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Reducing Phosphorus Runoff from Small Livestock Farms into Missisquoi Bay

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Prepared by
James K. Bushey, Jeffrey E. Carter, Jonathan R. Chamberlin, and Sally A. Flis, PhD

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Report to the

Lake Champlain Basin Program

and

New England Water Pollution Control Commission

Submitted by

James K. Bushey[1], Jeffrey E. Carter[2], Jonathan R. Chamberlin[1], and Sally A. Flis, PhD[1]

[1]Project Management Team
Bourdeaus' & Bushey Inc.
PO Box 187
Middlebury, VT 05753

[2] Project Coordinator, Lead Author
University of Vermont Extension
68 Catamount Park, Suite C
Middlebury, VT 05753

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Table of Contents

List of Figures

List of Tables

Executive Summary

In 2007, a two-year project was initiated to develop site-specific Nutrient Management Plans (NMP) for 30 Small Farm Operation (SFO) livestock farms to reduce phosphorus runoff within the Missisquoi Bay watershed in Vermont. The project was funded through a US federal appropriation to the International Joint Commission (IJC), US Section, and implemented by the Lake Champlain Basin Program (LCBP) and New England Interstate Water Pollution Control Commission (NEIWPCC). The project was managed by Bourdeaus' & Bushey Inc. Nutrient Management Team and a University of Vermont Extension Field Crops and Nutrient Management Specialist. The objective of the project was to document a reduction of Phosphorus loss from agricultural lands through the voluntary development and implementation of a standardized farm Nutrient Management Plan (NMP) based on the USDA-NRCS Conservation Practice Standard 590, Nutrient Management. Reductions in phosphorus loss were evaluated by the change in calculated Phosphorus Index (P Index) scores for all fields from 2007 to 2008. The project included data from 30 farms for 385 individual crop fields encompassing 4,286 acres of tillable crop land. The potential phosphorus loss reductions that could have been achieved were calculated as the difference between the 2008 Actual Total P, Sediment Bound P, and Dissolved P Index scores and the calculated 2008 P Index scores from practices outlined in the 2008 Plans.

During the summer of 2007 a total of 72 farms in the Missisquoi Bay watershed were identified for personal farmer interviews and a subset of 30 volunteer participant farms were enrolled in the project. Collection of farm data included crop management history, field characteristics, soil and manure tests, and GPS coordinates of field boundaries for mapping applications. Farmer interviews included discussions of current and planned management practices, a review of farm records for crop fields and a review of implemented Best Management Practices (BMPs) at the farmstead production facilities. In 2007, the first-year farm data collected was used to develop the initial Nutrient Management Plan and to generate a base P Index value for all the individual fields enrolled. During the winter and spring of 2008 the NMP was revised to reflect planned farm practices for 2008 that would bring the farms into compliance with the NRCS 590 Conservation Standard. During the fall of 2008 data collected during farm interviews were used to update the 2008 Actual records and generate a 2009 Plan for the upcoming year to provide the farm operators with a basis for continuing the implementation of the Nutrient Management Plan that was developed for their operation.

The actual farm records compiled from 2007 and 2008 were used to compare pre-and post-planning changes in farm practices, reported as a change in P Index scores for all fields. The 2007, 2008 and 2009 Plans were presented to each farmer for their use in their management decision process. The average Total P Index score across all farms decreased by 8% from 54.6 in 2007 to 50.3 in 2008. The Sediment Bound P Index score portion of the Total P Index score was reduced 10% from 17.0 to 15.3, while the Dissolved P Index portion was reduced 7% from 37.6 to 34.9. The overall reduction in Total P Index score was less than the potential reduction of 18% which could have been achieved if the 2008 nutrient management plan had been strictly followed by all farmers. Lack of adoption of specific practices including streamside vegetated buffers, manure spreading setbacks and reduction of total P applications from manure contributed to the lower than expected reductions achieved. Similar reductions in P Index scores were shown in the 2009 Plan which was provided to each participant farmer to enhance their ability to continue with the Nutrient Management Plan process.

Introduction

Agricultural runoff from farm fields that receive manure and fertilizer applications has contributed to the high phosphorus levels found in Missisquoi bay and has lead to excessive aquatic vegetation growth and algae blooms in Lake Champlain. Reducing phosphorus inputs to Lake Champlain to promote a healthy and diverse ecosystem while providing for sustainable human use and enjoyment of the lake was identified as a top priority to protect and restore ecological and cultural resources of the basin as outlined in *Opportunities for Action: An Evolving Plan for the Lake Champlain Basin.* The adoption of farm practices that are prescribed in a whole-farm Nutrient Management Plan (NMP) has the potential to reduce the amount of phosphorus that is transported into Lake Champlain from agricultural non-point sources. The current USDA-NRCS Conservation Standard 590, Nutrient Management, and related Statement of Work were used as the format for documentation of the completed NMPs for this project. The Vermont Phosphorus Index (P Index) is a required component of a Nutrient Management Plan and is a good indicator of the effects of farm management changes on the potential loss of Phosphorus to surface water.

This project was managed collaboratively by Bourdeaus' & Bushey Inc. in Middlebury and a University of Vermont Extension Field Crops and Nutrient Management Specialist. The project coordinators used a Nutrient Management Team approach to help the farmers with the development of their Nutrient Management Plan and implementation of recommended Best Management Practices in accordance with NRCS standards for environmental protection from agricultural non-point source pollution. Bourdeaus' & Bushey Inc. has previous experience in developing plans for farms in Vermont and New York and has shown dairy producers the value of having an NMP developed for their farm for the protection of the environment and for the financial viability of their business. Plans have been developed and maintained for a variety of livestock farms for compliance with programs for Large Farm Operations (LFO), Medium Farm Operations (MFO), Concentrated Animal Feeding Operations (CAFO) and for farms contracted with NRCS for program participation in Environmental Quality Incentives Program (EQIP). University of Vermont Extension has experience with developing nutrient management recommendations, conducting educational workshops for producers and planners on NMP development, and working directly with farmers to assist in decision-making processes during exploration and adoption of new management practices.

Farmer participants were asked to voluntarily implement nutrient management practices outlined in a Nutrient Management Plan which would be developed for their farm to meet the NRCS 590 Standard. The project grant paid for the cost of soil and manure samples, farm visit consultations, plan development and distribution. Farmers were asked to spend time learning about the NMP process, to meet with field staff for data collection, to keep a written record of their field activities and to meet with planners and other participants to discuss management practices that would reduce field P Index scores or reduce farmstead facility water contamination.

Objective

The objective of the project was to reduce Phosphorus loading in the Missisquoi Bay watershed through the development and voluntary implementation of Nutrient Management Plans on 30 small livestock farms in the Missisquoi Bay watershed. The primary goal was a measured reduction in Phosphorus loss to surface water as measured by a reduction in field P Index scores through the adoption of farm management practices designed to reduce agricultural non-point source pollution.

Identified Tasks

- Identify 30 Farmer Participants through on-site visits and interviews.
- Collect base farm information for 2007 and develop annual Nutrient Management Plans for 2008 and 2009 that conform to NRCS 590 guidelines.
- Consult with participant farmers to explain how to implement the recommended management practice changes prescribed in the nutrient management plan and record farm crop production activities for year-end evaluation of management changes they implemented.
- Evaluate the changes in field P Index scores from 2007 to 2008 due to changes in farm management practices.
- Compare P Index changes achieved by the farmers in 2008 after implementation of practice changes with the projected changes outlined in the prescribed 2008 Plan.
- Share results of project with Lake Champlain Basin Program, general public and farm community.

Methods

Farm Visits and Data Collection

During the summer of 2007 a total of 72 farms in the Missisquoi Bay watershed were identified for personal farmer interviews and a subset of 30 volunteer farms were enrolled in the project. The enrolled farms were distributed throughout the following sub-drainage areas of the Missisquoi Bay watershed as shown in Table 1.

Table 1. Distribution of Farms in Watershed

No. Farms	Sub-Watershed Drainage Area
5	Black Creek
3	Hungerford Brook
9	Missisquoi River
6	Pike River
5	Rock River
2	Tyler Branch

On-site interviews with the farm owners were conducted at least semi-annually to document current (2007) and planned (2008) farm practices on cropland fields and at the farmstead production facility. Initial data collection of farm practices and conditions were used to establish base P Index scores for all fields and also to develop a base summary of established BMPs on the farm. Data collected during subsequent interviews and production facility evaluations were used to develop practice implementation strategies and evaluate changes in field management practices.

Up to six individual farm site visits were conducted during the project for data collection and plan reviews. At the first visit the interviewer reviewed FSA provided field maps, planned crop rotations, manure management, fertilizer use and number of livestock housed at the farm. During subsequent visits the plan that was developed for the farm for 2008 was reviewed with the producer for accuracy and for any changes in crop plans (crop to be grown, manure application changes, or fertilizer changes). All the information in the NMP was reviewed with the farmer including how the recommendations were made, how a P Index is calculated and what changes were recommended to improve environmental management on the farm. Field record keeping sheets were provided to participant farmers for tracking field practices including manure, fertilizer and lime applications, soil tillage and land improvement activities, crop protection practices, and harvested crop yields. Field records were kept by the farmer and shared with the planner during each growing season so the information could be used to generate a year-end summary report for 2008 to compare with the prescribed 2008 NMP. The year-end reports were then used in conjunction with additional farmer interviews to form the basis for the following year 2009 NMP annual update.

All fields were mapped with a soil sampling unit equipped with GPS receiver and iPAQ handheld computer with SST Field Rover II software for mapping applications. Farm maps were generated using SST Toolbox software to develop field maps for land resource and conservation management, collection of soil and manure sampling coordinates, display location and extent of water resource concerns and to show topography, soil types and manure spreading setbacks.

The overall environmental management of the farm was discussed with each farmer using the New York State Agricultural and Environmental Management (AEM) Tier I & II worksheets (http://www.agmkt.state.ny.us/soilwater/AEM/techtools.html). These worksheets have been used by Bourdeaus' in developing Comprehensive Nutrient Management Plans for farms in both Vermont and New York. They provide a framework for an interview process to conduct an in-depth evaluation of farmstead concentrated sources. A thorough AEM interview was completed with participants willing to spend the required time to complete the process. All farms were evaluated for six specific concentrated source concerns with interviews and site visits to document current manure storage and management, barnyard design, silage leachate control, roof runoff management, milk house waste disposal and livestock mortality disposal practices.

The AEM worksheets used in the farm interview process addressed issues with Nutrient Management Manure/Fertilizer, Barnyard Runoff Control, Silage Storage, Process Wash Water, Management of Feed Nutrients, Water-Borne Pathogens, Soil Management, Pasture Management, Waste Disposal, Pesticide Use, Farmstead Water Supply, Stream and Floodplain Management, Petroleum Products Storage and Livestock Odor.

Soil and Manure Sampling

Field soil sampling to investigate soil fertility levels followed University of Vermont guidelines for randomized field sampling for soil testing. A representative soil sample for each field was collected using a mechanical auger soil sampling tool operated to a depth of six to eight inches in crop fields to represent the plow layer depth. The soil sample for each field consisted of a minimum of 12, and a maximum of 20 sub-samples per field depending on overall field size in acres. Spatial distribution of sub-samples was patterned on a square grid with sample point geographic coordinates recorded using GPS. All samples were labeled with collection site, date and observer information. At the time of soil sampling field information was recorded including a field sketch indicating slope percent, length and aspect, adjacent water resource concerns, cultural resources or other notable features present.

Field soil samples were submitted for a standard analysis basic test which included measurement of the soil pH, Cation Exchange Capacity (CEC), % Organic Matter (OM), available Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulfur (S), Manganese (Mn), Iron (FE), Copper (Cu), Zinc (Zn), available Aluminum (Al) and a Calculated base saturation (K, Ca, Mg, Na, H) percent. Soil test results were be shared with the farmers and used to evaluate crop nutrient requirements for the crop to be grown in the Nutrient Management Plan.

