Lake Champlain Basin Program

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Implementation of Whole Farm Nutrient Management to Reduce Phosphorus and Improve Farm Viability in the Lake Champlain Basin

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IMPLEMENTATION OF WHOLE FARM NUTRIENT MANAGEMENT TO REDUCE PHOSPHORUS AND IMPROVE FARM VIABILITY IN THE LAKE CHAMPLAIN BASIN

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1. EXECUTIVE SUMMARY

The goal of this project was to demonstrate how, through whole farm nutrient management, improvements can be made to water quality through reduced phosphorus (P) loading and improved farm viability. Through this project we worked closely with five farms located in critical source areas to build a program that implements comprehensive P management strategies on a whole farm level. This diverse group of farmers included a Large Farm Operation (St. Albans Bay Watershed), Medium Farm Operation (Lake Carmi), Certified Small Farm Operation (Rock River Watershed), organic grass-fed farm (Rock River Watershed), and one farm that had recently converted from milking dairy cows to boarding animals for other producers (Lake Carmi).

Farms were visited regularly in the first year to collect baseline data to base phosphorus (P) reducing recommendations. The primary focus was to reduce purchased feed and lower P loading at the farm level. Most of this work focused on monitoring feed rations and creating a plan for each farm to increase, where possible, the utilization of home-grown high-quality forages instead of purchased feeds. The project team evaluated in-field crop management, feed storage, feed rations, and barn management.

Recommendations were created for each farm and implementation occurred in subsequent years. Recommended practices included targeted fertility management on forages, enhanced forage diversity, improved bunk management and feed storage, cow management related to feeding, and ration management to maximize homegrown feeds. Our analysis of the forage programs on the farms resulted in the identification of feed storage being a major driver in feed degradation resulting the need to purchase grain to maintain viable levels of milk production.

Mass nutrient balancing, precision feed strategies, and agronomic practices were deployed on farms to target variables such as ration P levels, fecal P levels, herd health, soil health, soil test nutrient levels, milk quality and quantity. The Whole Farm Mass Nutrient Balance tool provided a baseline from which our team was able to document changes in P losses and load on the farm. During the project the pandemic hit creating supply chain interruptions and severe financial constraints on farms. This posed many challenges for the project including the ability to work directly with the farmers, severe stress on the farms, and reduced resources to implement projects. Although throughout the project period each farm experienced significant changes and challenges the program was still able to highlight reductions in P loading.

Farms increased the amount of farm grown forage being fed from 79.8% to 91.6% of the total ration during the project period. This meant grain as a percentage of the ration was reduced from 20.2 to 7.4%. These changes reduced the amount of surplus P on the farm from an average 2.14 tons per year to 0.70 tons P per year.

Reducing reliance on imported feed improves farm viability and reduces P loading and potential loss to watersheds. Outreach to over 328 stakeholders and a policy paper on the importance of feed storage was conducted to highlight the process and outcomes of the whole farm nutrient management project.

2. CONTENTS

Executive Summary 3

2. Tasks Completed 6
3. Methodology 12
4. Quality Assurance Tasks Completed 13
5. Deliverables Completed 14
6. Conclusions 15
7. References .... **Error! Bookmark not defined.**
8. Appendices 18

3. PROJECT SYNOPSIS

According to the EPA, as much as 43% of the phosphorus (P) loading into Lake Champlain is associated with the agricultural sector in Vermont, largely attributed to the manure produced by the state's 131,000 dairy cows. Although P is an essential nutrient for both dairy cows and agricultural crops, excessive P in feed, soils, and water can pose environmental and economic risks to our waterways and farm businesses. Efficient use of P sources on farms is critical to mitigating these risks. However, this requires a comprehensive approach to nutrient management.

The goal of this project was to demonstrate how, through whole farm nutrient management, improvements can be made to water quality through reduced P loading and improved farm viability. Through this project we worked closely with five farms located in critical source areas to build a program that implements comprehensive P management strategies on a whole farm level. This diverse group of farmers included a Large Farm Operation, Medium Farm Operation, Certified Small Farm Operation, organic grass-fed farm, and one farm that had recently converted from milking dairy cows to boarding animals for other producers. Farms were visited monthly in the first year to gain an understanding of farm management and to collect baseline data for which to base P reducing recommendations. The primary focus was to reduce purchased feed and lower P loading at the farm level. Most of this work focused on monitoring feed rations and creating a plan for each farm to increase, where possible, the utilization of home-grown high-quality forages instead of purchased feeds. This meant that the project team had to evaluate in-field crop management, feed storage, and feed rations. Recommendations were created for each farm and implementation occurred in subsequent years. Recommended practices included targeted fertility management on forages, enhanced forage diversity, improved bunk management and feed storage, cow management related to feeding, and ration management to maximize homegrown feeds.

