07/27/99	12/01/99
Gordon Cucullu	1.6	$4,580.00	$4,580.00	05/25/99	
Dan Flaherty	5.4	$14,063.00	$14,063.00	04/27/99	07/01/99
Gary Galley	15.4	$6,825.00	$6,825.00	09/22/98	03/01/99
Richard Latourette	7.0	$20,130.00	$20,130.00	08/24/99	12/01/99
Robert Latourette	13.0	$9,900.00	$9,900.00	06/29/99	12/01/99
George Morgan	19.1	$500.00	$500.00	06/29/99	08/01/99
Steve Shelton	3.1	$5,095.00	$5,095.00	06/29/99	07/01/99
Steve Shelton	16.2	$9,833.00	$9,833.00	06/29/99	
Herbert Truesdell	4.0	$7,500.00	$7,500.00	11/23/98	
Leland Ploutz	1.0	$550.00	$550.00	05/25/99	
Andrew Post	2.0	$6,500.00	$6,500.00	11/23/98	
D. Siniscalchi	3.5	$8,940.00	$8,940.00	06/29/99	
Tim McCumber	8.0	$11,800.00	$11,800.00	12/15/98	
DiBenedetto Farm	7.0	$4,600.00	$4,600.00	03/22/99	
J.J. Farber Farm	2.0	$3,175.00	$3,175.00		
Golden Acres	1.0	$3,275.00	$3,275.00	09/22/98	
Viggo Skovsende	2.7	$15,000.00	$15,000.00	06/29/99	
Steve Mostert	18.5	$16,125.00	$16,125.00	09/07/99	12/01/99
Total	**191.2**	**$221,219.00**	**$221,219.00**		

*These acres are estimates and may differ in the actual contracts

Program Accomplishments

Table 2 - Fiscal Year 1999 CREP Contracts

Contract #	Contract Years	Acres	1st Year rental Payment	Annual Rental Payment	Total Rental Payment	BMP's	Scheduled Installation Date	Date Installed	Estimated BMP Cost (50%)
990006	10 yrs. 3 mo.	4.4	$96.24	$385.00	$3946.24	Fencing Pipeline tree planting spring dev.	4/00 9/00	7/99 8/99	$4.101.00 $1,560.00 $ 125.00 $8,315.00
990005	14 yrs. 7 mo.	15.4	$746.88	$1280.36	$18.671.92	Fencing spring dev. Cattle crossing tree planting	6/00 6/00 4/00	5/99	$1,747.00 $2.650.00 $ 300.00 $ 800.00
990007	14 yrs. 3 mo.	19.1	$319.50	$1.917.45	$27.163.80	Tree planting	4/00		$ 500.00
990008	14 yrs. 3 mo.	3.1	$72.08	$288.30	$4.108.28	Fencing tree planting critical planting Animal trails	4/00 5/00 5/00	7/99	$ 848.00 $1,000.00 $ 370.00 $1,156.00
Sub-Total		42.0			$53.890.24				$23,472.0

Total Expenditures	
Total Rental Payments	$53,890.24
BMP Cost (USDA)	$23,472.00
BMP Cost (NYC)	$23,472.00
Technical Assistance(NYC)	$20,168.00
Total Program Cost	**$121,002.24**

Non-Federal CREP Expenditures

Technical Assistance	Percentage of Total Contract Cost	Non-Federal Expenditures
NRCS*	5%	$5042
CCE	5%	$5042
WAC	5%	$5042
SWCD	5%	$5042
Sub-total		**$20,168**
BMP Implementation		**$23,472**
Total		**$43,640 (36%)**

Note: NRCS Planning and Engineering Staff are paid by New York City through the Watershed Agricultural Program

Annual Monitoring Program

Since this is the first year of the program, there has not been a significant amount of monitoring. However in future years, Watershed Agricultural Program (WAP) Staff will meet annually with farmers to review and update their Whole Farm Plans and ensure that the farmers are following their CREP contract.

FY 2000 Goals

It is anticipated that at least 30 contracts totaling 400 acres (approximately 66 miles) of riparian buffers will be developed during fiscal year 2000. These contracts will require the implementation of fencing, alternative water sources and tree and shrub planting. The average riparian forest buffer width in this program is 50 feet. Therefore, the 400 anticipated acres equals approximately 66 miles of protected riparian areas. Fencing cattle out of the stream corridor and establishing the forested riparian buffers should greatly reduce the introduction of nutrients and pathogens into the streams that supply drinking water to New York City residents.

In addition, New York City DEP and WAC have been collaborating with a group of researchers from the US Geologic Survey, Cornell University, and USDA Agricultural Research Service to conduct a cooperative research, demonstration and evaluation project in the Town Brook subbasin in the headwaters of the West Branch Delaware River. A component of this research that should be initiated in FY 2000, will be to evaluate the effectiveness of streambank fencing and riparian buffers in protecting water quality in this region. This research should help to better quantify the environmental benefits of CREP.

Outreach Activities

There has been a wide range of outreach activities to inform landowners and other watershed residents about CREP and its benefits to protecting water quality. These activities included: direct mailings to farmers describing the program, articles in newsletters (FSA, WAC, CCE & SWCD), press releases and providing educational materials at agricultural events such as, County Fairs and Down on the Farm Day. In addition, New York City has posted information and links about CREP on its web site (www.ci.nyc.ny.us/dep).

The local FSA office often receives calls from farmers interested in the program. These referrals are then passed on to the WAP planning teams, so that they can meet with the farmer and discuss the program in more depth. In addition, planners have been presenting the program to the WAP farmers that have Whole Farm Plans and those that are in the process of developing a plan.

Partnerships Developed

A **CREP committee** which includes representatives from New York City DEP, WAC, NRCS, FSA and Delaware County SWCD was established to help coordinate efforts to implement the program. This group meets monthly to discuss issues raised by the field staff and find solutions, and also set priorities for the program.

With funding provided by New York City through its contract with WAC, Delaware County SWCD established a part time (0.5 FTE) position **CREP Program Coordinator (CPC)** to help coordinate efforts between the Whole Farm Planning Teams and FSA for farms in Delaware County. In Delaware County the CPC has been extremely helpful in assisting planning teams in assessing farm suitability and determining eligible acres for the program. The CPC will also assist in the layout of CREP plans and coordinate activities with private sector contractors for BMP implementation.

The WAC has received a $145,000.00 grant from the USDA Forest Service to establish a **Riparian Forest Buffer Coordinator** position for a two year period. This position will be established to accomplish the following:

- Serve as a single point of contact to landowners for technical and financial assistance on the use of riparian forest buffers.
- Work with agency personnel to establish priorities for the location and demonstration of riparian forest buffers.
- Conduct training on the design and establishment of riparian forest buffers.
- Develop riparian forest buffers on non-agricultural lands.

This position was filled November 1999 and it is anticipated that the candidate will help accelerate efforts to implement forest riparian buffers through CREP.

The CREP Committee is participating with the New York City DEP Stream Management Program, US Fish & Wildlife Service, Cornell University, Trout Unlimited and others to organize a seminar entitled, 'Building Effective Riparian Forest Buffer Network." This seminar will help promote the benefits of riparian forest buffers and also discuss the various resources available to help implement riparian buffers in this region. The seminar will be held on February 1 in Delhi, New York.

Program Recommendations

1. In order to achieve complete success of CREP and to reach the goals defined in the agreement between New York City and USDA, it is recommended that the land eligibility rules be amended as follows:

> *"Hay, used for harvest or grazing, in 2 out of the last 5 years meets crop history for purposes of continuous CRP/CREP."*

This change in land eligibility is extremely important in the New York City Watersheds for the following reasons:

- Due to the mountainous topography and relatively short growing season the dairy farms in the region are growing less row crops and many are going to all hay operations. This is reducing the program's ability to implement buffers uniformly across the farm and watershed.

- Even though hayfields are in permanent vegetation they still receive applications of manure from dairy farms. Recent research by the USDA ARS shows most soluble phosphorus is contributed by land adjacent to streams.

- Farmers who practice good stewardship by not planting row crops adjacent to streams and produce hay instead are in effect being penalized because they are not eligible to enroll in the program. This criterion significantly reduces the amount of riparian and sensitive acreage eligible for enrollment in this program.

2. The second recommendation would be to allow the utilization of harvested forage materials from permanently seeded HELs and grassed filter strips. It has been almost impossible to convince a farmer to enter his/her HEL cropland into the program because they are prohibited from utilizing the forage to feed their animals. This is also an issue with filter strips, since the farmer is required to mow the filter strips periodically and remove the material but may not feed it to his animals.

The CREP committee members unanimously agree that these two recommendations, if implemented, would greatly strengthen the program and would help to meet its goals. The committee encourages that these recommendations be implemented on a piloted basis in the New York City watershed area and be evaluated annually to determine their benefits.

Success Stories

1. **Number of sign-ups**: The farmers and landowners in the watershed have responded very positively to the announcement of this program with at least 75 landowners expressing interest in enrolling in the program. This far exceeds the single digit requests for CRP in the past.

2. **WAC Funding:** WAC approved a resolution at the June 29, 1999 Council meeting to set aside BMP funds to be used for CREP BMP implementation regardless of a farm's cost guideline. This allows all farmers who are interested in participating in CREP to receive WAC cost sharing even if the cost guideline on their farm has been exceeded. Since the passage of this resolution there has been a steady stream of Whole Farm Plan revisions with CREP components added.

3. **Agency Coordination**: Promoting this program to landowners, developing contracts with appropriate BMPs and integrating CREP into the whole farm planning process has required multiple agencies to coordinate their efforts to make it a success. FSA, NRCS, CCE and local SWCDs continue to work enthusiastically together to meet the program goals.

4. **Developing a Geographic Information System (GIS) Component Through the WAC Riparian Buffer Program:** The new WAC Riparian Buffer Coordinator plans to work with New York City DEP staff and the DEP GIS to identify priority areas that would benefit the most from the installation of riparian forest buffers and target these areas for CREP outreach activities.

Evaluation and Management of *Cryptosporidium parvum* and Phosphorus Contributions in the Town Brook Watershed

A proposal submitted to the
United States Department of Agriculture
National Research Initiative
Competitive Grants Program
by
Cornell University

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PROJECT SUMMARY

The Environmental Protection Agency's (EPA) Surface Water Treatment Rule generally requires filtration to remove pathogenic microorganisms from drinking water supplies. New York City (NYC) was granted an exemption from the filtration rule, providing that an acceptable watershed program plan and protective measures can be achieved. A panel of scientists convened by the National Research Council (NRC), a branch of the National Academy of Sciences, recently carried out an independent scientific review of the completed, comprehensive NYC Watershed Program's plan. The NRC panel recommended that NYC put its highest priority and resources on improved methods for detecting pathogens, understanding pathogen transport and fate, and demonstrating that best management practices (BMPs) will remove pathogens (NRC, 1999). Since *Cryptosporidium* oocysts are very resistant to chlorination and have multiple infectious routes between humans and animals, a major focus of this research will be on their detection, transport, and on BMP methods to remove them. Thus far, phosphorus (P) removal from the NYC water supply system has received the most attention. Since P accelerates the growth of algae within freshwater streams and reservoirs, it is also important to find effective methods of decreasing P loads. The growth and decay of algae produces dissolved organic compounds that have the potential to form toxic disinfection byproducts when the water is chlorinated. Although there are numerous differences in *Cryptosporidium* and P, we hypothesize that there are also several similarities in their source and transport behaviors from agricultural lands. As such, this proposal seeks to investigate the two simultaneously in terms of transport and methods to reduce the losses from agriculture. The information learned regarding fate and transport processes should also apply to other nonagricultural sources of these contaminants. The proposed effort will be carried out in both laboratory and field experiments within the NYC watershed. The research will also capitalize on partnership arrangements which have already been established in the watershed and will serve to synthesize and multiply the findings of numerous involved parties. The collaboration of scientists and cooperating landowners will result in a sharing of resources and more opportunity for the collection, exchange and analysis of research data. The early involvement of landowners in these efforts should facilitate their adoption of recommended practices so that agriculture may continue to thrive while NYC water consumers can be more assured of a high quality water supply.