Manure samples collected were representative of waste material in the form and concentration that was field applied. A representative manure sample for each distinct source of livestock waste was collected for each farm. The samples were contained and transported to the testing lab either fresh within 24 hours or frozen if after 24 hours from sample collection. The samples were taken by the planner or farmer at the time that the material was to be applied to the field to represent the actual material nutrient content as field applied. All samples labeled with collection site, date and observer information. Manure test results were shared with the farmers and used to evaluate crop nutrient contributions from on-farm manure for the crop to be grown in each field.

Soil and Manure Analytical Methods

Soil and manure samples were delivered to the University of Vermont Agricultural and Environmental Testing Laboratory for analysis of nutrient content and associated physical characteristics. The laboratory analysis for soil tests was completed as described in UVM publication BR 1390 Nutrient Recommendations for Field Crops in Vermont - Soil Testing Lab Methods. The standard manure analysis from UVM included the sample % Dry Matter (DM), density (lb/gal), Total Nitrogen (N), Ammonium Nitrogen (NH_4-N), organic Nitrogen (Org-N), Phosphorus (P_2O_5), Potassium (K_2O), Calcium (Ca), Magnesium (Mg), Copper (Cu), Zinc (Zn), Iron (Fe), Manganese (Mn), and Boron (B). The test results were reported as nutrient content in lbs/wet ton, lbs/1,000 gallons, and on a dry weight % basis. Manure samples taken in 2009 were submitted to Dairy One Cooperative Inc. Laboratory Services in Ithaca, NY as a result of University of Vermont Testing Lab discontinuing their testing services. The standard manure analysis report from the Dairy One lab included Total Solids % (DM), Density (lb/gal), Nitrogen (N), ammonia Nitrogen (NH_4-N), organic Nitrogen (Org-N), Phosphorus (P), Phosphate Equivalent (P_2O_5), Potassium (K) and Potash Equivalent (K_2O). The test results were reported as nutrient content on an as-received % basis, as lbs/ton and as lbs/1,000 gallons.

Nutrient Management Recommendations

Reported crop yields were used in conjunction with University of Vermont Nutrient Recommendations for Field Crops in Vermont (BR 1390) to determine nutrient application rates based on soil type and crop to be grown. The Nutrient Management Plans also considered the yearly and seasonal variations in weather and the risks associated with raising crops in Vermont. Manure is the main source of crop nutrients and the fertilizer value is directly related to the content of the dairy ration fed. Participants were very interested to discuss crop nutrients as they relate to stored feed quality. Manure samples taken from the storage structure or right out of the manure spreader were collected and delivered to the testing laboratory for analysis of nutrient content and associated physical characteristics.

The farm practices data from on-site interviews and the analytical lab test results of nutrient content and associated physical characteristics for soil and livestock waste were used to develop a Nutrient Management Plan in accordance with NRCS Vermont 590 Standard dated May 2005. The NRCS standard is available for review at the following web site:
http://efotg.nrcs.usda.gov/references/public/VT/VT590-051705.pdf

Nutrient Management Plan Outline

The individual farm Nutrient Management Plan (NMP) was presented to each participant and was divided into the following sections for easier reference.

1. Introduction and Farm Description, livestock and land summary, water resource concerns, how to use this plan for improved farm management
2. Best Management Practices (BMP) Summary
    a. Evaluation of installed, planned and additional recommended practices
    b. Applicable NRCS standards and associated operation and maintenance plans
    c. Schedule for implementation of individual conservation practices.
3. Concentrated Sources
    a. Production area site plan and description of BMPs for clean water exclusion and contaminated water control and disposal.
    b. Agricultural Environmental Management worksheets.
4. Nutrient Management
    a. Introduction to Nutrient Management practices
    b. Calculations for waste production, applications and nutrient balance
    c. Field specific plans for manure and fertilizer use, timing of application
    d. Phosphorus Index calculations
    e. Field boundaries, conservation plan, soil types, topography, water resource concerns and manure spreading setbacks.
    f. Crop Record Sheets
5. Soil and Crop Management
    a. Field assessments
    b. RUSLE 2 calculations
    c. Soil maps and descriptions
6. Emergency Management Plan
7. Producer assistance notes, agreements and correspondence
8. Manure and Soil test results

Vermont Phosphorus Index

The Vermont Phosphorus Index v. 5.1 (P Index) was used to evaluate the potential for off-site movement of phosphorus from each individual field based on a combination of site-specific source and transport variables. The current version of the P Index (Excel spreadsheet) is available at the web site: http://pss.uvm.edu/vtcrops/?Page=nutrientmanure.html#Phosphorus. Separate P Index values from 1 to 100 are generated for Total P, and apportioned into sediment-bound P and for dissolved P losses in surface runoff. The Phosphorus Index provides a relative rating as to the risk of P off-site losses based on factors including field location, soil test P level, reactive soil aluminum level, manure use and timing, fertilizer use and timing, soil type, soil erosion rate (RUSLE2), vegetation cover, distance to surface water, vegetated buffer width and other installed erosion controls. The generated values are used to prioritize fields for nutrient and soil management in developing a Nutrient Management Plan. There are four interpretation categories (Low, Medium, High or Very High) with specific nutrient management recommendations for each category. A Low (0-30) or Medium (31-60) P Index score indicates a lower potential for adverse impact to surface waters from P loss and N-based nutrient applications are acceptable. A High P Index score (61-100) requires a P-based nutrient management strategy to be followed which limts P applications to crop P removal rates. A P Index greater than 100 requires remedial action to reduce P movement to water and no manure or fertilizer P should be applied to the field.

Revised Universal Soil Loss Equation

The Revised Universal Soil Loss Equation (RUSLE2) is the approved methodology for predicting rill and inter-rill soil erosion for land treatment conservation planning in Vermont. The program was used to evaluate the current crop rotations on each field of each farm to determine the soil loss values for use in the Phosphorus Index in accordance with NRCS Vermont 590 Standard and is detailed at the following web site: http://www.vt.nrcs.usda.gov/technical/Rusle2/Rusle2_Index.html. The nutrient management standard requires that the crop rotation used in each field needs to be less than the tolerable soil loss (T) for the dominant soil type in the field. The rotations used on the farm were evaluated for being less than T and if they were not acceptable new crop rotations and inclusion of cover crops on corn fields were recommended.

Statistical Analysis

The Total, Sediment bound and Dissolved P Index scores for individual fields and for farm weighted averages, total manure P applied, and fertilizer applied were analyzed using ANOVA to test the main effects of farm, year, the interaction of farm by year, the contrast of the 2007 actual and 2008 actual P Index values, and the contrast of the 2008 actual and 2008 planned P Index values in Proc GLM of SAS v. 9.1.3 (SAS Institute, 2003). Significant differences were declared at $P \leq 0.05$ and tendencies at $P \leq 0.10$.

The P Index source and transport variables of soil test P, annual manure P application, annual fertilizer P application, erosion as determined by RUSLE 2 calculations, distance to water, field size, and the crop type in each field were analyzed by step wise multiple regression and correlation to the Total P Index field score using the Proc Corr and Proc Reg procedures of SAS v. 9.1.3 (SAS Institute, 2003). Three regressions were run using the 2007 actual date, with the 2008 actual data, and also with both the 2007 and 2008 actual farm practices data.

Quality Assurance Project Plan

The Quality Assurance Project Plan was submitted as required to provide criteria for planner certification, data collection and sampling process, analytical methods, plan assessment and reporting. Nutrient Management Plans were reviewed by the project Manager and the project Quality Assurance Manager prior to submission for Lake Champlain Basin Program Technical Advisory Committee review or for distribution to individual farmer participants. Five completed farm plans were submitted for review for completeness and conformance with the Vermont NRCS 590 standards for Nutrient Management. The plan reviews were conducted by a subset review team consisting of officials from the State NRCS office and Vermont Agency of Agriculture, Food and Markets and were selected by the LCBP project coordinators. The formal plan review was completed and the plans were determined to meet the required standards.

The farm data collected and nutrient management plans developed under this contract were managed to maintain confidentiality of individual farmer identification and location. Original soil and manure test results were used in the development and assessment of the base Nutrient Management Plan and annual updates. Soil and manure test results were forwarded to each farmer participant along with the 2008 Nutrient Management Plan and 2009 updates for on-farm use. A copy of each is held at the business office of Bourdeaus' & Bushey Inc. in Middlebury.

Results and Discussion

Thirty Nutrient Management Plans were developed for the participating farms in the watershed and encompassed a total of 385 fields including 4,286 acres of tillable land used for production of livestock feed crops. The producers that participated in the project made time available to meet with the interviewers and take the time to answer all questions asked. This allowed for a thorough collection of data on the farms. The greatest interest was in the results of the soil tests, as only a few of the farms had previously taken soil tests on their farms. Producers wanted to take the time to review the results of the tests and the UVM recommendations.

The completed Nutrient Management Plans were reviewed with each individual producer and most producers were interested to know what changes in recommendations had been made, for instance if fertilizer applications were increased or decreased, where lime applications were recommended, and where and when to apply manure. On most farms the manure recommendations were quite similar to the original farm management discussed in the initial interview. Part of the writing and review of the plan was to indicate to producers where a 25 foot buffer for manure and fertilizer application was recommended to meet the 590 conservation practice standard. Most farms were agreeable to observing the 25 foot setbacks on grass fields, but fewer were interested in establishing vegetated buffers plus manure setbacks in their corn fields. It is uncertain at this point how many of the farms will continue to update their CNMPs on an annual basis. However, interaction with the producers indicated that all producers did learn from the process and gained knowledge about their soils and how to improve their crop production practices.

Field Crop Production

There were 385 fields (4,286 ac) that were included in the 2007, 2008 and 2009 plans. The crop acreage on participating farms included a mixture of row crop production and hay crops that were grown in a variety of field specific crop rotations. The row crops grown included corn for silage, corn for grain and soybeans for grain. Row crops were grown in rotation with hay crops or continuously on individual fields based on historical farm practices. The hay fields consisted of either semi-permanent mixed stands of grasses and legumes alternated with row crops for specific time cycles or as permanent stands of grasses that remain as continuous perennial sod. In 2008 there were additional fields included in the annual update for some farms as additional land was included in the farm base as newly acquired fields or as a result of subdividing of existing fields. The data for comparisons between 2007 and 2008 includes only the 385 fields that were in the original 2007 Nutrient Management Plan Reports.

In 2007 row crops including corn and soybeans were grown on 34% of the crop acreage (1,456 ac) while 66% of the acreage (2,830 ac) was planted with a sod hay crop. There was a wide variation in mix of crops grown between farms as shown in Figure 1, ranging from farms with all hay to one farm with all corn. Hay fields consisted of either mixed grasses only or a mix of grass and legumes that included clover or alfalfa. In 2008 there was a 52 acre reduction in row crop acreage when 108 acres of the 2007 corn fields were seeded down to a hay crop and 56 acres of hay fields were converted to row crop corn production. The majority of fields are maintained as continuous hay or for continuous corn.