Mass nutrient balancing, precision feed strategies, and agronomic practices were deployed on farms to target variables such as ration P levels, fecal P levels, herd health, soil health, soil test nutrient levels, milk quality and quantity. The Whole Farm Mass Nutrient Balance tool provided a baseline from which our team was able to document changes in P losses and load on the farm. During the project the pandemic hit creating supply chain interruptions and severe financial constraints on farms. This posed many challenges for the project including the ability to work directly with the farmers, severe stress on the farms, and reduced resources to implement projects. One of the farms experienced a barn fire and lost their milking facility minimizing our ability to track changes during the project and another farm changed the type of animals they were boarding making it difficult to compare from baseline to current. Although throughout the project period each farm experienced significant changes and challenges the program was still able to highlight reductions in P loading. At baseline farms were feeding farm grown feed as 79.8% of the ration with the remaining 20.2% being imported feeds. At the end of the project farms were feeding an average 91.6% of the ration as farm grown feed with 7.4% coming from imported feed. The baseline P surplus on the farms averaged 2.14 tons per year. At the end of the project the P surplus on the farms average 0.70 tons per year.

All farms produce home grown forage and invest significant resources in growing, harvesting, and storing the feed produced on farm. Maximizing the quantity and quality of this feed both harvested from the field and stored on the farm is critical to reducing farm reliance on imported feedstuffs. Reducing reliance on imported feed improves farm viability and reduces P loading and potential loss in our watersheds. We expect that this focused approach could serve as a model for other regions. Outreach to over 328 stakeholders was conducted to highlight the process and outcomes of the whole farm nutrient management project.

4. TASKS COMPLETED

The overall outcome of this project was to decrease agricultural nonpoint source nutrient pollution, specifically P, to the Lake Champlain Basin watersheds. Our team worked towards meeting this goal by developing, evaluating, and verifying the effectiveness of whole farm nutrient management (WFNM). In addition to the approved QAPP, there were seven project tasks completed to achieve this goal.

Task #1 Finalize Participants

We identified the participating farmers very early in the project after the QAPP approval. For the selection of the farmers, we were looking for farms that were diverse from each other and located in critical source areas. Below is a description of the 5 farms that participated in the project:

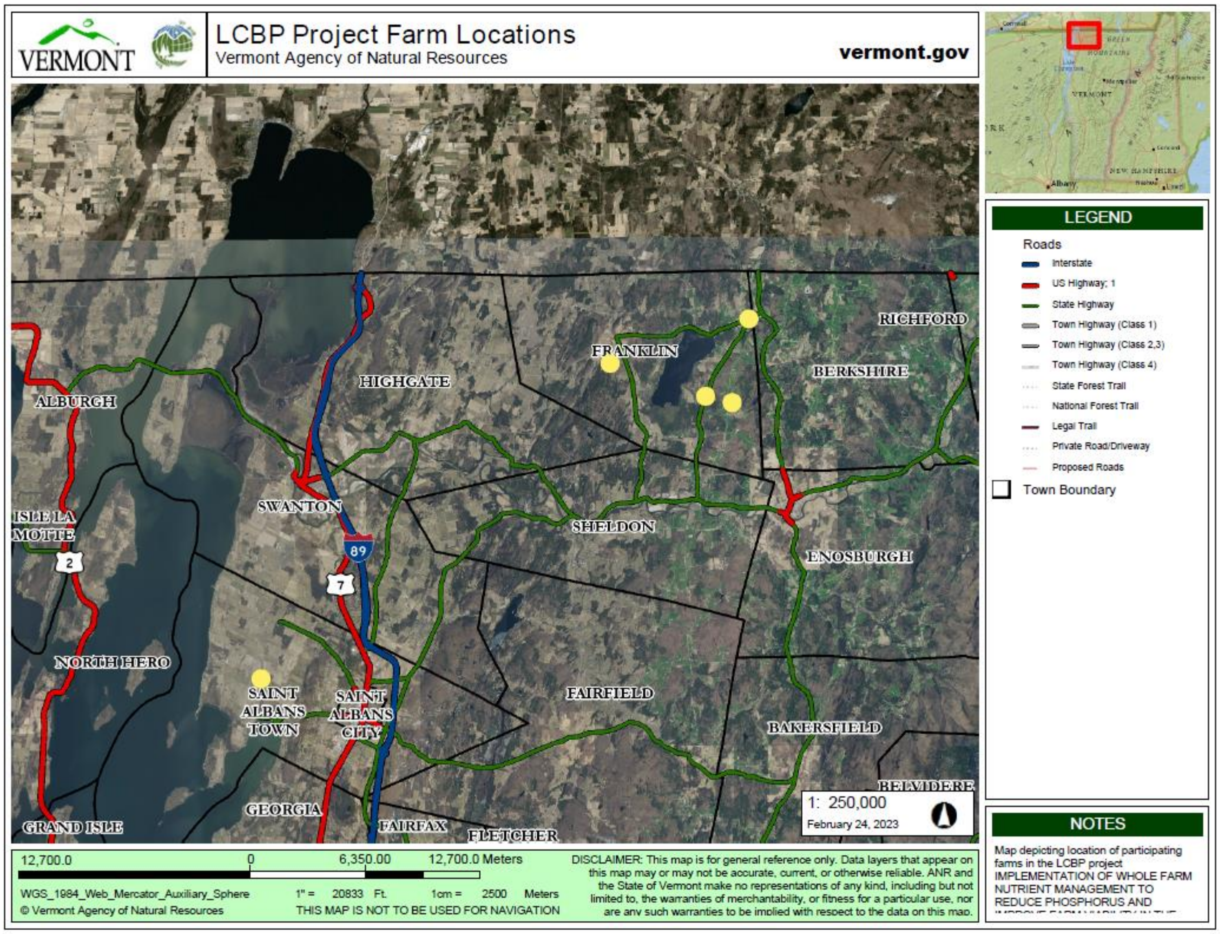
Farm #1: This farm is a Medium Farm Operation with 400 milking cows, and they raise their own replacements. They currently grow approximately 450 acres of corn and have 600 acres of perennial forage. A substantial portion of this farm's cropland is in the Lake Carmi Watershed.