PROJECT DESCRIPTION

Evaluation and Management of *Cryptosporidium parvum* and Phosphorus Contributions in the Town Brook Watershed

INTRODUCTION

An Overview

Watersheds are the natural boundaries for drinking water supplies for many cities. Natural processes in watersheds, combined with human activities, will determine the inherent quality of the water. Well managed forested and agricultural watersheds are believed to deliver the highest quality water. However, the quality and suitability of the water for a water supply is largely the result of the management effectiveness within the watershed. The management effectiveness depends to a significant extent on the scientific underpinnings of the approaches used in managing the water (NRC, 1999). This proposed research will provide additional scientific understanding for managing the mostly agricultural and forested 37-km^2 Town Brook Watershed (TBW), a sub-area of the upper Cannonsville Reservoir Watershed (CRW), used as a potable water supply for New York City (NYC). The research should also provide an enhanced understanding for managing other watersheds in the Northeastern United States.

Surface water supplies may be affected by a range of pollutants originating from various sources. Water quality constituents of primary concern in the NYC drinking water supply are microbial pathogens, phosphorus (P), nitrogen (N), organic carbon compounds, sediment, and toxic compounds (NRC, 1999). The National Research Council (NRC), established a 15 member committee for the purpose of evaluating the scientific issues associated with the 1997 NYC Watershed Memorandum of Agreement, a document that outlines strategies to maintaining high quality drinking water for the nine million residents in NYC and neighboring Westchester County. According to the NRC (1999) report, controlling microbial pathogens and P in the water supply should be two of the top priorities in the NYC watershed plan to protect the health of consumers.

Agriculture is a major land use in the Cannonsville basin, and is considered a significant source of P to the NYC water supply reservoir. Excessive P inputs to a water body can cause eutrophication, resulting in the impairment of water quality. Currently, the Cannonsville Reservoir is eutrophic so the contributing watershed has already been designated as P-restricted. Pathogenic microorganisms are also a concern since these can originate from domestic livestock, wildlife, and humans. *Cryptosporidium* and *Giardia lamblia* are considered the most dangerous microorganisms to a safe water supply because chlorination treatment is ineffective. Because less appears to be known with regards to *Cryptosporidium*, this proposal will focus on this microorganism.

The land use management program in the Cannonsville basin and other NYC watersheds is overseen by the Watershed Agricultural Program (WAP), and is funded by the Watershed Agricultural Council (WAC) and the NYC Department of Environmental Pollution (NYCDEP). WAP is charged with developing and implementing agricultural best management practices (BMPs) to minimize nutrient, pathogen, and sediment losses from farms, while simultaneously trying to sustain the economic viability of farming within the NYC water supply watersheds. A whole-farm planning approach is used for each participating farm within the program. Minimizing P loss from farms has been one of the primary goals of the WAP. The WAP expects to make progress toward the realization of this goal by developing and implementing nutrient management plans and through the installation of BMPs. Some attention has also been given to controlling pathogen loss, mostly by the installation of measures to isolate young livestock. In order to improve the whole-farm planning process, WAP identified the TBW as an area for conducting intensive nutrient management experimental investigations to further reduce P and pathogen losses from farms.

Under the leadership of the WAC, a team of researchers has met regularly during the past two years to plan various experimental approaches to reduce P and pathogen contributions from agricultural and other rural land uses. Dave Post, chairman of the WAC's Manure Infrastructure Committee and also a farmer in Town Brook, hosted the research team. The research team consists of Tammo Steenhuis and other researchers from Cornell University; Michael McHale and Pete Murdoch from the U.S. Geological Survey (USGS) in Albany, NY; William Gburek, Andrew Sharpley, and Peter Kleinman from the U.S. Department of Agriculture Agricultural Research Service (ARS), University Park, PA; and Elliot Schneiderman from the NYCDEP. This proposal seeks the necessary funding support for Cornell University in order to facilitate the plan, and to continue the cooperative effort with the various agency participants of the team. As such, a more comprehensive scientific effort can be initiated that will have important multiplier affect.

Traditional soil and water conservation practices have only demonstrated limited success in the reduction of nonpoint source pollution (Walter et al., 1979). Current design, implementation, and evaluation of BMPs directed towards reducing agricultural P nonpoint sources are problematic because of the complexity of nonpoint source generation and transport of P over the landscape. To effectively minimize P and pathogen inputs to surface waters, BMPs must not only consider the sources and transport factors, but also how these factors interact (Gburek and Sharpley, 1998). Numerous source factors are controlled by the farmer making decisions relative to land management, animal nutrition, where and when to locate animals, and on the storage and spreading of fertilizer and manure. On the other hand, transport factors are a function of the natural system, driven by hydrological processes that control water movement to streams and reservoirs. Unlike the individual landowner's decisions, transport factors are not sensitive to man-made boundaries or within a landowner's control. Transport factors operate at the landscape or watershed scale. Thus, effective agricultural management for controlling pathogen and P losses requires a watershed scale analysis of the source and transport factors so that BMPs can be effectively designed and implemented to target critical and specific locations of these losses at the farm scale. Additionally, a watershed scale analysis provides the basis for accounting for other land uses in the watershed that, along with agriculture, contribute to pathogen and P losses from the watershed.

Cryptosporidium

The waterborne mode of transmission of many bacterial pathogens (e.g., *Salmonella, Shigella, Vibrio cholerae*) and enteric viruses (e.g., Hepatitis A virus, Rotaviruses) has long been known (Geldreich, 1990). One reason for building the Cannonsville Reservoir water supply system was to provide NYC with a clean source of water to prevent disease outbreaks. On the other hand, waterborne disease outbreaks caused by the protozoa parasites, *Crytosporidium* and *G. lamblia*, were first reported in the 1970s (Bitton, 1999). *Crytosporidium* or *G. lamblia* was associated with 10 out of 30 drinking water-associated outbreaks reported in 1993-1994 (Kramer et al., 1996). MacKenzie et al. (1994) documented the largest *Crytosporidium* waterborne disease outbreak in Milwaukee, Wisconsin where 404,000 people became ill of whom 4,400 were hospitalized. Since chlorination is an effective disinfectant against waterborne bacterial pathogens and enteric viruses, these infectious microorganisms are not a significant threat to chlorinated water supplies. However, the protozoa parasites, *Crytosporidium* and *G. lamblia*, form (oo)cysts under adverse environmental conditions that make them quite resistant to disinfection with chlorine. As a result, chlorination treatment of a water supply is not an effective barrier to preventing waterborne diseases caused by *Crytosporidium* and *G. lamblia*.

With regard to *Crytosporidium*, *Crytosporidium parvum* is the major species responsible for infections in animals and humans (Adal et al., 1995). A minimum infective dose is 1 to 30 oocysts for animals and humans, respectively (Kwa et al., 1993: DuPont et al., 1995). Current and Garcia (1991) estimate that *C. parvum* is responsible for 250-500 million infections per year in developing countries. Based on examination of thousands of human fecal samples in North America and Europe, the prevalence of human cryptosporidiosis is within 1 to 5 percent (Ongerth and Stibbs, 1987). Within NYC, the prevalence of cryptosporidiosis is 2.8/100,000 persons per year (NYC DEP, 1999a). A National Animal Health Survey indicated that *Crytosporidium* oocysts were found on 59 percent of surveyed dairy farms and in 22 percent of the tested heifers (Garber et al., 1994). The highest incidence of disease was associated with calves between 1 to 3 weeks of age. In the NYC watershed, 0.66 percent of tested wildlife (6,261 specimens) and approximately 2 percent of cattle tested were found to be infected with *C. parvum* (NYCDEP, 1998a; NYSWRI, 1997). The zoonotic transmission route of *C. parvum*, the cross-infectivity between animals and humans, is suspected to be greater for *Crytosporidium* than for *Giardia* (AWWA, 1988). Evidence that animal derived oocysts from calves, pigs, and cats (as well as beaver and other aquatic animals) have resulted in human infections (Rose, 1997). Given the prevalence of *Cryptosporidium* in domestic animals, humans and wildlife, several modes of transmission, and the difficulty of removal and disinfection from a water supply; *Cryptosporidium* poses a significant risk to the NYC water supply.

Research on microbial transport through soil has largely concentrated on bacteria and viruses (Bitton, 1975; Daniels, 1980, Rosenberg and Doyle, 1990; Grotenhuis et al., 1992; Mills et al., 1994). Boria et al. (1992) reported that there were few published data on the transport behavior of *Cryptosporidium* through undisturbed soil. Bacteria and enteric viruses have been found at depths well below the surface and exhibit both vertical and horizontal movement. One documented incident of a cryptosporidiosis waterborne outbreak was via sewage contamination of a well (D'Antonio et al., 1985) where it was speculated that *Cryptosporidium* oocysts percolated through the soil and entered the well. Since *C. parvum* oocysts (4 to 6 μm in diameter) are somewhat larger than bacteria cells (generally 0.3 to 2 μm), and considerably larger than viruses (25 to 350 nm), this subsurface transport of oocysts is generally unexpected but obviously possible. There is less known on the fate and transport of *Cryptosporidium* than for *Giardia*, mainly because of methodological problems in environmental detection of oocysts in the past (Clancy et al. 1994). Nevertheless, more recent experiments by Mawdsley et al. (1996) and Brush (1999) show that *C. parvum* oocyst transport is similar to that of bacteria and viruses. The degree and rate of movement of bacteria and viruses in homogeneous soils is greater in coarse particles such as sand, as opposed to fine textured clay soils. Bacteria may be physically filtered out through small pores, although filtration may decrease with decreasing flow velocities (Smith et al., 1985). However, the variation in screening is also partly due to the number and size of soil pores and the differences in the adsorptive properties of soils. In addition, the presence of macropores in naturally structured soil may exacerbate the transport of microbes via preferential flow (Madsen and Alexander, 1982; Darnault et al., 1999). The movement of *Cryptosporidium* in preferential flow paths is one of the basic questions which this proposal will address.