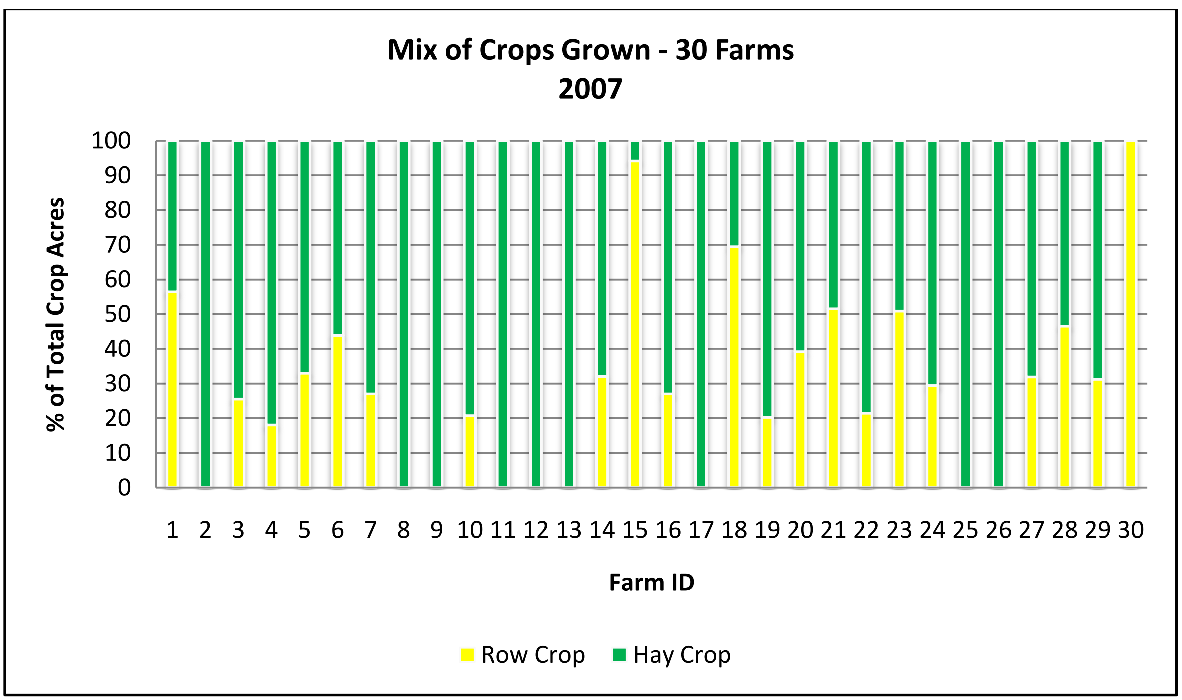

Figure 1. Mix of Crops Grown on All Farms in 2007

Livestock

Twenty-nine of the 30 farms had milking cows, with an average of 83 mature milk cows per farm, with total milk cow numbers ranging from 25 to 190. There were a total of 2,403 milking cows on the farms in the project and there was one farm that was a heifer growing operation with no milking cows. There was one certified organic farm that participated in the project. Farm data was collected on total livestock Animal Units (AU) housed at each farm and then compared to the number of acres available for manure spreading to determine a livestock density ratio of AU/acre (1AU=1,000 lb. live wt). The average number of acres available for manure application per farm was 149 ranging from 29 to 393 (SD 83.8). The animal units housed on all farms totaled 4,928 AU which included all milking and dry cows, bulls, heifers, and calves. The livestock density for the 30 farms averaged 1.15 AU/ac with a range of 0.43 to 2.17 (SD 0.44). There was very little correlation between livestock density for each farm and the associated average farm P Index as shown in Figure 2. Livestock numbers remained steady for the two years with normal losses of adults from the herds and replacement young animals raised on-farm.

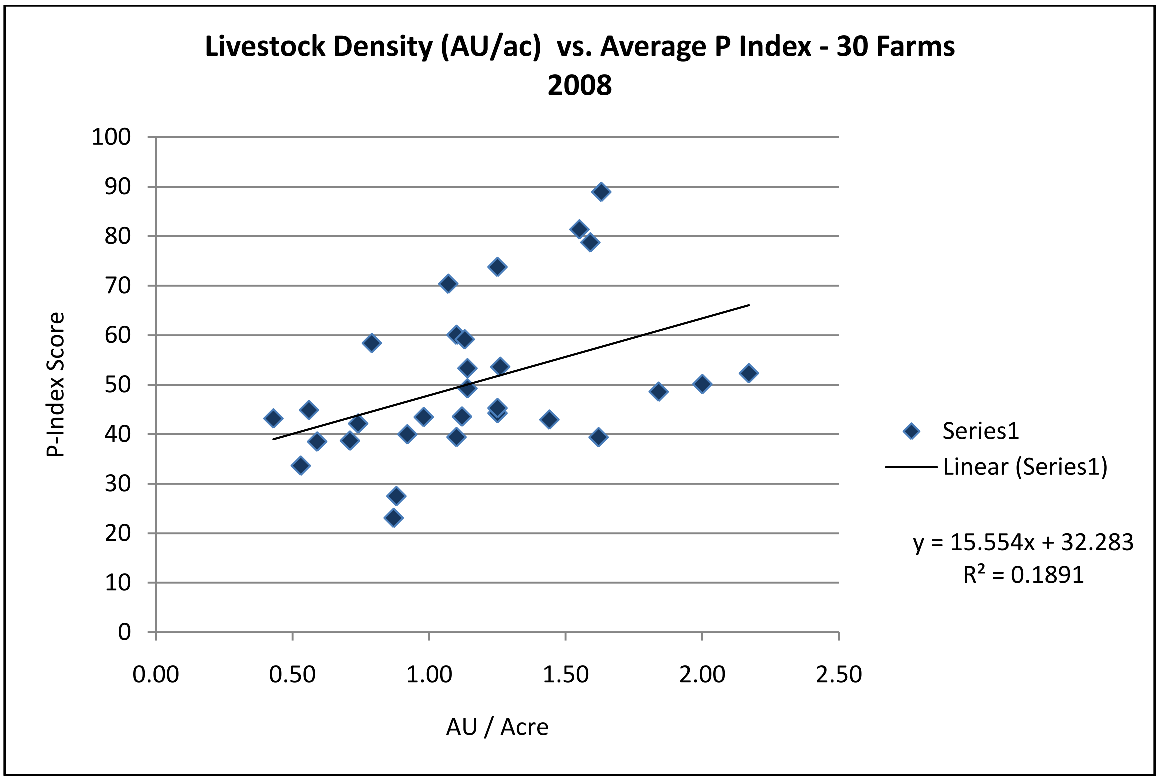

Figure 2. Average Farm P Index vs. Farm Livestock Density in Animal Units per Acre

Manure

Manure samples were taken from each manure source on each farm. On 27 of the 30 farms in the project liquid/slurry manure was stored in a waste storage structure that included milk house waste and at three farms the manure was handled as a solid (>20% DM) material. The manure test results for farms that had liquid/slurry storages are presented in table 2. Average values for Nitrogen and Potassium were similar to the typical values for nutrient content of manure from a data set of samples analyzed by the UVM lab. The average Phosphorus (P_2O_5) content of 10 lb/1,000 gallons for the liquid/slurry manure samples was within the range of the typical expected values of 8 lb/1,000 gallons for 7% DM liquid manure and 4 lb/ton of 17% DM slurry manure. The results for manure stored as a solid are shown in Table 3 and average nutrient content for N, P and K were also similar to UVM typical expected values.

The total annual manure production on the farms storing manure as a liquid was 28,427,319 gallons (approx. 117,973 tons). Average farm manure production was 1,093,358 gallons ranging from 260,002 to 2,353,355 gallons (SD 561,106). The total solid manure produced by the 3 remaining farms was 2,016 tons and averaged 672 tons per farm ranging from 541 to 914 (SD 210). The total manure production for all 30 farms was approximately 120,000 tons annually.

Table 2. Liquid/Slurry Manure Test Results

	% Dry Matter	Density lb/gal	Total N lb/1,000 gal	NH_4-N lb/1,000 gal	Org-N lb/1,000 gal	P_20_5 lb/1,000 gal	K_2O lb/1,000 gal
Mean	8.3	8.3	22.5	9.7	12.9	10.1	20.4
Min.	1.6	8.2	4.3	0.5	2.1	2.2	4.9
Max.	19.9	8.6	45.8	21.5	32.7	21.4	50.1
Std.Dev.	4.7	0.1	11.3	5.3	7.8	5.3	10.2
Typical Values	7	8.3	25	12	13	8	20

Table 3. Solid Manure Test Results

	% Dry Matter	Density lb/ft^3	Total N lb/ton	NH_4-N lb/ton	Org-N lb/ton	P_20_5 lb/ton	K_2O lb/ton
Mean	28.3	59.8	8.6	2.5	6.1	4.8	7.9
Min.	18.0	43.1	4.4	1.0	3.0	2.5	2.3
Max.	42.4	69.8	12.1	4.6	9.6	8.2	15.4
Std.Dev.	10.7	11.6	3.5	1.6	3.0	2.6	5.8
Typical Values	26	62	9	2	7	4.5	7

Soils

There were 33 different dominant soil types in the fields that the NMPs were written for. The most dominant soil types were Munson (15%), Peru (12%), Westbury (11%) and Raynham (8%), and Georgia (6%). Tolerable soil loss “T” values were determined by the dominant soil type in each field as determined by NRCS soil type maps. Tolerable soil loss factors for dominant soil type were 2 ton/ac in 27%, 3 ton/ac in 42%, and 5 ton/ac in 31% of all fields. The existing farm crop rotations were evaluated using the RUSLE2 software to determine that the plans were in compliance with the Farm Service Agency requirement that soil loss from farm fields cannot be planned to allow more than the tolerable soil loss (T) for the specific soil found in each field. Recommendations for crop rotation modifications and the use of winter cover crops were made for 31 of 110 corn fields to lower the soil loss below the required “T” level.

When soils were sorted by hydrologic group, 66% of all fields had dominant soil types classified as group C soils that are moderately fine to fine textured with a layer that impedes movement of water downward and have slow infiltration rates and slow rates of water transmission. Less than 20% of the fields were dominated by soils in group D with permanently high water tables and high runoff potential. The balance of fields had dominant soil types in group A and B that are moderate to well-drained and have a lower runoff potential. The four hydrologic groups and associated soils found are shown in Table 4.

Table 4. Hydrologic Grouping of Dominant Soil Types in Fields (n=385)

Hydrologic Group	% of Fields	Dominant Soil Types
A	3.6	Windsor, Missisquoi, Adams, Colton
B	10.1	Belgrade, Deerfield, Au Gres, Ondwana, Podunk, Winooski, Hadley
C	66.2	Peru, Westbury, Raynham, Georgia, Tunbridge, Buxton, Limerick, Binghamville, Lordstown, Scantic, Stowe, Eldridge, Massena, Wareham, Enosburg, Hinesburg, Rumney
D	19.3	Munson, Cabot, Woodstock, Carlisle, Peacham

Soil Test Phosphorus Levels

Soil tests for the 385 fields were submitted to the University of Vermont Agricultural and Environmental Testing Laboratory for analysis of nutrient content and associated physical characteristics. Two soil test values, available phosphorus (ppm) and reactive soil aluminum (ppm) are used as factors to calculate the P Index scores. The reactive soil aluminum level indicates the amount of reserve soil acidity in the soil and is an indicator of the soil capacity to fix or tie-up phosphorus. Aluminum soil test levels averaged 68 ppm (range 1 to 604, SD 61) with 12 fields having excessive levels of Al over 200 ppm. Phosphorus recommendations for crop production in Vermont are based on a combination of available P in the soil and the reactive Al test levels.

The soil test levels of Available P (modified Morgan's extract) for the 385 fields averaged 7.6 ppm with a wide range from 0.6 to 60.7 (SD 7.5). The mean value for all soil tests was slightly above the UVM Optimum P soil test category (4.1 to 7.0 ppm) which is the most desirable test range on an economic and environmental basis. The average P soil test levels varied significantly between farms as seen in Figure 3. There were 102 fields (26% of all fields) that tested in the High available P soil test category (7.1 to 20 ppm) and 24 fields (6%) that had soil test levels in the Excessive category above 20 ppm. One-third of all fields tested above optimum levels for crop production. Soil test P levels were found to be positively correlated with P index scores. Existing high soil test P levels on individual farms can be attributed to past additions of P from fertilizer and manure sources and are also influenced by parent soil type.