Farm #2: Farm two is a Large Farm Operation. They were milking 750 cows and have about 700 replacement animals. They have about 1050 acres of corn and 700 acres of perennial cropland. The farm suffered a devastating fire in February of 2022, and they are not milking any cows at this location currently. This farm is in the St. Albans Bay watershed on Jewett Brook.

Farm #3: This farm is a Certified Small Farm purchased recently by two brothers who are trying to be successful farming in Northern Vermont. They crop about 140 acres of for corn silage and 400 acres for perennial feed. The farm is in the Lake Carmi Watershed.

Farm #4: This farm has recently converted from dairy to housing 350 dry cows and heifers. While the project was going on he converted to about 300 beef animals and now currently back into dry cows. This farm crops 400 acres of perennial crop land. They have historically been a dairy farm but like many other farms in Vermont are turning to other methods of earning an income off the land. This farm is in the Lake Carmi Watershed.

Farm #5: This is a small grass-fed organic dairy located in Franklin Vermont. They have low input low output type of dairy operation. The UVM team thought it would be insightful to look at a dairy that doesn't utilize much for purchased feeds to see how they compare to others. This farm is in the Rock River watershed. The amount of land they farm varies greatly from year to year. In year one of the project, they cropped about 300 acres. Year two they purchased a farm, and they had access to about 500 acres. In year three they have given up a bunch of rented land and are back to 300 acres. They only grow perennial feed and some summer annuals to help the pastures during drought periods.



Map of farm locations. Also included as Appendix A.

Task # 2: Establish Benchmarks

Farm collaborators, UVM Extension, and project team members (nutritionist and vet) collected baseline data regarding the nutritional and agronomic aspects of the farm's operation. This required sampling of forages, manure, and concentrates. In addition, each farm's nutrient management plan was reviewed, and specific information collected for further assessment. The information was entered into Cornell's Whole Farm Mass Nutrient Balance software and the Forage and Land Inventory Calculator to determine the extent of P imbalance across the farm. This initial assessment helped to identify opportunities for implementation of P reduction strategies. The Mass Nutrient Balance program evaluates all the inputs going into a farm system and includes feed, fertilizer, forages, animals, manure/compost and bedding materials. It takes into account crop production and manure utilization and looks at the outputs such as milk, meat, animals, crops and manure. The result is a ratio of nutrient (N, P, and K) imports to exports and the implications that a high ratio may correspond to a potential for loss to the environment or the opportunity to save money by reducing imports. The Forage and Land Inventory Calculator helps to determine the quantity of homegrown forage required to feed the livestock herd and if the farm's land base and yields are suitable to meet the farm's forage needs. Collaborating nutritionists evaluated the farm's ration and options to optimize homegrown forage and minimize purchased inputs. The current NMP was reviewed to determine further gains that could be made with field-based strategies (i.e. rotations, no-till, manure management, fertilizer applications).

The results from the Cornell Whole Farm Mass Nutrient Balance are contained in Appendix B.

Task #3: Identify best strategies for reducing P on each farm

The UVM Extension team worked with collaborating nutritionists to create a list of P reduction strategies, informed by the data collected at the site visits, farm interviews, and subsequent one-on-one conversations with each farm. Once developed, the list of recommendations was discussed with the farmer and a plan developed for changes/modifications that could be implemented on the farm during the project timeline. The UVM Extension team helped farmers access additional support through technical service programs such as NRCS EQIP, VAAFM BMP, and other grants when applicable.

All the farms were considered leaders in field conservation practices. Farms had up to date and compliant nutrient management plans. Other practices such as no-till, cover crops, and buffers were all being implemented on the farms. The P imports from fertilizer were extremely low on a yearly basis ranging from 0 to 0.93 tons per year depending on the farm.

The primary strategy to reduce P was the improvement of quantity and quality of homegrown forage. Feeding a high-quality home-grown forage would reduce the need for purchased grains reducing P loading, potentially improving milk production/quality, improve herd health, and reduce farm input costs.