C. parvum oocysts may adsorb to soil during transport. Hydrophobicity, the presence of extracellular polysaccharides, and the net surface electrostatic charges between the soil and the particle are factors that control adsorption to soil. The chemical factors most critical in particle adsorption are ionic strength, the pH of the soil solution, and the soil organic carbon content (McCaulou et al., 1995). The retention of viruses in soil is primarily due to their small size and surface properties. Virus adsorption varies greatly depending on the type of soil, the amount of organic matter, the water content, soil pH, salt content of the soil solution, flow rate, and the physical and chemical nature of the viruses. However, little is known regarding the adsorption properties of *C. parvum* to soil and how *Cryptosporidium* is transported in the landscape.

Another large unknown is what BMPs are effective barriers to *Cryptosporidium* transport at the field and watershed scales. The installation of subsurface drains is an example. Tile lines reduce soil saturation thereby reducing overland flow and erosion. However, our experimental results indicate *Cryptosporidium* can also move readily through macropores to the tile line. The tile discharge is generally transported directly to a stream, whereas *Cryptosporidium* in overland flow may be filtered or deposited before it reaches the stream. Some effective BMPs to reduce *Cryptosporidium* transport may be manure composting and precision spreading away from tile lines and hydrologically sensitive areas that produce runoff. We will investigate the effectiviness of these practices.

One of the major difficulties with the investigation of *Cryptosporidium* lies with the detection methods. The traditional way of determining the concentration of *C. parvum* oocysts consists of a permeability assay combined with immunofluorescence staining. Depending on the concentration, samples from the effluent are either directly analyzed or concentrated by centrifugation. Several methods for the detection of *C. parvum* oocysts from environmental samples have been proposed but they are plagued by poor recovery efficiencies (Erickson, 1998). In addition, they are laborious, time consuming, expensive, and seldom provide information on the viability of the oocysts, which greatly limits the ability to study *Cryptosporidium* transport in the environment. The proposed effort will collaborate closely with Dr. A.J. Baeumner, an Assistant Professor in the Department of Agricultural and Biological Engineering at Cornell, whom has recently developed a simple bio-sensing instrument for measuring *C. parvum* rapidly and at low concentrations. It is based on the principles of flow-injection and test strip immunoassay systems (Durst et al., 1988: Baeumner and Schmid, 1998). Cooperative efforts with Dr. Baeumner and the sharing of collected water samples should lead to improved *Cryptosporidium* detection methods while at the same time enhance our ability to proceed with the proposed research.

Phosphorus

Phosphorus, a key nutrient in all life forms, chemically transforms through cyclical patterns of growth and decay. In agriculture, P serves a critical and essential role in cellular energy storage and transfer processes ultimately affecting plant growth (Wood, 1998). Due to P's importance to agriculture, various soil tests have been developed to detect the availability of phosphorus to plants. Phosphorus is not directly harmful to human health. However, P is directly linked to algae growth and accelerated eutrophication of surface waters. The U.S. EPA (1994) reported eutrophication as one of the leading problems facing the Nation's lakes and reservoirs. Eutrophication creates a variety of water quality problems including oxygen depletion and fish kills, noxious tastes and odors, clogged pipelines, and restricted recreation. More importantly, the eutrophic conditions lead to enhanced algal growth. When the algae decay, dissolved organic carbons are produced which leads to the production of potentially carcinogenic disinfection byproducts when the water is treated with chlorine. As a result, the control of P in the NYC watershed is also of critical importance.

Various studies have shown that a small number of P sources areally distributed within the watershed can contribute a significant share of total P load (Sharpley et al., 1993; Gburek et al., 1996; and Pionke et al., 1997). These typically nonpoint sources may behave like point sources during particular time periods. A study of the CRW revealed that a single period of precipitation caused 74, 34, and 75 percent of particulate P (PP), soluble P (SP), and total suspended solids (TSS) input to the reservoir, respectively, in 1996 (Longabucco and Rafferty, 1998). The acknowledgment and identification of critical contributing areas and potential runoff events could facilitate the implementation of targeted and concentrated watershed management efforts.

Cornell researchers in the Department of Agricultural and Biological Engineering have developed an analytical framework for classifying critical source-areas by their runoff potential. Three different types of critical areas have been identified: 1) shallow, sloping lands (Frankenberger et al., 1999), 2) barnyards (Kellog and Lander, 1999), and 3) flood plains (Weiler et al., 1999). Each of these areas is governed by different hydrological properties that create different patterns of P contribution. Accordingly, Hydrologically Active Areas (HAAs) refer to any area or field that has, on average, greater than 30 percent probability of runoff. Hydrologically Sensitive Areas (HSAs) are a subset of HAAs and are distinguished by their potential for contributing pollutants to water reaching a stream or drinking water. For management purposes, however, limited knowledge regarding pollutant transport in the watershed suggests that all HAAs be managed as HSAs (Porter et al., 1997).

Phosphorus is transported primarily via surface runoff in soluble and particulate form. However, subsurface leaching of SP may also be important in the NYC watershed. Particulate P transport is usually associated with surface erosion. Subsurface leaching of SP may occur rapidly through shallow soils (Scott et al., 1998a) or more slowly where leaching reaches a deeper ground water table. Particulate P is often the major portion (75 to 90 percent) of total P (TP) transported from cultivated lands, while SP is the major contributor from non-cultivated lands. The relative concentration of chemical species of P is important to management efforts because of varying reactivity and bio-availability to algae. It is generally assumed that SP is immediately available for algal growth. By contrast, the immediate availability of PP to plants and algae ranges from 10 to 90 percent of TP, depending on the concentration of TP in the receiving water (Correll, 1998).

Phosphorus management on farms and for a watershed is a complex problem involving a range of uncertainties and several myths (Sharpley, 1998). Quantifying the water quality impact of individual farms is inherently difficult. Any analysis must consider variations in farm management over time and due to weather conditions, management preferences, and resource availability. The environmental characteristics such as soils, topography, and hydrology of a farm in the context of the watershed are complex. Without direct monitoring, accurate estimation of pollutant loss may be hard to determine (Scott et al., 1998b). As a result, monitoring coupled with the use of models should make it more possible to deal with this complexity in watershed planning.

Best Management Practices

The approach taken by the WAP in developing cost-effective management practices has focused on WFP. Whole-farm planning is a farm systems approach to pollution prevention that results in strategies to integrate watershed hydrology, animal science, agronomy, and economics. In practice, WFP explores nutrient management and BMPs to determine practices that reduce pollution given a farm's specific land use and enterprise features. In this process, farmers are directly involved in planning, receive professional training, and cooperatively make decisions with technical field staff from various farm service agencies (e.g., Cornell Cooperative Extension, USDA-Natural Resources Conservation Service, and local Soil and Water Conservation Districts). The main difficulty with this approach is that impacts of most BMPs on water quality have not yet been well researched and are largely unknown, especially for the shallow, glacial till soils of the Catskill's region. This proposal will attempt to evaluate the affects of various BMPs on the fate and transport of *Cryptosporidium* and P.

Research and Monitoring in the TBW

Two stream flow gages already have been installed by USGS within the TBW of the CRW: 1) an "upper node" gage at the outlet of a mostly forested tributary and 2) a "lower node" gage at the TBW outlet. Stream stage (height) has been recorded since September, 1998, at the upper node gage, and since October, 1997, at the lower node gauge. In addition, 94 water samples at the lower gage and 52 samples at the upper gage have been collected to date for various water quality analysis. Samples were collected for an extremely large storm event on July 4, 1999, during Hurricane Floyd on September 16-20, 1999, as well as during low flow periods.

A major effort on determining soil P dynamics was also conducted by Kleinman et al. (1999a, b, c) in the TBW from 1997-1999. A method was developed to identify an environmental threshold for soil P. It was determined that 50 kg/ha Morgan soil test P was found to be a critical level for the soils that are characteristic of the TBW. In addition, changes in soil P fractions as a function of manure application rate and soil type were measured, indicating the critical role of liming on the solubility of P in the acidic Catskill soils (Kleinman, 1999). This background monitoring and the partnerships which have been established will facilitate the ability to carry out the objectives identified in this proposal.

OBJECTIVES

Practical considerations will dictate that only a limited number of BMPs can be implemented on a given field site. Consequently, a BMP should be multi-functional and control more than one priority pollutant. Since pathogens and manurial P are typically transported as colloids and attached to soil, our hypothesis is that BMPs that are effective in controlling manurial P may also be effective in controlling pathogen transport. Because of the highly infective nature of *Cryptosporidium,* direct field testing of BMPs to reduce *Cryptosporidium* poses a significant and potentially uncontrollable risk to the watershed. As a result, investigations with *Cryptosporidium* enriched manure will be limited to the laboratory.where relationships between *Cryptosporidium* and P can be developed and evaluated. These relationships will be verified and correlated to the field monitoring efforts. Based on these considerations and limitations, the objectives of this proposal are: 1) to improve detection methods for *Cryptosporidium,* 2) to investigate process-based factors of *Cryptosporidium* and P transport in the laboratory, 3) to evaluate P transport for various BMPs on field plots within the TBW, 4) to conduct field/subwatershed-scale studies for the determination of load factors, and 5) to develop and validate models for improved planning.

RATIONALE AND SIGNIFICANCE

The transport of *Cryptosporidium* and P from farms into the NYC water supply reservoirs is a critical concern. A recent review by a NRC panel of NYC's Watershed Plan to manage and prevent pollution of their reservoirs warned that the city needs to be more aggressive in tracking sources of waterborne parasites and in eliminating sources of organic compounds. Although significant efforts are already underway through the WAP to plan and implement BMPs on farms in the watershed, uncertainty regarding the effectiveness of these practices to improving water quality is still a major concern. The basis of concern is that the predominant, shallow glacial till soils in the watershed may not be effective filters of subsurface transported contaminants, an underlying premise for many of the BMPs used to reduce surface runoff. This proposal offers a systematic approach to improve the detection methods of *Cryptosporidium*, link the potential transport phenomena of *Cryptosporidium* simultaneously with that of P for these shallow soils, verify and collaborate on some intensive field and watershed scale monitoring, and develop improved models which should further facilitate pathogen and nutrient planning and implementation efforts. The proposed work will involve diverse collaborators from the College of Agriculture and Life Sciences at Cornell University in conjunction and cooperation with numerous NYC watershed participant cooperators including USDA-ARS Northeast region scientists, USGS, NYC Department of Environmental Protection, the Watershed Agricultural Council, and cooperating farmers. The work will include extensive investigations both in the laboratory and field, and a synthesis of collected data to support model validation. This project will be an important scientific component to the NYC watershed and should serve to enhance the understanding of *Cryptosporidium* and P transport through soils typical to the region, improve the reliability of BMP recommendations to improve water quality, and increase the availability of farm and watershed scaled models for pathogen and nutrient management planning.