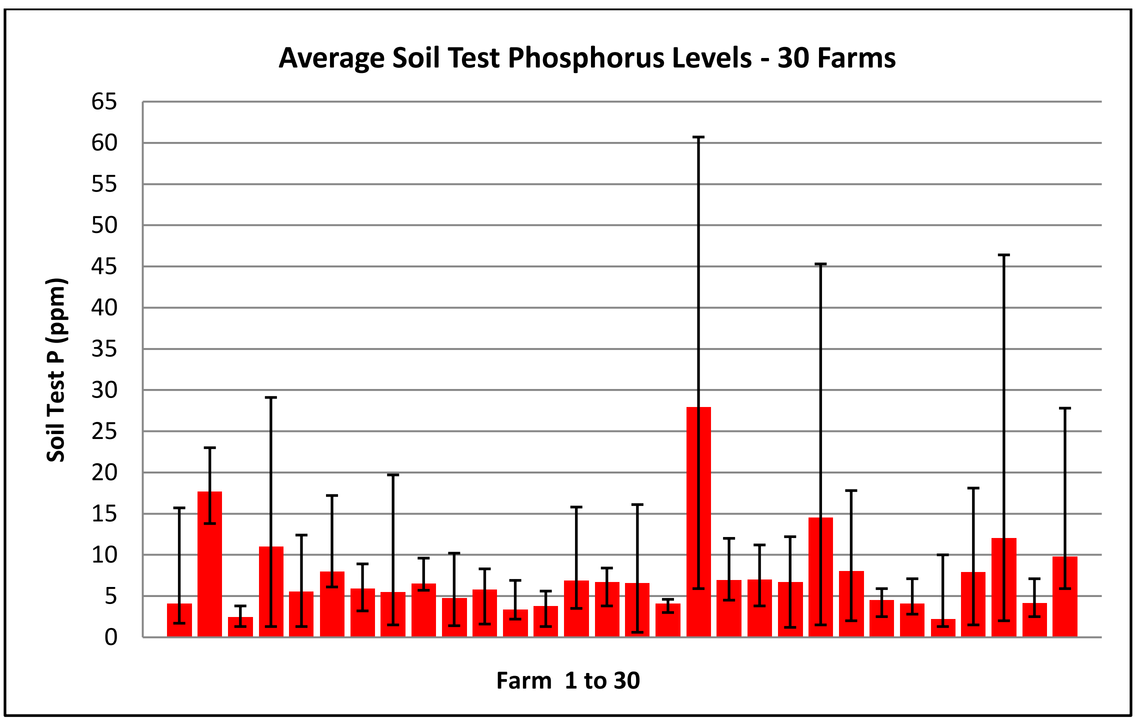

Figure 3. Average Soil Test Phosphorus Levels for 30 Farms

Sources of Phosphorus Fertilization

For all farms in the project the amount of applied Phosphorus from manure was greater than from fertilizer sources in all years. In 2007 (Figure 4) Phosphorus from manure applications accounted for 81% of all P applied to crop fields. The balance of P applications to fields was part of a complete blend fertilizer used for starter fertilizer in corn fields. There was no additional P from fertilizer sources applied to established hay fields, and only minimal P applied to newly seeded hay fields as an incorporated starter fertilizer. Commercial fertilizer applications to hay crops were primarily Urea N applied to grass during the growing season. The total amount of Phosphorus added to fields from both manure and fertilizer sources equaled 321,335 lb. P_2O_5 in 2007 and remained very similar in 2008.

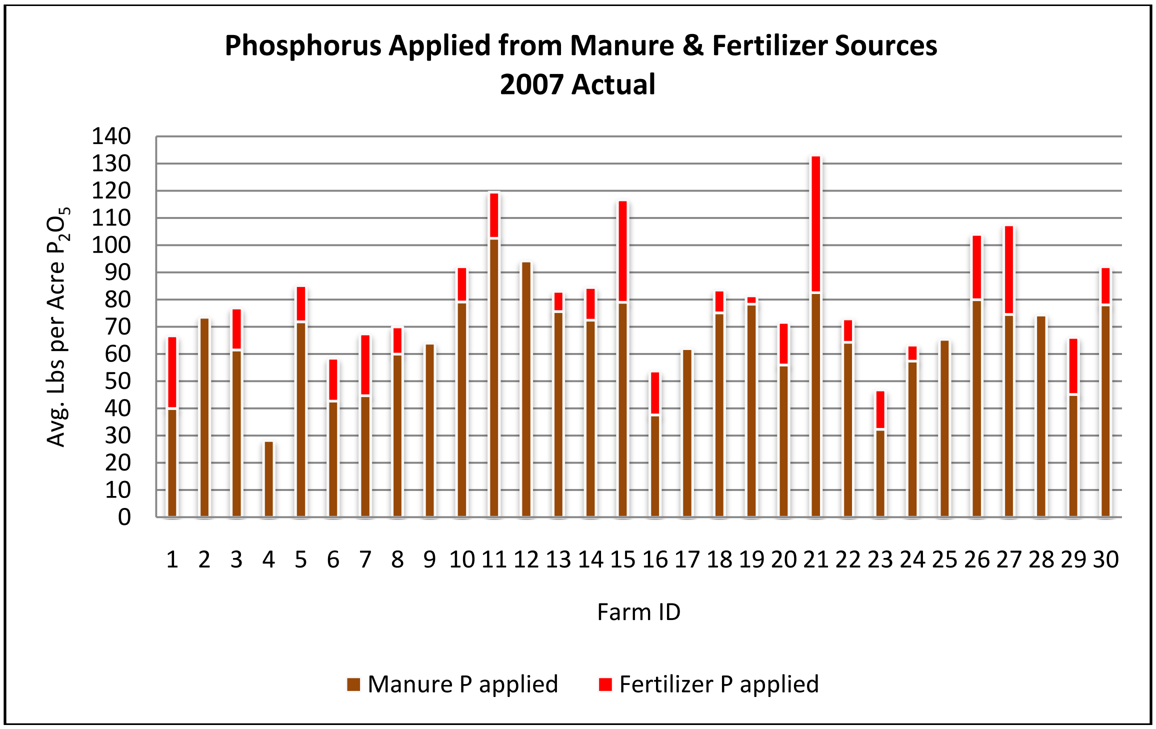

Figure 4. 2007 Applied Phosphorus from Manure and Fertilizer Sources

In 2008 fertilizer P applications were reduced by 14% across all farms, a savings of 8,580 lb of purchased Phosphorus. This was achieved through reductions in corn starter P content and also reduced rates per acre applied. The average applications of P from manure and fertilizer in 2008 are shown in figure 5. The rapidly rising cost of fertilizer in 2008 stimulated a greater use of on-farm stored manure and a reduction in purchased fertilizer materials. The 2008 NMP recommendations indicated that an overall reduction of 50% of purchased fertilizer P and a 6% reduction in manure P applied could be achieved and still meet the crop production needs as recommended by soil tests and University recommendations (Figure 6). The reluctance of farmers to reduce corn starter P to recommended levels is demonstrated by the lower reductions achieved (only 14%) in the 2008 Actual fertilizer P applications. The 126 fields in the study that have High and Excessive soil test P levels would be appropriate sites for reductions in P fertilizer rates without reducing crop yields.