Our analysis of the forage programs on the farms resulted in the identification of feed storage being a major driver in feed degradation resulting the need to purchase grain to maintain viable levels of milk production. We found that all the farms had goals of ensiling high-quality forage, but most farms could not adequately manage the feed storage facilities in a manner that maintained that quality. Contributing factors include, over-filling of the facility resulting in inadequate feed packing, poor infrastructure conditions leading to the infiltration of oxygen into the stored feed (the fermentation of feed is an anerobic process and oxygen drastically disrupts this process resulting in poor quality feed), and the lack of space which reduces the ability to segregate feed to better match the quality of the feed with the needs of the animals being fed. All these factors also result in an increase in feed respiration which produces leachate. This leachate is a very potent water pollutant.

Another aspect of this project was looking at the types of forages being grown in the fields. Early in the project we began to identify fields that could benefit from improvements in fertility and species selection. For most farms this was through efforts to increase the amount and quality of forages grown on the farm so that the percentage of forage in the herd's diet would increase. All the farms managed enough acres to provide for 85% -100% of their herd's total diet. However, none of the farms were reaching that potential with most farms feeding between 60 and 70% of the herd's total diet from forage produced on-farm. To optimize forage production, farms were asked to improve/diversify their forage species. Most fields were predominantly Kentucky bluegrass and white clover. These species have limited yields and quality. A seed mixture designed for high yields and quality was blended and recommended to farms.

Other recommendations included growing grain, better rotations, and improved fertility management on hay fields. In the barn, recommendations included grouping cows by production levels to target feed grain, reducing herd size to decrease crowding and increase forage intake, and precision feeding equipment to monitor fed quantities.

The reports generated for each farm are contained in Appendix C.

Task #4: Implement P reducing recommendations

There was a wide range of P reducing strategies recommended to the farms (Appendix C) and these ranged from changing how rations were fed to the herd to optimizing feed storage facilities to maintain feed quality.

Implementing P reducing recommendations was the most challenging aspect of this project. First this project started just as the COVID-19 pandemic hit and this created many barriers to collecting baseline data, meeting directly with farmers, and further assisting with implementation. At this time milk prices also plummeted, and farmers were in severe distress. It was a tough time and the project provided strong technical assistance during a very uncertain and challenging time.

The farms all had strategies they hoped to implement to reduce P loading, they also had numerous challenges on the farm which limited the ability to implement and in some cases the effectiveness of the strategies. The farms were constantly trying to adapt to changing weather, market, and operational considerations. The weather clearly has a major bearing on the quality of the feed that is harvested. Less than ideal feed results in increased need for purchased grain to maintain milk production and herd health. The changing prices of milk dictate how much the farmer can spend on making other changes in their operation to address environmental concerns. Operational considerations such as the reliability of harvesting equipment, feed storage practices, the availability of personnel to harvest crops all factor into the product and our ability to reach our goals.

There was a strong need to improve feed storage to protect the quality of the harvested feed. All the farms struggled with having adequate space to store the quantity and quality of feed needed to feed high forage diets. So even if everything was done correctly in the field those hard-earned gains could be easily lost under poor storage conditions. Feed storage is extremely costly to build and during the project period farms did not have resources to improve. Typical BMP programs do not cover feed storage. Hence this improvement, although central to high quality forage, was not implemented. This was the topic of the policy paper (Appendix D).

We then assisted the farmers in securing the forage seed and provided technical assistance when they went to seed down their fields with new forage mixtures. Some farms tried new crops to boost on-farm energy production including snaplage, high moisture corn, and Brown Midrib Sorghum (BMR) Sudangrass. Specific fertility plans were developed for perennial forage to optimize yield and quality. Other management strategies implemented included adjustments to harvest timing, cutting height, and chop length. All these changes were to help improve forage quality and forage intake of the herd.

In the barn, some farms started grouping cows by production levels to feed higher levels of grain to those animals with higher milk production. This kept them from wasting grain on cattle that required less energy because they were producing less milk. Several herds reduced the overall number of cows to reduce overcrowding in the free stall and feeding areas. Overcrowding results in some cows not meeting their dry matter demands and ultimately producing less milk. The UVM team helped farmers implement precision feed technology to track what and how much the herd is being fed. By the end of the project all but one farm had software/hardware to track how the cows are getting fed. This was beneficial to the farms, giving them the ability to feed the animals much more precisely and then being able to track those numbers over time. This helped farmers reduce the amount of grain being fed just through precise weighing of rations being mixed and fed each day.

Because this project was conducted on operating commercial farms, the farms also underwent significant changes during the duration of the project which made tracking the impact of feed ration changes difficult to see in the data. One large farm burnt, and all the cows left the farm, one farm changed from feeding dairy animals to beef and then to dairy heifers, two farms changed grain companies, and one farm eventually stopped milking cows altogether.