RESEARCH METHODS

Proposed timeline

Stream monitoring at the TBW outlet and forest site has already begun and will continue throughout the project duration. During the first three months of the project, investigators and collaborators will review past research and experiences with BMPs and the data which has been collected in the TBW. In cooperation with the TBW farmers and with assistance of the WAP farm planners, selection of the candidate BMPs for implementation and evaluation will be finalized. The evaluation of these practices will start at a small plot or field scale during the first year and continue throughout the duration of the project. Adaptations to the field research will be made as the understanding of *Cryptosporidium* and P transport mechanisms is enhanced based upon the laboratory work. Once a particular BMP is determined to effectively reduce the amount of *Cryptosporidium* and/or P entering the stream at the smallest scale, we will implement and evaluate the practice at a field or subwatershed scale. By comparing water quality before and after implementation, a judgement can be made regarding the effectiveness of the practice.

Laboratory and field plot studies will be initiated before the end of the first year of the project. The laboratory work on *Cryptosporidium* detection will establish standard protocol for the collection, handling, and analysis. The laboratory work will be carried out primarily to establish the basic *Cryptosporidium* and P transport relationships. The investigations will address the interrelationships of several variables such as background availability of soil P, the type and rate of manured applied, timing of events, and concentrations of *Cryptosporidium* and P in surface and subsurface flows.

Tool and model development and improvement will occur simultaneously with laboratory and field experimentation. As the understanding of transport processes improves, these will be incorporated into the appropriate model(s). Once a model is properly validated, it will be modified to a form that is more easily used by the WAP planners and non-scientists. It is anticipated that the first model prototype will be finished approximately four years after the start of the project. The GIS database for the NYC watershed is also expected to be completed by that same time.

Objective 1. Improving detection methods for *Cryptosporidium:*
Work to detect viable *C. parvum* oocysts in potable water is currently underway with existing funds by Dr. Baeumner. However, there is still a need to improve and adapt the detection method in order to make the sampling and detection process more efficient for drainage and stream water samples. It is very much desirable to be able to collect smaller water samples during routine monitoring that can still be reliably used to detect viable oocysts. Therefore, the work of Objective 1 is to cooperate with Dr. Baeumner in the testing and adaptation of the bio-sensing instrument method for environmental water samples.

The bio-sensing instrument method entails identifying viable oocysts via the mRNA of heat shock protein *hsp70*. The nucleic acid is amplified isothermally using nucleic acid sequence-based amplification (NASBA), and the RNA amplicons are detected using the bio-sensing device in which a "reporter" probe, conjugated to marker-loaded liposomes, hybridizes with the amplified target RNA. The complex is applied to a nitrocellulose strip, migrates by capillary action and is bound by a "capture" probe immobilized in a narrow zone on the strip. Liposomes bound in the capture zone are then lysed with a surfactant releasing the entrapped electroactive marker molecules. Using an equimolar mixture of ferri/ferrohexacyanide as the marker, the analytical signal is detected with an interdigitated ultramicroelectrode array (IDUA) and is directly correlated to the concentration of *C. parvum* oocysts. IDUAs, fabricated using photolithography and lift-off techniques, give a much higher sensitivity for the detection of the electrochemically reversible ferri/ferrocyanide, compared to conventional electrodes or single ultramicro-electrodes, because of the redox cycling that occurs between the two sets of fingers. Various IDUA designs have been investigated, and the integration of IDUAs and nitrocellulose strips in a specially designed and fabricated plastic cassette is currently being optimized.

For the detection of *C. parvum* oocysts the following analytical operations are involved: 1) Perform initial concentration of *C. parvum* oocysts by filtration of large amounts of water (up to 10L if necessary), 2) Conduct the Immunomagnetic separation (IMS) of *C. parvum* oocysts using the Dynal

Corporation or ImmuCell Company *C. parvum* IMS kit. Typically, 10 ml of retentate is used per IMS reaction and the procedure takes approximately one hour, 3) Apply heat shock and nucleic acid extraction and purification, a step which requires about 1.5 hours, 4) Perform the nucleic acid amplification using NASBA, a step requiring about 2 hours, and than 5) Conduct the bio-sensing analysis procedure which requires about 20 minutes. Due to the low detection limit of the detection system, samples containing more than 10 oocysts per 100 µL can be used directly in the detection assay. Thus, filtration and IMS reaction are not necessary which can significantly decrease the assay time and cost. Typically, ten samples can be analyzed simultaneously in the times indicated.

Preliminary results with environmental samples show that the detection of 50 oocysts derived from environmental samples (e.g., 10 mL of filter retentate spiked with 50 oocysts) is easily possible at this time with an expected detection limit in environmental samples at or below 10 oocysts per sample. Tests also indicate that the method only detects viable *C. parvum* oocysts. The proposed plan is to continue testing in order to determine the specificity of the test system to determine if false positive signals can be caused by other *Cryptosporidium* species or other microorganisms. The analysis of different water samples from the laboratory work under Objective 2 and those from various locations in the TBW will help to determine whether or not false negative signals are obtained due to varying sample matrix effects. The measured concentrations will be compared and correlated with the method of Anguish and Ghiorse (1997) which is described in more detail under Objective 2 and with EPA's standard method (1622) which uses Immunofluorescence Microscopy to detect viable *C. parvum* oocysts.

Once the bio-sensing method is validated, stream water samples will be collected from the TBW to investigate affects of various BMPs described in Objectives 3 and 4. To ensure detection of oocysts in stream water, filtered samples will be collected manually in addition to the automatically sampled, unfiltered samples. A minimum of 140 liters of sample will be filtered at 4 liters per minute through a 254 mm long, 1 µm nominal porosity, yarn-wound polypropylene cartridge honeycomb filter tube (Commercial M39R10A or Filterite) with pressure relief valve, fixed in a manifold (Hoefer FH225V). Filters are stored at 4° C, and within 96 hours, will be opened, cored, and washed with eluting solution which is subsequently stored at 4 C (LeChevallier et al., 1995).

Objective 2. Investigate process-based factors of *Cryptosporidium* and P transport in the laboratory:

Laboratory experiments under controlled environmental conditions can provide insight into the processes controlling P mobilization and P and pathogen transport, as well as the potential effectiveness of BMPs under field conditions. Manure recently spread on the land surface is potentially an important source of pathogen and P loss, and it is important to examine BMPs regarding their effectiveness in reducing these contributions. We will conduct the laboratory investigations to investigate the affects of composting, manure incorporation, spreading manure away from HAAs, and the affects of winter spreading of manure. In the laboratory, manure will be obtained from animals housed either at Cornell University's research farms or from Mr. Post's Farm in the TBW. Manure from either source will be collected from calves which are most susceptible to infection with *Cryptosporidium*. The Post Farm composts their manure waste so this will be the source for the composted manure studies. The manure will be applied in these laboratory investigations at rates that would be generally recommended to meet the agronomic nitrogen requirements for growing corn.

Cryptosporidium oocyst transport through undisturbed soil columns will be correlated with the movement of dissolved constituents, specifically phosphate, and blue dye under simulated rainfall in the laboratory. Based on extensive experience with the preferential flow characteristics of the other constituents, this component of the project will significantly improve the scientific understanding of the processes of oocyst and P transport and retardation in subsurface flow. These findings should improve modeling of oocyst and P transport.

In the TBW, the soils typically have a restrictive layer within 50 cm from the surface. Consequently, subsurface flow of water in the field is principally parallel to this restrictive layer. In the laboratory, undisturbed mini-hillsites with intact macropore cracks, wormholes and root channels will be simulated using undisturbed soil blocks 20 cm wide, 90 cm long (down the slope), and 60 cm deep. These soil blocks will be extracted from fields in the TBW. The soil blocks will be collected by hand-digging the pillars of soil using special not to remove vegetation from the soil surface, dislodge embedded rocks, or otherwise disturb the structure of the soil pillar. The soil pillar will be encased in a sheet metal container about 1 cm larger than the excavated pillar. Void space between the soil pillar and the sheet metal casing will be filled with impermeable, expanding foam insulation along the entire width and length of the soil block. After allowing the foam to expand and set for 24 hours, each soil block will be detached from the profile and loaded into padded bins for transport to the laboratory. During initial collection of the soil blocks, 5 cm diameter soil cores to a depth of 60 cm will be obtained also adjacent to the soil pillar excavations. These cores will be dissected into 5 cm increments to obtain indigenous amounts of P using Morgan, Mehlich-3, water and $CaCl_2$ extractable P test procedures.

Once in the laboratory, the soil blocks will be placed in a controlled environment room on specially constructed holding frames. A plastic drain system will be affixed to the lower end of each of the soil blocks such that all water percolating through the soil can be collected. To establish and compare flow transport processes, experiments will be carried out with the aid of a laboratory scale rainfall simulator which was developed at Cornell. The rainfall simulator is capable of applying water uniformly at low application rates to various laboratory sized soil columns. The rainfall simulator can uniformly distribute a constant flow of water to the soil surface. A rainfall dispersal grid is achieved by two electric motors whereby each motor moves a bar supporting ten 3cc syringes in the horizontal plane, one in a direction perpendicular to the other. The needles are suspended 20 cm above the soil surface. Ten 3 m lengths of 0.95 cm (3/8 inch) inside diameter nalgene plastic tubing connect the 10 syringes to the pumps. Five peristaltic pumps driving two pumpheads (Masterflex 7013) each deliver the desired flow to the soil blocks. The rainwater chemistry will be simulated by mixing the chemical constituents typical of rainfall in the Catskills region of NY with de-ionized water. A 25 mmol/L $CaCl_2$ solution will be also applied through the rainfall simulator as a tracer during the simulated rainfall events. The timing and duration of the tracer pulse will vary with the treatment investigation but will be carried out until the bulk of the tracer has passed through. The drainage from the soil blocks will be composite samples grab collected at different time intervals according to the different rainfall application rates and breakthrough response. These composite samples will provide the subsamples for *Cryptosporidium*, P, N, and chloride analysis and will also provide a measure of the bulk flows. A higher frequency of sampling will be used during the rising limb of the surface runoff and breakthrough hydrographs. All collected samples will be immediately placed into a refrigerator at 4° C, and stored there for analysis within the next 24 hours.

Composting Treatment Investigation:
In this experiment, *Cryptosporidium* and P concentrations in runoff and interflow will be compared between composted and fresh manure as a function of time after spreading for different environmental conditions. Composted and fresh manure will be obtained from the Post Farm. The oocyst concentration in the manure and compost heap will be measured periodically to determine the survivability rate of oocysts in the composting process. Likewise, the manure and compost will be evaluated for changes in P and N. After steady state flow is established in the undisturbed soil blocks, the composted and fresh calf manure will be surface applied at an agronomic rate. Separate experiments will be carried out using two rainfall rates of 0.75 and 3 cm/day, and two temperatures of 5 and 15° C. The experiment will be stopped after 60 to 90 days at which time it is anticipated that the P concentration will have reached the steady state flow background levels.

Manure Incorporation Treatment Investigation:
It has long been advocated that incorporation of manure shortly after application reduces the agronomic loss of nutrients, particularly N, and also reduces the loss of pathogens and P in surface runoff. Incorporation may increase pathogen and P concentration in the interflow but only limited research has been done in this area. This investigation will entail incorporating the manure to simulate surface application of manure followed by chiseling and manure injection. For this investigation we will use duplicate pairs of soil blocks and apply rainfall at a rate of 1 cm/day at room temperature.