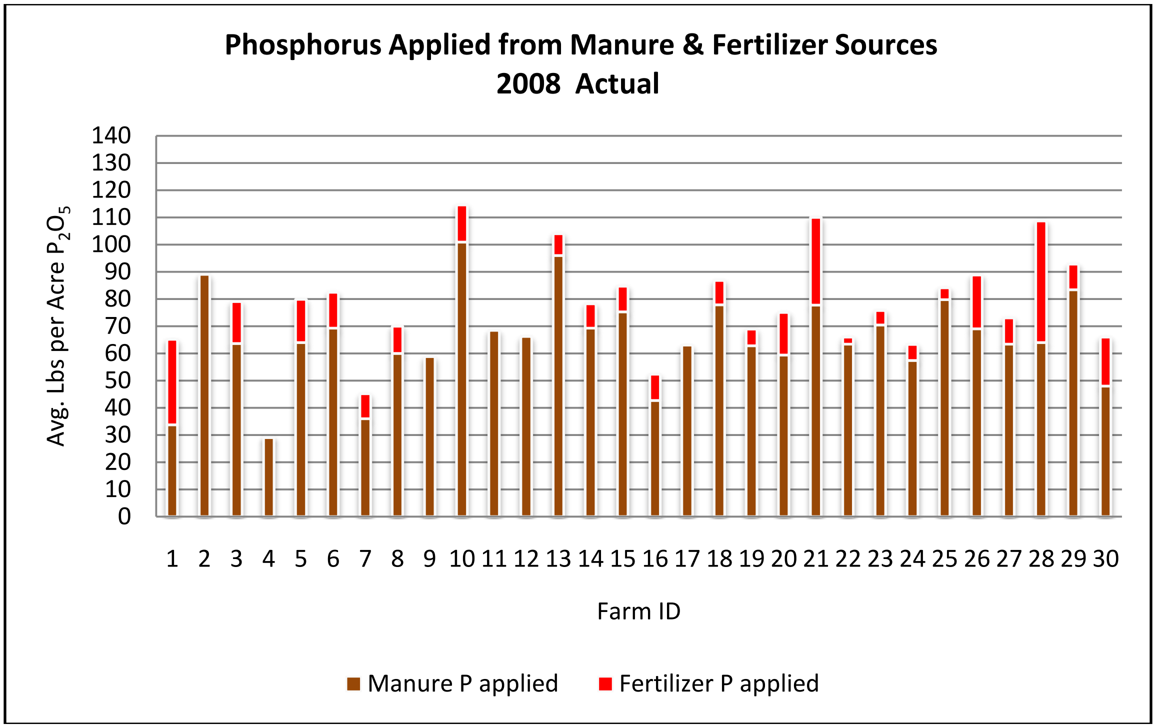

Figure 5. 2008 Applied Phosphorus from Manure and Fertilizer Sources

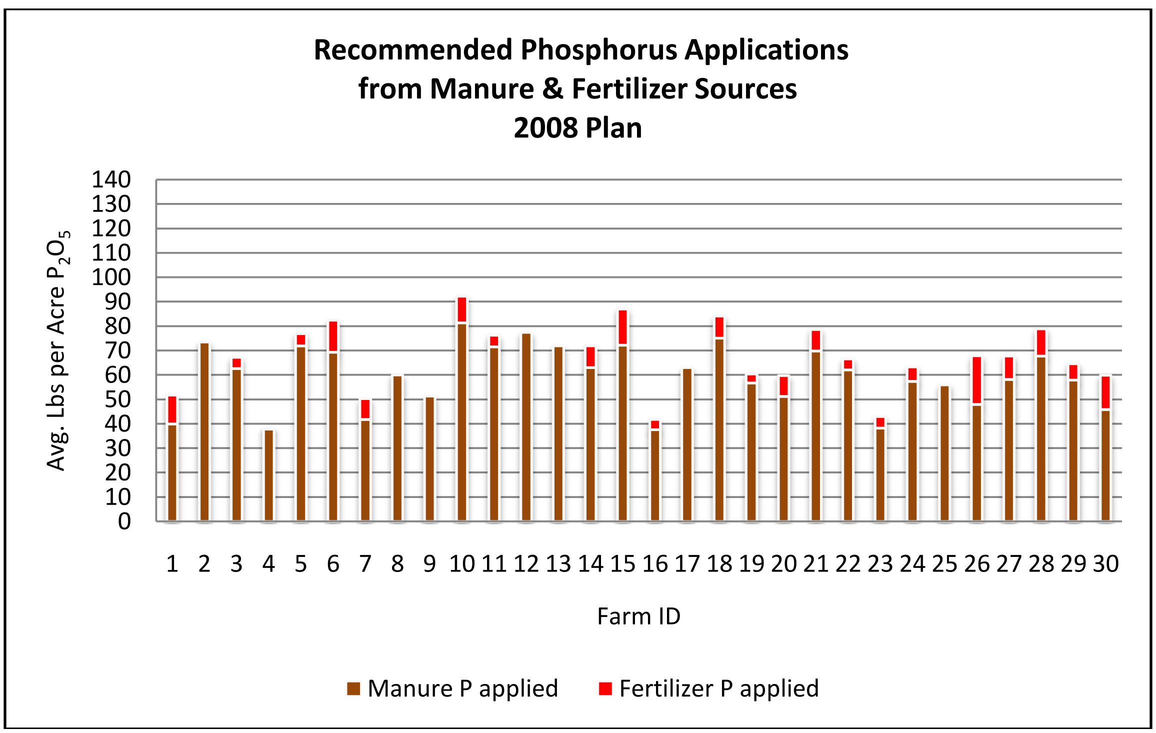

Figure 6. 2008 Recommended Application Levels for Manure and Fertilizer Sources

Agricultural Environmental Management (AEM) Evaluation

The Agricultural Environmental Management (AEM) evaluation interviews were completed on one-half of the farms. The remaining farms were not willing to commit to the approx. three hours required to complete the interview process for all the worksheets so informal interviews and observations were completed. Evaluations for 14 separate farm management areas were scored on a scale of 1 to 4 (1=low concern and 4=highest concern) following the AEM Potential Concern guidelines that included multiple questions about each area. The areas with the highest concern scores were manure management (2.8), silage storage (2.4), and management of feed nutrients (2.3) as shown in Table 5. For each farm the identified management concerns for manure management was addressed in the development of the nutrient management plan for each farm. The concerns for silage storage leachate control would require further on-site evaluation with the assistance of a professional engineer to properly implement new management strategies to address individual concerns. The management of livestock feeding is not specifically addressed in the NMP and requires the assistance of a qualified feed consultant to improve animal nutrition. The remaining areas of concern were generally scored in the lowest categories of concern and require minimal management changes. Some of the general concerns noted for each area for farms are listed.

Table 5. Summary of AEM Evaluations

Management Area	**Average Score**	**General Concerns**
Nutrient Management Manure/Fertilizer	2.8	Limited soil testing , no manure testing, limited use of field application records
Barnyard Runoff Control	1.5	Separation of Clean Water
Silage Storage	2.4	Drainage and collection of seepage
Process Wash Water	1.8	Solids not removed, little reuse of water
Management of Feed Nutrients	2.3	Infrequent forage testing and ration balancing
Water-Borne Pathogens	1.3	None
Soil Management	2.0	No soil erosion prevention plans
Pasture Management	1.8	Animals not fenced out of waterways
Waste Disposal	1.0	None
Pesticide Use	0.9	None
Farmstead Water Supply	1.8	No nitrate testing
Stream and Floodplain Management	1.6	Livestock access to water
Petroleum Products Storage	2.0	No Secondary containment for fuel tanks
Livestock Odor	1.0	None

Scale of 1 to 4 (1=low concern and 4=highest concern)

Farmstead Concentrated Sources Evaluation

Manure Storage

Twenty of the farms have manure storage systems designed and installed with NRCS assistance. Although 10 of the 30 farm manure storage systems were not designed and installed by NRCS, only two of the farms did not have adequate manure storage to meet the needs of the farm. One of these storages needs to be expanded and the other needs to have improved containment. Both producers are aware of the concerns and are interested to improve their manure storage.

Barnyard Design

Six of the farms do not have or use an outside barnyard for any of their animals. The other 24 farms use improved barnyards of which only nine of the barnyards were designed and installed with NRCS assistance. Eight of the barnyards have adequate curbing installed to retain liquids from uncontrolled runoff of which three are scraped directly into a manure storage structure and the other five have curb cuts (holes) that allow runoff directed to a grass filter area. Of the remaining 14 barnyards with no curbing, two of them are drained directly into a manure pit and 12 have runoff that goes to a natural grassed area that buffers a defined waterway. Most barnyards are used only for short periods during the day for exercise areas while barns are cleaned. A more complete evaluation of these barnyard runoff areas is recommended to determine if additional filter area improvements should be installed to prevent runoff from reaching surface water.

Silage Leachate

Silage leachate control is an area of concern on most of the farms in the project. Only five farms have silage or forage management systems that are adequate to eliminate silage leachate concerns. On these farms silage or forage is stored as wrapped round bales, dry hay or in plastic ag-bags. On the remaining farms the silage leachate runs to some sort of grassed area before reaching a waterway and three farms have an inadequate silage leachate control system installed. However, these farms should have further evaluation to determine what other best management practices could be implemented to further limit the loss of nutrients to surface or ground water.

Roof Runoff

Eight of the farms have no system installed to divert roof runoff away from the livestock production areas. The other 22 farms have some type of clean water drainage or diversion installed that prevents manure contamination. Sixteen of the farms have tile lines installed under roof eves to move water away from barns, around manure and silage storage areas, and out to grass field areas. The remaining six farms have some type of diversion in place to intercept and move water away from production areas. The farms that do not have a roof runoff system in place would benefit from installed drip-lines or drainages to move clean rain away from the livestock production areas. The farms with installed clean water conveyance systems would also benefit from upgrades and improvements to the current practices installed.

Milk House Waste

On twenty-four of the farms the milk house waste water is added to the liquid manure storage structure and applied to fields when manure is spread. Only two of the farms recycle wash water or plate cooler water. Two of the farms have milk house waste going directly into buried septic tanks and out to leach fields with no visible evidence of surface exposure. On four of the farms the milk house waste flows across the ground to an adjacent corn field or grassed area and does not directly enter a surface waterway. These four farms should be evaluated further to see if an improved wastewater filter area is needed to reduce the potential for process wastewater from entering a waterway.

Livestock Mortality Disposal

Fourteen of the farms dispose of livestock mortalities through burial of animals away from the main production area. Another 13 farms used carcass composting and field spreading as a method of disposal. Two additional farms use a combination of both composting and burial to dispose of dead animals. Only one of the farms pays to have animal mortalities removed from the farm and rendered.

Concentrated Sources Summary

The AEM and concentrated source evaluations identified silage leachate control as a main concern on the farms involved in the project. The concentrated source evaluations also indicate the need for further evaluation on some farms of barnyard management, roof runoff, and milk house waste systems. The roadblocks to the implementation of new best management practices in these four areas are the cost of implementing the practice, voluntary producer agreement that the investment is advantageous to their business profitability, and that these practices are perceived as critical to protect water resources.

Phosphorus Index Summary

The 2007 average Phosphorus Index scores for all farms are shown in figure 7. The Total P Index score is shown as the sum of the Sediment Bound P Index score plus the Dissolved P Index score. The P Index tool assigns a P Index value to each individual field and it is recognized that the contributions of total P loss to surface water varies with the size of an individual contributing field. The P Index scores for all individual fields were normalized for field size and used to calculate a farm weighted average P Index score for each of the three categories of Total, Sediment Bound and Dissolved P loss. For each farm the individual field P Index score for each field was multiplied by the acreage of that field, summed across all fields on the farm and then divided by total farm acres to calculate a farm weighted Index score.

In 2007 the farm weighted Total P Index score for all fields was 54.6, consisting of the sum of the sediment-bound P Index of 17.0 plus the Dissolved P Index of 37.6. In 2007 there were 79 fields that ranked in the High P Index category (61-100) and 41 fields that were scored in the Very High (>100) category. In 2008 (Figure 8), after one year of implementation of practice changes there were only 12 fields in the Very High category and the combined farm weighted Total P Index score for all fields dropped to 50.3.

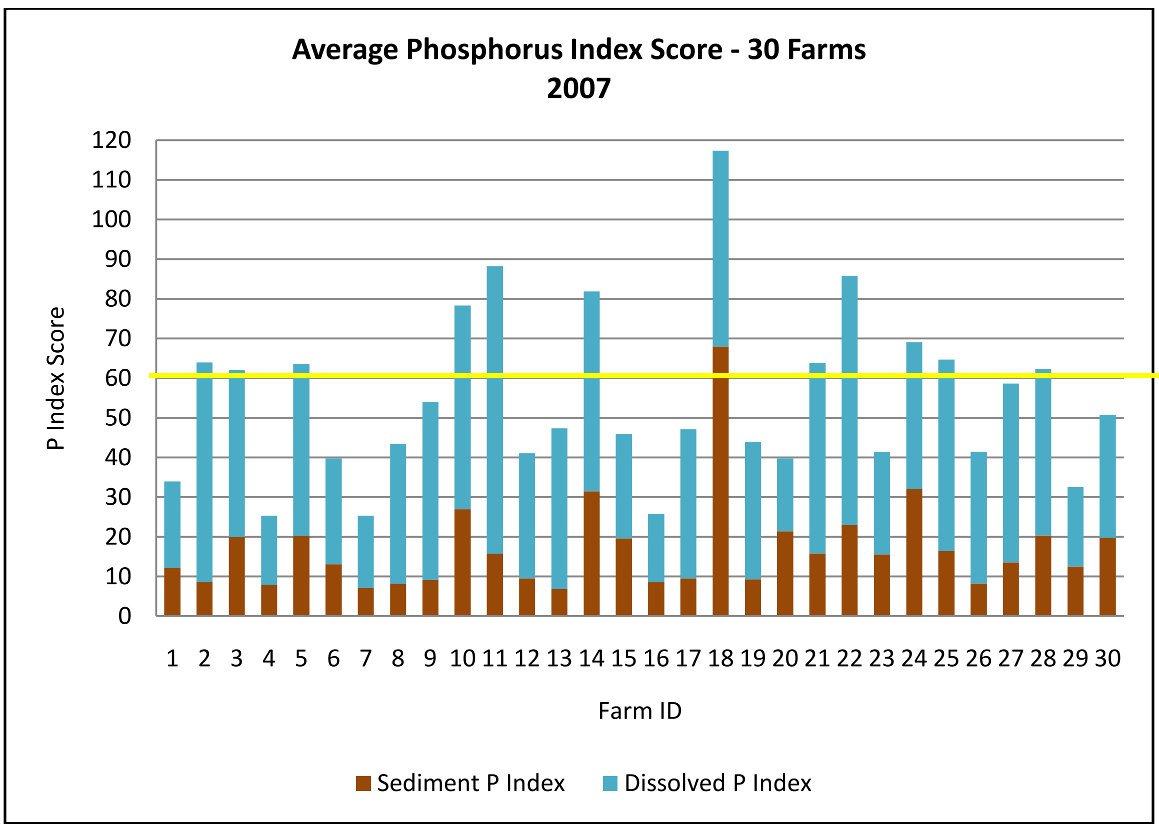

Figure 7. Farm Weighted Average P Index Scores for 30 Farms in 2007

Recommended Farm Management Changes to Lower P Index Scores

Changes that were recommended to improve P-Index scores were the use of vegetated buffer strips, revised crop rotations to reduce soil loss, reduction of P fertilizer applied, and changes in timing of application and incorporation of manure. Reducing the manure application rates was limited to fewer individual sites since most manure was already uniformly spread across all fields on the farms. It was recommended that for all fields with adjacent water courses a 25 foot vegetated buffer be adopted as a management strategy, for grass fields this required staying 25 feet from the stream bank when spreading manure and for corn fields establishing a permanent vegetated buffer that would not receive manure or fertilizer. Changes in crop rotations to reduce soil loss included the addition of a winter cover crop in corn, a reduced number of annual crop years in planned rotations, and the conversion of a field from corn to a permanent hay crop. Reducing the amount of P from fertilizer applications was limited to corn fields, as most grass fields were not receiving any P fertilizer. In the corn fields, the reduction of P fertilizer was achieved by changes in the formula of fertilizer used and reducing the application rates to meet UVM recommendations.