Task #5: Calculate reduction from implemented practices

The UVM team worked with all the partners to implement the strategies developed in Task #4. Farm visits were conducted at regular intervals to gather information about progress and challenges that each farm was encountering during this project. We worked with partners to secure funding for farms to implement practices or make changes that would improve the farm viability while addressing the concerns of this project. Several of the farms had feed storage issues which limit the ability to maintain high levels of feed quality which made it difficult to reduce imported feed requirements to the farm. We are currently still assisting farms in addressing these issues. We assisted two of the farms with securing VHCB Water Quality Grants that will help with feed storage modifications. We also helped the farmers incorporate new perennial forage species and management practices (cutting height and length) to improve forage quality. In addition, we assisted farmers with storage management including packing densities and feed out rates. Manure management and fertility recommendations were provided to help farmers improve yields. Feed rations were also analyzed every couple of months and modified to help farmers maximize the use of the feed they are growing at the farm. In many cases, grain was reduced on these farms just through better nutrition recommendations. At the end of the project Whole Farm Nutrient Balances were completed to compare baseline to final project results.

The results from the Cornell Whole Farm Mass Nutrient Balance are contained in Appendix B.

Farm 1. This farm's strategy was to reduce the importation of P through producing more home-grown feeds. They planted additional acres of high energy forage crops to reduce their need to purchase feeds. Forage chop length was shortened to allow better packing the limited bunk space and to increase dry matter intake by the herd. In the barn, herd size was optimized to minimize crowding and maximize dry matter intake of the herd. Rations were adjusted continuously to utilize their farm grown feed. They are also currently working to improve bunker storage to reduce feed losses and ultimately reduce purchased feed requirements. The whole farm mass nutrient balance (MNB) results suggest they were able to cut their imported phosphorus from 9.78 tons per year to 8.58 tons per year from 2019-2022 with most of this reduction coming from less grain being purchased. The farm was feeding 83% of their diet from homegrown feed an improvement from 80% at the start of the project. The farm was awarded a grant in 2023 to address feed storage issues.

Farm 2. This farm is currently rebuilding its milking facility and has no cows being milked on site. They diversified in 2021 and sold much of the crops they grew off the farm. They continue to work on growing high-quality feed and should have cows back at the home facility in early 2023. However, this farm made some significant changes to their feeding program throughout the project. Crop rotations improved with more fields being seeded to high energy perennial forages. This farm was buying haylage and had two years' worth of corn silage stored. Hence, we worked with the farm to move several hundred acres into perennial forage production. Their MNB data suggests that the farm had a slight increase in P surplus going from 2.90 tons to 3.05 tons between 2019-2022. Some of this change is that they switched grain companies and went from mixes to simple ingredients and lost some of their ability to substitute ingredients in the ration. This farm did however increase the amount of farm grown forage in the ration from 72% in 2019 to 87% in 2022.

Farm 3. Farm 3 expanded the amount of corn silage to avoid having to purchase grain. Their perennial forage quality is exceptional, but adjustments were made to fertility so additional yield could be realized. The nutritionists worked with this farm to create production groups within the herd. This allowed for more targeted grain feeding. This farm's major issue is adequate feed storage. The system results in significant losses forcing them to purchase more grain as high-quality feed put into the bunk is degraded due to poor storage conditions. The project team helped the farm develop a short-term plan to reduce losses through utilizing wrapped round bales. This short-term fix allowed the farm to move from feeding 75% of their own forage to 88% during 2022. Also, it led to a 66% reduction in P surplus per year. This is not a permanent solution as their entire feeding system is based on chopped haylage. Funds are desperately needed to fix or build a new bunker so they can continue to feed high forage rations.

Farm 4. In 2022 this farm has once again transitioned from beef back to dairy heifers, this time without any dry cows. This farm continues to look for ways to remain viable without milk as the basis of its revenue generation. This farm raises only perennial forage but was buying corn silage. The corn silage as well as animals moving onto and off from the farm were the primary import of P onto the farm. The P imports were significantly reduced during the project as the type of operation minimized imported animals and feed. The project nutritionists worked with the farm to maximize the perennial forage being fed to the herd since it is produced on the farm.

Farm 5. Farm 5 continues to be a grass only farm and function under a very simple model of farming, low input low output. This farm continues to contemplate selling the cows but hasn't done so yet. This farm does not import any grain, but they were purchasing forage. Overall, their yields were very low, and the team assisted with improved production, harvest timing, and chop length. Results of their MNB indicate that they have reduced P imports from 1.14 tons to 0.53 tons per year from 2019 to 2022. The reduction was a result of higher farm grown feed yields and quality.

Task #6: Disseminate Results

Project results were distributed through a variety of outreach events held at our collaborating farm's operations in June, July, and October of 2022. Each event was advertised to local farmers and agricultural stakeholders. The events had a combined total attendance of 328. In addition, presentations were given at the Vermont Agricultural Partners Working Group, Ben & Jerry's Caring Dairy Program, and at several professional meetings. A report was also generated to document possible policy implications of feed storage improvement.