Spreading Manure away from HAAs Treatment Investigation:
This treatment will be designed to investigate pathogen and P transport when manure is spread on saturated (defined as the HAA) or unsaturated soil conditions. Two soil blocks will be set up to drain freely (unsaturated condition), and two will be set up so that the subsurface drainage discharge can be restricted (controlled) to induce saturation and overland flow. The manure will be applied to the surface of all the soil blocks. A rainfall of 1 cm/day will be applied at room temperature. Both *Cryptosporidium* and P will be determined in the surface and subsurface runoff from the soil blocks. Similar to the compost treatment, the experiment will be stopped after 60 to 90 days.

Winter Spreading of Manure Treatment Investigation:
The winter spreading of manure will be investigated by placing the soil blocks outside and exposing them to the natural conditions of an Ithaca, NY, winter. Eight soil blocks will be used during this investigation. The manure will be applied to two of the soil columns beginning in January, to two of the soil columns beginning in February, to two of the soil columns beginning in March, and finally to the remaining two soil columns beginning in April. The interflow and surface runoff will be measured from all the columns simultaneously in response to any snow, rain, or snowmelt events. The soil blocks will be instrumented with thermocouples at 10 cm depth intervals in order to measure the temperature and frost front in the soil columns. In this treatment, no manure will be applied that contains viable *Cryptosporidium* oocysts.

Following the simulated rainfall studies, one replicate of the columns will be destructively sampled to quantify the amount and forms of soil P throughout the soil profile. The residual *Cryptosporidium* in the soil columns will also be determined. The other replicate of cores will be allowed to completely drain and dry for 10 days after the first application of manures and water, followed by a second application of manures, water, and tracer pulse using the same procedure described above. This will allow us to examine the affect of having a lower initial moisture content on the transport of *Cryptosporidium* and P, and evaluate the possibility of any regrowth of organisms. At the end of this second run, these columns also will be destructively sampled. Preliminary studies have shown that surface runoff P is most closely related to water extractable soil P, while leachate P is most closely related to $CaCl_2$ extractable soil P. This phase of the project will provide a more detailed understanding of *Cryptosporidium* and P transport processes through the TBW soils than what could be obtained from water quality monitoring and field studies alone.

The method that will be used to determine *C. parvum* oocyst concentrations in the water and manure samples was developed by Anguish and Ghiorse (1997) who adds a fluorescent antibody detection step to the method of Campbell et al. (1992). It consists of oocyst isolation, staining, and counting procedures. Non viable oocysts are permeable to 4',6-diamidino-2-phenyllindole (DAPI) and propidium iodide (PI). Highly potentially infectious oocysts are impermeable to DAPI and PI or low potentially infectious oocysts are permeable to DAPI, (Campbell et al., 1992). This method will be used until the bio-sensing method described in Objective 1 is fully tested and provides reliable results. In this method, eluted filter samples and direct effluent samples are transferred to graduated, polyethylene centrifuge tubes. The samples are than centrifuged at 2100 rpm for 12 minutes and the supernatant is transferred to a new vessel or discarded. The pellot is than rinsed with 0.5 ml of 0.01M PBS solution prepared with Azide and 0.05% Tween 20 (PBS-T) and 3 ml of distilled water and slowly vortexed to mix. An additional 3 ml of distilled water is added to each test tube and vortexed to bring any remaining oocysts in the tube into the solution. After centrifuging the tubes again at 2100 rpm for 12 minutes, the supernatant is discarded and 0.5 ml of PBS-T is added to the pellot. The pellot and the PBS-T is vortexed and the mixture is pipetted to a 1.5 ml microcentrifuge tube. Upon isolating the oocysts from the field samples, the oocyst staining preparation begins. The samples are vortexed for 30 seconds and sedimented into a microcentrifuge at 11,000 rpm for an additional 30 seconds. After properly discarding the supernatant, the tube contents are rinsed with 1 ml of 0.01M PBS Azide solution (PBS). The tubes are vortexed and centrifuged at 11,000 rpm for 30 seconds, and the supernatant is discarded. Primary antibody reagent prepared by EnSys, Inc. is diluted by 10 times with PBS and 50 µL of the solution is pipetted into each microcentrifuge tube and gently mixed. The samples are incubated for 35 minutes at room temperature with the primary antibody reagent. After incubation, the samples are rinsed with 1 ml of PBS, vortexed, and centrifuged, and the supernatant is discarded. The FITC-conjugated labeling reagent prepared by EnSys, Inc. is diluted by 10 times and 50 µl of the solution is pipetted into each tube and stirred. The samples are incubated in the dark at room temperature for 35 minutes. As before, the samples are rinsed with 1 ml of PBS, vortexed, centrifuged for 30 seconds, and separated from the supernatant following incubation.

Preparation for the hemacytometer consists of adding PBS to the 0.5 ml graduation on each tube and stirring to ensure equal mixing. Then 10 µl of sample is pipetted to each of the two counting chambers on the levy chambered hemacytometer. Each of four counting chambers holds 0.25 µl of sample and consists of a square counting grid with 25 major boxes, each box containing 16 minor grid boxes. Using a Zeiss LSM 210 Confocal Laser Scanning Microscope with 630x magnification, oocysts are counted and differentiated from other microorganisms via epifluorescence microscopy (Anguish and Ghiorse, 1996). A volume of 1 μl per sample is counted. The number of oocysts in the 1 μl of sample is multiplied by 1×10^6 and by the ratio of the counting volume (0.5 ml) to the original volume of manure in the microcentrifuge tube to arrive at the number of oocysts per milliliter of sample. This procedure is repeated five times to calculate average concentrations.

The *C. parvum* oocyst concentration in the soil is determinated after extracting oocysts from the soil by placing 15 to 20 g soil sample in a 50 ml centrifuge tube with 15 ml of PBS Tween extraction solution (1X PBS 0.1% Tween 80, pH 7.2 at 24°C). The tube is shaken horizontally for 20 min at low speed and 10 min at high speed. The slurry is underlain by a 15 ml cold sucrose (5°C, specific gravity 1.18) by injection with a syringe with an 18x40 mm hypodermic needle. The tube with the sucrose solution and slurry is then centrifuged at 2700 g for 20 min with brake off. Ten ml of liquid near the sucrose/solution interface is withdrawn using a syringe with a 18x40 mm hypodermic needle, and diluted with 1x PBS (1:4 v/v) to make a volume of 50 ml, and then agitated. This solution is centrifuged at 2700g for 30 min with brakes on resulting in a pellet in the bottom of the tube. The solution is aspirated except for the last 1 ml. The pellet and the1 ml liquid is vortexed and transferred into an 1.5 ml eppendorf tube. The content of the eppendorf tube is vortexed and 1 ml of sample is taken for the dye permeability assay procedure described above for the water analysis.

The water samples that will be analyzed for P, N, and chlorides will be done utilizing standard methods for the analysis of water and wastewater (Eaton et al., 1995). A Dionex DX-100 ion chromatograph will be used for the chloride analyses.

All the soil block experiments, except for the winter spreading treatment, will be conducted in a contained room away from other activities. All personnel will have to use lab coats, latex gloves, boot covers, and will have to pass through a disinfecting basin upon entering and exiting this isolated facility. All effluent not being analyzed will be collected and disinfected with Roccol-D (Winthrop Veterinary) so as to inactivate all oocysts according to established procedures. All the soil will be autoclaved also at the end of these experiments.

All the data from the measured outflow concentrations in the effluent samples, the column outflow rate, the column area, the sample time interval data, the initial concentration in the manure, and the volume of water applied to the column during the entire experiment will be used to determine relative concentration (C/Co) values. The relative concentration values will then be plotted versus the rainfall amount. The flux of chloride will be compared to the flux of *Cryptosporidium* and P to improve the understanding of the processes of *Cryptosporidium* and P transport and retardation in subsurface flow. The application versus outflow amounts will give us a collection efficiency and hopefully a mass balance closure to improve the ability to model the transport mechanisms. The data will be evaluated according to the different treatments. The duration of completing Objective 2 will be 2 years.

The results of these process-based studies will be incorporated into models which, when tested and verified, can be used to evaluate effectiveness of BMPs in the more generic watershed context. Due to the temporally and spatially variable pathogens sources, and the small amount of pathogens needed for human infection, risk based factors will be included in the models for *Cryptosporidium*.

Objective 3) Evaluating P transport for various BMPs on field plots within the TBW:
The research under this objective will be carried out in the 37-km^2 Town Brook Watershed (TBW) where some water quantity and quality monitoring and associated data collection are already underway by USGS. Selection of sites and BMPs to be evaluated will be done in cooperation with TBW farmers, WAP staff, USGS, ARS, and NYCDEP. The BMPs will be primarily selected to evaluate P reductions and most of the P investigations will be performed by ARS with other funding. Cornell researchers will collect the soil blocks from these same sites for Objective 2, and perform additional water sampling for *Cryptosporidium* analysis. It is recognized that P losses are associated with excess P in the soil and the application of manure P from all farm animals, whereas *Cryptosporidium* losses are only associated with manure from infected animals and are temporal in nature. Therefor, the procedure for selection of sites for BMP implementation and evaluation are based on: 1) testing BMPs for soils that already have existing high available P, and 2) testing BMPs intended to improve manure and fertilizer management.

BMP implementation and evaluation (with exception of the buffer strips) will be done in a replicated field/plot format. Selected fields within the TBW will be divided into bounded plots large enough to be individually representative of the field-scale processes controlling runoff generation and transport. All plots will be sampled for surface soil test P (the principle control on runoff P concentration) prior to the treatment, immediately thereafter, and at frequent intervals throughout the duration of the experiment. Each plot will also be instrumented to collect runoff and tile flow and water sampling will be carried out on a volume averaged basis. This means that most samples will be collected during a few specific storms. Subsurface flow water quantity and quality will be sampled with passive pan or wick samplers for the sites where tile flow sampling is infeasible or nonexistent. Particulate, soluble and organic phosphorus fractions will be measured. Soluble organics (as dissolved organic carbon, DOC) and various N species (e.g., nitrate-N and Total kjeldahl N) will be also measured on a subset of the samples. Sampling for *Cryptosporidium* will be more frequent during high flow periods when preferential flow is also likely to occur. In all cases, the TBW farmers will be compensated for land used in the research and impacts on their routine farming operations.

Objective 3.1 BMPs that moderate high P content of existing sources:
Four BMPs will be evaluated to address the soils with existing high P levels. These will be: 1) bufferstrips, 2) using additives or composted manure to reduce the availability for P solubilization and transport, 3) cover crops, and 4) deep tillage. Cornell will be involved only with the first two measures from which we intend to collect and analyze a subset of water samples for *Cryptosporidium*. Thus, only these two measures will be discussed.