The result was that the farmers changed management practices and achieved a 7.9% reduction in average farm P Index scores from 54.6 to 50.3 in one year. The 2008 average farm P Index scores are shown in Figure 8 where the Total P Index score is the sum of the Sediment and Dissolved P Index scores. Across all farms, from 2007 to 2008 the Sediment Bound P Index score was reduced 10% from 17.0 to 15.3 while the Dissolved P Index fraction of the total score was reduced 7.2% from 37.6 to 34.9. The overall reduction in total P Index scores was only 44% of the potential reduction of 18.1% which could have been achieved if the 2008 nutrient management plan had been strictly followed by all farmers. Similar reductions in P Index scores were shown in the 2009 NMP which was provided to each participant farmer.

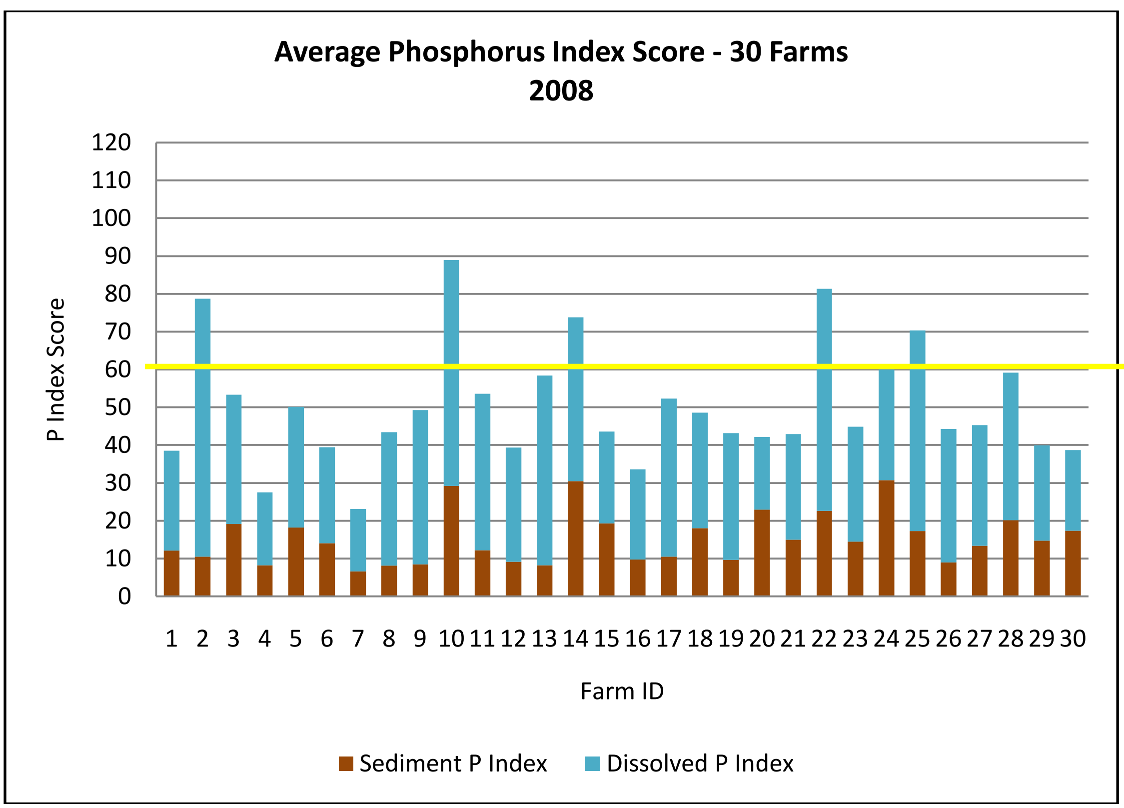

Figure 8. Farm Weighted Average P Index Scores for 30 Farms in 2008

Statistical Evaluation for P Index LS Means

The Total, Sediment Bound, and Dissolved P Index scores for all fields and for farm weighted averages, annual manure P applied, and annual fertilizer P applied were analyzed using ANOVA to test the contrast of what the farms reported doing in 2007 (2007 Actual), what the producers reported doing in 2008 (2008 Actual), and what was planned for in 2008 (2008 Plan). Significant differences were declared at $P \leq 0.05$ and tendencies at $P \leq 0.10$. The LS Means, standard error, and significance of contrasts (*P*-value) are shown in Table 6.

Table 6. P Index LS Means for 2007 Actual, 2008 Actual and 2008 Plan

	LS Means				***P* - value**		
Item	**2007 Actual**	**2008 Actual**	**2008 Plan**	**SE**	**Year**	**2007 Actual vs. 2008 Actual**	**2008 Actual vs. 2008 Plan**
385 Fields Total P Index Score	53.2	50.2	43.7	0.98	<0.001	0.03	<0.001
385 Fields Sediment Bound P Index Score	16.2	15.0	13.6	0.61	0.01	0.17	0.11
385 Fields Dissolved P Index Score	37.0	35.2	30.1	0.74	<0.001	0.09	<0.001
Farm Weighted Total P Index Score	54.6	50.3	44.7	3.20	0.10	0.34	0.22
Farm Weighted Sediment Bound P Index Score	17.0	15.3	14.0	1.61	0.42	0.46	0.57
Farm Weighted Dissolved P Index Score	37.6	34.9	30.7	2.34	0.12	0.42	0.20
Total Manure P Application (lb/ac/yr)	64.0	53.4	65.2	1.11	<0.001	0.45	<0.001
Fertilizer P Application (lb/ac/yr)	12.6	5.86	10.2	0.80	<0.001	0.03	<0.001
Hay Acres	2830	2882	2767	-	-	-	-
Corn Acres	1456	1404	1519	-	-	-	-

The Total P Index score for all fields (n=385) significantly decreased from 2007 to 2008 with more of the decrease related to the reduced amount of Dissolved P in surface runoff than from Sediment Bound P. The farm weighted Total P Index scores in Table 6 tended to be different among the three P Index evaluations but there was not a significant ($p<0.05$) statistical difference between the 2007 actual and 2008 actual or the 2008 actual and the 2008 plan (n=30). Similarly the weighted Sediment Bound P index scores and weighted Dissolved P Index scores were not statistically different among the three evaluations or for the contrasts of the different plans. The weighted Dissolved P Index scores were higher in all three evaluations than the weighted Sediment Bound P Index scores. This difference is influenced by the greater number of acres in grass hay production where manure or fertilizer P is not incorporated compared to corn where manure is typically incorporated with tillage. Fertilizer P applications decreased from 2007 to 2008 by 2.4 lb/ac/yr, and potentially could have decreased by 6.7 lb/ac/yr if the plans were more closely followed. The observed changes in fertilizer P applied were a result of changes in the formulation of fertilizer used for corn starter and decreases in the rate of corn starter applied. Many of the farms were advised to change from a standard 10-20-20 corn starter to a 20-12-20 starter containing less P and to decrease their normal rate of 300 to 400 lbs/acre to only 100 to 200 lbs/acre.

Multiple Regression of P Index Variables with Total P-Index Score.

The P Index variables for source and transport, including soil test P, annual manure P application, annual fertilizer P application, erosion rate as determined by RUSLE 2 calculations, and distance to water. The P Index variables were analyzed by step wise multiple regression and correlation to the Total P Index score using the Proc Corr and Proc Reg procedures of SAS v. 9.1.3 (SAS Institute, 2003). Three regressions were run using the 2007 Actual data, with the 2008 Actual data, and then with both the 2007 and 2008 Actual. Total fertilizer P (lb/ac/yr) was not used in the final regression evaluation due to the lack of a significant correlation with the Total P index score. The lack of a significant correlation of fertilizer P and Total P index score was likely influenced by application of the majority of the fertilizer P applied in corn starter at planting in a subsurface band, which is associated with a factor of zero in the P Index calculations (see Table 7).

Table 7. Multiple Regression Coefficients, *P*-value, and R^2 for Total P Index Score Factors.

	2007 Actual		**2008 Actual**		**2007 and 2008 Actual**	
Variable	Regression Coefficient	*P*-value	Regression Coefficient	*P*-value	Regression Coefficient	*P*-value
Soil Test P (ppm)	1.13	<0.001	0.63	<0.001	0.90	<0.001
Total Manure P (lb/ac/yr)	0.59	<0.001	0.40	<0.001	0.49	<0.001
Total Fertilizer P (lb/ac/yr)	-	-	-	-	-	-
RUSLE2 Erosion (t/ac/yr)	8.69	<0.001	5.84	<0.001	7.62	<0.001
Distance to Water (ft)	-0.06	<0.001	-0.05	<0.001	-0.05	<0.001
R^2	0.69	--	0.47	--	0.58	--
Intercept	6.98	0.004	20.2	0.008	13.6	<0.001

The primary factors of soil test P, total manure P, and RUSLE2 erosion all significantly ($P<0.001$) influenced the Total P Index score. The increase of these factors caused an increase in the total P Index score. Distance to waster was found to negatively influence the Total P Index score, showing that increases in distance to water decrease the total P Index score. The best relationship was found when only the data from the 2007 actual was used, with an R^2 of 0.69. Overall the three evaluations show the same relationship of these factors to the changes in Total P Index score.

Analysis of Soil Test P levels of Fields with High and Very High P Index Scores

There were a total of 757 acres in grass hay production and 580 acres of corn in 2007 in the fields with High (60 to 100) or Very High (>100) P Index scores as shown in Table 8. In 2008, the number of hay acreage within these categories of High and Very High P Index decreased by 24% to 576 acres, while corn acreage decreased by 42% to 334 acres. In 2007, 69% of the grass fields (34 fields) with a High P Index score had a Medium or Optimum soil test P values, while 59% of the grass fields (13 fields) with a Very High P Index score had High or Excessive soil test P values. The corn fields in 2007 were different than hay in that the majority of fields with High or Very High P Index scores also had High and Excessive soil test P levels. The elevated soil test P levels may be contributed to the typical farm practice observed of liberal applications of manure to fields in continuous corn production.

Grass fields with Very High P Index scores in 2007 were influenced more by soil test P levels and manure P applied (lb/acre/yr) than by distance to water. Corn fields that had a Very High P Index score in 2007 were influenced more by distance to water and soil test P levels than by manure P applied (lb/acre/year). In 2008 the Very High P Index Grass fields were influenced most by the manure P applied whereas corn fields were most influenced by excessive soil test P values in those two fields.

Table 8. Number of Fields in each Category of Soil Test P where P Index >60

Grass Hay Fields	**2007 Actual (Grass)**				**2008 Actual (Grass)**			
	High		**Very High**		**High**		**Very High**	
Soil Test P Level	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**
Low (0 to 2 ppm)	2	14	1	2.3	0	0	0	0
Medium (2.1 to 4.0 ppm)	17	192	3	30	12	111	3	17
Optimum (4.1 to 7.0 ppm)	17	254	5	32	14	198	3	21
High (7.1 to 20 ppm)	9	99	9	71	17	160	2	14
Excessive (>20 ppm)	4	21	4	42	6	51	1	4.4
Total	**49**	**580**	**22**	**177**	**49**	**520**	**9**	**56**
Manure P applied (lb/ac/yr)	76.1 ± 25.9		92.1 ± 30.7		73.2 ± 22.5		104 ± 24	
Fertilizer P applied (lb/ac/yr)	4.78 ± 10.7		5.36 ± 9.51		1.20 ± 6.69		3.0 ± 9.0	

Corn Fields	**2007 Actual (Corn)**				**2008 Actual (Corn)**			
	High		**Very High**		**High**		**Very High**	
Soil Test P Level	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**
Low (0 to 2 ppm)	1	3.4	1	8.7	0	0	0	0
Medium (2.1 to 4.0 ppm)	2	11	3	16.2	2	7.9	0	0
Optimum (4.1 to 7.0 ppm)	5	92	0	0	3	70	0	0
High (7.1 to 20 ppm)	19	184	6	89	9	120	0	0
Excessive (>20 ppm)	3	31.2	9	138	7	118	2	18
Total	**30**	**322**	**19**	**258**	**21**	**316**	**2**	**18**
Manure P applied (lb/ac/yr)	83.7 ± 12.5		85.9 ± 7.56		76.7 ± 22.4		80	
Fertilizer P applied (lb/ac/yr)	38.4 ± 22.2		29.1 ± 22.8		35.1 ± 24.7		14 ± 28	

Interaction of Crop and Distance to Water for Fields with High and Very High P Index Scores

Evaluation of all fields in 2007 with a High or Very High P Index score (>60) shows that a higher percentage of corn fields were at a distance greater than 100 ft. from water than grass fields (26.5% vs. 15.5%). There were also more hay fields than corn fields, 24 vs. 10, which had a P Index of High or Very High within a distance to water of 0 to 10 ft as shown in Table 9. In the group of fields with Very High P Index scores it is evident that there were 17 fields with a buffer width less than the state requirement of 10 ft from a water course and the implementation of wider buffers on these 17 fields would have the greatest impact to reduce the total number of Very High P Index fields. Within this group of farms in the project there were a greater number of hay crop acres (758) than corn acres (573) in fields that had High and Very High P Index scores. One factor is that the manure spread on hay fields without incorporation contributed to higher dissolved P Index scores in these fields compared to corn fields where manure is typically incorporated with mechanical tillage.