The outreach event information and policy paper are contained in Appendix D.

Task #7 Quarterly and Final Reports

All quarterly reports were sent to representatives at LCBP and NEIWPCC. This report serves as the final report.

5. METHODOLOGY

The work of this project involved establishing an initial benchmark and then monitoring progress made over the lifespan of the project. UVM staff initially interviewed the five farms that we selected to participate in this project. We collected a wide variety of feed related data that pertains to forages and the feeding of the cows on the farm. Through the initial interview process and data review UVM utilized the Cornell MNB model/tool to document what the phosphorus loading levels were for each farm. We worked with the results of the model to develop plans for each farm to address the need to produce high quality forages to feed the cows to reduce the importation of grain onto the farms which cut phosphorus loading in the Lake Champlain Basin. UVM collaborators developed a worksheet that calculates how much forage you will be able to feed your herd based on your land base and herd characteristics (Appendix E). This helped guide our decisions to how best approach each farm for making improvements in feed quality and quantity if needed. Through our interviews and site visits we worked with the farmers to identify limitations on the farm and how we might address them to promote higher forage diets being fed.

Task 1 - UVM Extension selected 5 farms in critical watersheds, including St. Albans Bay, the Rock River, and the Missisquoi River Basin, who were willing, able, and interested in participating in the project. Potential participants were approached about the opportunity by UVM Extension staff who communicated the project's objectives and goals to the farmers. Farmers were required to supply the partners with access to herd rations, grain/input purchases, herd health and production, and crop management information.

Task 2 - The UVM Extension Team visited each farm monthly during the first year to collect baseline data and to learn/understand farm operations. The UVM Team included agronomists, soil scientists, grazing specialists, and nutritionists. UVM Extension collected baseline data regarding nutritional, herd health, and agronomic aspects of the farm's operation. The information was entered into Cornell's MNB software and Land Inventory Spreadsheet (Appendix E) to determine the extent of P imbalance across the farm. The visits and farm assessment tools helped to identify opportunities for implementation of P reduction strategies.

Task 3 - The UVM Extension Team and farmers created a list of recommended changes that would reduce purchased inputs, maximize farm resources, and reduce potential P loading and losses from the farm. These plans/recommendations were informed by the data collected at the site visits. The UVM Extension team helped farmers access additional support through technical service programs such as NRCS EQIP, VAAFM BMP, VHCB, Working Lands, and DBIC.

Task 4, 5, and 6 – In year 2 and 3, the UVM Extension team worked closely with farmers to implement the changes monitor the outcomes as they relate to the rest of the farm enterprise.

Mass nutrient balancing, precision feed strategies, improvements in cropping systems and nutrient utilization happened on a continual basis to monitor changes in the target variables such as ration phosphorus levels, fecal phosphorus levels, herd health, soil health, soil test nutrient levels, financial statements, milk quality and quantity, etc. This project used proprietary software from Belisle Solution Nutrition to complete nutrition modelling. It used Cornell University's MNB software and precision feed management control spreadsheets to track nutritional benchmarks. It used goCrop™ for the NMP and field recordkeeping portion of the project.

Task 7 & 8 – Project reports, policy and incentive program recommendations. Disseminate results of project to farmers and other relevant stakeholders.

Task 9 – Completed final report.

6. QUALITY ASSURANCE TASKS COMPLETED

Tasks 2 and 5 required primary data acquisition. Each farm had one complete set of data collected. For establishing benchmarks feed samples (one for every type of feed used plus one for the TMR), and manure samples (one from every farm storage structure) were required for all 5 farms. All protocols for feed and manure sampling were outlined in the approved QAPP.

The data was collected beginning in January 2020 and ending December of 2021. Variances from normal sampling methods were documented on the data sheets collected at the time of data acquisitions and copies made and stored at UVM Extension. New sampling bags and bottles were used to collect all data and the protocols described in the QAPP were followed. QA samples were taken on one farm every sampling period. If a QA sample problem occurred corrective action was taken by simply resampling from the identified farm as soon as possible. All forage and manure analysis were conducted through the Dairy One Analytical Laboratory in Geneva, NY. Analytical methods used by the lab for these tests were outlined in the QAPP. All results were transferred to the QA Manager through electronic documents.

Much of the data associated with the changes in management resulting from the information gleaned from the primary data used in this project was secondary data. The rationale for the use of the data is that they are used in the Whole Farm Nutrient Balance Tool, Forage Inventory Spreadsheet, and Ration Balancing programs. Data such as milk production and milk component data will come from milk statements from participating farmers. Yield data and other forage and manure production data was derived from Nutrient Management Plans and records which are managed in most cases by professional crop consultants. Herd Health data was acquired from the farmers herd health records. Purchased feed inventories and feed usage was calculated from precision feed monitoring equipment which the farmers currently possess. Data was checked for quality using reasonable accounting methods. Most of the data gathered are records of farm operation related benchmarking data.

The project was in compliance and followed the approved QAPP and all approved protocols.