Bufferstrip Investigations:
It is important to identify if riparian zones within the TBW can act as significant sinks of *Cryptosporidium* and P loss from the watershed farms. Although little is known about the entrapment and fate of *Cryptosporidium* in bufferstrips, there is evidence that near-stream riparian zones bordering agricultural uplands can act as sinks for dissolved and particulate P and N. The effectiveness of these zones depends on several factors including flow path, vegetation type, soil

depth, aerobic status, and soil chemistry (Peterjohn and Correll, 1984; Cooper, 1990; Brüsch and Nilsson, 1993; and Basnyat et al., 1999). Two riparian buffer strips will be installed within the TBW. The buffer strips will be instrumented with ground water sampling wells, piezometer nests, and wick pan samplers to measure subsurface water chemistry, and overland flow collectors to measure surface water chemistry upgradient, within, and downgradient of the strips. By locating instrumentation above, within, and below riparian zones both the direction of subsurface flow and changes in surface and sub-surface water chemistry can be measured to determine the effectiveness of these zones to remove *Cryptosporidium* and P from farm runoff within the TBW. Cornell will analyze a subset of the collected water samples from these instruments for *Cryptosporidium* using procedures described in Objectives 1 and 2.

Reducing P availability in soil and manure by additives and/or composting:
Plot studies will be initiated to evaluate the effect of P-immobilizing manure additives (PIMAs) and manure composting on *Cryptosporidium* and P losses in surface runoff and leachate from TBW soils. Research by ARS and Cornell has identified a variety of PIMAs that may reduce the solubility of soil P or that of manure P prior to application. Thus, these may limit the potential for P loss in runoff and leaching. The three PIMAs that will be assessed are aluminum chloride, anthracite fly ash, and wollastonite (a calcium based meta-silicate mineral mined in New York). Since composting also reduces the amount of dissolved P in the manure, the addition of composted manure will also be evaluated. Thirty 100 m^2 bounded plots will be established on 12 fields within the watershed. Plots will be paired to allow for side-by-side comparison of treated and untreated manure. The plots will be instrumented and water samples analyzed similar to that described for the buffer strips. Manure application and cropping patterns will follow those of the farmers whose fields are included in the study. An economic assessment, including cost and potential crop yield impacts, will be conducted to determine the cost per unit of immobilized P.

Composting has the advantage above the other methods in that it also might be effective in killing oocysts. We will take weekly samples from the manure and compost pile from the calf house on the Post farm. Currenly, the compost is land applied. We will use some of this compost in Objective 2 as well as on the plot studies and sample the runoff from these plots for *Cryptosporidium*.

Objective 3.2 BMPs intended to improve manure and fertilizer management:
The affect of manure, fertilizer, and soil management on the transport of *Cryptosporidium* and P will be investigated at selected sites to represent local P and land management practices. The two practices that will be evaluated are manure application scheduling and the use of additives and/or practices to reduce the P input in feeds. Cornell will be involved only in the manure application scheduling evaluation.

Manure Application Scheduling Investigations:
Most surface runoff is produced from selected areas within the farm and these areas vary with season and short term climatic conditions (Gburek et al., 1996). Avoiding manure application to these areas when they are hydrologically active should reduce *Cryptosporidium* and P loss from the farm. In consultation with the TBW farmers, plots will be established on selected fields that exhibit hydrologic activity either seasonally or as the result of storm events. Manure will be spread on some of the plots when they are dry and no rain is evitable in the weather forecast. Some plots will receive a daily

spreading of manure as is typically the practice now. Manure application rates will be based on the nitrogen content to meet fertility requirements for corn. Some of the plots will not have had any manure or fertilizer P additions in the last six months as a basis of comparison to investigate the residual affect of soil P on surface runoff P.

Surface runoff and subsurface flow will be evaluated on these plots. The ARS team developed a portable rainfall simulator for 1.5 m^2 plots (2 m long and 0.75 m wide) that is currently being used to evaluate threshold soil P levels in areas where P enrichment of surface runoff impairs water quality. These small plots will be equipped with a gutter to divert surface runoff to in-ground bottles. Pan lysimeters will be also installed to collect any percolate after each runoff event. Chloride tracers will be applied to the plots also prior to the rain event. After each flow event, the surface runoff will be pumped from the collection bottles, measured, and subsampled for analysis of *Cryptosporidium*, P, and N forms. These analysis will include dissolved P, algal-available, and TP; nitrate-N and total N; and suspended sediment. At each field site, there will be two control plots while others will vary in manure application rate and timing. After the intensive rainfall simulations, any additional precipitation on the plots will be recorded and runoff and percolate samples will be periodically collected and analyzed. This will be continued for the balance of the growing season until adverse weather prevents further sampling. This data, along with the laboratory work, will allow for improved understanding of relationships between soil nutrient content, land management, and *Cryptosporidium* and P transport in surface and subsurface flow. This investigation will be implemented and examined cooperatively by ARS and Cornell.

Prior to manure spreading, the soil will be sampled to a depth of 1.0 m (using the average of three cores at 0-5, 5-15, 15-30, 30-45, 45-65, 65-100 cm depth increments) to establish background *Cryptosporidium* and soil nutrient status and availability. This characterization will include: soil moisture content; percent organic matter; chloride; Morgan, Mehlich-3, water, and $CaCl_2$ extractable P, available nitrate-N, and *Cryptosporidium*. Soil sampling will be repeated after the end of the irrigation event. The moisture content of the soil will be determined prior to and after the irrigation using standard oven drying gravimetric procedures, and the nutrient content of the soil will also be evaluated using standard test methods. The *Cryptosporidium* counts will be measured similar to that described for the soil columns in Objective 2.

Objective 4) Conducting field/subwatershed-scale studies for the determination of load factors: The BMPs detailed previously must ultimately be implemented and evaluated at the field or subwatershed scale. It is important to incorporate the variability inherent in climate and landscape into any BMP evaluation, because lab and plot scale studies do not always include these effects. Based on the work and field plot sites selected in Objective 3, complementary fields and/or subwatersheds sites within the TBW will be selected for monitoring and experimentation before and after BMP implementation. A minimum of four surface and subsurface water quality monitoring stations will be selectively installed at these locations. Surface monitoring stations will be established within existing drainage ditches and first-order streams, while subsurface flow will be monitored using existing tile lines. These monitoring stations will provide for continuous flow-integrated P and *Cryptosporidium* load under existing conditions, and also provide further insight into the watershed processes controlling P and *Cryptosporidium* loss.

The watershed-scale stream monitoring that is currently underway by USGS will be broadened to include *Cryptosporidium* analysis. Stream water chemistry samples will be collected weekly and on a storm event basis (using automated samplers). The minimum analytical suite for all samples will be: total phosphorus (TP), total dissolved phosphorus (TDP), soluble reactive phosphorus (SRP), nitrate+nitrite-N (NOX), total nitrogen (TN), total organic carbon (TOC), and total suspended solids (TSS). Samples for *Cryptosporidium* analysis will be collected by USGS and sent to Cornell for analysis after filtering. Stream water chemistry and flow data from this monitoring effort will be used to calculate nutrient and *Cryptosporidium* loads to determine the affects of BMP implementation at the TBW scale.

Objective 5) Developing and validating models for improved planning:
A suite of field and watershed-scale models will be evaluated as to their applicability in extrapolating the experimental findings. Models that can be validated based on the collected data will be further developed to support the nutrient management planning and BMP implementation efforts of the WAP. The modeling suite that will be evaluated will include: 1) a P-index model to gauge the relative risk of P loss from agricultural watersheds based on the analysis of P source and transport factors, 2) a spatially distributed hydrology-water quality model to map critical hydrologic source-areas and quantify pathogen and P loadings by simulating the small-scale processes that govern pathogen and P transport and determine the effectiveness of BMPs, and 3) a broad-scale watershed loading model to evaluate pathogen and P loadings to the TBW outlet and the Cannonsville Reservoir as a function of source and transport factors. In concert, these models will provide a comprehensive approach to tracking pathogen and P flows and to evaluate any reductions due to implementation of BMPs.

Currently, the NYCDEP estimates contributions of P to the water supply reservoirs with a generalized watershed loading function (GWLF) model (Schneiderman et al., 1998). The recently developed Soluble Phosphorus Export Model (SPEX) (Brooks et al., 1999) relates dissolved P concentrations to manure spreading. These models will be evaluated and improved to incorporate soil P-index and P transport aspects based on the data collected with this research. The modified distributed model will be based on the Soil Moisture Routing (SMR) Model (Zollweg et al., 1996; Frankenberger et al., 1999; Kuo et al., 1999), but may also incorporate facets of TOPMODEL (Beven and Kirkby, 1979). The SMR model is a spatially distributed water-balance model designed and tested for the sloped, shallow soils typical of the Catskill region. The model simulates variable runoff source-areas (areas on the landscape where runoff is generated) by identifying zones of saturation excess. It has been refined through discussions with farm planners to include a prediction of the probability of frozen soils. Output can be as graphical GIS images depicting the spatial and temporal distribution of soil moisture patterns across the farm, or as a tabular listing of months ranked according to their probability of producing runoff. TOPMODEL is also a spatially distributed water balance model. It incorporates spatial variability in topography and has been improved to include soil variability (Sivapalan, et al., 1987; Famiglietti et al., 1992). Additionally, TOPMODEL is designed to run on shorter time steps to improve the performance during storm events. Currently, there is no user friendly graphical interface for TOPMODEL.

Nutrient and pathogen transport will be incorporated into the final spatially distributed model through links to a series of process-based nutrient loading function submodels. These loading function submodels will include functions to simulate P sources and runoff concentrations in surface and subsurface runoff under various management conditions. Routines to simulate *Cryptosporidium* will be based on the laboratory and field plot experiments and to simulate the relatively rare occurrence of spreading manure from infected animals on each farm. Working versions of several of these submodels are currently in use. Tool and model testing and improvements to these models will occur throughout the duration of the project using the experimental data collected at the different scales. An important goal of this task is to develop software packages that can be used directly by the WAP farm planners, watershed managers, and farmers.

REFERENCES

Adal, K.A., C.R. Sterling, and R.L. Guerrant. 1995. *Cryptosporidium* and related species. In: Blaser, M.J., P.D. Smith, J.I. Ravdin, H.B. Greenberg, and R.L. Guerrant (Eds.), *Infections of the Gastrointestinal Tract*. Raven Press, NY. pp. 1107-1128.

Anguish L.J. and W.C. Ghiorse. 1997. Computer-assisted laser scanning and video microscopy for analysis of *Cryptosporidium Parvum* oocysts in soil, sediment and feces. *Appl. Environ. Microbiol.* 63(2):724-733.

AWWA. 1988. *Cryptosporidium* roundtable. *J. Am. Water Works Assoc.* 80:14-27.

Basnyat P., L.D. Teeter, K.M. Flynn, and B.G. Lockaby. 1999. Relationships between landscape characteristics and nonpoint source pollution inputs to coastal estuaries. *Environ. Management* 23:539-549.

Baeumner, A.J. and R.D. Schmid. 1009. Development of a new immunosensor for pesticide detection: a disposable system with liposome-enhancement and amperometric detection. *Biosensors & Bioelectronics* 13(5):519-529.

Beven, K.J. and M.J. Kirkby. 1979. A physically based, variable contributing area model of basin hydrology. *Hydrol. Sci. Bull.* 24:43-69.