Table 9. 2007 Fields with High and Very High P Index Scores by Crop and Distance to Water

	High				Very High			
	Grass		Corn		Grass		Corn	
Distance	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**
>100 FT	8	117	12	88	3	24	1	4
25 to 100 FT	18	190	11	87	2	18	5	56
11 to 24 FT	9	100	4	121	7	58	6	55
0 to 10 FT	14	174	3	26	10	78	7	136
Total	49	581	30	322	22	178	19	251

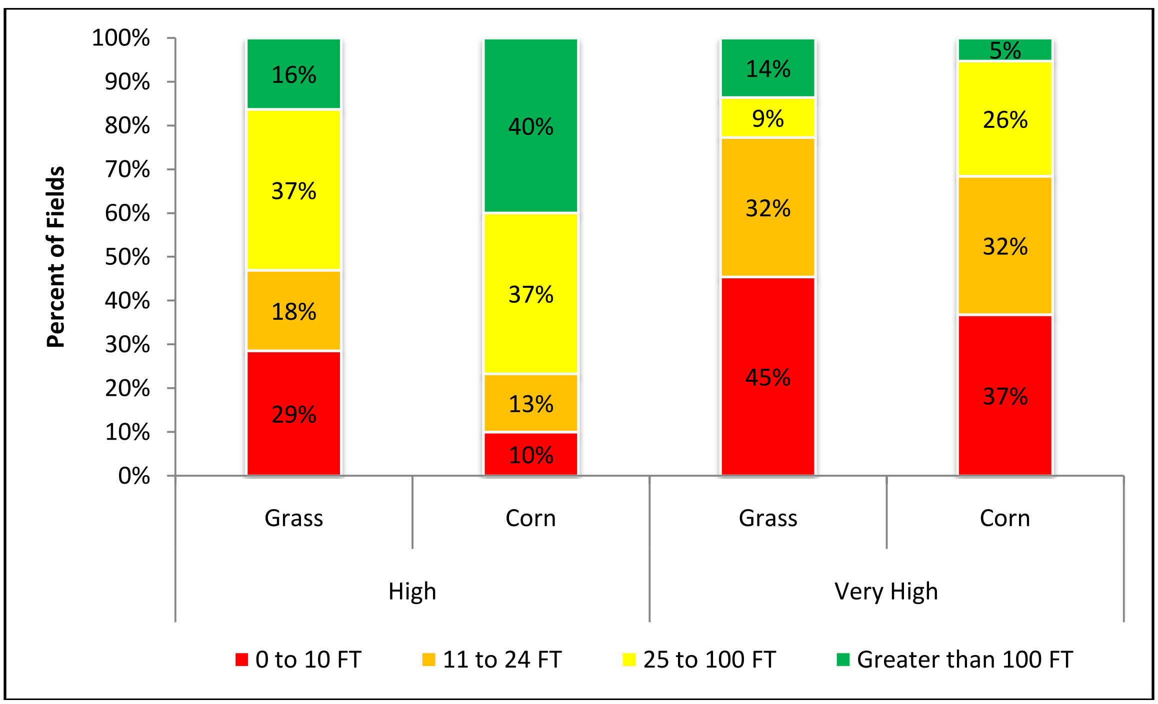

Figure 9. 2007 Fields with High and Very High P Index Scores by Crop and Distance to Water

Interpretation of P Index Results by Crop Type

In 2007 there were 41 fields (10.6%) of the 385 fields ranked in the Very High P Index category and that count decreased to 12 (3.1% of all fields) in 2008 as a result of changes in farm practices. The number of corn fields in the Very High category was reduced by 89% from 19 to 2 between 2007 and 2008 while there was also a decrease of 45% from 22 to 10 grass hay fields. The number of fields, acres, and percentage of fields in each of the four P Index categories are shown in Table 10 and Figure 10. In 2007 there was a higher percentage of corn fields (48%) than grass fields (25%) that were in the High and Very High categories, by 2008 only 23% of corn fields (24 out of 103) still had a High or Very High P Index while 33% of the hay fields remained in that High and Very High P Index categories. There was also a 41% increase in the number of corn fields with a Low and Medium P Index (<60) between 2007 and 2008 indicating a reduction in potential P loss from those fields. The primary management changes implemented by the farms included quicker incorporation of manure, changes in timing of manure application from fall to spring, and reductions in fertilizer P applications in corn.

Table 10. Number of all Fields in each P Index Category by Crop

	2007 Actual				2008 Actual				2008 Plan			
	Grass		Corn		Grass		Corn		Grass		Corn	
Category	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**
Very High	22	177	19	252	10	59	2	18	0	0	0	0
High	49	581	30	322	83	799	22	321	60	542	26	376
Medium	149	1289	39	625	145	1430	53	691	148	1366	50	702
Low	60	790	17	250	44	594	26	374	67	859	34	441
Total All Fields	280	2837	105	1449	282	2882	103	1404	275	2767	110	1519

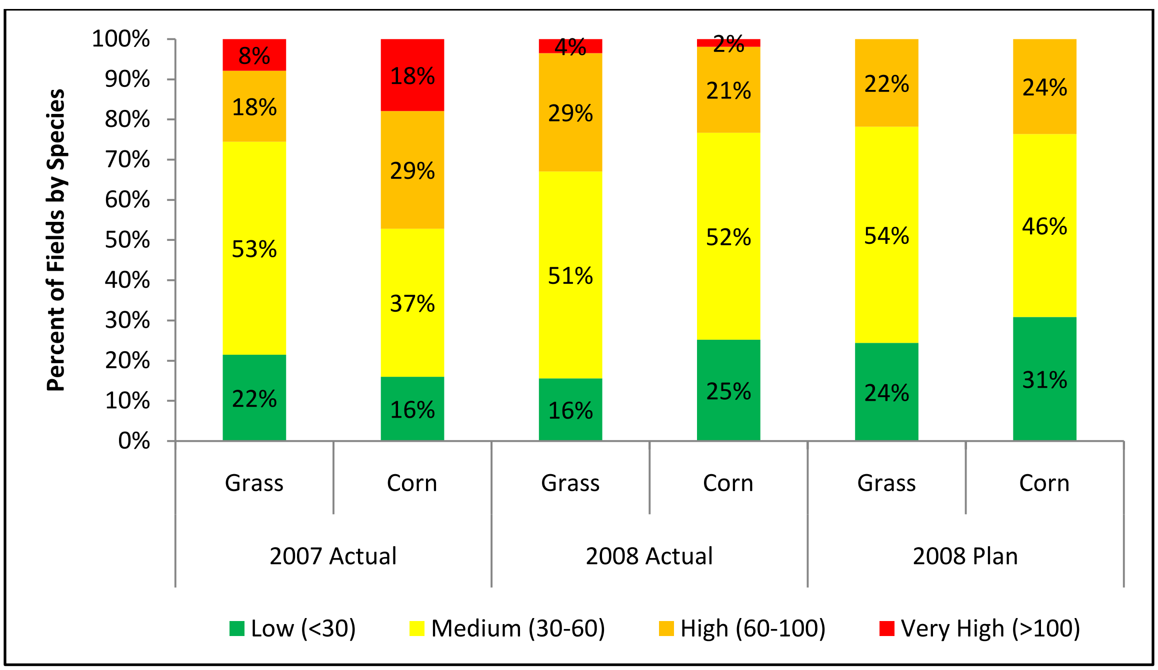

Figure 10. Percent of all Fields in each P Index Category by Crop

Analysis of Fields with High or Very High P Index scores by Crop Type

In 2007, 120 of the 385 fields in the project had a High or Very High P Index score, 66% of these were rated High (>60) and 34% were Very High (>100) (see Table 11). The distribution of these fields between corn (19) and grass (22) was similar but due to field size differences there was 29% more corn acres (252 vs. 177) with a P Index greater than 100. By 2008 the number of fields with Very High P Index scores decreased by 70% to 12 fields and the number of fields with a High P Index score remained the same. One-third of all these fields 40 out of 120) had reduced P Index scores to less than 60, moving them to the Medium or Low P Index score categories.

In the 2008 plan there were no Very High P Index fields planned, 47 fields would still have a High P Index between 60 and 100, and the majority, 73 fields (61%), would have reduced P Index values to below 60 (Medium and Low). In both the 2008 Actual and 2008 Plan, grass hay accounts for a greater portion of acres in the High P Index categories (>60).

Table 11. Number of Fields in P Index Categories by Crop where 2007 P Index >60

	2007 Actual				**2008 Actual**				**2008 Plan**			
	Grass		**Corn**		**Grass**		**Corn**		**Grass**		**Corn**	
Category	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**
Very High	22	178	19	251	10	56	2	18	0	0	0	0
High	49	581	30	322	48	521	21	316	21	433	26	375
Medium	0	0	0	0	11	138	27	244	48	302	22	195
Low	0	0	0	0	2	38	0	0	0	0	3	26
Total All Fields	71	759	49	573	70	753	50	578	69	735	51	596

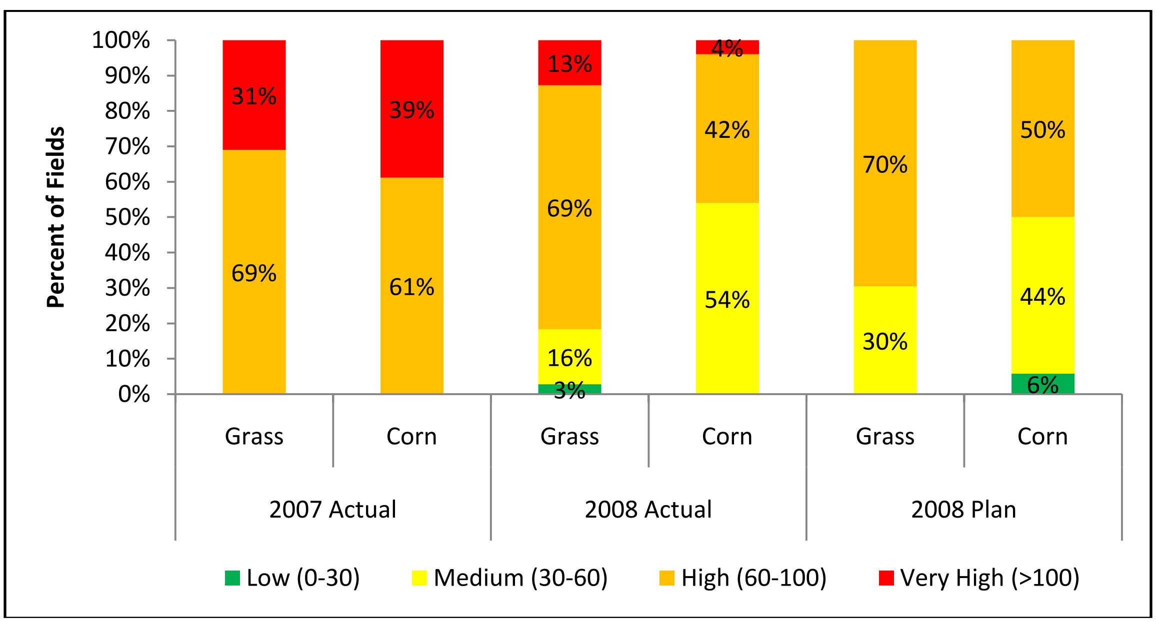

Figure 11. Percent of Fields in P Index Categories by Crop where 2007 P Index >60

Interpretation of P Index Results by Distance to Water

In 2007 there were 50 fields, 13% of all fields, which had a 10 foot or less vegetated buffer area maintained from the top bank of a water course to where manure or fertilizer was spread (Table 12 and Figure 12). The distance to water was not a major change that was made in 2008 by the producers (48 vs. 50) that would account for the overall decrease in the number of fields with Very High P Index scores. The 2008 plan was presented to the farmers with all fields having a 25 foot buffer prescribed in the plan to meet the 590 NMP Conservation Standard but the implementation of 25 foot buffers in corn or other row crop fields was challenging to achieve since land would have been taken out of production to meet this standard. The farmers were mostly unwilling to reduce productive crop acres without compensation for lost crop yield. Future reductions in P Index scores could be achieved if the recommended vegetative buffers are installed.