7. DELIVERABLES COMPLETED

The deliverables of this grant were all completed.

1) The QAPP was developed and approved in February of 2020. This document guided the data collection procedures used on this project.
2) The five farms were selected, and they were all located in critical source areas.
3) We worked with farms to identify and quantify the sources and amounts of P coming onto the five farms. The primary source of P coming onto the farm was from purchased feeds, primarily grain. Most of the P exported from the farm was from milk and animal sales. There was some P exported off from the farms from the sale of forages.
4) For each farm, the team developed individualized strategies to reduce P imports. Since most of the P imported onto the farm was from grain purchases, we sought to focus on strategies to reduce grain imports.
5) The outcome of deliverable 5 was to track, monitor and collect information on the implementation of the P reducing recommendations. This was completed over the 3rd year to collect information required to calculate the whole farm MNB.
6) Each farm had the MNB calculated again at the end of 2022. The results are contained in Appendix B.
7) For this project quarterly reports were provided to the LCBP staff. The policy recommendations accompany this final report (Appendix D). Project outreach at several on-farm events occurred in 2022. Information was delivered to over 328 stakeholders.
8) This is the final report for this project and the last deliverable.

Table 1. Tasks, objectives, timeline, and status of project deliverables.

Task #	Task Title	Objective	Deliverable	Timeline	Status
1	Finalize QAPP	Write QAPP	Approved QAPP in place.	Jan 2020	*Completed Feb. 2020*
2	Finalize participants	Secure 5 farms and their agronomists and nutritionists to participate in MNB program	5 participating farms in CSAs	Feb 2020	*Completed Feb. 2020*
3	Establish benchmarks	Collect data from farms to establishment preliminary benchmarks† Input data into the MNB software with farms.	Quantify and source of P inputs on farm	Feb-May 2020 & 2021	*Completed May 2020*
4	Identify best strategies for reducing P on each farm	Report outputs to farms and work with at least 5 farm's agronomists and nutritionists to establish strategies to reduce P loading.	Practical strategy to reduce P	Jun-Dec 2020 & 2021	*Completed Jan 2021*
5	Implement P reducing recommendation	Implement strategies that have been agreed upon by farmer and team.	Reduction of P on farms	Sep 2020-Dec 2022	*Completed Dec - 2022*
6	Calculate P reduction from implemented practices	Meet with farmers, nutritionists to recalculate MNB based on changes, document reduction in P loading and economic costs.	Quantify reduction in P for each farm	Jan - Dec 2022	*Completed Dec 2022*
7	Disseminate results	Project reports, policy and incentive program recommendations. Disseminate results of project to farmers and other relevant stakeholders	Project reports, brochures, presentations, and policy recommendations	May 2020-Dec 2023	*Completed Dec 2022*
8	Final report	Complete final report	Final report	May 2023	*Completed May 2023*

8. CONCLUSIONS

The goal of this project was to demonstrate how, through whole farm nutrient management, improvements can be made to water quality through reduced phosphorus (P) loading and improved farm viability. Through this project we worked closely with five farms located in critical source areas to build a program that implements comprehensive P management strategies on a whole farm level. This diverse group of farmers included a Large Farm Operation (St. Albans Bay Watershed), Medium Farm Operation (Lake Carmi), Certified Small Farm Operation (Rock River Watershed), organic grass-fed farm (Rock River Watershed), and one farm that had recently converted from milking dairy cows to boarding animals for other producers (Lake Carmi).

Farms were visited regularly in the first year to collect baseline data to base P reducing recommendations. All farms were actively engaged in conservation farming. The primary focus was to reduce purchased feed and lower P loading at the farm level. Most of this work focused on monitoring feed rations and creating a plan for each farm to increase, where possible, the utilization of home-grown high-quality forages instead of purchased feeds. The project team evaluated in-field crop management, feed storage, feed rations, and barn management.

Recommendations were created for each farm and implementation occurred in subsequent years. All farms had an adequate land base to produce enough homegrown forage to satisfy 85 to 100% of their herds' diets. However, no farms were meeting those levels due to low yields, poor forage quality, inadequate storage, and other herd management issues. Recommended practices included targeted fertility management on forages, enhanced forage diversity, improved bunk management and feed storage, cow management related to feeding, and ration management to maximize homegrown feeds. Our analysis of the forage programs on the farms resulted in the identification of feed storage being a major driver in feed degradation resulting the need to purchase grain to maintain viable levels of milk production.

Overall, the approach, process, and methods developed for this project helped us to assess the nutrient flows on a diverse set of farms. The Cornell MNB software which tracks nutrients onto and off from farms was used to determine P (Appendix B). Drawing conclusions simply based on the output from this tool may not be the best long-term strategy for monitoring P reductions on farms since they are so dynamic. The amount of data required and the farm's ability to keep the records was challenging. We wanted to evaluate different types of farms so we could make inferences about how certain farming practices influence water quality based on nutrient loading from purchased feeds. The work indicates that there are many improvements that farms can make that would help maximize farm grown forages and rely less on purchased feeds. However, what we did not know, and it is now apparent that these businesses are constantly changing and evolving much more than we anticipated and those changes influence the output of the model more than simply changing the dairy ration. Some examples are provided below to demonstrate why these types of assessments are challenging.