Bitton, G. 1975. Adsorption of viruses onto surfaces in soil and water. *Water Research*, 9:473-484.

Bitton, G. 1999. *Wastewater microbiology*, 2nd Ed. Wiley-Liss, Inc., New York, NY. pp. 111-113.

Boria, W.T., M.P. Wilson, and W.D. Gollnitz. 1992. Natural filtration in porous media aquifers. Proceedings American Water Works Association Water Quality Technology Conference, November 15-19, 1992, Toronto, Ontario, pp. 1871-1888.

Brooks, E.S., M.T. Walter, J. Boll, M.F. Walter, C.A. Scott, P. Kleinmann, and T.S. Steenhuis. 1999. Soluble phosphorus transport from manure-applied fields under various spreading strategies. (Submitted to *J. Environ. Qual.).*

Brüsch, W. and B. Nilsson. 1993. Nitrate transformation and water movement in a wetland area. *Hydrobiologia* 251:103-111.

Brush, C.F., W.C. Ghiorse, L.J. Anguish, J.-Y. Parlange, and H.G. Grimes. 1999. Transport of *Cryptosporidium parvum* oocysts through saturated columns. *J. Environ. Qual.* 28:809-815.

Campbell A.T., R. Haggart, L.J. Robertson and H.V. Smith. 1992. Viability of *Cryptosporidium parvum* oocysts: correlation of in vitro excystation with inclusion or exclusion of fluorogenic vital dyes. *Appl. Environ. Microbiol.* 58 : 3488-3493.

Clancy, J.L., W. Gollnitz, and Z. Tabib. 1994. Commercial labs: How accurate are they? *Jour. Of the Am. Water Works Assoc.* 86:(5):89-97.

Cooper, A.B. 1990. Nitrate depletion in the riparian zone and stream channel of a small headwater catchment. *Hydrobiologia* 202:13-26.

Correll, D.L. 1998. The role of phosphorus in the eutrophication of receiving waters: A review. *J. Environ. Qual.* 27:261-266.

Current, W.L. and L.S. Garcia. 1991. Cryptosporidiosis. *Clin. Microbiol. Rev.* 4:325-358.

Daniels, S. 1980. Mechanisms involved in sorption of microorganisms to soil surfaces. In: Bitton, G. and Marshall, K.C., (Eds.). *Adsorption of Microorganisms to Surfaces.* John Wiley and Sons, New York. pp. 5-58.

Darnault, C.J.G., P. Garnier, T.S. Steenhuis, J.-Y. Parlange, P.C. Baveye, M. Jenkins, and W.C. Ghiorse. 1999. Role of preferential flow for the subsurface transport of *Cryptosporidium parvum* oocysts through the vadose zone. (Poster) 1999 International Symposium on Subsurface Microbiology. Vail, CO.

DuPont, H.L., C.L. Chappell, C.R. Sterling, P.C. Okhuysen, J.B. Rose, and W. Jakubowski. 1995. The infectivity of *Cryptosporidium parvum* in healthy volunteers. *N. Engl. J. Med.* 332:855-859.

Durst, R.A., L. Locascio-Brown, A.L. Plant, and M.V. Brizgys. 1988. Liposome-enhanced flow injection immunoanalysis. *Clin. Chem.* 34:1700-1701.

Eaton, A.D., L.S. Clesceri and A.E. Greenberg (Eds.). 1995. *Standard methods for the examination of water and wastewater.* Am. Public Health Assoc., Washington, DC.

Erickson, B. 1998. EPA seeks alternative to indirect fluorescent antibody procedure. *Anal. Chem.* 70(1):49A-52A.

Famiglietti, J.S., E.F. Wood, M. Sivapalan and D.J. Thongs. 1992. A catchment scale water balance model for FIFE. *J. Geophys. Res.* 97(D17):18997-19007.

Frankenberger, J.R., E.S. Brooks, M.T. Walter, M.F. Walter, and T.S. Steenhuis. 1999. A GIS-based variable source area hydrology model. *Hydrol. Process.* 13:805-822.

Garber, L.P., M.D. Salman, H.S. Hurd, T. Keefe, and J.L. Schlater. 1994. Potential risk factors for *Cryptosporidium* infection in dairy calves. *J. Am. Vet. Med. Assoc.* 205:86-91.

Gburek, W.J. and A.N. Sharpley. 1998. Hydrologic controls on phosphorus loss from upland agricultural watersheds. *J. Environ. Qual.* 27:267-277.

Gburek, W.J., A.N. Sharpley, and H.B. Pionke. 1996. Identification of critical source areas for phosphorous export from agricultural catchments. In: Anderson, M.G. and S.M. Brooks, (Eds.), *Advances in Hillslope Processes*, Vol. 1, , John Wiley and Sons, pp. 263-282.

Geldreich, E.E. 1990. Microbiological quality of source waters for water supply. In: Mc Feters, G.A. (Ed.), *Drinking water microbiology,* New York, NY Springer Verlag.

Grotenhuis, J.T.C., C.M. Plugge, A.J.M. Stams, and A.J.B. Zehnder. 1992. Hydrophobicities and electrophoretic mobilities of aneaerobic bacterial isolates from methanogenic granular sludge. *Applied and Environmental Microbiology.* 58:1054-1056.

Kellogg, R.L. and C.H. Lander. 1999. Trends in the potential for nutrient loading from confined livestock operations. NRCS/USDA Conference Poster Presentation for "The State of North America's Private Land," Chicago, IL, January 19-21, 1999.

Kleinman, P.J.A. 1999. Examination of phosphorus in agricultural soils of New York's Delaware River Watershed. Ph.D. Dissertation, Cornell Univ., Ithaca, NY.

Kleinman, P.J.A., R.B. Bryant, and W.S. Reid. 1999a. Development of pedotransfer functions to quantify phosphorus saturation of agricultural soils. *J. Environ.Qual.* 28 (in press).

Kleinman, P.J.A., R.B. Bryant, W.S. Reid, A.N. Sharpley, and D. Pimentel. 1999b. Identifying environmental thresholds of soil phosphorus from Quantity/Intensity relationships. (Submitted to *Soil Science Society of America J.*).

Kleinman, P.J.A., M.N. Marshall, W. Tone, R.B. Bryant, and A.N. Sharpley. 1999c. Use of decision simulation model to evaluate alternative manure management strategies. (Submitted to *J. Soil and Water Conserv.*).

Kramer, M.H., B.L. Herwaldt, G.F. Craun, R.L. Calderon, and D.D. Juranek. 1996. Waterborne disease: 1993 and 1994. *J. Am. Water Works Assoc.* 88:66-80.

Kuo, W.L., T.S. Steenhuis, C.E. McCulloch, C.L. Mohler, D.A. Weinstein, S.D. DeGloria, and D.P. Swaney. 1999. Effect of grid size on runoff and soil moisture in a GIS-based, variable-source-area hydrology model. *Water Resour. Res.* (in press).

Kwa, B.H., M. Moyad, M.A. Pentella, and J.B. Rose. 1993. A nude mouse model as an in vivo infectivity assay for cryptosporidiosis. *Water Sci. Technol.* 27:65-68.

LeChevallier, M.W., W.D. Norton, J.E. Siegel, and M. Abbaszadegan. 1995. The evaluation of the Immunofluorescence procedure for detection of *Giardia* cysts and *Cryptosporidium* oocysts in water. *Applied and Environmental Microbiology* . 61:690-697.

Longabucco, P. and M.R. Rafferty. 1998. Analysis of material loading to Cannonsville Reservoir: Advantages of event-based sampling. *J. Lake and Reservoir Manage.* 14:197-212.

Mackenzie, W.R., N.J. Hoxie, M.E. Porter, M.S. Gradus, K.A. Blair, D.E. Peterson, J.J. Kazmierezak, D.G. Addiss, K.R. Fox, J.B. Rose, and J.P. Davis. 1994. A massive outbreak in Milwaukee of *Crptosporidium* infection transmitted through the public water supply. *N. Eng. J. Med.* 331:161-167.

Madsen, E.L. and Alexander M. 1982. Transport of Rhizobium and Pseudomonas through soil. *Soil Science Society of America Journal.* 46:557-560.

Mawdsley, J.L., A.W. Brooks, R.J. Merry. 1996. Movement of the protozoan pathogen *Cryptosporidium parvum* through three contrasting soil types. *Biology and Fertility of Soils.* 21:30-36.

McCaulou, D.R., R.C. Bales, and R.G. Arnold. 1995. Effect of temperature-controlled motility on transport of bacteria and microspheres through saturated sediment. *Water Resources Research.* 31:271-280.

Mills, A.L., J.S. Herman, G.M. Hornberger, and T.H. DeJesus. 1994. Effect of solution ionic strength and iron coatings on mineral grains on the sorption of bacterial cells to quartz sand. *Applied and Environmental Microbiology.* 60:3300-3306.

National Research Council (NRC). 1999. *Watershed management for potable water supply: Assessing New York City's Approach.* National Academy Press. Washington, DC. 442 pp.

New York City Department of Environmental Protection (NYCDEP). 1998a. DEP pathogen studies of *Giardia* spp., *Crptosporidium* spp., and enteric viruses. January 31, Valhalla, NY

NYCDEP. 1999a. Waterborne disease risk assessment program. 1998 Annual Report. Corona, NY.

New York State Water Resources Institute (NYSWRI). 1997. Science for whole farm planning. Cornell University Phase II 12th Quarter and Completion Report. Ithaca, NY.

Ongerth, J.E. and H.H. Stibbs. 1987. Identification of *Crptosporidium* oocysts in river water. *Appl. Environ. Microbiol.* 53:672-676.

Peterjohn W.T. and D.L. Correll. 1984. Nutrient dynamics in an agricultural watershed: Observations on the role of a riparian forest. *Ecology* 65:1466-1475.

Pionke, H.B, W.J. Gburek, A.N. Sharpley and J.A. Zollweg. 1997. Hydrological and chemical controls on phosphorus loss from catchments. In: Tunney, H., O.T. Carton, P.C. Brookes, and A.E. Johnston (Eds.). *Phosphorus Loss from Soil to Water*, New York, NY. Cab International, Chap. 10, pp. 225-242.

Porter, M.J., L. Beckhardt, K.S. Porter, B.Y. Perigard. 1997. Pollution prevention through effective agricultural management. Progress Report: Watershed Agricultural Program for the New York City Watersheds. Watershed Agricultural Council, December 1997.

Rose, J.B. 1997. Environmental ecology of *Crptosporidium* and public health implications. *Annual Reviews in Public Health* 18:135-161.

Rosenberg, M., and R.J. Doyle. 1990. Microbial cell surface hydrophobicity: History, measurement, and significance. In: Doyle, R.J., and Rosenberg, M., (Eds). *Microbial Cell Surface Hydrophobicity. American Society for Microbiology*, Washington, DC.

Schneiderman, E.M., D.G. Lounsbury, and R. Lohre. 1998. Application of generalized watershed loading function (GWLF) model to Catskill and Delaware Reservoirs. New York City Dept. Environ. Protection, Valhalla, NY, Jan.