Table 12. Number and Acres of all Fields in 4 groups of Distance to Water

	2007 Actual				**2008 Actual**				**2008 Plan**			
	Grass		**Corn**		**Grass**		**Corn**		**Grass**		**Corn**	
Distance	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**
>100 FT	123	1231	35	362	127	1258	32	329	124	1204	35	383
25 to 100 FT	70	663	37	542	69	672	39	554	151	1564	75	1135
11 to 24 FT	49	549	21	330	48	539	22	339	0	0	0	0
0 to 10 FT	37	386	13	222	38	412	10	181	0	0	0	0
Total All Fields	279	2830	106	1456	282	2882	103	1404	275	2768	110	1518

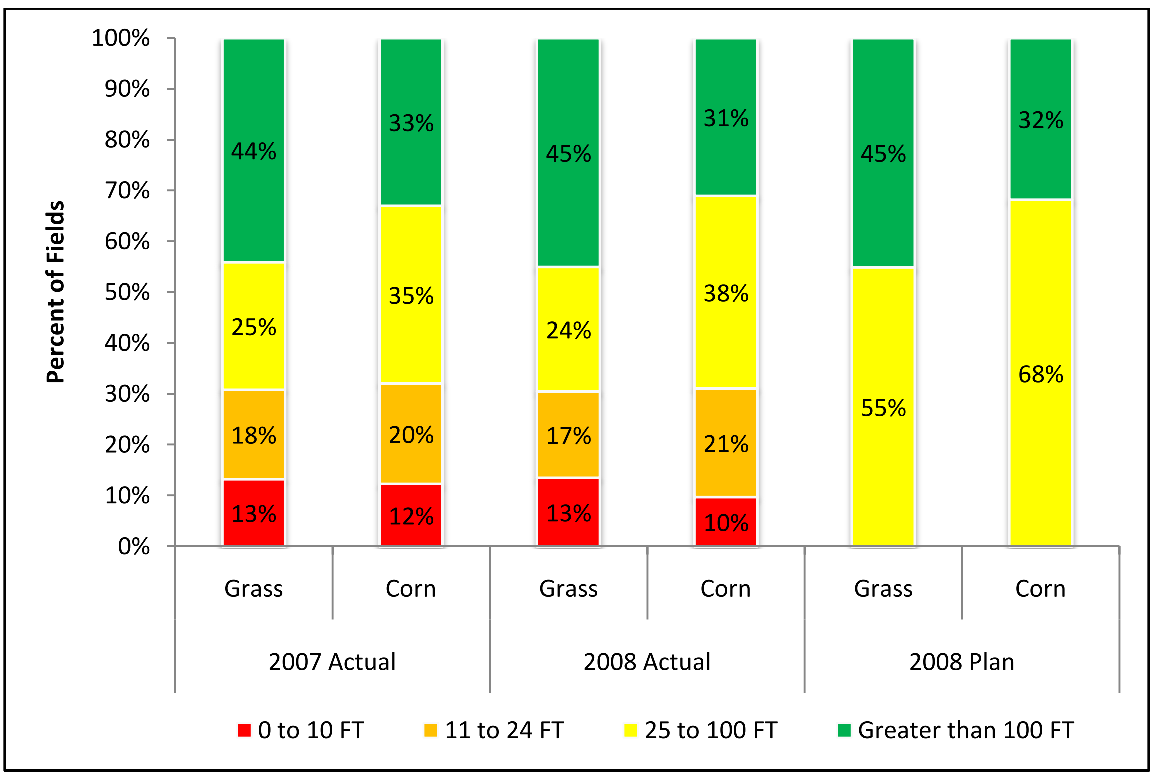

Figure 12. Percent of all Fields in 4 groups of Distance to Water

Analysis of Fields with High or Very High P Index by Distance to Water

The observed distance to water of the fields that had a High or Very High P Index score (PI>60) in 2007 was fairly evenly distributed among the 4 distance groups as shown in Table 13 and Figure 13. This distribution did not change in the 2008 Actual evaluation, indicating that changes in distance to water was not the major factor in changes to P Index scores between the two years. The largest change recommended in the 2008 Plan was shifting the fields in the 0 to 10 FT category to the 25 to 100 FT category by installing a minimum 25 foot vegetated buffer (no manure spreading) in all fields.

Table 13. Number of Fields in 4 groups of Distance to Water where 2007 P Index >60

	2007 Actual				2008 Actual				2008 Plan			
	Grass		Corn		Grass		Corn		Grass		Corn	
Distance	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**	**Count**	**Acres**
>100 FT	11	141	13	92	13	147	11	86	12	142	12	90
25 to 100 FT	20	208	16	143	20	214	18	152	37	592	39	537
11 to 24 FT	16	157	10	176	15	148	11	185	0	0	0	0
0 to 10 FT	24	252	10	162	23	245	9	154	0	0	0	0
Total All Fields	71	758	49	573	71	754	49	577	69	734	51	627

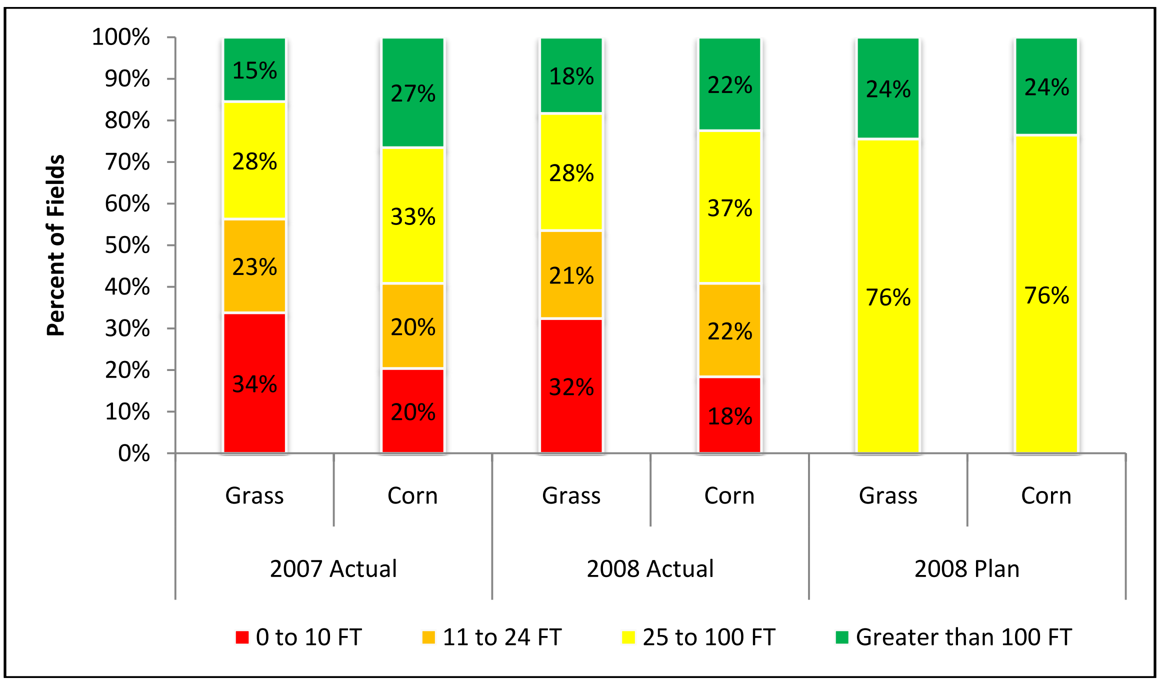

Figure 13. Percent of Fields in 4 groups of Distance to Water where 2007 P Index >60

Conclusions and Recommendations

In this project the reduction of Phosphorus Index scores from 2007 to 2008 on the 30 participating farms reflects a measurable and significant decrease in phosphorus loss from agricultural non-point sources to surface water streams and into Lake Champlain. The farmers implemented changes in crop management practices as a result of the information gained through this process of farm data collection, the process of developing individual farm Nutrient Management Plans, and discussions with crop advisors involved in the project. After only one year the actual reduction in P Index scores was nearly one-half of the potential reduction that could have been achieved by fully implementing the Nutrient Management Plan recommendations. Future reductions are expected as a result of this project based on the interest expressed by the farmers about the value of having a current plan with updated soil and manure tests and by having gained knowledge about how they can apply the recommendations of a Nutrient Management Plan to improve crop production in their fields. The continued presence of a personal farm advisor over a longer term would benefit most farmers in keeping a management plan current and provide incentive to implement recommended practices.

The farms involved in the project were a nice mix of dairy farms that are representative of the smaller family farms throughout the area of northern Vermont. The field crop base of two-thirds hay and one-third corn across the 30 farms allows for rotation of fields from annual row crops to hay crops although many fields remain continuously in one crop or the other. The challenges of using livestock manure as a primary crop nutrient source were evident since manure P applications had a far greater effect on P Index scores than fertilizer P applied. The surface applications of manure on hay crops without incorporation contributed to the findings that the Dissolved P portion was twice as great as the Sediment Bound portion of the Total P Index scores. It was interesting to note that high farm livestock density (AU/ac) was not strongly correlated with the farm's P Index values. There are many farm practices that can be changed to reduce phosphorus loss from crop fields and all must be addressed to make significant changes. The choice of growing corn or hay was not the predominant factor, nor was fertilizer selection, but the greatest reductions would have been achieved from adequately sized stream buffers of permanent vegetation that do not receive manure applications and also by incorporation of manure in all crop fields.

The use of the summary Phosphorus Index values (Total P, Sediment Bound P and Dissolved P) to quantify the impact of multiple farm practice changes in a field was a successful method of interpreting the effects of changing the variables that influence the potential loss of phosphorus. There have been attempts to attribute a set quantity of P loss in lb/ac/yr for a given P Index value, but after interpreting the data, conclusions of absolute P loss amounts are not reported in this project. The P Index is a useful tool to identify the potential sources of P loss from crop fields and compare differences between fields and between farm practices, but there are certain aspects of the P Index that does not allow for confidently measuring actual P losses to surface waters. Since the P Index represents the average for a whole field the possible contribution of specific sites in the field cannot be determined and there were specific production scenarios encountered that were not addressed in the P Index options. Although the P Index tool is a very good method to evaluate potential P loss, we recommend that financial resources should be dedicated for field research to measure the effects of emerging new practices and update the P Index model.