One farm went through a devasting fire and had to move all its milk cows off site or sell them. One farm lost all its contracts for housing dry cows and then beef cows and is now back to housing heifers. These animals have different nutrient requirements and drastically changes feeding regiments. Two farms changed grain companies during the project and the new companies bring their influence to bear on this project directly and indirectly. Overall, the feed commodity industry has a huge influence on how dairy cows are fed in Vermont and the model they utilize makes sure cows are fed substantial amounts of grain before looking at high forage-based strategies. One farm took on an additional farmstead, shifted to once-a-day milking, and now is no longer producing milk at all. One farm was in a constant state of flux in how it manages its feed inventories and this made for a lot of changes in the rations and fluctuations in grain usage over the course of the project. Lastly, most of the farms involved with this project were forced by their milk buyers into a basis-based quota system for milk sales influencing their production goals and strategies. This is not to mention the impact that COVID-19 had on the farm operations. The result has been a lot of variability on the farms over the course of this project.

Overall, this project did show that helping farmers improve homegrown feed quantity and quality can lead to reduction in imported feeds. Less imported feed can reduce P loading and also help improve farm viability. This project would help to meet the NEIWPCC's mission which is: To advance clean water in the Northeast through collaboration with, and service to, our member states. However, this approach is complex and requires a whole farm perspective, technical support that has a diverse set of skills (herd health, nutrition, agronomy, engineering), and a farm management team that is committed to optimizing what they can grow at home to minimize purchases. The farm owner was engaged; however, there are many people involved with each farm and every single person needs to be onboard. Working with the farm's nutritionist presented the most challenges. The UVM team would make suggestions to change rations to increase forage and the farm would request the nutritionist to do so. Generally, the nutritionist would make the change but if our team wasn't there constantly monitoring the feedingprogram the nutritionist would revert back to business as normal. As an example, one farm was buying corn when they had 2 years of corn in storage. The UVM team suggested a shift in the ration to utilize more homegrown forage and optimize the feeding of the corn produced on the farm. The farmer requested this modification and was told "yes" we can do that by the nutritionist. However, upon examination of the ration 3 months later the recommendation was not put into place. The farmer decided to change nutritionists and has gone with an independent option that does not work for a grain company. Unfortunately, independent nutritionists are very limited in VT and NY giving farmers few other options. The nutrition on a farm is complicated and hence for many farmers they need someone with that specific expertise to balance rations for their herd on an ongoing basis. Small farms are even more vulnerable as they often receive very little service from grain company nutritionists. For example, one farm in the study did not see their nutritionist for several months at a time. When the UVM team provided feedback on the ration it was from feed tests take 3 months prior by the farm nutritionists. The tests were not relevant to what the farm was actually feeding at that time and hence they were overfeeding grain. As soon as we requested the feed tests from the farm's nutritionist they came to the farm. This is the most significant challenge with long-term and broader scale implementation of this type of program.

As mentioned earlier, inadequate feed storage was a major barrier to feeding high forage diets. We found that all the farms had goals of ensiling high-quality forage, but most farms could not adequately manage the feed storage facilities in a manner that maintained that quality. Contributing factors include, over-filling of the facility resulting in inadequate feed packing, poor infrastructure conditions leading to the infiltration of oxygen into the stored feed (the fermentation of feed is an anerobic process and oxygen drastically disrupts this process resulting in poor quality feed), and the lack of space which reduces the ability to segregate feed to better match the quality of the feed with the needs of the animals being fed. All these factors also result in an increase in feed respiration which produces leachate. This leachate is a very potent water pollutant. Although poor feed storage can have direct (leachate) and indirect (increased grain purchases) impacts on water quality, it is not recognized as a critical component or strategy to reduce P loading and losses in watersheds. A policy paper was developed to express the needs for this practice to be a focus of water quality funding programs (Appendix D).

In summary, all livestock farms in VT feed forage to their animals. Perennial forages are critical to farms and the environment. Maximizing productivity and quality of perennial forages builds soil health, sequesters carbon, minimizes erosion, and provides nutritious and healthy feed to livestock. It is essential to managing soil and nutrient losses on our farms. This project demonstrated that a focus on producing higher quality farm grown feed can improve milk production, milk components, and reduce costs by reducing the amount of grain to be purchased. Less grain means less imported P into our watersheds ultimately reducing P loading into soils and potential losses.

9. APPENDICES

Appendix A – Project Farm Locations

Appendix B – Whole Farm Mass Nutrient Balances (before and after)

Appendix C – Individual Farm Recommendations

Appendix D – Outreach and Policy Recommendations

Appendix E – Forage Inventory Spreadsheet

Appendix F – Project data (Excel file)