Scott, C.A., L.D. Geohring, and M.F. Walter. 1998a. Water quality impacts of tile drains in shallow, sloping, structured soils as affected by manure application. *Applied. Engineering in Agric.* 14:599-603.

Scott, C.A., M.F. Walter, E.S. Brooks, J. Boll, M.B. Hes, and M.D. Merrill. 1998b. Impacts of historical changes in land use and dairy herds on water quality in the Catskills Mountains. *J. Environ. Qual.* 27:1410-1417.

Sharpley, A.N. 1998. Keep P in place. Farm Chemicals. Business Management, February 1998, p. 21.

Sharpley, A.N., T.C. Daniel, and D.R. Edwards. 1993. Phosphorus movement in the landscape. *J. Prod. Agric.* 6:492-500.

Sivapalan, M., K. Bevin and E.F. Wood. 1987. On hydrologic similarity, 2. A scaled model of storm runoff production. *Water Resour. Res.* 23:2266-2278.

Smith, M.S., G.W. Thomas, R.W. White, and D. Ritonga. 1985. Transport of Escherichia coli through intact and disturbed soil columns. *J. Environ. Qual.* 14: 87-91.

United States Environmental Protection Agency (USEPA). 1994. National water quality inventory: 1992 Report to Congress, EPA, Office of Water Report 841R94001, March.

Walter, M.F., T.S. Steenhuis, and D.A. Haith. 1979. Nonpoint source pollution control by conservation practices. *Trans. ASAE* 22:834-840.

Weiler, K., M.T. Walter, M.F. Walter, E.S. Brooks, and C.A. Scott. 1999. Temporarily dependent risk analysis for flood plains in the Delaware River Basin. (in press).

Wood, C.W. 1998. Agricultural phosphorus and water quality: An overview. In: Sims, J.T. (Ed.), *Soil Testing for Phosphorus. Environmental Uses and Implications.* SERA-IEG-17, USDA-CSREES Regional Committee. Southern Cooperative Series Bulletin No. 389.

Zollweg, J.A., W.J. Gburek, and T.S. Steenhuis. 1996. SMoRMod - A GIS-integrated rainfall-runoff model applied to a small Northeast U.S. watershed. *Trans. ASAE* 39:1299-1307.

FACILITIES AND EQUIPMENT

The active research budget for the Department of Agricultural and Biological Engineering at Cornell University was $ 6.7 million in 1996, with the majority of funding derived from external and competitive grants. The Department's on campus facility provides more than 100,000 square feet of space for laboratories and offices, with major facilities for physical properties and product storage (e.g., sieves, drying ovens, balances, portable pumps and tanks, on-site storage tanks, refrigerators, freezers, autoclave), a soil and water engineering (dry and wet) laboratory (with plumbing and electrical hookups and space for experimental apparatus and analysis), and physical and chemical instrumentation and sensors (e.g., pumps, flow recorders, data logging pressure transducers, centrifuges, sample bottle shakers, incubation chambers, laboratory chemicals and glassware, spectrophotometer, Dionex DX-100 ion chromatograph, TOC analyzer, and more). The Soil and Water Group has vehicles at their disposal for travel to the NYC watershed field sites and pumps and a portable generator for carrying out field work and transporting samples. A machine shop and research equipment development facility is also available for constructing the columns, the wick and pan samplers, and other necessary equipment. Sources of distilled water and ice are within the building. Some 30 Pentium based and 38 MacIntosh computers are also housed within the building. Dr. Steenhuis operates the Soil and Water Laboratory which also includes a controlled environmental room and facilities isolated from the rest of the building where experiments with contaminated manure and hazardous materials can be carried out. The laboratory facilities of other professors within the Department, such as Dr. A. Bäeumner, as well as laboratories at other Departments can also be utilized at cost for sample preparation and analysis.

BUDGET JUSTIFICATION

Salaries and Wages:

Senior Personnel - The four PI's will devote approximately 30% of effort on this project. Salary reimbursement is not requested and will be covered by Cornell University, the State of New York and the Federal Government.

Graduate Students - Two graduate students will be selected. These students will spend 100% of their time towards this project. Their duties will entail collection of manure samples, obtaining the soil cores, conducting the field experiments, chemical and experimental set-up, operation, sampling, sample preparation and analysis, data analysis, and report preparation. The universities calculate the cost of a student slightly different. The cost per student is between $23,000 and $25,000 per year.

Undergraduate Students - Undergraduate students will be employed 100% during summer break and part time during the academic year. These students will assist the PI's and graduate students.

Secretarial-Clerical - Support will be covered by Cornell University

Non expendable Equipment:

Covers the cost of water stage monitoring and sampling equipment (e.g., Isco sampler) to be used at the TBW plot and field sites.

METHODS

Origin

An NRCS method documented in the professional literature (Lemunyon and Gilbert, 1993) and an NRCS technical note (USDA SCS, 1994) inspired the NYC WAP indices. NRCS states that the method "will be used as a tool for understanding the contribution that individual landform and management parameters have toward risk of phosphorus movement and will provide a method for developing management guidelines for phosphorus at the site to lessen their impact on water quality."

The NRCS index is computed using a weighted sum of scores for eight factors, each having four or five levels. The scores are integers 0, 1, 2, 4, or 8 for five factors and 1, 2, 4, or 8 for three factors. 0 means "none", 1 means "low", 2 means "medium", 4 means "high", and 8 means "very high". The specific factors are:

- Factor N1 (weight=1.5): RUSLE soil erosion. Range is 0 to 15 tons/acre/year, scored by dividing into 4 intervals mapping to 1, 2, 4, and 8.
- Factor N2 (1.5): irrigation erosion rating of 1, 2, 4, or 8.
- Factor N3 (0.5): runoff class rating of 1, 2, 4, or 8.
- Factor N4 (1.0): P test result. Range of negligible to very high, 5 intervals.
- Factor N5 (0.75): Fertilizer application rate. Range of 0 to 150, 5 intervals.
- Factor N6 (0.5): Fertilizer application method rating of 0, 1, 2, 4, or 8.
- Factor N7 (1.0): Manure application rate. Range of 0 to 90, 5 intervals.
- Factor N8 (1.0): Manure application method rating of 0, 1, 2, 4, or 8.

The factor scores and weights are combined using the formula:

$$field\_index = \sum_{factors}\left(weight_j * factor\_score_j\right)$$

(In vector algebra, this is the dot product of the score vector and the weight vector.)

The field index value ranges from 4 to 62. NRCS maps the range to five segments: "low" 4-8, "medium" 9-14, "high" 15-32, and "very high" 33 and over. The boundaries between the index segments are derived by defining the highest "medium" index value to be the value that results from substituting all medium factor scores, and so forth.

The NRCS version and the WAP versions represent a single field. One can compute separate values for separate fields then compare the fields. Since the factors are dimensionless or per unit of field area, the index value has an implicit "per-acre" unit. One can reasonably compute the product of a field's area and its score to obtain area-weighted scores for comparing between fields or for summing or averaging across all fields on a farm. For example, one could compute a farm average index comparable to indices for other farms or the same farm at another time or under a different manure deployment scenario:

$$Farm\_index = \frac{\sum_{fields}\left(field\_index_i * area_i\right)}{\sum_{fields} area_i}$$

Klausner's WAP Phosphorus Index

Stu Klausner of Cornell's Soil, Crop, and Atmospheric Sciences Department derived an alternate index from the NRCS index that represents the special conditions and database of WAP's domain. The specialized index drops one factor (irrigation erosion), modifies the runoff factor to use WAP's "hydrologic sensitivity" classes (Klausner, 1995), changes four factors to use continuous instead of discrete values, and changes the distribution of weights among factors:

- Factor K1 (weight=1.5): RUSLE soil erosion rate, divided by 2, truncated at a score of 7.5 (15 tons/acre/year). Continuous scoring in the range of 0 to 7.5.
- Factor K2 (1.5): WAP hydrologic sensitivity of 1, 2 or 4 (risk 3 = score 4). Discrete scoring.
- Factor K3 (1.0): Cornell soil phosphorus test result divided by 10, truncated at a maximum of 8 (80 lb/acre/yr). Continuous scoring in the range of 0 to 8.
- Factor K4 (0.75): Fertilizer rate divided by 10, truncated at a maximum of 9 (90 lb/acre/yr). Continuous scoring in the range of 0 to 9.
- Factor K5 (0.5): Fertilizer application method rating of 1, 2, 4, or 8.
- Factor K6 (1.0): Manure application rate divided by 20, truncated at a score of 7.5 (150 lb/acre/yr). Continuous scoring in the range of 0 to 7.5.
- Factor K7 (1.0): Manure application method rating of 1, 2, 4, or 8.

The individual factor scores are assigned as follows:

SITE CHARACTERISTIC	Units	Weight	PHOSPHORUS LOSS RATING (value)				
			NONE	LOW	MEDIUM	HIGH	VERY HIGH
RUSLE Soil Erosion Rate	tons/acre/yr	1.5	n/a	<5	5-10	10-15	>15
Hydrologic Sensitivity	1, 2, or 4	1.5	n/a	Risk level 1 (1)	Risk level 1 (1)	Risk level 2 (2)	Risk level 3 (4)
Soil Test P	lb P2O5/ac	1	n/a	<9	9-39	40-80	>80
P Fertilizer Applic Rate	lb P2O5/ac/yr	0.75	none applied	<20	20-45	46-90	>90
P Fertilizer Applic Method	0, 1, 2, 4, 8	0.5	none applied (0)	Band placed at planting deeper than 1 inch (1)	Topdressed April 1 to Sept 1 or incorporated just before planting (2)	Applied Sept 1 to Nov 1 (4)	Applied Nov 1 to April 1 (8)
Organic P Applic Rate	lb P2O5/ac/yr	1	none applied (0)	<30	30-90	91-150	>150
Organic P Applic Method	0, 1, 2, 4, 8	0.75	none applied (0)	Injected deeper than 4 inches (1)	Topdressed April 1 to Sept 1 or incorporated just before planting (2)	Applied Sept 1 to Nov 1 (4)	Applied Nov 1 to April 1 (8)

In the first group, the elimination of a modest amount of manure (first vs second row) is not as effective as the halving of the erosion rate (first vs third row). This makes sense due to the higher weight on the erosion factor (1.5 vs 1.0). A quartering of erosion (fifth row) is about the same as a halving of erosion plus the elimination of manure applications (fourth row). Note how the subset index remains at "very high" – it is not sensitive to anything being changed.

In the lower group, the first row represents the original field with its original high erosion and exaggerated fertilizer and manure application. They lead to a "very high" full index score. Eliminating the fertilizer (second row), which is not needed because of the manure use and very high soil P test result, is a no-loss step. Since the field is very hydrologically sensitive, the third row further eliminates manure spreading during the fall and winter, keeping the annual amount the same. The fourth row then halves the annual manure rate. The original index has dropped from 46 to 30 with these three steps. Aggressive erosion control (fifth row) cuts the full index to 21. Further gains would require eliminating manure entirely (first group, sixth row).